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Methods and Applications for Advancing Distance Education Technologies

International Issues and Solutions

Mahbubur Syed

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In this chapter the authors present E-World, an e-learning platform able to manage and trace adaptive learning processes which are designed and created by means of a visual language based tool. To address the goal to have a platform easily extensible with new services, the authors have designed it selecting a software architecture based on the use of Web Services and a suitable Middleware component. To trace adaptive learning processes E-World also integrates as Web Service a suitable implementation of a Run-Time Environment compliant with the sharable content object reference model (SCORM) standard. Their proposal also supports the "anytime and anywhere" learning paradigm as it enables learners to enjoy linear or adaptive processes using any device equipped with a standard Web browser.

In developing traditional learning materials, quality is the key issue to be considered. However, for high technical e-training courses, not only the quality of the learning materials but also the efficiency of developing the courses needs to be taken into consideration. It is a challenging issue for experienced engineers to develop up-to-date e-training courses for inexperienced engineers before further new technologies are proposed. To cope with these problems, a concept relationship-oriented approach is proposed in this chapter. A system for developing e-training courses has been implemented based on the novel approach. Experimental results showed that the novel approach can significantly shorten the time needed for developing e-training courses, such that engineers can receive up-to-date technologies in time.

The sharable content object reference model (SCORM) includes a representation of distance learning contents and a behavior definition of how users should interact with the contents. Generally, SCORM-compliant systems were based on multimedia and Web technologies on PCs. The authors further build a pervasive learning environment, which allows users to read SCORM-compliant textbooks with multimodal learning devices. Respecting the learning contents for supporting such learning environment, an efficient authoring tool was developed for serving this goal. Some specific tags were defined to specify the corresponding information or interactions that cannot be performed in the hardcopy books. These tags can be printed in SCORM-compliant textbooks and recognized by Hyper Pen to facilitate the affinity between the physical textbooks and digital world. Therefore, users can read the SCORM-compliant hardcopy textbooks in a traditional manner. The authored course contents will be the same while applying to the multimodal learning devices with different layouts.

Selecting appropriate learning services for a learner from a large number of heterogeneous knowledge sources is a complex and challenging task. This chapter illustrates and discusses how Semantic Web technologies can be applied to e-learning system to help learner in selecting appropriate learning course or retrieving relevant information. It firstly presents the main features of e-learning scenario and the ontology on which it is based; then illustrates the scenario ontology with the training domain and the application domain. Finally, it presents Semantic Querying and Semantic Mapping approach.

The increasing popularity of online courses has highlighted the need for collaborative learning tools for student groups. In addition, the introduction of lecture videos into the online curriculum has drawn attention to the disparity in the network resources available to students. The authors present an e-learning architecture and adaptation model called Adaptive Interactive Internet Team Video (AI2TV), which allows groups of students to collaboratively view a video in synchrony. AI2TV upholds the invariant that each student will view semantically equivalent content at all times. A semantic compression model is developed to provide instructional videos at different level of details to accommodate dynamic network conditions and users' system requirements. We take advantage of the semantic compression algorithm's ability to provide different layers of semantically equivalent video by adapting the client to play at the appropriate layer that provides the client with the richest possible viewing experience. Video player actions, like play, pause, and stop can be initiated by any group member and the results of those actions are synchronized with all the other students. These features allow students to review a lecture video in tandem, facilitating the learning process. Experimental trials show that AI2TV successfully synchronizes instructional videos for distributed students while concurrently optimizing the video quality, even under conditions of fluctuating bandwidth, by adaptively adjusting the quality level for each student while still maintaining the invariant.

The abundance of knowledge-rich information on the World Wide Web makes compiling an online e-textbook both possible and necessary. In their previous work, the authors proposed an approach to automatically generate an e-textbook by mining the ranked lists of the search engine. However, the performance of the approach was degraded by Web pages that were relevant but not actually discussing the desired concept. In this chapter, they extend the previous work by applying a clustering approach before the mining process. The clustering approach serves as a post-processing stage to the original results retrieved by the search engine, and aims to reach an optimum state in which all Web pages assigned to a concept are discussing that exact concept.

Chinese brush calligraphy is a valuable civilization legacy and a high art of scholarship. It is still popular in Chinese banners, newspaper mastheads, university names, and celebration gifts. There are Web sites that try to help people enjoy and learn Chinese calligraphy. However, there lacks advanced services such as content-based retrieval or vivid writing process simulation for calligraphy learning. This chapter proposes a novel Chinese calligraphy learning approach: First, the scanned calligraphy pages were segmented into individual calligraphy characters using minimum-bounding box. Second, the individual character's feature information was extracted and kept. Then, a corresponding database was built to serve as a map between the feature data and the original raw data. Finally, a retrieval engine was constructed and a dynamic writing process was simulated to help learners get the calligraphy character they were interested in and watch how it was generated step by step.

In this chapter the authors investigate the use of latent semantic analysis (LSA), critiquing systems, and knowledge building to support computer-based teaching of English composition. They have built and tested an English composition critiquing system that makes use of LSA to analyze student essays and compute feedback by comparing their essays with teacher's model essays. LSA values are input to a critiquing component to provide a user interface for the students. A software agent can also use the critic feedback to coordinate a collaborative knowledge-building session with multiple users (students and teachers). Shared feedback provides seed questions that can trigger discussion and extended reflection about the next phase of writing. They present the first version of a prototype we have built and report the results from three experiments. They end the paper by describing their plans for future work.

Learning Objects (LOs) are increasingly considered potentially helpful to improve teachers' work and to spread innovation in the school system. Their technological roots, however, often make them scarcely appealing to the teachers. A key issue to tackle in order to boost their diffusion is to make them closer to actual teacher's work by emphasising pedagogical aspects. To this end, the authors propose a typology of LOs that allows teachers to highlight differences in the pedagogical approach embedded in their productions, hence sharing not only content but also educational competence. Moreover, in order to allow re-user teachers to explicit and share the pedagogical experience gained while re-using some material, they suggest endowing repositories with ad hoc facilities, such as comments and itineraries related to the repository's LOs. Comments would allow people to share narrations of experiences of use, while learning itineraries would point out logical connections of various kinds among small groups of LOs, hence helping the users overcome the content fragmentation induced by the granularity of LOs. These proposals are described and exemplified by drawing from our training experience.

Human motion animation has been one of the major research topics in the field of computer graphics for decades. Techniques developed in this area help to present human motions in various applications. This is crucial for enhancing the realism as well as promoting the user interest in the applications. To carry this merit to e-learning applications, the authors have developed efficient techniques for delivering human motion information over the Internet to collaborating e-learning users and revealing the motion information in the client machines with different rendering capability. Their method offers a mechanism to extract human motion data at various levels of detail (LoD). They also propose a set of importance factors to allow an e-learning system to determine the LoD of the human motion for rendering as well as transmission, according to the importance of the motion and the available network bandwidth. At the end of the paper, they demonstrate the effectiveness of the new method with some experimental results.

On-Line Testing is that sector of e-learning aimed at assessing learner's knowledge through e-learning means. In on-line testing, due to the necessity of evaluating a big mass of learners in strict times, the means for knowledge evaluation had to evolve to satisfy the new necessities: objective tests, more rapidly assessable, started gaining more credence in the determination of learners' results. In this chapter, the authors present an On-Line Testing system, named eWorkbook, which can be used for evaluating learner's knowledge by creating (the tutor) and taking (the learner) on-line tests based on multiple choice question type. Its use is suitable within the academic environment in a blended learning approach, by providing tutors with an additional assessment tool, and learners with a distance self-assessment means. Among other features, eWorkbook can record and visualize, in a suitable graphical format, learner's interactions with the system interface during the test session. This is valuable information for understanding the learner's behaviour when taking a test. In particular, the graphical analysis of the test outcomes has helped us in the discovery of several strategies employed by the learners to perform the test. In the chapter, the main characteristics of the system are presented together with a rationale behind them and an outline of the architectural design of the system.

Athabasca University – Canada's Open University evaluated Learning Management Systems (LMS) for use by the university. Evaluative criteria were developed in order to ensure that different platforms were tested against weighted criteria representing the needs of the university. Three LMSs (WebCt, LotusNotes, and Moodle) were selected for the evaluation. Moodle was chosen with 11 first place ratings and with only one third place rating. Lotus Notes was second with five first place ratings. Moodle garnered 40% of the total weighted score with Lotus Notes getting 32%, and WebCT 29%. The first place preferences within individual criteria show the following: WebCT 6; LotusNotes 7; and Moodle 58.

Computer Aided Assessment is a common approach used by educational institutions. The benefits range into the design of teaching, learning, and instructional materials. While some such systems implement fully automated marking for multiple choice questions and fill-in-the-blanks, they are insufficient when human critiquing is required. Current systems developed in isolation have little regard to scalability and interoperability between courses, computer platforms, and Learning Management Systems. The IMS Global Learning Consortium's open specifications for interoperable learning technology lack functionality to make it useful for Computer Assisted Marking. This article presents an enhanced set of these standards to address the issue.

Distance education is the delivery of educational programs to off-site students. It uses a wide spectrum of technologies such as the Internet and Multimedia systems to deliver the course material to remote students. This created new challenges regarding the delivery of continuous media (streaming), especially through the Internet. A challenging task when implementing Multimedia systems for distance education is to support the sustained bandwidth required to display Streaming Media (SM) objects, such as video and audio objects. Unlike traditional data types, such as records, text, and still images, SM objects are usually large in size and are isochronous in nature (i.e., have real-time display requirements). For the past few years, a number of studies have considered the design of SM servers. In this article, the authors consider the design of a framework for customized SM presentations, where each presentation consists of a number of SM objects that should be retrieved and displayed to the user in a coherent fashion. In addition, we provide different classification of applications (e.g., RPA, FPA) according to the restrictions imposed by the presentation (e.g., display-quality, delay). Next, they describe a retrieval optimizer (Prime) that captures the flexibilities and requirements imposed by the user query, user profile, and session profile. Then, it determines how this query script should be imposed against the Continuous Media (CM) server to reduce contention. Furthermore, they discuss the issues that are related to the optimizer such as: (1) search space, (2) cost model, and (3) a strategy to search for the best retrieval plan. They also provide a cost model to evaluate each correct retrieval plan that is being considered, and the search strategy explores the search space for the best retrieval plan based on the defined metrics. Finally, they explain the role of memory buffering in alleviating the server bandwidth fragmentation problem by allowing the emulation of higher server bandwidths when necessary using two mechanisms: 1) Simple Memory Buffering Mechanism (SimB), and 2) Variable Rate Memory Buffering Mechanism (VarB). Their preliminary experimental results show the feasibility and effectiveness of our proposed model and techniques in generating near optimal retrieval plans for scheduling and displaying SM objects.

The question why some learners successfully study through distance mode and others do not is increasingly becoming important as open and distance learning (ODL) has come to occupy a prominent place in providing higher education to large segments of the population in India. With barely 1112 students studying through distance mode in 1962, the number has crossed 2.8 million in 2006. This chapter presents the findings of an empirical research study conducted to investigate the study habits of successful distance learners of the India Gandhi National Open University (IGNOU). Every year, nearly 70,000-80,000 pass out of IGNOU. What strategies were adopted by these diverse groups, what media they utilized, and what modes of support they preferred are some of the major issues addressed in this study.

The prosperous development of wireless communication and sensor technologies has attracted the attention of researchers from both computer and education fields. Various investigations have been made for applying the new technologies to education purposes, such that more active and adaptive learning activities can be conducted in the real world. Nowadays, ubiquitous learning (u-learning) has become a popular trend of education all over the world, and hence it is worth reviewing the potential issues concerning the use of u-computing technologies in education, which could be helpful to the researchers who are interested in the investigation of mobile and ubiquitous learning.

In this chapter the authors describe the implementation of an emerging virtual learning environment to teach GIS and spatial sciences to distance education graduate students. They discuss the benefits and constraints of our mixed architecture with the main focus on the innovative hybrid architecture of the virtual GIS computer laboratory. Criteria that were used to develop the virtual learning environment entailed the following: (1) Facilitating student-instructor, student-computer, and student-student interactivity using a mix of synchronous and asynchronous communication tools; (2) Developing an interactive online learning environment in which students have access to a suite of passive and active multi-media tools; and (3) Allowing student access to a mixed web-facilitated / hybrid architecture that stimulates their cognitive geographic skills and provides hands-on experience in using GIS.

Individualised open and distance learning at the university continuing education and post-graduate education levels is a central issue of today. The advanced information and communication technologies together with several applications offer new perspectives, such as the so-called virtual university. Simultaneously, to gain market share, several organisational arrangements are emerging in the virtual university field, like consortia arrangements and joint venture initiatives between and among institutions and organisations. The dynamically changing social and economical environment where we live claims for new approaches to virtual and flexible university continuing and post-graduate education, such as the concept of Agile/Virtual University proposed by the authors. However, the implementation of this

In the past decades, English learning has received lots of attention all over the world, especially for those who are not native English speakers. Various English learning and testing systems have been developed on the Internet. Nevertheless, most existing English testing systems represent the learning status of a student by assigning that student with a score or grade. This approach makes the student aware of his/her learning status through the score or grade, but the student might be unable to improve his/her learning status without further guidance. In this chapter, an intelligent English tense learning and diagnostic system is proposed, which is able to identify student learning problems on English verb tenses and to provide personalized learning suggestions in accordance with each student's learning portfolio. Experimental results on hundreds of college students have depicted the superiority of the novel approach.

The chapter outlines a new paradigm and its underlying rationales for implementing networked learning environments that is emerging from new technologies such as multi-user platform, virtual worlds, virtual learning community, and intelligent agents. The proposed paradigm of the networked learning environments is described as inhabited virtual learning worlds (IVLW), which is a shared learning space in 3-D format and populated with avatars that are the representations of learners who are geographically dispersed around the world. The virtual learning worlds are also composed of objects such as intelligent agents and learning materials. A pilot system is created based on the discussed rationales of inhabited virtual learning worlds. A preliminary empirical study focusing on the selected learning behaviors in young learners also has been conducted with the pilot system. The results of the empirical study and suggestions for enhancing the pilot system are discussed in the closing section of the chapter.

Any view of el-earning in Canada must be informed by the uniquely Canadian feature of provincial jurisdiction over education. Therefore any investigation of e-learning in Canada must focus more on specific provincial initiatives in technologically enhanced learning rather than a Canadian overview. A distinctive "Canadian" model does not exist. The provinciality of Canadian e-learning serves to highlight the inability of Canada to sustain national strategies and focus as in other countries due to the fractious nature of federal/provincial relations in education.

Preface

Various definitions of distance education exist. A summarized definition of distance education may be seen as linking of teachers and students for all different types and levels of education including K-12, higher education, continuing education, trainings in corporate, military and/or government institutions, telemedicine and those devoted to the pursuit of lifelong learning. Advanced Distance Learning refers to a certain kind of education in which academic courses are delivered to places outside the campus via voice, video (live broadcast or rebroadcast), as well as real-time and non-real-time computer technologies. The educator and the learner may be separated by time, distance, or both. Open and distance learning (ODL) is increasingly occupying a prominent place in higher education. Chapter XVI reports that in India starting with barely 1,112 students studying through distance mode in 1962, the number had crossed 2.8 million in 2006. This chapter presents the findings of an empirical research study conducted to investigate the study habits of successful distance learners of the India Gandhi National Open University (IGNOU). Every year, nearly 70,000-80,000 pass out of IGNOU. The strategies adopted by these diverse groups of students, the media utilized by them, and the modes of support preferred by them are some of the major issues addressed in this study. Chapter XXIV discusses on major e-learning research programs, delivery consortia and professional development programs based in Canada.

E-learning is a critical support mechanism for organizations and individuals to enhance their skills. Chapter V presents major features of e-learning scenario, the ontology on which it is based and discusses on how Semantic Web technologies can be applied to e-learning system to help learner in selecting appropriate learning course or retrieving relevant information. It also illustrates the scenario ontology with the training domain and the application domain. Semantic Querying and Semantic Mapping approaches are also presented.

Assessing learner's knowledge in e-learning is an important issue. Due to the necessity of evaluating a large number of learners in short times, objective tests are gaining more popularity in the assessment of learners' performance. Chapter XVII presents an On-Line Testing system for evaluating learner's knowledge, named e-Workbook, which is suitable within the academic environment in a blended learning approach and can record and visualize, in a suitable graphical format the learner's interactions with the system interface during the test session to provide better understanding of the learner's behaviour. While some such systems implement fully automated marking for multiple choice questions and fill-in-the-blanks, but most systems are insufficient when human critiquing is required. Current systems developed in isolation have little regard to scalability and interoperability between courses, computer platforms, and learning management systems. Chapter XIV presents an enhanced set of the IMS Global Learning Consortium's open specifications for interoperable learning technology lack functionality to make it useful for computer assisted marking standards to address the issue.

Scores or grades obtained by a student in these evaluation processes reflects the learning status of that student, but is not capable of identifying students learning problems on areas of the subject, which might help him/her to further improve. In Chapter XXII the authors propose an intelligent English tense learning and diagnostic system that is capable of identifying student learning problems on English verb tenses and be able to provide personalized learning suggestions in accordance with each student's learning portfolio. The proposal has shown superior results from experiments conducted on hundreds of college students.

The use of online delivery management systems is gaining popularity in most campuses. The Athabasca University, - Canada's Open University - developed evaluation criteria (as detailed in Chapter XIII) for three learning management systems (LMS), namely WebCt, LotusNotes, and Moodle. Moodle was ranked first with 11 first places and only one third place rating, while Lotus Notes was second with five first place ratings.

Though some definitions of distance education emphasize on technology and others do not, it is obvious that technology is the most important vehicle for effective and quality distance education. In recent years, technologies have advanced at an amazingly fast pace. With the incredible development and pervasiveness of wireless, mobile and networking communication, and sensor technologies in our daily life we tend to focus on the task at hand without even noticing their use - making the technology effectively invisible to the user resulting in a paradigm shift known as ubiquitous learning (u-learning). Chapter XVII discusses various investigations those have been undertaken for applying the new technologies to distance education to make it more active and adaptive to the real world.

Several researchers claim that the paradigm of networked learning, with its passive nature, usually discourages learning engagement and creates strong student isolation. This environment is unable to engage student in active learning. Chapter XXIII outlines a new paradigm and its underlying rationales for implementing networked learning environments that is emerging from new technologies such as multi-user platform, virtual worlds, virtual learning community, and intelligent agents. The proposed paradigm of the networked learning environments, known as inhabited virtual learning worlds (IVLW), is a shared learning space in 3-D format and populated with avatars that are the representations of learners who are geographically dispersed around the world. The virtual learning worlds are also composed of objects such as intelligent agents and learning materials. A pilot system is created based on the discussed rationales of inhabited virtual learning worlds. Also a preliminary empirical study focusing on the selected learning behaviors in young learners has been conducted with this pilot system. The results of the empirical study and suggestions for enhancing the pilot system are discussed in this chapter.

One important area of research is to apply computer vision (CV) technologies to various automated e-learning multimedia systems. Chapter XX discusses the importance of a synchronous, peer-to-peer-based application of computer vision technologies to e-learning and introduces the schematic of a progressive work in Intelligent Video Detection Agent (IVDA) that supports an instructor's interaction with non-computer teaching equipments. Some most recent advancements in the interactive PTZ camera control from both the instructor and remote student is discussed and results that successfully address different challenges are illustrated.

Use of human motion animation in e-learning applications has the potential to create significant interest from the users. Chapter XI in this book discusses on the development of efficient techniques for delivering human motion information over the Internet to the collaborating e-learning users and revealing the motion information in the client machines with different rendering capabilities that include mechanism to extract human motion data at various levels of detail taking into consideration the available network bandwidth.

Distance education created new challenges regarding the delivery of large size isochronous continuous streaming media (SM) objects. Chapter XV considers the design of a framework for customized SM presentations, where each presentation consists of a number of SM objects that should be retrieved and displayed to the user in a coherent fashion. A retrieval optimizer (Prime) that captures the flexibilities and requirements imposed by the user query, user profile, and session profile is described. A cost model for evaluation of each proposed plan to impose user query script against the continuous media (CM) server to reduce contention has been developed. Preliminary experimental results show the feasibility and effectiveness of the proposed model and techniques in generating near optimal retrieval.

The dynamically changing social and economical environment where we live claims for new Agile/Virtual University approaches with individualized continuing and post-graduate education; Chapter XIX discusses a framework and a specific supporting environment, a Market of Teaching Resources necessary to the implementation of the Agile/Virtual University concept.

Motivation and independent learning are very important factors in students learning processes. Independent learning involves students meta-learning in a framework of goal-driven learning. Knowledge of learners related to interconnection and interrelationship between different components of the curriculum plays a vital role in both motivation and independent learning. In Web-based learning curriculum, especially for distance learners, it is often a challenge to conceptualize how different modules are related to one another and how the curriculum corresponds with their personal wills and objectives. Chapter XXI presents approaches and tools that can help learners to address such challenges of a Web-based learning curriculum and encourage them to become active participants in their learning. The proposed generic architecture is designed to be used in the context of an already existing Web-based learning system. The approach is based on a detailed modeling of the curriculum and intends to equip the learners with different computer-based tools facilitating a multiple point of view perception of the curriculum, while promoting self evaluation and self regulation of the learners' curriculum performance.

An effective tool in distance learning is possibility of forming "study groups" among students who can view the lecture videos together and pause, rewind, or fast forward the video to simulate the pedagogically valuable discussions that occur during on-campus lectures. However, conventional Internet video technology does not yet support collaborative video viewing by multiple geographically dispersed users. It is particularly challenging to support What I See Is What You See (WISIWYS) when some users are relatively disadvantaged with respect to bandwidth (e.g., dial-up modems) and local resources (e.g., old graphics cards, small disks). Chapter VI presents an e-Learning architecture and adaptation model called AI2TV (Adaptive Interactive Internet Team Video), which allows groups of students to collaboratively view instructional videos in synchrony.

Use of Learning Objects (LOs) by teachers would help increasing teaching performance, spread innovation and reduce cost through saving time by allowing reuse of potentially good teaching materials. A major obstructing factor in this is the amount of extra work that may be required by a teacher to integrate didactical resources prepared by other teachers in one's own lessons. To overcome this obstacle it is necessary to make them closer to actual teacher's work by emphasizing pedagogical aspects. To this end, Chapter X proposes a topology of LOs that allows teachers to share both content and educational competence.

Other chapters in this book focus on different research, design and implementation aspects of methods and application for advancing distance education and technologies. Chapters I to IV, VII to IX, and Chapter XVIII reports their design and development activities, as detailed below, those are very important to the advancement of distance learning initiatives.

- Development of a new automatic digital content generation system at Hosei University for students taking distance interactive classes over the Internet from overseas. The system enables the complete archiving of lectures including video/audio content, synchronized presentation materials, and handwritten traces on virtual whiteboards. The content is generated in real time and is immediately available at the end of the class. In addition, this system incorporates a unique video search algorithm which adopts a phonetic-based search technology. This enables quick review of the video content by typed-in keywords. The system can automatically create a vast amount of digital content and provide students with an efficient learning tool for distance students and review materials for in- class students.

- Development of an e-learning platform, supporting the “anytime and anywhere” learning paradigm, that is able to manage and trace adaptive learning processes. The platform designed and created by means of a visual language based tool have a software architecture based on the use of Web Services and a suitable Middleware component compliant with the Shareable Content Object Reference Model (SCORM) standard. Experiments have been carried out to assess the usability of the proposed e-learning platform is reported.
- Implementation of a system for developing e-training courses based on a concept relationship-oriented approach. It addresses the challenging issues in developing traditional learning materials for high technical e-training courses meeting both the quality of the learning materials and also the efficiency of developing the courses. Experimental results show that this approach significantly shortened the time needed for developing e-training courses for engineers to receive up-to-date technologies in time.
- Building a pervasive learning environment to allow users to read SCORM-compliant textbooks with multimodal learning devices.
- Development of an approach to automatically generate an e-textbook by mining the ranked lists of the search engine by applying a clustering approach before the mining process.
- Development of a novel approach for learning Chinese calligraphy.
- Investigation of the use of latent semantic analysis (LSA), critiquing systems, and knowledge building to support computer-based teaching of English composition. The English composition critiquing system makes use of LSA to analyze student essays and compute feedback by comparing their essays with teacher’s model essays.
- Development of a virtual interactive learning environment to teach GIS and spatial sciences to distance education graduate students facilitating student, instructor and computer interactivity using a mix of synchronous and asynchronous communication tools and students having access to a suite of passive and active multi-media tools and to a mixed Web-facilitated/hybrid architecture that stimulates their cognitive geographic skills and provides hands-on experience. The benefits and constraints of the innovative hybrid architecture of the virtual GIS computer laboratory are discussed.

The chapters in this book have demonstrated that the most essential requirements for advancing distance education for both teaching and learning are communication technologies, intelligent technologies and quality educational pedagogy.

Communication Technologies with high performance broadband and wireless network infrastructures, with quality service support, and with advanced communication tools and real time protocols are capable of supporting distributed synchronous multimedia streaming technology. The communication technologies must be supported by *Intelligent Technologies* to support high level secure personalized authentication mechanisms or in cases some degree of automation, effective and efficient authoring systems, online discussions, automated assessment, content individualization, automated response, intelligent tutoring and intellectual property and copyright protections using intelligent computation techniques such as neural network and statistical approaches with emphasis to behavior analysis.

In addition to the information technology components are also required development of quality educational pedagogy techniques that include practical and new learning models to adapt to the advancing information technologies and distance education demands and practices

The readers of this book will find answers to important issues necessary to be addressed for a successful distance education and will be reminded that the success of distance education requires effective use of instructional media, planning for instructional media use, visual communication, audio and motion media, computers as tools for learning, and evaluating the effectiveness of instructional media.

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Chapter I
Automatic Digital Content Generation System for Real-Time Distance Lectures

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ABSTRACT

This article describes a new automatic digital content generation system we have developed. Recently some universities, including Hosei University, have been offering students opportunities to take distance interactive classes over the Internet from overseas. When such distance lectures are delivered in English to Japanese students, there is a pressing need to provide materials for review after class, such as video content on a CD-ROM or on a Web site. To meet this need, we have developed a new automatic content generation system, which enables the complete archiving of lectures including video/audio content, synchronized presentation materials, and handwritten traces on virtual whiteboards. The content is generated in real time and is immediately available at the end of the class. In addition, this system incorporates a unique video search algorithm which adopts a phonetic-based search technology. This enables quick review of the video content by typed-in keywords. The system can automatically create a vast amount of digital content and provide students with an efficient learning tool.

INTRODUCTION

Hosei University has been providing numerous classes and lectures in the form of distance lectures through Hosei University Research Institute, California (HURIC). Since such distance lectures from abroad are delivered in English, we have strongly required an e-learning system for postproducing a lecture, including video/audio and other presentation materials, quickly into digital content, and making it available for review after class to Japanese students lacking sufficient language ability. It would be possible, were it merely a question of delivering distance lectures in real time, to suitably combine commercially available systems to display handwritten data in addition to video/audio and slide materials. However, in order to turn information presented in the lecture, including hand-written data, into video-synchronized digital content automatically, a data storage server is required in addition to a PC for the lecturer (Kaneko, Sugino, Suzuki, & Ishijima, 2000; Li, 2000; Panasonic, 2005). There was hitherto no system that was very portable and could be used with only a PC and a video camera. Further, since videotapes of the many lectures held every week create an enormous amount of stored content, students would be forced to waste time and energy if they had to play back a video in order to search for sections of a lecture they wanted to review. In order to conduct such a video search with precision, a search function using the lecture audio as keywords is required in addition to the conventional video search function using slide title indexes. To achieve such an audio-based keyword search function, the audio portion needs to be converted to text after a lecture and time information for each word or phrase added/edited manually. This would take too much time and be so costly that it would be difficult to achieve.

This article proposes an new automatic digital content generation system for lectures, developed and improved based on practical experience accumulated through distance classes at Hosei University (Hayashi, 2003), which allows hand-written data to be incorporated and audio-based keyword searching to be performed. Since the system can digitally reproduce and distribute videotaped information of a lecture, including handwritten data, immediately after class without any editing, students can play back sections that they did not fully understand as much as they like and continue their studies in detail after the lecture for a thorough understanding. Also, although still at a prototype stage, a function allowing applicable sections to be searched using audio data as keywords is automatically added so that any section requiring review may be located and played back immediately.

Real-Time Distance Lecture System

Since April 2002, Hosei University has been offering a pre-MBA course toward an MBA to be acquired by further studying abroad for a minimum of one year. Figure 1 shows photos of the pre-MBA class. In this course, a service is provided in which students can attend some MBA-accredited courses in advance at Kudan Hall in Ichigaya Campus through distance classes from the Hosei University Research Institute California. Furthermore, an international distance class on welfare engineering given by lecturers in the US, Korea, and Hosei University in Japan is being offered as an interdisciplinary as well as a crossover subject to Ichigaya, Tama, and Koganei Campuses from April 2003. Figure 2 shows a set of scenes of the classroom.

These e-learning classes employ the system illustrated in Figure 3 for the linkage between the HURIC and Ichigaya Campus, and they use the multicampus LAN and teleconferencing system shown in Figure 4 for linkages among the campuses. In the classroom, the teleconferencing system presents the lecturer's motion and voice to students, as shown in Figure 5, and the

Figure 1. Photos of Pre-MBA class

Lecturer site at HURIC in California

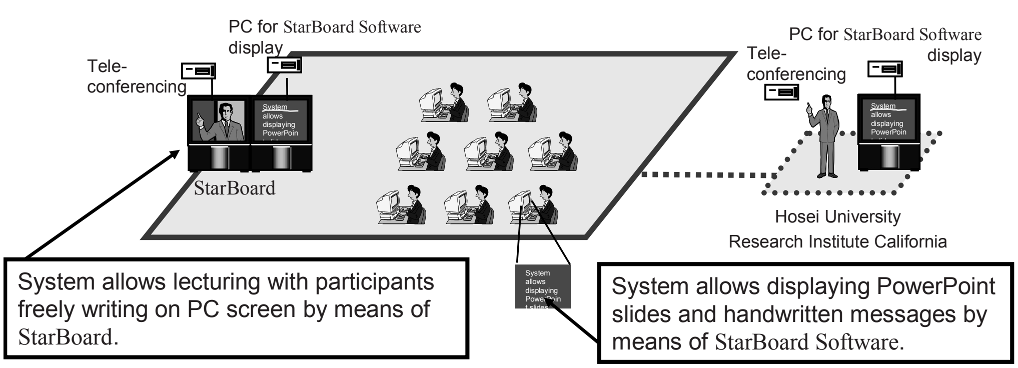
Student site at Kudan Hall in Ichigaya Campus

Figure 2. Photos of international distance class on "Welfare Engineering transmitted from South Korea

Student site in Tama Campus

Student site in Koganei Campus

Figure 3. Real-time e-learning system



Connection between HURIC and Kudan Hall at Ichigaya Campus in Tokyo

Figure 4. Inter-campus connections

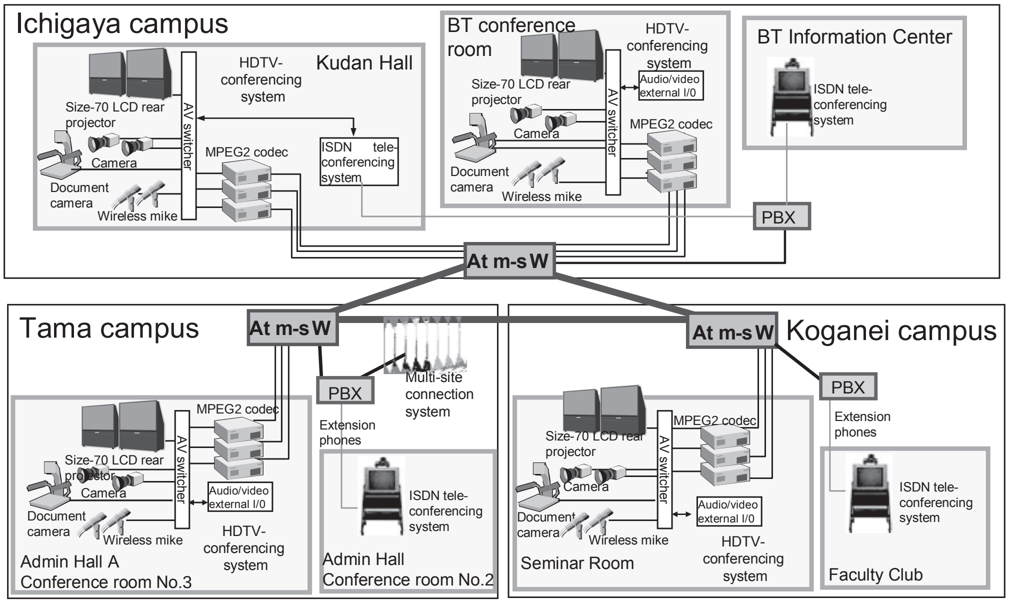
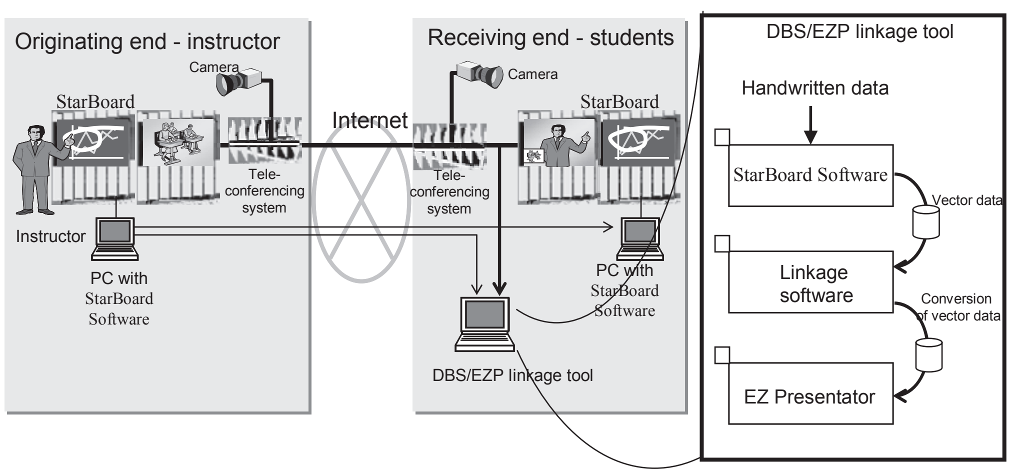


Figure 5. Handwritten data real-time storage system



StarBoard function supplied by Hitachi Software Engineering displays Microsoft's PowerPoint slides bilaterally between lecturers and students. Handwritten data drawn on the StarBoard can be performed in sync and in real time via the Internet. Meanwhile, the EZ Presenter (EZP), supplied by Hitachi Advanced Digital and installed in Ichigaya Campus, digitizes and stores class work data so that students can retrieve any part of it as Web content immediately after the end of class work (Hitachi, 2005).

In the past, however, data on slides and handwritten messages on the StarBoard could not be directly captured and stored in digital form in sync with classroom images for automatic generation of classroom content for later use. We were unable, therefore, to make available to students the classroom information in complete duplicate form. Hence, we first developed the software by working with Hitachi for linking the digital board with the EZP so as to store all class video images, including handwritten data.

In the meantime, if about 15 rounds of class work per semester are turned into digital content, it would be almost impossible to search and retrieve any portion of the recorded audio/video data for review or restudy, for one has to go through vast quantities of data, amounting to more than 20 hours worth per class subject. Unless this problem is overcome, students would be forced to expend many hours of wasteed effort in data search, to the detriment of their motivation for learning. To embed a useable video search function in digital contents, it was usually necessary to add time stamps and Meta-data to the contents manually after the end of class work. We then founded that adoption of a search technique based on phoneme analysis of voice data (NEXIDIA, 2005; Clements, Robertson, & Miller, 2002) would permit instantaneous search and retrieval by means of keywords without the intervening editing process. Thus, we started joint development with Network Solutions for incorporating such a search technique in our automatic digital-content production system.

Automatic Digital Content Generation System

This section describes the automatic digital content generation system for lectures developed and improved based on practical experience accumulated through distance lectures offered hitherto, which allows incorporation of handwritten data and audio-based keyword searching.

Real-Time Storage Function of Handwritten Data

Hosei University has been using the EZP, which can be built on a minimal set of PCs and video cameras. The EZP system cannot, however, capture handwritten data. To fill this gap and improve the system, we have added a linking function between the EZP and the StarBoard Software (SBS), so that

Figure 6. Browsing image of class content

handwritten messages entered on a digital board or a PowerPoint slide may be captured and stored as vector data in sync with motion video. As shown in Figure 6, the SBS first extracts vector data out of handwritten data. Then, the linking software converts the extracts into a format readable by the EZP, which then automatically produces digital content in sync with motion video. Figure 5 shows a browsing image displaying class content from our pre-MBA class. The right-hand side frame in Figure 6 clearly shows the lecturer's handwritten notation on a PowerPoint screen. The linking software developed in this project is expected to be commercially available as a part of the automatic digital-content production system from four companies, including Hitachi.

Search Function by Means of Voice-Data Keywords

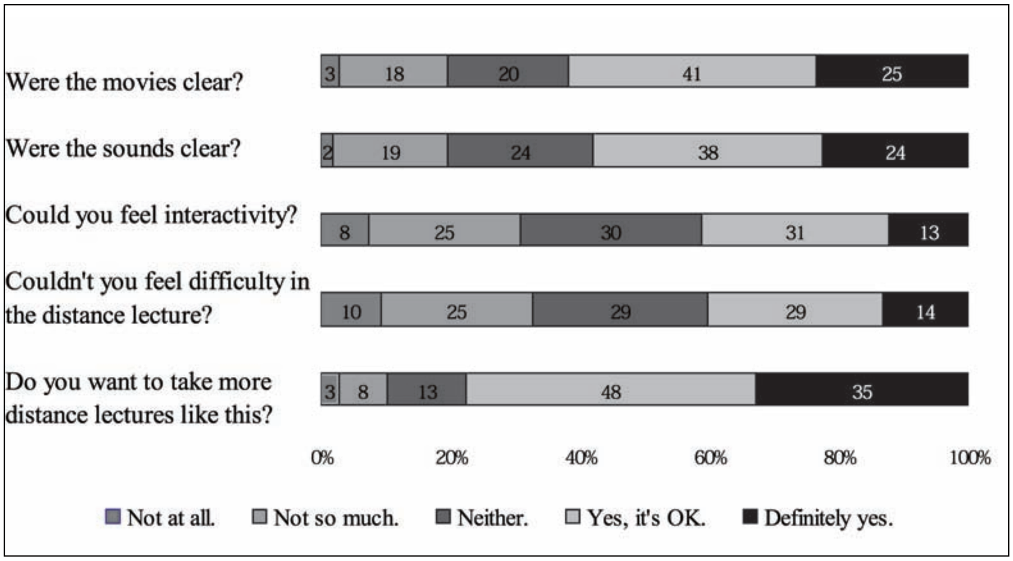
The Fast-Talk Phonetic-Based Searching technique developed by Fast-Talk Communications (now NEXIDIA) is designed to build search databases from phonemes, the smallest elements contained in voiced speech, and to allow high-speed searches into voice data obtained from unspecified speakers (Clements et al., 2002). Usually, when searches are to be made into video and audio files by means of keywords, the target voice data, for example, will have to be converted by preprocessing into text form, which is then subjected to searches. Accurate conversion of voices of unspecified speakers into text form is often difficult, and searches of such voice-based texts cannot be performed with high precision. The Fast-Talk Phonetic-Based Searching does not search for words but rather for phonemes, or basic elements of pronounced English words. The technique thus allows searches on novel words, slang, and inaccurate spellings, as well as proper nouns, phrases, and initials. Since phoneme patterns in voice data are indexed for comparison and searching in this method, recognition rates of as high as 98% can be obtained on unspecified speakers. The specifications published by Fast-Talk call for a recorded voice quality of "studio-quality S/N ratios," but recognition rates sufficiently high for practical purposes are attained when voice communications, encoded by G.728 at a bandwidth of 16Kbps, are transmitted across the Internet and recorded. For index searches on phoneme patterns, one has to build an index called the PAT (Phonetic Search Track) files. This preprocessing on classroom data can be performed on regular PCs in about one third of the time spent in class. Thus, high-performance servers would allow the preprocessing to be done in real time, making it possible to deliver classroom data immediately after the end of the class in the form of Web content that is searchable by voice-data keywords. We have prototyped a new digital-content production system hitherto unavailable, by adding the new search capability by means of voice-data keywords to the conventional content produced by the EZP. In the uppermost frame of the screen shown in Figure 6 (Class Content), a text box is provided on the left for entry of the voice-data keyword and a list box on the right for display of search results. The list box shows the search hits in the order of relative scores and the reference times of their occurrence in the class. By clicking on a hit entry, students can instantly jump to the spot of interest in the content.

Since our system conclusively generates about 600Mbyte content for a 3-hour lecture, the total contents of one-semester classes consumes about 9Gbyte disk space. The students can access the Web contents through the Internet with bandwidth connections of about 384Kbps.

EVALUATION BY STUDENTS

At the end of the last class on welfare engineering introduced in section 2, the students were surveyed on distance lectures and the use of lecture content. Figure 7 shows the results relating to distance lectures. As the Figure shows, approximately 60% of

Figure 7. Questionnaire survey on distance lectures



the students were favorably inclined to the video and audio. It can be seen that the results were good, with close to 80% feeling they might take similar distance lectures in the future. However, only about 40% felt favorably towards interactivity. In a lecture involving a small number of students and delivered point-to-point, such as one of the pre-MBA classes, interactivity was viewed favorably, but in a distance lecture such as a welfare engineering lecture, which is distributed to many locations and to a large audience, the problem of insufficient interactivity arises probably because it is difficult for the participants to communicate with one another. On this point, the instructor may need to proactively call upon the students to check on questions and reactions.

A series of lectures was post produced into digital content with the EZP and made available on the Web server after the lecture. Since the audio-based keyword search function was still at a prototype stage, however, it was not incorporated in the Web content. Approximately 90% referred to the Web content, as shown in Figure 8, indicating that an unexpectedly large number of students used the service to review materials.

Figure 8. The number of students who used the Web contents

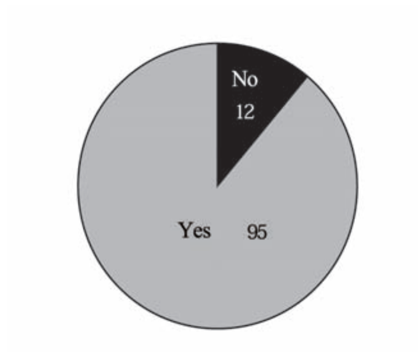
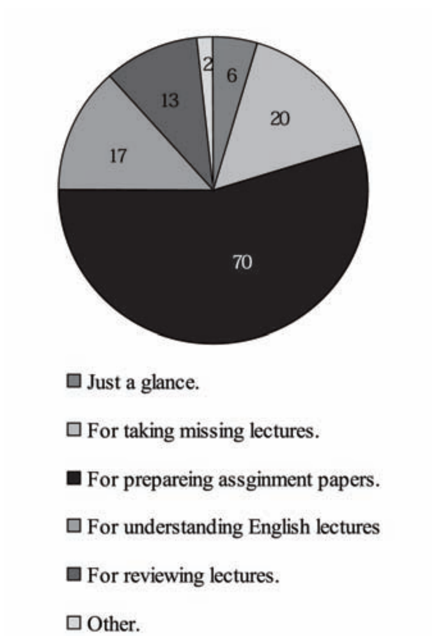


Figure 9 shows the ways in which the service was used. From the figure, it can be seen that a majority of the students referred to the content to prepare assignment papers. In Welfare Engineering, the lectures focus on the latest topics, and in preparing a paper, students need to base their considerations on knowledge acquired from the lecture itself rather than delving into reference books. This is believed to be why the ratio of students using the content to prepare papers was so high.

Figure 9. The ways in which the service was used



CONCLUSION

This article described an automatic digital content generation system for lectures, developed and improved based on practical experience accumulated through distance classes at Hosei University. By adopting this system, it is possible after a class not only to reproduce presentation material, including handwritten data, without any editing work, but also to provide a Web content that allows instant retrieval through an audio-based keyword search. Because the audio-based keyword search interface is still at a prototype stage, content generation is not yet fully automatic, and after extracting audio data manually, a PAT file is created for the content generated automatically by the EZP. We hope to complete a system that can automatically generate digital content that includes a phonetic-based keyword search function without a need for post processing.

We also plan to develop a system in which data written on a whiteboard in a normal classroom can be extracted and stored as vector data, and to adapt the audio-based keyword search to accommodate the Japanese language.

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Chapter II
E-World:
A Platform for the Management of Adaptive E-Learning Processes

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ABSTRACT

In this chapter the authors present E-World, an e-learning platform able to manage and trace adaptive learning processes which are designed and created by means of a visual language based tool. To address the goal to have a platform easily extensible with new services, they have designed it selecting a software architecture based on the use of Web Services and a suitable Middleware component. To trace adaptive learning processes E-World also integrates as Web Service a suitable implementation of a Run-Time Environment compliant with the Sharable Content Object Reference Model (SCORM) standard. Their proposal also supports the "anytime and anywhere" learning paradigm as it enables learners to enjoy linear or adaptive processes using any device equipped with a standard Web browser. In the chapter they also report on the experiment we have carried out to assess the usability of the proposed e-learning platform.

INTRODUCTION

During the last decade a surprising evolution of electronics, computer systems and information technologies, together with the worldwide accessibility to the Internet have made available an incredible set of applications. This trend has significantly conditioned the emerging and the evolution of new academic and industrial opportunities. In particular, the possibility to easily reach an extremely large number of users with significantly low costs has motivated the development of an increasing number of web applications for educational purposes. As a result, e-learning has achieved a worldwide acceptance in several domains, such as universities, secondary schools, companies, and public institutions.

The e-learning evolution proposes a good number of tools assisting instructional designer during the analysis, design, and delivery of instruction and on the other side provides powerful tools supporting students during the knowledge acquisition process. Nowadays, the traceability of learning process is becoming more and more interesting for both teachers and students. In particular, teachers use the achieved information to compare the expected target audience with the students, who really attend the course. Moreover, information on learning performances and the explicitness of teaching materials can also be analyzed to assess the agreement with the teacher expectations. From the student point of view, traceability information is used to assess the acquired knowledge and plan the efforts in the knowledge augmentation process. In order to trace the learning processes several kinds of e-learning platforms have been proposed in the market, see e.g. (IBM, 2008)(BlackBoard, 2008).

To make the knowledge delivery more effective the personalization of the learning process is crucial as didactic contents are usually intended for very large and heterogeneous groups of learners in settings where no teacher is available to help them. Thus, e-learning processes should adapt themselves to the learners' background and to their achieved knowledge. The use of adaptive processes should move e-learning from teacher-centered to student-centered, thus making the knowledge acquisition more flexible and effective.

Initially, different kinds of communication infrastructures between e-learning content objects and e-learning platforms were defined and used. On the other hand, in the last few years standards providing standardized data structures and communication protocols have been proposed. In particular, the ADL (Advanced Distributed Learning) consortium (ADL, 2004) produced the SCORM (Sharable Content Object Reference Model) (ADL SCORM, 2004), consequently the collaboration among government, industry and academia to enable interoperability, accessibility, and reusability of Web based didactic contents.

Currently, other relevant challenges characterize the e-learning research, such as interoperability, reuse and extensibility of software components. In order to understand that, it is worth noting that the success of e-learning has caused the proliferation of several kinds of e-learning related software applications, from content delivery to collaborative environments. As a result, many companies are entering in the learning market developing new products and often combining existing components opportunely configured. Thus, it is important to understand how these systems relate to each other and how they fit into a complete e-learning environment. Moreover, the issue of component interoperability is especially relevant to promote reuse of services and develop e-learning systems starting from heterogeneous components.

In order to address the above issues we propose an e-learning platform named E-World, whose software architecture is based on *Web Services* (Bosworth, 2001), (Roy & Ramanujan, 2001) and on a suitable *Middleware* component (McKinley *et al.*, 1999). *Web Services* technology provides a common infrastructure to integrate heterogeneous software components, thus enhancing interoperability between different components and component reuse. Whereas the extendibility feature of e-learning systems is ensured by the use of a specific *Middleware* component.

Further appealing features characterize the proposed e-learning platform. First of all, special focus has been put on e-learning standards that have been recommended in the last years. In particular, the proposal provides a suitable implementation of the *Run-Time Environment* (*RTE*) (SCORM RTE, 2004) suggested in the *Sharable Content Object Reference Model* (ADL SCORM, 2004) by the *Advanced Distributed Learning* (*ADL*) consortium (ADL, 2004). The *SCORM RTE* addresses an important issue, namely the traceability of student learning process. In particular, to enable the traceability of student's activities it defines the format of messages exchanged between the content and the e-learning system. E-World is also able to trace adaptive learning processes designed and created by a visual language based tool, namely ASCLO-S (Adaptive Self Consistent Learning Object Set) (Casella *et al.*, 2004). Moreover, to realize an accurate evaluation of each student, instructors can benefit from some information on the learning processes that the students enjoyed, such as the time spent to consume a didactic content or to complete a test.

Another notable characteristic of E-World is that it is also suitable for m-learning. In order to understand this aspect, it is worth noting that when designing e-learning applications that should be also apt for m-learning, the limitation of resources of mobile devices has to be considered. In particular, software architectures that do not require specific resources on the client side should be conceived. To this aim, we provide E-World with a thin client web architecture, thus ensuring that the delivered e-learning courses are suitable for any kind of client devices and also for mobile devices equipped with only an *HTML* browser and a wireless connection.

We also propose an empirical evaluation aimed at assessing both E-World usability and the students' performances on the teaching approaches pure and blended. The usability of the proposed platform was evaluated using a questionnaire, while the information traced by E-World was used to analyze the students' performances on the pure and blended teaching approaches. The analysis of the students' performances revealed the knowledge improvement of the subjects was not influenced by the used teaching approaches.

The remainder of the chapter is organized as follows. The key features of *Web Services* and the main concepts related to the *SCORM* standard are reported in the first two sections, respectively. Then, we describe E-World and the empirical evaluation we have conducted to assess it, respectively. Related work and final remarks conclude the chapter.

Web Services

Web Services are modular, self-describing applications universally accessible in a standardized and platform independent way (Bosworth, 2001), (Roy & Ramanujan, 2001). These applications communicate by standardized XML messages. *Web Services* are based upon three technologies: *Web Services Description Language* (*WSDL*), *Universal Description Discovery and Integration* (*UDDI*) and the *Simple Object Access Protocol* (*SOAP*).

In a typical *Web Services* scenario the service provider publishes all the information about a service in a *UDDI* registry. This registry stores descriptions and metadata for each registered service using the *WSDL* language, a common XML format. Once the service is deployed, each client application can ask for it to the registry. This registry sends to the client information to bind and use the required service. The client application sends a request to a service at a given URL using the *SOAP* protocol. The service receives the request, processes it, and returns a response. *Web Services* can be also directly used by accessing to the provider. The following are the most known advantages provided by the *Web Services* use:

- *Interoperability* – they improve the interoperability among different systems and operate on the "system boundaries" for communicating in a standardized way. They are described using a standard language to let external applications understand and invoke them.
- *Easy to use* – by their use the core business logic of systems is easily offered over the Web without knowledge of their target system's environment. Client applications can use one or more *Web Services* combining their results to accomplish a task. Moreover, developers use *Web Services* without changing their own component object model, architecture, and implementation strategy.
- *Reusability –Web Services* are software components that are reusable and extendable. They can be consumable by both humans and computers, for example, through a desktop application or API.
- *Ubiquity – Web Services* respect existing security systems and as a consequence they are accessible from anywhere.

e-Learning Standards

Components in an e-learning system can be distributed on different machines and provided by different suppliers. To support this distribution, ensure interoperability across systems, and guarantee reusability of instructional contents, several standardization initiative have been launched.

This section describes the main concepts related to e-learning standards and focuses on the *SCORM RTE* proposal (SCORM Sample, 2004). In order to better understand these notions, we start by briefly outlining the main components of an e-learning system and stressing the importance of student's activity traceability.

The Main Components of an e-Learning System

Usually e-learning systems provide a variety of capabilities. Nevertheless, a general agreement exists on the core functionality of an e-learning system. In particular, they are usually grouped in two components: the *Learning Management System* (*LMS*) and the *Learning Content Management System* (*LCMS*). Teachers and instructional designers exploit an *LCMS* for creating and modifying activities composing e-learning courses. In particular, the *LCMS* component supports authors in the creation and management of digital instructional contents, which are stored in a repository (Apple *et al*, 2002; Campbell & Mahling, 1998; Douglas, 2001). Thus, the tool provides functionality to define tests (Safoutin *et al.*, 2000), didactic contents (Designer's Edge, 2003), collaborative environments (Chang *et al.*, 1996; Cuthbert, 1999), and course editing (Goodyear, 1997; Kasowitz, 1997; Vrasidas, 2002).

On the contrary, an *LMS* (also known as e-learning platform) provides features to manage all the activities surrounding learning deployed via Web, such as user authentication, course deployment, and management of collaborative synchronous and asynchronous environments. Moreover, an *LMS* interacts with the run-time environment, which is addressed by learners and traces the student learning process while the e-learning course is enjoyed. The information collected during the traceability is processed and organized to obtain statistics on learners' behaviours and to improve the overall quality of the learning process. For instance, traceability information can be used to personalize knowledge contents, thus, improving students' welfare and their learning performances. Moreover, during assessment tests, information about each given question and the time spent to answer it can be usefully exploited by the instructor to get a deep evaluation of each learner.

The SCORM Standard

In general, the purpose of e-learning interoperability standards is to provide standardized data structures and communication protocols for e-learning content objects and systems. The use of these standards into e-learning products enables on one side instructional designers to reuse knowledge contents and on the other side organizations to purchase system components from multiple vendors with confidence that they will effectively work together (Rosenberg, 2001; Smythe *et al*, 2002; SUN, 2002).

Several international organizations, such as IEEE's Learning Technology Standards Committee (IEEE LTSC, 2004), IMS Global Learning Consortium (IMS, 2004), US Department of Defence, Aviation Industry CBT Committee (AICC, 2004), Advanced Distributed Learning consortium (ADL, 2004), ARIADNE (ARIADNE, 2004), PROMETEUS (PROMETEUS, 2004), are contributing to this standardization.

In particular, the Advanced Distributed Learning (ADL) initiative is a collaborative effort among government, industry, academia, and organizations to establish an environment that permits the interoperability of learning tools and course contents.

Starting from these collaborations *ADL* produced the *SCORM* standard (ADL SCORM, 2004), which specifies consistent implementations that can be used across the e-learning community. *SCORM* is composed by some specifications that enable interoperability, accessibility, and reusability of Web-based learning contents.

In the following we describe the main features of the *SCORM* standard, which are relevant for our proposal, namely *Metadata*, *Content Packaging*, *Content Sequencing and Navigation*, and *Content Communication*.

To enable a common nomenclature for the indexing, the storage, the discovery, the retrieval, and the exchange of e-learning resources *SCORM* provides *Metadata* to be applied to knowledge contents at several granularity levels (IEEE LTSC, 2004). Improving the completeness, carefulness, and flexibility of metadata, e-learning resources are better described and can be also reused in several learning contexts with different aims.

Responsibilities and requirements for *Content Packaging* are defined in the *SCORM Content Aggregation Model* and are characterized by *Content Aggregations*, *Activities*, *Sharable Content Object* (*SCO*[1]), and *Assets*. As a consequence, a content package is described by a manifest, which bundles content objects with content organization. A *SCO* can be meant as a course, a lesson, a module, or simply a collection of related content objects (*Asset*). It is worth noting that only *SCO* didactic resources can be traceable.

The *SCORM Sequencing and Navigation* book describes how the contents are sequenced through a set of learner or system navigation events (SCORM SN, 2004). The branching and flow of the contents are described by a predefined set of activities, which are typically specified by the teacher at the design time. *ADL* describes the content sequencing and navigation in terms of an Activity Tree, based on the results of learner's interactions with content objects and a designed sequencing strategy. *LMS* using that data structure is able to manage learning processes as the suitable sequence of content objects to deliver.

Content Communication defines standard methods to establish and exchange information on the learning process to implement the learner traceability. *ADL* describes the communication between content (in particular, a *SCO* element) and *LMS* in the *RTE* book (SCORM RTE, 2004). Indeed, *SCORM* standardizes a common way to launch contents, to enable the communication with the *LMS*, and predefined data elements that are exchanged between an *LMS* and content during its enjoying. Thus, in the *SCORM RTE* three aspects are specified, namely the *Launch*, the *Application Program Interface* (*API*), and the *Data Model*.

The *Launch* process defines a common way for *LMS* to start content objects. Moreover it specifies procedures and responsibilities for establishing the communication between the launched content object and the *LMS*.

Application Program Interface is a set of predefined functionality that should be considered by both *LMS* and *LCMS* vendors to enable communication between them. These functionality complete the launch process by establishing a *handshake* between the *SCO* and the *LMS* that launched it and breaking that *handshake* once the *SCO* is no longer needed. Assessment process, content enjoying, and errors that occur during these learning processes are traced by using *SCORM* content, which *set* and *get* data on the *LMS*.

In the *Data Model* vocabulary we can find the definitions of the actions "to *get* and *set* data from and to an *LMS*" when *SCORM API* functions are called. For instance, when passing a test score from a learner, a *SCO* would use the *SCORM Data Model* element known as *cmi.score.scaled* to inform the *LMS* on the learner's performance.

e-World

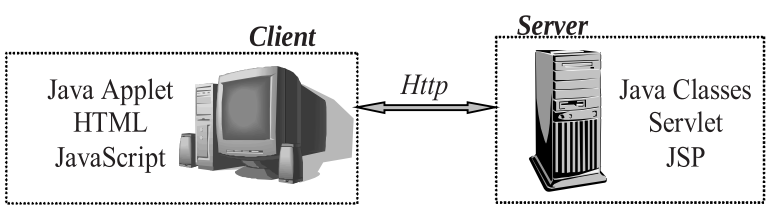
In this section the main features of E-World and its software architecture are described. In particular, we first report on the implementation of the *SCORM RTE* suggested by the *ADL* organization and then we outline our proposal.

ADL Implementation of SCORM RTE

To fill the gap between the early standardization stages and the widespread adoption the ADL initiative proposes content examples, a conformance test suite, and a sample Run-Time Environment (RTE). Concerning the Run-Time Environment (RTE), the ADL proposes a realization of the API (Application Programmer's Interface) enabling the communication between didactic contents and e-learning platforms to implement the traceability, and the content sequencing and navigation. This implementation is based on a typical client/server Web architecture. The server component implements the RTE by J2EE technology, while the client component needs a Web browser supporting ECMA script and Java applets to enable the communication between didactic contents and an e-learning platform. Figure 1 shows the communication conceptual schema proposed by *SCORM*.

It is worth noting that the sample implementation proposed by *ADL* is not suitable to ensure also an effective m-learning. Indeed, it requires

Figure 1. The communication conceptual schema of the SCORM sample



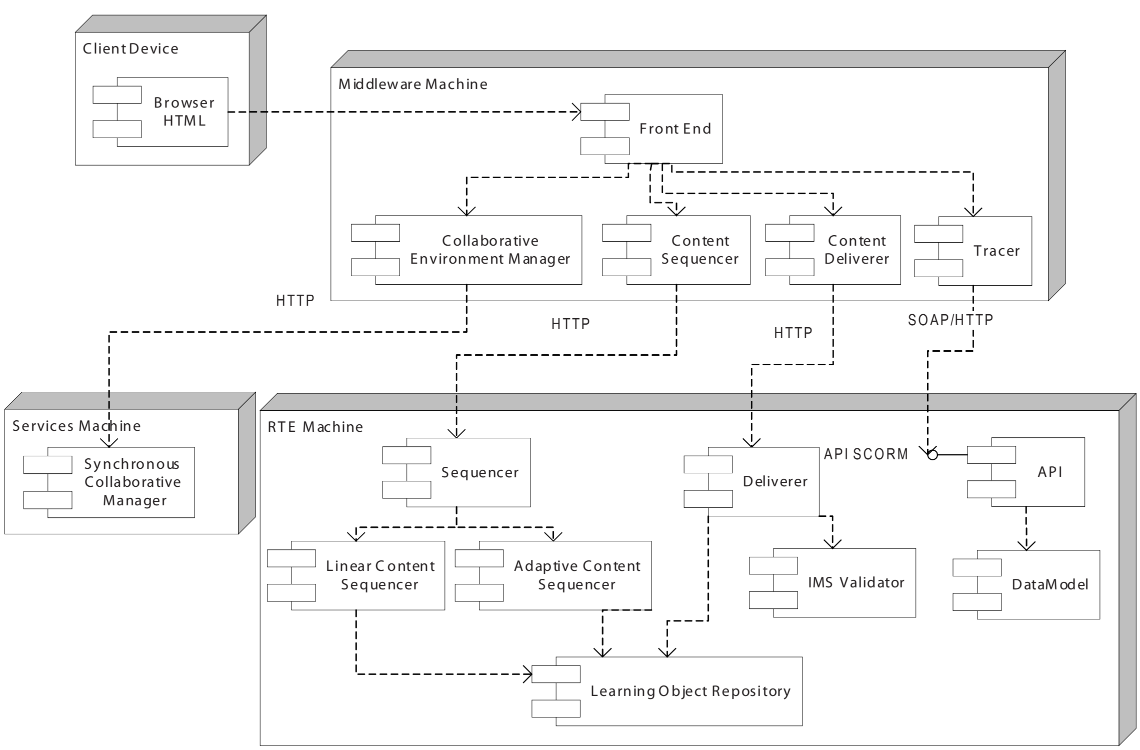
that the browser is able to support technologies such as Java and ECMA script, which could not be the case in the context of m-learning due to the limited resources available on the client side.

The Architecture

To simplify on the client side the technology infrastructure proposed by *ADL* we propose an alternative implementation of the communication schema, which is based on pure HTML. We adopt here the communication schema and extend the platform proposed in Casella *et al.* (2007) to enable the traceability of adaptive didactic contents, and synchronous and asynchronous collaborative environments. The contents and the collaborative environments are designed and created by two visual authoring tools named ASCLO-S (Adaptive Self consistent Learning Object SET) editor (Casella *et al.*, 2004) and SYCLE (SYnchronous Collaborative Learning Environment) editor (Costagliola *et al.*, 2004), respectively. Figure 2 shows the relationship between the run-time components and the hardware nodes of the extended e-learning platform, named E-World. For space reasons and for the scant relevance, the component diagram in Figure 2 does not contain the software components implementing the user profiling and identification.

The *Middleware Machine* node is composed of five software components that together compose the *Middleware* of the E-World software architecture. The *Front End* component aims at presenting the appropriate features and contents to the students and teacher using the components on the *Middleware Machine* node. In particular, *Front End* uses *Content Sequencer* to show the suitable knowledge content to the students, while to trace the learning process the *Tracer* component is proposed. Differently, the *Content Deliverer*

Figure 2. A UML deployment diagram representing the allocation of components to different nodes



component allows the instructional designer to deploy single e-learning activities or whole courses. Finally, the *Collaborative Environment Manager* component is used to manage the co-operation among students and teachers.

The *RTE Machine* node contains the software components to manage and deploy linear and adaptive didactic contents as well as to trace learning processes. The *Sequencer* component is used by the *Content Sequencer* component to manage learning processes. Currently, E-World is able to manage linear content sequencing, as proposed in the standard SCORM, and adaptive content sequencing as suggested in (Casella *et al.*, 2004). It is worth noting that because of the flexible architecture, this platform can be easily extended to manage different adaptive models. The *API* software encapsulates a Run Time Environment (RTE) compliant with the SCORM standard and provides an interface to enable the traceability of didactic contents. The interface is the same as described by the ADL in the RTE book (ADL SCORM, 2004). These *APIs* are used to establish a handshake between didactic contents and the RTE of the e-learning platform. The *API* software component is also used to store information on the student interaction with the presented didactic contents into the E-World database.

The deployment of a process based on synchronous and asynchronous activities (Costagliola *et al.*, 2004) first requires the validation of its e-learning activities and then the updating of the system database. It is worth mentioning that the platform also enables the deployment of single e-learning activities. Concerning the e-learning activities two different validations are performed. In particular, didactic contents, adaptive learning processes, and tests are validated differently from the synchronous collaborative activities. In order to deploy linear and adaptive didactic contents in E-World their SCORM IMS Manifest have to be validated using a suitable parser. Differently, a QTI (Smythe, 2002) parser is required to validate the manifest of a test.

The *Synchronous Collaborative Manager* component on the *Service Machine Node* provides means to handle and use synchronous and asynchronous collaborative environments. Collaborative environments can also be used and managed separately from E-World. The database for the learners' profiling is not considered when this component is integrated in the proposed platform.

E-World has been developed using J2EE technologies. We have exploited Apache (Apache, 2004) and Tomcat (Apache Jakarta Tomcat, 2004) as Web Server and Web container, respectively. Moreover, to integrate the component to trace the learning process we used a *Web Service*. It has been implemented by exploiting *AXIS SOAP* engine (Apache Axis, 2004), which is a framework developed in Java by the Apache Group for constructing *SOAP* processors such as clients and servers.

Assessing e-World

In this section we report an experimental evaluation aimed at assessing the E-World usability and students' performances on two teaching approaches, i.e., blended and pure. The usability was assessed using a questionnaire, while we have used the information traced by E-World to compare the two considered teaching approaches.

Definition and Context

The subjects of the experiment were fifteen students attending the Web Development Technologies course of the Bachelor program in Computer Science at the University of Salerno. They were volunteers with comparable background as the questionnaire used to asses the E-World usability and filled in at the end of the experimental evaluation revealed. The experiment has been performed online at the University of Salerno in the Web Development Technologies research laboratory.

We performed the experiment in two laboratory sessions. In particular, the subjects that used the blended approach accomplished the laboratory session first. They were nine and attended a classroom lesson and after an online lesson on the same knowledge contents. The subjects experimented the pure teaching approach were six and enjoyed only the online lesson. It is worth noting that the subjects were involved only in one of the laboratory sessions.

Two learning tasks to be accomplished within two hours have been used:

- T_1: enjoying a course on XML (eXtended Mark-up Language) and performing a self assessment test evaluate the acquired knowledge;
- T_2: enjoying a course on XSLT (eXtensible Stylesheet Language Transformations) and performing a self assessment test evaluate the acquired knowledge.

The subjects selected to experiment the blended approach performed the first task, while the remaining subjects accomplished the second task.

It is worth noting that the perceived usability was assessed using a questionnaire that was the same for all the subjects involved in the experimentation (further details on the questionnaire can be found in the section Preparation, Material, and Execution).

Hypotheses Formulation and Selected Variables

To assess students' learning performance on the considered teaching approaches a null hypothesis has been defined. Indeed, we have formulated this hypothesis with the aim of comparing the teaching approaches blended and pure:

- **H_{n1}:** There is not a significant difference between the knowledge that the subjects acquired performing the learning tasks in the blended and pure contexts.

The alternative hypothesis is:

- **H_{a1}:** There is a significant difference between the knowledge that the subjects acquired performing the learning tasks in the blended and pure contexts.

In order to properly design the experiment and analyze the results, we considered the following independent variable:

- **Method:** this variable indicates the factor on which the study is focused, i.e. blended and pure.

The following dependent variable has been identified:

- **Score:** the score of a self assessment test used to evaluate the acquired knowledge. The test was composed of ten multiple choice questions concerning the didactic contents that the subjects enjoyed in the laboratory sessions.

Preparation, Material, and Execution

We have used as server a PC, where the E-World platform and the required technical infrastructure were installed. On the other hand, the subjects used PCs equipped with the web browser Internet Explore 6.0. A training session of fifteen minutes has been carried out to give subjects an equal prior knowledge of the experiment. We also presented E-World to let subjects get confidence with it. The training session was concluded presenting instructions on the learning tasks.

Once the subjects accomplished the learning tasks the supervisors collected the information traced by E-world, namely the time spent to enjoy each knowledge fragment and the score of the self assessment test. It is worth noting that to avoid frustration and disappointment during the fruition of the content within the two tasks; the students were not informed of the traceability of the learning process. For privacy reasons, the students were informed after the accomplishment of the experiment.

At the end of the laboratory sessions a questionnaire was presented to the subjects of both the laboratory sessions. This questionnaire aimed at collecting information on the usability perceived by the subjects on the E-World platform. To investigate different usability issues 41 questions were included in the eight categories of the questionnaire. *Student Background (A)* category was composed of three questions to assess the homogeneity of the statistic sample. The general reaction of the students in terms of satisfaction degree has been evaluated by the questions belonging to the *General Reaction (B)* category. The questions of the *Page Structure (C)* category aimed at assessing layout and structure of the pages, as well as their contents. The satisfaction degree of the students about the terminology that the platform used was evaluated by the *Terminology (D)* category. The *Platform Learning (E)* and *Platform Capability (F)* categories aimed at investigating the satisfaction degree of the system learning simplicity and its performances, respectively. Finally, the satisfaction degree on the used multimedia objects and the enjoyed knowledge contents was evaluated by the questions of the *Multimedia Object Management (G)* and *Student Satisfaction (H)* categories, respectively. The questions composing the usability questionnaire, except those of the *A* category, are shown in see Table 1. The

Table 1. Questionnaire

Id	Question
B	Cross one of the numbers that better reflect your judgment of the E-World Platform. (*General Reaction)*
B.1	From *horrible* to *wonderful*
B.2	From *frustrating* to *satisfying*
B.3	From *difficult* to *easy*
B.4	From *boring* to *exciting*
B.5	From *incomprehensible* to *understandable*
C	Judgment of the E-World pages (*Page Structure*)
C.1	Reading the characters in the pages is (from *simple* to *difficult*)
C.2	The characters appear (from *fuzzy* to *clean cut*)
C.3	The chosen fonts are (from *incomprehensible* to *understandable*)
C.4	The character colours are (from *appropriate* to *inappropriate*)
C.5	The character size is (from *appropriate* to *inappropriate*)
C.6	The contrast between the text and the background lets you distinguish the page content (from *not well* to *well*)
C.7	During the navigation the page structure supports you (from *never* to *always*)
C.8	The amount of the information that can be visualized in a page is (from *inappropriate* to *appropriate*)
C.9	The way the page contents are arranged is (from *illogical* to *logical*)
C.10	The sequence of the pages is (from *unclear* to *clear*)
C.11	The page navigation is (from *unpredictable* to *predictable*)
C.12	Coming back to the previous page is (from *difficult* to *simple*)
C.13	Coming back to the home page is possible (from *never* to *always*)
C.14	The orientation while you navigate is (from *difficult* to *simple*)

continued on following page

Table 1. continued

C.15	The graphical layout of the pages is coherent (from *never* to *always*)
D	Used terminology and provided information (*Terminology*)
D.1	The use of nomenclatures and terminologies of the platform is (from *inconsistent* to *consistent*)
D.2	The nomenclatures and the terminologies are difficult to understand (from *often* to *never*)
D.3	The terminologies is appropriated with the performed actions (from *often* to *never*)
D.4	Technical terminologies is used (from *often* to *never*)
D.5	Links, names, and titles of the pages are (from *confusing* to *appropriate*)
D.6	E-World advised you during the contents fruition (from *never* to *always*)
D.7	The action accomplishment leads to predictable result (*from* never to *always*)
D.8	The page contents are introduced by the page title (from *never* to *always*)
E	Judgment on the learning of E-World (*Platform Learning*)
E.1	Learn to use E-World is (from *difficult* to *simple*)
E.2	How long does it take to master the platform? (from *much* to *little*)
E.3	Finding the sensible maps is (from *difficult* to *simple*)
E.4	Remembering the names and using the platform commands is (from *difficult* to *simple*)
E.5	The steps to accomplish an operation are (from *much* to *little*)
F	Performance and simplicity of the E-World platform (*Platform Capability*)
F.1	The platform is (from *slow* to *fast*)
F.2	The pages are downloaded (fro *slowly* to *quickly*)
F.3	Your expertise level conditioned the E-World usage (from *yes* to *no*)
G	The quality of the multimedia objects (*Multimedia Object Management*)
G.1	The image quality is (from *bad* to *good*)
G.2	The images are (from *fuzzy* to *clean cut*)
H	Satisfaction degree of the presented knowledge objects (*Student Satisfaction*)
H.1	The presented knowledge contents integrate the classroom lesson (from *no* to *yes*)
H.2	The knowledge contents are clear and well organized (from *no* to *yes*)
H.3	Unclear knowledge contents could be enjoyed more than once (from *never* to *always*)

answer for each question ranges between 1 and 9. For example, the value 1 for the question *2.1* represents the worst judgment (*horrible*) that the tester can express on the platform user interface, while the best judgment (*wonderful*) is expressed by the value 9.

The subjects were asked to fill in the designed questionnaire at the end of the laboratory session. Moreover, it was also kindly required to annotate any type of problem they found during the use of the platform. To carry out the controlled experiment each subject was also provided with a folder with a pencil, some white sheets, and the E-World user manual.

Usability Results

The students of the blended group expressed a good general judgment on the platform. The students' suggestions revealed that on one side the platform did not produce any kind of disorientation or problem and on the other side that students considered this platform not rousing. The second group of students, namely pure group, had a different reaction. In particular, the questionnaire answers revealed that the students were divided in two groups. 50% of the students expressed a sufficient satisfaction degree, while a mediocre judgment was expressed by the other students. As expected, students who first attended a traditional classroom lesson reached a greater satisfaction degree than the students enjoying only digital contents.

Better results were achieved by the answers of the questions of the C category. Indeed, the students of both the groups expressed a satisfaction degree on the page graphical layout in terms of characters, images colours, and navigation. Despite the positive reaction of the students, some of them suggested improving both the page platform navigability and the fruition of the knowledge contents by a larger central frame.

The analysis of the D category revealed that on the average the satisfaction degree of both the group of students is sufficient. In particular, three groups of students having the same size and belonging to the pure group expressed a general judgment between mediocre and fairly good. On the other hand, 20%, 50%, and 30% of the students of the blended group expressed a mediocre, sufficient, and fairly good judgment, respectively. Once again the platform was more appreciate from students who first attended a traditional classroom lesson.

Concerning the E category, 40% and 60% of the students of the blended group found the platform fairly good and good to learn, respectively. Similarly, 83% of the students generally expressed a fairly good judgement, while the remaining students expressed a mediocre judgment. They expressed a worse satisfaction degree for the number of steps to accomplish an operation. Concerning the F category the students of both the groups expressed almost the same positive judgment.

Unlike the students of the blended group, the students of the pure group expressed a scant satisfaction about the multimedia objects. They found the images fuzzy and of a poor quality. However, both the groups provided a sufficient judgment, in general.

The assessment of the subjective findings was concluded analyzing the answers provided for the questions of the H category. A mediocre judgment on the average was expressed from the pure group, while the blended group expressed a more positive judgment.

The evaluation of the objective findings was concluded by analyzing the information gathered by the experiment supervisors and E-World platform. The achieved information was used to identify further problems on platform usability and delivered knowledge contents. For instance, on the self-assessment test presented at the end of the lesson, a meaningful usability problem was revealed. The traceability information showed that most of the recruited students confused the meaning of two buttons, namely next and submit. The next button should be intended for skipping the question, while to answer to a question the latter button had to be used.

Comparing the Approaches Blended and Pure

The analysis of the data traced by E-World during the two laboratory sessions revealed that the pure approach does not significantly affect the knowledge acquisition of the subjects. This result was achieved using the one-way ANOVA test. To apply this parametric test the following four assumptions had to be verified: the observations are independent; the scale of measurement for the observations is interval; the distribution of the observations in each group is normal; and the variance of the observations in the groups is the same.

The first and the second assumption were easily verified since the two groups of subjects are composed of separate individuals and the scale of measurement for *Score* and *Time* is continuous. To verify the normality of the distributions we have performed both the Kolmogorov-Smironov and Shapiro-Wilk tests (Roston, 1982). The results of these tests revealed that the normality is verified for the considered variables. To verify the last assumption, we adopted the Levene statistic test. The null hypothesis of the test cannot be rejected, thus the variance of the variable *Score* is homogenous. Therefore, the one-way ANOVA can be applied to confirm or reject the defined null hypothesis.

The results of the one-way ANOVA are shown in Table 2. This test suggests that the null hypothesis H_{n1} cannot be rejected. This means that there is not a significant difference between the knowledge augmentation of the subjects who experimented the blended and pure teaching approaches.

Related Work

Nowadays there are many e-learning products existing in the market, which are implemented using different technical infrastructures. Often these products are not compatible with each others. To overcome the incompatibility problem Web Services represent a valid solution. In fact, some researchers propose a *SOA*-based architecture for defining a decomposition of a generic *e-learning* system (Shih *et al.*, 2003)(Vossen & Westerkamp, 2006)(Wang *et al.*, 2005). Even e-learning standards and guidelines producers, as *IMS*, have started to focus their attention on Web services, proposing ad hoc specifications (IMS WS, 2005). For example, Shih *et al.* (2003) suggested the use of *SOAP* to implement *API Adapter* and transport parameter part in *LMS*. The *LMS Web Services* are implemented in .Net, while to enjoy knowledge contents the client needs specific software components. The components include a *SOAP* engine to allow the communication between *LMS* and client machine. Xiaofei *et al*., (2003) also propose a functional architecture based on Web Services for building standard-driven distributed and interoperable learning systems. The functional architecture defines components that make up an e-learning system and the objects that must be moved among these components. Costagliola *et al.* (2008) propose a SOA-based reference model to offer the SCORM Run-Time Environment functionalities as a service, external to an e-learning platform. The works proposed by Xiaofei *et al*., (2003) and Costagliola *et al.* (2008) differ from our proposal for the lack of a Middleware component to support m-learning and integrate new functionality.

Other SOA-based architectures are more focused on the search of LOs, which may or may not use standard functionalities. Tamura and Yamamuro (2006) propose a Web Services based architecture to allow LMS servers to share learning-related information, such as learning material, learner data and learning strategies. Each of the previous categories of information is kept by a different subsystem. According to Hussain and Khan (2006), Web Services can be used in the field of content repositories, in order to obtain an infrastructure for the centralized search and discovery of SCORM-based learning contents.

A proposal for a Middleware component was suggested by Apostolopoulos and Kefala (2003) with the aim to bridge the lack of a consistent management scheme in the integration of

Table 2. One-way ANOVA results

Source	Type III Sum of Squares	df	Mean Square	F	p-val
Method	100.000	1	100.000	0.025	0.878
Error	52830.333	13	4060.410		
Total	581000.000	15			

e-learning services. They implemented the e-learning components as agents, which are maintained in a local Management Information Base, and can communicate with the agent manager through the *SNMP* protocol. Nevertheless, their *LMS* is not compliant with any e-learning standards and does not provide support for m-learning.

An architecture based on J2EE has been proposed from Wang & Zhang (2003) to run the e-learning services on different platforms. In their system, Platform Independent Model artefacts are modelled using UML, whereas Platform Specific Model artefacts are modelled using the UML profile for EJB for the target platform.

Finally, it is worth noting that the market and the academy community propose to use *Web Services* and other technologies based on software components with different aims. These technologies are useful for integrating new software components in e-learning systems and can provide a new communication schema between the server and the client machines.

CONCLUSION

Current advances in computing and the development of pervasive applications, intensify the diversity problem, giving rise to many variations in terms of performance, environments, and device characteristics. The use of a Middleware provides us with an integration framework for multiple and potentially diverse computing platforms. Moreover, the synergistic use of a *Middleware* component and *Web Services* turns out to be a suitable solution to integrate different software components, to easily extend the e-learning system with new features, and to improve interoperability among different systems.

In the chapter we have described E-World, an e-learning platform with a software architecture based on Web Service and a Middleware component. An important issue addressed by this platform is the effective support of the traceability of linear and adaptive learning process. As a matter of fact, the designed software architecture of E-World integrates components, which have been specifically conceived to trace the student learning process, to deploy e-learning courses, and to manage the knowledge sequence to be presented at a learner. Moreover, the software that enables the learner traceability has been developed to be compliant with *SCORM* standard. Finally, the system architecture has been also conceived to effectively realize the learning in "anytime" and in "anywhere". To this aim our efforts were addressed to let a learner enjoy knowledge contents via pure *HTML* browsers.

To assess the E-World effectiveness, we have also performed an empirical evaluation aimed at analyzing the E-World usability. The study revealed that the subjects generally found the platform easy to learn and use. A good satisfaction degree was manifested as well. The study has allowed us also to compare the students' performances on two teaching approaches, i.e., pure and blended. Indeed, the analyses of the learning performances of the recruited subjects revealed that there is not a significant difference in terms of acquired knowledge both using the blended and pure teaching approaches.

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ENDNOTE

[1] It is worth noting that often the knowledge content is meant as *SCO*.

Chapter III
An Efficient and Effective Approach to Developing Engineering E-Training Courses

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ABSTRACT

In developing traditional learning materials, quality is the key issue to be considered. However, for high technical e-training courses, not only the quality of the learning materials but also the efficiency of developing the courses needs to be taken into consideration. It is a challenging issue for experienced engineers to develop up-to-date e-training courses for inexperienced engineers before further new technologies are proposed. To cope with these problems, a concept relationship-oriented approach is proposed in this paper. A system for developing e-training courses has been implemented based on the novel approach. Experimental results showed that the novel approach can significantly shorten the time needed for developing e-training courses, such that engineers can receive up-to-date technologies in time.

INTRODUCTION

In recent years, technologies have advanced at an amazingly fast pace; therefore, almost all of the high technical engineering knowledge and skills need to be updated or replaced with very high frequency; for instance, the engineering knowledge of the semiconductor and the electronics industries. One of the most important management strategies of the modern enterprises is to keep on improving the knowledge and skills of engineers via frequent training and practice. Take Motorola, for instance. The company budgets $120 billion annually for conducting employee training programs. American IDC (International Data Corp.) predicted that the e-learning market all over the world will triple in the next two years, and will share 40% of the entire training market.

The advantages of e-learning have been documented by researchers (Hwang 1998, 2002; Sun & Chou, 1996), including the feasibility of anytime and anywhere education, the availability of various learning styles, the reduction of education cost, the reusability of well-constructed and well-managed subject material modules, and so forth. Most of the engineering training programs that enterprises scheduled were designed and planned within their own organizations. Senior and experienced engineers of the organizations usually play the role of training instructors and course designers. That is, the responsibility of sharing experiences, skills, and knowledge heavily rely on those experienced engineers. As most of the engineers are not trained for tutoring, it is usually time consuming for them to design learning materials, and the training programs for those up-to-date technologies are often seriously delayed.

To cope with this problem, we shall propose a concept relationship-oriented approach to assisting the engineers in developing e-training courses. A course design system, CRETS (Concept Relationship-based Engineering Training System), has been developed based on the novel approach. Experiment results showed that the novel approach can assist experienced engineers to design quality e-training courses efficiently, and hence inexperienced engineers can receive up-to-date information of those rapidly advanced technologies.

RELEVANT RESEARCHES

Engineering training is not only a frequent activity but also a heavy burden to enterprises, owing to the rapid advance of new technologies. As engineering courses need to be replaced or updated frequently, researchers have attempted to apply e-training technology to efficiently and effectively develop and manage the learning materials and the training process. For example, a system that can assist in organizing system knowledge and operational information to enhance operation performance was proposed by Vasandani and Govindaraj (1991, 1995); moreover, a system that automatically determines exercise progression and remediation during a training session based on past student performance was presented by Gonzalez and Ingraham (1994). Meanwhile, various techniques and tools for developing intelligent tutoring systems have also been proposed, including the use of a neural networks technique to model student behaviors in the context of intelligent tutoring systems (Harp, Samad, & Villano, 1995), planning methods, consistency enforcement, objects and structured menu tools to construct intelligent simulation-based tutors for procedural skills (Rowe & Galvi, 1998), and technology for detecting online status of students to establish interactive intelligent tutoring system (Hwang, 1998; Giraffa, Mora, & Vicari, 1999). It can be observed that such e-learning or e-training systems have been widely applied to schools and industries recently (Ozdemir & Alpaslan, 2000; Hwang, 2002).

E-training approach has shown its superiority, such as the fact that skills and knowledge of experienced engineers can be retained and transferred to new employees, the learners are allowed to receive training courses without being limited by space and time, and so forth. However, the rapid advance of engineering technologies also reveals several problems of applying them, and one of the most challenging issues is to efficiently design quality learning materials to keep the skills and knowledge of senior engineers up-to-date and to train the new engineers (Tseng, Tsai, & Hwang, 2005).

Engineering training program contents are usually designed and planned by senior or experienced engineers. The training contents focus mainly on realistic needs of the industry. The procedure for designing a training course usually consists of several stages, A0~A10, where A0 is the preparation stage, A1 is the stage to determine the training topic, A2 is the stage to define course outlines, A3 is the planning and analyzing stage, A4 is the information collecting stage, A5 is course design stage, A6 is the purchase request stage, A7 is media design stage, A8 is the media making stage, A9 is the testing stage, and A10 is the training stage. Usually it will take nine to twelve months to complete an e-training course unit, which is obviously unacceptable for practical needs, especially for timely needs of new engineering skills.

To cope with this problem, a more efficient and effective approach for developing e-training courses is needed, and the relationships among those concepts to be learned seem to provide a natural way for engineers to represent their experiences and knowledge. In many pedagogic and psychological literatures, "conception" is defined as the common attributes of same category and the objects or events which are given the same names (Ausubel, 1963, 1968; Ausubel, Novak, & Hanesian, 1978). During tutoring, students learn new concepts and new relationships among previously learned concepts, and this knowledge can be represented as a concept map (McAleese, 1998). Salisbury indicated that learning information, including facts, names, labels, or paired associations, is often a prerequisite to efficiently performing a more complex, higher level skill (Salisbury, 1998). For example, the names and abbreviations of chemical elements and their atomic weights must be thoroughly learned to comprehend scientific writings or chemical formulae. Such concept relationship-oriented approaches have been used in education, policy studies, and the philosophy of science to provide a visual representation of knowledge structures and argument forms. They provide a complementary alternative to natural language as a means of communicating knowledge (Shaw & Gaines, 1992).

In the past decade, the notations of "concept" and "concept relationship" have been applied to the development of various systems or tools to support large volumes of multimedia materials generated in a variety of contexts, such as knowledge acquisition (Gaines & Shaw, 1992), large-scale project support (Gaines & Norrie, 1994), and diagnosis of student learning problems (Hwang, 2003; Hwang, Hsiao, & Tseng, 2003). Some researchers have attempted to develop a general visual language technology supporting customizable interactive concept maps (Gaines & Shaw, 1993) and semantic networks (Gaines, 1991). Such concept relationships may be used as stand-alone documents or embedded as interactive pictures in active documents (Gaines and Shaw, 1993); that is, it is an open architecture, and user interaction with the concept relationships may be programmed to initiate any available operation on the host system. Moreover, each set of concept relationships can be linked to other sets for retrieval purposes, and may be used to retrieve, play, and edit multimedia materials via remote access.

Representing knowledge as concept relationships is helpful to people in restructuring prior knowledge as well as organizing new experiences; that is, it is an effective way to represent knowledge and the learning process (Okebukola, 1984; Roth & Roychoudhury, 1992, 1993, 1994). In the following sections, a concept relationship-oriented environment for developing quality e-training courses is presented and some experimental results are given to depict the effectiveness of the novel approach.

Concept Relationship-Oriented Approach For Developing e-Training Courses

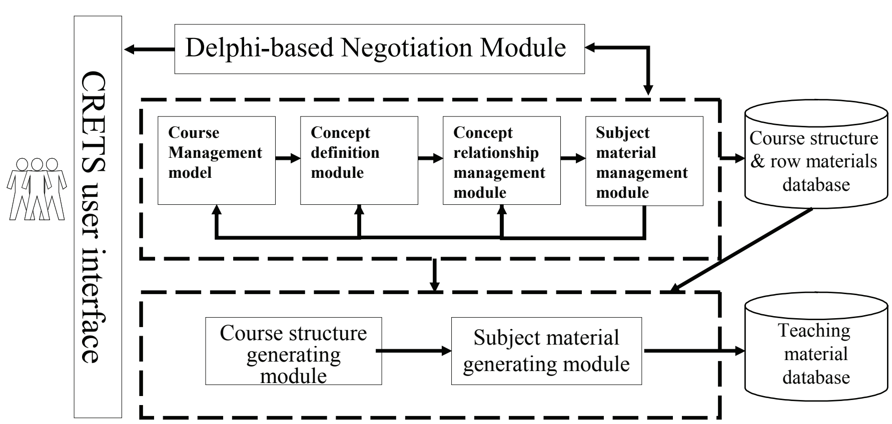
In this section, we shall present an engineering training material development environment, CRETS (concept relationship-oriented engineering training system). As shown in Figure 1, CRETS consists of a course management module, a concept management module, a course-concept relationship management module, a concept content management module, and a Delphi-based negotiation module.

Course management module is used to define the course profile, including title and description of the course, and the names of the authors. Concept definition module provides an interface for the authors to define a set of concepts that are relevant to the course. Concept relationship management module can assist the authors in describing the relationships among the concepts. Subject material management module allows the authors to import subject materials from other tools or edit the existing subject materials.

Moreover, a Delphi-based negotiation module is provided to assist the authors in making consistent decisions in defining concepts to be learned and the relationships among concepts if there are more than five engineers participating in creating new learning materials. Delphi has been defined by Delbecq, Ven, and Gustafson (1975) as "a method for systematic solicitation and collection for judgments on a particular topic through a set of carefully designed sequential questionnaires interspersed with summarized information and feedback of opinions derived from earlier responses," which contains three features: (1) anonymous group interaction and responses, (2) multiple iteration or rounds of questionnaires or other means of data collection with researcher-controlled statistical group responses and feedback, and (3) presentation of statistical group responses (Murry & Hammon, 1995). Figure 2a depicts the questionnaire of the Delphi-based negotiation module.

To properly translate the course structure defined by the authors to SCORM or HTML format, five types of concept relationships are defined to efficiently represent the layout of the course structure, that is, "subclass," "relevant subject," "application," "sequence," and "reference":

Figure 1. System structure of CRETS



- **SUBCLASS**: is a kind of relationship. If concept $C_i \subset$ Concept C_j, we say that C_i is a subclass of C_j. In generating the subject materials, the main (super) concept will be treated as the upper level of selection item, and the subconcepts will be treated as the lower level concepts. In an e-training Web page, a subclass represents a “subitem” or “subunit” linking relationship, and will be located in the menu area as shown in the illustrative example given in Figure 2b.
- **RELEVANT SUBJECT**: is an instance of relationship. If $e_k \in C_j$, we say that e_k is a subject material belonging to C_j. That is, the lower level concept e_k is an illustrative example or a part of the upper level concept C_j. In the e-training Web page, the lower level concepts are treated as the presentation materials of the upper level concept that is usually depicted as a selection item. In this case, a hyper link from selection item C_j to presentation material e_k is generated to represent such a concept relationship. An illustrative example of the relevant subject relationship is also given in Figure 2.
- **APPLICATION**: possible applications or demonstration examples of some technique or concept. If $e_k \rightarrow e_r$, we say that e_r is an application of e_k. That is, a hyper link is generated to link from presentation material e_r to e_k. Figure 3 shows an illustrative example of applying the application relationship to the presentation material of Figure 2.
- **SEQUENCE**: a set of ordered concepts that forms a sequential description to introduce a technique or concept. If $e_1 < e_2 < \ldots < e_k < \ldots < e_n$, we say that e_k’s form a sequence relationship. Therefore, a sequential presentation for the lower level concepts will be given if the corresponding upper level concept is selected. An illustrative example of the sequence relationship is given in Figure 2.
- **REFERENCE**: a link from a concept to another concept. The reference relationship enables the learner to jump from one learning material to another. In Figure 3, there are several reference links, such as the “RNA,” “Protein,” “Carbohydrate,” and “Fat” icons.

Figure 2a. Questionnaire of the Delphi-based negotiation module

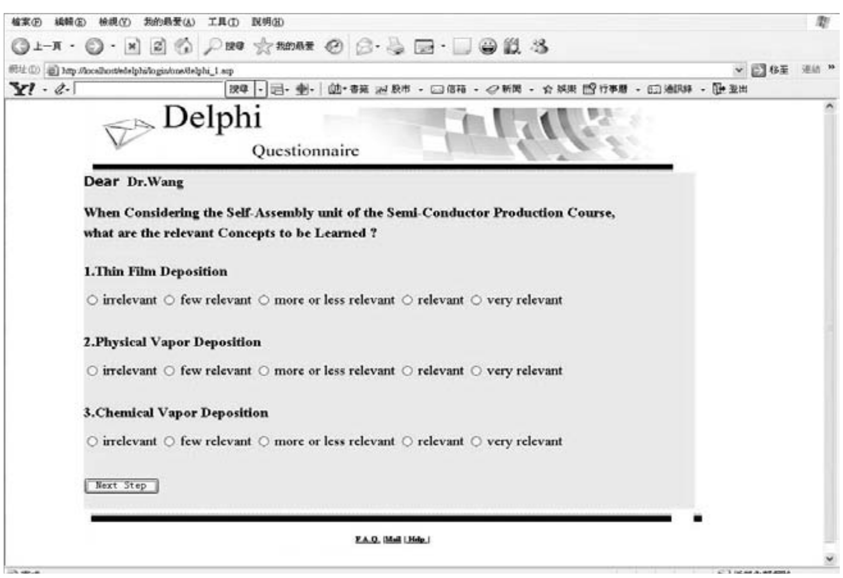


Figure 2b. Web page of the e-training course with four types of concept relationships

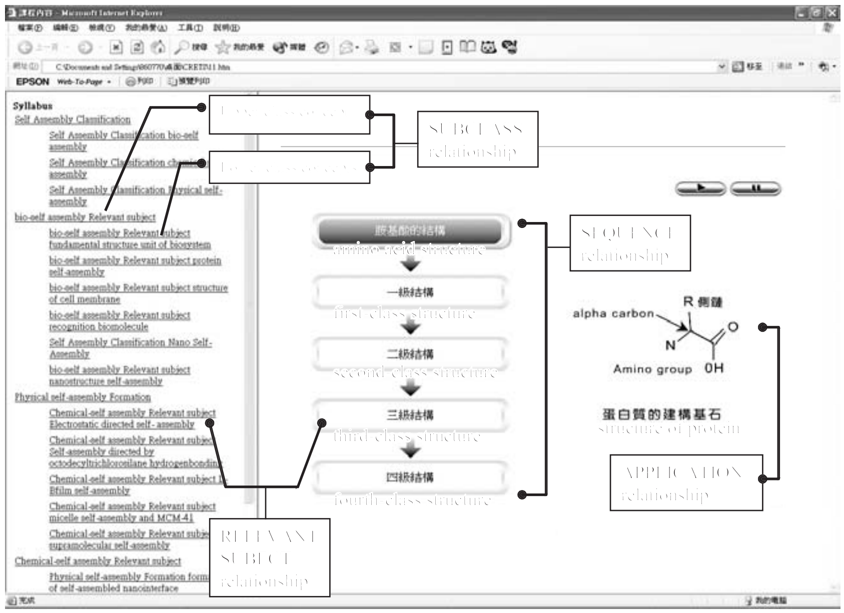
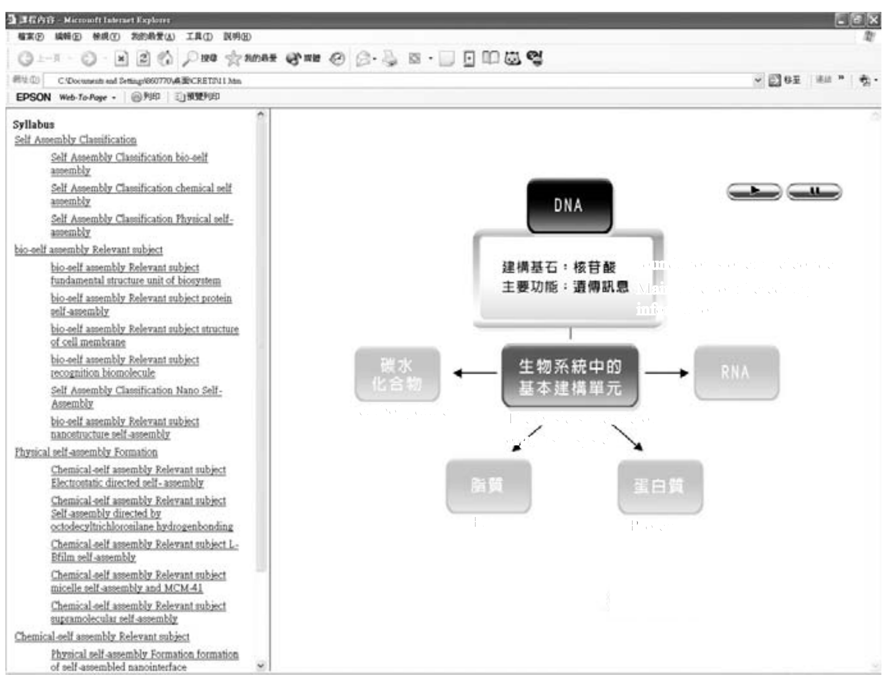


Figure 3. Illustrative example of the application relationship



It can be seen that those five types of relationships enable the authors to construct learning materials with a variety of different structures, including the hierarchical and the mesh structures.

Development of CRETS

CRETS was implemented on the Windows Server 2000 environment. In the following subsections, a practical application is used to demonstrate the functions of CRETS. The training course is titled "nano material and nano structure," which is designed for training inexperienced engineers in an electronic company.

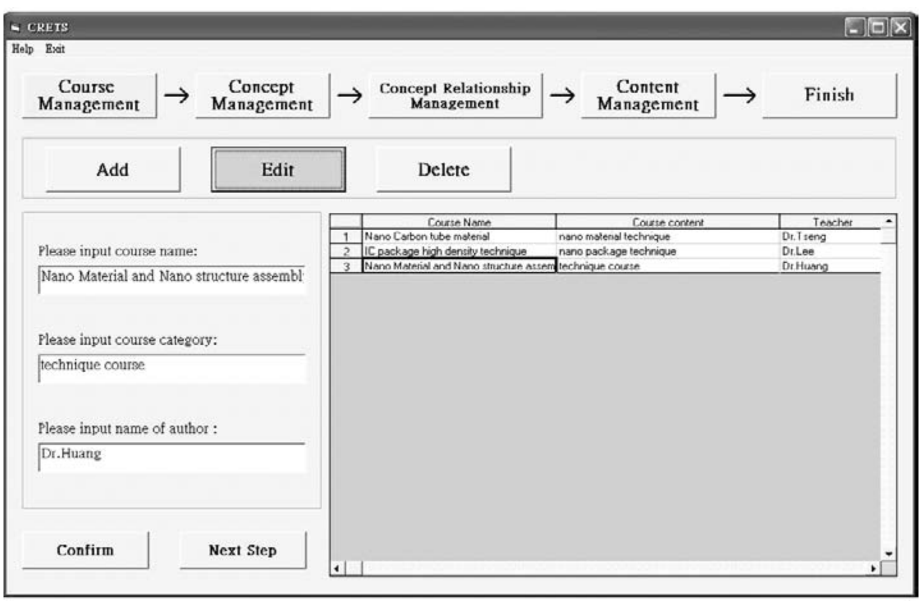
Traditional Course Structure for "Nano Material and Nano Structure"

Traditionally, this course was structured as three chapters. The first chapter, titled "Nano Self-Assembly and Bio-Self Assembly," includes the concepts of definition of nano self-assembly, fundamental structure unit of self-assembly, formation of self-assembled order structure, and recognition biomolecule self-assembly. The second chapter, titled "Physical Self-Assembly" includes the concepts of definition of physical self-assembly, Electrostatic directed self-assembly, self-assembly directed by octodecyltrichlorosilane hydrogen bonding, LB film self-assembly, micelle self-assembly, copolymer self-assembly, supramolecular self-assembly, and dendrimer self-assembly. The third chapter, titled "Chemical Self-Assembly," includes the concepts of formation of self-assembled nanointerface, quantum dot self-assembly, and self-assembly of charged powder. The concepts within each chapter have been designed as sequential units or sections.

Concept-Based Course Structure for "Nano Material and Nano Structure"

With the guidance of CRETS, experienced engineers can structure the concepts of a training course via a systematic step-by-step procedure. Figure 4 shows the first step of constructing the

Figure 4. First step: Enter title, description, and author name of the course



training course, to enter the title and description of the course and the name of the author. As shown in the example, the title of the course is "Nano Material and Nano Structure Self-Assembly."

The second step is concerned in the management of the concepts in the course. The author can define new concepts or edit the existing concepts via this interface. Figure 5 shows the concepts that are relevant to the course. The concepts given in this step include nano self-assembly, bio - self-assembly, chemical self-assembly, physical self-assembly, fundamental structure unit of biosystem, protein self-assembly, structure of cell membrane, recognition biomolecule, biomolecular self-assembly, nanostructure self-assembly, electrostatic directed self-assembly, self-assembly directed by octodecyltrichlorosilane hydrogen, LB film self-assembly, micelle self-assembly and MCM-41, copolymer self-assembly, supramolecular self-assembly, dendrimer self-assembly, biomedical, formation of self-assembled nanointerface, quantum dot self-assembly and self-assembly of charged powder.

The third step is to conduct the management of the relationships among the concepts given in the previous step. Figure 6 shows the CRETS interface for selecting the concepts that are relevant to chemical self-assembly (the upper level concept). The relationship is "relevant subject" and the selected lower level concepts include fundamental structure unit of biosystem, protein self-assembly, structure of cell membrane, recognition biomolecule, biomolecular self-assembly, and nanostructure self-assembly.

After all of the relationships among the concepts have been defined, CRETS system generates a concept relationship graph as shown in Figure 7, such that the author of the course can review the correctness of the relationships already defined. In the graph, each node represents a concept and each link represents a relationship between two concepts. Each type of relationship is depicted in a different color. It can be seen that the graph has presented a natural way for designing the linking structure of a Web-based teaching material.

After defining the course structure, the author is asked to provide the subject contents for each

Figure 5. Second step: Define new concepts or edit existing concepts of the course

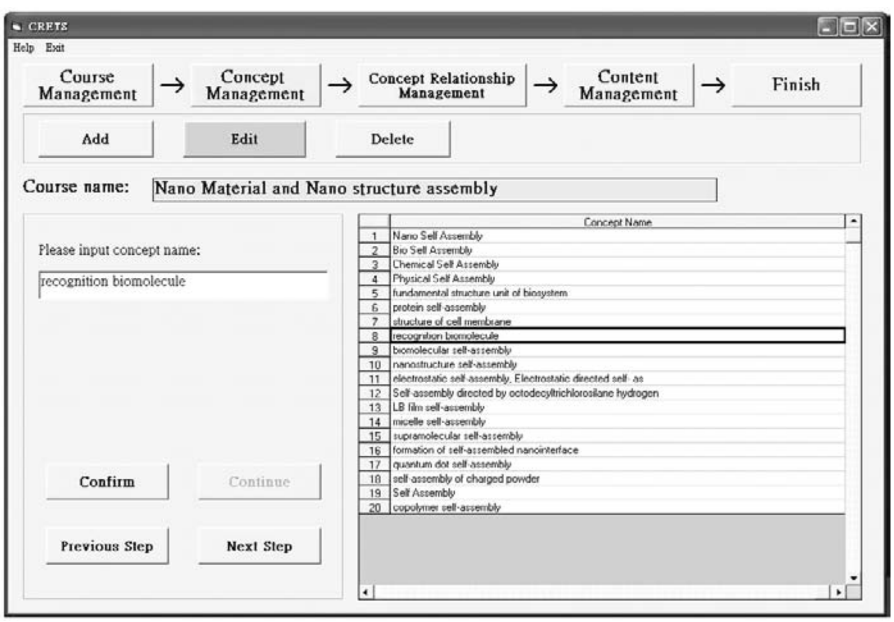


Figure 6. Third step: Conduct the management of the relationships among concepts

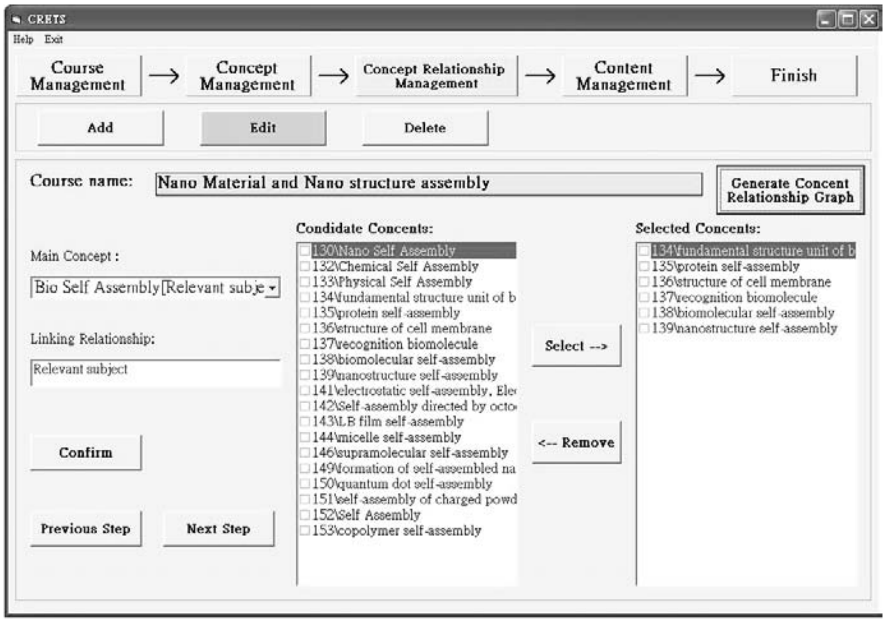


Figure 7. Illustrative example of a concept relationship graph generated by CRETS

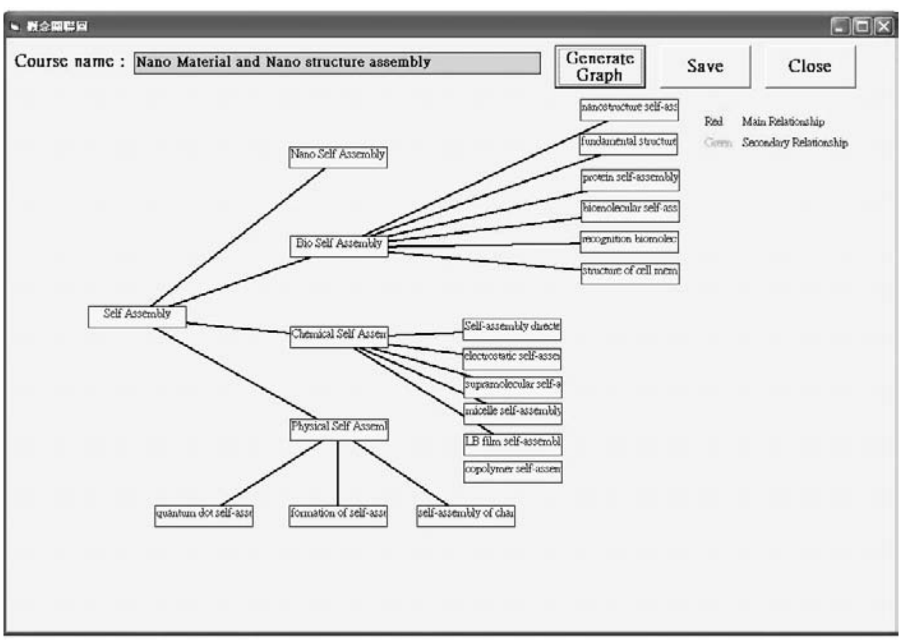
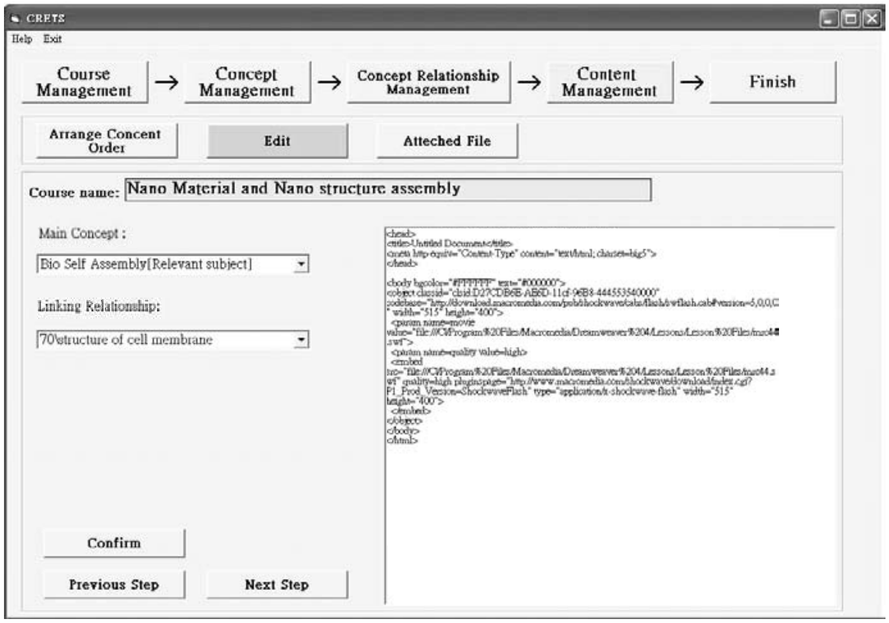


Figure 8. Fourth step: Conduct the management of subject contents



concept. The subject materials can be imported from other Web page development tools, such as Front Page and Dream Weaver, or developed by using the CRETS editor. The subject contents are presented in HTML format. Figure 8 shows an illustrative example of editing subject contents the lower level concept of protein self-assembly that is relevant to the upper level concept 'bio-self assembly in the course "Nano Material and Nano Structure Self-Assembly."

After completing the subject contents, the final learning materials are saved by clicking the "Finish" button (see Figure 9). To facilitate the usability of the generated learning materials, CRETS supports two types of teaching material formats, SCORM format and HTML format. Figure 10 demonstrates the learning materials generated by CRETS in SCORM format.

Experiments and Evaluation

To evaluate the performance of the novel approach, an experiment has been conducted on two engineering training courses, "Electricity Analysis" and "Heat Management for Electronic Products." Four experienced engineers (labeled E1, E2, E3, and E4) participated in the experiment.

In the first phase of the experiment, E1 and E2 were asked to work together to design the learning material for the "Electricity Analysis" course by using traditional tools, while E3 and E4 were asked to design the same teaching material by using CRETS. The actual working hours accrued by both groups of the engineers designing the learning materials were recorded. After both of the groups completed the design process, the engineers were asked to review the work done by the other group to ensure the quality of the developed learning materials. In the second phase of the experiment, both of the groups were asked to design the learning material of the "Heat Management for Electronic Products" course. This time E1 and E2 were asked to use CRETS, and E3 and E4 were asked to use traditional tools.

Tables 1 and 2 show the experiment results. It can be seen that no matter which one of the groups employed CRETS, the time needed for

Figure 9. Interface for finishing the course content design and generating learning materials

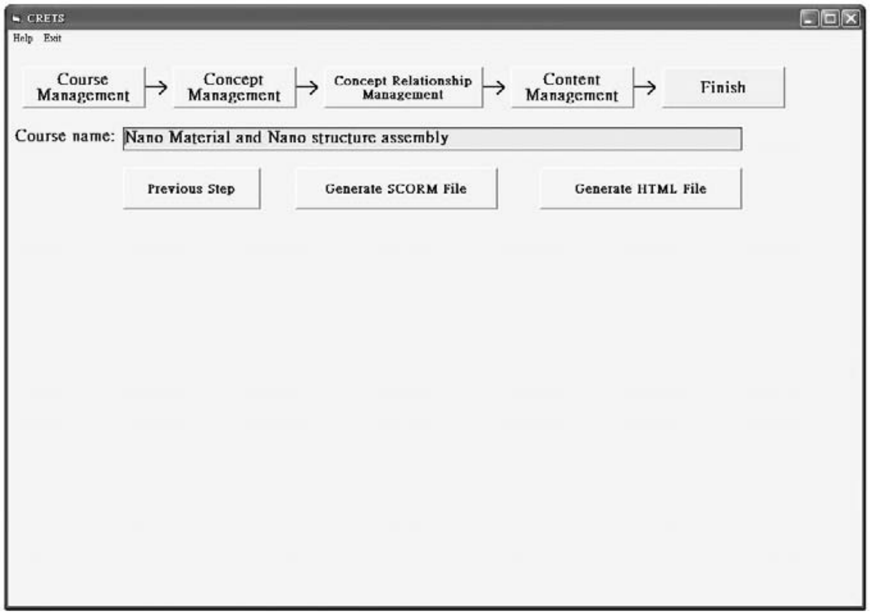


Figure 10. Learning materials in SCORM format

Table 1. Experiment on "Electricity Analysis" course

	Time required to design the e-training material
E1&E2 - Traditional Method	96 hours
E3&E4 - CRETS	48 hours
Time saved (%)	50%

Table 2. Experiment on "Heat Management for Electronic Products" course

	Time required to design the e-training material
E3&E4 - Traditional Method	85 hours
E1&E2 - CRETS	42 hours
Time saved(%)	51%

designing the learning materials was significantly reduced. In designing the learning material of the "Electricity Analysis" course, working hours were reduced by 50% by using CRETS; in designing the teaching material of the "Heat Management for Electronic Products" course, working hours were reduced by 51%. Consequently, we conclude that the concept relationship-oriented approach is helpful to those experienced engineers in shortening the time needed for design quality e-training materials.

Note that in this experiment, there are only two engineers in each group; therefore, it is not necessary to employ the Delphi-based negotiation module. When many engineers are asked to work together in designing a large scale of learning materials, the negotiation module might be helpful to them in making consistent decisions on the course structure, which need to be proven by conducting further experiments in the future.

CONCLUSION

This paper proposed a concept map-oriented approach to developing e-training courses. An e-training course design system, CRETS, has been implemented based on the novel approach. Experiment results have shown that our approach can significantly shortened the time needed for developing e-training courses, such that naive engineers can receive new technologies from experienced engineers as early as possible.

Currently, CRETS has been adopted by an electronics company in Taiwan to preserve experiences and knowledge of experienced engineers and to train the inexperienced engineers and operators. In the future, we plan to extend the functions of CRETS, so that several experienced engineers can work together to design quality e-training materials via network communications. In addition, large-scale experiments are going to be conducted to more precisely evaluate the performance of CRETS.

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Chapter IV
A SCORM Compliant Courseware Authoring Tool for Supporting Pervasive Learning

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ABSTRACT

The sharable content object reference model (SCORM) includes a representation of distance learning contents and a behavior definition of how users should interact with the contents. Generally, SCORM-compliant systems were based on multimedia and Web technologies on PCs. We further build a pervasive learning environment, which allows users to read SCORM-compliant textbooks with multimodal learning devices. Respecting the learning contents for supporting such learning environment, an efficient authoring tool was developed for serving this goal. Some specific tags were defined to specify the corresponding information or interactions that cannot be performed in the hardcopy books. These tags can be printed in SCORM-compliant textbooks and recognized by Hyper Pen to facilitate the affinity between the physical textbooks and digital world. Therefore, users can read the SCORM-compliant hardcopy textbooks in a traditional manner. The authored course contents will be the same while applying to the multimodal learning devices with different layouts.

INTRODUCTION

From time immemorial, the pedagogy evolved in line with its contemporary technologies and requirements. The innovation of the evolutional education is not only on the instructional methods, but also on the learning contents. With the widespread deployment of information technologies and network services, the trend of education nowadays is toward diverseness and convenience.

An obvious example is distance learning. However, distance learning does not on its complete substitution for traditional education. Instead, the two paradigms should work together to realize a better future educational style.

Most conventional learning models focus on the physical world only, and thus the interesting multimedia learning content cannot be used in the learning process. On the contrary, recent learning technology focuses on digital input/output. It will cost large amount of effect to transform all physical contents into digital contents. A natural way to fully utilize contents resources is to use both physical and digital contents, simultaneously. The advantages of physical contents include easy thinking, comfortable reading, rich content in library and familiar learning experience. On the other hand, the advantages of digital contents include fast searching, easy sharing, supporting interesting multimedia, and high interactivity. Thus, if advantages of both sides can be put together, the learning performance will be improved. Fortunately, there are pen-like OCR devices available to allow users to scan through textbooks. In our project, we call these types of pen devices the *Hyper Pens*. The name of Hyper Pen comes from the fact that a hyper jump is performed from one is using the device in the physical world for reading, to a virtual world in an electronic device which pronounces a vocabulary, or even shows motion pictures on a computer.

The key factor of the successful distance learning popularization is based on the well-developed e-learning standards. In addition, from the aspect of constructing learning materials, the shareability and the reusability of the various learning contents are the main issues for saving the cost of building the e-learning materials. As a result, we aim to provide an authoring tool for instructors to construct learning courseware based on SCORM (*http://www.adlnet.org*) specification for supporting pervasive learning environment with multimodal learning devices. Thus, we call this new definition of Hyper Pen-based learning mechanism as the *Hard SCORM* (Wang, Chang, Sie, Chan, Tzou, & Shih, 2005). Two important issues arose in building up such SCORM-compliant instructions. They are the conformance with the SCORM specification, and the content layouts for applicable learning devices. We proposed an effective courseware authoring tool, named the Hard SCORM Authoring Tool, for solving these issues. By using the Hard SCORM Authoring Tool, instructors are allowed to aggregate the various learning objects and to pack them into deliverable courseware. The courseware can be easily accessed by different devices including Hyper Pen, which recognizes a set of Hard SCORM tags.

In the following sections, we would like to present a brief survey on the related researches, starting from a detailed introduction of SCORM. The relevant third party authoring tools and some interesting Human-Computer Interaction researches for the affinity between physical and digital worlds are discussed. The architecture of our proposed Hard SCORM project and a formal definition of the Hard SCORM tags are also addressed. The implementation of our proposed Hard SCORM Authoring tool and some experimental results of our proposed ideas are illustrated as well. Finally, we give a brief conclusion and the future works as shown in the last section.

Related Works

As previously mentioned, the shareability and the reusability facilitate the constructing of various learning contents. A well-defined e-learning standard, named "SCORM," was designed to serve this goal. In addition, there exist many applications for generating the learning content in the distance learning environment, and here we outline the features of other SCORM-compliant authoring tools. Furthermore, some interesting researches on the interactions between the physical world and the digital world in computer and cyberspace are addressed to bridge the gap for the affiliation.

SCORM Specification

With the improvement of e-learning, there exist some acknowledged standards for the asynchronous education. In order to reduce the time and money costs of a good course presentation, ADL (*http://www.adlnet.org*) proposed the shareable content object reference model (SCORM) specification in 1997 and tried to solve the problem. SCORM has been in wide use within the distance learning community for several years now. The original purpose of the SCORM was to enable interoperability between learning content and learning management systems (LMS). Over the years, ADL has updated the specification three times, from SCORM 1.0 to 2004, in attempts to better meet this goal.

The SCORM 2004 specification has technical issues presented in three parts: the *content aggregation model* (CAM) for the format of courseware, the *run-time environmen*t (RTE) for the protocol of courseware running, and the *sequencing and navigation model* (SN) for the learning status tracking, sequencing rules, and the application program interfaces. The former two parts are responsible for learning objects to support adaptive instruction. And the last part servers the dynamic presentation of learning content based on learner needs.

As we mentioned above, the purpose of the shareability and the reusability is a great help to save the cost of building the e-learning materials. The content aggregation model (CAM) in SCORM specification is designed for these issues. CAM mainly contains the content model, the metadata, and the content packaging. The content model represents the different levels of content components for learning experiences, such as assets for representing the most basic forms of learning resource, SCOs (shareable content objects) for communicating with the backend LMS, and content organization for indicating the intended use of learning contents. Metadata in SCORM represents a form of labeling for each learning resource, and provides an easy way for learning contents identifying, categorizing, and searching. Furthermore, by using the appropriate metadata, the purposes of sharing and reuse can be facilitated. Metadata definitions in SCORM 2004 specification are categorized into nine parts with more than 70 items. Content packaging provides a standard way to exchange learning content between different systems or tools, such as the learning content management system and the content authoring tool. A content package contains an XML-based document, named "imsmanifest.xml," for describing the learning content structure and all the referenced physical files, such as the media files, text files, assessment objects, or other pieces of data in electronic form. A content package binds the two above mentioned components in the format of a compressed archive file, named Package Interchange File (PIF), for the content exchanging and delivering in general purposes.

Respecting the interoperability, the SCORM RTE can be used to establish a standard protocol for the learning content to communicate with back-end LMSs. While a learning activity starts, a launch process defines the relationship between LMSs and SCORM-compliant learning content, and then all the content relies on a SCORM conformant LMS can be delivered and displayed to the learners. During the learning phase, a set of predefined functionalities (a.k.a. the APIs) enable communication between an LMS and the SCOs it launches. Eventually, the information about the learning activities will be tracked and passed to the backend LMS by using the data model.

A systematic control mechanism, named the sequencing and navigation (SN) model, between the learner and the LMS, is defined to provide a standard way to specify the navigation of course content browsing and the behavior of the individual leaner. The SN allows components in a courseware to be specified in a relative order, in which conditions and selections are precisely defined. The sequencing definition model contains a set of elements that can be used to describe and affect various sequencing behaviors. Some of the SN setting can be applied to the sequences of the course content delivery, and some of them can be considered as the conditions for the learning performance after the assessment. Instructors can specify the applicable SN setting by using the SCORM-compliant authoring tools. And the process of sequencing controls can be applied to each learner with the learning activity tree, which is a conceptual structure of learning activities managed by the LMS for each learner. The outcomes of the sequencing process may update the learning activity status of each individual learner.

Third Party SCORM-Compliant Authoring Tools

From the perspective of learners, the most attractive things in the e-learning environment are the various types of learning content. Hence, courseware authoring tools can be considered as the foundations for building up an attractive e-learning environment. Usually, the categories of SCORM-compliant authoring tools can be generalized as three parts: the SCORM content development, the meta-data generation and editing, and the content packaging. Here, we briefly introduce some applications for creating the SCORM-compliant courseware from the three directions.

The RELOAD Editor (*http://www.reload.co.uk/*) is a content package and metadata editor, which serves the purposes of the creation, sharing, and reuse of the SCORM-compliant learning objects. RELOAD tries to make an easy way to construct the SCORM-compliant learning content by avoiding working directly with XML, such as the metadata and the mentioned imsmanifest.xml for content packaging. RELOAD also allows instructors to take their own electronic content, for instance, the Web pages, images, flash animations, Java applets, and so forth, and to package and describe it ready for storage in content repositories.

Another interesting work of SCORM-compliant authoring tool is Manifest Maker Version 2.0, which is proposed by E-learning Consulting (*http://www.e-learningconsulting.com*). The Manifest Maker can be applied to easily create a manifest for a content aggregation which is compatible with the SCORM 1.2 specification. There are several additional toolkits integrated with the Manifest Maker, such as the HTML Course Development Toolkit for creating the e-learning courses in HTML file format, and the Flash Course Development Toolkit for generating the SCORM-based learning content with Flash animations. An extra toolkit, named Test Builder, is also included within the Manifest Maker for the assessment. The Test Builder provides the functionalities of creating tests and quizzes in multiple question types. A question pool is developed for the repository of the assessment content.

With respect to the various learning content, the HunterStone (*http://www.hunterstone.com/*) developed the THESIS which provides SCORM 1.2 compliant e-learning authoring tools for Microsoft Office. The advantages of the THESIS enable a user to author e-learning resources and objects straight from the familiar Microsoft Office applications such as Word, PowerPoint, Excel, Visio, and Producer from different sources.

As previously mentioned, Metadata serves as the auxiliary information for describing and searching of the learning content, and accordingly, the reusability and the shareablity will be easily achieved. The Metadata Generator Lite (*http://www.jcasolutions.com/*) from the JCA Solutions provides a SCORM 1.2 conformant tool for serving this purpose. It utilizes the concept of templates to support the metadata generating by one-touch operation. Because the SCORM uses plenty metadata for describing the learning content, it reveals the fact that the metadata in SCORM specification should be easily made without consuming time. The metadata Generator Lite supports the importing learning content by searching and exchanging as well.

The Course Creation Toolkit from the Graphic Education Corporation (*http://info2.graphiced.com/newsite/home/index.asp*) provides a WYSIWYG (What You See Is What You Get) user interface to construct the SCORM compliant learning content. The operations for the toolkit use the one-button insertion of Multimedia in the learning content. The creation of the questions for testing and assessment is also comprised in this toolkit.

There exist many serviceable applications for generating the SCORM compatible learning contents with diverse features. However, most of the systems are currently compatible with SCORM 1.2 specification. In this paper, we will introduce our proposed Hard SCORM Authoring Tool to facilitate the generation of SCORM 2004 compatible learning content, which can be brought to the learners via multimodal learning devices.

Human-Computer Interaction Issues

Even though Web technologies and Internet are popular, as a practical situation among several virtual universities, textbooks are still widely used. Paper remains a fundamental resource for many human activities. The fact is people still prefer reading books instead of facing screens. Paper is very convenient, familiar, flexible, user modifiable, portable, inexpensive, and offers excellent readability properties, but it is static and does not offer the dynamic content and hyperlinking. Human-computer interaction then becomes an essential discussion issue from this perspective. Practically, advanced hardware and communication technologies need to be used in conjunction with the affinities between real-world and computers, known as the proper noun "Augmented Reality." Some of those augmented systems are equipped with extra facilities for serving the goal of the gap bridging. The researches in the HCI scope are quite miscellaneous and imaginative, and the researchers tried to ease the ways to connect the two isolated worlds.

The Listen Reader system (Back, Cohen, Gold, Harrison, & Minneman, 2001) used RFID embedded in a real book, with images and text. An electronic field sensor is then used to connect to a back-end device, for presenting sound tracks. The RFID is now widely used in many occasions, such as tickets for the subway, keys for the gate, and many objectives for pattern recognition. RFID in Listen Reader contains a thin flexible transponder tag with a unique ID that can be embedded in the paper of each page for recognition of the page identification, and a special tag reader is affixed to the binding of the back of the book. The system was demonstrated in a museum for bringing out the information that cannot be displayed in the paper-based collections. Another work is ENHANCEDDESK proposed by Koike, Sato, and Kobayashi (2001). It provides the smooth integration of paper and digital information on a desk and direct manipulation of the digital information with the hands and fingers of users. By using an infrared camera instead of a regular CCD camera, the regions of a user's arms are found in an input image, fingertips are searched for in those regions with a certain range of temperature. However, these systems require specific instruments for connecting the digital world and physical worlds. As a result, it may not be portable to cope with the need of mobile learning, and may be too costly to benefit general learners while learning in their daily life.

Paper++ (Luff, Heath, Norrie, Signer, & Herdman, 2004) is another notable research which utilizes a nonobtrusive pattern on the page to interlink papers and digital resources. The system includes an authoring tool which allows users to create "active" pages. The relation between the physical and the digital can be defined by using conductive inks as the tags and a co-axial pen for the object recognition. Nevertheless, Paper++ will be bound with a specific printer for generating the conductive and nonobtrusive ink patterns on the hard copies. Accordingly, the portability and flexibility of paper will be detracted.

Other interesting work in Ariel (Mackay, Pagani, Faber, Inwood, Launiainen, Brenta, & Pouzol, 1995) detects the x-y positions on paper-based documents by recognizing the red-colored pointers. A similar work, the InteractiveDESK (Arai, Machii, Kuzuniki, & Shojima, 1995), identifies the objects on its desktop by reading special color coded tags attached to the objects. The NaviCam (Denari, 1996) is another approach for viewing the augmentations of those objects through the camera image by using the color coded strips to recognize objects. However, the coarse resolution of the printing will diminish the performance of those tagging systems.

Another system to allow support digitally augmented paper via an authoring tool was presented in Norrie and Signer (2003). The system is able to provide a hypermedia access between hard copy papers and multimedia devices. In addition, a multilayered linking technology is developed with digitally augmented paper (Signer & Norrie, 2003). These systems all point out an important message: hard copy textbook is required in learning, even though multimedia presentations may provide a higher degree of interaction for learning. Some of the above surveyed ideas are worthy to us in developing the Hard SCORM project. Contrarily, some of the issues, such as the cost, mobility, and convenience, should be take into considerations as well while developing such a pervasive learning environment.

Architecture and System Design of Hard SCORM Authoring Tool

Considering different sorts of learners, including those who prefer to read from a book, we aim to facilitate the SCORM-compliant courseware to be delivered to a pervasive e/m-learning environment, which can be accessed via different presentation devices. Thus, the gap between digital cyberspace and our physical world can be eliminated. In this section, we would like to talk about the architecture of the Hard SCORM project and the authoring process of the Hard SCORM Authoring Tool. Furthermore, the courseware can be easily accessed by different devices including Hyper Pen, which recognizes a set of Hard SCORM tags. We'll discuss the definition of these tags and the interrelations between the tags and the corresponding digital information.

Constructing a Pervasive Learning Environment

In our proposed idea, three main components are needed for constructing SCORM-compliant multimedia courses on hard copy books in the pervasive learning environment, and they are Hard SCORM Authoring Tool for the related course content generating, a learning management system based on the Web Service architecture for managing the content delivering and the specified services needed in the environment, and finally, an auxiliary learning tool for sending the information that Hyper Pens recognized to the backend server side. The outline of the system architecture can be illustrated as following:

- **Hard SCORM authoring tool:** The Hard SCORM Authoring Tool deals with the editing of SCORM-compliant course contents. Not only the learning contents for the general learning behavior on PCs, but also the learning content for the hard copy books can be created by using the Hard SCORM Authoring Tool. Instructors can easily build up the course by some simple operations, even though they are not familiar with the specific computer skills. Furthermore, the detailed information that is compatible with SCORM specification, such as the metadata information and the sequencing rules setting, will be also available after using the authoring tool. The detailed illustration of the tool will be presented in the next section.

- **A SCORM/Hard SCORM learning management system:** The SCORM-based LMS (Shih, Chang, & Lin, 2003) is able to provide various services for the pervasive learning devices, such as the Hyper Pen, PC or PDA (Shih, Lin, Chang & Huang, 2004). This run-time environment normally delivers course contents to students in different formats. The environment also records the navigation behavior of learners. Some additional sophisticated mechanism for controlling the learning behavior should be integrated within the specified LMS, for instance, the undesired learning behavior while learning through the SCORM-compliant hard copy books. In addition, the embedded specified Hard SCORM tags will be recognized by Hyper Pen, and the result should be transferred to the LMS. A set of corresponding actions can be performed or brought out to learners, such as the multimedia files referencing or the learning records maintaining.
- **An auxiliary learning tool:** This auxiliary tool is responsible for the Hyper Pen to communicate with the supplementary learning devices. While learning on the hard copy books, the learner should open the auxiliary tool for the Hyper Pen to send the recognized result of Hard SCORM tags to the backend LMS. The corresponding actions or information will be returned to the leaner through the learning device where the learning tool runs. Wireless communication for the pen-like OCR devices will be used in the near future to enhance the flexibility.

The first two components are SCORM compliant, and the third tool serves as the front-end medium between the first two components, with additional functions, such as the detection and automatic revision of identified tags.

The Hard SCORM Tags

From the perspective of learning content, there exist many multimedia references while learning in the digital world. However, the same references might not be displayed functionally within the hard copy books (that's the reason why we call them "Hard Copies"). For this reason, those media which cannot be presented in the hard copy books should be transformed into another way to be displayed. The related digital information will be shown by the multimodal learning devices, such as the PCs or the PDAs, in a seamless manner of the traditional learning behavior. Thus, learning activities may be extended to both physical and digital worlds. On the other hand, the SCORM standard is extended to a hard copy form. As a result, the learning behavior and records on the paper-based books could be standardized and compliant to the SCORM specification.

In order to allow Hyper Pen and the back-end LMS to communicate with each other, a special communication mechanism is necessary. We need to define a set of Hard SCORM tags, which can be embedded between the lines in the Hard SCORM textbooks, and be recognized by Hyper Pen. During a session of reading, these tags are scanned and recognized by the Hyper Pen. The definition of Hard SCORM tags considers effective interaction and fits with the navigation and sequencing specification of SCORM. Currently, the recognition of Hard SCORM Tags is in text forms, because OCR-based technology is well-developed. By using the Hard SCORM Authoring Tool, these tags are printed on hard copy books automatically. Hard SCORM Tags are divided into four categories for different purposes:

- **Navigation tags:** User navigations are controlled by using navigation tags. These tags are generated automatically by the authoring tool according to the definition of sequence specification given by the author.
  - ***p* – Page Tag** is associated with a SCO page number, ***p***, which indicates current navigation focus. Activation of the tag changes the status of an activity tree.
  - – **Next Page Tag** allows a navigation to move forward to the next SCO page and change the status of an activity tree (i.e., flow control).
  - – **Previous Page Tag** is similar to the Next Page Tag.
  - ***p* –Page Index Tag** allow users to jump to a particular page (i.e., choice control).
- **Reference tags:** Multimedia resources can be displayed on electronic devices as references, which is triggered by reference tags.
  - ***id* – Video Reference Tag** shows a video.
  - ***id* – Audio Reference Tag** presents an audio clip.
  - ***id* – URL Reference Tag** launches a Web site.
  - ***id* – Flash Reference Tag** brings out a Flash animation.
- **Answer tags:** Answers in a test can be recorded by a SCORM LMS.
  - – **Start Quiz Tag** starts a quiz session. All answers will be recorded.
  - – **End Quiz Tag** ends a quiz session. Evaluation of the quiz is given.
  - ***id* – Question Tag** allows the user to identify a question to give the answer.
  - **1 | 2 | 3 | 4 | 5 –*Multiple*-Choice Tag** allows a learner to give an answer.
  - **Yes | No | Y | N | True | False | T | F – True-False Tag** is similar to the Multiple-Choice Tag.
  - – Fill-in-Bl**ank Tag** allows a learner to give an answer to LMS. A popup window on PC or PDA is used.
- **Auxiliary tags:** These tags turn on/off or control Hard SCORM.
  - – **Start Tag** turns on Hard SCORM.
  - – **End Tag** turns off Hard SCORM.
  - – **Pause Tag** suspends Hard SCORM.
  - – **Continue Tag** resumes Hard SCORM.
  - – **Learner Status Tag** provides status parameters to learners as an output.

Some of the above mentioned Hard SCORM tags can be allocated by instructors, and some of them could be generated automatically from the existing information, such as the sequencing rules setting and the context of the learning content itself. As we know, there are many media that could not be displayed on the hard copies, and accordingly the reference tags should be extensible, even though there are currently four types of multimedia supported in the authoring process.

From the inner view of the Hard SCORM tags, the interrelation to the digital information can be recorded in specific data structures according to the mentioned categories. For the navigation tags, they can be bound with the unique identifier with the corresponding learning contents, and furthermore, the sequencing setting should be included regarding the navigation behavior in the pervasive learning environment. For the reference tags, the unique identifier should be provided as well. This is because the learner can turn to any page on a textbook without letting the underlying sequence engine gain the navigation control. Thus, the leaner may reference to the forbidden information while accessing to unanticipated reference tags in the hard copy books. Some essential infoamtion is required in reference tags, such as the file type, the relative reference path, and the order number.

A URL reference tag may contain the hyperlink information to the desired Web site in addition. For the answer tags, the identifier of the quiz should be taken respectly. The answer and items for each quiz is also addressed. Furthermore, the overall results of the assessment will be sent back to the backend LMS server for the evaluation. Finally, the auxiliary tags contain the identifier of the specific content aggregation and the identification information of learners. As a result, the learning records can be precisely maintained while learning through Hyper Pens.

The Authoring Process of Hard SCORM Authoring Tool

The Hard SCORM Authoring Tool is responsible for constructing multimedia courseware, which can be delivered to the multimodal learning devices, based on the SCORM 2004. Two issues should be taken care of here. Firstly, because all the authored learning materials should be conformant with SCORM 2004 specification, the conformance then becomes an important principle while developing SCORM-compliant authoring tools. Secondly, the Hard SCORM tags should be embedded between the lines in the Hard SCORM textbooks for the affinity between books and digital information, and the transformation of original learning contents into paper-based learning contents then will become an essential subject in our development.

While considering the authoring process for constructing the practical learning materials, a series of tasks can be sketched as following:

1. Prepare the required assets that will be brought to the learners via different kinds of learning devices.
2. Create a content aggregation that will contain all the learning contents.
3. Load the required assets into the resources pool and place them in the aggregation with the drag-and-drop operations.
4. Arrange all the learning contents into the content aggregation. Modules and clusters are optional to be considered as the categories in the aggregation.
5. Attach the metadata information based on SCORM specification to the components in the content aggregation. The metadata can be filled automatically or manually.
6. Decide the corresponding learning sequencing and navigation rule depending on the instructor's disposition for supervising the learners' behavior in the SCORM-compliant RTE.
7. Using Hard SCORM editor to transform the learning materials into paper-based contents respectively, and build up the interrelations between embedded Hard SCORM tags and the corresponding digital information.
8. Print out the Hard SCORM textbooks, and save the content aggregation. Finally, export it to the backend LMS in a PIF file.

This authoring process for instructors is very simple and straightforward. The main benefit of this authoring process is its generality, because it fits well with the needs of generating SCORM-compliant learning contents. Besides, it also avoids the direct manipulating with the heavy XML descriptions for a nonexpert instructor in computer science to produce such kind of learning contents.

Implementation on Hard SCORM Authoring Tool

Why is courseware authoring tool essential to the e-learning community? The most attractive things in the e-learning environment are the various types of learning contents. Hence, the authoring tool can be considered as the foundation for building up an attractive e-learning environment and the whole learning processes. To construct the learning contents for multimodal learning devices in our proposed pervasive learning environment, we develop a user-friendly authoring system, named "Hard SCORM Authoring Tool" based on SCORM 2004 specification. Additionally, as we introduced many outstanding authoring tools for building the SCORM-compliant learning objects in the second section, we devised some specialized functionalities to facilitate and enhance the constructing of the courseware in our proposed Hard SCORM Authoring Tool.

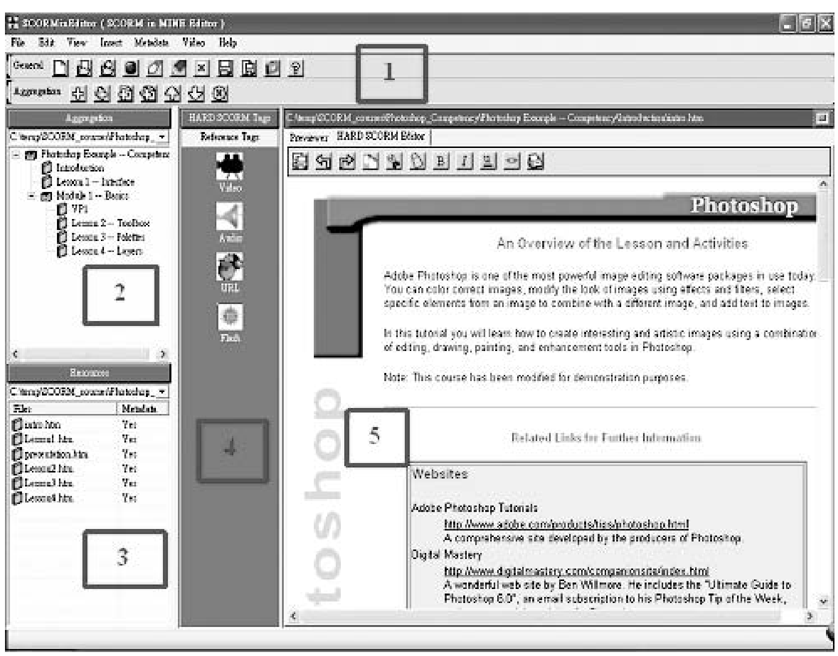
Our Hard SCORM Authoring Tool contains all the necessary functionalities for constructing the learning contents, such as the metadata description, the sequencing setting, the content aggregation, and the content packaging. For the consideration about the generation of hard copy books, the Hard SCORM tags should be automatically or manually placed and recognized by the Hyper Pen in the hard copies for making the physical world in books to affiliate with the digital world in the computer.

The Hard SCORM Authoring Tool is a content aggregation and packaging tool. The interface is divided into five areas. As illustrated in Figure 1, these areas are:

1. Menu and tool bars
2. Content aggregation window
3. Resource pool window
4. Hard SCORM tag bar (optional)
5. Content design/preview window

A menu and tool bars include a set of rich editing functions, which are similar to ordinary Windows applications. The content aggregation window visualizes SCOs and assets, which can be inserted, deleted, moved, renamed, and rearranged by ordinary drag and drop operations as the operations provided by Windows Operating System. The Hard SCORM Authoring Tool can create a new course or load an existing course with the content package, known as the imsmanifest.xml, or in the compressed archive file format. The multiple content aggregations can be loaded as well to the authoring tool for advanced editing.

Figure 1. The GUI of the hard SCORM authoring tool



This will allow the insertion of the current course aggregation into another one.

The Resource Pool Window shows the learning resources in the current course content aggregation. Furthermore, it displays the available assets which can be stored in different directories or searched from the local and remote sites by some criteria according to the metadata definition for the use of inserting to the current content aggregation. The Hard SCORM Tag Bar currently contains four types of reference tags, which can be added to a Hard SCORM textbook. These reference tags, when triggered by a Hyper Pen device, can present multimedia resources such as flash animation, audio, video, and even the Web pages for referencing on a computer or other learning devices. The Content Design/Preview Window provides a visualized preview window for the content previewing. The metadata editor and sequencing editor are available within this area as well. It also allows the final design of assets. The Hard SCORM Authoring Tool can be used with ordinary Web presentation design tools which generate standard HTML files as assets.

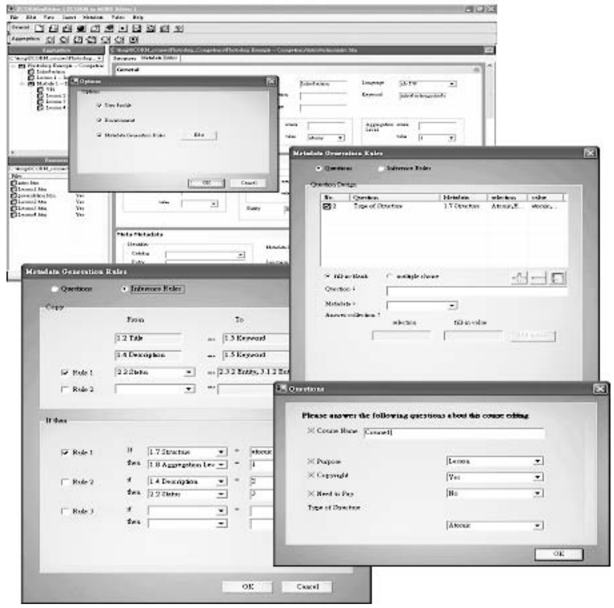
In addition to course content, some interesting and imaginative toolkits are integrated with the Hard SCORM authoring tool. We aim to provide an easy way for instructors to build up the diverse SCORM-compliant learning content which can be applied to the pervasive learning environment. Also, under this scheme, an interface for the instructor to pick up the questions and exams in the question database is also available in the authoring tool for supporting the assessment. An exam is composed from a set of questions, which is designed based on another distance learning standard. At the time this proposal is written, SCORM does not incorporate the IMS Question & Test Interoperability (QT&I) specification.

A tree structure for representing the content aggregation is utilized instead of directly manipulating the xml-based imsmanifest.xml. The tree structure has its remarkable advantages for instructors to perform some essential operations with the content aggregation. All the operations of the tree structure can be done as easily as the ones in Windows operating system platform. Furthermore, a well-designed context menu for the responding course node will facilitate the various setting of each different node. The assets in the resource pool can be easily integrated into the current content aggregation by drag-and-drop operations as well. Those assets could be loaded from the local file systems. In addition, a search mechanism is also available for finding the precise learning content from the local system or the remote server.

With respect to shareability, the advantage of using metadata allows users to search for a learning object in a precise manner according to accurate descriptions or predefined vocabularies of SCORM metadata. According to SCORM 2004, the number of entries of metadata is more than 70 for each learning object. An efficient metadata editor is integrated with our authoring tool for the completion of SCORM-compliant learning contents. The metadata editor is associated with different levels of content details of an individual learning resource. The use of metadata can be shown in a query process module, which helps instructors search for suitable and reusable learning resources.

By analyzing the CAM specification of SCORM 2004, the metadata can be separated into two parts: the optional and the mandatory metadata. The former represents the auxiliary information for the searching and reusing, and the latter indicates the required information for describing the learning content. We further consider the data fields of all the mandatory metadata with the internal relationship for their attributes, and we found some of them could be derived from the preexisting information, such as the system environment, the user profiles, and so forth. Hence, we developed a toolkit named the Metadata Wizard for easing the generation of all the metadata for different levels in our Hard SCORM Authoring Tool, as shown in Figure 2.

Figure 2. The Metadata Wizard in hard SCORM authoring tool



To avoid the omission of metadata setting for each learning resource, the completeness checking of the required metadata is necessary in the saving phase. This will ensure that all the learning resources within the current content aggregation will be exchangeable and shareable. We also allow the instructor to make some inference rules and questions to extract the information for describing the metadata in the Metadata Wizard. As a result, instructors can easily create all the necessary metadata without additional costs in time and efforts.

The learning sequencing is a supplement to the SCORM specification in the latest version. It can be applied to control and specify the navigation behavior of a learner while learning. Those sequencing and navigation information can be stored in the CAM by specifying a sequencing node in xml format, as shown in Figure 3. However, this kind of sequencing node is hard for instructors to design due to the complexity of XML syntax. As a result, we aim to provide an effortless toolkit for instructors to specify applicable sequencing setting for serving this purpose. We call it the Sequencing Editor. In the Sequencing Editor, we hide the complexity of the XML syntax in specifying the sequencing rules; instead, we transform

Figure 3. An XML-based sequencing node representation

```
-<imsss: sequencing>
   <imsss: controlMode choice= "true" choice
     exit= "false" .ow=  "true"/>
 - <imsss: sequencingRules>
   - <imsss:preConditionRule>
     - <imsss:ruleConditions>
          <imsss: ruleCondition condition=
          "completed" />
        </imsss:ruleConditions>
        <imsss: ruleAction action = "disabled" />
     </imsss:preConditionRule>
   -<imsss:exitConditionRule>
     -<imss:ruleConditions>
        <imsss:ruleCondition condition =
          "completed" />
       </imsss:ruleConitions>
       <imsss:ruleAction action = "exit" />
   </imsss:exitConditionRule>
 </imsss:sequencingRules>
</imsss:sequencing>
```

them into a list of items. Instructors can simply set the various sequencing rules by the drop-down menu and fill the information for the data value. Currently, the schema of the items is stored in the database for the conceivable extension in SCORM specification. Figure 4 shows the user interface of the Sequencing Editor.

A mechanism for content developers to check the accuracy of the specified sequencing information can be found in Chang, Wang, Wang, Jan, and Shih (2006). It's possible that a learning content that might not be reached all the time even if it has already been in the content aggregation, or when the learners start to browse the learning content but they cannot browse another learning content anymore due to the improper sequencing setting. The improper situations might be caused by the unreasonable learning sequencing strategies or the careless filling of the information of sequencing. Figure 5 represents two examples of the improper sequencing setting in the Hard SCORM Authoring Tool. The course node marked in yellow represents the unreachable course node, and the one in red indicates the node which might cause blocking.

The Hard SCORM Course Editor, as shown in Figure 6, is responsible for creating the SCORM-compliant hard copy books for the pervasive learning. The Hard SCORM Tag Bar currently contains four types of reference tags, which can be added to a Hard SCORM textbook with affiliated digital learning resources. Hard SCORM tags, when triggered by a Hyper Pen device, can present digital multimedia resources for reference or perform the corresponding interactions while learning with the hard copy books. The system will automatically assign an identification number, known as the SCO number, to the selected course node, and this information is useful in the sequencing controlling of the Hard SCORM text-

Figure 4. The sequencing editor in hard SCORM authoring tool

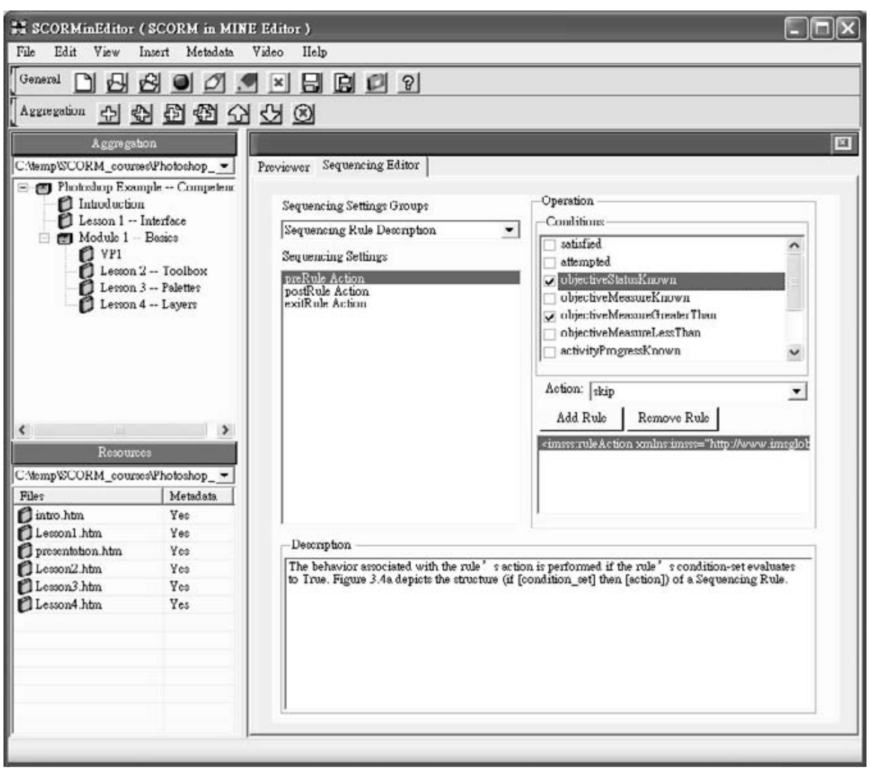


Figure 5. Sequencing testing mode in the hard SCORM authoring tool

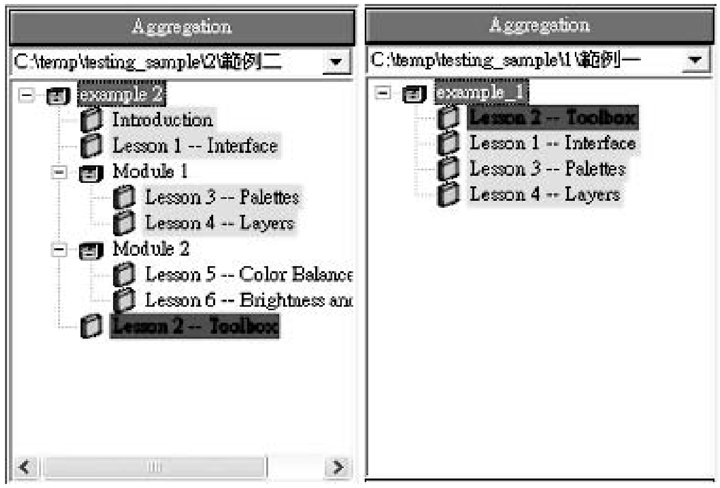
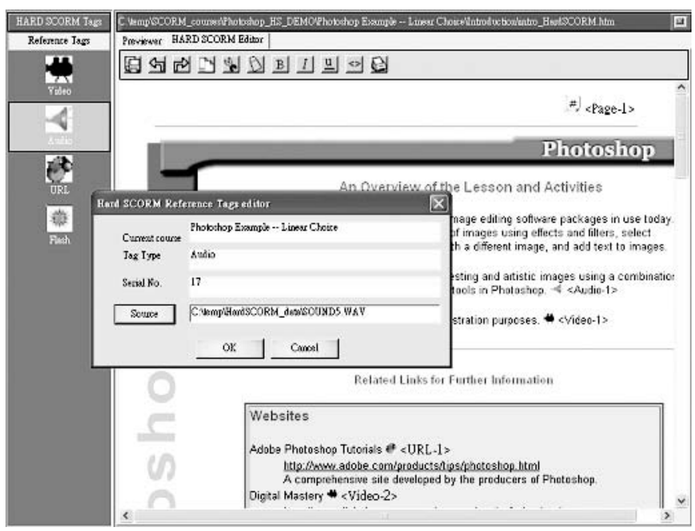


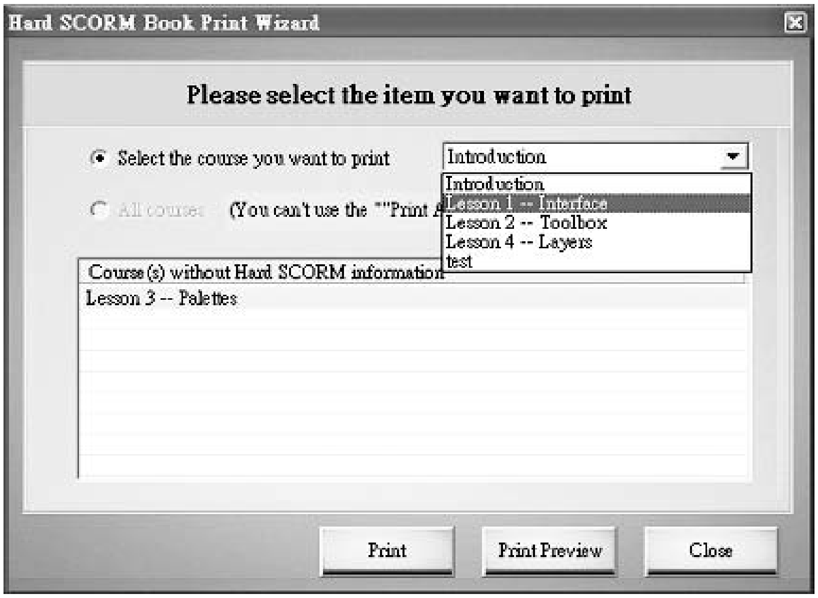
Figure 6. Hard SCORM course editor user interface



book. Each SCO number will be bound with the unique ID of the specified course node within the content aggregation. As a result, after the leaner scanned the SCO number in the Hard SCORM text book with a Hyper Pen, the recognized result will be sent back to the backend LMS and the learning record of the leaner will be updated to the current state.

The relations between the digital files and the physical tags in the hard copy books are recorded during the design phase, and then all the information will be integrated into the current content package for uploading to the LMS. Due to the advantages of Web Service architecture, we can easily build up the relations between the Hard SCORM digital file resource and the recognized

Figure 7. The Printing Wizard for creating the SCORM-compliant textbooks



tag item. Regarding the SCORM-compliant hard copy book printing issues, we provide a printing wizard, as shown in Figure 7, to print out all the Hard SCORM courses within the current course aggregation.

Basically, the most important reason for creating metadata according to the SCORM specification is to allow users to precisely search for learning objects for reuse. The Hard SCORM Authoring Tool provides a search interface (see Figure 8), which allows the user to search for reusable learning objects in the local machine or on the remote server side. The search criteria have the same definition as the metadata. Learning objects allocated by the search engine can be loaded into the resource pool and applied to a new content aggregation. A local resource buffer is used to hold the local search results. For the search on the server side, users can download the result as a new course within their computers by clicking the "Download" button or double-clicking the item in the result list. Then the shareability will be accomplished.

With respect to the federation, the Hard SCORM Authoring Tool also allows system administrator to set up multiple servers, which contain different learning objects that can be discovered for reuse. Figure 9 illustrates such an interface for Web services configuration. The allocation of Web services can be selected while requiring the Web services, such as searching for reusable learning objects remotely and uploading the PIF to different LMS servers.

There are some advanced toolkits integrated with our Hard SCORM Authoring tool, such as the Video Presentation Course Toolkits and the Video SCORM Authoring Tool. Those advanced toolkits can be applied to enhance the variety of the course contents. The outcome of those toolkits can be considered as the learning resources within the resources pool for the use in the content aggregation. We briefly discuss these toolkits.

The Video Presentation Course Toolkits contains three functions for the video presentations creating. The Video Presentation Recording allows the user to bring up a MS PowerPoint file and

Figure 8. Metadata searching engine in the hard SCORM authoring tool

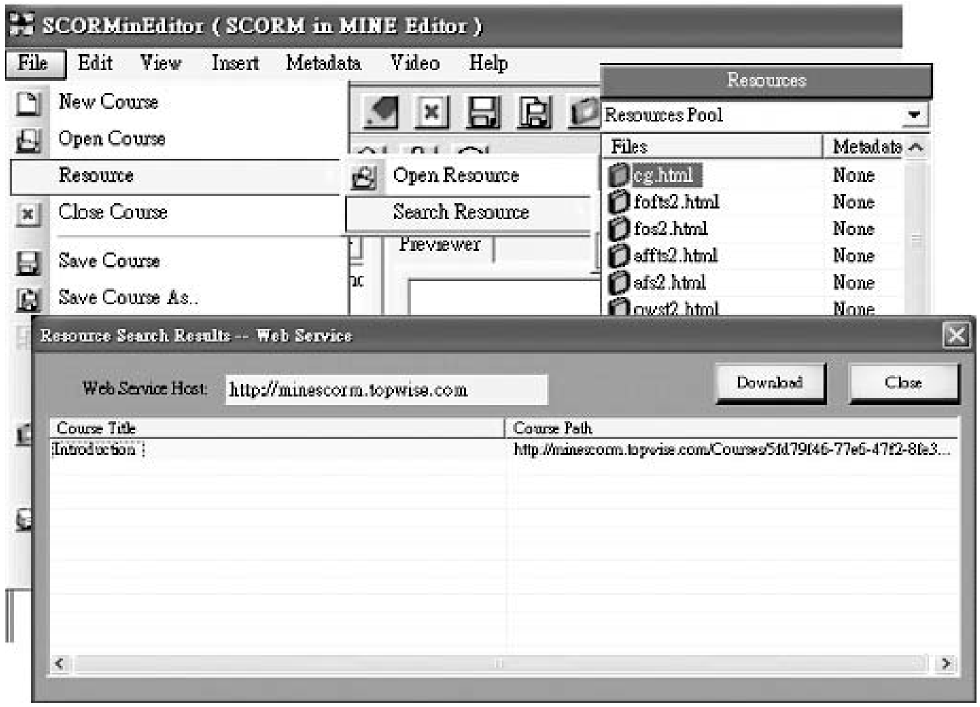
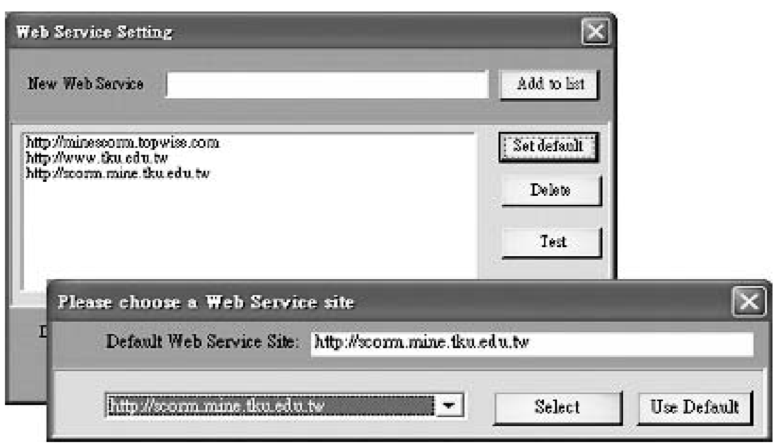


Figure 9. Allocation and selection of remote server



use a CCD camera to record a lecture. The video will be synchronized to the change of PowerPoint slides. The Video Presentation Editor allows users to combine several video presentations, trim a video presentation, or reorganize presentation sequences. All the video records and the PowerPoint slides in the video presentation course will be rearranged automatically. The Video Presentation Post Processing Toolkit is responsible for embedding some relevant information to an existed video clip at specific time scale. The outcome of the tool is in html file format and can be considered as a

Figure 10. The video presentation toolkits and the layout of the video presentation course

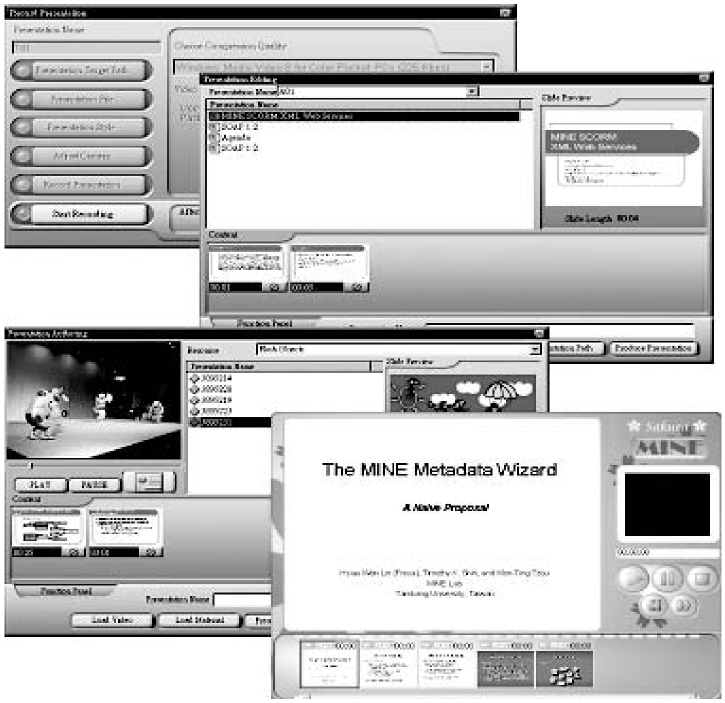


Figure 11. The video SCORM authoring tool

single SCO and multiple assets in the SCORM specification. The layout and the user interface of the toolkit can be shown in Figure 10.

The Video SCORM (Wang, Chang, Chen, & Shih, 2006) is a project for building the SCORM-compliant course on TV. In another words, this project aims to provide a TV-based learning environment for supporting SCORM. The course content should be in the video file format and can be browsed not only on the Web-based LMS, but also on the set-top-box of a digital TV. The authoring tool for Video SCORM can be shown as Figure 11, and instructors can make various scenes and actors to indicate the information or knowledge that is going to be passed to the learners. After a Video SCORM course generated, the outcomes are able to be loaded into the resource pool in Hard SCORM Authoring tool as a Video SCORM Project. Then the Video SCORM course can be added into the current content aggregation by using simple drag-and-drop operations. The Video SCORM course node in the content aggregation can be redesigned by invoking the Video SCORM Authoring Tool.

Experiments Results

Content Layout for Applicable Learning Devices

The Hard SCORM Authoring tool runs on a PC for instructors to build the SCORM compliant courses which will be delivered to multimodal learning devices for supporting the pervasive learning environment. Thus, course contents should be kept available while applying to the PDA or on a hard copy book. Even the various types of display devices may have different layouts; the content will still be the same. The courseware also maintains a consistent access and an interaction strategy. Thus, students using different interfaces will use the same sequencing and navigation control module of the SCORM/Hard SCORM LMS. Furthermore, the layout of the Hard SCORM books will be considered as a key factor to the success in the paper-based learning environment which can be connected to the digital world.

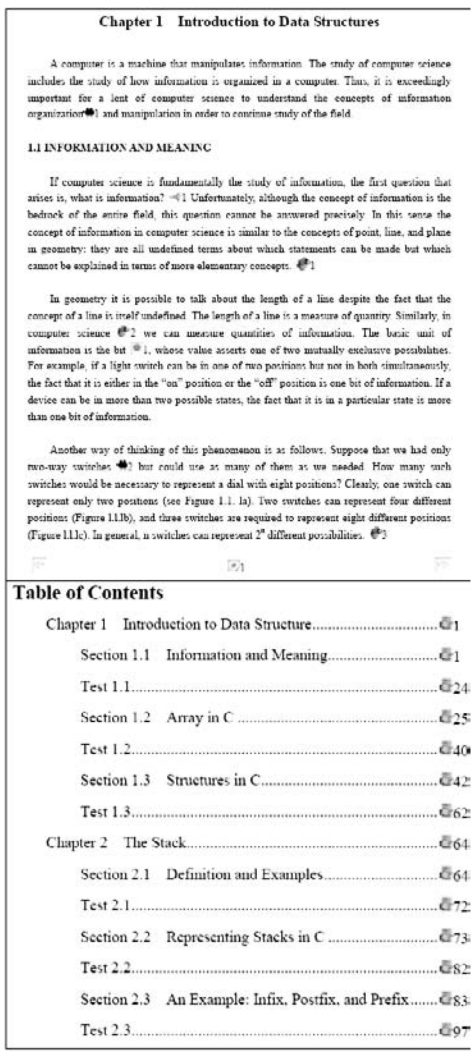
Generally, the organization of a Hard SCORM textbook printing is similar to a traditional textbook. We believe that it is easier for the readers to follow if traditional reading behavior is considered. Thus, in the development of the Hard SCORM project, we carefully consider the behavior of ordinary readers while they are reading. Their detailed learning behaviors are considered in the design of tag printing, as well as in how Hyper Pen should be used. Following a typical textbook, with a limited modification, a Hard SCORM textbook includes several portions:

- **The Hard SCORM Control Panel:** contains special tags for navigation control.
- **Table of Contents:** of a Hard SCORM-compliant textbook allows a choice mode of sequencing and navigation specification. The hierarchy can be extended to an arbitrary level. The sequence engine should be able to recognize the page index tags on the table of contents, and guide the user to flip to a specific page.
- **Chapters and Sections:** (include tests) represent the aggregation. Each chapter, section, and test may contain Navigation Tags, Reference Tags, and Answer Tags in the corresponding SCOs.
- **Index:** contains a list of term and page index tag pairs. Invocation of a page index tag allows the user to navigate to a specific page which contains such term. The sequence engine should be able to guide the user to flip to a specific SCO page.

The Hard SCORM Control Panel will be printed as a separated page for each Hard SCORM-compliant textbook. Invocation of tags in the control panel will change the navigation status of

Figure 12. Example of a hard SCORM student ID and control panel

Figure 13. Example of a hard SCORM textbook



Chapter 1 Introduction to Data Structures

A computer is a machine that manipulates information. The study of computer science includes the study of how information is organized in a computer. Thus, it is exceedingly important for a lent of computer science to understand the concepts of information organization 1 and manipulation in order to continue study of the field.

1.1 INFORMATION AND MEANING

If computer science is fundamentally the study of information, the first question that arises is, what is information? 1 Unfortunately, although the concept of information is the bedrock of the entire field, this question cannot be answered precisely. In this sense the concept of information in computer science is similar to the concepts of point, line, and plane in geometry: they are all undefined terms about which statements can be made but which cannot be explained in terms of more elementary concepts. 1

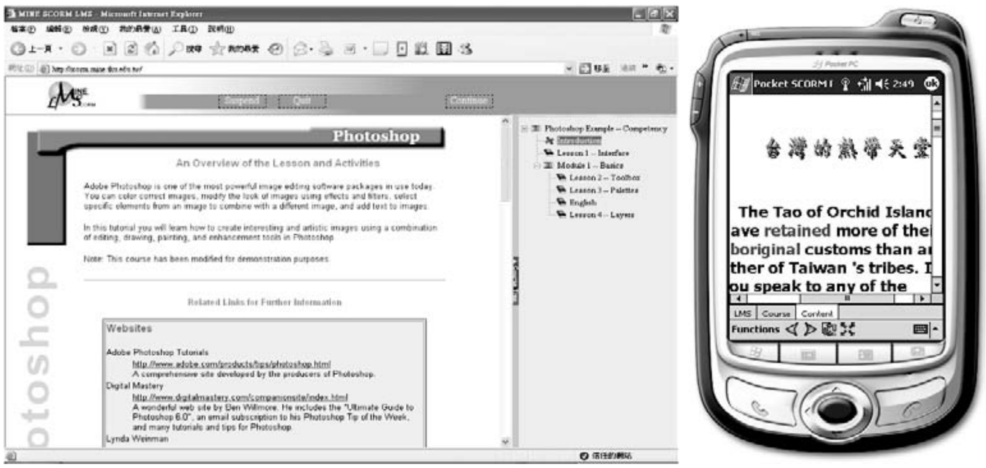
In geometry it is possible to talk about the length of a line despite the fact that the concept of a line is itself undefined. The length of a line is a measure of quantity. Similarly, in computer science 2 we can measure quantities of information. The basic unit of information is the bit 1, whose value asserts one of two mutually exclusive possibilities. For example, if a light switch can be in one of two positions but not in both simultaneously, the fact that it is either in the "on" position or the "off" position is one bit of information. If a device can be in more than two possible states, the fact that it is in a particular state is more than one bit of information.

Another way of thinking of this phenomenon is as follows. Suppose that we had only two-way switches 2 but could use as many of them as we needed. How many such switches would be necessary to represent a dial with eight positions? Clearly, one switch can represent only two positions (see Figure 1.1. 1a). Two switches can represent four different positions (Figure 1.1.1b), and three switches are required to represent eight different positions (Figure 1.1.1c). In general, n switches can represent 2^n different possibilities. 3

1

Table of Contents

Figure 14. Various layouts of the SCORM-compliant courseware on different learning devices



an individual learner. In addition, a Hard SCORM Student ID is printed for each student to use while logging in to the system with different lectures, respectively. An LMS supports the administrative functions and an underlying database will keep the student records, which is used to produce the IDs. Figure 12 shows an example of ID and Hard SCORM Control Panel. A Hard SCORM textbook will have a table of contents, chapter and sections, tests, and index. An example of Hard SCORM textbook is shown in Figure 13.

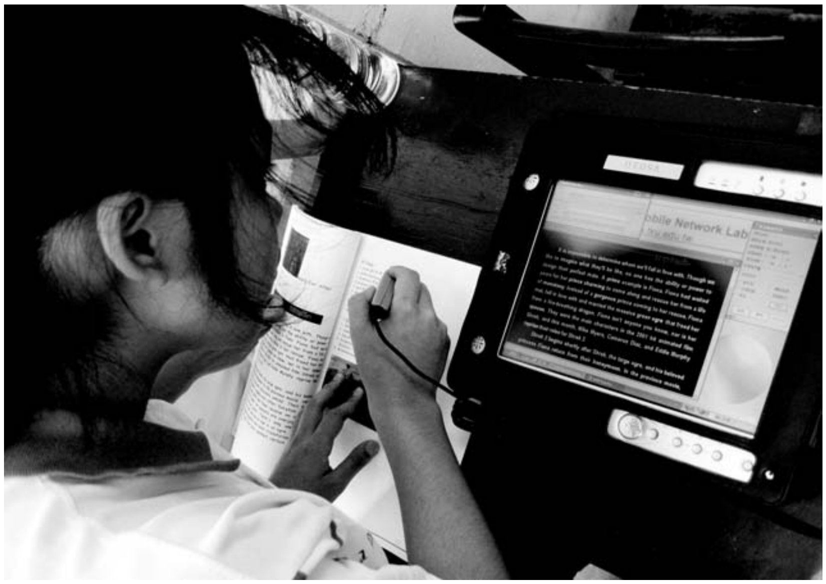
The authored learning contents can be delivered to the multimodal learning devices as well for supporting different types of learning styles. Figure 14 shows the authored learning contents on PCs and mobile devices.

Experiment Results and Evaluations

In summer 2005, the Hard SCORM project was used by a domestic high school (see Figure 15). Two English teachers used our Hard SCORM Authoring Tool and designed six units of course materials based on contents supported by the Ivy League Analytical English, Taiwan. Some auxiliary information such as the bilingual terminology glossaries, the synonyms, the antonym, the pronunciation, and even the online dictionary, can be bound with the embedded reference tags in the Hard SCORM textbook. Most of the auxiliary learning resources are formed in Micromedia Flash file format, and the rest of them are formed in video, audio, and even hyperlinks to the remote sites.

The learners use tablet PCs or PDAs, which were equipped with Hyper Pens for the innovative learning. From the perspective of learners, according to their learning experience, most students are interested in using high-tech devices such as PDAs and Smart Phones for learning. Furthermore, the Hard SCORM textbooks, which contain the six learning units and the associated digital references, are quite attractive to the students due to the variety and extension that conventional textbooks lacked. As a result, by utilizing the Hard SCORM textbooks, the learning performance is improved, especially in English vocabulary and pronunciation. From the viewpoint of instructors, the Hard SCORM Authoring Tool facilitates the learning contents generation. For an instructors who are nonexperts in computer, they are able to design an attractive courseware simply by using the Hard SCORM Authoring Tool. The instructors need not take account of the SCORM

Figure 15. Experiment on practical learning



specification, and the interoperability among those multimodal learning devices.

With respect to the performance of our proposed Hard SCORM Authoring Tool, we ask two professors in computer engineering to evaluate the software performance. The result of the evaluation shows the functionalities are sufficient and convenient for constructing SCORM-compliant learning contents for supporting multimodal learning devices, and the auxiliary toolkits are beneficial in creating the attractive learning materials for the various learning activities.

We also have a questionnaire designed by a professor in education school on the evaluation of authoring tool for the instructors and course contents for the students, respectively. We summarize user experiences and feedbacks from these two aspects. A few important comments can be summarized, as in Table 1.

Table 1. The evaluations of hard SCORM authoring tool and the learning materials

	Advantages	Drawbacks
Evaluation of the Hard SCORM Authoring Tool (from the instructors)	• The operations for generating course contents are simple and accommodating. • The Hard SCORM tags are easily assigned. • The auxiliary toolkits are beneficial for generating multimedia courses. • A user manual is helpful to understand the instructions.	• The sequencing rule setting is complex, according to the SCORM specification. • The Hard SCORM Tags will be broken while running into the margin of the document.
Evaluation of the course contents in multimodal learning devices (from the learners)	• The hyper links from a textbook to multimedia presentations are useful. • The use of Hyper Pen for learning fits ordinary reading behavior. • The Hard SCORM textbooks are attractive and interactive.	• The Hard SCORM Tags may mix with text instructions and handwritten notes in hardcopy books.

Conclusion and Future Works

Courseware authoring tools can be considered the fundamental systems for constructing attractive learning materials in an e-learning environment. Furthermore, the well-developed e-learning standards facilitate the whole learning processes, and simplify the interoperability regarding the diverse learning contents. The Hard SCORM Authoring Tool allows instructors to develop courseware based on the SCORM 2004 specification, such as the learning content aggregation, the metadata generating, the sequencing rules setting, and the navigation behaviors specifying. Some auxiliary toolkits were integrated with the tool for enriching the variety of multimedia presentations to fit the pedagogic needs. Out of the ordinary third party tools, the learning contents generated via the Hard SCORM Authoring tool can be delivered to learners via multimodal learning devices. It is also the first time that Hyper Pen device is used in a SCORM-based learning environment.

The proposed pervasive learning environment supports students to use multimodal learning devices to read the same course materials, and the individual learning records can be maintained in a central server consistently. Furthermore, the outcomes of the Hard SCORM Authoring tool can be in the hard copy form for serving the advantage of ordinarily comfortable and long-time reading for learners in a traditional learning manner. The Hard SCORM Authoring Tool is available at our site for a free try. A video demonstration section is also included, and interested readers are welcome to visit http://www.mine.tku.edu.tw/SCORM/.

In the near future, we are looking at two directions in our future research. Firstly, the current Hard SCORM tags are static. That is, even the navigation topology can vary from student to student, and the activation of a tag results in a unique outcome. However, it is possible to use an encoding technique to embed multiple branching of tag activation. In general, the encoding technique could be used with an intelligent tutoring system, which is based on the revision of sequence and navigation specification, as well as an assessment on student test performance. Thus, with the same hard copy textbook, supplementary references on PC or PDA are used as remedial lectures for those who need help. The second approach is to enhance the recognition of the Hard SCORM tags. Currently, the Hard SCORM tags contain a part of text-based information for representing the unique feature of specific digital information, and it's hard to be precisely recognized due to the tag appearance in small size. The automatic generation of unique Hard SCORM tag appearance in image-based should be considered with the relation to the specific digital information. We aim to use content-based image retrieval technologies, which allow graphical tags to be recognized by using a built-in camera on PDA or cellular phone. Therefore, a student is able to use a PDA or cellular phone to read a Hard SCORM textbook and display the attractive digital information with the same learning devices.

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Chapter V
An Ontology-Based e-Learning Scenario

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ABSTRACT

Selecting appropriate learning services for a learner from a large number of heterogeneous knowledge sources is a complex and challenging task. This chapter illustrates and discusses how Semantic Web technologies can be applied to e-learning system to help learner in selecting appropriate learning course or retrieving relevant information. It firstly presents the main features of e-learning scenario and the ontology on which it is based; then illustrates the scenario ontology with the training domain and the application domain. Finally, it presents Semantic Querying and Semantic Mapping approach.

INTRODUCTION

E-learning is a critical support mechanism for organizations and individuals to enhance their skills. The incredible velocity and volatility of today's markets require just-in-time methods for supporting the need-to- know of employees, partners and distribution paths. New styles of e-learning are the new challenges for the next century and will be driven by the requirements of the new economy.

Recent advances in technologies for e-learning provide learners with a broad variety of learning content available. Numerous documents resources may be used during e-learning. Some are internal and made by several actors implied in the e-learning, others are available on the web: on-line courses, course supports, slides, bibliographies, frequently asked questions, lecture notes, etc. Learner may choose between different lecture providers and learning management systems to access the learning content. On the other hand, the increasing variety of the learning material influences effort needed to select a course or training package. Adaptive support based on learner needs, background and other characteristics can help in selecting appropriate learning and during learning.

In order to better support humans in carrying out their various tasks with the web. Semantic web technologies are used to enable machines to interpret and process information. It could offer more flexibility in e-learning systems. Many of so far developed semantic web technologies provide us with tools for describing and annotating resources on the web in standardized ways, such as XML, RDF, XTM, OWL, DAML-S, and RuleML. These offer a way to make such components mobile and accessible within the wide sea of web information and applications. Personalisation is becoming increasingly important in the educational Semantic Web context by enabling shared content and services to be tailored to the needs of individual users (learners, content creators, providers, and instructors). The ambitious target is to offer manageable, extendable and standardised infrastructure for complementing and collaborating learning applications tailored to the needs of individual users.

Ontologies are a way of representing formal and shared information. They can be used to index data indicating their meaning, thereby making their semantics explicit and machine- accessible. They also can be used in e-learning as a formal means to describe the organization of universities and courses and to define services. An e-learning **ontology** should include descriptions of educational organizations (course providers), courses and people involved in the learning process.

This paper represents our effort toward a problem of semantic solution in e-learning system. It is organized as follows: Section 2 reviews the related works, Section 3 describes Metadata and Ontologies concepts. Section 4 shows our e-learning scenario. Section 5 describes our ontology design and representation. Section 6 shows our semantic querying and semantic mapping approach. Section 7 gives conclusions and future works.

RELATED WORKS

Among the variety of modern trends in educational technology development, the application of ontological research is probably one of the most fashioned and rapidly evolving. After the first dedicated workshop in 1999, more and more workshops and special journal issues have been brought out. Numerous papers in related conferences, journals, and books have been published.

Kay (1999) and Chen and Mizoguchi (1999) noted the advantage of using ontologies for learner/user models. Mizoguchi and Bourdeau (2000) studied how ontologies can help to overcome problems in artificial intelligence in education. Razmerita et al. (2003) proposed a generic **ontology**-based user modelling architecture. Mitrovic and Devedzic (2004) proposed the M-OBLIGE model for building multitutor ontology-based learning environments. The model allows domain expertise to be shared and can be used as a framework for integrating multiple tutors on the web. Moreale and Vargas-Vera (2004) developed an e-learning services architecture offering semantic- based services to students and tutors, in particular, ways to browse and obtain information through WS.

Metadata is the Internet-age term for information that librarians traditionally have used to classify books and other print documents. It has been widely used to structurally describe learning resources so that they can be better reused. At its most basic level, metadata provides a common set of tags that can be applied to any resource, regardless of who created it, what tools they used, or where it's stored. Tags are data describing data. Metadata tagging enables organizations to describe, index, and search their resources and this is essential for reusing them.

Metadata for e-Learning

Different communities have developed their own standardized **metadata** vocabularies to meet their specific needs. One of the most common metadata schemes on the web today is the "Dublin Core Schema" (DC) by the DCMI. The Dublin Core Metadata Initiative (DCMI) is an organization dedicated to promoting the widespread adoption of interoperable metadata standards and developing specialized metadata vocabularies for describing resources that enable more intelligent information discovery for digital resources.

Since Dublin Core is designed for metadata for any kind of digital resource, it pays no heed to the specific needs in describing learning resources. The "Learning Objects Metadata Standard" (LOM) by the Learning Technology Standards Committee (LTSC) of the IEEE was therefore established as an extension of Dublin Core. Each learning object can now be described using a set of more than 70 attributes divided into nine categories.

Metadata for Describing the Content of Learning Materials

Compared to traditional learning in which the instructor plays the intermediate role between the learner and the learning material, the learning scenario in **e-learning** is completely different: instructors no longer control the delivery of material and learners have a possibility to combine learning material in courses on their own. So the content of learning material must stand on its own. However, regardless of the time or expense put into creating advanced training material, the content is useless unless it can be searched and indexed easily. This is especially true as the volume and types of learning content increase.

The shared-understanding problem in e-learning system occurs when one tries to define the content of a learning document in the process of providing learning materials as well as in the process of accessing to particular learning material.

In an e-learning environment there is a high risk that two authors express the same topic in different ways. This means semantically identical concepts may be expressed by different terms from the domain vocabulary. For example, one may use the following semantically equivalent terms for the concept "Agent": "agent", "actor", "contributor", "creator", "player", "doer", "worker", "performe". The problem can be solved by integrating a domain lexicon in the **ontology** and thus define mappings from terms of the domain vocabulary to their meaning. E.g. in our example "agent", "actor", "contributor", "creator", "player", "doer", "worker", "performe" are symbols used in the real world and they are all mapped to the same concept "Agent" in the domain ontology.

Metadata for Describing the Context of Learning Materials

Learning material can be presented in various learning or presentation contexts. We may e.g. distinguish learning contexts like an "introduction", an "analysis" of a topic, or a "discussion". An example or a figure is some usual presentation contexts. The context description enables context-relevant searching for learning material according to the preferences of the user. For example, if the user needs a more detailed explanation of the topic, it is reasonable to find learning material that describes an example of the given topic. In order to achieve a shared-understanding about the meaning of the context vocabulary, a context-ontology is used.

Metadata for Describing the Structure of Learning Materials

Because e-learning is often a self-paced environment, training needs to be broken down into small bits of information that can be tailored to meet individual skill gaps and delivered as needed. These chunks of knowledge should be connected to each other in order to be able to build up a complete course from these chunks. Learning material is usually more complex in its structure than continuous prose, so it requires greater care in its design and appearance. Much of it will not be read continuously. The structure isn't a static one, because a course structure is configured depending on the user type, the user's knowledge level, his or her preferences and the semantic dependencies that exist between different learning chunks, e.g. an example might depend on first giving the corresponding definition. But, again shared understanding about used terms is also needed for describing the structure of a learning course.

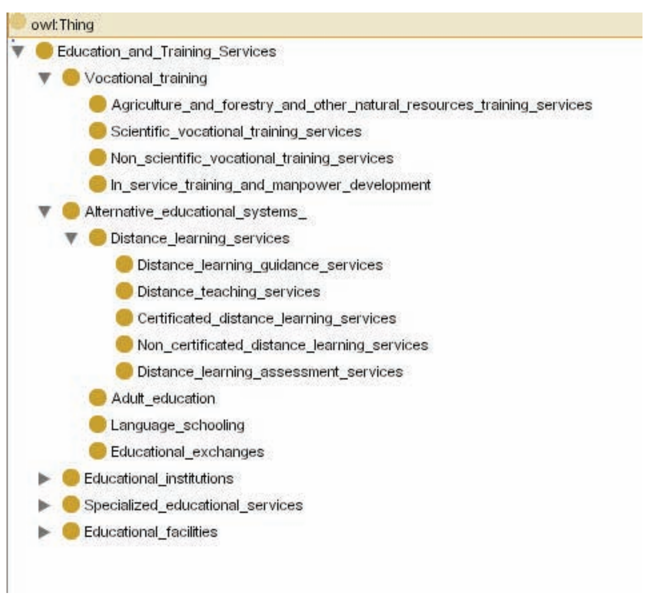
In order to standardize semantic metadata, specific ontologies are introduced in many disciplines. Typically, such ontologies are hierarchical taxonomies of terms describing certain topic. Figure 1 represent a subset of Education and Training Services according The ECCMA codes (http://www.eccma.org/unspsc/browse/86.html).

Our e-Learning Scenario

While metadata is a starting point to describe content, as most of those metadata standards lack a formal semantics. Although these standards enable interoperability within domains, they introduce the problem of incompatibility between disparate and heterogeneous metadata descriptions or schemas across domains. This lack of a shared understanding between terms in one vocabulary as well as between terms in various metadata vocabularies might be avoided by using ontologies as a conceptual backbone in an e-learning scenario. Ontologies are a more sophisticated way of modelling metadata and knowledge is relevant information delivered at the right time and context. It can be seen as an improvement over metadata as they formally define not only keywords but also relationships among them.

In an e-learning situation, learners are often geographically distant. It is thus necessary for them to have an easy access to documents and more generally to resources they need. To illustrate our

Figure 1. Ontology for education and training services



approach, we refer to a sample scenario. Mary is trying to improve her skills in English by looking for a training package. She wants to enroll in an English course in a University in Britain in Summer 2005. So Mary has an application to access and search a network of learning providers. The learning provider provides a routing and mapping between its scheme and the service identification schemes.

Ontology Design and Representation

Consider above E-Learning scenario, we define two classes: The first one (application ontology) specifies the individual who wants to choose the course to study. The second one describes the providers of the training domain, including courses (Chinese, English, French, German, Italian), location (USA, Britain, China), time (Fall_2005, Spring_2005, Summer_2005, Winter_2005).

We have following requests from Mary, and our ontology design is shown in Figure 2.

Request: -enroll(Mary, English_course) & location(English_course,Britain) & time (english_course, summer_2005).

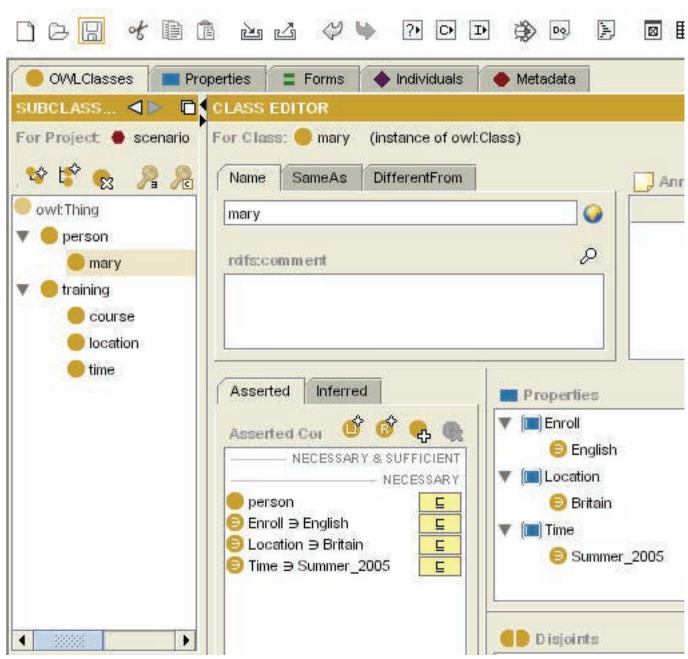
Approach

The process of achieving semantic solution here involve two basic operations: Semantic Querying and Semantic Mapping. We briefly describe each in the following subsections.

Semantic Querying

For above structure. We have the request from Mary and the corresponding OWL code is as following:

Figure 2. Ontology design and representation for our e-learning scenario (Screen shot using Protege 2000)



```
<?xml version=”1.0”?>
<rdf:RDF
    xmlns:rdf=”http://www.w3.org/1999/02/22-
rdf-syntax-ns#”
    xmlns:xsd=”http://www.w3.org/2001/
XMLSchema#”
    xmlns:rdfs=”http://www.w3.org/2000/01/rdf-
schema#”
    xmlns:owl=”http://www.w3.org/2002/07/
owl#”
    xmlns=”http://www.owl-ontologies.com/un-
named.owl#”
  xml:base=”http://www.owl-ontologies.com/un-
named.owl”>
  <owl:Ontology rdf:about=””/>
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Semantic Mapping

In an e-learning environment there is a high risk that two authors express the same topic in different ways. This means semantically identical concepts may be expressed by different terms from the domain vocabulary. In the context of the Web, ontology provides a shared understanding of a domain. Such a shared understanding is necessary to overcome differences in terminology.

One application's zip code may be the same as another application's area code. Another problem is that two applications may use the same term with different meanings. In university A, a course may refer to a degree (like computer science), while in university B it may mean a single subject (CS 101). Such differences can be overcome by mapping the particular terminology to a shared ontology (shown in Figure 3) or by defining direct mappings between the ontologies.

For our scenario, Letαbe the set of all training provider in a given repository. For a given query Q, the matchmaking algorithm of the repository host returns the set of all training providers that are compatible matches(Q):

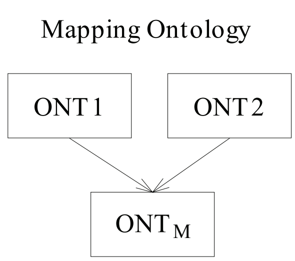
$$\text{matches}(Q) = \{A \in/ \ \alpha\text{compatible}(A, Q)\ \}$$

Two descriptions are compatible if their intersection is satisfiable, the query from the requester:

Query = (trainingprofile(items Course.{English }∏Location {Britain}∏ Time{Summer_2005}

The intersection of this query with provider is satisfiable. Finally, matchmaking∈matches(Q uery)

Figure 3. ONT_M contains rules that map concepts between ontologies



Conclusion and Future Works

In this paper we presents an approach for implementing the e-learning scenario using Semantic Web technologies. It is primarily based on ontology-based descriptions of the learning materials and thus provides flexible and personalized access to these learning materials. However, in this paper, we are only concerned by the fact that a service is represented by input and output properties of the service profile, we still need do more research on other key operations necessary to support e-learning interactions in the future, such as negotiation, proposals and agreements. So that the Semantic Web can provides an ideal framework for the standardization of the e-learning. As the learner data are sensitive, the trust and security issues have to be further investigated. The technical infrastructure for this approach to personalization has to be investigated in more detail

Mapping or mediating between different schemas should be investigated as well when we want to provide communication between different peers. Different identification schemes have to be investigated more deeply to support better exchange of learner profile fragments between distributed nodes.

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Chapter VI
Adaptive Synchronization of Semantically Compressed Instructional Videos for Collaborative Distance Learning

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ABSTRACT

The increasing popularity of online courses has highlighted the need for collaborative learning tools for student groups. In this article, we present an e-Learning architecture and adaptation model called AI2TV (Adaptive Interactive Internet Team Video), which allows groups of students to collaboratively view instructional videos in synchrony. Video player actions, like play, pause and stop, can be initiated by any group member and and the results of those actions are synchronized with all the other students. These features allow students to review a lecture video in tandem, facilitating the learning process. AI2TV upholds the invariant that each student will receive semantically equivalent content at all times.

Experimental trials show that AI2TV successfully synchronizes instructional videos for distributed students while concurrently optimizing the video quality, even under conditions of fluctuating bandwidth, by adaptively adjusting the quality level for each student while still maintaining the semantic content of the instructional videos.

INTRODUCTION

Distance learning programs such as the Columbia Video Network (www.cvn.columbia.edu) have evolved from Fedexing lecture video tapes to their off-campus students to streaming videos over the Web. The lectures might be delivered "live," but are more frequently post-processed and packaged for students to watch (and re-watch) at their convenience. This introduces the possibility of forming "study groups" among students who can view the lecture videos together and pause, rewind, or fast-forward the video to discussion points, thus approximating the pedagogically valuable discussions that occur during on-campus lectures. However, conventional Internet video technology does not yet support *collaborative video viewing* by multiple geographically dispersed users. It is particularly challenging to support What I See Is What You See (WISIWYS) when some users are relatively disadvantaged with respect to bandwidth (e.g., dial-up modems) and local resources (e.g., old graphics cards, small disks).

AI^{2}TV is an e-learning architecture supporting virtual student groups. To that end, we have developed the technology for "semantically adapting" standard MPEG videos into sequences of still images. This technology automatically selects the most semantically meaningful frames to show for each time epoch and can generate different sequences of JPEG images for a range of different compression (bandwidth) levels. It was designed with typical lecture videos in mind: for instance, it recognizes that it is more important to see the blackboard content after the instructor has finished writing, rather than showing the instructor's back as he/she writes it on the board.

Other technical challenges are *synchronizing* and *adapting* the downloading and display of the image sequences among the distributed students, including support for shared video player actions. We have developed an approach that achieves this using three mechanisms working in tandem: First, the software clocks of the video clients for each student are synchronized using NTP (Network Time Protocol), hence they use the same time reference with respect to the image sequences, where each image is associated with its start and end times relative to the beginning of the sequence. Second, the video clients communicate with each other over a distributed publish-subscribe event bus, which propagates video actions taken by any user to the rest of the group, as well as other events occurring on the video clients. Finally, since we are particularly concerned about disenfranchised user communities that have relatively low bandwidth, the final contribution of AI^{2}TV concerns enabling the optimization of the video quality according to the bandwidth constraints of each user, while enforcing group synchronization through a distributed feedback control loop that dynamically adapts each video client.

This paper presents the architecture and dynamic adaptation model of AI^{2}TV, describes how it tackles the challenges of quality optimization and synchronization in collaborative video viewing, and provides an evaluation of the effectiveness of our approach, with empirical results obtained using real lecture videos from Columbia's Video Network.

Motivation and Background

Correspondence courses have been available for over a century, for example, the University of Wyoming began offering extension courses in 1892 (Miller, Ditzler, & Lamb, 2003) correspondence courses have traditionally been designed for individual students with a self-motivated learning style, studying primarily from text materials.

A National Science Foundation report (NSF, 2002) discusses how technology, from radio to television; to audio and video cassettes; and to audio and video conferencing has affected distance education. The report states that the recent use of Internet technologies, especially the Web, has "allowed both synchronous and asynchronous communication among students and between faculty and students" (p. 1) and has "stimulated renewed interest in distance education." (p. 4) It also mentions that "stimulating interaction among students" (p. 4) can help reduce dropout rates, which it says may be higher in distance education than in traditional courses. Finally, it cites some studies that "suggest the Web is superior to earlier distance education technologies because it allows teachers to build collaborative and team-oriented communities."

Even though some Internet-based tools, like instant messaging, desktop sharing, and co-browsing can be used to facilitate the communicative aspects of synchronous collaboration, dedicated support for synchronous collaboration in long distance education over the Web remains a major concern in courses where group work is encouraged (Wells, 2000), since there are few educational tools that offer that kind of support to a group of online students (Burgess & Strong, 2003). However, it seems that Web-based video streaming should enable synchronous collaboration "situated" by collaborative lecture video viewing, approximating the experience of on-campus students physically attending the class discussion.

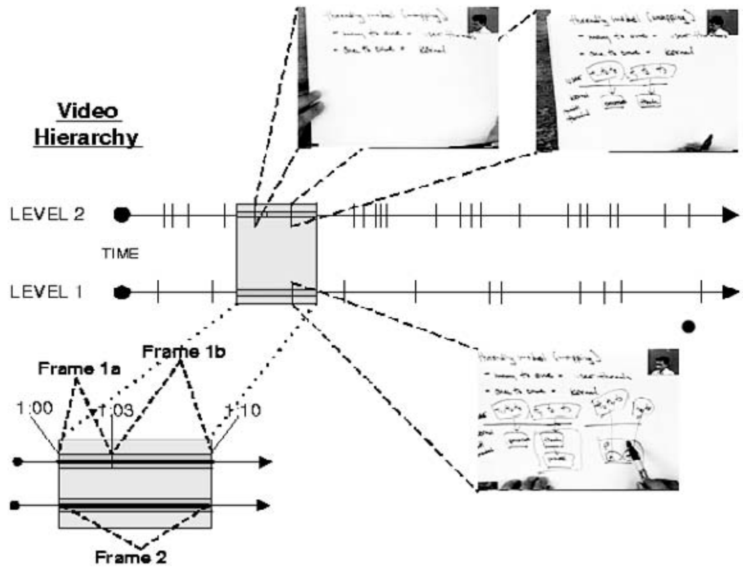
Our AI^{2}TV project contributes to synchronous collaboration support for life-long and distance education, and specifically to the problem of collaborative video viewing, to foster virtual classrooms and borderless education. Our design is intended for small classes or study groups within a larger class and reaches out to disenfranchised users with relatively low bandwidths, who constitute a significant portion of the Internet user community (Richtel, 2004), to allow collaboration with other users who enjoy higher bandwidth. Since it is likely that future bandwidth improvements will also be unevenly available, our architecture will remain effective even when the disparity is between bandwidths that all have a higher absolute level of performance than today's.

Collaborative video viewing poses a twofold technical challenge: on the one hand, all users *must* be kept synchronized with respect to the content they are supposed to see at any moment during play time; on the other hand, each individual user *should* be provided with a level of quality that is optimized with respect to his/her available resources, which may vary during the course of the video.

One way to address the problem of balancing the group synchronization requirement with the optimization of individual viewing experiences is to use videos with cumulative layering (McCanne, Jacobson, & Vetterli, 1996), also known as scalable coding (Li, 2001). In this approach, the client video player selects a quality level appropriate for that client's resources from a hierarchy of several different encodings for that video. Thus a client could receive an appropriate quality of video content while staying in sync with the other members of the group.

We use *semantic compression* to produce a video with cumulative layering. Our semantic compression algorithm (Liu & Kender, 2001) reduces a video to a set of semantically significant key frames. That tool operates on conventional MPEG videos and outputs sequences of JPEG

Figure 1. Semantic video scenario



frames. The semantic compression algorithm profiles video frames within a sliding time window and selects in that window key frames that have the most significant instructional information.

A conceptual diagram of a layered video produced from this semantic compression is shown in Figure 1. While a detailed discussion of that video compression algorithm and system is available in the *Semantic Compression of Instructional Videos* Section, it is interesting to note at this point that the semantic compression algorithm produces key frames based on semantic content of instructional videos: when there are pockets of relatively high frequency semantic change, that is, more key frames are produced. Therefore, the resulting video plays back at a *variable* frame rate, which adds substantial complexity to the bandwidth demands of the client.

The bottom left inset in Figure 1 shows the juxtaposition of individual frames from two different quality levels. Each frame has a representative time interval [start:end]. For the higher level, Frame 1a represents the interval from 1:00 to 1:03, and Frame 1b represents the interval from 1:04 to 1:10. For the lower level, Frame 2 represents the entire interval from 1:00 to 1:10. In this diagram, Frame 2 is semantically equivalent to Frame 1a and 1b together. However, in real JPEG frame sequences produced from the same MPEG video for different quality levels, start and end times of frame sets rarely match up that precisely, and the determination of the optimal frame to semantically represent a given frame set remains a research issue.

Our goals are to provide semantically equivalent content to a group of students with diverse resources simultaneously providing the best quality video possible at any given moment. We achieve these goals by taking advantage of the semantic instructional video compression algorithm and by dynamically adjusting the compression level assigned to each client while watching the video. Thus, for our purposes, synchronization of collaborative video boils down to showing semantically equivalent frames at all times. To adjust the video clients in response to the changing environment, we use an "autonomic" controller to maintain the synchronization of the group of video clients while simultaneously fine tuning the quality seen by each student.

This controller remains conceptually separate from the controlled video system and employs our decentralized workflow engine, named Workflakes (Valetto, 2004). Said workflow coordinates the behavior of software entities, as opposed to conventional human-oriented workflow systems (the use of workflow technology for the specification and enactment of the processes coordinating software entities was previously suggested by Lemer et al. [2000]). Workflakes has also been used in a variety of more conventional "autonomic computing" domains, where it orchestrates the work of software actuators to achieve the automated dynamic adaptation of distributed applications (Parekh, Kaiser, Gross, & Valetto, in press; Valetto & Kaiser, 2003). In AI^{2}TV, Workflakes monitors the video clients and accordingly coordinates the dynamic adjustment of the compression (quality) level currently assigned to each client.

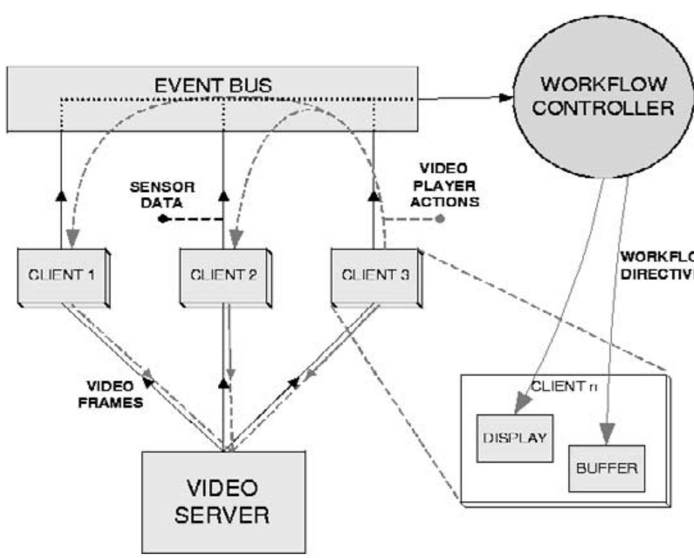
System Architecture

AI^{2}TV includes a video server, several video clients, an autonomic controller, and a common communications infrastructure (the event bus), as shown in Figure 2.

The video server provides the educational video content to the clients. Each lecture video is stored in the form of a hierarchy of versions, produced by running the semantic compression tool with different settings. Each run produces a sequence of JPEG frames with a corresponding frame index file. The task of the video server is simply to provide remote download access to the collection of index files and frames over HTTP. The task of each video client is to acquire video frames, display them at the correct times, and provide a set of basic video functions. Taking a functional design perspective, the client is composed of four major modules: (1) a time controller, (2) video display, (3) a video buffer that feeds the display, and (4) a manager for fetching frames.

The time controller's task is to ensure that a common video clock is maintained across clients. It relies on NTP to synchronize the system's software clocks, therefore ensuring a common time base from which each client can reference the video indices. Since all the clients refer to the same time base, then all the clients are showing

Figure 2. AI^{2}TV Architecture



semantically equivalent frames from the same or different quality levels.

The video display renders the JPEG frames at the correct time into a window and provides a user interface for play, pause, goto, and stop. When any participant initiates such an action, all other group members receive the same command via the event bus, thus all the video actions are synchronized. Video actions are time stamped so that clients can respond to those commands in reference to the common time base. The video display uses the current video time and display quality level to index into the frame index for the frame to be displayed. Before trying to render the needed frame, it asks the video buffer manager if it is available. The video display also includes an actuator that enables the autonomic controller to adjust the current display quality level.

The video manager constitutes a downloading daemon that continuously downloads frames at a certain compression (or quality) level into the video buffer. It keeps a hash of the available frames and a count of the current reserve frames (frames buffered) for each quality level. The buffer manager also includes an actuator that enables external entities, such as the controller, to adjust the current downloading quality level.

The main purpose of the autonomic controller is to ensure that, given the synchronization constraint, each client plays at its highest attainable quality level. The architecture provides an end-to-end closed control loop, in which sensors attached to the target system continuously collect and send streams of data to "gauges." The gauges analyze the incoming data streams and recognize adverse conditions that need adaptation, relaying that information to the controller. The controller coordinates the expression and orchestration of the workflow needed to carry out the adaptation. At the end of the loop, actuators attached to the target system effect the needed adjustments under the supervision of the controller.

In the AI^2TV case, sensors at each client monitor for the currently displayed frame, its quality level, the quality level currently being fetched by the manager, the time range covered by buffer reserve frames, and the current bandwidth. Gauges are embedded together with the controller for expediency in design and to minimize communication latency. They receive the sensor reports from individual clients, collect them in buckets, similar to the approach in Gautier and Diot (1998), and pass the bucket data structure to the controller's coordination engine. A set of helper functions tailored specifically for this application operate on this data structure and produce triggers for the coordination engine. When a trigger is raised, it enacts a workflow plan, which is executed on the end hosts by taking advantage of actuators embedded in the clients.

Communication among the video clients, as well as between the sensors and actuators at the clients and the autonomic controller, is provided by an asynchronous event bus that channels video player actions, sensor reports, and adaptation directives.

Semantic Compression of Instructional Videos

An effective video compression model for collaborative distance learning environments is required to provide multiple different "versions" of a video to students that may access instructional content using devices that differ significantly in resolution, computing capability, storage, and available network resources. Several additional requirements exist in this kind of video compression process: First, the compression should be content based, by analyzing instructional content; Second, the semantic video compression should produce different levels of content summarization, with each level showing different details of video content; Third, the compression should be dynamic so that it can also handle live instructional videos recorded in classrooms, enabling real-time multicasting of instructional videos; Fourth, the compression model should be computationally efficient.

Taking into consideration the aforementioned requirements, we have developed a semantic video compression model for real-time adaptation of instructional videos. The compression ratio is tunable, thus different levels of compression can be achieved. Each layer contains semantic information of the instructional video at a certain level of detail. Since this model is specially designed for instructional videos with emphasis on the characteristics of this video domain, it is different from previous work on signal-level video compression. The scalable coding scheme adopted in MPEG-4 compression standard (Koenen, 2002) is still based on signal-level video compression. Previous video key-frame-based compression and summarization methods (Ardizzone & Hacid, 1999; Chang, Sull, & Lee, 1999; Girgensohn & Boreczky, 1999; Smith & Kanade, 1997; Zhuang, Rui, Huang, & Mehrotra, 1998) are tuned for professionally edited videos such as movies, sports, and news videos. By comparison, instructional videos are (mostly) unedited videos without salient video structures like shots and scenes, and the visual content is mostly embedded in handwritten or printed characters/figures.

The model of semantic compression of instructional videos is illustrated in Figure 3. Basically, it is a dynamic video buffer in which video frames are evaluated and comparatively insignificant video frames are dropped. For a video buffer of n slots (slots $S_1, S_2, \ldots, S_n$), the video stream comes into S_1, moves through the buffer slots $S_2, S_3, \ldots, S_n$ in order, partially leaks from the buffer at any slot, and finally goes out of the buffer at slot S_n. The surviving outgoing frames form a semantically compressed version of the instructional video.

For each video frame coming into the video buffer, a content analysis module first extracts its instructional content. Here the instructional video content refers to the textual content on board, paper, and slides. To extract the text area from video frames efficiently, we use a block-based processing approach. We divide each frame into blocks of size of 16 by 16 and classify these blocks into three categories: paper/board blocks, irrelevant blocks, and uncertain blocks, based on the portion of paper background color pixels in a block. Paper blocks have only paper and/or text, and irrelevant blocks have images of the instructor and other noncontent areas. Uncertain blocks are those that fail this initial coarse filter and are further processed by more sophisticated and expensive techniques, that is, using region merging and growing techniques to remove holes in a region. As shown in Figure 4, the written content is extracted and the irrelevant regions are removed.

Figure 3. Dynamic buffer model for semantic compression of instructional videos

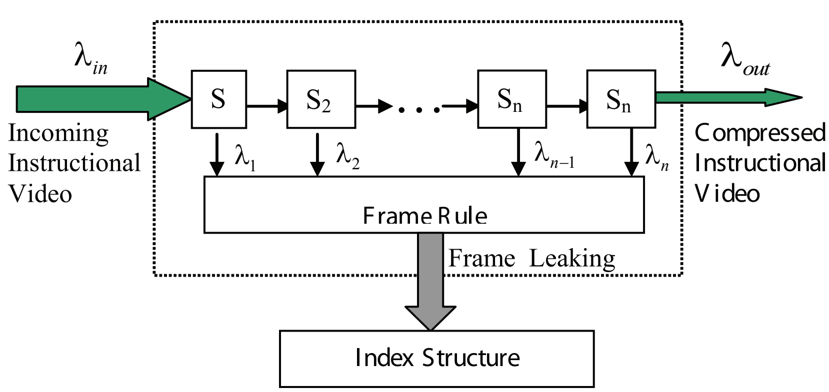
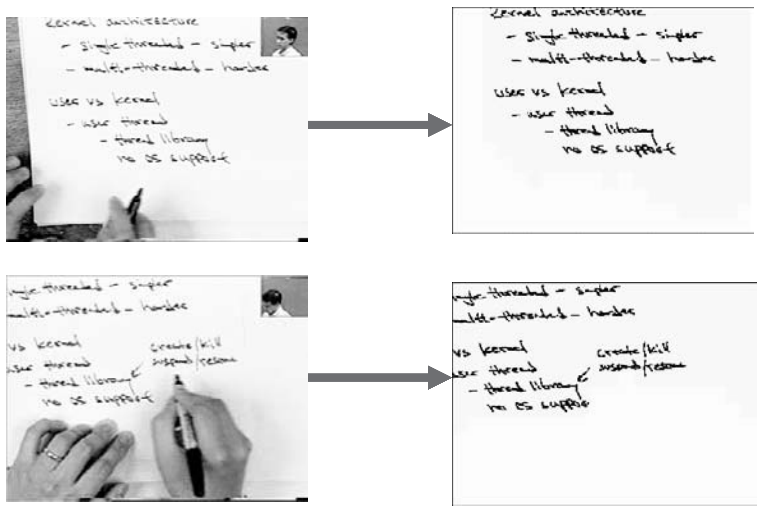


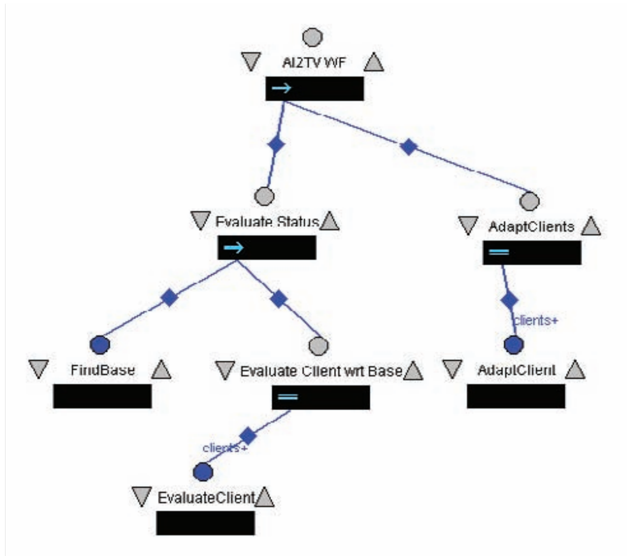
Figure 4. Content analysis of instructional video frames



Based on the content analysis of instructional videos, we define the semantic distance between two adjacent video frames as the amount of different textual content pixels and apply a leaking rule to the video to achieve semantic video compression. In compressing instructional videos, the frames in the video buffer are dropped at a leaking rate determined by the incoming frame rate (set by the video source or server) and the output frame rate (set by the available bandwidth to the client). The leaking process selects which frame in the video buffer to drop and removes it from the queue. The queue, implemented as a doubly linked list, then shifts all the frames in lowered numbered slots to their successor buffer slots, freeing up the first slot again.

In a n-slot (slots $S_1, S_2, \ldots, S_n$) video buffer, let $d_{i,j}$ be the distance from frame f_i to frame f_j. We first find the minimum of all distances between adjacent frames in the video buffer. Suppose the minimum distance is $d_{k,k+1}$, i.e., $d_{k,k+1} = \min_i \{d_{i,i+1}\}$. The frame f_k and f_{k+1} have the minimum distance in the buffer, indicating that the content of these two frames are the most similar among all frame pairs in the buffer. Thus we may choose to delete one of f_k and f_{k+1} to reduce the content redundancy in the buffer. The decision of deleting which one comes from the test: Suppose frame f_k and f_{k+1} are adjacent to frame f_{k-1} and f_{k+2}, respectively. If $\min\{d_{k-1,k+1}, d_{k+1,k+2}\} > \min\{d_{k-1,k}, d_{k,k+2}\}$, we delete frame f_k in the buffer, otherwise we delete frame f_{k+1}. This test measures the impact of the deletion, so we always remove the frame that makes the remaining frames less redundant in the video buffer. This leaking rule computes the effect that dropping either frame f_k or f_{k+1} has on their temporal context, and chooses to drop the frame that accentuates the semantic individuality of the neighboring frames of the evolving compressed video stream. This "Min-Min" leaking rule appears to maintain larger semantic differences in the buffer. This compression model is applicable to both prerecorded videos and live video signals, and the leaking activities can be recorded in a data structure, which is further used for indexing and retrieval applications. By choosing different output frame rates λ_{out}, we can compress an instructional video into different layers with different level of details. We take advantage of the semantic compression al-

Figure 5. AI²TV Workflow diagram



gorithm's ability to provide different layers of semantically equivalent video by adapting the client to play at the layer that provides the client with the richest possible viewing experience.

Adaptation Model

The adaptation scheme we adopt consists of two levels: a higher level data flow and a lower level adjustment heuristic. The former directs the flow of data through a logical sequence to provide a formal decision process, while the latter provides the criteria as to when to make certain adjustments.

The higher level logic is shown in Figure 5. The diagram shows the task decomposition hierarchy according to which the adaptation workflow unfolds. Note that the evaluation of clients' state with respect to the group (EvaluateClientBase) and the issuing of adaptation directives (AdaptClient) are both carried out as a set of parallel steps. Also note that the multiplicity of those parallel steps is dynamically determined via the number of entries in the clients variable.

The adaptation scheme at the lower level falls into two categories: (1) directives that adjust the client in response to relatively low bandwidth situations, and (2) those that take advantage of relatively high bandwidth situations. When a client has (relatively) low bandwidth, it may not be able to download the next frame at the current quality level by the time it needs to begin displaying that frame. Then both the client and buffer quality levels are adjusted downwards one level. If the client is already at the lowest level (among those available from the video server), the controller calculates the next possible frame that most likely can be successfully retrieved before its own start time while remaining synchronized with the rest of the group. The client is then directed to jump ahead to that frame. When a client has instead (relatively) high bandwidth, the buffer manager starts to accumulate a reserve buffer.

Once the buffer reaches a threshold value (e.g., 10 buffered frames), the controller directs the manager to start fetching frames at a higher quality level. Once sufficient reserve is accumulated at that higher level, the client is then ordered to display frames at that quality level. If the bandwidth drops before the buffer manager can accumulate enough frames in the higher level reserve, the buffer manager drops back down one quality level.

EVALUATION

Our assessment considers the ability of AI^{2}TV to synchronize the clients and to optimally adjust their video quality. Our results were computed from client configurations simulating small study groups which consisted of 1, 2, 3, and 5 clients together running a semantically summarized video for 5 minutes, with sensors probing clients' state every 5 seconds. The compression hierarchy we employed has five quality levels.

We define a baseline client against which the performance of our approach is compared. The average bandwidth per level is computed by summing the size in bytes of all frames produced at a certain compression level and dividing by the total video time. The baseline client's quality level is static for the duration of the video. We provide the baseline client with the corresponding bandwidth to the video server for its chosen level by using a bandwidth throttling tool. Note that using the average as the baseline does not account for the inherent variability in video frame rate and likely fluctuations in real-world network bandwidth, where adaptive control can make a difference. Each controller-assisted client is assigned an initial level in the compression hierarchy and the same bandwidth as the baseline client for that hierarchy level. For each experimental trial, we record any differences resulting from the controller's adaptation of the clients' behavior versus the behavior of the baseline client, with respect to synchrony and frame rate.

Evaluating Synchronization

The primary goal of our system is to provide synchronous viewing of lecture videos to small groups of geographically dispersed students, some possibly with relatively meager resources. Our initial experiments evaluate the level of synchronization for several small groups of clients involved in a video session. Each client is preset at a designated level of compression and given the average baseline bandwidth required to sustain that compression level. To measure the effectiveness of the synchronization, we probe the video clients at periodic time intervals and log the frame currently being displayed. This procedure effectively takes a series of system snapshots, which we can evaluate for synchronization correctness. We check whether the frame being displayed at a certain time corresponds to one of the valid frames for that time, on *any* quality level. We allow an arbitrary level here because the semantic compression algorithm ensures that all frames designated for a given time will contain semantically equivalent information. We obtain a score by summing the number of clients *not* showing an acceptable frame and normalizing over the total number of clients. A score of 0 indicates a fully synchronized system.

These experiments showed a total score of 0 for all trials, meaning that all of the clients were viewing appropriate frames when probed. Notwithstanding the variations in the frame rate and/or occasional fluctuations in the actual bandwidth of the clients, no frames were missed. This result demonstrates that the chosen baseline combinations of compression levels and throttled bandwidths do not push the clients beyond their bandwidth resource capacity.

Then we ran another set of experiments, in which the clients were assigned more casually selected levels of starting bandwidths. Said casual selection is representative of real-world situations, such as receiving Internet audio/video streams, where users must choose a desired frame rate for the transmission of the content. The user may have been informed that he/she is allocated a certain bandwidth level from his/her Internet service provider, but may actually be receiving a significantly lower rate. The clients were assigned bandwidths one level lower than the preset quality level. We ran this set of experiments first without the aid of the autonomic controller and then with it. In the former case, clients with insufficient bandwidth were stuck at the compression level originally selected, and thus missed an average of 63% of the needed frames. In the latter case, the same clients only missed 35% of the needed frames. Although both situations show a significant fraction of missed frames, these results provide evidence of the benefits of the adaptive scheme implemented by the autonomic controller.

These data show how in typical real-world scenarios, in which network bandwidth fluctuations and the variable video frame rate do not permit an informed decision about the most appropriate quality level, the adaptive technology of our autonomic controller makes a significant positive difference.

Evaluating Quality of Service

The most interesting technical innovation of the AI^{2}TV system is our autonomic controller approach to optimizing video quality. Here we analogously use a scoring system relative to the baseline client's quality level. We give a weighted score for each level above or below the baseline quality level. The weighted score is calculated as the ratio of the frame rate of the two levels. For example, if a client is able to play at one level higher than the baseline, and the baseline plays at an average n frames per second (fps) while the level higher plays at 2*n fps, the score for playing at the higher level is 2. The weighted score is calculated between the computed average frame rates of the chosen quality levels. Theoretically, the baseline client should receive a score of 1. Note that we formulated this scoring system because other scoring systems (e.g., [Baqai et al., 1996; Corte, Lombardo, Palazzo, & Schembra, 1998; Wang, Ostermann, & Zhang, 2002) measure unrelated factors such as the synchronization between different streams (audio and video), image resolution, or human perceived quality, and are not constrained by the group synchronization requirement. This restriction mandates a scoring system sensitive to the relative differences between quality hierarchies.

Our experiments show that baseline clients scored a group score of 1 (as expected), while the controller-assisted clients scored a group score of 1.25. The one-tailed t score of this difference is 3.01, which is significant for an α value of .005 (N=17). This result demonstrates that using the autonomic controller enabled our system to achieve a significant positive difference in the quality of service (QoS) aspect that relates to received frame rate. Note that the t score does not measure the degree of the positive difference: To demonstrate the degree of benefit, we measure the proportion of additional frames that each client is able to enjoy. We found that, overall, those clients received 20.4% (±9.7, N=17) more frames than clients operating at a baseline rate.

Running the client at a level higher than the average bandwidth needed puts the client at risk for missing more frames, because the autonomic controller is trying to push the client to a better but more resource-demanding level. To evaluate that risk, we also count the number of missed frames during a video session, which is intended as a separate measure of QoS characteristic with respect to the measure of relative quality described previously. In all of our experiments, there was one single instance in which a controller-assisted client missed some frames: in particular it missed two consecutive frames in a time region of the semantically compressed video that demanded a higher frame rate, while at the same time the fluctuating bandwidth available to that client was relatively low.

RELATED WORK

Yin, Lin, Zhuang, and Ni (2004) provide an adaptive multimedia distribution system based on streaming, multicast, and compression technology. They show that they can improve the level of QoS, but do not discuss user-level action synchronization, and use quality degradation rather than semantic compression to adapt to client resource constraints. Walpole et al. (1997) provide a distributed real-time MPEG player that uses a software feedback loop between a single server and a single client to adjust frame rates. Their architecture incorporates feedback logic to each video player, which does not support group synchronization, while the work presented here explicitly supports the synchronization of (semantically equivalent) video frames across a small group of clients.

An earlier approach to AI^{2}TV is described in Gupta and Kaiser (2004). In that version, a collaborative virtual environment (CVE) supported a variety of team interactions (Dossick & Kaiser, 1999), with the optional lecture video display embedded in the wall of a CVE "room." Video synchronization data were piggybacked on top of the UDP (User Datagram Protocol) peer-to-peer communication used primarily for CVE updates, which did not work very well due to the heavyweight CVE burden on local resources.

Our approach to synchronization can be classified as a distributed adaptive scheme that employs a global clock and operates proactively. The main difference compared to other approaches, such as the Adaptive Synchronization Protocol (Rothermel & Helbig, 1997), the work of Gonzalez and Adbel-Wahab (2000), or that of Liu and Zarki (2003), is that our approach is not based on play-out delay. Instead, we take advantage of layered semantic compression coupled with buffering to "buy more time" for clients that might not otherwise be able to remain in sync, by putting them on a less demanding level of the compression hierarchy. Liou, Toklu, and Heckrodt (1999) develop a system for synchronizing videos, but that work provides no scalable videos and instructional video analysis.

Liu, Li, and Zhang (2003) provide a comprehensive summary of the mechanisms used in video multicast for quality and fairness adaptation as well as network and coding requirements. Our work can be framed in that context as a single-rate server adaptation scheme to each of the clients because the video quality we provide is tailored specifically to that client's network resources.

Instructional video compression, adaptation, and indexing are crucial for distance learning. Previous key frame selection methods (Idris & Panchanathan, 1997; Mandal, Idris, & Panchanathan, 1999) are based on video segmentation, frame clustering, or some hybrid of these two (Das & Liou, 1998). In general, segmentation-based, key frame selection methods choose one or more representative frames for each segmented video structural unit as key frames; clustering-based, key frame selection methods classify frames of the original video sequence into clusters, then choose one key frame from each frame cluster.

However, video indexing and summarization methods based on video segmentation (Ardizzone & Hacid, 1999; Chang et al., 1999; Smith & Kanade, 1997) appear tuned to highly structured and professionally edited commercial products. For instructional videos, segmentation-based, key frame selection is no longer appropriate because there are no salient structural units. Video indexing methods based on clustering (Girgensohn & Boreczky, 1999; Zhuang et al., 1998) avoid segmentation preprocessing; however, most video key frame clustering methods highly depend on thresholds that determine the size of cluster, the number of key frames, or the level of key frames in a key frame hierarchy. Since these thresholds vary greatly among different video genres or even within the same video genre, they are difficult to choose. Furthermore, most clustering-based methods are expensive in time and storage.

CONCLUSION

We present an e-learning architecture and prototype system that allows small, geographically dispersed student groups to collaboratively view lecture videos in synchrony. To accommodate disenfranchised users with relatively low bandwidth and to achieve the goal of providing clients with the best video quality attainable while remaining in synchrony, AI^{2}TV's employs an "autonomic" (feedback loop) controller that dynamically adapts the video quality according to each client's network resources. We rely on a semantic compression algorithm to guarantee that the semantic composition of the simultaneously viewed video frames is equivalent for all clients. Our system distributes appropriate quality levels of video to clients and automatically adjusts them according to their current bandwidth resources. We have demonstrated the advantages of this approach through experimental trials using bandwidth throttling to show that our system can provide synchronization of real-world, distance learning lecture videos together with optimized video quality to distributed student groups.

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Chapter VII
Refining the Results of Automatic e-Textbook Construction by Clustering

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ABSTRACT

The abundance of knowledge-rich information on the World Wide Web makes compiling an online e-textbook both possible and necessary. In our previous work, we proposed an approach to automatically generate an e-textbook by mining the ranked lists of the search engine. However, the performance of the approach was degraded by Web pages that were relevant but not actually discussing the desired concept. In this article, we extend the previous work by applying a clustering approach before the mining process. The clustering approach serves as a post-processing stage to the original results retrieved by the search engine, and aims to reach an optimum state in which all Web pages assigned to a concept are discussing that exact concept.

INTRODUCTION

The World Wide Web has evolved into one of the largest information repositories. It now becomes feasible for a learner to access both professional and amateurish information about any interested subject. Professional information often includes compiled online dictionaries and glossaries;

course syllabi provided by teachers; tutorials of scientific software; overviews of research areas by faculties from research institutes; and so forth. Discussion boards sometimes offer intuitive descriptions of the interested subjects that are beneficial for students or beginning learners. Both these resources greatly enrich and supplement the existing printed learning material. The abundance of knowledge-rich information makes compiling an online e-textbook both possible and necessary.

The most common way of learning through the Web is by resorting to a search engine to find relevant information. However, search engines are designed to meet the most general requirements for a regular user of the Web information. Use Google (Brin & Page, 1998) as an example. The relevance of a Web page is determined by a mixture of the popularity of the page and textual match between the query and the document (Chakrabarti, 2002). Despite its worldwide success, the combined ranking strategy still has to face several problems, such as ambiguous terms and spamming. In the case of learning, it becomes even harder for the search engine to satisfy the need of finding instructional information, since the ranking strategy cannot take into account the needs of a particular user group, such as the learners.

Recently, many approaches have been proposed to improve the appearance of Web search engine results. A popular solution is clustering, providing users a more structured means to browse through the search engine results. Clustering mainly aims at solving the ambiguous search term problem. When the search engine is not able to determine what the user's true intention is, it returns all Web pages that seem relevant to the query. The retrieved results could cover widely different topics. For example, a query for "kingdom" actually referring to biological categories could result in thousands of pages related to the United Kingdom. Clustering these results by their snippets or whole pages is the most commonly used approach to address this problem (Ferragina & Gullí, 2004; Zamir & Etzioni, 1999; Zeng, He, Chen, & Ma, 2004). However, the structure of the hierarchy presented is usually determined on the fly. Cluster names and their organized structure are selected according to the content of the retrieved Web pages and the distribution of different topics within the results. The challenge here is how to select meaningful names and organize them into a sensible hierarchy. Vivisimo is an existing real-life demonstration of this attempt.

The clustering approach works well to meet the needs of a regular user. But when the application is narrowed down to an educational learning assistant, it is possible to provide the learners with more "suitable" Web pages that satisfy their needs in the pursuit of knowledge. Users seeking for educational resources prefer Web pages with a higher quality of content. Such Web pages often satisfy the criterion of being "self-contained," "descriptive," and "authoritative" (Chen, Li, Wang, & Jia, 2004). Limited work has been done to distinguish higher quality data from the Web. An important one (Liu, Chin, & Ng, 2003) is where the authors attempt to mine concept definitions of a specific topic on the Web. They rely on an interactive way for the user to choose a topic and the system to automatically discover related salient concepts and descriptive Web pages, which they call informative pages. Liu et al.'s work (2003) not only proposed a practical system that successfully identified informative pages, but also more importantly pointed out a novel task of compiling a book on the Web.

Chen et al. (2004) presented an approach to automatically construct an e-textbook on the Web. They extend Liu et al.'s (2003) work by adding a concept hierarchy that outlines the user-specified topic. In the concept hierarchy, also called a *concept tree*, each node corresponds to a concept and the ancestor relationship of nodes represents the containing relation of the concepts. The use of the concept tree is essential and benefits the learning experience to a great extent. It is used to gather Web pages that are more likely to be of learning importance, and also readily serves as a table of content for the final e-textbook. The concept tree is easier for the users to understand compared with the cluster hierarchy generated on the fly, thus saves time for browsing. The approach is described concisely in the following:

1. **Dataset collection.** The concepts in the concept tree are used to generate a query phrase for each node.
2. **Mining process.** "Suitable" pages from the retrieved list of each concept tree node are mined and re-ranked according to a combined ranking strategy.
3. **Expansion.** For some nodes that do not have sufficient "suitable" pages, an expansion process is activated.
4. **Result presentation.** Remaining Web pages are presented to users with the concept tree in the left area of the screen, serving as a navigation guide.

In the approach, the mining process is performed on the retrieved result of the search engine. However, the ranking strategy of the search engine cannot guarantee that the main theme of a highly ranked Web page is actually about the query. Often, a Web page describing an ancestor or offspring concept is ranked high in the list. For instance, for a query "infinite series," a Web page actually discussing a subtopic "geometric series" is ranked high in the list. The phrase "infinite series" appears several times in the Web page, since "geometric series" is a subtopic of the broader "infinite series." The search engine only notices to what extent this page is related to the search term, but cannot determine the main theme of the page. It should not be blamed for such a relevance measure, but in our scenario it is better that the page about "geometric series" is considered a candidate page for the node "geometric series" rather than for "infinite series." The algorithm proposed by Chen et al. (2004) tries to stress on the search terms by giving higher priority to them, but is too simple and not sufficient to successfully identify a Web page's main theme. So the quality of the mining process is affected by these "noises" that could have been "hits" for other concept tree nodes.

Our Contribution

In this paper, we add a clustering procedure before the mining process to adjust the distribution of the Web pages in the concept tree. The performance of the mining process is improved because Web pages are associated with the appropriate concept tree nodes in the adjusted Web page collection. In our approach, we treat the retrieved results of all nodes in the concept tree as the initial clustering condition and perform a clustering procedure upon it to optimize the distribution of the documents in the collection. In order to make the clustering process suitable for such an application, we propose a new Web page representation model, which projects a Web page onto the concept tree. The projection is called an *instance tree*. The new Web page representation model can well describe the distribution and the relationship of the concepts appearing in a Web page, and consequently, characterize its main theme precisely. It also reduces the dimension of the representation and improves the efficiency of the clustering process. Then, the corresponding tree distance measure is defined to evaluate the distance between two instance trees. When the clustering process terminates and the optimum status is reached, Web pages are assigned to the appropriate concept tree nodes that match with their main themes.

Web Page Representation Model

The most popular document representation model in modern information retrieval is the vector space model (VSM) (Salton & McGill, 1983).

A document is considered as a bag of terms and represented as a high-dimensional vector where a term stands for a dimension. A nonbinary weight is assigned to each term in the term space. Based on the vector space model, the similarity of Web pages can be measured through computing the cosine distance between the two vectors.

But the vector space model is not very suitable in our scenario. Web pages associated with "close" concept tree nodes are sometimes similar with each other in their distribution of terms, even though they are not describing the exact same concepts. The previous example of infinite series and geometric series explains why their features can overlap. So the VSM cannot represent Web pages precisely and the similarity between pages cannot be evaluated accurately. In our case, preciseness is required. We must identify the main theme a Web page is describing at the presence of other "close" concepts in the concept tree. The Web page representation model must also be able to record the information of the relationship of the concepts contained in the Web page along with their concept distribution.

Instance Trees

The central idea of our approach is about a user-specified concept hierarchy, which we call the concept tree. The concept tree should provide a hierarchical outline of the concerned topic, where nodes on the upper part of the tree represent more general concepts and those in lower positions stand for more specific topics. A concept tree is a labeled ordered rooted tree. The root node of our concept tree represents the main topic the user is interested in. We consider the concept tree as ordered mainly for clarity in description. The concept tree is defined as follows:

De. nition 1. Let CT denote a concept tree.

- |CT| represents the number of nodes in the concept tree CT.
- $V_{CT}[i]$ is the i-ism vertex of CT in a preorder walk of the tree.
- C(x) stands for the corresponding concept to vertex x.
- EdgeDist (x,y) denotes the edge distance between vertex x and y, which is calculated by the minimum number of edges between x and y.

A concept tree of the topic "Data Structures & Algorithms" is displayed in Figure 1. With the vertexes $V_{CT}[4]$ and $V_{CT}[7]$ as the example, the edge distance between them is 3 according to the definition.

By mapping a Web page onto a concept tree, it is possible to analyze the relationship of the concepts in a Web page, thus further determining the main theme of the document. In our approach, each Web page is represented as a tree structure identical to the concept tree, called an *instance tree*.

Definition 2. Let T_x be an instance tree from a Web page W_x to the concept tree CT. $|T_x|$ denotes the number of nodes in T_x. Let $V_{Tx}[i]$ be the i-ism vertex in a preorder walk of T_x. Let C(x) be the corresponding concept to vertex x in T_x. Function ψ: T_x->CT is a projection from an instance tree T_x to the concept tree CT such that the i-ism vertex in T_x is mapped to the i-ism vertex in CT in preorder. The value of a vertex val($V_{Tx}[i]$) is denoted as the number of occurrences of the concept C($V_{CT}[i]$) in Web page W_x.

The following conditions are held for an instance tree and its corresponding concept tree:

- $|T_x|=|CT|$;
- $\psi(V_{Tx}[i]) = V_{CT}[i]$ for any $0 \leqq i \leqq |T_x|$;
- $C(V_{Tx}[i]) = C(V_{CT}[i])$ for any $0 \leqq i \leqq |T_x|$.

Figure 2 depicts three different instance trees corresponding to the concept tree in Figure 1. The

Figure 1. Example of a concept tree

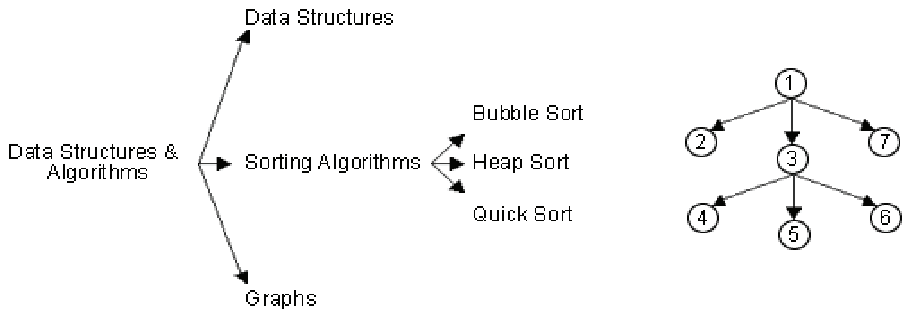
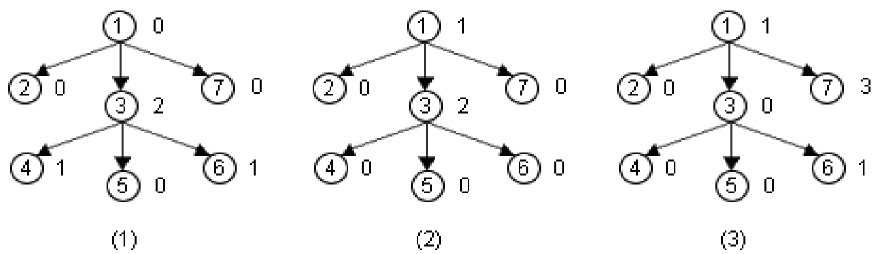


Figure 2. Three different instance trees



numbers on the right side of each concept tree node stands for the value of the node.

Distance Measure

In k-means clustering and many other clustering approaches, it is necessary to calculate a "distance" between two objects or an object and a cluster centroid. In our approach, an object is an instance tree. A popular means to compare the difference between two trees is the edit distance. This method tries to convert one tree into the other and analyzes the distance by counting the number of steps needed for the transformation. They call the whole series of transformation an "edit script" (Chawathe, Rajaraman, Garcia-Molina, & Widom, 1996). Chawathe et al. gives a general description about edit distance, and the measure is widely used in many tree comparing tasks (Nierman & Jagadish, 2002; Wang, DeWitt, & Cai, 2003). However, edit distance is mainly for evaluating structural similarity in two different tree structures, while the instance trees are all of the same structure. In addition, the instance tree not only reflects the distribution of the concepts in a Web page but also records the relationship of the appearing concepts. The relational information is important and should not be ignored.

To take the relational information into account, given a vertex x in an instance tree T_1, we are first interested in its "closest" vertex y in T_2. The "closeness" is measured by the EdgeDist($\psi(x)$, $\psi(y)$) defined previously. Such a distance is called the distance between the vertex x in T_1 and the instance tree T_2. We also define the following function σ which indicates whether a concept has occurred in a Web page:

$$\sigma(x) = \begin{cases} 1, & if\ val(x) > 0; \\ 0, & elsewise \end{cases}$$

Definition 3. Let x be a vertex in an instance tree T_1, the distance between x and instance tree T_2 is defined as:

$$dist(x, T_2) = \sigma(x) \times \left(min\left\{ EdgeDist(\varphi(x), \varphi(y)) \mid \sigma(y) = 1, y \in T_2 \right\} + 1 \right)$$

The σ(x) in the previous equation guarantees that the distance makes sense only when the value of vertex x is not zero.

Given the distance of a vertex in T_1 and another instance tree T_2, the distance between two instance trees T_1 and T_2 can then be defined:

Definition 4. Given two instance trees T_1 and T_2, the distance between them can be seen in Box 1.

It can be easily proved that the instance tree distance satisfies the following constraints:

- treedist(T_1, T_1)=0;
- treedist(T_1, T_2)≧0;
- treedist(T_1, T_2)= treedist(T_2, T_1).

However, the instance tree distance is not normalized. In the example of the three instance trees, the following can be easily calculated, as seen in Box 2.

Clustering Process

K-means clustering is a well-known member of the family of clustering algorithms (Chakrabarti, 2002). The user first defines a preset number k of clusters. Initially, the objects can be arbitrarily divided into k clusters. Each cluster is represented as the centroid of the documents within it. Thereafter, an iterative process begins by assigning objects to the appropriate cluster by picking the closest centroid to the objects. A detailed implementation of the k-means clustering algorithm can be found in the paper by Kanungo et al. (2002). This approach is especially useful when the k clusters are already formed by some other algorithm. For the ranked lists provided by the search engine, Web pages are naturally clustered to the concept tree node used to generate the queries. The k-means clustering algorithm can then be applied as a post-processing stage to move the misplaced points to the appropriate cluster.

The centroid of a cluster of instance trees is defined as follows:

Definition 5. Let C_i denote the centroid of the cluster corresponding to the concept tree node $V_{CT}[i]$. N_i represents the number of instance trees in cluster C_i. C_i is calculated as:

$$Val(V_{C_i}[k]) = \frac{\sum_{T_j \in C_i} val(V_{Tj}[k])}{N_i}$$

A distortion metric is minimized during the clustering process. We choose to minimize the

Box 1.

$$treedist(T_1, T_2) = \frac{\sum_{i=1}^{|T_1|} | val(V_{T_1}[i]) - val(V_{T_2}[i]) | \times dist(V_{T_1}[i], T_2) + \sum_{j=1}^{|T_2|} | val(V_{T_2}[j]) - val(V_{T_1}[j]) | \times dist(V_{T_2}[j], T_1)}{\sum_{i=1}^{|T_1|} \sigma(V_{T_1}[i]) + \sum_{j=1}^{|T_2|} \sigma(V_{T_2}[j])}$$

Box 2.

$$treedist(T_1,T_2)=\frac{((2-2)\times 1+(1-1)\times 2+(1-0)\times 2)+((1-0)\times 2+(2-2)\times 1)}{3+2}=\frac{6}{5}$$

$$treedist(T_1,T_3)=\frac{((2-0)\times 2+(1-0)\times 3+(1-1)\times 1)+((1-0)\times 2+(1-1)\times 1+(3-0)\times 3)}{3+3}=\frac{5}{2}$$

$$treedist(T_2,T_3)=\frac{((1-1)\times 1+(2-0)\times 2)+((1-1)\times 1+(3-0)\times 2+(1-0)\times 2)}{2+3}=\frac{12}{5}$$

total distance between all objects and their centroids for simplicity. The minimal distortion and the instance tree distance together determine the shape of the optimum clusters.

Implementation Issues

It can be easily seen that the conversion from a Web page to an instance tree is a crucial process to the success of our algorithm. The instance tree should correctly portrait the main theme of a Web page, which cannot be guaranteed by simply analyzing the entire page. Some "noise" in a page may bias the instance trees and devastate the performance.

The most obvious noise is the index pages, which usually serve as access portals to the related Web page collection. Although the index page is very useful for helping us to find more related resources, they lack the definitional paragraphs that are essential to an e-textbook. In addition, the index page generally contains many related concepts in the concept tree. So, it is difficult to decide which cluster, one index page belongs to, which consequently confuses the decision on the cluster of nonindex pages, In our experiment, we found that too many instance trees generated from index pages will bias a cluster towards an upper concept in the tree.

Another potential "noise" to our algorithm is the publication list of a Web author. Many authors tend to add a list of publications related to the content of their Web page. The publication list often contains many concepts in the concept tree. The problem is that the publication list does not necessarily reflect the main theme of the content, but often biases towards a subtopic. This results in a biased instance tree towards the related subtopic.

In order to avoid the harm from the often misleading index pages and publication lists, we filter them out to concentrate on the content of the Web page. In our Web page purification method, the Web pages are first partitioned into *index page* and *topic page*. Compared to the index page, the topic page focuses on describing a concept or topic in detail. For topic pages, the descriptive paragraphs are kept and link information is removed. For detailed information see Zhang, Chen, and Li (2004).

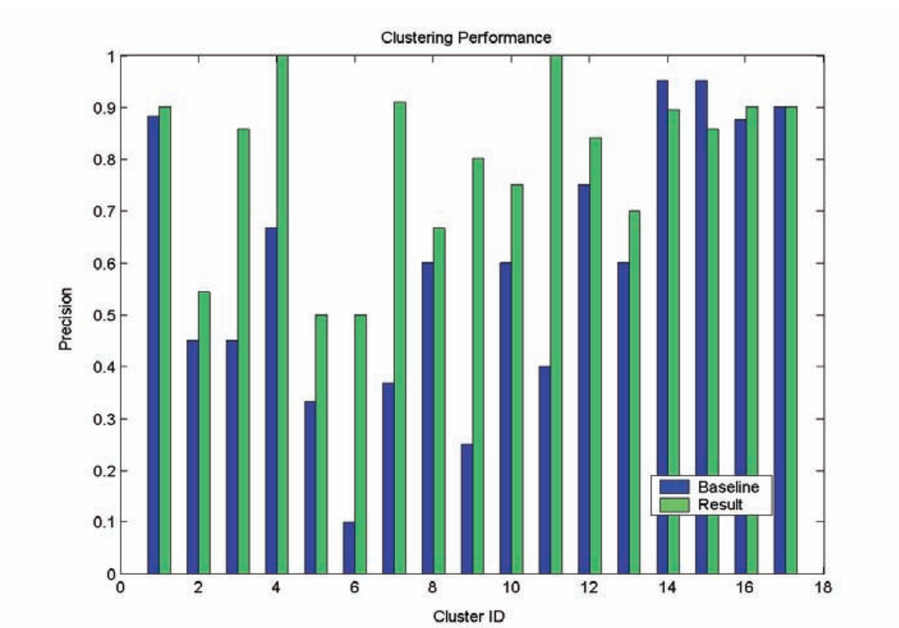
Experimental Results

In our experiment, the following concept tree for data mining (Figure 3) was used to gather the dataset collection. A number is assigned to each concept node to represent the corresponding cluster. An abundance of 50 pages were crawled from the result list of Google. Page types other than HTML are ignored. A preprocessing step filters out the index pages and publication lists in a Web page. It also removes pages that do not contain any concept in the tree. For each node in the concept tree, about 20 results are reserved after the preprocessing.

Figure 3. Concept tree for "data mining" with the cluster ID for each node

```
1  data mining
2  |-------clustering
3  |     |-------hierarchical clustering
4  |     |     |-------agglomerative clustering
5  |     |     |-------divisive clustering
6  |     |-------relocation clustering
7  |     |-------probabilistic clustering
8  |     |     |-------mixture models
9  |     |-------k-medoids
 10  |     |-------k-means
 11  |     |-------density functions clustering
 12  |-------association rules
 13  |-------classification
 14  |-------naive bayes
 15  |-------neural network
```

Figure 4. Performance of the clustering algorithm for data mining



The results of our clustering algorithm are displayed in Figure 4. The precision of the results originally collected by Google and of our clustering algorithm are defined respectively as follows:

$$baseline\ precision_i = \frac{\#of\ documents\ belonging\ to\ cluster_i}{\#of\ documents\ originally\ in\ cluster_i}$$

$$precision_i = \frac{\#of\ documents\ correctly\ clustered\ to\ class_i}{\#of\ documents\ clustered\ to\ class_i}$$

For most of the clusters, our clustering algorithm worked well and outperformed the original baseline. For several clusters such as "agglomerative clustering" (4 in Figure 3), "relocation clustering" (6 in Figure 3), the results of our clustering approach was dramatic. This is due to the removal of index pages and publication lists. For the last few clusters, the precision was comparable to or slightly worse than the baseline because the original results were already quite good, so one miss in the clustering results will lower the precision.

CONCLUSION

In this paper, we target at improving the results of an automatically generated online e-textbook. We propose a new Web page representation model, which we call the instance tree, which highlights the relationship of concepts contained in the Web page as well as their numerical appearance. A clustering algorithm is introduced to cluster the instance trees and obtain an optimum state where all Web pages are assigned to their appropriate concept tree node.

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Chapter VIII
Chinese Brush Calligraphy Character Retrieval and Learning

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ABSTRACT

Chinese brush calligraphy is a valuable civilization legacy and a high art of scholarship. It is still popular in Chinese banners, newspaper mastheads, university names, and celebration gifts. There are Web sites that try to help people enjoy and learn Chinese calligraphy. However, there lacks advanced services such as content-based retrieval or vivid writing process simulation for calligraphy learning. This article proposes a novel Chinese calligraphy learning approach: First, the scanned calligraphy pages were segmented into individual calligraphy characters using minimum-bounding box. Second, the individual character's feature information was extracted and kept. Then, a corresponding database was built to serve as a map between the feature data and the original raw data. Finally, a retrieval engine was constructed and a dynamic writing process was simulated to help learners get the calligraphy character they were interested in and watch how it was generated step by step.

INTRODUCTION

When computers and the Internet become more and more popular to the general public, less and less people have chances to write with a pen and to enjoy the beauty of writing. Calligraphy is a kind of writing, and a popular communication tool in ancient China. It is not only delightful to the eye and an inspiration to the spirit, but also a creative art. Yet, you do not have to be an "artist" to learn calligraphy, you can learn the skills and write them every time you want. According to thousands of years of learning experience, Chinese calligraphy learning process can be divided into three main consecutive steps: reading, understanding, and simulating.

In terms of Web-based learning, key issues in such process are: how to manage all the data to display the beauty of the different styles of the same calligraphy to learners; how to help learners find the context of an interesting character; and how to help learners follow good writing examples since it is impossible to trace the entire history and show how a particular calligraphy character was written. Correspondingly, our system consists of a large database managing all the scanned original data and the corresponding feature data, a retrieval engine helping learners find the same calligraphy character written in different styles by different people in different dynasties, and a simulator helping learners get a vivid idea about how a calligraphy character was written.

The remainder of this paper is organized as follows: the second section discusses the related works. The third section presents the system architecture of our system. The fourth section gives the data structure. In the fifth section, the main functions of our Web-based calligraphy learning system were described in detail. In the sixth section, the implementation and evaluation were done. And in the final part, conclusions and future works are given.

RELATED WORKS

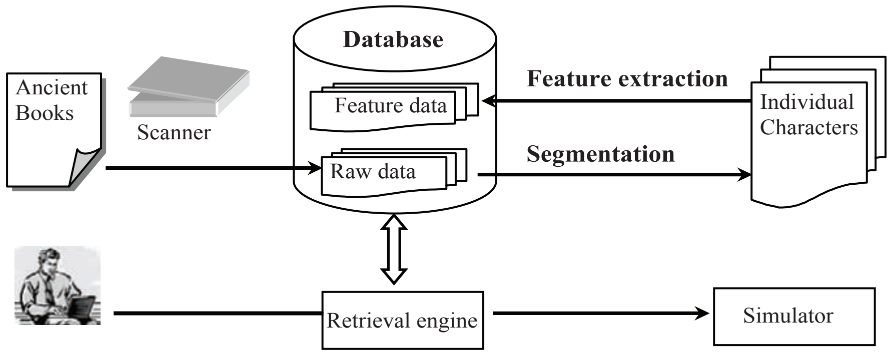
Numerous researches have been done on exploring techniques for Web-based learning (such as Zhuang, 2002; Zhuang, 2004). But, these techniques do not fit Web-based Chinese calligraphy learning well. Some Web sites have been developed to try to fit learners' needs to enjoy and learn Chinese calligraphy (such as http://www.wenyi.com/art/shufa; http://www.shw.cn/93jxsd/jxsd.htm). They do provide some basic information and many useful learning materials; however, they provide no advanced dynamic services such as content-based search, and they do not tell the vivid writing process of an individual calligraphy character that may be of interest by a learner.

If it is a text query, Google is the biggest and fastest search engine. It also provides image-searching function based on the name of the image. Yet, you cannot submit a text query and retrieve character images similar to it. Many previous content-based image retrieval works used low-level features such as colors, textures, and regions. However, such features cannot represent shape properties of character, hence irrelevant images are frequently retrieved. Recently, there has been work done to handle shape features effectively (Belongie, Malik, & Puzicha, 2002; Park, 2004). Still, they do not work well for calligraphy character image retrieval. Our previous work (Yueting Zhuang, 2004) has proposed a new approach to retrieve calligraphy character.

System Architecture

Figure 1 gives out an overview of our system architecture of Web-based Chinese calligraphy learning. Its infrastructure mainly includes data collection, segmentation, and feature extraction, which serve for advanced learning purposes.

Figure 1. Architecture of Web-based Chinese calligraphy learning system



Data Collection

The original books, mostly ancient, were scanned at 600 dpi (dots per inch) and kept in DjVu format by researchers of our China-U.S. Million Book Digital Library Project (Zhao & Huang, 2004). These digitized resources, together with their corresponding metadata are saved and packaged. The metadata standard (Edocument Metadata,Version 2.0) we used is released by Zhejiang University Libraries. It combines two kinds of metadata: DC and MARC.

Segmentation

When digitized page images are obtained, segmentation is needed in order to get feature information of an individual calligraphy character. Much research has been done on segmentation of printed page (such as Breuel, 2002; Manmatha, Han, Riseman, & Croft, 1996). Yet no published paper has been done successfully on Chinese calligraphy pages' segmentation. It is mainly because calligraphy characters have more connection, and the background has more noise such as man-made seals. Our proposed segmentation approach first adjusts color luminance to get rid of red seals and smooth them to take out some noises. Then binarization was done followed by projecting. After that, pages were cut into columns according to the projecting histogram, and columns continued to be cut into individual characters using minimum-bounding box as used in Manmatha et al. (1996). Figure 2 gives an example of our experiment, showing how a calligraphy page was cut into individual calligraphy characters.

Compared with Manmatha et al. (1996), our segmentation approach made special constrained parameters to fit the characteristics of Chinese calligraphy. Let $x_{i,s}$ and $x_{i,e}$ denote the start and the end position of the *th cutting* block, then according to our long term segmentation experiences it subjects to the following constrains:

$$x_{i,e} - x_{i,s} \geq 5,\ i=0,1,2,3,.......n \quad (1)$$

$$2.5 \times \frac{1}{n}\sum_{i=1}^{i=n}(x_{i,e} - x_{i,s}) \geq x_{i+1,s} - x_{i,e} \geq 0.35 \times \frac{1}{n}\sum_{i=1}^{i=n}(x_{i,e} - x_{i,s}) \quad (2)$$

This is because according to thousands of years of calligraphy writing experience, the width of individual character images on the same page tend to be similar, that is to say they have a minimum and maximum threshold for width, as described in formula 2. Let $wide_i$ and $height_i$ be the width and height of a cutting block, then

$$0.6 \leq \frac{height_i}{width_i} \leq 1.2 \quad (3)$$

Formula 3 tells the story that Chinese characters are always in square as introduced in You-Shou and Xiao-Qing (1992). With the aforementioned idea, most of the characters are segmented correctly. But still, there are few man-made connections that cannot be correctly segmented automatically such as in Figure 2, the fourth column from the right. Then, we draw the minimum-bounding box, which can be dragged and dropped manually.

Feature Extraction

After the segmentation was done, the next step is to extract features of individual calligraphy characters. In our approach, a calligraphy character is represented by its contour points instead of its skeleton. This is because skeleton representation is very sensitive to noise. As a result, it produces distorted strokes and the proper shape of the character cannot be detected.

According to the minimum-bounding box, we first normalize the individual character to 32×32 in pixels. Then, canny edge detector as introduced in http://homepages.inf.ed.ac.uk/rbf/HIPR2/canny.htm was employed to get its contour point's positions in Cartesian coordinates. Finally the values that denote the position of contour points were serialized to a string and kept in the database.

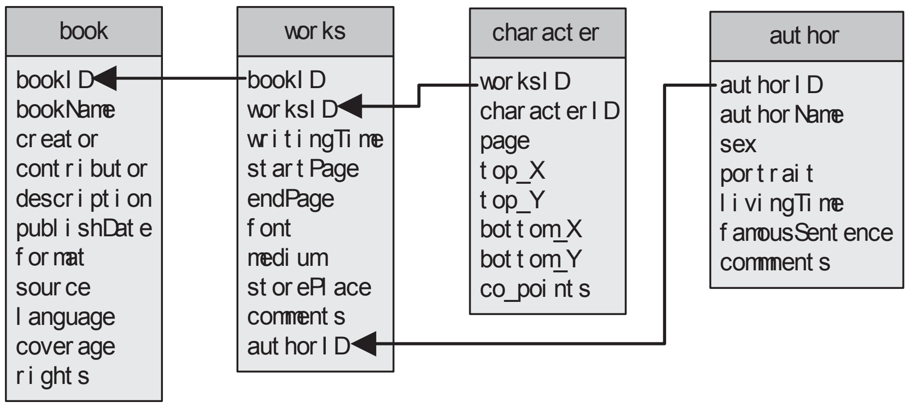
For learning purposes, a learner may want to know where an individual calligraphy character comes from and who wrote it. So, the original location of individual calligraphy characters, that is to say the location of the minimum-bounding box, should be kept too.

Data Structure

The scanned original data are large and in disorder, and they need further management. We built a special data structure to map the extracted feature data to the original raw data. The map consists of four tables: *book*, *works*, *character,* and *author*, as shown in Figure 3. Many individual calligraphy characters compose a calligraphy works created by a calligraphist, namely an author. And many calligraphy works build up a calligraphy book.

Figure 2. An example of segmenting a page into individual characters using minimum-bounding box

Figure 3. Data structure for mapping feature data to raw data



The arrows show how these four tables are related by special elements. In the table of *character*, *co-points* are a string produced by the feature data of an individual calligraphy character.

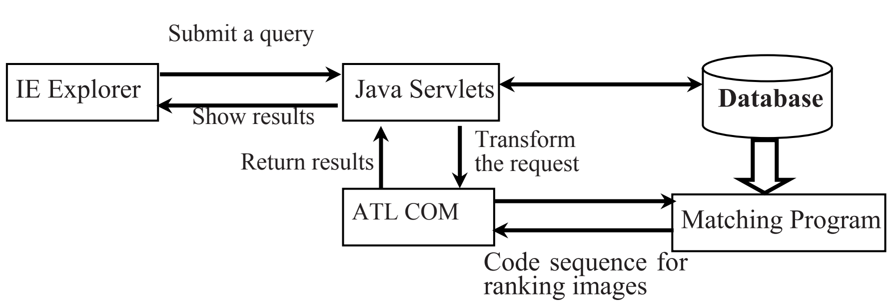
Then, it is natural that when we get an individual calligraphy character, we can tell in which works and in which page it is located by checking the table of *character* to find the *worksID*, the *page* and the minimum-bounding box (represented by "*top_X,*" "*top_Y,*" "*bottom_X,*" and "*bottom_Y*"). We can also tell in which book to find this character by searching the table of *works* using the key of "*bookID,*" and also who wrote this calligraphy character by checking the table of *author* using the key of "*authorID.*"

Key Calligraphy Learning Services

Learning Object Retrieval

For personalized learning purposes, different learners may be interested in different styles of the same calligraphy character. In our system, we use our new content-based calligraphy character image retrieval approach (see detailed description in Yueting Zhuang, 2004). In that, we use inexact shape context matching. However, in terms of Web-based learning its response time is beyond endurance: the average retrieval time is about 3.6 minutes for 336 isolated characters. In this paper, we develop a new architecture fit

Figure 4. Diagram flow of retrieval



for Web-based calligraphy character learning, as shown in Figure 4.

Three ways are proposed to speed up the retrieval time, one is preprocessing, another is classification, and the third is dimensionality reduction to reduce computing time. In preprocessing, shape features of every individual calligraphy character were extracted in advance, then serialized to a string and stored in the database, together with their corresponding metadata. Thus, only the features of the query image need to be extracted dynamically.

For classification, complexity index was used besides the metadata. Let $f(x,y)$ be the gray value of a pixel. If a pixel belongs to the background, then let $f(x,y)$=0, else $f(x,y)$=1. The moment m_{ij} can be defined as:

$$m_{ij} = \iint x^i y^j f(x, y)dxdy \quad (4)$$

And the root of second-order central moment in X and Y direction are defined as follows:

$$\sigma_x = \sqrt{(m_{20} - m_{10}{}^2/m_{00})/m_{00}} \quad (5)$$

$$\sigma_y = \sqrt{(m_{02} - m_{01}{}^2/m_{00})/m_{00}} \quad (6)$$

Then complexity index can be computed as:

$$C = (L_x + L_y)\Big/\sqrt{\sigma_x{}^2 + \sigma_y{}^2} \quad (7)$$

Where L_x and L_y are the length of the longest stroke in X direction and Y direction respectively. If $|C_i-C_j| \leq 7$, then the character i and j are considered in the same complexity degree range, in which the retrieval function search.

The number of sampled points dominates the computing time of each shape-matching process. So dimensionality reduction is needed. The Number of Connected Points (NCP) is defined as the number of contour points existed in its 8-neighbourhood as introduced in (Lau, Yuen, & Tang, 2002). If $NCP \geq 2$ and three consecutive points are in the same direction, then they are considered as parts of the same stroke. The middle point was taken out, and the reminder two points keep the structure information.

In order to measure the efficiency of these three speeding up approaches, we compare our proposed *shape corresponding approach* after implemented speeding approaches with *projecting approach* (Manmatha et al., 1996) and *Earth movers' distance approach* (Cohen & Guibas, 1999), as shown in Table 1. All of the tests are performed on a regular Intel(R)/256RAM personal computer. Compared with our early method, the database in this paper is enlarged from 336 individual calligraphy characters to 1,750 calligraphy characters, which are segmented from works of about 60 calligraphists living in different dynasties. Table 1 indicates that an average single calligraphy character matching takes about 640 ms (336 character, 3.6minutes) in our early method, while here only 52 ms (1,750 character, 1.52 minutes).

Dynamic Writing Process Simulating

After an individual calligraphy character is displayed before the learners, together with corresponding information of where it comes from and who wrote it, the next service is to offer a

Table 1. Comparison of average retrieval time of three approaches

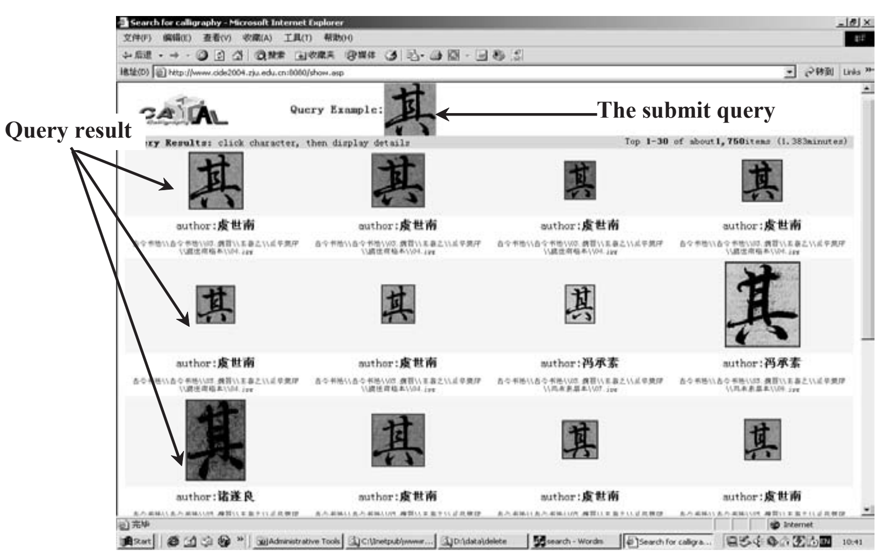
Approach / Time	Earth movers' distance	Projecting	Shape corresponding
	16.6 minute	5.31 minute	1.52 minute

Figure 5. A calligraphy character example and the corresponding video simulating its writing process

visualization of how such a calligraphy character was written step by step, which may help immersion learning.

In order to simulate the dynamic writing process, stroke extraction and stroke sequence estimation should be made. We use contour segments to extract strokes of calligraphy character as introduced in Lee, Wu, and Huang (1997). Strokes in a handwritten calligraphy character are often connected together (see Figure 5), and they are not necessarily corresponding to those of well printed characters. Yet it does not matter for extracting connected strokes, as long as the correct writing sequence is estimated. One assumption for estimating the order of the stroke sequence is that people always write a calligraphy character from left to right and from top to bottom (You-Shou & Xiao-Qing, 1992, p.14). The other assumption is that people always write a calligraphy character as fast and convenient as possible. So, if strokes are connected, total distance traveled in the writing process should be minimized as introduced in Lau et al. (2002), and when a cross corner is encountered, we choose to follow the most straightforward contour segment, which has the biggest angle—"people write it as convenient as possible." Based on the aforementioned assumptions, we estimated the stroke sequence and develop a video to simulate how a calligraphist wrote a calligraphy character step by step, as show in Figure 5.

Figure 6. Screen shot of a retrieval example



Implementation and Evaluation

In the experiment, approaches described previously are used and tested with the database and it consists of 1,750 individual calligraphy characters. These characters are segmented from a book named *Chinese Calligraphy Collections,* which consist of 12 volumes. Figure 6 shows a retrieval example.

If a learner interested in one style of the character, for example, the last one in the second row in Figure 6, then this particular calligraphy character can be clicked and a new page (see Figure 7) will pop up showing its original page with a minimum-bounding box marked out where it is, and also who wrote it. In Figure 7, when the name of the author is clicked, a portrait of the author accompanied by a brief resume will be shown. And if the individual character is clicked, a plug-in video will show up playing the estimated and visualized writing process.

Recall and precision are the basic measures used to quantitatively speculate the effectiveness of retrieval approach. Recall is the ratio of the number of relevant records retrieved to the total number of relevant records in the database, and precision is the ratio of the number of relevant records retrieved to the total number of irrelevant and relevant records retrieved. Here, we use average recall and average precision. They are defined as:

$$recall_{average} = \frac{1}{C}\sum_{i=1}^{i=c} recall_i / n_i \tag{8}$$

$$precision_{average} = \frac{1}{C}\sum_{i=1}^{i=c} precision_i / n_i \tag{9}$$

Where is the number of character, n_i is the number of total styles of the same character *i*. We randomly chose 20 characters (each has more than six different styles) from the database, that is to say when C=20 and $n_i \geq 6$, then Figure 8 can be

Figure 7. Screen shot of browsing the original works, with a minimum-bounding box mark out where the interested individual character is

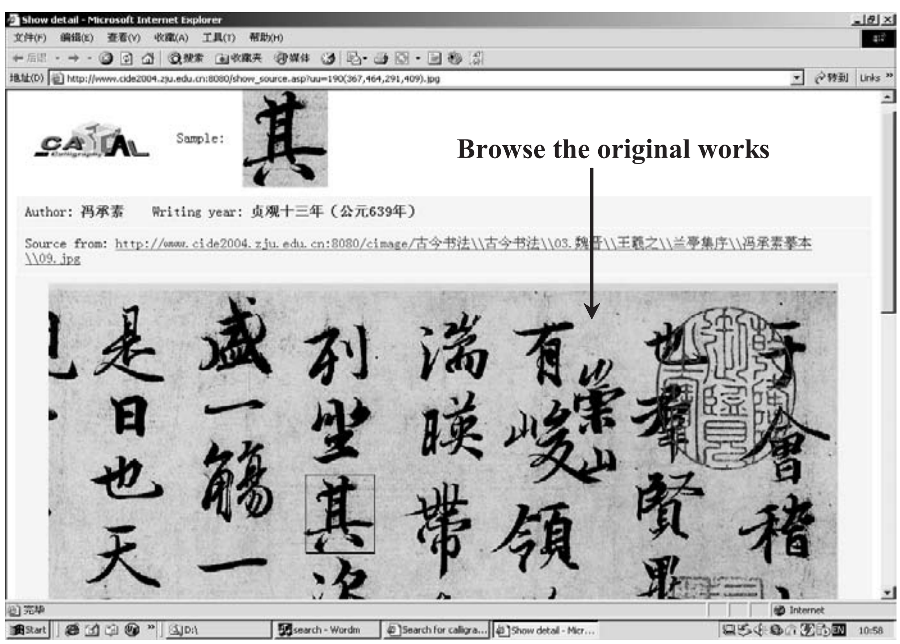
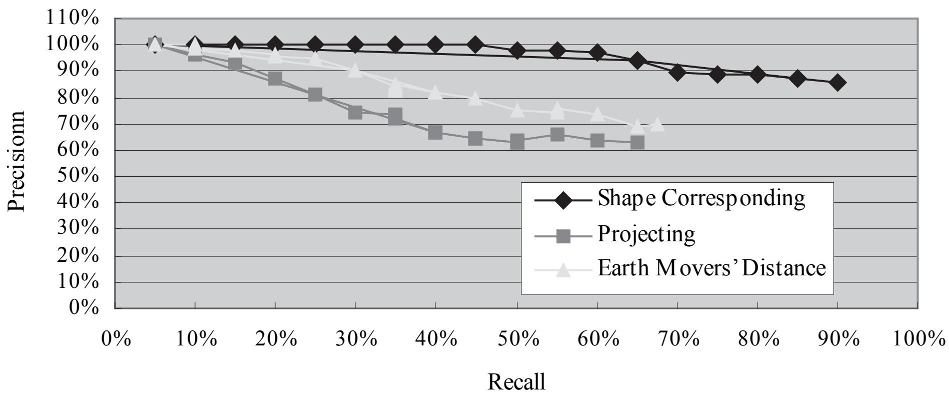


Figure 8. Comparison of three approaches of their average recall and precision ratio on 20 characters with each having more than six different styles



drawn. It is obvious that the recall ratio is higher than traditional content-based image retrieval.

Conclusion and Futurework

We proposed a new system to help people who are interested in calligraphy to enjoy the beauty of different styles of the same Chinese character, to learn its detailed corresponding information of a particular style of a character (for example, who wrote it, and in what environment), and also to learn how it can be generated step by step. While the experiment is somewhat preliminary, it works efficiently and clearly demonstrates the applicability of our system to enhance Web-based Chinese calligraphic learning.

Our further development of this system will include speeding up the retrieval, developing a bigger and robust database, and offering more convenient ways for query submitting, such as scratching a query or typing in a text query by keyboard.

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Chapter IX
Grounding Collaborative Learning in Semantics-Based Critiquing

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ABSTRACT

In this article we investigate the use of latent semantic analysis (LSA), critiquing systems, and knowledge building to support computer-based teaching of English composition. We have built and tested an English composition critiquing system that makes use of LSA to analyze student essays and compute feedback by comparing their essays with teacher's model essays. LSA values are input to a critiquing component to provide a user interface for the students. A software agent can also use the critic feedback to coordinate a collaborative knowledge-building session with multiple users (students and teachers). Shared feedback provides seed questions that can trigger discussion and extended reflection about the next phase of writing. We present the first version of a prototype we have built and report the results from three experiments. We end the paper by describing our plans for future work.

INTRODUCTION

English is the preferred second language for many people and learning it occurs in many ways. For example, young people are quite apt to learn spoken English phrases while watching TV, browsing the Internet, and communicating with peers on mobile phones (e.g., SMS). However, previous studies have shown these influences may have a negative effect on vocabulary development (Rice, Huston, Truglio, & Wright, 1990; Weizman & Snow, 2001). As a consequence, students' reading and writing skills do not keep pace with listening, viewing, and speaking. Furthermore, English composition is primarily taught in the classroom and practiced in homework assignments, supported by qualified teachers and parents. These are important but scarce resources, creating an imbalance of textual and oral language exposure. We address this dilemma by augmenting classroom-based composition training integrated with computer support.

The article is organized as follows. We start by characterizing English composition as a design activity and identify the components of a computer-based design environment to support it. Next, we explain how LSA can be used to provide feedback on student compositions within this context, and how we have incorporated LSA as part of system architecture. We show a prototype of a critiquing system we have built, discuss our efforts in integrating it with a knowledge-building environment (FLE) and report the results from three experiments, including comparing LSA with manual teacher feedback on a set of essays.

RELATED WORK

Essay writing can be viewed as a design activity, producing a textual artifact—a document. A document consists of words and sentences. It has structuring (abstraction) and content production (composition) elements (Yamamoto, Takada, Gross, & Nakakoji, 1998). These are key aspects of any design process. More specifically, structuring defines the organization of the document in terms of sentences, paragraphs, and sections (i.e., levels of abstraction); whereas content production is about finding words and phrases and sequencing them into readable sentences, which again become part of paragraphs, and so on. A well-composed essay will communicate certain ideas, topics, or themes about some area of shared concern. Intermediate level abstractions, such as paragraphs and sections, serve as placeholders for complex ideas extended over multiple paragraphs so that the writers and readers can focus on one idea at a time while suppressing unimportant details.

The two basic activities of design are action and reflection (Schön, 1983), supporting composition and abstraction, respectively. Action means to create an artifact by selecting building blocks and combining them into functional arrangements, and reflection means to evaluate the artifact from multiple viewpoints (McCall, Fischer, & Mørch, 1990). When this occurs without external disruption other than situation-specific feedback, it is referred to as reflection-in-action (Schön, 1983). In a good process of design, the designer will rapidly cycle between action and reflection until the design is completed. During this process, the "back talk" of the situation signals to the designer when there is a need to switch to the other mode. This is communicated by means of an incomplete design (e.g., missing parts), inconsistency in arrangement of parts, or a need for restructuring the overall activity.

DESIGN CRITIQUING

Computational support for reflection-in-action is provided with the critiquing approach (Fischer, Lemke, Mastaglio, & Mørch, 1991; Qiu & Riesbeck, 2004; Robbins & Redmiles, 1998). Critiquing is defined as "presentation of a reasoned opinion about a product or action" created by a user with a computer (Fischer et al., 1991). A critiquing system integrates computational support for design-as-action and design-as-reflection and operationalizes Schön's (1983) notion of "back talk" with computational critics (Fischer et al., 1991). Critics make the situation talk back so that non-expert designers can understand it, giving them task-specific feedback about the artifact-under-construction. Examples of critiquing systems are Janus (McCall et al., 1990), ArgoUML (Robbins & Redmiles, 1998), and the Java Critiquer (Qiu & Riesbeck, 2004). These systems were developed for the domains of kitchen design, Unified Modeling Language (UML) and Java programming, respectively. For example Janus allows designers to create kitchen designs at different levels of abstraction (from appliances to work centers), ArgoUML knows about the elements and relations of UML and can tell the designer when a software architecture diagram violates the rules of UML (Robbins & Redmiles, 1998). Similarly, the Java Critiquer identifies statements in a program that can be improved by readability and best practice (Qiu & Riesbeck, 2004). These critics provide feedback on partially completed software artifacts, pointing out inconsistency and incompleteness in the design.

We believe the critiquing approach can be useful for computer-supported English composition for the following two reasons. First, writing can be modeled as a design activity (Yamamoto et al., 1998); and second, critic feedback can supplement teacher feedback on student essays in certain situations (after school hours, in distributed environments, distance education). In this context we propose to integrate knowledge building (a distributed collaborative learning activity) and LSA with critiquing in the following ways: (1) LSA to compute the critic feedback and (2) knowledge building to support joint reflection. This is different from past work on critiquing systems and educational applications of LSA. The previous work on LSA has focused almost exclusively on individual learning by integrating it with Intelligent Tutoring Systems (Steinhart, 2001). A goal for us is to provide computer support for both action and reflection, and individual and collaborative learning.

Knowledge Building

Knowledge building (Scardamalia & Bereiter, 1994) requires that new knowledge is not simply assimilated with the help of a more knowledgeable person or mediated by a computer system, but also jointly constructed through solving problems with peers by a process of building shared understanding. This type of teaching and learning takes its inspiration from pedagogical models such as problem-based learning and case-based instruction. These are models for teaching that require students to explore open-ended problems and generalize from exemplary cases. The basic idea of knowledge building is that students gain a deeper understanding of a knowledge domain from a research-like process by generating or responding to shared problems or questions, proposing tentative answers (personal explanations) and searching for deepening knowledge collaboratively.

Knowledge building and its subsequent refinement Progressive Inquiry (Hakkarainen, Lipponen, & Järvelä, 2002) are well suited to be supported by Internet technologies such as Web-based discussion forums and have received considerable attention in the Computer Supported Collaborative Learning (CSCL) community. A reason for this is that the regularity of knowledge building, which is modeled after scientific discourse, provides students with a well-defined scaffolding structure built into the online learning environments. Knowledge building environments are pedagogically designed discussion forums and include CSILE (Scardamalia & Bereiter, 1994), Knowledge Forum, and Future Learning Environment (FLE) (Leinonen, 2005). They are used in schools in Canada, Hong Kong, and Scandinavia, as well as elsewhere in the world.

The rationale for our wish to integrate knowledge building with a critiquing system is twofold. First, critiquing systems do not provide full support of design-as-reflection because they address primarily individual designers' reflection needs, inspired by Schön's (1983) notion of reflective practice. This is necessary but not sufficient in order to support the needs of a networked design community. Knowledge building, on the other hand, can add a multi-user dimension by supporting joint reflection, even though knowledge building was not originally conceived as such. Joint reflection occurs during "talk with peers" (e.g., Maybin, Mercer, & Stierer, 1992) in shared tasks and meaningful contexts, that is, collaboratively addressing problems or questions shared by a community of learners in which shared understanding can emerge (Arnseth & Solheim, 2002). Knowledge building thus becomes an important part of the integrated collaborative learning and problem-solving environment.

Second, one of the authors has previously participated in a study to evaluate a knowledge-building environment (FLE) to support problem-based teaching of natural science in two high school classes in Norway (Ludvigsen & Mørch, 2003; Mørch, Omdahl, & Ludvigsen, 2004). One of the results of this study was that students found knowledge building difficult. In particular they did not properly understand how to use the message categories to post messages in the forum. This was manifest in that interaction over time became less knowledge-building intense and more task specific, revolving around the respective schools' local situations, thus grounding the interaction.

Grounding is the process of making sure one's utterances are understood in communication with others, and the basis on which one builds further understanding. The concept of common ground has its roots in linguistics and arises from a model of conversation developed by Clark and Brennan (1991). It is suggested that that collaborating partners continually add and update information to the common ground and gradually improve understanding as the conversation proceeds. Similar notions like mutual belief, inter-subjectivity, and shared knowledge have been applied to collaborative learning and problem solving (e.g., Arnseth & Solheim, 2002; Baker, Hansen, Joiner, & Traum, 1999; Brennan, 1998). However, grounding is not exclusively tied to communication and social interaction, and we propose four types of grounding that can impact the success and failure of computer-supported learning environments:

- communication and social interaction (linguistic grounding);
- practice situation (work-oriented grounding);
- artifacts and work-arounds (tacit grounding); and
- knowledge base (semantic grounding).

Each of the four types of grounding may need attention when building computer support for collaborative learning and problem solving. Work-oriented grounding is the grounding that occurs at a workplace, for example, when one is using tools and materials of a specific profession to create artifacts required for the business. Schön (1983) characterized this form of grounding as "reflective conversation with the materials of a situation." It connects professionals with the physical (material) world of their profession. On the other hand, tacit grounding is the form of grounding one resorts to when selecting (sometimes without being aware of it) artifacts from the immediate environment to support an utterance (e.g., pointing to a watch as an excuse to leave a meeting early) or work-arounds (e.g., automatically selecting "back-up" technology when the primary technology fails). The latter is relevant when interacting with advanced learning environments. Finally, semantic grounding is the grounding that makes use of already established knowledge, that is, the rules, facts, and arguments defining a domain of interest.

The complexity of the "grounding problem" (Brennan, 1998) is in part related to the interdependencies among the four types of grounding just mentioned. It is outside the scope of this article to address them in detail. Therefore readers are encouraged to consult the referenced sources. In the current project we focus on semantic grounding by integrating a knowledge-building environment with an LSA-based critiquing system.

Latent Semantic Analysis

LSA is a mathematical technique for computing the semantic similarity between words and text segments with the help of a large corpus. The corpus can be a set of related documents. It can also be one document broken down into smaller text segments such as paragraphs or even sentences, as in our case. The input to LSA is the set of text segments, which may need pre-processing by the computer in various ways.

LSA computes first the semantic relationship between words using word co-occurrence statistics and then the similarity of two input texts (student and teacher) accordingly as follows. First, both input texts are segmented to form part of the corpus. Normally, the corpus should also be supplemented by additional related documents sourced from the Internet or student model essays. Then, the word-segment association matrix D is constructed. In the matrix D, each row typically stands for a unique word and each column stands for a text segment. Note that it is common to call each column the feature vector corresponding to a particular text segment. For the simplest case, each cell entry can be the frequency of a given word in a given text segment. As an example, consider the segment "International Conference on Web-based Learning focuses on research works that enhance teaching and learning experience." If the j^{th} column corresponds to the aforementioned segment and the i^{th} row corresponds to the word "learning," then the value in D_{ij} would be 2 as the word "learning" occurs two times in the segment.

As weighting words based on their individual importance is known to be also effective in obtaining better matching results, we used entropy values instead for computing D_{ij}, given as

$$D_{ij} = \log\left(f_{ij} + 1.0\right) * \left\{ 1 - \frac{1}{\log(N)} \sum_{j=1}^{N} \left[\frac{f_{ij}}{gf_i} \log \frac{f_{ij}}{gf_i} \right] \right\}$$

$$gf_i = \sum_{j=1}^{N} f_{ij}$$

where N is the number of text segments in the stored corpus and f_{ij} is the frequency of the i^{th} word in the j^{th} text segment.

Once the matrix D is computed, it will be first decomposed using Singular Value Decomposition (SVD) (Strang, 1980), and then trimmed for some of the unimportant semantic dimensions (to be explained in the following paragraph), and finally reconstructed to a matrix with its dimension same as the original one. In particular, using SVD, the matrix D can be expressed as a unique product of three matrices: $D = P\lambda Q'$ such that P and Q have orthonormal columns and λ contains the singular values along its diagonal or otherwise zero. By comparing the diagonal elements of λ, we only keep those elements with large values and set the others to zero, with the effect that the dimension of λ is reduced. This is equivalent to removing the corresponding columns from P and rows from Q. The resulting "semantic space" is commonly considered the space that is spanned by the orthonormal columns of the matrix Q.

After the semantic space has been computed, the new D can be "reconstructed" from the new P and Q. The similarity between two text segments can then be computed by calculating the geometric cosine between their corresponding vectors in D, given as

$$\cos\theta = \frac{< x, y >}{\|x\| * \|y\|}$$

where $\langle x, y\rangle$ is the inner product of vectors x and y, defined as $\langle x, y\rangle = x_1y_1 + x_2y_2 + ... + x_ny_n$, and $\| x \|$ is the length of a vector x defined as $\| x \| = (\langle x, x\rangle)^{1/2} = (\sum_{i=1...n} x_i^2)^{1/2}$.

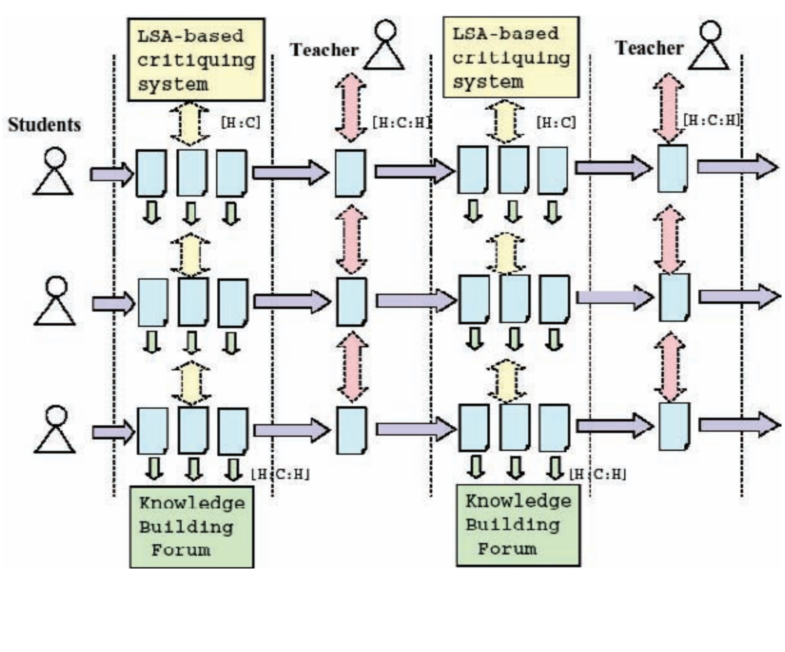
Using this similarity metric, words that have appeared in similar segments, and segments with similar semantic content, will be considered to be near one another (Steinhart, 2001). Words that do not co-occur (e.g., bicycle and bike), but occur in similar contexts will also be grouped together.

Remark. Direct application of the aforementioned steps to our case is a costly computational process because it requires invocation of SVD each time the similarity value is computed. To alleviate the limitation, we, as suggested by Deerwester, Dumais, Furnas, Landauer, and Harshman (1990), projected the text segments extracted from the latest submitted essay to the semantic space characterized by the orthonormal columns of the matrix Q computed based on the corpus only. The projection of the latest submission can then be accomplished using the corresponding $\lambda^{-1}P^T$ as the transformation matrix. Note that the projected vectors are sometimes called pseudo text segments. Similarly, the text segments extracted from the corpus can all be projected to the same semantic space so that they can be compared directly with the pseudo text segments of the latest submission. The major advantage of this is that we then only need to compute the SVD once (as far as the corpus is not changed) instead of per submission. Additional technical details on LSA can be found in Landauer, Foltz, and Laham (1998).

Components of a Learning Environment of Essay Writing

We have incorporated LSA together with critiquing and knowledge building to form an integrated learning environment for English essay writing. The LSA-based critiquing component of this environment allows us to compare student and model essays and provide critic feedback to the students when they submit their work in progress; whereas the knowledge building component provides support for collaboratively resolving critic feedback that is not well understood by the students on their own. The overview of this environment is shown

Figure 1. English composition integrated learning environment system architecture



in Figure 1 and the workings of its components are explained next.

The teacher first decides on the topic to be taught and writes and/or collects a set of samples articles and essays that represent the domain in some detail. These samples are then input into the system so that the LSA analyzer can build a semantic space for the domain. Student model essays, suggested answers by teachers, as well as articles from external sources (which could be anything from online newspapers to scanned essays of textbooks) constitute this set.

The students write their essays using the English Composition Critiquing System (see below). When they require assistance they can request automated feedback (critique), which points out the missing items in their text (compared with the corpus samples). Before the text can be input into LSA, all the articles are broken down into sentences and preprocessed by techniques such as stop-word removal and stemming (Baeza-Yates & Ribeiro-Neto, 1999). The Analyzer then computes the word-segment association matrix. SVD (Strang, 1980) is performed on the matrix and the semantic similarity between all possible sentence pairs, one from the student and the other from the model samples, is computed. This allows the system to identify the sentences in the model essays that contain themes that are missing in the students' submissions, as we described in the previous section.

The final steps are semantic matching and summarization. The identified sentences containing the missing themes can be summarized as a trunk of keywords or short phrases preset by the teacher or automatically by the system, using computational text summarization techniques. This will result in a summary that is reported as critic feedback in the user interface. In the prototype we describe later on, we have modeled our critics' feedback based on the phrasing and organization of Hong Kong English teachers' marking schemes. When the critique is presented as feedback immediately after the students have completed part of their essay, it will allow them to revise their essays in a meaningful context.

The roles of teachers and students could be much more active than merely providing model samples and improving essays based on the predefined critic feedback. Teachers can monitor how well the different themes are handled by the students. They may provide more insights into how individual students incorporate the missing themes, and participate as facilitators of student collaboration sessions to provide feedback when the students run out of ideas Their participation serves the purpose of supportive interaction through which an expert assists a group of learners to develop a higher level of understanding (e.g., Maybin et al., 1992) and pushes the learner's zone of proximal development (Vygotsky, 1978). A recent large-scale language learning survey has confirmed the observation that most students in East Asian and European countries have a positive attitude towards cooperating in groups in order to achieve common goals, and they would like to see themselves as active participants in the classroom learning process (Littlewood, 2003).

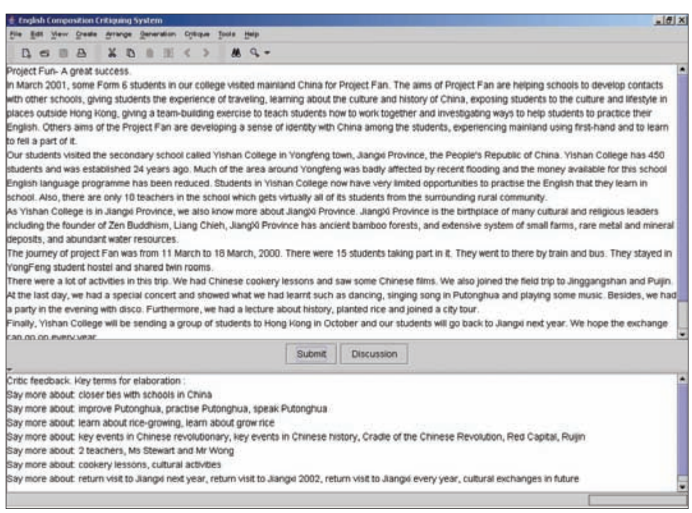
The LSA-based critiquing and knowledge building environment marks the contours of a "double-loop" learning process (see Figure 1). It alternates between inner (human-computer interaction) and outer (computer-supported collaboration) phases. The process can be repeated several times before the students submit their final essay for grading or commenting on by the teacher. In a good process of writing, we anticipate this learning environment will support reflection-in-action at two levels: (1) individual (inner loop) activity when students switch between essay composition and modification by responding to a well understood automated critique and (2) collaborative (inner + outer loop) activity by entering a collaborative mode of interaction through responding to critique that is not well understood or where the understanding can be broadened or made more interesting for the students by sharing their ideas with others. Whether or not our computational environment can provide adequate scaffolding for reflection-in-action in English essay writing at these two levels is currently a hypothesis. Its conceptual basis and technological platform are provided in this article. In the remaining of this article we present our system development efforts (two prototypes) and evaluation results (three experiments).

System Prototypes

In order to support English essay writing as a design activity based on the models and techniques presented previously, we had decided to reuse and integrate existing and freely available systems, making modifications if necessary. When selecting the critiquing component we considered both ArgoUML (Robbins & Redmiles, 1998) and the Java Critiquer (Qiu & Riesbeck, 2004). The latter has the advantage of supporting the design of a textual artifact (program code), but ArgoUML has the advantage of being an open source system. We finally decided on ArgoUML due to its accessibility. However, we had to modify the system extensively (see Figure 2). In particular, we removed all the features we did not need and added the features that are unique to our domain. So, the current version requires students to input their essays in terms of characters and words (i.e., the composition area is a text processing window), whereas LSA Analyzer perceives each essay as a sequence of sentences. We hid some of the Argo features such as the building block palette and the to-do list, which we anticipate to be useful in the future versions of our system. For instance, the building block palette could be useful for representing and manipulating more intermediate-level building blocks like paragraphs, sections, and other higher level abstractions, which has shown to be useful for writing (Akin, 1978; Yamamoto et al., 1998) and can allow students to acquire skills in not only composition but also organization. It may simplify LSA preprocessing by reducing the need for sentence segmentation. Also, the to-do lists that can keep track of overlooked critic messages and suggest when they should be attended to can help students manage multiple missing subthemes.

For the knowledge-building component, we decided on another open source system, FLE

Figure 2. The English composition critiquing system has a "Submit" button to generate LSA-based critique and a "Discussion" button to trigger a knowledge building session (Figure 3).



(Leinonen, 2005). FLE is a knowledge-building environment developed in accordance with the progressive inquiry model (Hakkarainen et al., 2002). It is an asynchronous, Web-based groupware for computer-supported collaborative learning. It is designed to support collaborative learning in the form of a discussion forum with message categories (knowledge types) named after the stages of the progressive inquiry model. These stages and corresponding categories can help students improve their collaboration and ability to solve open-ended problems. The categories that are provided with the system (Fle3) are: "problem," "my explanation," "scientific explanation," "summary," and "comment." Two of these categories are displayed in Figure 3.

Figure 3 shows the reader's interface of the knowledge-building forum of Fle3 from a simulated session, involving two students who have been invited to join the forum by a coordinator agent to resolve a missing essay topic. The missing essay topic is picked up by the agent and serves as a seed question. In knowledge building these initial questions are often formulated by teachers, based on their knowledge of the subject to be taught. In this case it is handled by a software agent based on its ability to identify students who receive the same feedback, and a belief that the two students receiving the same feedback have something in common so that they can resolve by information sharing and discussion. The reason why a discussion forum may be the appropriate form of resolving the feedback is based on the fact that missing subthemes define open-ended questions, that is, they can be addressed in many different ways. We have not yet tested these claims, but the forum is built on our previous (empirical-based, system building) work on integrating agents with FLE (Dolonen, Chen, & Mørch, 2003) and adaptive user interface agents (Liu, Wong, & Hui, 2003).

Evaluation and Preliminary Results

In order to assess the feasibility of our critiquing system regarding its ability to suggest missing/

Figure 3. The Fle3 Web-based knowledge-building forum shows a persistent storage of discussions related to students' missing essay topics. An agent initiates a thread when it discovers an essay topic that is missing by more than one student. The KB forum has not yet been fully integrated into our environment and it has not yet been tested with students.

uncovered sub-themes, we conducted three experiments. It is through these experiments that we investigated the performance of LSA, studied the factors that can improve LSA performance, and compared its performance with the conventional keyword matching technique.

Experiment 1: Performance of LSA

In this experiment, our objective was to investigate the feasibility of using LSA to suggest missing subthemes. Seven high school students in Hong Kong were invited to write a 400 to 500-word essay on the topic "Write an essay about the experience of traveling to China." At the same time, a teacher was asked to provide a number of subthemes (25 in this study) of this topic, which the students were expected to include in their essays.

The teacher assessed the finished essays to identify the subthemes that were missing, based on the set of predefined subthemes. Then the essays were assessed by our system. Each text segment in the student essay was compared with each sample segment suggested by the teacher. If the semantic similarity (which was represented by the cosine value calculated by LSA) was below a preset threshold, we considered the subtheme of the sample segment to be missing in the student essay. Finally, the missing subthemes identified by the teacher and our system were compared to evaluate the performance of the system. The system identified 35 missing subthemes in the seven student essays, 22 of them were judged to be correct (i.e., also identified by the teacher as missing subthemes), whereas the remaining 13 were considered inappropriate. On the basis of this, we get a tentative precision rate of 63%.

A reason for this relatively low number is the small size of the corpus. We used a corpus of about 3,000 words to build the semantic space. This is a smaller corpus than what has been used in related studies, such as TASA-all (a large knowledge space consisting of text samples from the K12 [grade 1-12] curriculum in the United States) (Steinhart, 2001). The TASA-all corpus comprises approximately 11 million words. We believe that a larger corpus for constructing our semantic space will further improve the accuracy of our system in identifying missing subthemes. Therefore, another experiment is conducted.

Experiment 2: Enhancements to LSA

In this experiment, our objective was to improve the performance of LSA. We proposed some enhancements to the generic LSA.

In addition to the three pre-processing steps: (1) removal of stop words, (2) change of plural nouns to singular ones, and (3) change of verbs in different tenses to their present tense form (using WordNet) as performed in Experiment 1, the system was further enhanced by converting the adverbs to their equivalent words in the adjective form to further unify the words with the same meaning. In addition, the top 20 words with the highest entropy value were removed as these words were more evenly distributed in the subtheme paragraphs and corpus, which could have a negative effect on the system's ability to discriminate between texts. It was believed that these words did not provide any value-added semantic information for identifying subthemes. For example, in the context of "Mobile Phone Impact," the words "mobile" and "phone" do not add new semantic information for discriminating among the different subthemes associated with mobile phones. Furthermore, after the removal of the aforementioned top 20 words, the remaining top 25 words in all the subtheme vectors after performing SVD were further checked. If these words appeared in more than or equal to half the number of the subthemes, they were removed. The objective was to make the subthemes more distinguishable.

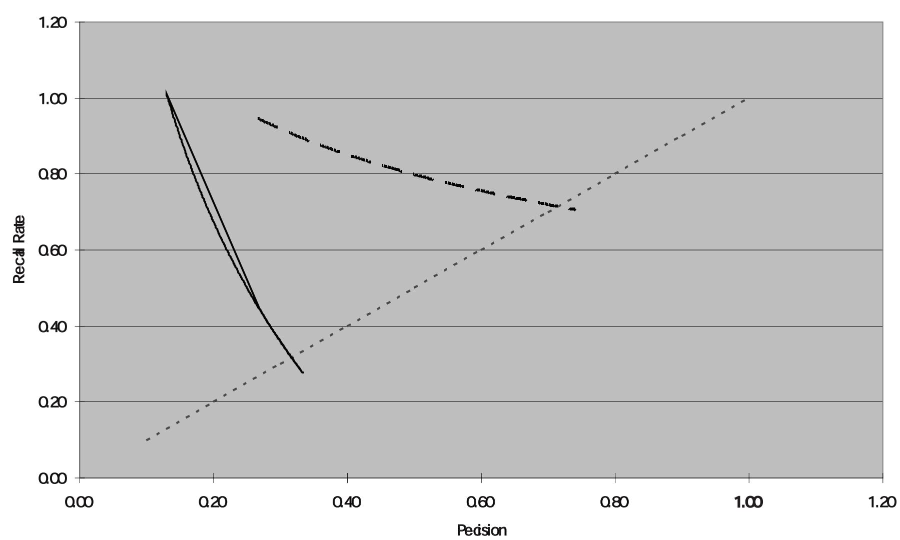
Apart from enhancing the preprocessing steps, we also attempted to further enrich the text segment representation. The enhancement was based on the observation that the semantic context of a sentence, sometimes, can only be captured by considering its neighboring sentences. To incorporate this enhancement, we modified each column of the LSA matrix by adding to it a weighted version of the sum of the columns corresponding to its neighbors. One can consider this idea to be similar to the moving window concept commonly used in image processing.[1]

In this experiment, 12 students were invited to write a composition on the topic of "Mobile Phone Impact." A teacher was asked to identify the covered subthemes in the composition and a total of 26 subthemes were marked. The performance of generic LSA and the enhanced LSA were compared. The threshold on the cosine value was set to be 0.15 for determining whether a subtheme was found. Without the enhancements, our system identified 23 subthemes, out of which 11 were members of the "Mobile Phone Impact" dataset, giving an overall precision of 0.32 and a recall of 0.42. With the proposed enhancements, 20 out of the 27 subthemes identified by our system were judged to be correct. This gives a precision of 0.74 and a recall of 0.77. We consider the improvement to be significant.

Experiment 3: Performance Comparison with Simple Keyword Matching

The objective of Experiment 3 was to verify the performance gain brought by LSA using simple keyword matching as the baseline. Keyword matching was implemented using the "Mobile Phone Impact" dataset as adopted in Experiment 2. We completed all the steps described in the previous section, excluding all the LSA related steps (i.e., the use of corpus, SVD and subtheme keyword removal). Not surprisingly it was found that keyword matching was inferior to LSA. In particular, the keyword matching method identified 34 subthemes, out of which only 11 were found to be correct, giving a precision of 0.32 and a recall of 0.42. Figure 4 shows the recall-precision curves of the enhanced LSA (the dotted curve) and the keyword matching (the solid curve). The

Figure 4. Performance comparison between the enhanced LSA and keyword matching applied to identifying subthemes in student essays



corresponding break-even points were 0.71 and 0.32 respectively. This result indicates that the enhanced LSA is a significant factor contributing to the accuracy of the sub-theme identification process.

Conclusions and Directions For Further Work

Many students find essay writing stressful because they do not have sufficient ideas to fully cover the topic they are asked to write about. They usually run out of ideas before they have completed their essays. When the class size is large and when running in-class writing exercises, it is difficult for teachers to give proper feedback to individual students on the missing subthemes because it requires a considerable amount of teachers' time.

We believe that the use of our semantic-based critiquing system can support students by autonomously suggesting what missing subthemes they should pay attention to when revising their essays. Students can submit their draft essays to the system for feedback whenever they run out of ideas. If the feedback is incomplete or poorly understood (e.g., due to LSA truncation steps), the students can enter a system-initiated, contextualized discussion forum that provides support for knowledge building according to the progressive inquiry pedagogical model. We believe that this combination of theory foundation and computer support for individual and collaborative learning can help students enrich their essay content with a richer vocabulary in contexts that are meaningful to them. We are also interested in ascertaining the way in which students view the critiquing system and the extent to which the knowledge-building forum will be used. On the technical (algorithmic) side, it is worth investigating the factors that will affect the performance of LSA in the essay-writing domain. Knowing how to determine both the optimal number of dimensions of the semantic space and the optimal threshold value for similarity matching are important and these questions require further research to answer.

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ENDNOTE

1 In our experiment, the weighting factor for the neighboring sentence is 0.2 where the neighbor of a sentence is defined as the sentences following it up to the end of the current paragraph.

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Chapter X
Improving the Usefulness of Learning Objects by Means of Pedagogy-Oriented Design

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ABSTRACT

Learning Objects (LOs) are increasingly considered potentially helpful to improve teachers' work and to spread innovation in the school system. Their technological roots, however, often make them scarcely appealing to the teachers. A key issue to tackle in order to boost their diffusion is to make them closer to actual teacher's work by emphasising pedagogical aspects. To this end, the authors propose a typology of LOs that allows teachers to highlight differences in the pedagogical approach embedded in their productions, hence sharing not only content but also educational competence. Moreover, in order to allow re-user teachers to explicit and share the pedagogical experience gained while re-using some material, they suggest endowing repositories with ad hoc facilities, such as comments and itineraries related to the repository's LOs. Comments would allow people to share narrations of experiences of use, while learning itineraries would point out logical connections of various kinds among small groups of LOs, hence helping the users overcome the content fragmentation induced by the granularity of LOs. These proposals are described and exemplified by drawing from our training experience.

INTRODUCTION

Learning Objects (LOs) can result useful in education, by decreasing production costs, exploiting experience and saving time (Littlejohn et al. 2003). Not only are they a source of study materials, but can also give suggestions about teaching strategies (Chiappe Laverde et al. 2007). They can provide a valuable contribution to innovate education, because sharing good quality educational materials among a large number of peers can facilitate the circulation of good ideas (Malcolm 2005). Being able to fruitfully make use of LOs, however, entails overcoming a number of issues of both conceptual and practical nature (Busetti et al. 2004a).

From a practical point of view, integrating didactical resources prepared by other teachers in one's own lessons is not always straightforward, because it requires to work out connections to the new context of use. Even more work can be necessary for recycling, that is, making use of some elements for a different task. This holds true, in particular, for educational material on complex tasks, which, on the other hand, is what teachers are likely to be most interested in, since their preparation requires time and effort. Analogously, preparing educational materials suitable to be reused, that is, able to raise peers' interest and easily adaptable to different learning situations, is a rather challenging task (Feldstein 2002, Griffith et al. 2007, Lehman 2007) entailing to split lessons into modules which are consistent and self-contained yet easy to articulate with each other.

From a conceptual point of view, difficulties are brought about by the fact that the concept of LO was initially created and worked out by technologists rather than by experts in education. This fact is relevant, because technologists and teachers have different focus and aims and often even use different technical languages (Friesen 2004, Ip et al 2001). As a consequence, the construction of LOs was seen as production of software more than as production of learning and LOs resulted more fit to support presentations than to propose activities of constructive nature. Metadata, which are key to retrieve and re-use LOs, were standardized (Anido et al. 2002, IEEE 2002) not much in line with the current didactical practice (Farance 2003), so that they comprise information which is of limited use from the didactical point of view, such as semantic density, and omit other which is relevant to re-use in real educational contexts, such as the pedagogical and epistemological choices underlying the development of materials. Moreover, standard international metadata did not result apt to take into consideration the peculiarities of national educational systems (Friesen et al. 2002). This limitations should not appear surprising, however, because the variety of needs and points of view that should be taken into consideration by online material makes it complex to devise a set of metadata able to combine simplicity of production with easiness of resource detection (Duval et al 2002).

These issues have been widely discussed over the last years. For instance, the need to endow LOs with metadata which express the underlying educational paradigm was pointed out (Alvino et al. 2007, Qin and Godby 2004), so as to allow teachers to retrieve LOs based on features that they usually take into consideration in their didactical planning. Approaches to the evaluation of pedagogical metadata, so as to verify their quality, have also been worked out (García-Barriocanal et al. 2007). Extensions of the current metadata standard were formulated, integrating or modifying the LOM based on the needs of some group of learners (see for example Alvino et al. 2008, Krull et al. 2006, Yahya and Yusoff 2008). Metadata application profiles including pedagogical descriptors that meet the needs of educators have also been proposed (i. e. Godby 2004). We recall for example the Gateway to Educational Materials project (GEM, http://thegateway.org), an initiative of the US Department of Education based on the Dublin Core Metadata Standard (http://dublincore.

org/). GEM introduces a metadata application profile for describing educational resources in a semantically rich way and with an accompanying set of controlled vocabularies (Qin and Paling 2001). GEM's guiding principles and metadata form the basis for the proposal formulated by EdNA, a network of the Australian education and training community (Education Network Australia, http://www.edna.edu.au/).

Moreover, attention was given to the importance of certifying the quality of the materials included in a repository. A well known example in this respect is offered by Merlot (a repository for teachers of any subject of secondary school and higher education, which is accessible free of charge; see www.merlot.org), that provides a peer review for many of the LOs included in the repository (Vargo et al. 2003). Another example is constituted by DLESE (www.dlese.org), the (free of charge) Digital Library for Earth System Education funded by the National Science Foundation, USA, aimed at supporting the teaching/learning of the Earth system. The resources that meet specific review criteria are included in the so-called DLESE Reviewed collection.

Finally, the importance to motivate and encourage teachers to use LO repositories was recognized, and some work was done to foster reflection on the applicability of shared materials and on the impact of using them within an educational plan. An early example in this direction is provided by the cited Merlot repository, which allows users to insert brief comments on a LO and proposals for activities with it.

Nevertheless, more work appears still necessary to turn LOs into real pedagogical resources frequently and fruitfully used by the teachers. As Minguillón (2007) points out, a variety of research studies would be necessary to advance the field, such as experimental studies, application of learning theories and pedagogical design guidelines, techniques for describing pedagogical assumptions or hypotheses, and critical analysis of the ability by the standards to deal with the pedagogical perspective.

Our work on LOs aims to give a contribution to improve the exploitation of LOs in education. It develops along two directions:

- We propose a methodological approach to the design of LOs aiming to help teachers realize digital educational materials based on a pedagogy-oriented design. This consists in the proposal of a typology of LOs that allows one to distinguish among different kinds of educational materials and to point out the underlining pedagogical orientation. It allows one to shape educational materials of constructivist nature in form of LOs and is therefore suited to support the development of complex tasks and address learning in complex domains (Busetti et al. 2007). It differs from other classification proposals e.g. Churchill 2007) in that it models a typology of LOs according to the perspective teachers usually adopt when preparing an educational plan.
- We propose to endow LO repositories with *ad hoc* communication facilities to allow teachers to share pedagogical experience besides materials, hence turning their activity with LOs into a learning experience. In our proposal, two kinds of item in particular are foreseen as object of exchange among teachers, that is, narrations of experience of use of LOs (Dettori et al. 2006) and the construction of articulated learning itineraries made by sequences of LOs (Busetti et al. 2008). Such communication channels aim to help the teachers reflect on their own pedagogical choices and construct digital learning materials consistent with their own educational aims and preferred teaching approach. They also aim to transform LO repositories into communities of teachers who learn from each other while sharing materials and experience (Busetti et al. 2006). Transforming repositories into learning communities of teachers is in line

with the results of several research studies, which suggest it as a viability factor to LO technology (Haughey and Muirhead 2005, Liber 2005).

In this chapter we describe our two proposals, pointing out their potential to improve the exploitation of the LO paradigm in education.

Devising A Typology of LOs

Adopting a Teacher's Perspective in the Design of LOs

In order to orient the design of LOs so as to include teacher's perspective, we started from observing teachers' behaviour. When planning an educational path on a complex task for a group of students, teachers initially devise an overall learning experience, based on the educational work already carried out by the students, as well as on the new contents to be learned and abilities to be acquired. Then, they organise the overall path in a number of educational modules, each focused on addressing a specific topic, by explaining a theory or assigning some applicative activity, often by making use of (traditional or technological) educational tools. Each of such modules aims to initiate a learning experience, and therefore embeds the educational objective and the pedagogical approach that the teacher considers most suitable for the learning situation at hand. Teachers usually plan to also make use of complementary materials of wide applicability, besides of the specific modules related to the considered task, such as dictionaries, glossaries, maps, etc.. Then they organise the use of a number of tools - be they of conceptual nature or concrete ones - which appear necessary to support learners' activity and their interactions with each other or with the teachers or other experts involved in the leaning experience. The more the considered domain is complex, the more this conception of educational material appears useful.

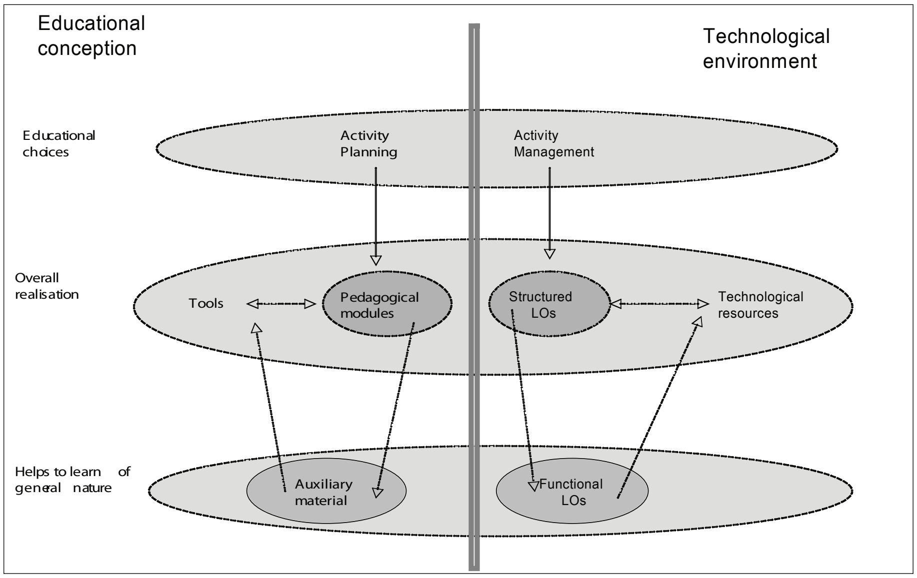
In order to implement this conceptual view by means of LOs, we thought that it would be necessary to work out a typology, clearly distinguishing task-related LOs from auxiliary materials, so as to mirror the articulated organization of work that experienced teachers usually set up. Such correspondence is shown in Figure 1.

This organization implies having at disposal LOs of two different types, depending on the characteristics of the educational modules they embody:

1. *Structured LOs,* corresponding to content modules with a clear pedagogical orientation; these are based on a precise educational objective and must be further specified by determining their structure and didactical function.
2. *Functional LOs,* corresponding to auxiliary educational materials; these do not include a specific pedagogical orientation but rather have a wide-angle approach that makes them suitable to a variety of learning situations.

Structured LOs can make use of, or refer to, functional LOs, which correspond to materials necessary to carry out the proposed activities. This fact does not violate the principle that LOs should be self-contained, since functional LOs have a different nature and only contain auxiliary material that the user can substitute with analogous ones, or even eliminate, without much effort and without changing the nature of the activity. For instance, a structured LO could contain the indication "Use a glossary of terms in this field; one such glossary can be found at the address ...". Obviously a re-user could well decide to use a different glossary or not to use one at all, if his/her students have already a good knowledge of the necessary terms, and this fact does not affect the validity of the structured LO including this refer-

Figure 1. Correspondence between conceptual and technological elements involved in a complex learning activity



ence. On the other hand, it is correct to consider auxiliary modules as LOs, because they actually are self-consistent learning materials with a clear educational purpose.

These two types of LOs are, in turn, divided into different subtypes, according to their nature and function, as shown in Figure 2.

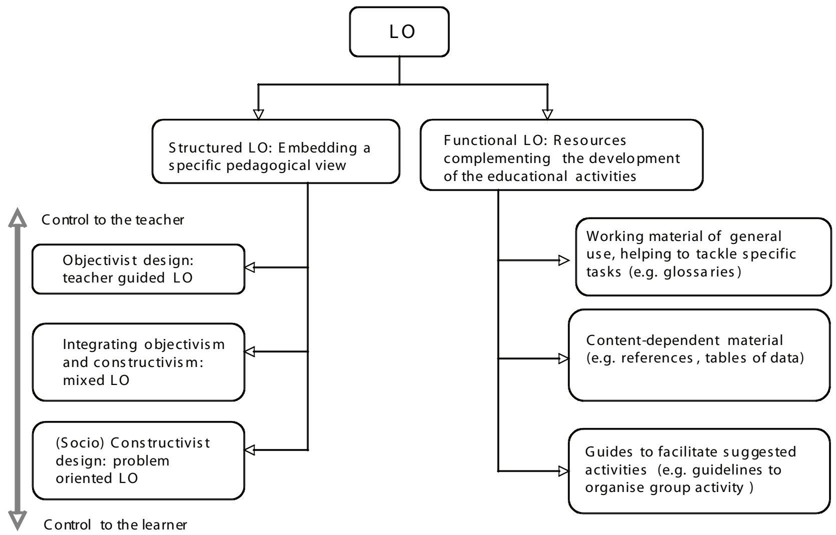
Functional LOs can be of three main types, that is:

1. *general-purpose*, whose content may be relevant in many modules of an articulated course of studies; examples are dictionaries, maps, templates, etc.;
2. *content-dependent*, containing material for deepening some particular content; these include presentations, glossaries, assessment modules, references, etc.;
3. *activity-oriented,* suitable to guide the students to carry out activities related to the learning of some topic by supporting the acquisition of 'soft skills', that is, interdisciplinary behavioural and relational abilities that influence the interaction with others.

The different forms that *Structured LOs* can take mirror the fact that teachers can decide to vary the educational approach to a given task, from teacher-directed to learner-directed, based on the specificities of the situation at hand, such as students' competence and maturity or the importance of the addressed topic within the global learning path. This possible diversification led us to introduce the following characterization of educational modules, and correspondent *Structured LOs,* based on their didactical aims:

1. *Guided LOs, corresponding to modules guided by the teacher.* In this case, the control of the activity initially relies mostly on the teacher and gradually passes to the students while they increasingly gain ability. Such modules aim to introduce content knowledge or some basic approach to problem solving.

Figure 2. The proposed typology of LOs



In this case, teaching and learning are very structured, even when they entails a good amount of students' activity.

2. *Problem LOs, corresponding to modules oriented to autonomous exploration, where the control is strongly demanded to the students (individually or in groups).* In this case, a problem situation is proposed. Modules of this kind are based on questions addressing some activity necessary to solve the given problem, as well as on materials and tools relevant in the activity assigned. Here the work evolution can not be completely planned *a priori*, nor can it easily be evaluated with traditional methods. This approach is suitable when students have already acquired a basic preparation that allows them to work on problems without much teacher's guidance. They aim to develop higher level cognitive abilities, as well as to support metacognition and autonomous learning.
3. *Mixed LOs, corresponding to modules based on a mixed approach, combining teacher guidance and autonomous exploration.* These represent a merge of the kind of activities and guidance that characterize the previous two types. Usually different mixed LOs are possible for a same kind of activity, with a focus closer to teacher's guidance or to student's autonomous work.

Examples of Structured LOs

The choice whether to use a *Problem LO* or a *Guided LO* depends on the educational aim. A same learning content may be proposed by means of either of them, based on the pedagogical approach that a teacher considers most suitable in the learning situation at hand.

This is exemplified by the following LOs, which are both addressed to students of educational design and aim to make them aware of the issues to tackle when deciding a course organization (e.g. choosing whether to offer a course completely online, or in presence, or finding a satisfactory blending of these two delivery modes). This task is not trivial, since the considered problem has more than one possible solution; the process to find a satisfactory one can not be straightforwardly expressed in algorithmic way and implies considering a number of context variables, such as the background of the expected participants, their socio-cultural-economical situation, the type of content, the technological infrastructures at disposal, etc.. The complexity of this task motivates the need to create LOs of different kinds to be proposed to students with different levels of expertise. In both cases, it is necessary that students become aware that different problem situations are possible and become able to analyse them. They must learn to look for relevant variables and reflect on their impact and possible interaction in the situation at hand. The necessary guidance and work organization, however, differ according to the students' expertise level.

If the students are at the beginning of their work in this field, and have no practical experience, much guidance is necessary to help them observe how experts reason on this kind of problems. Hence, we will make use of a Guided LO, like the one sketched in Fig. 3. At the beginning, the teacher gives a general idea of the situation and motivates the problem. The second phase is then devoted to observation and reflection. A narrative presentation of a case of study is provided (e.g., a movie showing a group of experts discussing pros and cons of possible course organizations), then the students are asked to spot the main points considered by the experts, as well as to compare and discuss their points of view on this matter. The aim of this phase is to develop analytical skills, rather than to acquire some procedure to tackle this kind of problems, since it is obviously not possible to acquire problem solving ability on complex tasks just by observing one group of experts. In the next phase, documents used by the experts to analyse the considered case are given, such as minutes of meetings, data and documents used, simulations, etc., and students are asked

Figure 3. An example of Guided LO

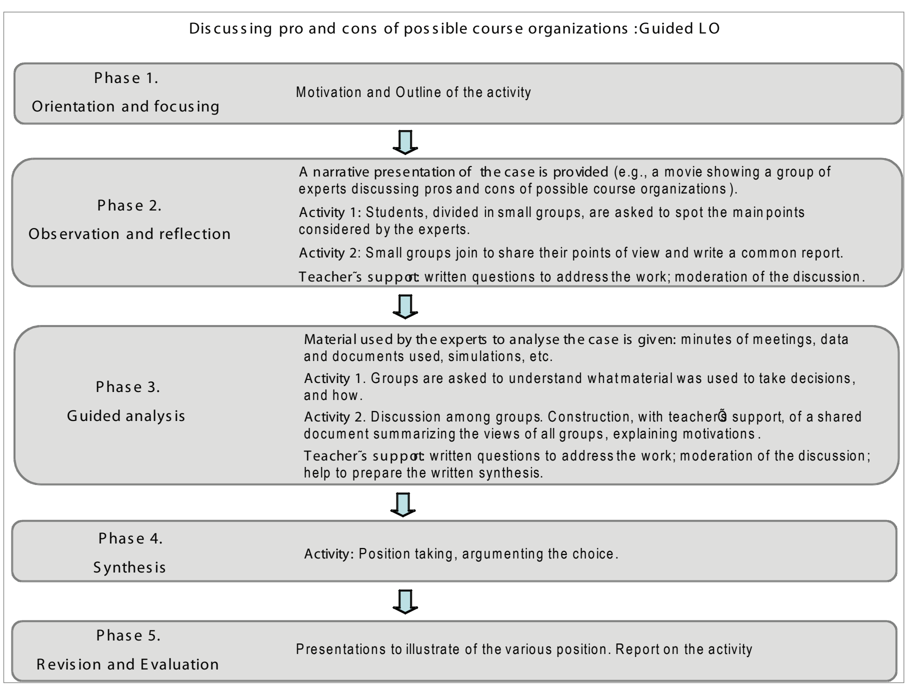
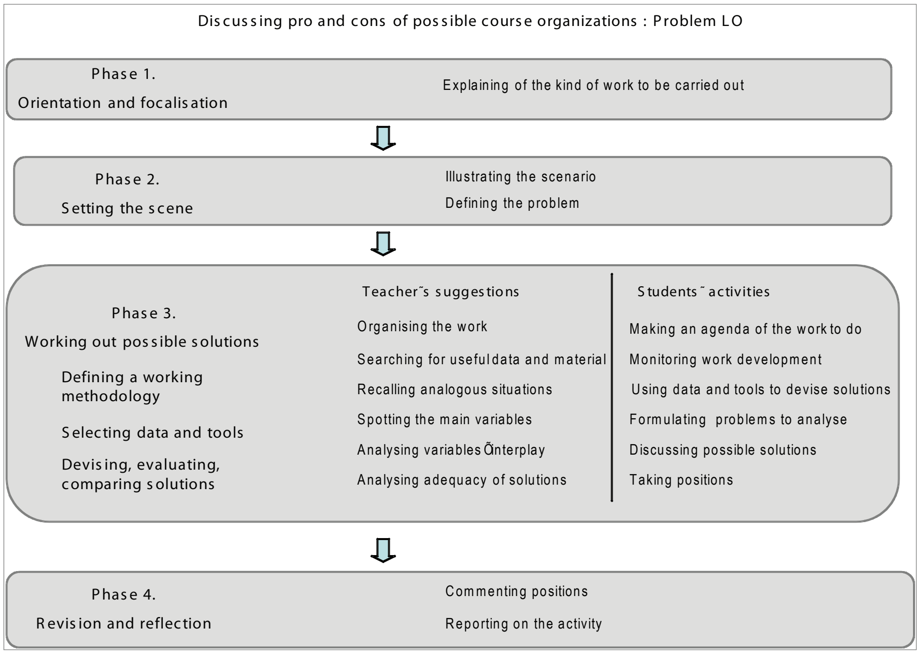


Figure 4. An example of Problem LO



to try to understand in which way each material was used. Points of view are again shared and compared. In both Phases, the teacher supports the activity by providing questions to address the work, moderating the discussion, helping to prepare the written synthesis. Finally, in the last two phases students are requested to take a position, justifying their choices, and to make a presentation on it.

Figure 4, on the other hand, shows the structure of a Problem LO on the same topic. Here, the activity consists of only 4 phases, where the third and most important one must be carried out essentially autonomously. Initially the teacher explains the kind of work to be carried out (Phase 1), then defines the problem and illustrates the scenario (Phase 2). In Phase 3 the teacher gives a number of suggestions on how to proceed and the students carry out the work, partly autonomously or divided in small groups and partly with the whole class, making an agenda of the work to do, monitoring its development, formulating problems to analyse, using documents and tools to devise a solution, discussing possible solutions and taking positions. Finally, choices are presented, motivated and discussed.

Both kinds of LOs appear to be necessary to build articulated educational paths, because the first one helps the students build experience by observing and analysing, in a structured way, expert's behaviour, while the second allows the students to become aware of the acquired competence and test their ability on practical problems. Such alternation is very important in complex domains, where solving problems is not simply a matter of applying rules and algorithms to new data, but rather requires to learn how to reason within the constraints of the considered field. Limiting a course's proposal to Guided LOs would negatively influence students' self confidence and ability to work autonomously, while assigning Problem LOs to beginners would give rise to disorientation and discouragement, or even to serious damages, as in the example on robot's unexpected behaviour described in a previous paper (Busetti et al. 2007) in relation with tele-presence courses on mechatronics.

Sharing Pedagogical Expertise In LO Repositories

Paying attention to pedagogical aspects while designing LOs is important to convey the producer's teaching aims and experience. It can not help, however, to highlight the knowledge and competence generated through re-use. This, on the other hand, could be an important source of learning for all teachers involved, because re-use helps highlight differences in points of view and teaching approaches, hence possibly helping materials' authors to gain a different perspective on their own work. Re-users' experience can obviously not be directly included in LOs, but it can be saved in repositories, as materials associated to LOs, so as to be always at the disposal of all users, thus enriching the value of the repository's global pedagogical offer. To this end, we designed and implemented the prototype of a repository enriched with communication facilities, LODE (Learning Object Discussion Environment) (Busetti et al. 2006). Besides a number of forums to discuss issues of general educational nature or related to individual LOs, this environment offers re-users two features to share pedagogical experience, that is, comments to share narrations of use experiences, and itineraries to describe how to build articulated learning paths by sequencing a number of LOs. The importance of these two facilities is discussed below, together with the realisation made in the LODE environment.

Sharing Experiences of Use

From a pedagogical point of view, re-use of educational materials should be focused not only on products but also on experiences of use in different contexts (Busetti et al. 2004a). Thanks to re-use, LOs are not seen as static materials (as in a purely technological view of re-use) but rather as something constantly in evolution, since each experience of use differs from the others depending on the situation where it takes place, the learners' involved and the teachers' pedagogical orientations and teaching approach.

Hence, two different kinds of knowledge constitute the re-use process of a given educational material:

1. The educational material themselves, with the initial intentions of the producers and possibly hints to guide prospective re-users. This knowledge should be organised so as to lead the users to reflect on their own educational view, make comparisons with the view of the initial producer, highlight analogies and differences among various intentions.
2. The experience deriving from the use of the material, by the producer her/himself and by other teachers, expressed by means of narrations of such experiences and reflections on them. These should not be considered as optional appendices to the educational materials, but keys to stimulate teachers' reflection, and therefore should be included in the repositories as well.

Reflecting on differences among use experiences carried out with a same material can constitute for the teachers a learning opportunity and a powerful tool for professional development. This can result useful also to the material's producer, since it leads her/him to take into consideration different perspectives on her/his own work. In this view, re-use constitutes a knowledge transfer process in which both user and producer can actively take part, with mutual advantage.

Such activity can also constitute a good basis for the creation of communities of teachers engaged in learning from each others' experience while sharing educational material, and can help building and circulating pedagogical innovation. It can improve the cohesion within teachers' communities, helping to overcome the problem pointed out by Parr and Ward (2005) of teachers feeling scarcely inclined to share their own productions if they don't perceive the participation in a community of practice as useful and rewarding.

Learning Itineraries

A problem that contributes to limit the appreciation of LOs by school teachers is content fragmentation. Being atomic materials, i.e. self-contained and addressing a single topic is an essential feature of LOs, which determines their possibility to be re-used across different learning situations and to be adapted to a variety of educational needs. In school teaching, however, it is extremely important to construct knowledge as a connected whole, since only in this condition students can become effective problem solvers. It is not by chance that teachers often plan their activity in the form of itineraries rather than of single lessons.

Building articulated paths by extracting LOs from a repository is not always easy, since detecting LOs which are related and consistent as concerns both topic and pedagogical approach is often a complex task. Without suitable cues, teachers may end up to limit their choice to some materials and build other modules on their own, in order not to spend too much time looking for suitable contributions.

Studies analyzing the practical difficulties of teachers in using a repository for the construction of learning itineraries are still limited. Some indications in this respect may be obtained by a few studies on what characteristics of a repository support teachers to integrate LOs in their educational plans. For instance, Recker et al. (2004), through the analysis of the behaviour of a group of teachers dealing with a repository, try to detect teachers' motivation in using online resources, what barriers they perceive, what strategies of search and selection they use, how they adapt the resources at disposal for teaching and for autonomous training, what functions they expect to find in digital resources. This study suggests that guaranty of quality, peers' positive opinion and a materials' organization that responds to educational needs are key points for teachers' satisfactory use of a repository. Christiansen & Anderson (2004), on the other hand, focus on benefits and issues associated with the creation of courses entirely from available LOs, by analyzing the results of three case studies. The outcomes of their experience show that quantity and quality of material is an essential condition, while heterogeneity of material constitutes a difficulty.

Quantity and quality are very important features, but, in our opinion, are not sufficient. In order to help users to build meaningful itineraries it is necessary that conceptual connections among LOs are explicitly specified in repositories and that materials can be retrieved efficiently and effectively. It would be very useful, moreover, to store in repositories also itineraries constructed by teachers with the repository's materials, so as to offer examples and suggestions. Itineraries should not be mere lists of LOs, but possibly include pedagogical ideas to help shaping a whole from several disjoint pieces.

Itineraries are actually a way to share pedagogical competence and experience connected with the use of LOs, as much valuable as the narration of use experiences. Devising educational itineraries may be an important component of teacher training on the use of LOs in that it can helped understand from an operative point of view the pedagogical competence necessary to successfully deal with LOs (Busetti et al. 2008).

A Repository Oriented to Sharing Pedagogical Competence

The possibility to share experiences of use and itineraries related to each LO are implemented in the LODE's repository. Figure 5 shows the home page of a LO. It shows the name of the LO followed

Figure 5. The home page of a LO in LODE. Experiences of use and Itineraries are listed on the left hand side

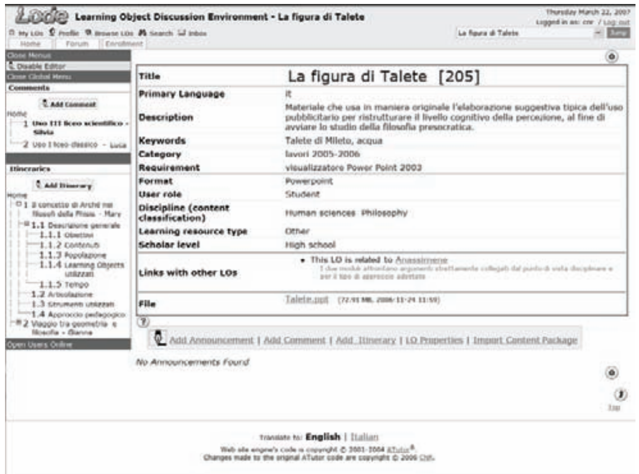


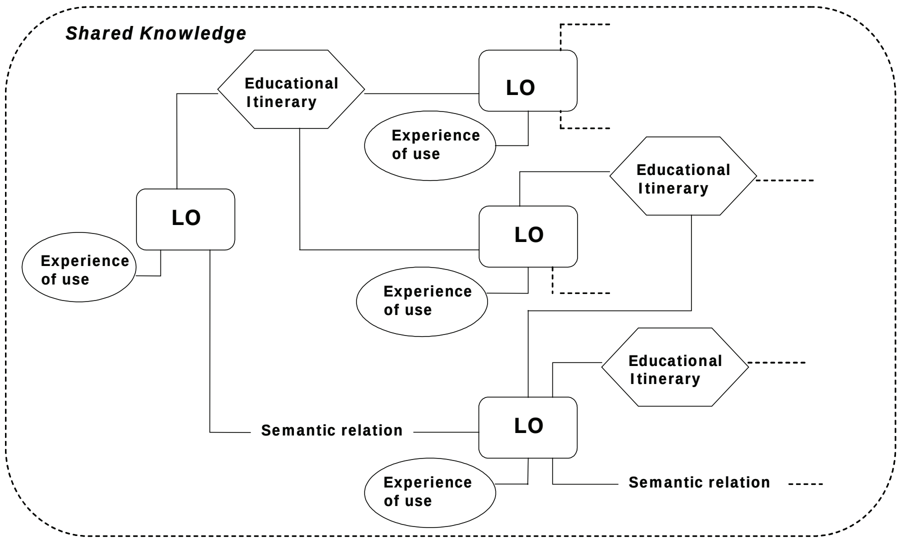
Figure 6. An example of learning itinerary as specified in LODE

by the metadata and by a list of links pointing to LOs which are conceptually connected with it according to the LO's author. Experiences of use (named "comments") and itineraries available for this LO are listed on the left hand side.

Comments to any LO in the repository can be added by any user. They take the form of texts freely structured by their authors. Itineraries, on the other hand, are described by specifying information of several kinds, namely objectives, content, target population, LOs used, time required, development, necessary tools, pedagogical approach (see Fig. 6). The names of the LOs are clickable, to facilitate their retrieval. When a user adds an itinerary for a LO, the same itinerary is automatically associated to all LOs mentioned in it. Any user can add itineraries even if he/she is not the author of any of the LOs included.

With the addition of these two features, the knowledge shared within the repository results composed by items of three different kinds, as depicted in Fig. 7.

Figure 7. Organization of LODE's shared knowledge. LOs are connected by semantic relations and complemented by comments and educational itineraries, that represent the pedagogical knowledge arising from re-use



CONCLUSION

The idea of LO emerged from traditional software design approaches with the aim to propose effective and economical strategies to manage and re-use resources in networked environments. Its technological roots initially led to pay attention more to technological features than to pedagogical ones, which limited teachers' enthusiasm in this respect. Introducing pedagogical elements in the design of LOs and of repositories could improve this situation, hence making LOs closer to the actual work of teachers and spreading their use in the school besides then in networked learning. Our work on LOs aims to give a contribution in this direction.

We suggest to improve LOs and repositories by means of pedagogy-oriented design. As concerns LOs, we propose to rely on a typology able to highlight the pedagogical intentions and teaching approach of LO's authors. As concerns repositories, we propose to store not only LOs but also reports of use experiences and learning itineraries based on LOs, so as to capture and share the pedagogical experience of re-users, in addition to that of authors.

Emphasising pedagogical aspects can make the use of LOs more interesting and useful for the teachers, overcoming the mono-directional view of technology-oriented re-use. When pedagogical experience is shared, engaging in a re-use activity can be an effective and powerful approach to teachers' professional development, helping them to learn from each other's experience.

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Chapter XI
Adaptive Animation of Human Motion for E-Learning Applications

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ABSTRACT

Human motion animation has been one of the major research topics in the field of computer graphics for decades. Techniques developed in this area help present human motions in various applications. This is crucial for enhancing the realism as well as promoting the user interest in the applications. To carry this merit to e-learning applications, we have developed efficient techniques for delivering human motion information over the Internet to collaborating e-learning users and revealing the motion information in the client machines with different rendering capability. Our method offers a mechanism to extract human motion data at various levels of detail (LoD). We also propose a set of importance factors to allow an e-learning system to determine the LoD of the human motion for rendering as well as transmission, according to the importance of the motion and the available network bandwidth. At the end of the paper, we demonstrate the effectiveness of the new method with some experimental results.

INTRODUCTION

Human motion animation (Badler, Palmer, & Bindiganavale, 1999) has been incorporated in varieties of applications, such as engineering simulation, virtual conferencing, gaming, military, and education. It can play different roles in the applications. More specifically, as a major supporting role, it helps present certain motions, such as dance performance of the main virtual human characters in an application. This kind of animation must be done in significant fine detail to allow users to have a good understanding of the motion of the virtual human characters. However, doing this would need to involve complicated and costly computations, which may not be able suitable for real-time applications. On the other hand, as a minor supporting role, human motion animation helps reveal motions of supporting characters. For example, it may animate the crowd in an evacuation training application. The level of detail of animation of this type may be decreased without affecting how the users to perceive the motion of the crowd. Although the computation workload for animating an individual virtual character may be greatly reduced in this situation, applications may still incur high computation work if one needs to animate a large amount of virtual characters at the same time.

With the dramatic improvement in networking capabilities and the possible consolidation of rich learning resources over the Internet, e-learning has been admired as a very useful learning environment. It offers remarkable features, which are hardly found in the traditional learning environment. First, unlike traditional learning that requires students to gather at a specific time and place to attend a lesson, e-learning allows students at different geographical locations to join a lesson without physically traveling there. Second, e-learning allows the consolidation and distribution of e-learning contents from a vast amount of Internet Web sites to students. Third, e-learning natively supports the presentation of various types of media, such as 3-D graphics, animation, and sound, to help students visualize and understand concepts in an easier way. For example, Canós, Alonso, and Jaen (2004) propose a multimedia-enabled emergency evacuation training system for an underground metropolitan transportation environment. The system makes use of text, images, audio, video, and simple 3-D graphics to construct the user interface and present evacuation training materials. Results show that such an arrangement could improve students' understanding on complex procedures.

To further enhance the interactivity of the learning environment and motivate the student participation, 3-D virtual environments with animation (Sims, 1995) would definitely be a crucial complement to the e-learning systems, such as the emergency evacuation training system (Canós et al., 2004). The possible incorporation of such an environment would allow students to be actively trained in various emergency situations. While it is important for students to fully visualize the emergency situations and learn to respond to them interactively, it is also necessary for the instructors to be able to visually monitor the progress of the students from different angles in the virtual environment. Despite these benefits, as we have discussed, 3-D animation, in particular when animating human motions, can be very demanding in terms of rendering. In addition, owing to the large size of the human motion data, the transmission of such data to the e-learning users over the Internet would induce a significant bandwidth consumption on the networks.

In this article, we present an adaptive human motion framework to support real-time rendering and transmission of human motions in e-learning systems. The rest of this article is organized as follows. The second section provides a survey on related work. The third section describes the foundation of 3-D-based e-learning systems.The fourth section shows the adaptive human motion framework in detail. The fifth section presents some experimental results of our method. Finally, the sixth section concludes the work presented in this article.

RELATED WORK

Formulation of Human Motions

An intuitive way to incorporate human motion animation in e-learning applications is key-framing (Burtnyk & Wein, 1976). This approach requires the animators to construct a virtual character to represent a human, and to define and draw key-frames of a motion sequence of the virtual character to be animated. However, manipulating and coordinating the limbs of a virtual character via key-framing is a complicated and tedious task. In addition, it is also difficult to produce realistic and natural looking motions with key-framing. To ease the construction process of human motions, we may alternatively make use of motion capturing devices (Meyer, Applewhite, & Biocca, 1992) to acquire the movement of live objects and then apply the captured position and orientation information on virtual characters to drive their motions. This approach has been widely accepted in real-time applications as it helps to produce realistic and natural looking character animations. In general, regardless of which approach is being used, motion data is often large in size since it comprises a continuous data stream describing the spatial changes of all joints of each articulated figure. This likely poses a significant burden when we need to deliver the motion data over the Internet.

On the other hand, an animator may further edit and combine the motion sequences of a virtual character to create new motion sequences for use in different applications. Inverse kinematics (Wang & Chen, 1991), which is a process for computing the pose of a virtual character from a set of analytically constrained equations of motion, could be adopted to achieve physical realism in motion editing. For example, Popović and Witkin (1999) suggest a variety of modifications to running and jumping motion data using a low resolution physical model to constrain the search space and trajectory optimization to generate physical realism in motion modifications, while Rose, Guenter, Bodenheimer, and Cohen (1996) propose a minimum energy solution for transitions between motion sequences using an inverse kinematics model.

Level of Detail of Human Motions

During a 3-D interaction, users normally have different perceptions on different objects in the application environment. Such differences could be evaluated from a set of viewing parameters (Lau, To, & Green, 1997), including viewer-object distance, viewer's line of sight, viewer's depth of field, and object moving speed. To take advantage of this, numerous methods have been developed to adjust the LoD of 3-D geometry models, behavior, and animation data to achieve better run-time performance for character animations.

In LoD of geometry models, a 3-D model of a virtual character could be simplified by various multi-resolution modeling methods (Hoppe, 1996; To, Lau, & Green, 1999). Most of these multi-resolution modeling methods construct an edge collapse sequence of a 3-D model to allow the model to be rendered with a selected number of polygons during run time. However, the simplification of a virtual character does not directly correspond to a simplification of its animation. In LoD of human animation, Endo, Yasuda, and Yokoi (2003) propose a framework to support the transmission of human motion data with different LoDs. In this framework, human motion data is modeled according to the H-Anim specification (H-Anim, n.d.), which allows a virtual character to be modeled in several levels of articulation (LoA), in which different LoAs of the virtual character comprise different numbers of representative joints. To transmit the human motion data, the server determines an appropriate LoA of the virtual character for a client based on the importance of the figure and the available bandwidth of the client network connection. It then delivers only the motion data of the representative joints contained in the selected LoA of the articulated figure. However, this method does not consider the optimization of the motion sequence of each joint. In contrast, Naka, Mochizuki, Hijiri, Cornish, and Asahara (1999) consider this factor as the primary way to reduce the transmission workload of human motion data. This method proposes to choose only a subset of motion data of each joint for transmission. This is done by regularly discarding motion data of each joint over the motion sequence. However, without analyzing the characteristic of the motion sequence, the method may likely remove some important motion data. As mentioned in the previous section, since motion data is typically large in data size, the lacking of a good method for handling the transmission of human motion data would probably hinder the incorporation of character animations in Web-based applications, in particular, the e-learning applications.

Foundation of 3-D-Based e-Learning Applications

E-learning has been admired to be a more interactive, intelligent, and collaborative learning environment as compared with the traditional learning platform. To further promote the usability of e-learning applications, 3-D-enriched learning materials and their supporting platform are urged to augment such applications. For instance, traditionally, a medical student needs to mentally process and correlate lots of MRI images to "visualize" possible defects of a patient's internal organs. However, since techniques for constructing 3-D graphic models from the MRI images have been available (Lorensen & Cline, 1987), the learning process of the medical students could then be sped up significantly, as they are now able to visualize and understand medical problems in a straightforward way.

To implement a 3-D-based e-learning application, the retrieval and the delivery of 3-D e-learning content are considered as the primary features to be included; however, these are not trivial tasks. Typically, there may be a vast array of e-learning contents stored either at the e-learning server or over the Internet—an efficient retrieval technique should be developed to locate the relevant learning content to be delivered to the users who request the information. Another problem is the network bandwidth problem, as some users may be connected to the e-learning server with only a slow modem connection and others may use mobile devices for accessing e-learning materials. In Li and Lau (2006) we have developed a progressive content distribution framework to address the aforementioned issues; the framework helps transmit suitable quantity and quality of the learning content to the users. Experimental results show that the framework offers very impressive transmission performance for distributing geometric information of 3-D-enriched learning materials. We have also built an urban walkthrough system and a Moai study system to demonstrate the functionality of the framework.

Our progressive content distribution framework (Li & Lau, 2006) works well for 3-D-enriched learning materials that do not involve any human motion. However, since human motion animation is crucial for some valuable e-learning applications, such as a dance performance training application or an evacuation training application, we therefore propose a new method in this article to augment our content distribution framework to cope with this need. Our method supports both real-time rendering and transmission of human motion information in e-learning applications.

ADAPTIVE HUMAN MOTIONS

Problem Issues

Incorporating human motion information in the e-learning applications is a challenging research problem. In contrast to handling static 3-D e-learning objects, which involve only a predefined set of geometry information including the object model definition and the texture images used, handling 3-D objects with human motion animation may be more demanding in terms of the amount of data involved and the dynamic nature of the data. For example, one may associate multiple motion sequences to an object for motion animation. Some motion sequences may describe motions of virtual characters for a prolonged period of time, resulting in a very large data size. Another demanding task is the rendering of human motion on the client side in e-learning applications, as it may incur time-consuming, computation processes to reveal the motion of the 3-D objects to the users. To address these problems, our new method decomposes human motions into different LoDs and a metric to determine the appropriate LoD of the motion data for different parts of a virtual character. To maintain human motion information, our method makes use of the data structure as defined in the Biovision Hierarchy (BVH) data format (Lander, 1998), which is a character animation file format for storing the skeleton hierarchy as well as the motion informaiton.

Human Motion Decomposition

Technically, it is not an easy task to efficiently transmit human motion data over the Internet, particularly when a lot of virtual characters are involved, the data size of the human motion data would likely become very large. The motion data is ordered as a sequence of sets of key values. Each set of key values indicates the positions and orientations of individual joints of the virtual character at a particular frame. Although many data compression methods are available, most of them could not handle human motion data efficiently. It is because motion data is represented by a time-dependent data stream of hierarchically defined and highly corelated spatial information. In addition, human beings are also very sensitive to sudden changes in human motion, which can be produced by compressing the motion data with generic data compression algorithms. On the other hand, human motion may not necessarily be restricted to any regular patterns and sudden changes may appear in the motion data.

To address the aforementioned problems, we have developed a human motion decomposition mechanism based on wavelets analysis (Stollnitz, Derose, & Salesin, 1996). Wavelets are a mathematical tool for hierarchically decomposing data series into multiple LoDs using wavelets functions. The major advantage of wavelets is that wavelets functions are local in nature. In other words, wavelets could describe data series with a relatively small number of wavelets functions. Hence, the transformed data representation of a data series by wavelets analysis is compact in data size. On the other hand, this also enables wavelets to describe any sharp changes appearing in the data series. Although wavelet analysis has been applied in many applications, such as image compression, it is relatively new in the area of human motion.

To perform human motion decomposition, we read the human motion data from the BVH file for each articulated figure. The motion sequence of each joint of a character is handled separately using wavelets analysis. We express the motion sequence of each joint, that is, $\boldsymbol{c}^n=[c^n_1, c^n_2, ...c^n_{2^n+3}]$, as a linear combination of B-spline basis functions (Piegl & Tiller, 1995), where each c^n_i in $\boldsymbol{c}^n$ is assigned as the coefficient of the i^{th} B-spline basis functions and n represents the highest possible LoD of a joint. As B-spline basis functions are semi-orthogonal, this provides a sufficient condition for us to fit the human motion data into the wavelets analysis process. After executing wavelets analysis, we could obtain a coarse representation and a set of refinement records for the human motion data. To this motion data, we first distribute the coarse motion representation of the required virtual character to the client machine. The system may then refine the animation quality of the virtual character by sending more refinement records of the motion data to the user under the control of our proposed metrics.

When animating a virtual character, if only a subset of the motion data of a virtual character is made available at the client machine, the animation quality of the character may be deteriorated. To remedy this, we use B-splines to interpolate the low resolution motion data to generate a smooth motion path. In our implementation, for each joint of a virtual character, we use a cubic B-spline curve to interpolate the motion sequence of the joint. The choice of a cubic degree of B-splines is for its simplicity in run-time computation and the ability to provide smooth interpolation of the motion sequence. Another important contribution of applying B-spline interpolation is to ensure that the transition of human motion from one LoD to the next could be presented smoothly to the users.

Determination of Animation Quality

When animating a virtual character, different parts of the character may have different importance values depending on the application as well as on the view parameters of the viewer. For example, the wrist joint of a virtual character may play a more important role and have a higher visual importance in a punching motion than in a pure walking motion. For an e-learning training system to adjust both the transmission and the rendering qualities of human motion data, we consider the motion performed by the virtual character and the possible contribution of the character to the user attention (Treisman & Gelade, 1980). We model these factors by *joint importance* and *visual importance*, respectively. They are considered as the primitive parameters to construct the metric for selecting the level of decomposition of the human motion data. The details are depicted as follows:

Joint Importance

This parameter measures the importance of each joint of a virtual character by analyzing the human motion data acquired from the BVH file. Given a motion sequence, we compute the accumulated motion difference for each joint across the sequence. We then determine the degree of influence of a joint by evaluating the ratio of the accumulated motion difference of the joint against the maximum accumulated motion difference among all joints of the virtual character. Finally, we normalize the degree of influence of a joint by the LoD of the motion data of this joint received by a client machine to yield the joint importance.

Visual Importance

To model the importance of a virtual character to a viewer, we measure the following dynamic view parameters of the viewer relative to the character:

1. **Distance of the virtual character from the viewer, D.** It is obvious that virtual characters closest to the viewer could be visualized more clearly by the viewer than those virtual characters located farther away from the viewer. So, the closer a virtual character is to the viewer, the higher its visual importance value.
2. **Viewing direction of animating virtual characters from the viewer, M_o.** We notice that the motion details of a virtual character will be more visible to the viewer if the movement direction of the character is perpendicular, instead of parallel, to the

viewing direction of the viewer. We can take advantage of this and compute the visual importance of a virtual character according to the orientation of its motion plane with respect to the viewing direction of the viewer.

We may now compute the visual importance of a virtual character according to the previous view parameters as follows:

$$Visual\ Importance = w_D \cdot D + w_M \cdot M$$

where w_D and w_M are the weights for the distance factor and for the motion plane orientation factor, respectively.

Results and Discussions

We have conducted experiments to evaluate the performance of our approach on *data error* and *smoothness of transition*.

Experiment 1—Data Error

In this experiment, we have performed a walking animation. The animation consists of 131 frames and is rendered at 30 frames/second. We examine the joint with the highest total movement. Table 1 records the accumulated movement of each joint within the whole animation sequence. From the table, we can see that the Left Up Arm has the highest total movement and hence, we examine this joint here.

Figures 1 to 3 illustrate the data error rate of the Left Up arm in *x, y,* and *z* axes. For the legend shown on the right hand side of each chart, C7 refers to motion of highest detail, that is, the nondecomposed motion. C6, C5, and C4 refer to the motions after one, two, and three levels of wavelets decomposition, respectively. In our implementation we store the joint positions/orientations in polar coordinate, that is, we represent each value by two angles in order to reduce the storage requirement of the motion data. Hence, the error of each joint is expressed in terms of *degrees*.

From Table 2, we could see that for the Left Up Arm (with the highest accumulated joint movement), the average data error for C6 is no more than 2.5 degrees, for C5 it is less than 2.8 degrees, and for C4 it is less than 3.7 degrees. This result is very encouraging. As the maximum error is less than 3.7 degrees, the user would not easily notice the difference. As a comparison, the data error for (Naka et al., 1999) can reach as high as 8 degrees. Therefore, we are about 1.2 times better than their method.

Figure 1. Data error rate of left up arm in z axis

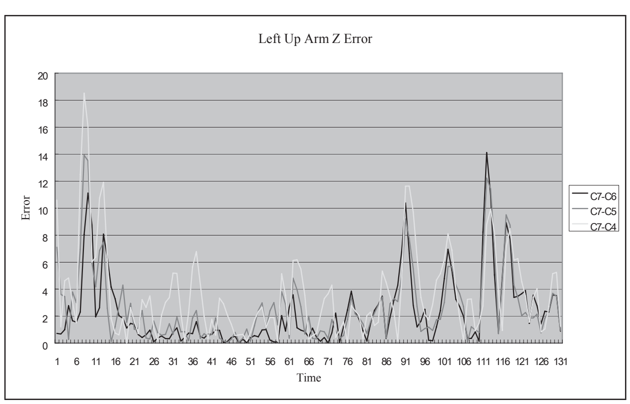


Table 1. Accumulated movement of each joint on z, x and y axes

Joint name	Accumulated movement of the joint			Total movement
	z	***x***	***y***	
Hips Position	5	0	3	8
Hips Rotation	0	1	3	4
Left Up Leg Rotation	105	29	35	169
Left Low Leg Rotation	265	2	6	273
Left Foot Rotation	113	6	45	164
Left Toes Rotation	184	0	3	187
Right Up Leg Rotation	82	17	14	113
Right Low Leg Rotation	218	4	6	228
Right Foot Rotation	111	4	34	149
Right Toes Rotation	160	0	5	165
Upper Back Rotation	4	1	1	6
Chest Rotation	4	10	8	22
Neck Rotation	8	11	11	30
Head Rotation	18	11	14	43
Chest Rotation	0	0	0	0
Left Up Arm Rotation	301	3	315	619
Left Low Arm Rotation	42	8	30	80
Left Hand Rotation	0	9	12	21
Left Fingers Rotation	0	0	0	0
Chest Rotation	0	2	0	2
Right Up Arm Rotation	216	19	285	520
Right Low Arm Rotation	69	4	41	114
Right Hand Rotation	0	12	63	75
Right Fingers Rotation	0	0	0	0

Figure 2. Data error rate of left up arm in x axis

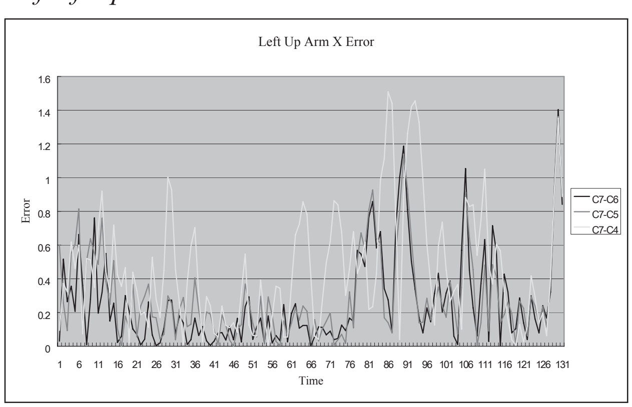


Figure 3. Data error rate of left up arm in y axis

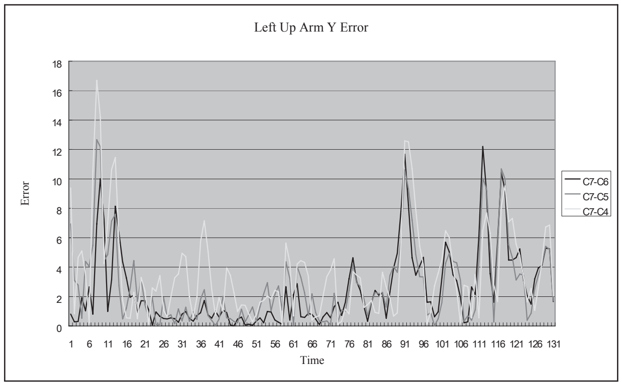


Table 2. Average data error for each level of detail.

Axis of joint	Average data error for each level of detail		
	C6	C5	C4
Left Up Arm Z	2.306 ^{o}	2.691 ^{o}	3.655 ^{o}
Left Up Arm X	0.2596 ^{o}	0.292 ^{o}	0.463 ^{o}
Left Up Arm Y	2.483 ^{o}	2.782 ^{o}	3.586 ^{o}

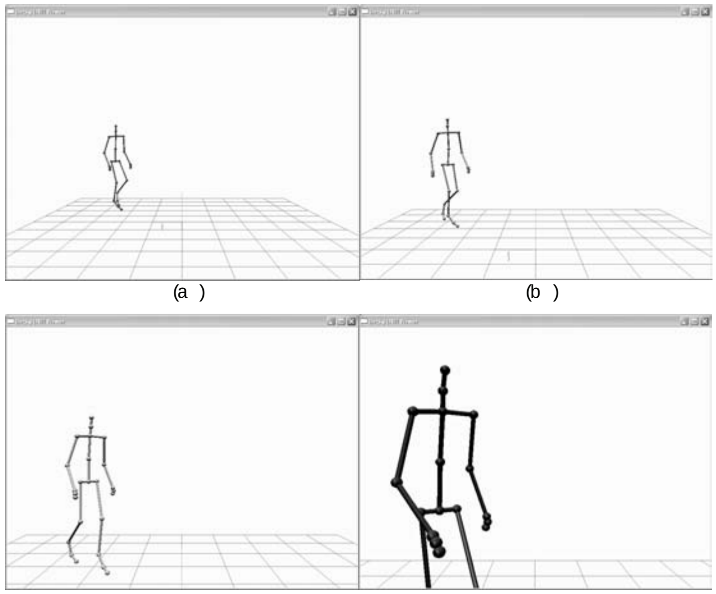
Experiment 2—Smoothness of Transition Between Different LoDs

In this experiment, we study the smoothness of switching between different LoDs of human motion. We start at a distant location from the virtual character and we gradually move closer and closer to the character. During this movement, the virtual character will switch itself to a higher and higher LoD. To make the changes more visible, we use different colors to represent different levels of motion. Figure 4 shows a sequence of four major screen shots showing the motion transitions from a lower LoD to a higher one. If we do not use different colors to separate different LoD's, the user will not easily notice the changes. In the trial run of our prototype we could see that the transition is very smooth and natural.

CONCLUSION

In this article, we have proposed an adaptive human motion animation method to support real-time rendering and transmission of human motions in e-learning applications. Experimental results show that our method could efficiently reduce the size of human motion data. This is particularly useful to support distributing 3-D animation data in e-learning applications. On the other hand, our method could also render human motion at different levels of detail. By taking advantage of this feature, an e-learning application could provide a compromise between rendering performance and output quality.

Figure 4. Screen shots of motion transition between different levels of detail.



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Chapter XII
eWorkbook:
An On-Line Testing System with Test Visualization Functionalities

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ABSTRACT

On-Line Testing is that sector of e-learning aimed at assessing learner's knowledge through e-learning means. In on-line testing, due to the necessity of evaluating a big mass of learners in strict times, the means for knowledge evaluation had to evolve to satisfy the new necessities: objective tests, more rapidly assessable, started gaining more credence in the determination of learners' results. In this chapter, the authors present an On-Line Testing system, named eWorkbook, which can be used for evaluating learner's knowledge by creating (the tutor) and taking (the learner) on-line tests based on multiple choice question type. Its use is suitable within the academic environment in a blended learning approach, by providing tutors with an additional assessment tool, and learners with a distance self-assessment means. Among other features, eWorkbook can record and visualize, in a suitable graphical format, learner's interactions with the system interface during the test session. This is valuable information for understanding the learner's behaviour when taking a test. In particular, the graphical analysis of the test outcomes has helped us in the discovery of several strategies employed by the learners to perform the test. In the paper, the main characteristics of the system are presented together with a rationale behind them and an outline of the architectural design of the system.

INTRODUCTION

In blended learning the electronic means are mixed with the traditional didactics, in order to train and to assess the learners. *Learning Management Systems* (LMS), enhanced with collaborative environment support, and *On-Line Testing* tools are more and more widely adopted in the academy. At the University of Salerno some systems and platforms have been tested to support blended learning. Even if some good existing LMS with *On-Line Testing* capabilities, such as *Moodle* (Moodle, 2005) and *Sakai* (Sakai, 2005) have been used, none of them satisfied us at all: we needed an advanced assessment tool which could have helped the lecturers to speed up the onerous task of assessing a huge mass of learners and should have provided the tutor with valuable information for evaluating the whole assessment process.

A state of the art analysis undertaken at our department, which involved several lecturers and students, allowed us to identify the following important requirements for an effective environment for developing and using assessment tests:

- Item sharing features;
- Didactics organized in courses and classes;
- Possibility of administering both self-assessment tests and proctored laboratory exams;
- Availability of statistics on tests and questions;
- Availability of a rich reporting section on test outcomes.

A project for a comprehensive Web-based assessment system, named *eWorkbook*, was then started. The system can be used for evaluating a learner's knowledge by creating (the tutor) and taking (the learner) on-line tests based on multiple choice question types. Even though *eWorkbook* enables the creation of on-line tests for both assessment and self-assessment, it was planned above all for *summative* (evaluation) purposes. The questions are kept in a hierarchical repository, that is, it is tree-structured, in the same way as the file system of an operating system. In such a structure, the files can be thought of as questions, whether the directories can be thought of as *macroareas*, which are containers of questions usually belonging to the same subject. Every item (a macroarea or a question) has an owner, which is the tutor who authored it. The tutors can choose whether to share their questions or not, assigning a value to the permissions associated to each item. Permissions are for reading, writing and using the items.

The tests are composed of one or more sections. This structure facilitates the selection of the questions from the repository, but it is still useful for the assessment, where it can be important to establish if one section is more important then another to determine the final grade for the test. The selection of the questions can occur both statically, by directly choosing the questions from the repository, and dynamically, leaving the system to choose the questions randomly.

Didactics are organized into courses and classes: the tutors responsible for a course manage its class and choose the tests that must be taken by the learners of that class. With such an organization, the system can be used by a large set of users, such as the learners and the tutors of an entire faculty. Within a course interface, the learner can easily access the self-assessment tests. Restrictions on the access rules can be defined for proctored laboratory tests.

Different assessment strategies can be bound to a test, before it is published in a course. The assessment strategy affects the way in which some parameters concur to determine the grade of the test. Some strategies are preloaded in the system and are referred to as *predefined assessment strategies*. Others can be defined by the tutors and saved in his/her reserved area. We will refer to them as *customized assessment strategies*.

A complete history of learners' performance on tests of the valuable list is available to the tutor and to the learners themselves. Each record in the history contains the date and the time when the learner has joined a test, the amount of time needed to finish the test and some information about assessment (test score and state). The detail of the answers to each question can be seen as well and can be viewed in a printer-friendly format. The tutor has the possibility of analyzing the behaviour of each learner during a test, by simply inspecting a suitable chart, which graphically summarizes learner's interactions with the system interface during the test session. By analyzing the data visualization charts from several test outcomes, we have detected several previously unknown test strategies used by the learners.

The rest of the paper is organized as follows. In the section *"The Main Features of eWorkbook"* the main features of the systems are described in detail. The section *"eWorkbook Architecture"* is devoted to outlining the architecture of eWorkbook. An example of system use can be found in section *"AnExample: The English Knowledge Test"*. In section *"Related Work"*, a comparison is made with some interesting systems related to ours. Some final remarks and a description of future work conclude the paper.

The Main Features of eWorkbook

In the following subsections we will outline the main characteristics of the eWorkbook system. It is worth noting that eWorkbook was intended to be used by a large number of users, so it has a typical LMS didactics organization, based on courses and classes. A course is a place in which the tutors can publish tests and the learners can take them. Learners can only view the tests published in the courses in which they are members. The tutor manages the class and can accept or deny learners' affiliation requests and expel a learner from the course.

Question Management

An important matter for On-Line Testing, and more generally for e-learning, in order to accelerate the teaching and the assessment processes, is the reusability of the authored content. The on-line material needs a huge initial effort to be created, while it can be easily modified and reused later on. Therefore it is very important that existing material can be easily found, modified and selected by a tutor who wants to use it for a lesson or a test. There are two main ways to boost the reuse of learning material:

1. Good organization of material kept in an e-learning platform or On-Line Testing system.
2. Interoperability among systems and platforms, to share and exchange material.

Our system was designed to have a well organized question repository to facilitate the tutor in the question management, share and reuse: the question repository of eWorkbook has a hierarchical structure, similar to the directory tree of an operating system. Each item in our repository is a disciplinary *macroarea* (internal node) or a *question* (leaf). The membership of a question to a given macroarea is determined by its subject: each macroarea is a container of questions that holds items dealing with a specific subject. It can be further split in other sub-macroareas, which hold questions belonging to a more specific matter. The question types allowed are multiple choice, multiple response and true/false. The tutor can choose if a question should be used for assessment only, for self-assessment only or for both of them.

An effort for the interoperability has been made supporting the *IMS Question & Test Interoperability* specification (IMS QTI, 2005): our system can import and export information regarding questions and tests through this widely known and adopted XML-based format.

Permissions

Author's right protection is an important matter too. An e-learning system should offer the tutor the choice to share his own material or not. In eWorkbook, the owner (the tutor who authored the question) and a permission set are associated to each item. The owner establishes the values for each field of the permission set. A permission is a Boolean value that indicates whether other users beyond the owner can perform the action associated to that permission.

For a macroarea, the value for the following permissions must be set:

- *ReadPermission*: the permission to read the property and the contents of this macroarea.
- *WritePermission*: the permission to overwrite the property and manage this macroarea (add a sub-item to it, delete it).
- *UsePermission*: the permission to select a question from this macroarea for a test.

For a question, the permissions are the following:

- *ReadPermission*: the permission to read the question.
- *WritePermission*: the permission to delete and overwrite the question.
- *UsePermission*: the permission to select this question for a test presentation. Its default value is the value of UsePermission of the macroarea which this question belongs to.

It's worth noting that permissions are a good way to protect author's right and to avoid that the material owned by a tutor is modified or used without his/her consensus. Other systems only give the possibility to share or not all of the tutor's questions. A permission based system gives more flexibility to the system, allowing different grades of item sharing.

Question Metadata

Each question in the repository has a metadata set associated to it. Some of the parameters are decided by the tutor when he/she instantiate the metadata and they can be updated later, others are inferred by the system during its use. Inferred metadata are updated whenever a learner submits a test. Metadata are used in question selection in a way that will be clear in the sequel. The following is a list of the metadata fields:

- *Language*: the human language in which the question is expressed.
- *Keywords*: a set of keywords that describe the content of the question.
- *Use*: the aims the question is for. It can be *self-assessment*, *valuable* or *both*.
- *TestOccurrence*: an inferred field that is increased by one whenever this question is scheduled for a test.
- *AverageAnswerTime*: an inferred field. It can be used on our system because it is able to track the time spent by the learner on each question.
- *Difficulty*: this field has both an inferred and a tutor chosen value. It's a value between 0 and 1 that expresses a measure of the difficulty of the question, intended as the proportion of learners who get the question correct. The tutor can guess this value at the question creation time and can update it during the question's lifecycle. The system calculates the inferred value with a simple formula.
- *Discrimination*: this field is an inferred one. Its value is a measure of how well this question discriminates between learners. A good question should give full mark to good learners and penalize bad ones. Starting from this information, a great deal of criteria can be adopted. A solution is proposed in (Lira et al., 1990): it identifies a good question as the one which the better 20% of learners answers well and the worse 20% of learners

answers incorrectly. We adopted a common solution applied in *Item Analysis*, calculating discrimination as the Pearson correlation between the score achieved on the question and the total score achieved on the test in which the question was scheduled. Its value is given by the following formula:

$$r = \frac{\frac{\sum (x-\overline{x})(y-\overline{y})}{n-1}}{\sqrt{\frac{\sum (x-\overline{x})^2}{n-1}}\sqrt{\frac{\sum (y-\overline{y})^2}{n-1}}}$$

where the following rules are valid:

- $-1 \leq r \leq 1$,
- x is the series of the results got on the question,
- y is the series of results got on the whole test.

Question Quality Improvement through Question Lifecycle

In On-Line Testing systems it is important that the quality of the questions is kept high, so that the tutor can assess learners properly, using unambiguous questions that really distinguish between good learners and bad ones. eWorkbook adopts the statistical indicators (Difficulty and Discrimination, seen in the previous chapter) from *Item Analysis* to get information about the effectiveness of the questions.

The improvement of the quality of the question requires the use of a process which allows the tutor to analyze the entire lifecycle of a question, including all its previous versions and the learners' answers to them. Our question repository has a *Version Control System* that allows tutors to change some data of the questions, e.g. text, distractors or metadata, still keeping the previous versions of the question: the upgrade of a question does not imply the erasing of the previous version. This could be an important feature for reasons bound to the history of learner's responses to the question too: the question could already have been used in some tests before the upgrade, and the system has to remember which version of the question the learner answered. However, the *Version Control System* is important for reasons related to the quality of the questions: thanks to the tracking of the question lifecycle the tutor has feedback on the variation of statistical indicators over time. In this way, the tutor can modulate the difficulty of the question and make sure that the changes he/she made to it (maybe eliminating misspellings and ambiguities), affected positively the quality of the question. Other information, useful to establish the effectiveness of a question, is available: the tutor can easily inspect how many times it was selected to be presented in a test, the number and the percentage of correct, incorrect and not answered responses and the average time needed to get the response.

In the light of the previous arguments, we can argue that the definition and the use of questions from the hierarchical repository for more than one session of tests, combined with the *Version Control System*, allows the tutors to have a wide choice of high quality questions to select for their online tests.

Test Management

A test is composed of *sections*. eWorkbook has two ways of selecting the questions to be presented in a test: through a static creation-time choice or a dynamic run-time one. In the first case, the tutor has to choose the questions directly during the creation of the test; in the latter case, she/he has only to specify some selection parameters, letting the system choose randomly the questions across the chosen macroareas whenever a learner takes a test.

Therefore, we have two kinds of sections: a *static* section is an explicit selection of the questions to present performed at test creation time, while a *dynamic* section is characterized by a set of rules that perform a selection on the entire repository. For a dynamic section, there are three kinds of selection rules:

1. Definition of the macroarea. This rule limits the selection only to the questions belonging to the specified macroarea. A flag can be set, that further selects also the questions belonging to the descendent macroareas.
2. Definition of keywords. This rule limits the selection only to the questions that match the input keywords. Some logical connectors, in a search engine style can be used. By default, the questions which contain even one of the input keywords are selected. No relevance rate is associated to the results.
3. Definition of some assertions on metadata fields. They are of the following form: *<metadata_field> <connector> <value>*. As an example, for a section, we can choose to use only those questions that have *difficulty > 0.5.*

The same three rules are also used to search the questions for a static section through a wizard in the Web-based interface. The tutors can choose to use just one of them to select the questions, or to combine them to narrow or to expand the search results. The tutors can also choose whether to use only their material or the one shared by the other tutors too.

These rules allowed us to overcome problems related to question selection: different tests for each learner can be generated still getting an objective assessment through the selection of ranges for the difficulty and the average answer time. The discrimination was decided not to be used for question selection assertions, in order to avoid the neglecting of low quality questions. Our policy was to encourage the tutor to review low quality questions, in order to correct their anomalies and increase their quality.

Test Presentation

Two different lists of tests are presented to the learner within the course interface: the *valuable* and the *self assessment* test lists. Each test in the former list is used to determine the learner's evaluation and is characterized by an access control specified by a prerequisite expression and a maximum number of attempts. The latter list is just a guide for the learner to self train and assess: each test in it has not got any access restriction and does not affect the learner evaluation. Each test presented in a course is bound to some test execution options. These options allow the tutor to customize the test with further information which could not be available or decided at the test creation time, so we choose not to hard-code them in the test. Test execution options include the following information:

- *IP Limitation*: an option through which the tutor can authorize or deny access to some clients, according to their IP. A selection of authorized IP lists must be chosen. This option can be particularly useful for official exams, whose tests are required to be taken only by the learners that physically present in a laboratory. An IP list can be defined and selected for all the PCs of that laboratory. Wildcards and IP ranges can help to define IP lists.
- *Assessment*: a list of options that specify the numeric scale for the mark, the threshold to pass the test and the marking strategy. Details about marking strategies can be found in section *"Assessment Strategies"*.
- *Shuffle*: this Boolean option can be checked if the tutor wants to randomize the sequence of the questions, to make it more difficult for the learners to cheat.
- *Access Control*: this section of options is valid only for valuable tests. The tutor can

choose the maximum number of attempts allowed for the test and the prerequisites for accessing it. Prerequisites establish, through a simple even powerful expression, the learner's right to access the test. If not fulfilled, prerequisites can deny learner's access to the test. Prerequisites for a test are based on the learner results on the previous tests in the valuable test list. The language supported for the expression is *aicc_script*; a string expressed in such a language has a Boolean value and it is composed of the following elements:

- *Identifiers*: nouns that univocally identify a test in the valuable list.
- *Constants*: values that define the state of a test (passed, completed, browsed, failed, not attempted, and incomplete).
- Logic, equality and inequality *operators*.
- A special syntax to define a set and to specify at least n elements from a set. As an example: the expression *test1 & 2*{test2, test3, test4}* is true if the state of *test1* is *passed* or *completed* and at least two among *test2*, *test3* e *test4* are *passed* or *completed*. A simple visual interface helps the tutor to define the prerequisites string without knowing *aicc_script* language. There is also an *aicc_script-to-natural* language translator to help the learner to better understand the prerequisites for a test. A better and more complete explanation of aicc_script can be found in (ADL, 2001).

An instance of test execution options is a configuration that can be saved with a name and recalled in a second time, whenever a new test must be added. The tutor can opportunely define different sets of execution options in order to choose the most suitable configuration for a given test type (self-assessment, proctored laboratory exam, etc.).

Assessment Strategies

eWorkbook provides a wide choice of predefined assessment strategies and the possibility to define a new customized assessment strategy. An assessment strategy is a set of choices of the values to give to some parameters taken into account during the test assessment process. The predefined strategies are preloaded in the system and cannot be changed. They are at the disposal of all of the tutors. The customized strategies can be defined by a tutor, and they remain visible only in his reserved area. All the strategies calculate the final mark on the test by summing the results achieved on the single questions. The maximum mark which can be obtained on a single question depends on the weight of the question. A weight is assigned by the tutor to each section of questions in a test and the weight of a question is easily calculated by dividing the weight of the section by the number of questions in it. The customizable parameters are the following:

- *Weighting*: this parameter, if set, enables the *weighted assessment* for a test, that is, the maximum mark got on the question depends on its weight. If a tutor wants a section to be more important than the others, he/she has to give a higher weight to it during the test authoring, and he/she has to choose an assessment strategy with the weighting parameter set. If this parameter is not set, all the questions equally contribute to get the mark on the whole test.
- *BonusOnCorrect*: this parameter, if set, allows the tutor to specify a positive real factor (bonus) by which the mark obtained on the correctly answered questions during the assessment process must be multiplied.
- *PenaltyOnIncorrect*: this parameter, if set, allows the tutor to specify a negative real

factor (penalty) by which the weight of the incorrectly answered questions during the assessment process must be multiplied. If not set, the mark obtained on the questions answered incorrectly is zero. It is possible to choose a *fair* penalty, which gives to the questions answered incorrectly a mark of –(*1/NC-1)*, where *NC* is the number of choices for a question. The use of the fair penalty should set to zero the mean mark for a question guessed by a learner who does not know the right answer to it.

- *PenaltyOnNotAnswered*: this parameter, if set, allows the tutor to specify a negative real factor (penalty) by which the weight of the unanswered questions during the assessment process must be multiplied. If not set, the mark obtained on the unanswered questions is zero.

Table 1 summarizes the values given to the parameters above for each predefined strategy. The names of the strategies have been taken from (IMS ASI, 2004). As we can see, for each strategy, there is a weighted version. None of the predefined strategies adopts bonuses on correct or penalty on not answered questions. *NumberCorrect* is a 'plain' strategy: none of the parameters is set. Its name is due to the way in which it calculates the mark on the whole test: just summing the number of corrected answers (and scaling the result to 30 or 100). *GuessingPenalty* and its weighted version *WeightedGuessingPenalty* use 1 as factor for the PenaltyOnIncorrect parameter. This means that they subtract the entire weight of the incorrectly answered questions from the final mark on the test. *GuessingFairPenalty* and its weighted version *WeightedGuessingFairPenalty*, use the fair penalty, explained above.

History Tracking

A complete history of a learner's performances on valuable test list is available to the tutor and to the learner him/herself. The tutor can view the results achieved by all the learners in his/her classes, while the learner view is restricted only to his/her results. Each record in the history contains the date and the time when the learner joined a test, the amount of time needed to finish the test and information about assessment (test score and state).

To consult the history, a search engine style form must be filled. The fields of the form allow the seeker to select a course, a learner and a test whose instances must be shown. Further advanced parameters, which allow to narrow the research, are: the state (terminated, not terminated) and the result (passed, not passed) of the test, a date range during which the test was taken, and the number of results per page.

Each instance present in the result pages has a link to a pdf file that contains a printable version of the test with all the learner's answers. A

Table 1. Parameters settings for predefined assessment strategies

Strategy Name	Weighted	BonusOn Correct	PenaltyOn Incorrect	PenaltyOn NotAnswered
NumberCorrect	NO	NO	NO	NO
WeightedNumberCorrect	YES	NO	NO	NO
GuessingPenalty	NO	NO	YES (1)	NO
WeightedGuessingPenalty	YES	NO	YES (1)	NO
GuessingFairPenalty	NO	NO	FAIR	NO
WeightedGuessingFairPenalty	YES	NO	FAIR	NO

unique pdf file for all the instances is available as well. In such a way, all the tests can be saved or printed in one operation.

Test Visualization

eWorkbook tracks learner's interactions during the execution of a test. This can be useful for understanding the strategy used by the learner to complete the test and for giving him/her advise on how to perform better in future tests. Several experiments have been performed to this aim (Bath, 1967; Johnston, 1977; McClain, 1983) in the past. Our approach is the following: learner's interactions during tests are logged and stored in XML files; then the information gathered is analyzed and visualized in a suitable chart.

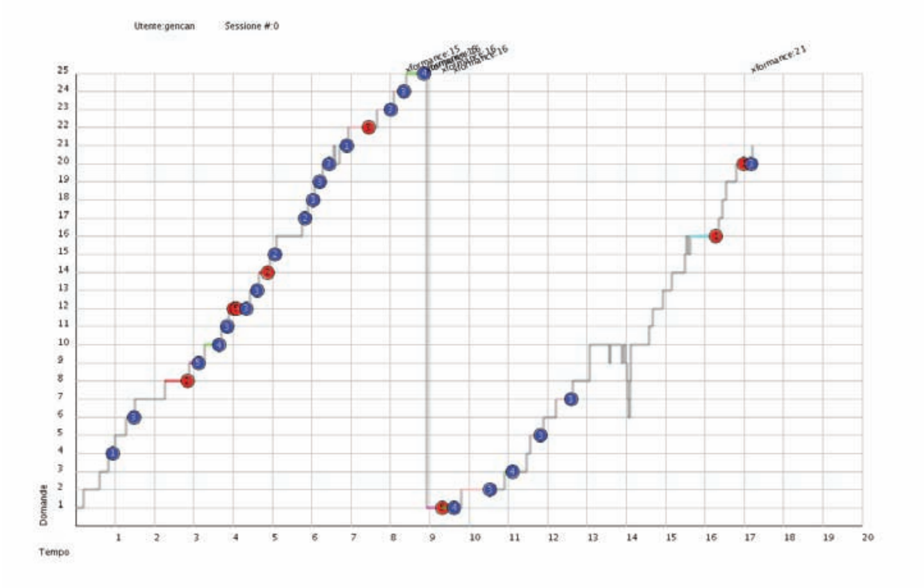
By showing the salient points of a test execution, a chronological review of the test is available to the tutor. The chart shows, at any time, the item browsed by the learner, the mouse position (intended as the presence of the mouse pointer on the stem or on one of the options) and the presence of response type interactions, correct or incorrect. The chart is two-dimensional: the horizontal axis reports a continuous measure, the time, while the vertical axis displays categories, the progressive number of the item currently viewed by the learner. The test execution is represented through a broken line. The view of an item for a determined duration, is shown through a segment drawn from the point corresponding to the start time of the view to the one corresponding to its end. Consequently, the length of the segment is proportional to the duration of the visualization of the corresponding item. A vertical segment represents a browsing event. A segment oriented towards the bottom of the chart represents a backward event, that is, the learner has pressed the button to view the previous item. A segment oriented towards the top is a forward event.

The responses given by a learner on an item are represented through circles. The progressive number of the chosen option is printed inside the circle. The indication of correct/incorrect response is given by the filling color of the circle: a blue circle represents a correct response, while an incorrect response is represented through a red circle. The color is also used for representing the position of the mouse pointer during the item view. The presence of the mouse pointer in the *stem* area is represented through a black color for the line. As for the options areas, the red, yellow, green, blue and purple colors have been used, respectively, for 1 to 5 numbered options. More than 5 options are not supported at present. Lastly, grey is used to report the presence of the mouse pointer in a neutral zone. The graphical chronological review of a sample test is shown in Figure 1.

By analyzing the charts obtained with system use, we realized that learners often follow common strategies for completing on-line tests. In our experiments we have identified the following three mostly employed strategies:

- **Single Phase.** This strategy is composed of just one *phase* (a part of the test execution needed by the learner for sequentially browsing all or almost all of the questions in a test). The time available to complete the test is organized by the learner in order to browse all the questions just once. The learner tries to reason upon a question for an adequate time and then gives a response in almost all cases, since he/she knows that there will not be a revision for the questions. Eventual *phases* subsequent to the first one have a negligible duration and no responses.
- **Active Revising.** This strategy is composed of two or more *phases*. The learner intentionally browses all the questions in a shorter time than the time available, in order to leave some time for revising *phases*. The questions whose answer is uncertain are skipped and the response is left to subsequent *phases*. As a general rule, the first *phase* lasts a longer time and the subsequent *phases* have decreasing durations.

Figure 1. Graphical chronological review of a sample test



- **Passive Revising.** This strategy is composed of two or more *phases*. The learner browses and answers all the questions as fast as possible. The remaining time is used for one or more revising *phases*. As a general rule, the first *phase* lasts a longer time and the subsequent *phases* have decreasing durations.

For both the definition of the strategies and the classification of test instances, the charts have been visually analyzed by a human operator. The above tasks are rather difficult to perform automatically, while a trained human operator can establish the strategy used by the learner from a visual inspection of the charts of the test instances and giving advice to the learners on how to perform better next time. Samples of the strategies are shown in Figure 2.

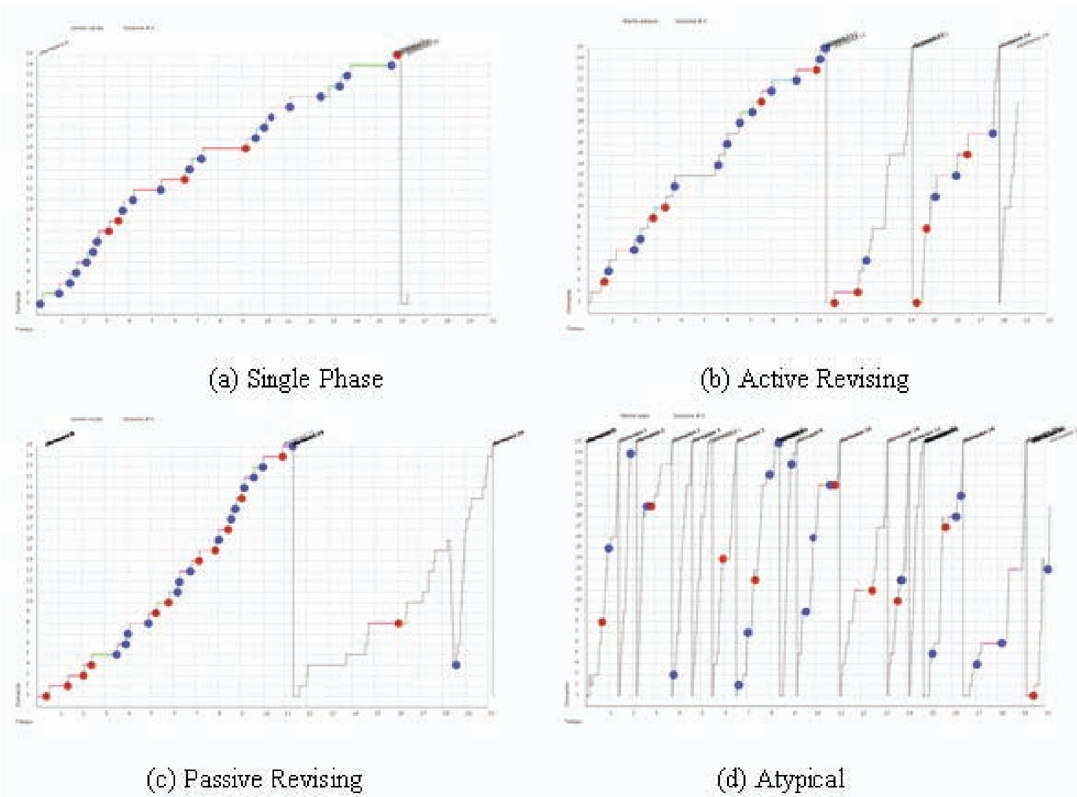
Other uses of the above described method are the detection of correlation among questions and the detection of cheating during tests. The reader can refer to (Costagliola et al., 2007) for obtaining a more detailed description on the educational results of our experiments with the tool.

eWorkbook Architecture

As shown in Figure 3, eWorkbook has a layered architecture. The *Jakarta Struts Framework* (Struts, 2005) has been used to support the *Model 2* design paradigm, a variation of the classic *Model View Controller* (MVC) approach. Struts provides its own Controller component and integrates with other technologies to provide the Model and the View. In our design choice, Struts works with *Java Server Pages* (JSP, 2005), for the View, while it interacts with *Hibernate* (Hibernate, 2005), a powerful framework for object/relational persistence and query service for Java, for the Model.

The application is fully accessible with a Web Browser. Navigation is facilitated across the simple interfaces based on menus and navigation bars. User data inserting is done through HTML forms and some form data integrity checks are performed using Javascript code, to alleviate the server side processes. A big effort was made to limit the use of client-side scripts only to the standard *EcmaScript* language (ECMAScript, 2005). No browser plug-in installations are needed.

Figure 2. Sample of test execution strategies



(a) Single Phase (b) Active Revising

(c) Passive Revising (d) Atypical

It is worth noting that the system has been tested on recent versions of the most common browsers (i.e., *Internet Explorer*, *Netscape Navigator*, *Firefox* and *Opera*).

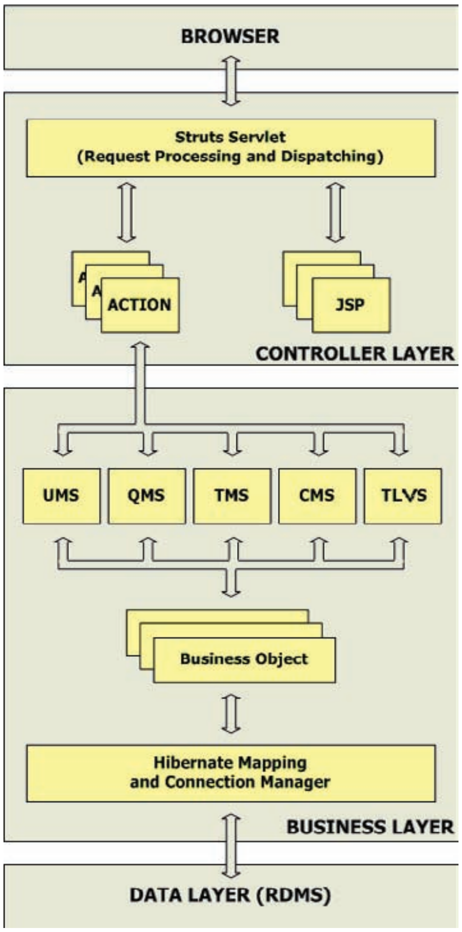
The Web Browser interacts with the *Struts Servlet* that processes the request and dispatches it to the *Action Class*, responsible for serving it, according to the predefined configuration. It is worth noting that the Struts Servlet uses the JSP pages to implement the user interfaces. The Action Classes interact with the modules of the *Business Layer*, responsible for the logic of the application. The Business Layer accesses to the *Data Layer*, implemented through a Relational Data Base Management System (RDBMS), to persist the data across the functionalities provided by Hibernate framework.

Controller Layer

This layer has many duties, among which are: getting client inputs, dispatching the request to the appropriate component and managing the view to return as a response to the client. Obviously, the Controller layer can have many other duties, but those mentioned above are the main ones.

In our application, following the Struts architecture, the main component of the Controller layer is the Struts Servlet, which represents the centralized control point of the Web application. In particular, the Struts Servlet processes each client request and delegates the management of the request to a helper class that is able to execute the operation related to the required action. In Struts, the helper class is implemented by an Action Class that can be considered as a bridge between a client-side action and an operation of

Figure 3. Architecture of eWorkbook



the business logic of the application. When the Action Class terminates its task, it returns the control to the Struts Servlet that performs a forward action to the appropriate JSP page, according to the predefined configuration.

To reduce the effort to maintain and customize the application, we chose to limit the use of the JAVA code in the JSP pages, using as an alternative the Struts taglibs. In this way the Web designers are able to work on the page layouts without shouldering the programming aspects. Finally, thanks to the use of the Struts framework, eWorkbook has the complete support for the internationalization of the Web-based interface. Even if, in its earlier releases, it only came with the English and Italian versions, the translation is quite an easy duty: to add a new language version all that our system needs is the translation of some phrases in a .properties (plain text) file. The Web pages are returned to Web browsers in the language specified in the header of the request.

Business Layer

This layer contains the business logic of the application. In any medium-sized or big-sized Web application, it is very important to separate the presentation from the business logic, so that the application is not closely bound to a specific type of presentation. Adopting this trick, the effort to change the look & feel of eWorkbook is limited to the development of a new user interface (JSP pages), without affecting the implementation of the other components of the architecture.

As mentioned before, every Action Class of the Controller Layer is able to execute an operation of the business logic of the application. To this aim, the Action Classes interact with four different subsystem of the Business Layer (see Figure 3). These subsystems are:

1. *User Management Subsystem* (UMS): this subsystem is responsible for user management. In particular, it provides insert, update and delete facilities.
2. *Question Management Subsystem* (QMS): this subsystem manages the question repository of eWorkbook and controls access to it. It is composed of two modules:
   a. *Question Repository Manager*: this module allows the management of the hierarchical structure of the question repository. Each internal node in it is a disciplinary macroarea, while each leaf is a question. This module allows the insertion, update and deletion of a macroarea and/or a question from the repository.
   b. *Access Permission Manager*: this module controls access to the ques-

tion repository. For each node of the question tree it is necessary to specify the owner (i.e., the tutor who authored the macroarea or the question) and a permission set. The owner establishes the value for each field of the permission set.

3. *Test Management Subsystem* (TMS): this subsystem manages the test repository of eWorkbook. To achieve this, we have divided this subsystem into four modules:
    a. *Authoring Manager*: this module permits to create a new test, defining the questions that compose the test and the test execution options. The Authoring Manager also allows the publishing of an existing test in one or more courses;
    b. *Assessment Manager*: this module performs the test evaluation and manages the assessment strategies;
    c. *Execution Manager*: this module manages the test execution. To aim this, the Execution Manager gets a test instance from the Authoring Manager and performs the necessary operation to present it to the user. At the end of the test execution this module passes the control to the Assessment Manager to valuate the test;
    d. *History Manager*: this module manages the history of a learner's performance and a test's execution.
4. *Course Management Subsystem* (*CMS*): this subsystem manages the courses. In particular, it allows the insertion, update and deletion of a course.
5. *Test Logging & Visualization Subsystem (TLVS)*: this subsystem is composed of a *Logging Framework* and a *Log Analyzer*. The former is an already existing OO Java Framework which captures and logs all of the learners interactions with the on-line testing system interface and can be instantiated in any on-line testing system. It is further composed of a client-side, based on AJAX technologies, and a server-side module. The latter is a module that analyzes the logs in order to extract information from them and to graphically represent it.

It is worth noting that all the subsystems described above access to one or more business objects to manipulate information that is stored in the database. The Hibernate framework is used to manage those business objects that accede to the data layer across an appropriate mapping. The target of this mapping is to transform a relational database (stored in the data layer) in a light OO database; in this way it is possible to manage the data exploiting the advantages provided by the OO paradigm.

Data Layer

This layer contains the information stored in a RDBMS. It is worth noting that eWorkbook is not closely bound to a specific RDBMS, but supports much of the most popular RDBMS (i.e., *MySQL* (MySQL, 2005), *Firebird* (Firebird, 2005), etc). All that eWorkbook needs, to be used with a different RDBMS, is the modification of the connection URL in the Hibernate configuration file: the creation and initialization of the DB is an automatic process.

An Example: The English Knowledge Test

eWorkbook was installed on the Web Server of the Faculty and successfully tested for the latest sessions of the *English Knowledge Test*, which is mandatory in our university. In our faculty, the system was used to replace the traditional oral exam with an on-line objective test, more suitable for assessing a huge mass of students.

The test is aimed at evaluating learners' reading comprehension. The syllabus of the exam is composed of twenty passages taken from the textbooks of some ordinary exams. On the day of the exam each learner takes a randomly chosen passage on which his/her test is based. The time to complete the test is 20 minutes, during which the student has to answer 25 questions. A sixty-seat laboratory is available for the exams, an adequate number of users to test the system in a typical academic usage scenario.

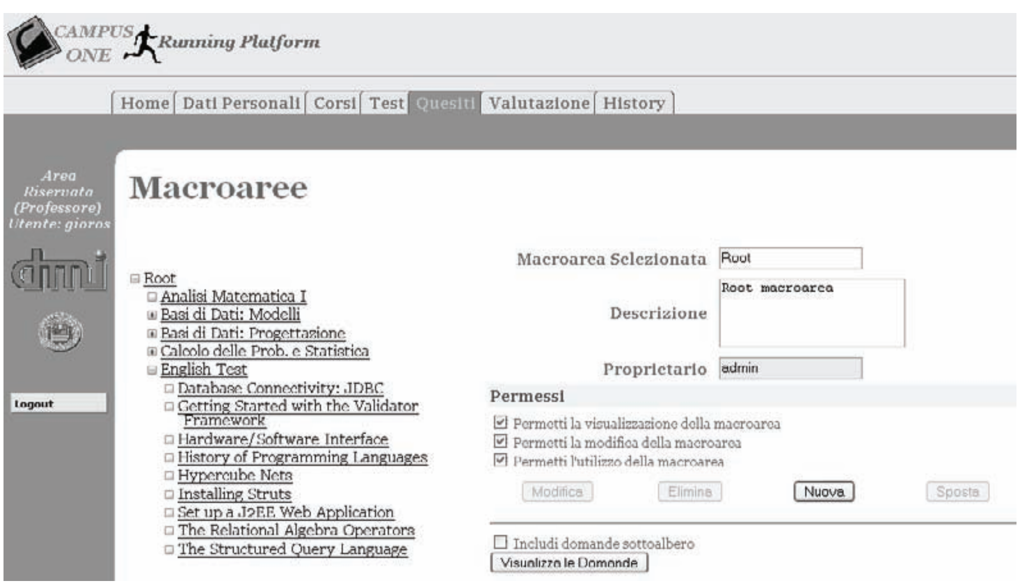
Question and Test Authoring

In eWorkbook, the tutors can edit the question repository through a simple visual Web based interface. This is quite similar to the *my computer* browser program which allows an operating system user to edit the file system structure. As shown in Figure 4, the interface is split in two views: one on the left, which shows the question repository tree, and one on the right, which shows in an HTML form the attributes of the selected item, so that they can be easily changed. Every sub-tree on the left view can be expanded or collapsed using the '+' and '-' image controls close to the macroarea icon. A set of buttons, shown in a proper toolbar, allows the tutor to execute various tasks on the items. Each user can only browse the macroareas on which he has the UsePermission set. If an action is not allowed, the corresponding button is shown greyed.

The insertion of a question in the repository can be done through a wizard interface provided by our system. The wizard consists of a sequence of screens where the tutor must insert the question, its *stem* and *options*, the metadata and some assessment information. The insertion of a question bank is possible too: it is done by importing the question definition, from a text file or an XML text expressed in an *IMS QTI* (IMS QTI, 2005) conformant format.

A new macroarea, named *English Test*, was added to the root of the tree. A new course with the same name was activated as well. In the macroarea *English Test* twenty (one for each passage) sub-macroareas were added. In each of them, several questions were added. All the permissions for the new added macroareas and questions were set.

Figure 4. A Screenshot of the question repository structure



A new test was created for each passage. Every test is composed of three sections. The difficulty is increasing over them: an easy section containing five questions with difficulty between 0 and 0.4; a medium one containing fifteen questions with difficulty between 0.3 and 0.7; a difficult one containing five questions with difficulty between 0.6 and 1. All the tests were added to the valuable list of the *English Test* course, limiting the execution of the tests only to the computers with an IP address in the range of the laboratory in which the exam takes place.

The same test list was also published in the self-assessment section. To encourage the students to get trained, a small part of the questions used for the exam were also used for the self-assessment tests. A screenshot summarizing the test's feature is shown in Figure 5.

Assessment Policy and Test Results

The *WeightedNumberCorrect* assessment strategy has been chosen to evaluate the tests: to the easy, medium and difficult sections have been given, respectively, 25%, 35% and 40% of the total score. The score has been calculated in a /30 scale, with 18 as a passing threshold. So doing, we consider a student as worthy to get the exam if he/she gets all of the easy and the medium questions and just one of the difficult ones.

All the students interested in taking the exam are asked to obtain an account on the system some days before the exam itself. Once the learner takes a test, a timer starts to measure the time he/she spends on that attempt. If he/she hasn't already done it before, he/she must deliver the test as the timer expires. Even the time spent on each question is recorded. Once the test is delivered, a table summarizing test results is shown. Two screenshots of the test execution and some pages of the test pdf format are shown, respectively, in Figure 6 and Figure 7.

At the moment, several exam sessions have been done. The mean pass rate is between 60% and 70% of the students. Some items with poor discrimination have been modified through the

Figure 5. A screenshot of the test details

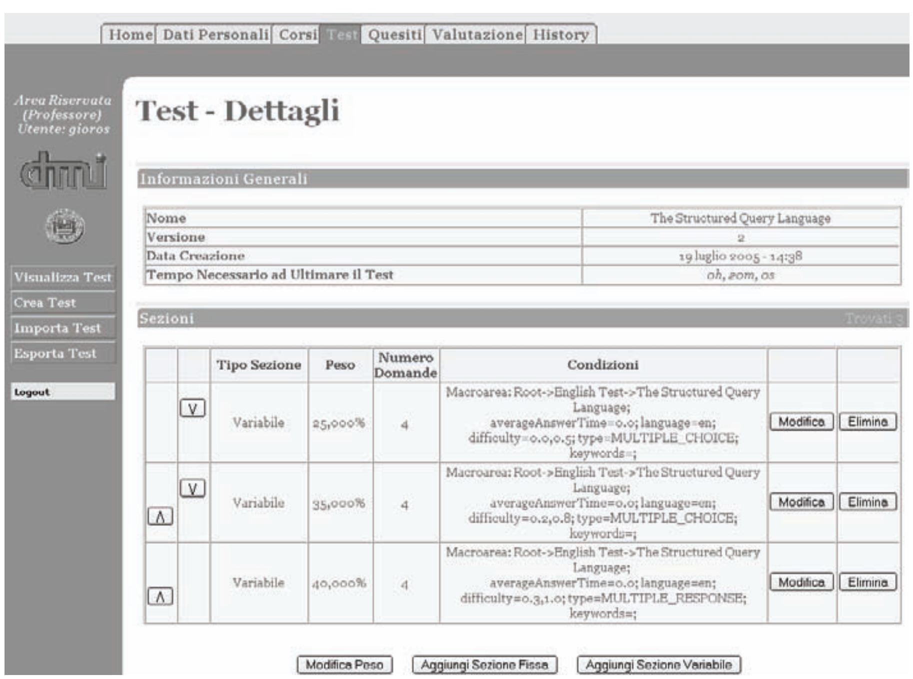


Figure 6. A screenshot of the test execution

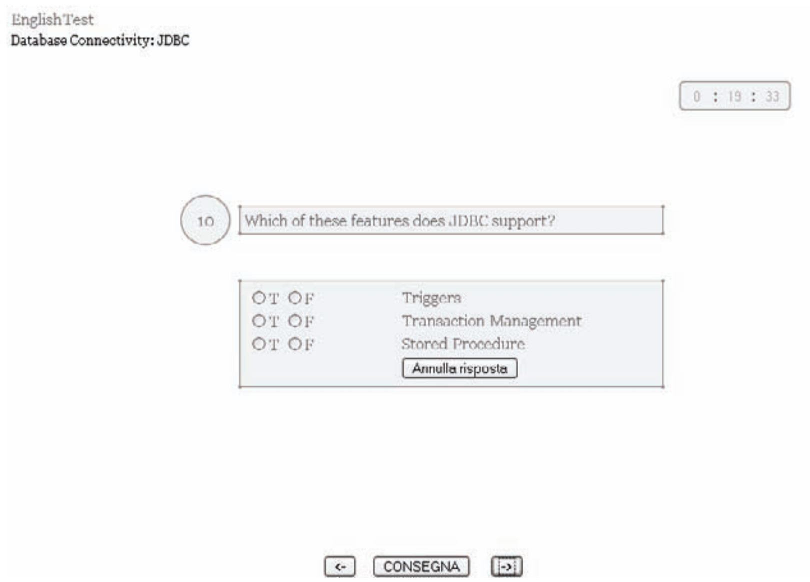
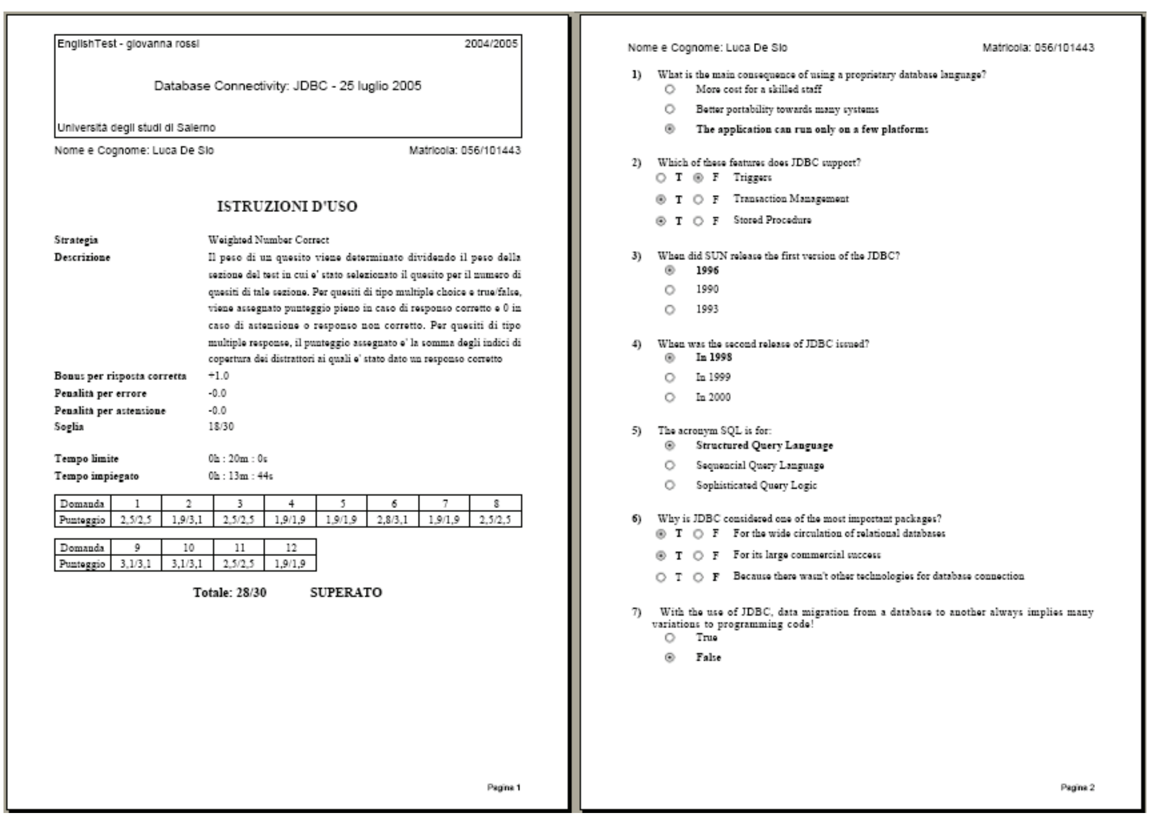


Figure 7. The test PDF format



EnglishTest - giovanna rossi 2004/2005

Database Connectivity: JDBC - 25 luglio 2005

Università degli studi di Salerno

Nome e Cognome: Luca De Sio Matricola: 056/101443

ISTRUZIONI D'USO

Strategia Weighted Number Correct

Descrizione Il peso di un quesito viene determinato dividendo il peso della sezione del test in cui e' stato selezionato il quesito per il numero di quesiti di tale sezione. Per quesiti di tipo multiple choice e true/false, viene assegnato punteggio pieno in caso di responso corretto e 0 in caso di astensione o responso non corretto. Per quesiti di tipo multiple response, il punteggio assegnato e' la somma degli indici di copertura dei distrattori ai quali e' stato dato un responso corretto

Bonus per risposta corretta +1.0

Penalità per errore -0.0

Penalità per astensione -0.0

Soglia 18/30

Tempo limite 0h : 20m : 0s

Tempo impiegato 0h : 13m : 44s

Domanda	1	2	3	4	5	6	7	8
Punteggio	2,5/2,5	1,9/3,1	2,5/2,5	1,9/1,9	1,9/1,9	2,8/3,1	1,9/1,9	2,5/2,5

Domanda	9	10	11	12
Punteggio	3,1/3,1	3,1/3,1	2,5/2,5	1,9/1,9

Totale: 28/30 **SUPERATO**

Pagina 1

Nome e Cognome: Luca De Sio Matricola: 056/101443

1) What is the main consequence of using a proprietary database language?
- More cost for a skilled staff
- Better portability towards many systems
- **The application can run only on a few platforms**

2) Which of these features does JDBC support?
- T F Triggers
- T F Transaction Management
- T F Stored Procedure

3) When did SUN release the first version of the JDBC?
- **1996**
- 1990
- 1993

4) When was the second release of JDBC issued?
- **In 1998**
- In 1999
- In 2000

5) The acronym SQL is for:
- **Structured Query Language**
- Sequencial Query Language
- Sophisticated Query Logic

6) Why is JDBC considered one of the most important packages?
- T F For the wide circulation of relational databases
- T F For its large commercial success
- T F Because there wasn't other technologies for database connection

7) With the use of JDBC, data migration from a database to another always implies many variations to programming code!
- True
- **False**

Pagina 2

sessions. We finally got good discrimination on most of the questions.

Learners' Strategies Analysis

By visually analysing the data of our experiment it came out that the most frequently adopted strategy is *Active Revising*, which was used by 40 learners over 71 (56.5%), followed by the *Passive Revising* strategy (20 learners over 71, 28.2%), and by the *Single Phase* one, used only in 9 cases over 71 (12.7%). Only two learners have adopted an atypical strategy (see Figure 2d), which cannot be classified in any of the previously described patterns.

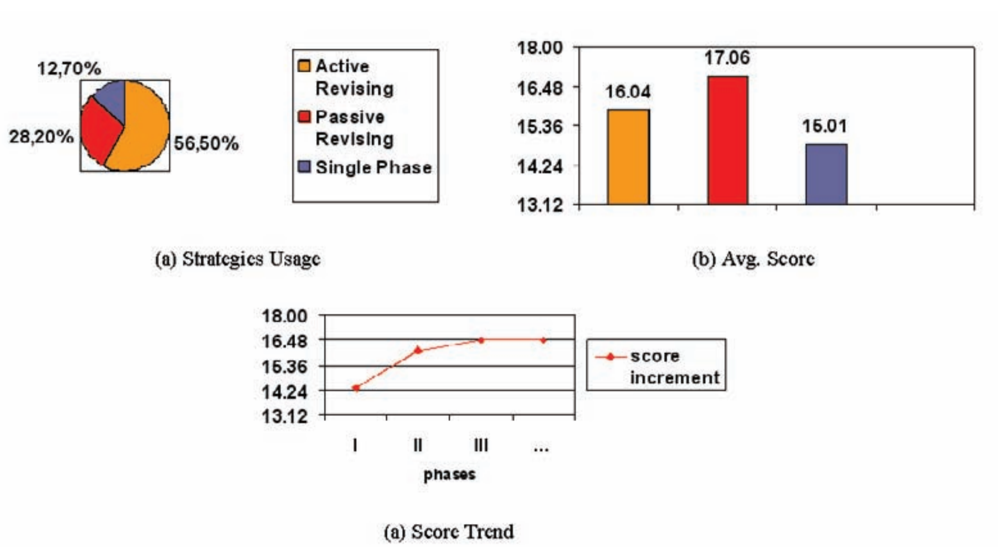
The best results have been achieved by learners who adopted the *Passive Revising* strategy, with an average score of 17.6 exact responses over the 25 test questions. With the *Active Revising*, instead, an average score of 16.4 has been achieved. Lastly, the *Single Phase* strategy turned out to be the worse one, showing an average score of 15.1. Therefore, it appears that a winning strategy is one using more than one phase, and this is confirmed by the slightly positive linear correlation (0.14) observed between the number of phases and the score achieved on the test. For both strategies using more than one phase (*active* and *passive revising*) the score is often improved through the execution of a new phase.

The improvement is evident in the early phases and tends to be negligible in subsequent phases: starting from a value of 14.3 obtained after the first phase, the average score increases to 16.2 after the second phase. The presence of further phases brings the final score to an average value of 16.5. The average duration of the first phase in the *Passive Revising* strategy (14'50") is longer than the one registered for the *Active Revising* strategy (11'51"). This result was predictable, since, by definition, the *Active Revising* strategy prescribes the skipping (= less reasoning) of the questions whose answer is more uncertain for the learners.

Another predictable result, due to the above arguments, is that the *Passive Revising* strategy has less phases than the *Active* one, on average (2.55 and 3.2, respectively).

The above results have been summarized in Figure 8.

Figure 8. Strategies analysis



RELATED WORK

Several different assessment tools and applications to support blended learning have been analyzed, starting from the most common Web-based e-learning platforms such as *WebCT 4.1 Campus Edition* (WebCT, 2005), *Blackboard 6* (Blackboard, 2005), *Click2Learn Aspen 2.0* (Aspen, 2005), *EduSystem* (EduSystem, 2005), and *The Learning Manager 3.2* (The Learning Manager, 2005). The analysis has been carried out both by exercising the systems and by studying literature surveys and benchmark analyses (EduTools, 2005). Special emphasis has been placed on evaluating the existing systems with respect to the requirements identified in the previous section.

In the literature we can find two main categories of assessment systems: those which automatically generate questions from the lecture material, and those which make use of a pre-populated question repository from which questions are chosen randomly. The first kind of systems often requires the prior creation of a knowledge structure, like a concept graph or ontology, as for the system described in (McAlpine, 2005). Other systems of this type (Mitkov, 2003) use Natural Language Parsing to extract information from a text and generate the questions. Using these techniques, it is hard to bet on the good quality or readability of the generated questions. Such drawbacks often relegate the use of this kind of systems only to experimental purposes.

The systems which involve the tutor in the task of creating a set of questions to be stored in a repository prove to be more reliable and consequently are used more for official exams, in order to obtain an objective assessment. Those systems, such as the ones described in (Li & Sambasivam, 2003) and in (Lister & Jerram, 2001), sometimes use an XML test configuration file to define some rules for the question selection. In question repository based systems; the challenge is to give a good organization to the repository, to avoid question replication, and to use a good question selection procedure in order to assess learners' skills on the desired subjects. Some systems, like Claroline (Claroline, 2005) just use a plain container to keep questions. In Moodle (Moodle, 2005) and (Capuano et al., 2003), the question repository is partitioned in sets, often called *categories* or *macroareas*, in order to have a per-subject organization of the questions. In (McGough et al., 2001) and (Gusev & Armenski, 2002) a hierarchically structured organization of the repository is exploited. In (McGough et al., 2001), a tree is associated to a lesson and each of its branches is used for assessing learners on a part of the lesson. A leaf in this tree is a set of questions. In (Gusev & Armenski, 2002) a more complete but complex system is described, where questions are classified exploiting similarities among them.

Only a few systems adopt some kinds of author's right protection. Claroline and Moodle let the tutor choose whether to make his/her questions visible to other tutors or not.

Few systems among the analyzed ones have some forms of quality control of the questions. An interesting feature is the opportunity to judge a question or a test analyzing the learners' responses to it. Starting from this information, many criteria can be adopted. In particular, Hicks (Hicks, 2002), reporting his experience with a large class at the University of Newcastle upon Tyne, identifies a good question as the one to which the better 20% of learners answers well and the worse 20% of learners answers incorrectly. In (Lira et al., 1990) the degree of difficulty of a test is calculated using the maximum possible (max) and minimum possible (min) score and the average score (avg) of the class according to the following formula:

$$((avg - min) / (max - avg)) * 100.$$

eWorkbook has a complete tracking system to judge the quality of a question: every time a significant change is made to a question, a new version of it is generated. For each version of the question, all the history of the learner's answers is kept. From a statistical analysis, explained in detail in section *"Question Quality Improvement Through Question Lifecycle"*, we can guess the quality of the question and its improvement over time. The attempt to judge difficulty and quality of question items is not a new subject. Two main theories are noteworthy: *Item Analysis* and *Item Response Theory* (Hambleton & Swaminathan, 1985). Unfortunately, it is quite uncommon to find an assessment system that uses one of the effectively. Some explanations and a comparison between them can be found in (Fan, 1998).

As for question selection from a large database to compose tests, two algorithms were analyzed: the proposals of (Sun, 2000) and (Hwang et al., 2006).The former is aimed at constructing tests with similar difficulties. The difficulty is calculated using Item Response Theory model. The latter takes into account other parameters too, such as discrimination degree, length of the test time, number of test items and specified distribution of concept weights.

Most of the analyzed systems are complete LMS. The assessment tool is an integral part of them. eWorkbook was thought to be used by the large number of users of our university, so we gave to the didactics an organization in courses and classes, to support multiple channels in which to publish the tests.

As for a means for sequencing and control access to the tests, none of the tools analyzed has a flexible system. The system described in (Li & Sambasivam., 2003) permits the learner to sit an exam many times, until a minimum acceptable score is achieved. In (McGough et al., 2001) the questions are grouped into sets, and the strategy to pass a set, and consequently access to the next, is to give the correct response to 3 answers in a row for that set.

CONCLUSION AND FUTUREWORK

In the paper, we have presented eWorkbook, a system for the creation and deployment of assessment and self-assessment tests. The proposed system can significantly accelerate the assessment process, thanks to the reusability of the authored content. We achieved reusability by allowing the tutors to share their questions with other tutors and by adopting a hierarchical subject-based question repository. Such an organization makes it easier to find, modify and select the questions for the tests. The system is even able to interoperate with other systems that support *IMS QTI* specification. The chance to mix fixed banks of questions with randomly chosen question sections, gives the tutor the chance to get the right compromise between an objective assessment and the sureness to include a wide coverage of subjects. Author's rights are protected through the use of separate permissions for reading, writing and using the questions.

The use of eWorkbook can help tutors in keep high the quality of the assessment, thanks to the Version Control System. This system tells the tutor if the changes he/she make to the questions positively affect the quality of the question. Other feedback information on questions are available too.

Our effort to make the application portable and usable makes it especially suitable for the academic use for which it was conceived, even though it is still a good choice in different environments. The wide choice of assessment strategies and the possibility to extend that choice with new user-defined strategies, help the tutor to tailor the test evaluation to the competency and skill level of the class. The learner can self-assess and fully reap the benefits of blended learning. The definition of access rules, like prerequisites and attempt limitation, compels the learner to follow the right learning path.

The report section is rich with information and fit out of charts and tables. The tutor can have a complete and deep control over the performance of the class and the learners even on a single macroarea, and over the effectiveness of the authored resources. The system lets tutors monitor learners' strategies during on-line tests. The approach exploits data visualization to draw the data characterizing the learner's test strategy, in order to trigger tutor's attention and to let him/her discover previously unknown behavioural patterns of learners. In this way the tutor is provided with a powerful tool that let him/her review the whole assessment process, and evaluate possible improvements.

The system has been used for the English knowledge test by the students and the teachers of our faculty. The testing has shown that teachers, also with very little technical skills, can easily use eWorkbook to create assessment tests thus fully taking advantage of blended learning. Nevertheless, a more accurate evaluation of the effectiveness of the approach is foreseen for the current academic year. Moreover, future work will be devoted to test the scalability of the system with a larger number of simultaneously on-line users. Other interesting developments are planned as future work. Although multiple choice is the most common and widely adopted question type, and it is enough to arrange structured online tests, we are working in order to support other types of questions (e.g. fill-in, matching, performance, sequencing, likert, numeric) and questions based on external tools, like those proposed in (Hicks, 2002). Other efforts will be spent to introduce multimedia elements, like images, video and sound, and rich text capabilities in the rendering of the questions.

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Chapter XIII
Choosing MOODLE:
An Evaluation of Learning Management Systems at Athabasca

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ABSTRACT

Athabasca University—Canada's Open University evaluated learning management systems (LMS) for use by the university. Evaluative criteria were developed in order to ensure that different platforms were tested against weighted criteria representing the needs of the university. Three LMSs (WebCt, LotusNotes, and Moodle) were selected for the evaluation. Moodle was chosen with 11 first place ratings and with only one third place rating. Lotus Notes was second with five first place ratings. Moodle garnered 40% of the total weighted score with Lotus Notes getting 32%, and WebCT 29%. The first place preferences within individual criteria show the following: WebCT 6; LotusNotes 7; and Moodle 58.

INTRODUCTION

At Athabasca University (AU), a learning management system (LMS) committee was struck to report to the Academic Council composed of up to 30 faculty and staff members. The LMS committee discussed strategies for making the transition to a single learning management system as was identified in the AU Strategic University Plan (SUP) (Athabasca University, 2002 #1). In the AU SUP developed in 2002, the university community decided that the future development of the university's learning systems required the adoption of a single learning management system. Three LMSs were proposed for evaluation, *WebCT*, *Lotus Notes,* and *Moodle*. *WebCT* was being used by faculty in the Centre for Nursing and Health Studies and in the Master of Distance Education programs. *Lotus Notes* was being used in two different formats, by the School of Business and the Centre for Innovation and Management. Another LMS, *Bazaar*, which was developed at AU and was being used by smaller groups in the Master of Arts in Integrated Studies program, was not considered, as it did not garner significant support for continuation among faculty.

The final evaluation of these LMSs was conducted through a rating system. This rating system was based on different criteria, including the university's mandate as an open distance learning institution, systems administration, initial and ongoing costs, instructional design features, and the teaching and learning tools available.

Mandate

The chosen LMS would need to accommodate the unique nature of AU's mandate as an open distance education institution. In choosing an LMS, the evaluation committee members considered the need for:

- Flexibility in start and end dates for students enrolling in courses
- Support for paced and individualized study courses
- Affordability for students
- Accessibility for students with disabilities
- Access at different connection speeds (dial-up vs. high speed)

Systems Administration

Systems administration features had to facilitate:

- Integration with current registration procedures
- Single sign on capabilities and compatibility with current authentication systems
- Flexible administration across centres and programs
- Secure access, authorization, and virus protection
- Interoperability using SCORM, IEEE LOM, and CanCore

Cost

The price tag for the system chosen was an important consideration, and included:

- Licensing fees
- Hardware and software costs
- Costs related to integration with the Banner registration system
- Cost of ongoing support (external and in-house)
- Staff training costs

Instructional Design

Most of the criteria listed under this category in the Appendices tables are self explanatory. Some require further explanation:

- *Granularity* refers to the LMS's capacity to separate content from presentation so that the content can be reused or redirected, accommodating content delivery on a variety of devices, including mobile devices and sharing learning objects across courses.
- *Templates and modularization* refers to the LMS's capacity for customizing the

look and feel of different AU Centres and programs.

- *Student Experience* refers to the intuitive logical layout in the LMS from the students' point of view, if it supports standard Web browsing, multiple platforms, systems, low bandwidth, and Java.

Teaching and Learning Tools

Criteria in this table are self-explanatory. For example, researchers evaluated whether or not the LMS had a workable assignment drop box, or whether or not it could accommodate XML and mobile device delivery. The testers also determined if the LMS had course authoring tools to create effective online quizzes or could display correct mathematical notation. Please see the tables in the Appendix for a complete list of criteria.

Methodology

Fourteen individual survey forms and two written submissions were used in the evaluation. Most of the forms were completed in their entirety, while some evaluators only completed the sections they felt comfortable with. Forms were sent out to all faculty who expressed an interest in the evaluation process, and 17 completed forms were returned

Data was submitted for evaluation using a standard Excel spreadsheet. The spreadsheet allowed the evaluator to enter a priority value, which was used to weight the rating for each criterion. The spreadsheet was used to total the computed values for each submission in a summary table. In cases where a zero was entered, this was removed. In all cases, an evaluation had to rate the three platforms for each criterion. If all three were not evaluated, a value of zero was given for that particular criterion.

In order to ensure that the evaluations were rated on a consistent weighting scale, the submissions were averaged. This was done by taking the values from each evaluator's priority column and placing them into the criteria weighting average table. A mean average value was then computed for each criterion labeled the average weighting index (AWE). This AWE was applied to each evaluator's individual platform rating scores, removing the potential for bias to the rating scores from a consistently high weighting by any particular evaluator. It further allows a determination of the criteria that are considered most important to the decision.

The AWE was placed into the Criteria Totals sheet in the formerly labeled priority column. The values for each criterion rating under each platform were compiled as a summation of all the rating values submitted by the evaluators.

1. The summed value was multiplied by the AWE to yield a weighted score for each criterion under each platform.
2. These weighted scores were then added up in their respective categories to give the total category weighted score for the respective platform.
3. The category scores were then added up to yield a total platform weighted score.

RESULTS

The LMS Place Preference table shows the evaluators' choices either from their numeric or their written submissions. The overwhelming choice was Moodle with 11 first place ratings and with only one third place rating from any of the evaluators. Lotus Notes was second with five first place ratings.

The criteria totals table presents the final results. Reflecting the place preferences, Moodle is clearly the group's preferred choice. Moodle garnered 40% of the total weighted score, with Lotus Notes getting 32% and WebCT 29%. The first place preferences within individual criteria show the following:

WebCT	Notes	Moodle
6	7	58

CONCLUSION

Moodle has been selected by the group as the best choice for AU with a clear and unambiguous majority. It should be noted, however, that the characteristics of the testing group are nonrandom. Not all of the constituencies were equally represented and some, in fact, were over represented. Although, as a group, the sample of testers may be technologically adroit, they also bring biases and preferences to the testing arena, as a result of their background, that are likely reflected in the data. This may in-part explain some surprises in relation to individual criteria ratings. Nonetheless, the strength of preference of the committee for Moodle would indicate that such biases did not determine the final evaluation results and that a broad consensus was reached with regard to the selection of Moodle.

Moodle Next Steps

In order for Moodle to be implemented effectively at AU, it ought to be introduced within a controlled and coherent framework. An operating team should be established and charged with the development and implementation of a plan to commission and operate Moodle. Moodle will affect a broad range of university groups:

- Students
- Help-desk analysts/Call Centre analysts
- Tutors/coaches
- Course coordinators
- Course administrators
- Faculty
- Course producers
- Course designers
- Course materials providers
- Instructional designers
- System administration
- ITS infrastructural administration

There are also a significant number of tasks to be completed:

Commissioning
- Security
- System availability
- Authentication
- Version control
- System architecture
- Application configuration

Conversion
- Existing online courses
- Existing off-line courses

Training
- Tutors
- Help desk
- Faculty
- Designers
- System administrators

Presentation Framework
- Interface design
- Customising
- Templates
- Accessibility standards

Human Resources
- Training
- Workload assignments

Communication
1. Reporting
2. Informing

Research and Development

1. Test environment
2. Piloting methodology
3. Test procedures
4. Programming standards
5. Commissioning and upgrade procedures

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Western Consortium for Educational Technology (WCET) LMS Comparison Web site. Retrieved March 8, 2007, from http://www.edutools.info/course/compare/compare.jsp?product=142,176,235

Web Sites about Moodle

A list of articles about Moodle:

http://moodle.org/mod/resource/view.php?id=102/
Humboldt State University Web site Moodle introduction:
http://learn.humboldt.edu/login/index.php
A Blackboard Moodle comparison:
http://www.humboldt.edu/~jdv1/moodle/all.htm
Lotus
Basic corporate page:
http://www-306.ibm.com/software/lotus/
School of Business demo page:
http://sb.athabascau.ca/course/demo.nsf

Webct Vista
(Note, at Au, we currently use the ce version)

Main corporate Web page:
http://www.webct.com/

APPENDIX A. LMS Evaluation Provisional Results

RESULTS

For presentation purposes, the identity of the evaluators as it relates to the weighting index have not been included. The development of the average weighting index (AWE) was an open and collaborative exercise allowing transparency in developing a metric for determining the university's needs as they relate to an LMS. Individual criteria rating preferences have been withheld, as they are believed to be representations of a personal viewpoint and are private to each evaluator.

The LMS place preference table shows the choices of the evaluators either from their numeric or their written submissions. The overwhelming choice of the evaluators was Moodle, with 11 first places and never lower than a second place rating from any of the evaluators. Lotus Notes was second with five first places.

The criteria weighting average table shows the calculation of the AWE. As stated above, the AWE is a mean average of all the submitted values for each criterion. The AWE values are in bold, while values of 9 and above have also been highlighted, indicating the criteria of most concern to the group. The high proportion of 9 values in the Systems Administration and Mandate indicate common views on the importance of these criteria. The lower AWE values in the Instructional Design and the Teaching and Learning demonstrate a broader range of opinion on the value of each of the criteria.

The potential weight figure is the maximum value the category could obtain if all categories were valued at 10. This is to indicate the relative importance the survey form gives to each category. The actual weight for the category is the realized weighted value for the category after the evaluator's submissions. The highest actual potential was the Mandate, while Teaching and Learning and Instructional Design were the two lowest.

The criteria totals table presents the final results. The values under each platform have been calculated as stated above. Reflecting the place preferences, Moodle is clearly the preferred choice of the group. Moodle garnered 40% of the total weighted score, with Lotus Notes getting 32% and WebCT 29%.

The first place preferences within individual criteria show the following:

WebCT	Notes	Moodle
6	7	59

Moodle was overwhelmingly seen to provide the best fit for these.

The percentage value to the right of the total weighted score column represents the final proportion of the weighted ratings that were attributed to the respective category. For example, 6% of all scores were attributed to the Mandate category. This can be taken to mean that of the total consideration given to the acceptance of a new LMS, 6% was based on our mandate. Given this, the 41% attributed to teaching and learning would seem appropriate, as it represents the highest category on which the evaluation is based.

The percentage values to the right of each of the LMS totals shows the proportion of the total weighted score gained by the respective platform. Thus, Moodle attained 44% of all scores for the Mandate category. Moodle achieved a higher share in all categories, resulting in a total of 40% of the total weighted scores. Interestingly, the lowest value for Moodle was 37% in the Teaching and Learning category. This may again reflect the divergence of opinion on requirements and capabilities within this category.

DECISION

Moodle has been selected by the group with a clear and unambiguous majority. It has apparently been seen to offer the best choice among the three options. While there are some surprises in relation to individual criteria ratings, there can be little doubt that there is a consensus in regard to the selection of Moodle.

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Chapter XIV
Enhancing the IMS QTI to Better Support Computer Assisted Marking

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ABSTRACT

Computer aided assessment is a common approach used by educational institutions. The benefits range into the design of teaching, learning, and instructional materials. While some such systems implement fully automated marking for multiple choice questions and fill-in-the-blanks, they are insufficient when human critiquing is required. Current systems developed in isolation have little regard to scalability and interoperability between courses, computer platforms, and learning management systems. The IMS Global Learning Consortium's open specifications for interoperable learning technology lack functionality to make it useful for computer assisted marking. This article presents an enhanced set of these standards to address the issue.

INTRODUCTION

Computer aided assessment (CAA), one of the recent trends in education technology, has become common-place in educational institutions as part of delivering course materials, particularly for large classes. This has been driven by many factors, such as:

- The need to reduce educational staff workloads (Dalziel, 2000; Jacobsen & Kremer, 2000; Jefferies, Constable et al., 2000; Pain & Heron, 2003; Peat, Franklin et al., 2001);

- A push for more timely feedback to students (Dalziel, 2001; Jefferies, Constable et al., 2000; Merat & Chung, 1997; Sheard & Carbone, 2000; Woit & Mason, 2000);
- Reduction in educational material development and delivery costs (Jefferies, Constable et al., 2000; Muldner & Currie, 1999); and,
- The proliferation of online education (White, 2000).

Internet-based technologies in CAA can be broadly categorised into the following system types: online quiz systems, fully automated marking, and semiautomated/computer assisted marking systems. The most common form of CAA, online quizzes, typically consist of multiple choice questions (MCQ) (IMS, 2000), as they can be automatically marked. Yet, there is much conjecture on the effectiveness of MCQs, particularly in the assessment of Bloom's higher learning outcomes (1956) such as analysis, synthesis, and evaluation (Davies, 2001). This limits the scope by which a student's abilities can be assessed. Short response and essay type questions are commonly used to assess the higher order skills of Bloom's taxonomy. Still, these types of assessments are time consuming to mark manually (Davies, 2001; White, 2000).

A more ambitious approach to CAA involves the use of fully-automated marking systems. These can be defined as systems that can mark electronically submitted assignments such as essays (Palmer, Williams et al., 2002) via online assignment submission management (OASM) (Benford, Burke et al., 1994; Darbyshire, 2000; Gayo, Gil et al., 2003; Huizinga, 2001; Jones & Behrens, 2003; Jones & Jamieson, 1997; Mason & Woit, 1999; Roantree & Keyes, 1998; Thomas, 2000; Trivedi, Kar et al., 2003), and automatically generate a final grade for the assignment with little to no interaction with a human marker. The obvious benefit to this approach is the ability to assess some higher order thinking as per Bloom's Taxonomy (1956) in a completely automated manner, thus improving marking turn-around times for large classes. Fully automated systems include MEAGER, which is designed to automatically mark Microsoft Excel spreadsheets (Hill, 2003), automatic essay marking systems, such as those evaluated by Palmer, Williams et al. (2002), and English and Siviter's system (2000) designed to assess student hypertext mark-up language (HTML) Web pages, to name a few. Unfortunately, this approach is not suitable for all assessment types and can often require significant time to develop the model solution. In addition, most of the automated functionality examines students' solutions against model solutions. This may lead to issues relating to marking quality when it is impossible for the assessment creator to identify all possible solutions.

The last approach is the use of semiautomated or computer assisted marking (CAM). This is a compromise between online quiz and fully automated systems. CAM assists with the reduction of poor marker consistency and the quantity and quality of feedback in marking team situations. By using CAM, many of the laborious and repetitive tasks associated with marking can be automated (Baillie-de Byl, 2004), resulting in more timely returns to students. CAM describes systems that have some components of the marking process automated, but still require at least some human interpretation and analysis to assign grades. For example, CAM systems have been developed to support the routine tasks associated with marking programming assignments, like compilation and testing of student submitted programs (Jackson, 2000; Joy & Luck, 1998). Although allocation of a final grade is the sole responsibility of the marker, this determination can be achieved faster, with greater accuracy and consistency, by relying on the results of automated tests (Joy & Luck, 1998). In cases where human interpretation and analysis occurs, this is referred to as manual marking.

One example of CAM is implemented in the Classmate system. It is designed to assist in automating many of the typical laborious tasks associated with marking, such as retrieval and presentation of submissions, feedback and grade storage, application of late penalties, and student returns (Baillie-de Byl, 2004). Other contributions in this area include an MS-Word Integrated CAM Template (Price & Petre, 1997), development of a CAM prototype based on research into how markers rate programming assignments (Preston & Shackleford, 1999), and Markin, a commercial CAM product by Creative Technology (Creative-Technology, 2005).

One of the major problems with current CAM systems is that much of the work is being undertaken by independent or small groups of researchers who are developing systems to service the particular needs of their courses and institutions, without regard for interoperability. The IMS global learning consortium (IMS, 2005) are addressing this problem through the production of open specifications for interoperable learning technology, and have developed a well adopted specification (IMS, 2004). The IMS question & test interoperability (QTI) specification provides an interoperable standard for describing questions and tests using extensible mark-up language[1] (XML) (IMS, 2000). The QTI specification is broken down into multiple subspecifications. Two of significance to the research herein are the *assessment, sections and items* (ASI) and the *results reporting* (RR) bindings. The ASI binding is used to describe the materials presented to the student, such as which questions, called *items*, form part of an assessment, how they are marked, how scores are aggregated, and so forth. The RR binding is responsible for describing students' results following completion of the marking process.

A major focus of the design for the QTI to date has been to support the interoperability of online quiz systems. These systems are typically fully automated and require little human intervention. Thus, the QTI lacks specific functionality for online systems providing student assessment that relies heavily on human intervention and critiquing. By enhancing the IMS QTI specification to better support CAM, tools can become interoperable, such that assessment materials can be exchanged between CAM systems in the same way as quiz question banks can between online quiz systems. The research presented in this paper introduces the QTICAM specification addressing the shortcomings of the IMS QTI in support of CAM.

QTIC Computer Assisted Marking Specification

The QTI Computer Assisted Marking (QTICAM) specification has been designed as an extension to the IMS QTI to address the lack of support for human intervention and critiquing. Its architecture ensures it remains backward compatible with the existing QTI specification. This ensures existing QTI XML documents can be validated against QTICAM. Furthermore, the QTICAM specification allows a mixture of automatic and manually marked items within the same assessment. The QTICAM provides improvements to both the ASI binding and RR binding as outlined in the following sections. A more complete description for the IMS QTI ASI (IMS, 2002a), and the IMS QTI RR (IMS, 2002b) can be accessed from the IMS Web site (http://www.imsglobal.org).

Mark Increments

The QTI provides scoring variables to track the marks associated with an assessment question. These scoring variables can be aggregated in various ways to derive a total score for the students' work. For example, the XML:

```
<decvar varname="SCORE"
    vartype="Integer"
    minvalue="0"
    maxvalue="10">
```

declares a variable with <decvar>[2] called SCORE to store a result. In this case, the result is restricted to a whole number (decimal) between and inclusive of the values 0 and 10.

This current format, while dictating some boundaries for a marker, does not restrict the marker from using their own part-marking scheme between the minimum and maximum values. The QTICAM provides the increment attribute to address this issue. For example, if the previous result should only be marked in increments of 2, the XML would be:

```
<decvar varname="SCORE"
    vartype="Integer"
    minvalue="0"
    maxvalue="10"
    increment="2">
```

This enhancement provides two advantages. Firstly, it improves the consistency in marks within a marking team, ensuring the markers adhere to the scoring criteria, and secondly, it provides clearer instructions to an electronic marking tool as to what values it can allow as legal scores for a particular question.

Manual Marker Rubrics

In addition to expressing the response processing of an item in machine terms, the QTICAM also supports response processing for human interpretation via a marking rubric. The <interpretvar>[3] element structure from the QTI ASI has been reused to describe such marking rubrics within the QTICAM ASI. For each <interpretvar> element, there is a matching scoring variable. The scoring variable is used to track the performance of the student against its rubric within the <interpretvar> element. There are no facilities for recording rubrics within the QTI RR for the marker. Therefore, an <interpretscore> element has been included in the QTICAM RR binding. This is demonstrated in Listing 1, along with its scoring variable SCORE.

The contents of the <interpretscore> element structure are derived from the <interpretvar> element of the ASI binding. The varname attribute defines the scoring variable SCORE with which the <interpretscore> rubric is associated. This is illustrated at the bottom of Listing 1 using the <score>[4] element, highlighted in bold. The example is a marking rubric for an IT-related short response question. Students are asked to briefly compare flat and hierarchical directory structures provided by network operating systems.

Recording the Marker

Typically, the QTI is used to describe objective tests that will be marked by computer. With manual marking, it is necessary to record the identity of the marker for quality control. The allocation of student assessments among a group of markers can vary. For example, assessments can be allocated by student or by individual questions. The QTICAM therefore requires the ability to record the marker of each individual item. Thus, using QTICAM RR XML achieves this:

```
<manualscorer>
 <name>Damien Clark</name>
 <generic_identi. er>
  <identifier_string>clarkd</identifier_string>
 </generic_identifier>
</manualscorer>
```

The <manualscorer> element content reuses the existing <name>, <generic_identifier>, and <identifier_string> elements of the QTI RR specification, which are currently used to describe the student. If an item has not yet been marked, there will be no <manualscorer> element structure, or its contents will be empty.

Currently, the QTICAM does not support the recording of multiple markers. Such an instance might occur in a peer revision process where several markers are assigned the task of providing a score for the same item. The authors recognise

Listing 1. Manual marker Rubric (QTICAM RR)

```
<interpretscore varname="SCORE">
 <material label="solution">
  <matemtext>
   A hierarchical directory structure is considered superior for enterprise
   networking.
  </matemtext>
  <matbreak/>
  <matemtext>
   A flat directory structure is slower and less efficient than a hierarchical
   directory structure.
  </matemtext>
  <matbreak/>
  <matemtext>
   It is much harder to find things in a flat directory structure than in a
   hierarchical directory structure.
  </matemtext>
 </material>
 <material>
  <mattext>
   One mark is allocated for each point above that the student has in their answer.
  </mattext>
 </material>
</interpretscore>
...
<outcomes>
 <score varname="score   ">
  <score_value>0</score_value>
  <score_increment>1</score_increment>
  <score_min>0</score_min>
  <score_max>3</score_max>
 </score>
</outcomes>
```

the need for this feature and expect to implement it in future revisions.

Recording Marker Feedback and Marks

The QTI RR binding provides support for the <feedback_displayed> element structure which identifies feedback already displayed to the student, as a result of automated marking. This feedback is fixed and prescribed in the ASI XML when the item is conceived. This further illustrates the focus of the QTI on automated marking systems. It is not possible for the item author to foresee all potential errors made by students, and therefore it is necessary to provide support for feedback not prescribed within the item definition (QTI ASI). To support this function, QTICAM includes the <manualfeedback> container element. All feedback and marks are stored within this structure, as demonstrated in Listing 2.

Within <manualfeedback> are <scorefeedback> elements. Each <scorefeedback> can contain a feedback comment (<comment>), a mark (<score_value>) or both. Each <scorefeedback> is associated one-to-one with a scoring variable through the varname attribute. This provides an import linkage. It allows a comment or mark to be associated with a specific rubric (<interpretscore>). Furthermore, each <scorefeedback> is also uniquely identified within the scope of

Listing 2. Recording marker feedback and marks (QTICAM RR)

```
<manualfeedback>
 <scorefeedback varname="SCORE" ident="1">
  <score_value>0.5</score_value>
 </scorefeedback>
 <scorefeedback varname="SCORE" ident="2">
  <score_value>0.5</score_value>
 </scorefeedback>
 <scorefeedback varname="SCORE" ident="3">
  <score_value>0.5</score_value>
 </scorefeedback>
 <scorefeedback varname="SCORE" ident="4">
  <score_value>1</score_value>
 </scorefeedback>
 <scorefeedback varname="SCORE" ident="5">
  <score_value>0.5</score_value>
 </scorefeedback>
 <scorefeedback varname="SCORE" ident="6">
  <comment>
   One output line transmits the data and the other transmits the complement of the
   signal.
  </comment>
  <score_value>0.5</score_value>
 </scorefeedback>
 <scorefeedback ident="7">
  <comment>
   Refer to the model solution for other factors you have not considered.
  </comment>
 </scorefeedback>
</manualfeedback>
```

the item through the ident attribute. The ability to uniquely identify each comment or mark is described in the following section.

Linking Feedback and Marks to the Student Response

Feedback on student assessment is an important element of the learning process (Dalziel, 2001). A novel approach to improving feedback presentation in CAM systems was investigated by Mason, Woit et al. (1999) where feedback is provided in-context of the students' submission, rather than summarised at the end. This is equivalent to the way a marker would assess a paper-based submission, providing comments and marks in proximity of the passages being addressed. This is achieved in the QTICAM, as illustrated in Listing 3.

The solution provided by the student already stored within the QTI RR <response_value> element is copied verbatim into the <taggedresponse> element. Next, passages of the student's response are tagged with the <tagresponse> element. Recall from Listing 2 each <scorefeedback> element had an ident attribute. Listing 3 shows the linkage of this ident attribute with the <tagresponse> element's ident attribute. This linkage is how a comment or mark is associated in-context with the student's response. Therefore, the comment:

One output line transmits the data and the other transmits the complement of the signal

Listing 3. In-context feedback of a student's response (QTICAM RR)

```
<taggedresponses>
<!--The taggedresponse is the same as response_value (below) except tagresponse elements tag parts of
it. These will be highlighted in some way when presented back to the candidate, and the feedback assigned
will be shown (perhaps through mouseover or in another window)-->
 <taggedresponse ident_ref="CommQ2"><tagresponse ident="1">RS-232 has a slow data rate of 19.6
kbps.</tagresponse>
<tagresponse ident="2">It is also only capable of distances up to 15 metres.</tagresponse>
<tagresponse ident="3">RS-422a is capable of much faster transfers.</tagresponse>
<tagresponse ident="4">RS-232 is unbalanced, while RS-422a is balanced.</tagresponse>
<tagresponse ident="5">RS-232 has one signal wire</tagresponse>, <tagresponse ident="6">while RS-
422a has two data output lines.</tagresponse>
<tagresponse ident="7"/>
 </taggedresponse>
</taggedresponses>
```

from Listing 2 is associated with the student passage

```
while RS-422a has two data output lines
```

from Listing 3.

This <taggedresponse> feedback can be presented to the student in various ways. For example, if presented in a Web-browser, the material within a <tagresponse> element could be a hyperlink to a popup window which displays the comment or mark. Alternately, a mouseover javascript event could present the comment or mark when the student places their mouse over the <tagresponse> area. If the feedback is to be printed, the comments or marks could be placed at the start or end of the underlined <tagresponse> material. How the material is presented is up to the implementer. The QTICAM ensures comments or marks are provided in-context of the student's solution.

Recording Question Content Presented to the Student

The QTI RR binding does not include support for recording the question material that was presented to the student in completion of an item. To support the manual marking process, it is advantageous for the marker to see exactly what was presented to the student. This provides complete context for the student's solution. Furthermore, it is also necessary where parameterised questions are implemented (Clark, 2004). The QTICAM RR binding provides the <material_presented> element. This element should contain all the material that was presented to the student when they attempted the question, in HTML format. An example of the <material_presented> element looks like:

```
<material_presented>
 <![CDATA[
        <p>In your own words briefly compare flat and hierarchical
directory structures provided by NOS.</p>
 ]]>
</material_presented>
```

Use of a CDATA[5] node is recommended to quote all HTML elements within the <material_ presented> element as illustrated. This material can be presented to the marker when marking the students' solutions.

Recording a Model Solution for an Item

The QTI RR binding provides support for recording the solution to an item through the <correct_response> element. This element is designed to identify a selectable choice or a model answer. Unfortunately, this element provides for only a textual value with no formatting. To improve readability for the manual marker, the <solutionmaterial> element is provided in the QTICAM RR binding. The <solutionmaterial> element is illustrated in Listing 4.

The <solutionmaterial> element incorporates the <material>[6] element used throughout the QTI specification to provide basic formatting of material for presentation. This allows the question author to provide a model solution to an item with basic formatting. The solution shown in Listing 4 is for a C programming item.

QTICAM Implementation

The design of the QTICAM is implementation independent, meaning it does not constrain or dictate how a CAM tool should be implemented. It provides the supporting data model of how material from a testing system should be exchanged for marking. Therefore, an implementation of QTICAM could be written in various languages such as Java, Perl, or C++. Furthermore, a CAM tool could be implemented as an online or off-line application. For example, an online marking tool would maintain a connection with a network server and exchange QTICAM XML as required during marking. In an off-line environment, the marking tool would download large batches of QTICAM XML assessments. This could then be taken off-line during the marking process. Off-line implementation is of particular benefit to those with poor bandwidth such as analogue modem users, or for those with a roaming laptop. Alternately, a hybrid approach could be implemented where the marking tool supports both online and off-line operation.

The following section introduces the computer assisted marking prototype (CAMP), which demonstrates the use of the QTICAM specification.

Listing 4. Record of the model solution for an item (QTICAM RR binding)

```
<solutionmaterial>
 <material label="solution">
  <mattext texttype="text/html" xml:space="preserve"><![CDATA[
<pre>
void replaceAll(char *aString, char *c1, char c2)
{
 char *ptr;
 ptr = aString;

 while(*ptr != '\0')
 {
  if (*ptr = c1)
   *ptr = *c2;
 }
}
</pre>
]]></mattext>
 </material>
</solutionmaterial>
```

CAMP: PROTOTYPE MARKING TOOL

To demonstrate the QTICAM specification at work, the CAMP system has been developed. CAMP is a CAM tool implemented in Java. It is currently a prototype and not yet optimised for complete usability. However, it demonstrates the features of the QTICAM specification. CAMP makes use of the XML document object model (DOM) application programming interface (API)[7] to manipulate the QTICAM RR XML containing the material that is to be marked. It can load multiple RR XML files, which it stores in memory. As an item is marked, the changes are kept in memory. Once the marker clicks the *save* button, moves onto another item, or otherwise closes the application down, the changes in memory are written to their respective XML file.

The CAMP tool supports the following functions:

- The ability to open multiple QTICAM RR XML documents and display a hierarchical tree structure, which summarises all items broken down into sections and student assessments.
- For each item loaded, it displays:
    - the material presented to the student;
    - the student's submission/s;
    - an optional model solution;
    - all the marking rubrics;
    - the student score for the item;
    - the student score for the assessment; and
    - the student and marker's names.
- The ability for the marker to tag passages of the student's solution and attach feedback with a comment or mark.
- The modification of the comments and marks by clicking on an existing tagged passage.
- The deletion of existing comments and marks by clicking on an existing tagged passage.
- The saving of changes back to the XML file during the marking process.
- The flagging of an item as marked when marking is complete.

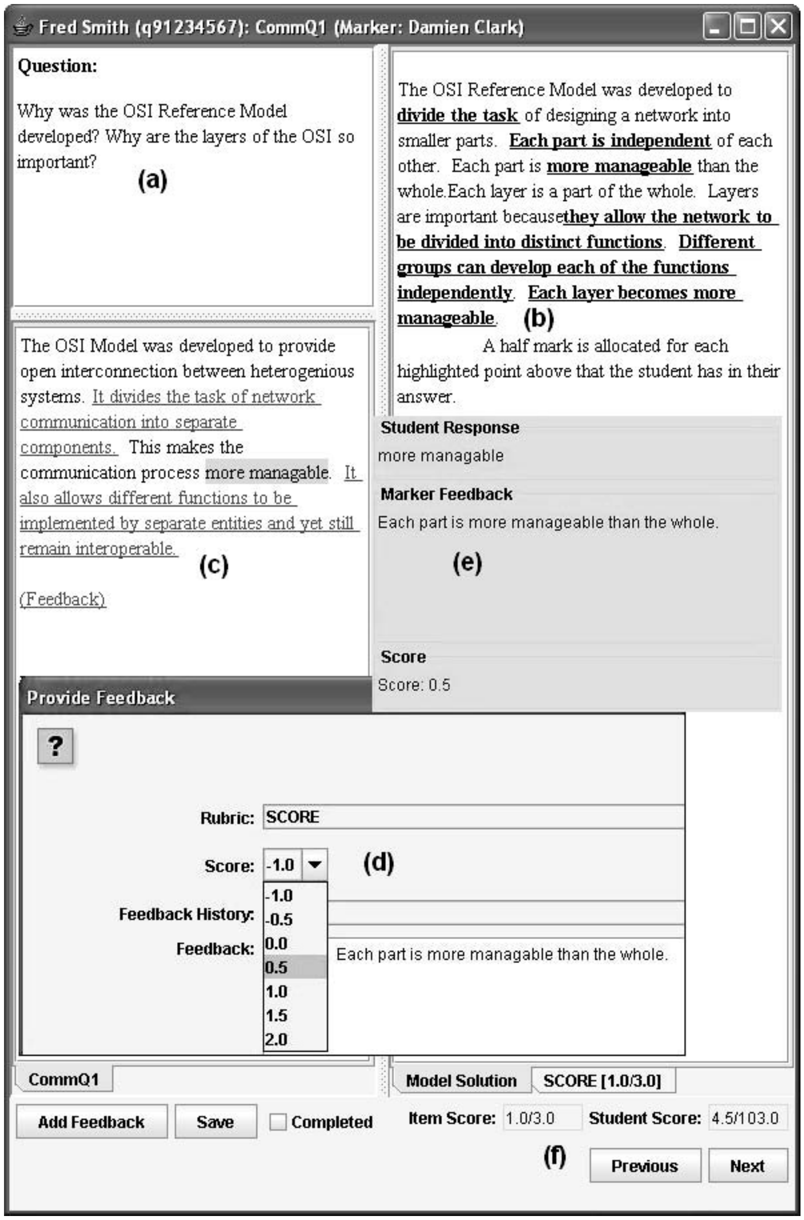
Automatic aggregation of marks is supported, totaling scoring variables for rubrics and item, section and assessment scores. Figure 1 illustrates the process of assigning feedback to a student's solution using CAMP.

This figure highlights the functionality provided by the QTICAM: (a) the assessment question; (b) the marking rubric; (c) the student's assessable answer where the marker has highlighted the passage more manageable for feedback, before clicking the Add Feedback button to present the feedback dialog (d). The dialog allows the marker to assign only a legitimate mark (0.5) within the bounds for the item and a comment: *Each part is more manageable than the whole*. Placing the mouse over the tagged passage more managable in (c) will display (e), a popup window showing the recorded feedback for that passage; and (f) The total score of the item and Fred Smith's assessment score before the 0.5 mark was assigned.

To elaborate futher, Figure 1 shows that the marker has highlighted the passage more managable from the student's solution. To open the dialog box shown in Figure 1(d), the marker clicks the *Add Feedback* button. This dialog allows the marker to select the rubric to which their comment or mark is associated. On selecting the required rubric, the marker can only enter a mark that meets the constraints of the rubric. For example, the marker cannot assign a mark that would push the total for the rubric beyond its upper or lower limits defined in the QTICAM. In this case, the rubric score has been specified with:

```
<decvar varname="SCORE"
    vartype="Decimal"
    minvalue="0"
    maxvalue="3"
    increment="0.5">
```

Figure 1. CAMP: Selecting passage for feedback



It restricts the assigned mark to values between 0 and 3 with increments of 0.5. This improves consistency in the marking and makes it quicker for the marker to select a mark. The dialog also contains a list of comments (*Feedback History*) made previously by this marker for the same item answered by other students. This helps with consistency in feedback and efficiency in allowing the marker to reuse comments. On selecting a comment from the dropdown list, it is placed in the *Feedback* text area at the bottom of the dialog. The marker can choose to customise the comment if they wish. Alternately, the marker can create a new comment by typing directly into this empty text area.

Listing 5. QTICAM RR XML: Changes to XML after adding feedback

```
<taggedresponses>
 <taggedresponse ident_ref="CommQ1">The OSI Model was developed to provide open interconnection between heterogeneous systems. <tagresponse ident="1">It divides the task of network communication into separate components.</tagresponse> This makes the communication process <tagresponse ident="2">more managable</tagresponse>. <tagresponse ident="3">It also allows different functions to be implemented by separate entities and yet still remain interoperable.</tagresponse>

<tagresponse ident="4"/>
 </taggedresponse>
</taggedresponses>
<manualfeedback>
 <scorefeedback ident="1" varname="SCORE">
  <score_value>0.5</score_value>
 </scorefeedback>
 <scorefeedback ident="3" varname="SCORE">
  <score_value>0.5</score_value>
 </scorefeedback>
 <scorefeedback ident="4" varname="SCORE">
  <comment>Other points to consider include that each layer is independent and that each part is more manageable than the whole. The layers are also distinct functions. Good effort.</comment>
 </scorefeedback>
 <scorefeedback ident="2" varname="SCORE">
  <comment>Each part is more manageable than the whole.</comment>
  <score_value>0.5</score_value>
 </scorefeedback>
</manualfeedback>
```

On feedback completion, the associated passage from the student's solution (originally highlighted by the marker) appears underlined to indicate it has feedback associated with it, and the QTICAM RR XML for this item has changed, as illustrated in Listing 5.

The code presented in bold illustrates the changes made to the XML file once a marker has provided feedback using CAMP.

When item marking is complete, the *Completed* tick box at the bottom of Figure 1 is selected. By forcing the marker to make the conscious decision to flag an item as complete, this ensures items are not overlooked, when for example, a marker moves from one item to another comparing different students' solutions. When an item is flagged as unmarked, it is represented in QTICAM RR XML as:

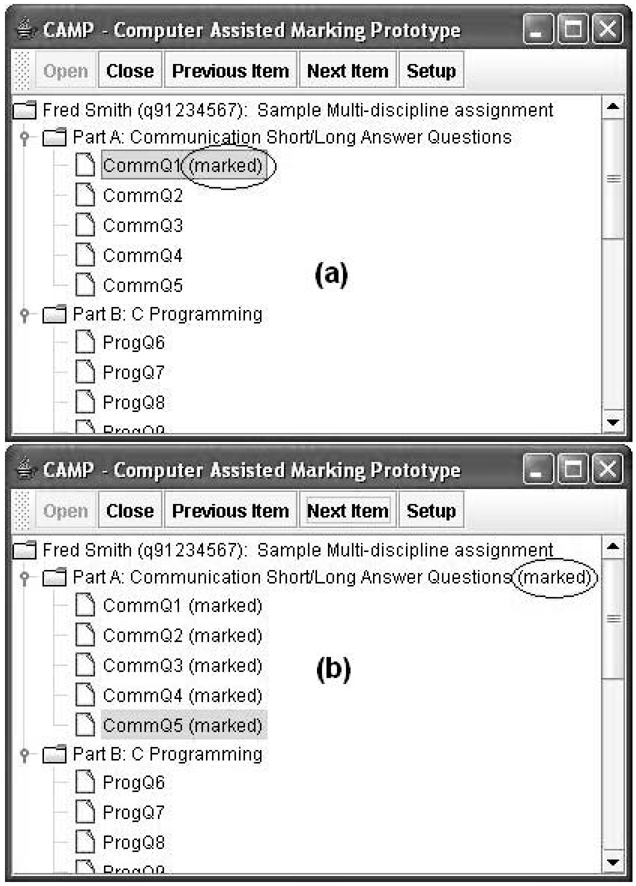
```
<manualscoring>
 <status>
  <status_value>Unmarked</status_value>
 </status>
</manualscoring>
```

When a tick is placed in the Completed tick box, the XML is changed to:

```
<manualscoring>
 <status>
  <status_value>Marked</status_value>
 </status>
</manualscoring>
```

The marker navigation window, as illustrated in Figure 2(a), shows that question CommQ1 of Section Part A has now been marked.

Figure 2. CAMP: Navigation window flagging marked items



This window gives a hierarchical view of all student assessments that have been loaded into memory. Once an entire branch of the hierarchy has been completely marked, its parent branch will also be flagged as marked. This is demonstrated in Figure 2(b).

When section *Part B* is marked, this will flag the entire assessment *Sample Multi-discipline assignment* for *Fred Smith* as marked, in the same manner. This allows the marker to see at a glance what remains to be marked from their allocation of student assessment.

CONCLUSION

QTICAM is an enhancement of the IMS QTI specification and provides support for interoperable computer assisted marking. Its functionality has been illustrated via the demonstration of CAMP. Features of the QTICAM include: support for limiting mark increments, inclusion of human readable marking rubrics, ability to record the marker for each marked item, recording manual marker feedback including comments and marks, linking marker feedback to passages of the students' solutions, recording the material presented to the student in the results report, and the ability to record formatted model solutions for items.

One of the main benefits for markers in the use of CAM software is increased productivity through automation of repetitive mechanical tasks (Joy & Luck, 1998). Such benefits include: automatic collation of marks at the item, section, and assessment levels, and the ability to easily reuse feedback comments by selecting from a list. Another major benefit to CAM software is improved quality. For example, typically a marker will, after completion of marking, add the marks assigned and record the total on a marking sheet. This manual process introduces a high risk of error during the addition and transcription of the marks. Through CAM, marks can be collated and recorded automatically, eliminating this quality issue. Other benefits to CAM include:

- Improved marking consistency: providing constraints on scoring variables ensures the markers assign marks consistently within the scope of the marking rubric
- Manual handling of results is eliminated: results from student assessments can be automatically uploaded into a LMS reducing staff workload and errors
- Improved marking feedback: permitting the marker to associate feedback with passages of the student's solution allows the student to interpret the feedback in the context of their own work (Mason, Woit et al., 1999)
- Potential to automate correction of marking errors across large assessment collections

The QTICAM specification currently adds essential support to the QTI for computer assisted marking. Future development will see the inclusion of advanced features that will:

- Automate late submission penalty application
- Share feedback between multiple markers
- Classify markers' comments for later analysis
- Automate marking moderation

With the adoption of an interoperable CAM specification such as QTICAM, interoperable CAM applications can be a reality.

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ENDNOTES

1 Readers not familiar with XML are directed to read the following online resources: http://www.xml.com, http://xml.coverpages.org/xml.html, http://www.w3.org/XML/, http://www.xml.org.

2 The <decvar> element is used within the QTI ASI specification for declaring a scoring variable. It allows the question author to define attributes for a scoring variable such as minimum, maximum, and default values.

3 The <interpretvar> element describes how to interpret the meaning of scores assigned to scoring variables.

4 <score> is used within the QTI RR binding to record the score achieved by a student as defined by the <decvar> element of the QTI ASI.

5 A CDATA node is a quoting mechanism within XML syntax to allow the special meaning of other XML characters to be escaped as part of an XML document.

6 The <material> element provides a container object for any content to be displayed. It allows various data types such as plain or emphasised text, images, audio, videos, or applets.

7 The XML DOM API is a standard platform independent programming interface for manipulating the content of XML documents in computer memory.

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Chapter XV
Streaming of Continuous Media for Distance Education Systems

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ABSTRACT

Distance education created new challenges regarding the delivery of large size isochronous continuous streaming media (SM) objects. In this paper, we consider the design of a framework for customized SM presentations, where each presentation consists of a number of SM objects that should be retrieved and displayed to the user in a coherent fashion. We describe a retrieval optimizer (Prime) that captures the flexibilities and requirements imposed by the user query, user profile, and session profile. Then, it determines how this query script should be imposed against the continuous media (CM) server to reduce contention. We also provide a cost model to evaluate each proposed plan. Finally, we explain the role of memory buffering in alleviating the server bandwidth fragmentation problem. Our preliminary experimental results show the feasibility and effectiveness of our proposed model and techniques in generating near optimal retrieval.

INTRODUCTION

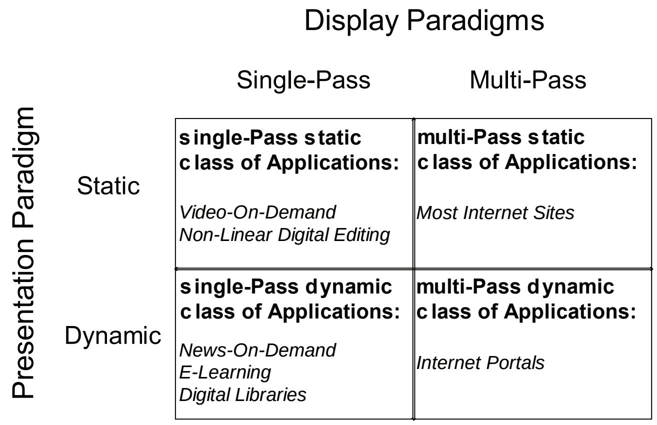
Distance education is the largest growing section of education in the world today. It defines a new way of interacting teaching that uses a number of different technologies to deliver the course material to remote students (usually off-campus). In order to keep in pace with the rapid developments in the field of higher education, Kuwait University established a nonprofit center specialized in the area of distance education and videoconferencing, The Kuwait University Distance Learning and Videoconferencing Center, in 2001. Such a center is a large consumer of educational technology, especially multimedia systems (MM). The audiovisual system used by the instructors displays media from different sources, such as a dedicated personal computer, laptop, VCR, DVD, or digital camera. The media is usually delivered through the Internet, cable, or satellite television, which created new challenges regarding the delivery of continuous media (streaming), especially through the Internet.

Multimedia (MM) systems utilize audio and visual information, such as video, audio, text, graphics, still images, and animations to provide effective means for communication. These systems utilize multihuman senses in conveying information, and they play a major role in educational applications (such as e-learning and distance education), library information systems (such as digital library systems), entertainment systems (such as video-on-demand and interactive TV), communication systems (such as mobile phone multimedia messaging), military systems (such as Advanced Leadership Training Simulation), and so forth. Due to the exponential improvements (of the past few years) in solid state technology (i.e., processor and memory) as well as increased bandwidth and storage capacities of modern magnetic disk drives, it has been technically feasible to implement these systems in ways we only could have dreamed about a decade ago.

A challenging task when implementing MM systems for distance education is to support the sustained bandwidth required to display *streaming media* (SM) objects, such as video and audio objects. Unlike traditional data types, such as records, text, and still images, SM objects are usually large in size. For example, a 2-hour MPEG-2 encoded movie requires approximately 3.6 gigabytes (GB) of storage (at a display rate of 4 megabits per second (Mb/s)). In addition, the isochronous nature of SM objects requires timely, real-time display of data blocks at a prespecified rate. For example, the NTSC video standard requires that 30 video frames per second be displayed to a viewer. Any deviation from this real-time requirement may result in undesirable artifacts, disruptions, and jitters, collectively termed *hiccups*. There has been a number of studies on the design of SM servers (Berson, Ghandeharizadeh, Muntz, & Ju, 1994; Gemmel, 1996; Gemmel, Vin, Kandlur, Rangan, & Rowe, 1995; Ghandeharizadeh, Dashti, & Shahabi, 1995; Ghandeharizadeh, Zimmerman, Shi, Rejaie, Ierardi, & Li, 1997; Goel, Shahabi, Yao, & Zimmerman, 2002; Muntz, Santos, & Berson, 1997; Ozden, Rastogi, & Silberschatz, 1995; Shahabi, Zimmerman, Fu, & Yao, 2002; Zimmermann, Fu, Shahabi, Yao, & Zhu, 2001). For a complete overview of SM server design issues, see Dashti, Kim, Shahabi, and Zimmerman (2003).

In many new SM applications, the result of a user request (i.e., query) is a set of SM objects that should be retrieved and displayed to the user in a coherent fashion. In general, these applications can be classified according to their: (1) display, and (2) presentation paradigms. The former specifies whether the application displays the SM objects in a single-pass or in multiple-passes, while the latter specifies whether the presentations are generated statically or dynamically according to user requirements (e.g., user profile, user query, etc.). Figure 1 illustrates the four classes of MM applications. The multipass class of applications do not impose new challenges in the retrieval of SM objects, because the user displays objects individually (i.e., no temporal constraints are imposed between their retrievals). However, the single-pass class of applications do impose temporal constraints on the display of the identified objects. The focus of our study is on the design of a MM system that can support single pass paradigm applications given the new challenges temporal constraints impose. To illustrate single-pass paradigm applications, consider the following examples:

Figure 1. Display and presentation paradigms



- **Customized news-on-demand:** A user submits the following query: "Show me today's news." The next generation multimedia management systems (e.g., multimedia DBMS) would employ user profiles to hone such general query into a more manageable set of video clips that are displayed to the user one after the other (similar to TV news), with minimum user interaction.
- **Customized advertisement:** With the explosion of the Internet and the advent of digital broadcasting, marketing agencies want to find new ways of attracting customer's attention. One such way is to use customized advertisement, where a number of advertisements that pertain to the user's interest are displayed. One possibility is to feed these advertisements in between the news-on-demand clips or during the advertisement slots of a TV program.
- **Digital libraries & museums:** Traditionally, these applications have used the multipass paradigm. However, a number of applications can be built on top of these repositories that use the single-pass paradigm for educational and entertainment purposes. For example, an educator might show the result of the following query to his or her students as a single presentation: "Show a documentary on the Persian Gulf war for a class of 12-year-old students."

This article reports an ongoing research project at Kuwait University. In the second section, we present the general framework of the research project. The third section explains the profile aware retrieval optimizer. Then, in the fourth and fifth sections, we discuss the search space, cost model, and a strategy to search for the best retrieval plan. The sixth section explains the role of memory buffering in alleviating the server bandwidth fragmentation problem. Finally, in the seventh and eighth sections, we present our preliminary findings, conclusions, and future directions.

FRAMEWORK

With the multipass display paradigm, during each pass, a set of objects (that satisfy the presentation requirements) are identified. Subsequently, the user interactively selects the objects of interest for display (i.e., the user pulls the objects). To assist the user, textual and thumbnail information are used to represent different objects. Most Internet sites (e.g., online version of the *LA Times*) are examples of multipass static class of applications, where a set of objects is specified statically during each pass (e.g., when the user clicks on the Business News link, a prespecified set of news items are presented to the user). On the other hand, the multipass dynamic class of applications dynamically specifies the set of objects to be presented during each pass. A number of Internet portals are striving to accomplish this task effectively (Chen & Shahabi, 2003; Shahabi, Zarkesh, Adibi, & Shah, 1997).

With the single-pass paradigm, a set of temporal relationships (among the set of identified SM objects) governs the display timing of the objects[1]. The display of the objects is considered to be coherent when all of the temporal relationships are satisfied. Therefore, after the submission of the request, no user interaction is necessary. That is, the system starts the display as soon as it can guarantee that the SM server can display all of the objects in the set to the user with no interruptions, while satisfying the temporal relationships and other user requirements. Examples of single-pass static class of applications are video-on-demand and none-linear digital editing applications. It is important to note that video-on-demand applications are a special case of this class of applications, because they require the retrieval and display of only one SM object per presentation.

On the other hand, it is possible to generate the presentations dynamically according to user requirements. Examples of single-pass dynamic class of presentations include: customized news-on-demand, customized advertisement, and digital libraries and museums. Some of the new Internet applications that use the push paradigm can be considered as a variation of the single-pass paradigm presented above. In the pure push paradigm, the user does not make a request; rather the system keeps broadcasting the information to the user (i.e., *data driven*)(Shahabi, Dashti, & Ghandeharizadeh, 1998).

FLEXIBILITIES

The single-pass class of applications (whether generated statically or dynamically) can be classified according to the restrictions imposed by the presentation as either: (1) restricted presentation applications (RPA), or (2) flexible presentation applications (FPA). RPA, such as nonlinear editing applications, have a very strict set of temporal relationships that have to be met. This strict timing requirement results in a single retrieval plan, and hence very limited retrieval optimization is possible. However, in FPA, the set of temporal relationships among the objects is not as strict, yielding a number of equivalent retrieval plans that can be used for retrieval optimization purposes.

RPA imposes very strict display requirements. This is due to the type of queries imposed by users in such applications. It is usually the case that the users can specify what objects they are interested in and how to display these objects in concert. To illustrate, consider the following environment. During the postproduction of a movie, a sound editor accesses an archive of digitized audio clips to extend the movie with the appropriate sound effects. The editor might choose two clips from the archive: a gunshot and a screaming sound effect. Subsequently, the editor authors a composite object by overlapping these two sound clips and synchronizing them with the different scenes of a movie. Multimedia systems have to guarantee that the SM server can retrieve all the objects in the set and can satisfy the precise time dependencies, as specified by the user. In Chaudhuri, Ghandeharizadeh, and Shahabi (1995) and Shahabi (1996), the scheduling of continuous media retrievals for RPA, and the time dependencies are guaranteed by using memory buffers while in Shahabi et al. (1998), they are guaranteed by using the in-advance knowledge at the time of data placement.

FPA, however, provide some flexibilities in the presentation of the streaming media objects. It is usually the case that the users do not know exactly what they are looking for and are only interested in displaying the objects with some criteria (e.g., show me today's news). In this case, depending on the user query, user profile, and session profile, there are a number of flexibilities that can be exploited for retrieval optimization. We have identified the following flexibilities:

- **Selection flexibility:** Which specifies the possible set of objects that the user might be interested in
- **Delay flexibility:** Which specifies the amount of delay the user/application can tolerate between the displays of different continuous media clips (i.e., relaxed meet, after, and before relationships (Allen, 1983)
- **Ordering flexibility:** Which refers to the display order of the objects (i.e., to what degree the display order of the objects is important to the user)
- **Presentation flexibility:** Which refers to the degree of flexibility in the presentation length and presentation startup latency
- **Display-quality Flexibility:** Which specifies the display qualities acceptable by the user/application, when data is available in multiple formats or in hierarchical or layered formats (based on layered compression algorithms (Keeton & Katz, 1995)

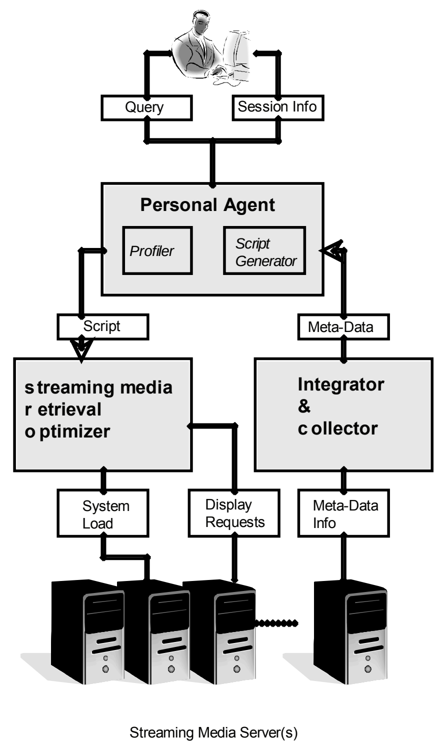
To illustrate the flexibilities, assume a news-on-demand application where a user submits the following query: "Show me today's news." Due to the generality of the query, it will result in a large number of candidate video clips that would be very cumbersome for the user to view. The user can simplify the browsing by explicit definition of some of its priorities (or flexibilities). For example, in SQL one can use a filter expression to specify the selection criteria and a ranking expression to impose ordering. However, the next generation multimedia management systems (e.g., multimedia DBMS) would use user profiles to hone such general queries into more manageable sets of video clips. For example, assume that from the user profile, we know the following about the user: (1) he is interested primarily in business and sports news, (2) he owns a set of stocks, bonds, and money market accounts, (3) he currently lives in the Bay Area, (4) he has family members living the Middle East, (5) he graduated from the University of Southern California (USC), and (6) he is planning to travel to Hong Kong the next day.

Then the system might select sports news that is relevant to the USC football team and USC baseball team and business news relevant to his stock, bonds, and money market portfolio. Moreover, the system might select other news worthy of his attention (e.g., war in Iraq or the weather in Hong Kong). It is clear that a large number of objects might satisfy the user query and that the user might not have time to display all objects; therefore, the system may select or suggest a subset of the objects for display (selection flexibility). The order of the display of these objects may also be flexible (order flexibility). For example, during the sports news session, the user might not care if the highlights of the USC vs. UCLA football game are shown first, or the highlights of the USC vs. Stanford baseball game are shown first (or alternatively the user might care about the order of the display). This can also be extracted from the user profile (e.g., user is a football fan). When displaying the selected video clips, the user might require a minimum delay (e.g., 1 second) between the displays of two objects and might tolerate a maximum delay (e.g., 3 seconds) between the displays of two objects (delay flexibility). The startup latency and the length of the presentation may also be specified by the user (presentation flexibility). For example, the user might require that the presentation starts no later than 10 seconds after the submission of the request and that the length of the presentation be 4.5 minutes to 5.5 minutes. Finally, depending on the user requirements and the availability of multiple display formats, it is possible to display objects at a lower quality when the system load is high (display-quality flexibility). For example, if the system load is high during the display of the USC vs. Stanford water-polo game, then a lower (i.e., MPEG I) bandwidth might be acceptable by the user.

In RPA, because the presentations are fixed, a single retrieval plan can be imposed on the SM server per presentation. This plan is also independent of the server load. Hence, very limited intrapresentation optimization can be performed. In FPA, the flexibilities allow for the construction of multiple retrieval plans per presentation. Subsequently, the best plan is identified as the one which results in minimum contention at the SM server. To achieve this, three steps should be taken: Step 1: gathering flexibilities, Step 2: capturing the flexibilities in a formal format, and Step 3: using the flexibilities for optimization. In our system architecture, Figure 2, the Personal Agent carries out the first two steps. This agent builds the user profile either explicitly (i.e., by user interaction) or implicitly (i.e., by monitoring the user actions, as in Shahabi et al. (1997). It also takes as input the user query and the session profile (e.g., type of display monitor) to generate a query script (as output). The job of the integrator and collector is to build the necessary meta-data information for the SM server(s) (whether centralized or distributed), which is used by the agent to generate a query script (as output). This query script would capture all the flexibilities and requirements in a formal manner. The query script is then submitted to the Streaming Media Retrieval Optimizer, which in turn would use it to generate the best (or a good) retrieval plan for the SM server.

In a previous study Shahabi et al. (1998), we defined a query-script for the SM retrieval optimizer. Using the query script, the optimizer defines a search space that consists of all the correct retrieval plans. A retrieval plan is correct if and only if it is consistent with the defined flexibilities and requirements. The optimizer also defines

Figure 2. System architecture



a cost model to evaluate the different retrieval plans. The retrieval plans are then searched (either exhaustively or by employing heuristics) to find the best plan depending on the metrics defined by the application. Using a simple simulation model and simple search algorithms, we were able to show that the optimizer can improve system performance significantly when the system load is moderate.

In our current research, we are investigating the following. First, we are investigating the theoretical bounds on the size of the search space and the search time. It seems that both problems are NP-Hard. Second, we are investigating the design of efficient algorithms to define the search space and find a good retrieval plan (i.e., search algorithm). Third, we are investigating the impact of caching at the user terminal on the system performance. Fourth, we are investigating the design of SM integrators and collector for a distributed environment. Finally, we are investigating the design of a personal agent that can generate good query scripts, based on user query, user profile, and session profile.

Profile Aware Retrieval Optimizer (Prime)

The query script received by Prime captures formally the flexibilities and requirements imposed by the user query, user profile, and session profile. It is the responsibility of Prime to determine how this query script should be imposed against the Continuous Media (CM) server to reduce contention[2]. This process consists of accepting a query script and then finding the best retrieval plan (among a set of correct retrieval plans) to be scheduled on the CM server. Therefore, the optimizer Prime is concerned with three issues: (1) search space, (2) cost model, and (3) a strategy to search for the best retrieval plan (Ozsu & Valduriez, 1996). The search space is defined by the query script. The number of correct retrieval plans determines the size of this search space. The cost model is a set of metrics used to evaluate each correct retrieval plan that is being considered. The search strategy explores the search space for the best retrieval plan based on the defined metrics.

The CM server, utilized by Prime, guarantees the uninterrupted display of the continuous media objects. There have been a number of studies describing the design and implementation of such servers (see Berson et al., 1994; Chen & Little, 1993; Gemmel et al., 1995; Ozden, Rastogi, & Silberschatz, 1996; Rangan & Vin, 1993; Tobagi, Pang, Baird, Gang, 1993). We ignore the detail architecture of the CM server and conceptualize it as a server bandwidth, termed R_{CM}.

In this section, we start by describing the flexibilities and a formal definition for query script. After that, we consider the search space, the cost model, and the search strategies, while optimizing for one query script at a time (thus, it is limited to intrapresentation optimization.

Query Script

We are considering four types of flexibilities that might be tolerable by user/application submitting a request: delay, ordering, presentation-time, and display-quality. To capture the delay flexibility, we define a minimum and a maximum tolerable delay between the finishing time of one object and the start time of the subsequent object (T_{Delay}^{Min} and T_{Delay}^{Max}). For ordering flexibility, we define three variations: (1) unordered-object-retrieval (UOR), (2) suggested-object-retrieval (SOR), and (3) ordered-object-retrieval (OOR). To illustrate, consider a query script q that references n continuous media objects, $q = \{o_1, o_2, ...o_n\}$. UOR imposes no ordering constraint on the display of the n objects. SOR suggests an ordering for the n objects; however, this ordering is not restrictive; rather it is given with some confidence. It is expected that a large number of queries imposed on multimedia applications will be of this type. OOR requires the display of the n objects in a specific order, and it is necessary to satisfy this ordering. Consider the following three user queries:

- **Q1:** Display three video clips where President Clinton mentions taxes in his State of the Union speech
- **Q2:** Display three video clips where President Clinton mentions taxes in his State of the Union speech, while ordering the display of these clips chronologically
- **Q3:** Display three video clips where President Clinton mentions taxes in his State of the Union speech, while ordering the display of these clips according to their relevance to my taxes

The first query, Q1, is an example of UOR. The users request the display of the video clips but they do not specify any order preference. Therefore, the optimizer may choose one of the n! alternative retrieval plans permutations to find the best possible one. The second query, Q2, is an example of OOR. The user specifies the exact ordering of the display of the objects, and hence the optimizer has only one retrieval plan at its disposal and it cannot search the different retrieval plans to improve the system performance. The third query, Q3, is an example of SOR. The user is specifying an order for the display of the objects; however, this order is not strict; rather, it is given with some confidence. This is due to the fact that the ordering is done by qualitative analysis of the video clips and user profile, and it is given with some confidence. The optimizer may search the retrieval plans to improve system performance; however, the confidence level of the retrieval plans considered has to stay above a threshold given by the query script. We show that UOR and OOR are special cases of SOR.

To capture the presentation-time flexibility, we define two variables: (1) the presentation length, T_{Length}, as the total time to display all objects in a request plus the delays between them, and (2) the presentation start-up latency, $T_{Startup}$, as the time elapsed from the submission of the request to the start of the presentation. Furthermore, we define a minimum presentation length, T_{Length}^{Min}, and a maximum presentation length, T_{Length}^{Max}, tolerated by the user and the application. We also define a minimum startup latency time, $T_{Startup}^{Min}$, and a maximum startup latency time, $T_{Startup}^{Max}$. To capture the display-quality flexibility, we define a function C that returns a set of m acceptable display bandwidths for an object o, ($C(o) = \{c_1(o), c_2(o), ...c_m(o)\}$). We assume that this function returns all display formats that are available on the CM server and that are acceptable to the user.

The three ordering variations we are considering (UOR, SOR, and OOR), require the retrieval of n objects with the constraints that:

- **Delay-flexibility:** Delay, Δ, between the finishing time of an object and the starting time of the subsequent object is bounded by T_{Delay}^{Min} and T_{Delay}^{Max} ($T_{Delay}^{Min} \leq \Delta \leq T_{Delay}^{Max}$)
- **Presentation-flexibility:** Presentation length, T_{Length}, is bounded by T_{Length}^{Min} and T_{Length}^{Max} ($T_{Length}^{Min} \leq T_{Length} \leq T_{Length}^{Max}$), startup latency, $T_{Startup}$, is bounded by $T_{Startup}^{Min}$ and $T_{Startup}^{Max}$ ($T_{Start-}^{Min} \leq T_{Startup} \leq T_{Startup}^{Max}$)
- **Display-quality:** For all objects in the request, there are enough system resources to satisfy one of the bandwidths requirements ($c,c,...,c_m$) returned by C

Using Table 1 as a reference, consider the following definition for a query script:

- **Definition 1:** A query script q submitted to the optimizer (Prime) consists of the following parameters:
  - n objects $o_j \in O$ (O is the set of all continuous media objects available on the CM server) for $\forall j: \leq j \leq N$, where $N = |O|$.
  - T_{Delay}^{Max} & T_{Delay}^{Min} as the maximum and minimum tolerable delay between the finishing time of o_j and the starting time of o_{j+1}.
  - Confidence level threshold ø, $0 \leq ø \leq 1$ (minimum acceptable confidence in the object ordering).
  - Function $\alpha(o_j, \forall i, j: 1 \leq i, j \leq n)$, where $0 \leq \alpha(o_j, i) \leq 1$, (confidence in displaying object o_j in the *ith* position).
  - T_{Length}^{Max} & T_{Length}^{Min} as the maximum and minimum tolerable presentation lengths.
  - $T_{Startup}^{Max}$ & $T_{Startup}^{Min}$ as the maximum and minimum tolerable startup latency.
  - Function $C(o_j)=\{c_k(o_j) | \forall j, k{:}1 \leq j \leq n$ and$1 \leq k \leq m, 0 < c_k(o_j) \leq 1\}$, where $\forall j$: $1 \leq j \leq n, C(o_j) \neq j$.

Table 1. Terms used repeatedly in the article and their corresponding definitions

Term	Definition
o_j	A continuous media object identifier; no ordering is associated with the subscript.
$l(o_j)$	The length of the object o_j .The unit is in time intervals.
$C(o_j)$	A function that returns the set of m acceptable consumption rates for object o_j , $(\{c_1(o_j), c_2(o_j), ..., c_m(o_j)\})$. This rate is normalized by the CM server bandwidth RCM , $\forall i, k : 1 \leq j \leq n,\ 1 \leq k \leq m,\ 0 < c_k(o_j) \leq 1$.
$MinBand(o_j)$	A function that returns the minimum bandwidth requirement for object o_j (i.e., the minimum value returned by $C(o_j)$).
$s(o_j)$	Object o_j start time. It is the time at which the display of o_j starts.
$f(o_j)$	Object o_j finish time. It is the time at which the display of the object o_j finishes, $f(o_j)= s(o_j)+ l(o_j)$.
$Band(k)$	Available bandwidth at time interval k, $0 \leq Band(k) \leq 1$ (normalized by the CM server bandwidth, RCM)
$\alpha(o_j ,i)$	A function that returns the confidence value of displaying object o_j in the ith position.
q	A *query-script*, q, is a formal definition of the user, system, and application flex-ibilities and requirements. This is the input to *Prime*.
$r(q)$	A query script release time. It is the time at which the query script is released to the optimizer.
p	A *retrieval-plan*, p, consists of tuples $< o_j ,i >$, $\forall i, j : 1 \leq i, j \leq n$,where o_j is one of the n objects to be displayed from the query-script, and i is one of the n possible posi-tions.
$\beta(p)$	The confidence level of the retrieval plan p, $\beta(p)=\sum_{i=1}^{n-1} a(o_j, Pos(o_j,p))/n$
$s(p)$	Retrieval plan p start time. It is the time at which the first object of the retrieval plan is displayed, $s(p)= s(o_j)$where $Pos(o_j ,p)=1$.
$Pos(oj ,p)$	A function that returns the position of object o_j in the retrieval plan p.
$f(p)$	Retrieval plan p finish time. It is the time interval at which the last object of the retrieval plan finishes its display, $f(p)= f(o_j)$where $Pos(o_j,p)= n$.
$\sigma(p)$	*Retrieval schedule*, σ, of retrieval plan p. It consists of n triplets: $< o_j ,i,s(o_j) >$, where o_j is the object being displayed, i is the position of the object in the plan, and $s(o_j)$ is the start time of object o_j .
$T_{Response}$	The time elapsed from the release time of the query script $r(q)$ to the finish time of the plan $f(p)$, $T_{Response}(p)= f(p) - r(q)$.
$T_{Latency}$	The time elapsed from the release time of the query script $r(q)$ to the start time of the retrieval plan $s(p)$, $T_{Latency}(p)= s(p) - r(q)$.
$\Delta_{Avg}(p)$	The average delay between the finish time of an object and the start time of the subsequent object, $\Delta_{Avg}(p) = \sum_{i=1}^{n-1} \Delta_{(i,i+1)}(p) \big/ n-1.$
$\Delta_{Var}(p)$	The delay variance, $\Delta_{Var}(p) = \sum_{i=1}^{n-1} (\Delta_{(i,i+1)}(p) - \Delta_{Avg}(p))^2 \big/ n-1.$
$\Delta_{(i,i+1)}(p)$	Delay between the completion time of object *or* at position i, and starting time of object o_s at position $i+1$, $\forall i : 1 \leq i \leq (n-1)$.

Search Space

The number of I/O's to retrieve streaming media objects from the SM server is fixed. However, different retrieval plans influence retrieval contention at the server. Hence, it is vital to find a retrieval plan such that it minimizes contention at the SM server, in order to improve system performance. The query script captures the flexibilities and requirements imposed by the user query, user profile, and session profile. It is then necessary to determine how this query script should be imposed against the SM server to reduce contention. This process consists of: (1) accepting a query script that defines our search space, (2) finding the correct retrieval plans that satisfy our query requirements, and (3) applying a strategy to search for the best retrieval plan (among a set of correct retrieval plans) to be scheduled on the SM server.

A retrieval plan p, whether correct or not, consists of n tuples $< o_j , i >$ $(\forall i, j{:}\ 1 \leq i, j \leq n)$, where o_j is one of the n objects to be displayed from the query script and i is one of the n possible positions. The search space consists of all of the correct retrieval plans, where the correctness of a retrieval plan depends on the display order being considered with the given confidence threshold.

- **Definition:** A retrieval plan p consists of n tuples $< o_j , i >$ $(\forall i, j{:}\ 1 \leq i, j \leq n)$. This retrieval plan is said to be correct if and only if:
  - $\forall i, j{:}\ 1 \leq j \leq n, 1 \leq Pos(o_j, p) \leq n$ (all of the objects in the query script q are considered in the retrieval plan p).
  - $\forall i, j{:}\ 1 \leq i, j \leq n$ if $i \neq j$ then $Pos(o_j, p) \neq Pos(o_j, p)$ (two objects do not occupy the same position).
  - $\beta(p) = \alpha(o_j, Pos(o_j, p)) / \mathrm{n} \geq \Phi$ (the average confidence level of the retrieval plan is above the given threshold).

The above query script and retrieval plan definitions capture all three variants of the ordering flexibilities. It naturally captures SOR, because the query script definition allows the optimizer to consider the different retrieval plans as long as their confidence level $\beta(p)$ is above the confidence threshold Φ. To capture UOR, it is important to generate all the n! possible retrieval plans. To achieve this, the value of $\beta(p)$ has to be independent of the ordering, constant for all permutations, and always greater than the threshold Φ. This can be accomplished by setting $\Phi = 0$ and fixing $\alpha(o_j, i) \geq 0$ for all i and j. This setup would allow all possible retrieval plans. In case of OOR, it is important to allow only one retrieval plan. This can be accomplished by setting the threshold to the highest value , $\Phi = 1$, and making the confidence evaluator $\alpha(o_j, i)$ return 1 when the object is being displayed at the correct order and 0 otherwise. Therefore, a correct query script setup would result in capturing the appropriate query variation. As defined above, the search space consists of all the correct retrieval plans. However, in general, finding the complete search space seems to be an intractable problem. We show that this problem is actually NP-hard by reducing our problem to the bin-packing problem (Garey, Graham, Johnson, & Yao, 1976) and cutting-stock problem (Garey & Johnson, 1979).

Search Complexity

For many important practical or theoretical problems, the objective is to choose a "best" solution out of a large number of candidate solutions or the solution space. Such problems are typically known as combinatorial optimization problems. A combinatorial optimization problem is formalized as a pair (S,w), where S is finite or a countable infinite set of configurations (or search space) and w is a cost function, $w{:}S \rightarrow \mathcal{R}$, which assigns a real number to each configuration. For convenience, it is assumed that w is defined such that the lower the value of w, the better (with respect to the optimization criteria) the corresponding configuration. The problem now is to find a configuration for which w takes its minimum value, that is, an (optimal) configuration i_o satisfying $w_{opt} = w(i_o) = \min_{i \in S} w(i)$ where w_{opt} denotes the optimum (minimum) cost. In our work, the search space S consists of all the correct retrieval plans, where the correctness of a retrieval plan depends on the display order being considered with the given confidence threshold, and the cost function w tries to optimize for the response time ($T_{response}$) and the latency time ($T_{Latency}$). The objective of Prime is to find the best retrieval plan in the search space, where best is dependent on the metrics used. In the next two subsections, we will show that finding the complete search space is an intractable problem (*NP–hard*) by reducing our problem to the bin-packing problem (Garey et al., 1976) and cutting-stock problem (Garey & Johnson, 1979).

Bin Packing

The bin packing problem (BPP) can be described as follows: Given a set of n "items" with integer size $x_1, ..., x_n$, and a supply of identical "containers" of capacity C, decide how many containers are necessary to pack all the items. This task is one of the classical problems of combinatorial optimization and is *NP-hard* in the strong sense (Coffmann, Garey, & Johnson, 1997; Garey & Johnson, 1979). One approach to deal with *NP-hard* problems is to develop approximation algorithms. These are polynomial time algorithms that have some (worst-case) performance guarantee compared to the optimum solution. Even though there are many excellent theoretical results, including polynomial approximation schemes, there is still a lack of methods that are able to solve practical instances optimally. A generalization of bin packing problem is multidimensional bin packing, called box packing. While box packing is a natural step from bin packing, the problem seems to be more difficult, and the number of results is smaller.

- **Problem definition:** Let $d \geq 1$ be an integer. In the d-dimensional box-packing problem, we are given a finite set $O = \{o_1, o_2, ..., o_N\}$ of "items." Each item o has a fixed size, which is $s_1(o) \times ... \times s_d(o)$, where $s_i(o)$ is the size of o in the *ith* dimension. We have an infinite number of bins, each of which is a d-dimensional unit hyper-cube. Each piece must be assigned to a bin and a position $(x_1(o) \times ... \times x_d(o))$, where $0 \leq x_i(o)$ and $x_i(0) + s_i(o) \leq 1$ for $1 \leq i \leq d$. Further, the positions must be assigned in such a way that no two items in the same bin overlap. A bin is empty if no piece is assigned to it; otherwise it is used. The goal is to minimize the number of bins used. Note that for $d = 1$, the bin-packing problem reduces to exactly the classic bin-packing problem.

Our optimization problem can be reduced to the two-dimensional bin packing problems. In two-dimensional problems, given a set of items and a set of bins whose shapes are two-dimensional, you are asked to lay out items inside bins in such a way that the number of used bins is minimized and the yield (area of item over area of bounding rectangles of layouts) is maximized. In our case, each media object can be considered as a 2D item (rectangle) and the bins are discrete time intervals over the system bandwidth. Problems of this type are obviously harder than one-dimensional bin packing, and thus *NP -hard* (Chung, Garey, & Johnson, 1982; Coffmann et al., 1997; Garey & Johnson, 1979).

Cutting Stock

One common combinatorial optimization problem that arises frequently in applications is the problem of allocating rectangular or irregular shapes onto a large stock sheet of finite dimensions in such a way that the resulting scrap will be minimized. This problem is common to numerous real-world applications from computer science, industrial engineering, logistics, manufacturing, management, production process, aerospace, ship building, VLSI design, steel construction, shoe manufacturing, clothing, furniture, and so forth. This problem is commonly known as the cutting stock problem.

In the two-dimensional free-form (irregular shapes) bin packing (2D-FBP) problem, which is also called the free-form cutting stock, cutting and packing, or nesting problem, given a set of 2D free-form items, which in practice may be plate parts, and a set of 2D free-form bins, which in practice may be plate materials from which parts are to be cut, you are asked to lay out items inside one or more bins in such a way that the number of bins used is minimized and the yield (area of items over area of bounding rectangles of layouts) is maximized. Algorithms for the problem generally consist of procedures for approximating input bins and items, and for placing items into bins (Daniels & Milenkovic, 1996; Milenkovic, 1998).

Another variant of the cutting stock problem is rectangle layout, in which the essential task is to place a given set of rectangles, or pieces, in a given larger rectangular area or, stock sheet, so that the wasted space in the resulting layout is minimized subject to the layout being feasible. We call a placement feasible if there are no overlapping pieces in the layout, and the items must stay within the confines of the larger shape. Additional constraints can be such as a requirement on the minimum or maximum number of a particular piece that should appear or, that the pieces be recoverable from the stock sheet by making full length, or guillotine, cuts across the piece. This latter requirement is important for industries such as glass cutting where partial cuts across a stock sheet are either forbidden or are prohibitively expensive. Because the 2D-FBP problems belong to the class of *NP-hard* combinatorial optimization problems, which means that there is no hope of finding polynomial-time exact algorithms unless $P = NP$, approximation algorithms play an important role in practical applications.

The cutting stock problem is an example of a large-scale optimization problem. It is unlikely to be solved by an algorithm whose run time is bounded by a polynomial function. This is an example of *NP – hard* problems (Garey & Johnson, 1979). This means that this problem requires a computing effort that increases exponentially with the problem size. Because the cutting stock problem is of practical importance, therefore, a large variety of solution-methods, exact and approximate, have been devised. Efficient approximation algorithms, namely, algorithms that do not produce optimal but rather close-to-optimal solutions, have been developed. These include linear and integer programming (Dyckhoff, 1981; Haessler, 1980), dynamic programming (Beasly, 1985a; Sarker, 1988), tree-search algorithms (Beasly, 1985a; Hinxman, 1980), genetic algorithms (Burke & Kendall, 1999), and simulated annealing (Lutifiyya & McMillin, 1991; Sechen & Vincenelli, 1986). These proposed approaches have restrictions on the size and type of applications.

There are two different types of the two-dimensional cutting stock problems: the constrained and the unconstrained problems. The *constrained two-dimensional cutting stock problem* (CTDC) applies orthogonal guillotine cuts and is not of free-form type. The unconstrained two-dimensional cutting has been solved optimally by dynamic programming (Beasly, 1985b) and by the use of recursive (tree search) procedures (Hifi, & Zissimopoulos, 1996). Very interesting sequential exact and approximate algorithms have been developed for guillotine CTDC. Two exact approaches are called the top-down approach (Christofides & Whitlock, 1977; Hifi, 1994), a depth-first search method, and the bottom-up approach (Hifi, 1997; Viswanathan & Bagchi, 1993),a best-first search method. The CTDC version has been solved optimally by applying a general tree search based upon a depth-first search method (Hifi, 1994) and also by the use of branch-and-bound procedure based upon a best-first search method (Hifi, 1997). Previous works have also developed heuristic approaches to the unconstrained and constrained ones (Fayard, Hifi, & Zissimopoulos, 1996).

We study in our work one of the most interesting problems of cutting stock, the Constrained Two-Dimensional Cutting stock problem (CTDC), which applies orthogonal guillotine cuts and not free-form. In CTDC, we assume that our time vs. bandwidth graph represents a large stock rectangle S of given dimensions $L \times W$ and our media objects are represented as n items of smaller rectangles (pieces) where the *ith* item has dimensions $l_i \times w_i$. Furthermore, each item i, $i = 1,..., n$, is associated with a cost c_i. The problem now is to cut off from the large rectangle a set of small rectangles such that: (i) all pieces have fixed orientation, that is, a piece of length l and width w is different from a piece of length w and width l (when $l \neq w$), (ii) all applied cuts are of guillotine type, that is, cuts that start from one edge and run parallel to the other two edges; and (iii) the overall profit obtained by $c_i x_i$, where x_i denotes the number of rectangles of type i in the cutting pattern, is maximized.

Search Strategy

We have proven that finding the complete search space is an intractable problem (*NP-hard*) by reducing it to the *bin-packing* and *cutting-stock* problems. Even though the problem is *NP-hard*, it is possible to do exhaustive search when there are a small number of objects being referenced. However, when the number of referenced objects is large, alternative search strategies have to be employed, such as: heuristic search strategies, or randomized search strategy.

In this section, we propose employing heuristics to find a subset of the search space by pruning all permutations that do not seem promising. Those heuristics depend on some metrics such as the confidence level of the retrieval plans. In this case, only the retrieval plans with an average confidence level ($\beta(p)$) above a threshold (Φ) given by the query script are investigated.

The first heuristic (*Heuristic*$_1$) applies a greedy strategy that strives to generate a retrieval plan with the highest average confidence level ($\beta(p)$) by scheduling the objects with the highest confidence values $\alpha\ (o_j,\ Pos(o_j,\ p))$ at each position ($Pos(o_j,\ p)$). It starts first by sorting the objects at each position by their confidence level ($\alpha\ (o_j,\ Pos(o_j,\ p))$). Second, it tries to schedule the objects with the highest confidence values at each position. If the same object appears at more than one position, it schedules the one with the highest confidence value and replaces the object at the other position with the next object (in the sorted list of objects) in its position. The algorithm terminates when it schedules different objects at all the positions in p (see *Algorithm A* in Appendix).

Because the object picked next by *Heuristic*$_1$ is always the one with the highest confidence value that can be legally scheduled, the object picked is thus a "*greedy*" choice in the sense that, intuitively, it maximizes $\alpha\ (o_j, Pos(o_j, p))$. That is, the greedy choice is the one that maximizes $\beta(p)$.

To generate more retrieval plans a second heuristic (*Heuristic*$_2$) can be applied. With this heuristic, instead of scheduling the objects with the highest confidence level at each position of plan p (as in *Heuristic*$_1$), we force the scheduling of an object (o_j) with a specific confidence value at a specific position ($\alpha\ (o_j, i)$). Then, to generate a new scheduling plan with the same or a lower average confidence value, we force the scheduling of an object with a lower confidence value than o_j at the same position i (see *Algorithm B* in Appendix). With the new heuristic, an additional n retrieval plans can be generated at level l with the same or lower confidence value as the n retrieval plans of level l-1. To generate the n retrieval plans at level l we have to apply *Heuristic*$_1$ n times. When we apply *Heuristic*$_1$ for the ith time ($\forall i : 1 \leq i \leq n$) we fix the display of the lth object in the sorted list of objects at position i (even if it has a higher confidence to be displayed at another position), and schedule different objects at the other positions (see *Algorithm B*). Hence, we reduce the total confidence value of the generated retrieval plan.

The worst-case execution time of the *while* loop in *Algorithm A* is $O(n^2)$; because in the worst case, we process all the elements in matrix SOPC $[n,n]$ (of size n^2). Hence, the running time of *Algorithm A* is dominated by the sorting time of the n columns of OPC matrix to generate matrix SOPC. It takes $O(n \log n)$ to sort each column, and because we have n columns, then the total sorting time is $O(n^2 \log n)$. Therefore, the total running time of *Algorithm A* is $O(n^2 \log n)$.

Note that we can further enhance our algorithms by applying some modifications. For example, in *Algorithm A* and *Algorithm B*, instead of randomly extracting an element from S that represents a position *pos*, we can do the following: (1) sort the positions in ascending order according to the confidence values of the objects with the highest confidence value at each position (i.e., sort the objects in first row of matrix SOPC), (2) pick the position that has the object with the highest confidence value as *pos*. More retrieval plans can also be generated by a simple extension/modification of *Algorithm B*. Instead of fixing the scheduling of only one object at a time, we can fix m objects at a time, for $1 \leq m \leq n$. Hence, we pass three parameters to *Algorithm B* instead of two. Furthermore, instead of terminating the execution of *Algorithm A* and *Algorithm B* when S is *empty* (i.e., scheduled different objects at *all* the positions), we can stop the execution whenever $\beta(p)=\alpha\,(o_j, Pos(o_j, p))/n \geq \Phi$ if $k < n$ (i.e., S is not empty). In this case, we can randomly pick objects to be scheduled at the rest of the position S, as long as they generate a correct plan.

Sometimes when the number of all permutations of the objects being referenced $n!$ is smaller than or equal to some threshold[3] N, then the system may choose the *exhaustive search*. The exhaustive search examines all possible retrieval plan permutations $n!$ to find the best correct retrieval plan. Therefore, the complexity of the general exhaustive search in worst case is $O(n! \times T_{Schedule})$. On the other hand, if the number of objects $n!$ is greater than the threshold N, then all permutations cannot be exhaustively searched in a reasonable time. Therefore, $Heuristic_1$, or $Heuristic_2$ described in this section may be used to find a partial search space. If the cardinality of the resulting partial search space $|S_{partial}|$ is smaller than or equal to N, then the system may exhaustively search the partial search space in a reasonable time. The complexity of exhaustively searching the partial search space is $O(n^2 \times \log n + |S_{partial}| \times T_{Schedule})$.

Besides heuristics, a randomized search strategy can also be considered. The randomized search strategy selects K arbitrary retrieval plans from the partial search space, and then exhaustively searches them to find the best retrieval plan. The run time of such a randomized search strategy is $O(n^2 \times \log n + (K \times T_{Schedule}))$.

Role of Memory in Retrieval Optimization

When the server load is moderate to high, it is difficult to find time slots (i.e., a rectangle) that can satisfy the display requirements of the objects for their entire duration. This is due to the fact that: (1) the available server bandwidth is less than the display requirements of the objects (i.e., not enough height), and (2) there might be time slots that satisfy the display requirement of the objects; however, the length of these time slots is shorter than the length of the objects (i.e., not enough length). We refer to this problem as the server bandwidth fragmentation problem, and it leads to larger $T_{Response}$ and $T_{Latency}$.

Memory buffering can play a role in alleviating the server bandwidth fragmentation problem by allowing the emulation of higher server bandwidths when necessary. There are two ways of applying memory buffering: (1) Simple Memory Buffering Mechanism (SimB), and (2) Variable Rate Memory Buffering Mechanism (VarB). The SimB mechanism treats the system load on the server as a discrete function over time. Either there is enough bandwidth to satisfy the minimum bandwidth requirement of the object being scheduled, or there is not enough bandwidth. The objective of SimB is to mend two or more time slots such that a larger time slot can be emulated. Hence, when a single time slot cannot accommodate the retrieval of an object, it is possible to apply SimB repeatedly so that two or more time slots are mended to accommodate the display of a single object. The other memory buffering mechanism, VarB, takes a more general approach. Its objective is to use the variable server bandwidth with memory to emulate a constant bandwidth for the display of the objects. Therefore, it treats the system load as a continuous function over time, and it uses concepts similar to the pipelining concept presented in Ghandeharizadeh et al. (1995). In this article, we present SimB mechanism as a simple way to use the available memory at the client side (or at the server side) to reduce the delays and improve system performance.

To illustrate the SimB mechanism, assume a system is loaded such that there are two time slots of length 30 seconds starting at times t = 0 and t = 40 seconds (Figure 3). Moreover, assume that these time slots can satisfy the bandwidth requirements of object o_x, which is 60 seconds in length. Without memory buffering, it is obvious that o_x cannot be scheduled using the two time slots. However, using the SimB mechanism, it is possible to mend the two 30-second time slots such that a longer 60-second time slot is emulated. That is, starting the retrieval of half of object o_x in the first time slot, and the retrieval of the second half of the object in the second time slot (Figure 3). To ensure the uninterrupted display of o_x, it is necessary to have 10 seconds of the o_x prefetched into the memory prior to the start of its display (Figure 3 and Figure 4). The amount of memory required to mend any two time slots is dependent on the bandwidth requirement of the object ($c(o_x)$) and the length of the gap being mended (T_{Gap}): $MemBuff_{(SimB)} = c(o_x) \times T_{Gap} / 8 \times R_{cm}$ Mbytes. Therefore, if $c(o_x) = 0.01$, $R_{cm} = 1000$ Mbps, and $T_{Gap} = 10$ seconds, then $MemBuff_{(SimB)} = 12.5$ Mbytes. Note that SimB is only applicable if the resulting latency time is tolerable by the user (i.e., consistent with presentation flexibility).

SimB is a simple mechanism that can be used in mending two time slots into a longer time slot; however, in the general case, it is necessary to apply this mechanism repeatedly such that the object fits in the emulated time slot. It is the responsibility of the scheduler to apply this mechanism when necessary to improve system performance. The scheduler looks at the server load, a retrieval plan, and the maximum available memory as inputs. Subsequently, it produces a retrieval schedule such

Figure 3. Object retrieval and display

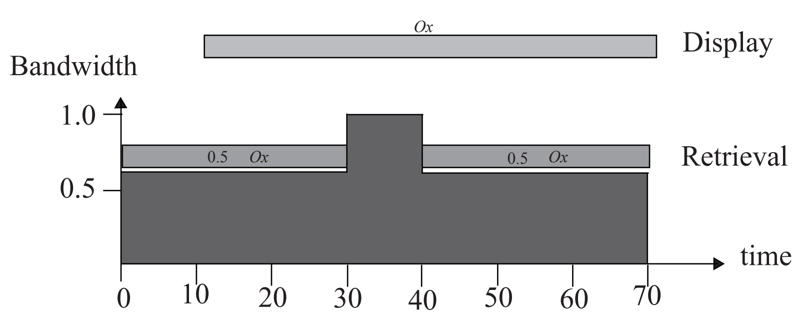
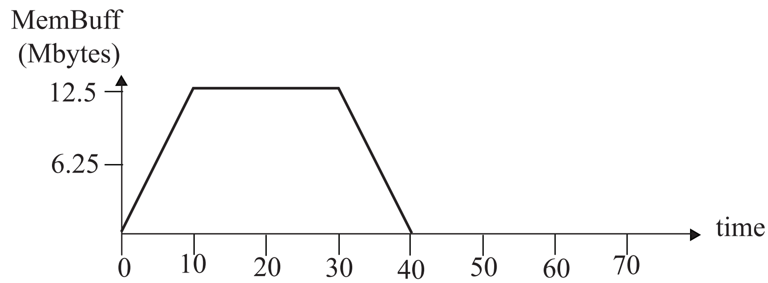


Figure 4. Memory requirements when using SimB



that the query script flexibilities and the maximum memory requirements are not violated.

Performance Evaluation

In this section, we report on the results of our experiments on Best Retrieval Plan (plan with the highest confidence) with three different planning techniques, Just In Time, Compact, and Before Time:

- **Just in time (JIT):** Each request in the script is scheduled to be shown at the minimum required time (i.e., the first request is scheduled to be shown after adding the minimum latency time required by the user to the arrival time of the script, while the rest of the requests are scheduled to be shown after adding minimum delay to the ending shown time of its previous request).
- **Compact:** Each request in the script is scheduled to be shown at the arrival time without adding any time (i.e., the first request is scheduled to be shown after adding the minimum latency time required by the user to the arrival time of the script, while the rest of the requests are scheduled at the ending shown time of its previous request).
- **Before time:** This technique is the same as Compact where each request in the script is scheduled to be shown before the required time by a specific time (minimum or maximum delay time) (i.e., the first request is scheduled to be shown after adding the minimum latency time required by the user to the arrival time of the script, while the rest of the requests are scheduled before the ending shown time of its previous request (by minimum or maximum delay time)).

The percentage of missed requirements (flexibilities) will be considered as performance metric. We implemented a simulation model to test the performance of the system when different planning techniques are considered with different system utilization.

Simulation Model

For the purposes of this evaluation, we assumed a streaming media server with a constant transfer rate. All the objects in the media server are MPEG-2 video clips with 6 Mbps bandwidth requirement and the size of objects is random and varies from 10 seconds to 6 minutes. We have three different users with different ranges of flexibilities: *Relaxed*, *Moderate*, and *Busy*. Each of the users has a different set of values for their flexibilities parameters such as: *Minimum latency*, *Maximum latency*, *Minimum delay*, *Maximum delay*, *Minimum presentation length*, *Maximum Presentation length*, and *Confidence*. We employed a Poisson distribution for script arrivals to generate variable load on the server depending on the target utilization where we want to test the performance of our system in order to find the best technique to be used by the optimizer. For each script size, we generated 10000 scripts normally distributed among the three users and with random objects size. The simulation model was implemented in C language a Pentium 4 PC.

Experimental Results

Table 2 and Table 3 show the performance results using the three different planning techniques (i.e., Just In Time, Compact, and Before Time), and using a simple scheduling technique with a target system utilization of 98%. Table 2 shows the results when the system is without buffering, while Table 3 shows the results when the system has a buffer.

We can conclude the following from Table 2 and Table 3:

- Percentage of minimum startup time missed deadlines: By the definition, the minimum startup time cannot be missed in the three scheduling techniques where the first object of the scripts is always scheduled to meet this requirement.
- Percentage of maximum startup missed time deadlines: Because of the high utilization of the system, most of the scripts miss the maximum startup time required in the three scheduling techniques.
- Percentage of minimum delay missed deadlines: Because most of the scripts missed the maximum startup time (and maximum delay time) this leads to some requests missing the minimum delay (i.e., if we have a script with three objects to be retrieved from the SM, and the Optimizer chooses and schedules the plan. If the first object misses the maximum startup, then there will be a high probability that the next request misses the minimum delay time. And the same happens if the second request misses the maximum delay (there will be a high probability that the

Table 2. Performance of JIT, Compact, Before planning techniques using simple scheduling technique with 98% utilization and without buffering.

Planning Technique	**Average Actual Utiliza-tion**	**Missed Deadlines**								**Required Buffer (Mbit)**
		Min Startup	Max Startup	Min delay	Max delay	Min Pres.	Max Pres.	total	Script	
JIT	97.16	0.00	0.95	0.34	0.61	0.05	0.11	0.43	1.00	17000
Compact	97.28	0.00	0.95	0.45	0.51	0.09	0.07	0.44	1.00	24656
Before	97.31	0.00	0.95	0.60	0.36	0.16	0.03	0.44	1.00	34684

Table 3. Performance of JIT, Compact, Before planning techniques using simple scheduling technique with 98% utilization and with buffering.

Planning Technique	**Average Actual Utiliza-tion**	**Missed Deadlines**								**Required Buffer (Mbit)**
		Min Startup	**Max Startup**	**Min delay**	Max delay	Min Pres.	Max Pres.	total	Script	
JIT	97.16	0.00	0.95	-	0.61	-	0.11	0.29	65	-
Compact	97.28	0.00	0.95	-	0.51	-	0.07	0.22	55	-
Before	97.31	0.00	0.95	-	0.36	-	0.03	0.14	42	-

third request misses the minimum delay)).

- Percentage of maximum delay missed deadlines: Because of the high utilization of the system there are some misses in the maximum delay time required in the three scheduling techniques.
- Percentage of minimum presentation time missed deadlines: We have this percentage of missing minimum presentation time requirement because of the missing minimum delays.
- Percentage of maximum presentation time missed deadlines: We have this percentage of missing minimum presentation time requirement because of the missing minimum delays.
- Percentage of total missed deadlines: This is the percentage of the total missing requirement (minimum and maximum startup, delay, and presentation).
- Percentage of scripts has at least one missed deadline: All the scripts that have at least one missed deadline.

While the three different planning techniques have the same average actual utilization (close to the targeted system utilization of 98%), they differ in the percentages of missed deadlines. JIT planning technique has the lowest minimum delay missed deadlines, while *Before* time planning suffers the most from missed deadlines because of missing minimum delay requirement. However, the opposite is true when it comes to missing maximum delay requirement. Before time is the best planning technique, while JIT is the worst. With buffering, we implement a buffer within the system; therefore, we remove the missing deadlines in minimum delay and minimum presentation (see the results in Table 3).

In Figure 5 and Figure 6, we show the required buffer size and system utilization as the system processed in time and receives more jobs to schedule. If we ignore the two areas that are required to warm-up and to cool-down the system, we can see from Figure 5 that the required buffer fluctuates and has a maximum size of 2000 Mbits. This is due to the fact that as new jobs are required to be scheduled, old jobs finish processing. Figure 6 shows that the system was almost always fully utilized as projected.

In Figure 7, we compare the buffer size required for the three different planning techniques as a

Figure 5. Buffer size vs. time period (simple scheduling with 98% target utilization)

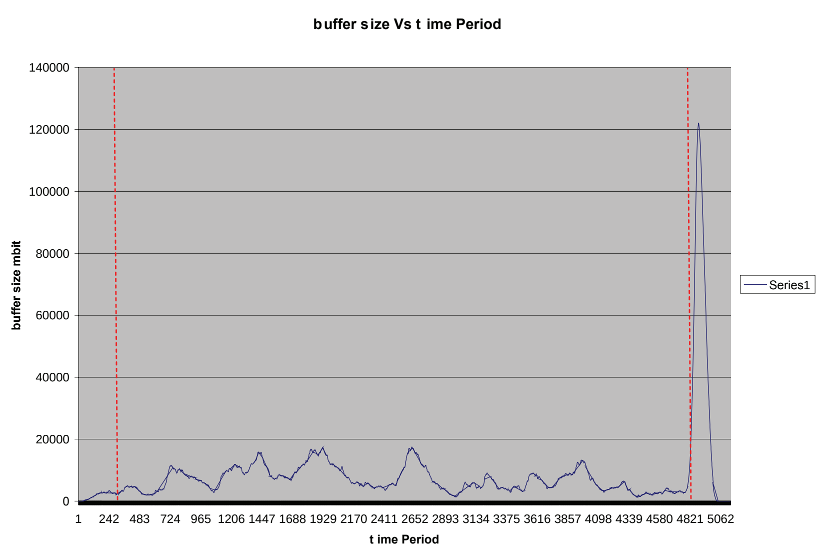


Figure 6. System utilization vs. time period (simple scheduling with 98% target)

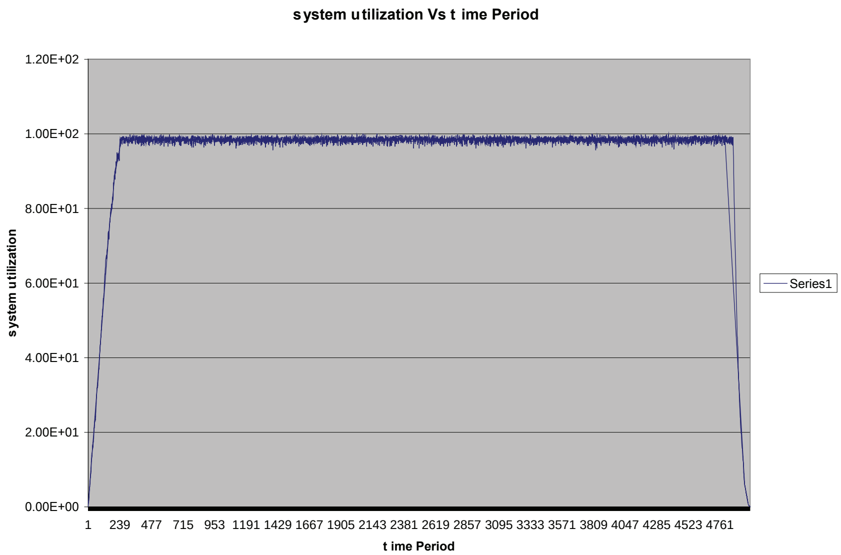
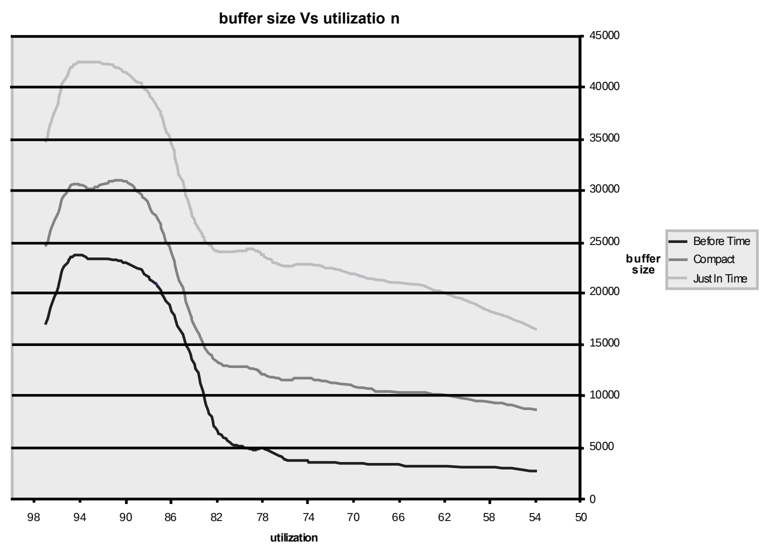


Figure 7. Buffer size vs. utilization (simple scheduling with 98% target utilization)



function of the required system utilization. If we ignore the two areas that are required to warm up and to cool down the system, in general, the three different planning techniques behave exactly the same. As the required system utilization increases, the required buffer size increases. However, for the same system utilization value, JIT planning techniques requires the largest buffer size, while Before time technique requires the least buffer size. This is due to the fact that with the Before time technique, each request is scheduled to be shown before the required time by a specific time (minimum or maximum delay time), and hence, less buffer is required. In the next experiment, we investigated the role of memory in retrieval optimization using Simple Memory Buffering Mechanism, SimB. We treated the system load on the server as a discrete function over time.

Table 4. Simulation results without SimB

No. of Objects	Two level optimization improvement (or degradation) over worst/avg cases				$T_{Response}$ improvement (or degradation) over worst/avg cases	
	Primary optimization metric	Secondary optimization metrics				
n	$T_{Response}$	$T_{Latency}$	Δ_{Avg}	Δ_{Var}	***SOF*** **Heuristic**	***LOF*** **Heuristic**
3	36% / 22%	93% / 87%	0% / (-91%)	4% / (-74%)	0% / (-22%)	36% / 22%
4	52% / 33%	75% / 57%	11% / (-56%)	27% / (-20%)	11% / (-26%)	32% / 4%
5	47% / 27%	57% / 36%	27% / (-45%)	36% / (-11%)	24% / (-4%)	34% / 10%
6	36% / 22%	42% / 26%	28% / (-74%)	38% / (-18%)	22% / 4%	24% / 7%

Table 5. Simulation results with SimB (using 4 Mbytes of memory per presentation)

No. of Objects	Two level optimization improvement (or degradation) over worst/avg cases				$T_{Response}$ improvement (or degradation) over worst/avg cases	
	Primary optimization metric	Secondary optimization metrics				
n	$T_{Response}$	$T_{Latency}$	Δ_{Avg}	Δ_{Var}	***SOF*** **Heuristic**	***LOF*** **Heuristic**
3	30% / 16%	47% / 29%	2% / (-63%)	8% / (-95%)	30% / 13%	5% / (-14%)
4	43% / 24%	54% / 34%	4% / (-55%)	1% / (-97%)	26% / 2%	11% / (-18%)
5	40% / 24%	48% / 31%	4% / (-56%)	3% / (-97%)	24% / 4%	17% / (-5%)
6	38% / 22%	46% / 30%	8% / (-82%)	7% / (-90%)	20% / 2%	18% / 0%

We varied the number of objects to be scheduled from three to six objects, and applied a two level optimization once using SimB and another time without the use of SimB. When using SimB, we assumed that the presentation could have a total of 4 Mbytes. Table 4 shows simulation results without using SimB, while Table 5 shows simulation results with SimB.

CONCLUSION

In a previous study (Shahabi et al., 1998), we defined a query-script for the SM retrieval optimizer. Using the query script, the optimizer defines a search space that consists of all the correct retrieval plans. A retrieval plan is correct if and only if it is consistent with the defined flexibilities and requirements. The optimizer also defines a cost model to evaluate the different retrieval plans. The retrieval plans are then searched (either exhaustively or by employing heuristics) to find the best plan, depending on the metrics defined by the application. Using a simple simulation model and simple search algorithms, we were able to show that the optimizer can improve system performance significantly when the system load is moderate. In this article, we investigated the following. First, we investigated the theoretical bounds on the size of the search space and the search time. We concluded that both problems are NP-Hard. Second, we designed efficient algorithms (Algorithms A & B) to define the search space and find a good retrieval plan (i.e., search algorithm). Third, we discussed the impact of caching at the user terminal on the system performance. Our experimental results showed the effectiveness of our proposed model, algorithms, and techniques in generating near optimal retrieval plans for scheduling and displaying SM objects. The personal agent was able to generate good query scripts, based on user query, user profile, and session profile. We plan to further investigate the design of SM integrators and collectors for a distributed environment, and further enhance the personal agent.

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ENDNOTES

1 These temporal relationships can be defined by the user or the application.

2 The number of I/O's to retrieve continuous media objects from the CM server is fixed; however, different retrieval plans influence retrieval contention at the server. *Prime* finds a retrieval plan such that it minimizes contention at the CM server, in order to improve system performance.

3 This threshold could be specified by user or by system.

APPENDIX

Consider the following notations:

- RP [2, n]: A 2D array, where RP[1, j]($\forall$j: 1 ≤ j ≤ n) fives the position of object j (o_j) in the retrieval plan (p) (i.e., Pos(o_j, p)), and RP [2, j] gives the confidence value of displaying object o_j in the Pos(o_j, p)th position in the retrieval plan (i.e., α(o_j, Pos(o_j, p)))
- OPC [n, n] A 2D array, where OPC [i, j] ($\forall$i: 1 ≤ i, j ≤ n) specifies the confidence of displaying o_i at position j in p (α(o_i, j))
- SOPC [n, n]: A 2D matrix, where each column of the matrix (i.e., elements from SOPC [1, i]…SOPC [n, i], $\forall$i: 1 ≤ i ≤ n) contains the objects ordered descendingly by their confidence level value of appearing at position i in plan p (i.e., ordered descendingly by their α(o_j, i) values).
- SAP [n]: An array that contains n pointers to the n columns of SOPC [n, n], where SAP [i] ($\forall$i: 1 ≤ i ≤ n) points to the next element that we want to check/examine if it can be scheduled at postion i in p or not.

Algorithm A

1. Initialize all RP[2, n] entries to zeros;
   % We do not know the display positions of the objects and their confidence values.
   % The algorithm terminates when all positions are filled
   %(i.e., RP[1, i] ≠ 0 and RP[1, i] ≠ RP[1, j]: $\forall$i: 1 ≤ i, j ≤ n and i ≠ j

2. Apply a sorting algorithm for each column of the OPC [n, n] matrix and store the sorted objects in the corresponding column in matrix [n, n];

3. Initialize all SAP [n] entries to ones;
   % The ith pointer is pointing to the first element of the n sorted objects at
   % position i of the display order (the element with the highest confidence value
   % to appear to position i).

4. Create a set S that contains n elements that represents all the positions at which the objects will be displayed;

5. Randomly extract an element from S that represents position pos;

6. Pick the first element from the sorted list at pos (i.e., object (o_c) at SOPC [1, pos];
   % Assume that o_c is o_j and pos is i.

7. While S is not empty do
   {
   % Next we want to check if o_j is already scheduled at another position other than
   % i or not? If it is scheduled at another position, does it have a higher
   % confidence value to be scheduled at position i or the other position?

Case 1 Object o_j is not scheduled at any other position (check if RP[1, j] = 0)

a) RP[1, j] = i; (schedule o_j at position i)
b) RP[2, j] = OPC [j, i]; (save the confidence value of scheduling o_j at position i)
c) SAP [i] = SAP [i]+ 1; (the pointer points to the next element with the hightest confidence value after o_j to be scheduled at position i)
d) Randomly extract an element from S that represents that represents a new position pos

Case 2 Object o_j was scheduled at another position (i.e., RP[1, j] ≠ i) but with a higher confidence value (RP[2, j] > OPC [j, i]). Then we have to look for another element to be scheduled at position i (look at next element in SOPC [SAP [i], i])
a) SAP [i], = SAP [i] + 1; (Then we have to look for next element with a lesser confidence value to be scheduled at postion i)
b) Object o_j is now the new object to be scheduled at the new postion SAP [i];
c) Continue; (The same algorithm will re-apply, except now we have another scheduling problem; i.e., we now want check if we can schedule the new object o_j at the new position i)

Case 3 Object o_j was scheduled at another position (i.e., RP[1, j] ≠ i) but with a lower confidence value than if it gets scheduled at position i (i.e., RP[2, j]< OPC [j, i]). Hence, we need to schedule object at position I and look for another object (which is at SAP [RP[1,j]]) to be scheduled at position RP[1,j].
a) Temp-Position = RP [1, j]; (temporarily save the position where o_j was scheduled)
b) RP[1, j] = i; (the new position for o_j is i)
c) RP[2, j] = OPC [j, i]; (the new confidence value for scheduling o_j at postion i)
d) SAP[i] = SAP [i]+1; (the pointer points to the next element with the highest confidence value after o_j to be scheduled at position i)
e) SAP[Temp - Position] = SAP[Temp - Position] + 1; (the pointer points to the next element (o_{temp}) with the highest confidence value after o_j in the old positioin to be scheduled at the old position)
f) Object at o_{temp} is now the ne object to be scheduled at the new postion Temp – Position;
g) Continue; (The same algorithm will re-apply, except now we have another schedulig problem; i.e., we now want check if we can schedule the new object o_{temp} at the new position Temp – Position)

}

Algorithm B (inputs: level (*l*), position (*fp*))

fp: is the position at which we want to fix the schedule of an object, for 1 ≤ fp ≤ n).

l: is the level that we want to fix the schedule of an object, for 1 ≤ l ≤ n).

1. Initialize all RP[2, n] entries to zeros;
   % We do not know the display positions of the objects and their confidence values.
   % The algorithm terminates when all positions are filled
   % (i.e., RP[1, i] ≠ 0 and RP[1, i] ≠ RP[1, j]; ∀i: 1 ≤ i, j ≤ n and i ≠ j)

2. Apply a sorting algorithm for each column of the OPC [] matrix and store the sorted objects in the corresponding column in matrix SOPC [n, n];

3. Initialized all SAP [n] entiries to ones except for SAP [fp] that should be initialized and locked (never changes) to l;
   % The ith pointer is pointing to the first elelment of the n sorted objects at
   % position i of the display order (the element with the highest confidence value
   % to appear to position i), except for the fpth pointer is pointed to the lth
   % element (o_l)(with the lth confidence value to spear to position fp)

4. Create a set S that contains n-1 elements that represents all the positions at which the objects will be displayed, except position fp;

5. Randomly extract an element from S that represents positions pos;

6. Pick the first element from the sorted list at pos (i.e., object (o_c) at SOPC [1, pos]
   % Assume that o_c is o_j and pos is i.

7. While S is not empty do
   {
   % Next we want to check if o_j is already scheduled at another position other than
   % i or not? If it is scheduled at another position, does it have a higher
   % confidence value to be scheduled at position i or the other position?

Case 1 object is not scheduled at any other position (check if RP[1, j] = 0)

a) RP[1, j] = i; (schedule o_j at position i)
b) RP[2, j] = OPC [j, i]; (save the confidence value of scheduling o_j at position i)
c) SAP [i] = SAP [i] + 1; (the pointer points to the next element with the highest confidence value after o_j to be scheduled at position i)
d) Randomly extract an element from S that represents a new position pos

Case 2 Object o_j was scheduled at another position (i.e., RP[1, j] ≠ i) but with a higher confidence value (i.e., RP[2, j] > OPC[j, i]). Then we have to look for another element to be scheduled at position i (look at next element in SOPC [SAP [i], i])

a) SAP[i] = SAP [i] + 1; (Then we have to look for next element with a lesser confidence value to be scheduled at position i)
b) Object o_j is now the new object to be scheduled at the new postion SAP [i];
c) Continue; (The same algorithm will re-apply, except now we have another scheduling problem; i.e., we now want check if we can schedule the new object o_j at the new position i)

Case 3 Object o_j was scheduled at another position (i.e., RP[1, j] ≠ i) but with a lower confidence value than if it gets scheduled at postion I (i.e., RP[2, j] < OPC[j,i]). Hence, we need to schedule object o_j at position i and look for another object (which is at SAP [RP[1, j]]) to be scheduled at postion RP[1, j]. However, if $o_j = o_l$, then look at the next element (object at position SAP [i] + 1 to schedule at position i

$o_j = o_l$ a) SAP [i] = SAP [i] + 1; (Then we have to look for next element with a lesser confidence value to be scheduled at position i)

b) Object o_j is now the new object to be scheduled at the new position SAP [i];
c) Continue; (The same algorithm will re-apply, except now we have another scheduling problem; i.e., we now want check if we can schedule the new object o_j at the new position i)

$o_j \neq o_l$ a) Temp-position = RP [1, j]; (temporarily save the position where o_j was scheduled)
b) RP[1, j] = i; (the new position for o_j is i)
c) RP[2, j] = OPC [j, i]; (the new confidence value for scheduling o_j at position i)
d) SAP [i] = SAP [i] + 1: (the pointer points to the next element with the highest confidence value after o_j to be scheduled at position i)
e) SAP [Temp – Position] = SAP [Temp – Position] + 1;(the pointer points to the next element (o_{temp}) with the highest confidence value after o_j in the old position to be scheduled at the old position)
f) Object at o_{temp} is now the ne object to be scheduled at the new position Temp – Position;
g) Continue; (The same algorithm will re-apply, except now we have another scheduling problem; i.e., we now want check if was can schedule the new object o_{temp} at the new position Temp – Position)

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Chapter XVI
How Did They Study at a Distance?
Experiences of IGNOU Graduates

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ABSTRACT

The question why some learners successfully study through distance mode and others do not is increasingly becoming important as open and distance learning (ODL) has come to occupy a prominent place in providing higher education to large segments of the population in India. With barely 1112 students studying through distance mode in 1962, the number has crossed 2.8 million in 2006. This article presents the findings of an empirical research study conducted to investigate the study habits of successful distance learners of the India Gandhi National Open University (IGNOU). Every year, nearly 70,000-80,000 pass out of IGNOU. What strategies were adopted by these diverse groups, what media they utilized, and what modes of support they prefered are some of the major issues addressed in this study.

INTRODUCTION

India has emerged as one of the largest distance education systems in the world, with more than 2.8 million people studying through distance mode, which is equal to 24% of the total students in higher education in the country. The Ministry of Human Resource Development has assigned the target to distance education institutions of enrolling 40% of the total students in higher education by the end of the Tenth Plan period in 2007 (IGNOU, 2006).

Today, the Indian ODL system comprises a National Open University, 12 State Open Universities, and 106 dual mode conventional universities. IGNOU alone contributes to 10% of the total enrollment in higher education in the country (Srivastava & Ramegowda, 2006). In fact, it can be said that "IGNOU is leading a silent revolution in the higher education system of the country" (Dikshit, IGNOU, 2005, p. 4). It has emerged as the largest international education institution in 2006, with 1.4 million students on its rolls from India and 32 other countries (IGNOU, 2006).

Like other open universities of the world, IGNOU has adopted a multimedia approach to instruction. The learning (print material) package is based on instructional design and comprises printed materials (Self-learning materials), audio and video programmes, assignments, and limited face-to-face counseling sessions. In some professional programmes, practicals/ hands-on-experience and project work are also included.

To give more weightage to the component of interactivity in the learning process, IGNOU in the 1990s introduced teleconferencing through downlink stations and interactive radio counseling through radio and FM stations throughout the country (Manjulika & Reddy 2000). Since 2002, there has been an extensive use of the Internet for providing instruction in a few programmes, but mainly for supporting learners. Through a dedicated satellite for education, satellite-based education, namely EduSat, has commenced its operations since 2005. It has made two-way videoconferencing possible through a network of receiving-end terminals all over India.

Since IGNOU's students are spread all over the country, it has set-up, and since its inception in 1985, it has a network of Learner Support Centres comprising Regional Centres (RCs), and Study Centers (SCs) located at major cities, towns, and even in some rural and remote areas of the country.

The details of IGNOU's increasing student enrolment, staff strength, support services network, academic programmes, and so forth, is given in Table 1.

Table 1. An overview of IGNOU's growth

Head	2001	2002	2003	2006
Programmes on offer **Courses on offer**	62 673	72 754	75 820	125 1000
Regional Centres **Study Centres** **Subregional Centers** **Overseas Centres**	41(13) 650(17) …. ….	46(13) 798(21) …. ….	48 1081 …. 23	58 1409 6 37
Students enrolled (in 000s) **Students on rolls (cumulative) (in 000s)** **Students awarded (degrees/ diplomas/certificates)**	304,681 750.873 62,369	301,724 804.271 76,704	316,547 1013.631 81,931	429542 1433490 75174
<u>Faculty Staff:</u> **Academic Counsellors (at SCs)** **Teachers/Academics** **Administrative staff**	20364 257 875	20500 269 874	25,500 300 1415	48000 325 1137
No. of audios **No. of videos**	1109 1246	1175 1445	1235 1520	8000 2000

Today, IGNOU has a cumulative enrolment of 1400 thousand students. The success rate is increasing annually. Nearly 600 thousand IGNOU learners have been awarded degrees, diplomas, and certificates to date (IGNOU, 2006).

Rationale For Study

By nature, distance education (DE) programmes offered by IGNOU, like any other Distance Teaching University, rely heavily on the individual learners' abilities to manage and control their personal and situational circumstances, and remain motivated in order to achieve success. By "success," it is implied that the programme of study had been successfully completed. There are definitely some factors which contribute to the successful completion of a programme. While studies of distance learners have focused on problems and barriers faced by distance learners, few studies have focused upon individual learning strategies and study habits, and preferred modes of support, including the instructional design adopted by the institution in relation to their success.

However, only a few studies on Indian distance learners have focused on the relationship of learner characteristics to success in DE, namely those conducted by Arun (1990), Das (1992), Kumar (1996), Villi(1999), Taplin (2000), and Biswas (2001).

These studies have focused on the predisposing characteristics of learners and the institutional variables that contributed to their success (Arun, 1990). Biswas (2001) and Das (1992) have also analyzed the approaches to studying at a distance and their study habits.

Arun (1990) and Das (1992) did a comparative study of learners enrolled in a Dual-mode university. They did statistical comparison of conventional learners and distance learners and proved that the former had performed better than the latter.

Villi (1999) examined the study habits of distance learners enrolled at Madras University, which is a Dual-mode university. He focused on their study strategy just before and during the exams.

Of these studies, only three pertain to IGNOU learners. Kumar (1996) presented the attitudes of IGNOU learners in general toward DE and related it to their academic performance. Taplin's (2000) study focused on the women learners. She presented a few case studies of successful IGNOU women learners and investigated their empowerment through DE. Biswas' study (2001) was limited to a small sample of learners, which is not representative of IGNOU learners who are spread throughout the country.

In the absence of substantial research in this area, particularly in the context of IGNOU, which is a Mega Open University enrolling more than 350 thousand, with nearly 70,000-80,000 successfully completing their programmes of study every year. The researcher was inspired to do a study on the study strategy of successful IGNOU learners, which would not only give an insight about what these successful learners have done to succeed, but also about the media and support services they utilized during their course of study. Hence, the study was conducted.

Purpose

The purpose of this study was to examine the relationship of the learners' perception of the IGNOU's instructional and support systems as well as their own study habits that contributed to their successful completion of the programmes of study. The study addressed four main research questions:

- Who participates and succeeds in distance education?
- How do distance learners of IGNOU study?

- Which instructional inputs contributed to the completion of their programme of study?
- What were the modes of support preferred by these successful learners?

Methodology

Universe and Sample

The empirical research study was accomplished by surveying the successful graduates of IGNOU who attended the 13th Convocation held at New Delhi and 3 Regional Centres viz, Bhubaneshwar, Ranchi, and Cochin, in March 2002. Graduates of traditional programmes like Bachelor Degree Programmes (BDP), namely Bachelor of Arts (BA) and Bachelor of Commerce (B.Com), and professional programmes, like Bachelor of Library Sciences (BLIS) and Bachelor of Computer Applications (BCA), were selected as the sample for the study.

Thus, the sample selected included learners from different backgrounds, diverse educational qualifications, professions, experiences, regional locations, and ages, as the entry requirements varied from programme to programme. These are also the programmes that attract more learners as compared to other programmes.

In 1989-1990, 75% of the students were enrolled in BDP (i.e., BA and BCom programmes). Today, barely 25% are enrolled in these programmes. On the other hand, nearly 60% of the students are enrolled in the Computer (40%) and Management (20%) programmes put together. This trend has been noticeable ever since IGNOU introduced the MBA programme, and even more so with the introduction of Computer programmes. This shift is in tune with the national demand for more Management and Computer professionals.

Tools Developed

A questionnaire was developed by the researchers, which was pretested and modified before being administered to the graduates who came to collect their degrees in person at the above mentioned locations.

The questionnaire distributed comprised two major sections, a student profile which had 16 items covering all the background characteristics of distance learners, and Study Habits, which had 28 items covering various aspects pertaining to the strategy adopted for studying at a distance, media utilized for studying, and usefulness of support provided by IGNOU. The questionnaire comprised both structured and open ended questions

Data Collection and Analysis

Questionnaires were mailed to the selected 967 graduates. Thereafter, interviews were conducted at random, with 10 of the respondents from each programme based in Delhi (where the researcher is based) in order to get a deeper insight. The SPSS package was used for analysis of data.

Of the 967 graduates who were sent questionnaires, 278 returned them within a few months and 50 questionnaires were returned back as undelivered mail. Hence, the final sample of this study constituted 917 students. The overall response rate was 34%, which was quite satisfactory. For details, refer to Table 2.

Profile of the Respondents

The data presented in Table 2 reveals that 54.3% of the respondents were from Delhi as compared to other regions, even though an attempt was made to avoid the Delhi bias. This was probably because Delhi covers two regions (Delhi 1 and Delhi 2) which not only enroll a large number of students every year, but also the number who pass out from this region dominate in terms of actual numbers.

Males dominated and accounted for 72.3% of the respondents. Women were mostly enrolled in the traditional programmes like BA and BCom

Table 2. Response rate and distribution of sample: programme-, region-, and gender-

Prog.	Qs. sent	Returned	NR	Delhi Region	Ranchi Region	BhubaRegion	Kochi Region	Male	Female
BLIS	176	56	6	32	2	14	8	48	8
BCA	197	72	20	39	3	18	12	70	2
BDP	594	150	24	84	22	30	14	83	67
ALL	967	278	50	151	32	52	43	201	77

Source: Field Data
NR: Not Responded

Table 3. Age of the respondents

Program	**Age(in years)**				
	20-25	**26-35**	**36-45**	**46+**	**NS**
BLIS	41.7	44.4	5.6	NIL	8.3
BCA	86.0	12.0	NIL	NIL	2.0
BDP	43.5	37.1	11.3	6.5	1.6
ALL	53.3	32.4	7.6	3.8	2.9

Source: Field Data
NS: Not Specified

that constitute BDP, although 13% of the women had successfully completed BLIS (10.4%) and BCA (2.5%) programmes.

Age-wise data presented in Table 3 reveals that a majority of the respondents (53.3%) were in the 20-25 years age group and barely 3.8% were above 46 years of age.

BCA learners (86%) constituted the major bulk of young learners in the below 25 years age group. It is noteworthy that none of the BCA learners were above 35 years of age and BLIS above 45 years.

The employment status of the respondents was as follows: 41% were full time employees, 7.1% part-time employees, 6.7% were self-employed, 16.1% were unemployed, and 28.1% stated that they were full-time learners (refer to Table 4).

Mainly, BCA learners had more access to computers than BDP and BLIS learners. Of the traditional media, TV was the most accessible electronic medium for all the learners. For details, see Table 5.

DISCUSSION

The data collected through questionnaires was subjected to programme-wise analysis as well as profile-wise analysis, taking into consideration

Table 4. Employment status of respondents

Program	**Full-time**	**Part-time**	**Self-employed**	**Unemployed**	**Full time learners**	**NS**
BLIS	27.8	19.4	5.6	28.3	18.9	Nil
BCA	26.0	2.0	6.0	28.0	38.0	Nil
BDP	58.8	5.6	7.3	14.6	12.1	1.6
ALL	41.0	7.1	6.7	16.1	28.1	1.0

Source: Field Data

Table 5. Respondents' access to media

Prog.	Comp.	Internet	TV	VCR	Radio	A/V Tapes	Library	None	NS
BLIS	41.7	11.1	55.6	16.7	19.4	5.6	2.8	Nil	16.7
BCA	92.0	70.0	60.0	30.0	42.0	10.0	Nil	Nil	2.0
BDP	28.2	20.2	47.6	8.9	21.8	4.8	Nil	3.2	30.6
ALL	45.7	30.5	51.9	15.2	26.2	6.2	0.5	1.9	21.4

Source: Field Data

factors like gender, age educational background, employment status, income, and so forth, as all these factors in one way or another influence the study habits and learning styles adopted by distance learners. Detailed analyses covering various aspects have been presented below.

Objective of Studying at IGNOU

The majority of the BCA students (78%) responded that their purpose of study was to get a degree. Interestingly, students from BDP (67%) and BLIS (66%) responded that their objective of study was promotion/career advancement. However, overall 69.5% studied for career advancement, 23.3% students mentioned that their purpose of study was to get a degree, 18.6% also expressed that they were keen to enrich their knowledge skills, 3.3% to get job, and 3.8% for enjoyment purposes (refer to Table 6 for details). Those enrolled for enrichment were mostly women and the majority of them were above 40 years of age.

Use of Media

Interestingly, none of them preferred to adopt any innovations in their learning process, not even technological interventions provided by IGNOU. On the contrary, they were very passive learners, as they mainly relied on the printed Self-learning materials (SLMs). A majority of them (89.8%) found the printed materials the most useful, and other media like teleconferencing (15.2%), video tapes (2.9%), audio tapes (2.9%), and interactive radio counseling (6.7%) was hardly found useful by the learners, which is indicated by the small percentage of learners who found them useful (See Table 7). It is noteworthy that 73.8% found

Table 6. Objective of studying at IGNOU

SN	Item	All	Programmes			Age				
		All	BLIS	BCA	BDP	20-25	26-35	36-45	46-55	NS
1	Enjoyment	3.8	2.8	10.0	1.6	4.5	2.9			16.7
2	Enrichment	18.6	11.1	22.0	19.4	19.6	11.8	18.8	62.5	19.3
3	Career Enhancement	69.5	66.7	12.0	66.9	68.8	73.5	68.8	50.0	66.7
4	Getting a Degree	23.3	19.4	78.0	29.0	22.3	27.9	18.8	12.5	16.7
5	Getting a Job	3.3	5.6	2.0	3.2	2.7	5.9			
6	Not Specified	0.5	2.8			1.9				
7	All	100	100	100	100	100	100	100	100	100

Table 6. continued

SN	Item	Gender		
		Male	Female	NS
1	Enjoyment	3.3	5.2	
2	Enrichment	15.5	50.0	
3	Career Enhancement	68.0	74.1	50.0
4	Getting a Degree	25.3	19.0	
5	Getting a Job	2.7	5.2	
6	Not Specified	1.7		
7	All	100	100	100

Source: Field Data

Table 7.

Item	All	Programmes		
	All	BLIS	BCA	BDP
Printed material provided by IGNOU	87.8	80.6	86.0	85.5
Discussions in counseling sessions	51.0	61.1	38.0	53.2
Lectures by counselors	53.8	58.3	62.0	49.2
Attending practicals	34.8	58.3	54.0	20.2
Reference books (library)	51.0	63.9	70.0	39.5
Assignments	73.8	66.7	78.0	74.2
Private tutors	12.9	13.9	24.0	8.1
Internet-based resources	12.4	8.3	28.0	7.3
Audio tapes	2.9	-	-	4.8
Video tapes	2.9	2.8	-	4.0
Radio counseling	6.7	2.8	-	10.5
Teleconferencing	15.2	11.1	6.0	20.2
Other study guides.	14.2	11.0	10.0	16.9
All	100	100	100	100

Source: Field Data

the assignments followed by lectures given by academic counselors (53.8%), library facilities (51%), and discussions in counseling sessions (51%) very useful in their learning endeavour. Barely 12.4% found Internet-based resources and study guides (14.2%) useful in their learning endeavour. Private tutorials/coaching was patronized mainly by the BCA learners (24%), who were young and mostly full-time learners who were unemployed. Also, BCA was a tougher course, with a demand for hands on training, which was provided for limited hours at the Study Centre, which was not enough for the learners to master the subject. Radio counseling and teleconferencing were mainly utilized by BDP learners.

Place of Study

More than 95% expressed that they studied from their home because that was the most convenient place in terms of facilities and timings, taking into consideration the nature of their job, domestic demands, and so forth. Reading at libraries was noticed more in BLIS (81%), compared to BCA (68%) and BDP (48%), which really coincides with their nature of jobs, as all BLIS learners were employed at libraries.

Learners from BCA (58%) had expressed that they used a "friend's house" as a study place because many of them were full-time learners between 20-25 years of age. Students studying from tuitions/private institutions for additional coaching were noticed mainly from BCA because the programme involved lots of "hands-on-training" and separate practical final examinations, which normally would have made learners go for additional coaching for theory and practice.

Region-wise analysis revealed that there was not much variation with regard to home-based study. However, variations were noticed with regard to study at "office/work place" (Delhi 38%, Bhubaneshwar 42%, Cochin 24%, and Ranchi 13.5%) (Refer to Table 8).

Input of Study Hours

The respondents can be divided into four categories, as far as the number of study hours put in by them per week, as 26.2% of them put in 1-5 hours per week, 34.3% 6-10 hours, 19.0% 11-15 hours, 12.9 % 16-30 hours, and 6.7% more than 30 hours per week.

Gender-wise analysis revealed that males had put in more hours per week compared to women. For women, although they might be working outside their homes, the major responsibility of managing the house and children rested squarely on them, and was hardly shared by their spouses or other family members.

Many of the BLIS students were employed, and hence they devoted less hours (1-5 hrs) compared to BCA and BDP students. It was clearly noticed that BCA learners had spent more hours for their study because BCA involved a large number of hands-on-practical sessions (75% of these sessions were compulsory to attend).

Table 8. Place of study

Item	**All**	**Programmes**			**Regions**			
	All	BLIS	BCA	BDP	Delhi	Bhuba	Ranchi	Kochi
Home	96.7	94.4	98.0	96.8	97.4	97.4	94.6	95.2
Office	32.9	33.3	26.0	35.5	37.7	42.1	13.5	23.8
Friends' home	43.3	36.1	58.0	39.5	40.4	50.0	54.1	28.6
Park	9.5	5.6	4.0	12.9	11.4	7.9	8.1	4.8
Library	58.1	80.6	68.0	47.6	55.3	71.1	62.2	42.9
Traveling	13.3	16.7	14.0	12.1	14.0	5.3	18.9	14.3
Tuitions/Pvt. Institutes	2.4		10.0		1.8		8.1	
SC/PSC	1.4		2.0	1.6	2.6			
Not Specified	1.4			2.4	0.9		5.4	
All	100	100	100	100	100	100	100	100

Source: Field Data

Table 9. Input of study hours

S No	Item	All	Programmes		
		All	BLIS	BCA	BDP
1	1-5 Hours	26.2	46.1	6.0	27.4
2	6-10 Hours	34.3	26.1	38.0	36.3
3	11-15 Hours	19.0	11.1	22.0	20.2
4	16-30 Hours	12.9	13.9	18.0	10.5
5	More than 30 Hours	6.7	2.8	14.0	4.8
6	Not specified	1.0	-	2.0	.8
7	All	100	100	100	100

Source: Field Data

BCA and BDP, being degree programmes of 3 years duration, also had a heavy work load of 32-34 credits per year (1 credit = 30 study hours). The data presented in Table 9 confirms this.

Methods Adopted for Learning

Nearly 60% (58.7%) of the respondents simply read the materials and tried to understand everything they read; 33.4% of them underlined the printed material; 35.6% made notes in the margins, 15.2% made separate notes; 13.9% answered Check your progress questions given in the course materials; 17.2% prepared concept maps and flowcharts; 28.4% made summaries; and barely 13.1% simply memorized everything. But the basic method adopted was no doubt learning by rote, which was confirmed by them when the researcher interviewed them.

When asked to specify how much they studied from the examination point of view, 63.9% of them answered in the affirmative.

Utilization of Support Services

Access to media at the Study Centre and home varied depending on their backgrounds. Interestingly, the Mean Score value for usage of these

Table 10. Methods adopted for learning

Item		Programmes		
	All	BLIS	BCA	BDP
Memorizing everything by heart	13.1	13.9	14.0	11.3
Understanding everything by reading	52.9	55.6	54.0	49.2
Mode concept maps/ flow charts	17.2	19.4	24.0	8.1
Made summaries	28.4	36.1	28.0	21.0
Underlined printed materials	33.4	36.1	40.0	24.2
Made notes separately	35.6	30.6	44.0	32.3
Made notes in the margins	15.2	8.3	26.0	11.3
Answered the Check your Progress	3.9	5.6	20.0	16.1
Use of reference books	7.1	0.5	2.8	
Not specified	2.9	2.8	2.0	4.0

Source: Field Data

Table 11. Media used at study centre, home and office

Media used at Study Centre (%)

Prog.	**Radio**	**TV**	**Phone**	**Audio Tapes**	**Video Tapes**	**Computer**	**Internet**	**Tele conf.**	**Journals**	**Reference Books**	**F-to-F Sessions**	**Practical/ Activities**
	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score
BLIS		1.9	1.7	1.4	1.2	2.3	1.6	1.6	2.6	2.9	2.8	2.8
BCA		1.3	1.4	1.2	1.2	2.5	1.8	1.3	1.5	2.3	2.5	2.7
BDP		2.1	1.4	1.8	1.2	1.4	1.5	1.2	1.7	2.6	2.6	2.2
All	NIL	1.9	1.4	1.6	1.6	2.1	1.6	1.3	2.0	2.6	2.6	2.5

Media Used at Home (%)

Prog.	**Radio**	**TV**	**Telephone**	**Computer**	**Internet**	**Journals**	**Reference Books**
	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score
BLIS	2.0	2.0	7.9	1.8	1.0	2.0	2.7
BCA	1.6	2.0	1.9	2.8	2.5	2.3	2.7
BDP	2.1	2.2	1.6	1.3	1.2	2.1	2.5
All	2.0	2.1	1.8	2.2	1.8	2.2	2.6

continued on following page

Table 11. continued

Media Used at Office (%)

Prog	Telephone	Computer	Internet	Journals	Reference Books
	Mean Score	Mean Score	Mean Score	Mean Score	Mean Score
BLIS	1.0	1.8	1.0	1.7	2.6
BCA	1.6	2.1	2.2	1.7	2.1
BDP	1.0	1.2	1.3	1.4	1.8

Source: Field Data

media at the home was higher as compared to the Study Centre. Many of the BLIS learners and some of the BCA and BDP employed learners had also used their office infrastructure/facilities (Refer to Table 11 for more details).

A variety of media was used for supporting the learning endeavour at the Study Centre, such as face-to-face counseling sessions, practicals, reference books, journals, magazines, radio, TV, telephone, audio and video tapes, computers, Internet, and teleconferencing (under electronic media). However, widely used media at the study centre varied from programme-to-programme, depending on the nature of the programme. For example, the BCA programme has a large component of hands-on-training; hence, 40% of respondents mentioned that they extensively used computers at the Study Centre. The same is true with regard to BLIS (19.4%). "Reference books" were another major source of study for BLIS learners, as the programme had two practical-based courses that required the use of the library.

The Mean Score values for the support service used and its usefulness, on a 4-point scale (very useful, fairly useful, just about useful, and not at all useful), have been presented in Table 12 .Face-to-Face counseling sessions was the most preferred choice among all the learners, irrespective of the programme. After counseling sessions, it was the Study Centre library that was utilized by the learners, and also the laboratories for practical sessions. The services provided by the Study Centre staff were acknowledged by the respondents who rated it as high. The least priority was given to the interactive media such as e-mail, teleconferencing, and radio counseling.

Students were also asked to rate the usefulness of the print materials (SLMs), assignments, and support services. Most of the students (excluding the not specified group) rated the SLMs very high, mentioning that they were useful for the successful completion of their courses. Similarly, assignments were found to be extremely beneficial.

CONCLUSION

There were several factors that contributed to their success; namely, the SLMs and assignments, and the support and the guidance provided by the counselors, Regional Centres, and peer groups. Among the instructional media used, undoubtedly print was the predominant media, followed by face-to-face sessions. Among electronic media, it was television, followed by Internet and radio, that was mostly used. Home was the most preferred place of study, followed by libraries, friends' houses, and the work place.

The purpose of this study was to give an account of the IGNOU distance learners, their characteristics, their study habits, and the study strategies adopted by them to successfully complete their programmes of study. Academic success depended to a great extent on the study strategy adopted by the distance learner. In essence, students who lacked motivation could still perform well, provided they adopted appropriate study strategies. The results of this survey confirm this point of view.

Only a small percentage was able to complete the programme of study within the minimum period. The others were able to complete their programmes according to their convenience and did not drop out of the system, which revealed that the Indian distance learners are high achievers.

The majority represented the typical Indian learners who were examination-oriented. They were mainly studying to get a degree for the purpose of career advancement, and were therefore more examination-oriented and studied only as much that was required for successful completion of their programme. Although the university provided them instruction and support through multiple media to give them a richer perspective, they mainly used printed SLMs provided by IGNOU, and did not find it necessary to use other media even though they had access to it. The basic method adopted for learning was by rote, and besides print, the other preferred medium was face-to-face counseling sessions and library facilities.

Implications for IGNOU and other Open Universities

Open universities (OUs) like IGNOU have undoubtedly developed very comprehensive course materials for the benefit of their learners. But as education is more about learning than teaching, OUs should adopt a definite approach toward empowering the learners not only with regard to knowledge, but also with regard to utilization of media. They should improve the awareness of the learners about the multimedia system and its advantages over print medium. Student induction should be made compulsory for all freshly enrolled learners.

Another important strategy is to follow an integrated approach with regard to the adoption of media. Because each OU has to invest resources, both human and material, for deploying various media for providing instruction and supporting its learners, optimum utilization of media by learners should be the norm. This could be successfully implemented if the media used is integrated systematically with the curriculum delivery.

The examination-oriented approach of distance learners could be replaced by giving more weight to continuous evaluation and through introduction-innovated evaluation mechanisms like work books, projects, seminars, and so forth, which encourage more active learner participation and also foster interactive learning environments that are beneficial to learners, as learners are able to integrate material from different areas and in a variety of settings to solve problems, and in turn evaluate their own learning.

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Chapter XVII
Ubiquitous Computing Technologies in Education

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ABSTRACT

The prosperous development of wireless communication and sensor technologies has attracted the attention of researchers from both computer and education fields. Various investigations have been made for applying the new technologies to education purposes, such that more active and adaptive learning activities can be conducted in the real world. Nowadays, ubiquitous learning (u-learning) has become a popular trend of education all over the world, and hence it is worth reviewing the potential issues concerning the use of u-computing technologies in education, which could be helpful to the researchers who are interested in the investigation of mobile and ubiquitous learning.

UBIQUITOUS LEARNING: The New Age For Education

In recent years, digitalization around the globe has been proceeding toward wireless communication and sensor technologies, which are able to detect the contexts of our daily lives, and provide personal supports accordingly. Such technology has been called ubiquitous computing (u-computing). The innovation and advance of those new technologies have led to a new research issue in education; that is, to develop an innovative learning environment so that the students can learn in any place at any time. Moreover, with the help of context-aware (sensor) technology, the learning system is able to detect the student learning behaviors in the real world, and hence more active and adaptive learning activities can be conducted. Such a learning scenario is called context-aware ubiquitous learning (context-aware u-learning), which has gradually become a popular trend of education.

Researchers have demonstrated how a context-aware u-learning environment can be used to help the learners in increasing their ability for solving problems in the real world. For example, a group of researchers in Japan has employed u-computing technologies to conduct students to learn Japanese under real-world situations. The systems can provide learners with appropriate expressions according to different contexts (e.g., occasions or locations) via mobile devices (e.g., PDA, Personal Digital Assistant).

Ubiquitous Computing Technologies that Facilitate Education

U-computing technologies can be used to provide personalized services in the context-aware u-learning environment. For instance, when a student enters a lab or stands in front of an instrument, the context-aware devices are able to detect the location of the student and transfer the information to the server. Based on the decision of tutoring program in the server, relevant information, such as the operating procedure for each device, the need-to-know rules for working in the lab and emergency handling procedures, will be timely displayed to the student based on the personal and environmental contexts. Some ubiquitous computing technologies that might be useful in educational applications are given as follows:

- Sensors for Detecting Personal Contexts

Researchers have proposed several significant characteristics of u-learning, which make it different from conventional e-learning, including seamless services, context-aware services, and adaptive services. In an ideal context-aware u-learning environment, the computing, communication and sensor equipment will be embedded and integrated into the articles for daily use. In addition, researchers also indicated that "time" and "location" might be the most important parameters for describing a learner's context.

There are several ways to detect the timely location of a learner. GPS (Global Positioning System) is one of the popular technologies for continuously detecting an object's position by satellites, which trace air waves shot from the IC chips embedded in the objects. The object's location is described with longitude, latitude and elevation. Other sensors, such as RFID (Radio Frequency Identification), which is an automatic identification method relying on storing and remotely retrieving data using devices called RFID tags or transponders, can also be used to detect the location of a learner by reading the messages from the tags, and then calculating the learner's position based on the intensity of the signals.

- Advanced Technologies for Detecting Personal Contexts

Learners might feel distressed or confused while encountering problems in the u-learning environment. Under such circumstances, a u-learning system could actively provide timely hints or assistance if the contexts concerning human emotions or attitudes can be sensed. Recent studies have depicted the possibilities for detecting such advanced personal contexts. Sensing devices with affective aware ability can not only capture the expressions of human faces, but also tell apart their emotional conditions. For example, the Affective Computing Group in MIT Media Lab of America have presented significant progress in this field, which can be used to create more friendly interaction between human and computer by the detection of affective computing. Other studies concerning facial expression detection also demonstrated the ability of computers in recognizing emotional conditions of people via various sensors and algorithms.

Human voice is another context for describing the learner's status, which might be affected by personal emotion, health condition, or surrounding noise. It is suggested that voice cognition could be used to work with facial expression and be physiological aware, to more precisely realized the status of the learner.

Another advanced technology concerning personal context detection is the development of wearable computers, which can derive information from human actions as well as psychological/physiological conditions. Interactions between human and environment could produce physiological changes directly or indirectly, including human body temperature, pulse, blood pressure and heartbeat, which can be automatically detected by those wearable sensors or context-aware clothes for further analysis and explanation of the learner's behaviors.

- Technologies for Detecting Timely Environmental Contexts

Context awareness is an important feature in a u-learning environment. The learning system can detect the contextual changes around learners, and gather related parameters via various kinds of sensors to provide students with adaptive learning resources and assistance actively or passively.

Temperature is an important environmental context for many applications, such as plant cultivation, physics and chemistry experiments. In the industries of precision instruments, such as semiconductor productions, it is very important to control the temperature in the laboratory. Making humidity stable is also an important factor, because some electrical instruments are easily oxidized in the humid environment. On the other hand, electrical instruments are easily affected and out of order by static electricity in the dry environment.

In addition, for some labs with special purposes (e.g., precise instruments, biotechnology and medical science), it is necessary to detect the volume of particles in the air. Taking semiconductor as an example, these particles may cause instruments a short circuit and even disable the devices.

Research Issues and Target Subjects

In Taiwan, the Conference on Mobile and Ubiquitous Learning was initiated in 2006 (which is called Ubilearn'2006). Based on the issues discussed in Ubilearn'2006 and Ubilearn'2007, several potential issues have been taken into account:

1. Architectures and infrastructures for ubiquitous learning systems
2. Adaptive and adaptable learning environments using mobile and ubiquitous devices
3. Agent support for mobile and ubiquitous learning
4. Architectures and implementations of context-aware learning technology systems
5. Designs for wireless, mobile and ubiquitous technologies in education
6. Design of learner-supportive interfaces of ubiquitous learning applications
7. Evaluation and evaluation methodologies for ubiquitous learning
8. Entertainment computing for ubiquitous learning

9. Mobile and ubiquitous computing support for collaborative learning
10. New pedagogical theories for ubiquitous learning environments and society
11. Innovative and practical use of wireless, mobile and ubiquitous technologies for education, learning and training
12. Psychological or theoretical foundations for mobile and ubiquitous learning and training

Moreover, a special interest group on Mobile and Ubiquitous Learning Environment (MULE) was established in 2007. Based on the previous experiences from these researchers, some potential applications of context-aware ubiquitous learning have been given, including art courses (painting or drawing from life or nature), physical education courses (motor skill training), language courses (conversation training), natural science courses (plant and animal classification) and engineering courses (equipment operating and work flow training).

Nowadays, u-learning is gradually becoming an important learning style owing to the popularity of sensor and wireless network technologies. As long as we strive toward the aim and develop a feasible and effective learning model, the ideal learning environment will become reality. In this innovative learning environment, the system can more actively provide more adaptive assistance to the student based on their learning behaviors in the real world, which have revealed the coming of a new educational age.

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Chapter XVIII
An eLearning Portal to Teach Geographic Information Sciences

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ABSTRACT

In this chapter the authors describe the implementation of an emerging virtual learning environment to teach GIS and spatial sciences to distance education graduate students. They discuss the benefits and constraints of our mixed architecture with the main focus on the innovative hybrid architecture of the virtual GIS computer laboratory. Criteria that were used to develop the virtual learning environment entailed the following: (i) Facilitating student-instructor, student-computer, and student-student interactivity using a mix of synchronous and asynchronous communication tools; (ii) Developing an interactive online learning environment in which students have access to a suite of passive and active multi-media tools; and (iii) Allowing student access to a mixed web-facilitated / hybrid architecture that stimulates their cognitive geographic skills and provides hands-on experience in using GIS.

INTRODUCTION

Geographic information systems (GIS) are a rapidly evolving technology that is integrated in mainstream undergraduate and graduate curricula. Spatial sciences and GIS are multidisciplinary in nature and have important relevance beyond their traditional disciplinary homes. Currently, spatial sciences and GIS courses are offered through geography, civil engineering, geomatics, soil, water and environmental science and other programs. A GIS is a computer-based system for managing, storing, analyzing, and presenting spatial data. GIS have three important components – computer hardware, sets of application software modules, and a proper organizational context including skilled people (Burrough and McDonnell, 1998). As such, the GIS curriculum is particularly suited to the development of innovative learning models adaptable to students from different disciplinary backgrounds. GIS courses and programs are also ideally suited to use novel technologies as the discipline itself is technologically enabled, or even technologically driven. Zerger et al. (2002) pointed out that it is important to infuse spatial science theory with practical examples / assignments and projects to optimize learning outcomes. Thus, transforming on-campus GIS courses into a virtual learning environment requires maintaining both lecture and lab components. Spatial sciences aim to stimulate cognitive geographic thinking skills that involve solving geospatial problems, to comprehend and integrate huge amounts of geospatial data, and to facilitate understanding of both large-scale and small-scale geographic features of ecosystems. These cognitive geographic skills are a prerequisite to understanding the underlying mechanisms for spatially-explicit modeling using GIS software. Hands-on GIS assignments and projects facilitate student learning about GIS functionality and help them build their own spatial models.

Distance education courses and programs have adopted a variety of multimedia and Internet technologies. Recent changes in information technology have challenged instructors not only in terms of *what* they teach, but also *which* technology they use to teach. The proliferation of web-based and interactive multimedia technologies that are used to teach spatial sciences has transformed numerous on-campus courses into web-facilitated, hybrid (blended) and distance education courses. Hybrid courses mix traditional face-to-face instruction with a substantial portion that is delivered online. Virtual learning environments are diverse, ranging from simple web-pages to complex hard- and software solutions. A virtual learning environment is a set of teaching and learning tools designed to enhance a student's learning experience by including computers and the Internet in the learning process. Criteria to distinguish virtual learning environments include: (i) delivery type - audio, video-based systems (e.g. Power Point slides, videoclips, compressed interactive video, virtual reality worlds, and others); (ii) delivery media (e.g. books, journal articles, CD, DVD, Internet); (iii) communication type (synchronous and asynchronous) and student involvement – (active and passive); (iv) level of abstraction – content (e.g. text, maps, 3D models, 4D simulations, interactive virtual models); (v) presence of the instructor (e.g. availability and accessibility of instructor by students); (vi) level of interactivity between students, instructor and computerized entities (student-student-, student-, student-instructor-, instructor-, and student-computer centered); and (vii) user access (local e.g. physical lab or field trip that requires the presence of a student at a particular geographic place or remote e.g. Internet-based access or simulated/emulated equipment and instruments). Virtual environments present a multimedia library of shapes, landscapes and sounds that establish a system for construction and symbolic transformation. The virtual environment as projective construction provides an opportunity for participants to collaborate in a variety of multisensory interactions: visual-spatial, audio-spatial, and kinesthetic.

Existing GLS Learning Systems

Student-instructor interaction including face-to-face interaction and hybrid settings where students interact with an instructor using synchronous (e.g. interactive video, chatroom) or asynchronous (e.g.

message board, email) communication tools are commonly used to teach spatial sciences courses. Other virtual learning environments for GIS and spatial sciences focus on student-centered, self-paced instruction. For example, virtual GIS classrooms are offered through the Environmental Systems Research Institute (ESRI) virtual campus for GIS learning (http://campus.esri.com) and the UNIGIS program (http://www.unigis.org). These initiatives are not interactive, instead they simply deliver existing curricula via a hyperlinked Internet delivery mechanism. Students have to provide their own GIS software to take these courses. Other disadvantages include that no tutors or instructors are available for students. Students receive support only through online message boards that may not be able to replace an interactive synchronous learning environment. Other implementations use webGIS and virtual GIS tools which are student-computer centered. Peng and Tsou (2003) define webGIS as a GIS distributed across a computer network to integrate, disseminate, and communicate geographic information on the WWW (Peng and Tsou, 2003). Wright et al. (2003) discussed implications of a webGIS, a computational environment and toolset that provides scientists and educators with simultaneous access to data, maps and query wizards. They stress that webGIS is only a preliminary step rather than a final solution to teach GIS since spatial data must be also linked to models for better exploration of new relations between observed values, refinement of numeric simulations, and the quantitative evaluation of scientific hypotheses. ArcIMS software developed by ESRI has been used in numerous applications to develop webGIS (Wright et al., 2003; Mathiyalagan et al., 2005), however, it has limited capabilities to teach GIS in a virtual learning environment. Other open source GIS tools have been developed to support teaching. For example, Stainfield et al. (2000) presented a Java/VRML standalone multidimensional interface explorer with basic GIS functionality. Though such tools provide display and query capabilities for spatial datasets they fall short in GIS instruction due to limited functionality for spatial modeling.

Motivation and Goals

Sui and Bednarz (1999) stress the need for student-instructor interaction in geographic education especially when considering the inherent multiple intelligences possessed by each individual. In other words, students have varying learning needs and hence they respond differently to different delivery models. Figure 1 summarizes student-instructor-computer interaction that varies from passive to active engagement using a variety of delivery media. Barraclough and Guymer (1998) and Fisher and Unwin (2002) argued that interactivity enhances the perception and interpretation of spatial datasets (e.g. environmental systems). Deadman et al. (2000) used a multimedia approach to teach GIS interactively using a high-resolution, computer-based classroom for delivering lecture-based live presentations of the GIS software. Their hardware configuration provided high-speed, high-quality video linkages to broadcast GIS demos to distance education students at remote sites.

The architecture of virtual learning environments to teach GIS and spatial sciences range from centralized, closed systems to complex distributed open systems (Figure 2a to 2e). Systems differ in respect to the access to spatial datasets that (i) can be hosted on a desktop computer, (ii) a computerized entity that provides data a/o map services, (iii) a server or (iv) nodes that are part of a distributed open system (Pseng and Tsou, 2003). Likewise different architectures facilitate different access to GIS software. For example, in a centralized, closed system the GIS software (e.g. ArcGIS, IDRISI) is installed on a desktop machine. Web-facilitated instruction provides limited GIS functionality through the Internet

Figure 1. Pyramid of delivery types of content to teach GIS and spatial sciences courses

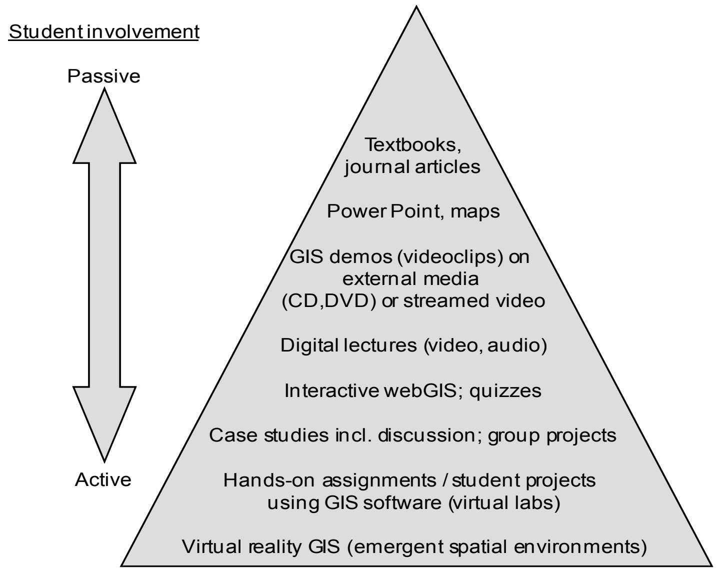
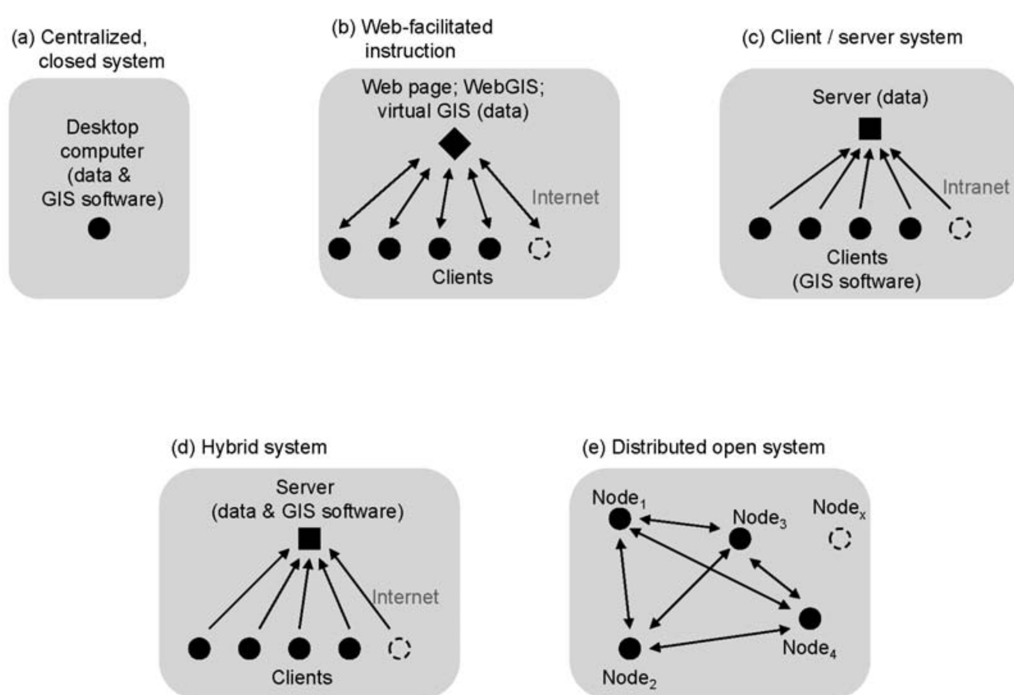


Figure 2. Architectures to teach GIS and spatial sciences courses



while client/server systems require that the GIS software is installed on all client machines. The latter architecture has been used extensively to teach GIS and spatial sciences courses at the University of Florida (UF) and elsewhere. At many universities, site licenses for expensive GIS software packages are available that do not extend to off-campus use, therefore favoring on-campus client/server systems. An emerging architecture that uses a hybrid setup in which the GIS software is installed only on the server eliminates the need for clients to install expensive software on their machines. Clients access the spatial data and GIS software through the Internet providing complete independence from a geographic location. Advantages of a hybrid system include flexible 24/7 access of clients to the server and fast performance of complex spatial operations on the server machine. Hybrid systems provide a collaborative virtual learning environment that is shared by students and the instructor. Other possible architectures are based on a distributed open system where each node can become a client or a server based on the task (Pseng and Tsou, 2003).

In this chapter we describe the implementation of an emerging virtual learning environment to teach GIS and spatial sciences to distance education graduate students. We discuss the benefits and constraints of our mixed architecture with main focus on the innovative hybrid architecture of the virtual GIS computer laboratory. Criteria that were used to develop the virtual learning environment entailed:

a. To provide student-instructor, student-computer, and student-student interactivity using a mix of synchronous and asynchronous communication tools,
b. To develop a liberal online learning environment in which students have access to a suite of passive and active multi-media tools,
c. To provide students access to a mixed web-facilitated / hybrid architecture that stimulates their cognitive geographic skills and provides hands-on experience in using GIS.

The virtual learning environment was utilized to teach GIS and spatial sciences in context of land resource management for distance education graduate students enrolled in the Distance Education Graduate Track in Environmental Science offered through the Institute of Food and Agriculture Sciences (IFAS), UF [http://soils.ifas.ufl.edu/distance/]. The course is an elective in the GIS certificate program coordinated by the Interdisciplinary Concentration in GIS. The course is also open to non-degree seeking distance education students interested in GIS and spatial sciences. Thus, the science background of students enrolled in this course is diverse and multi-cultural.

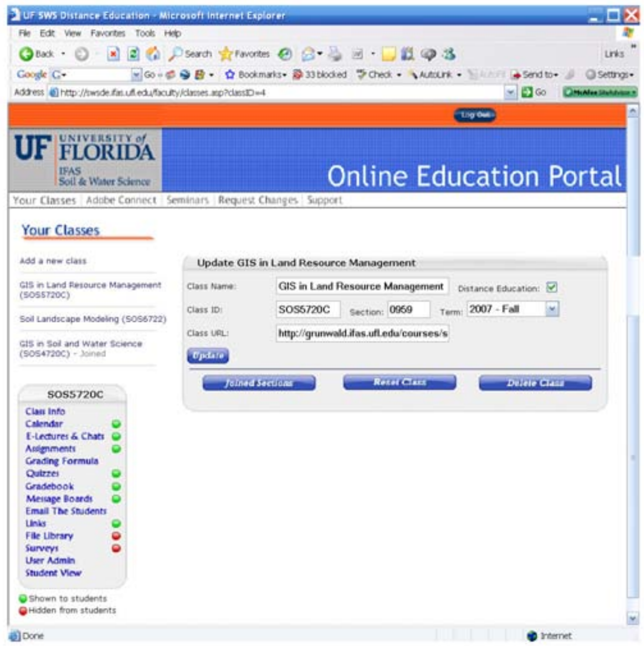
Implementation

Development of Virtual Learning Entities

We adopted a multi-tier approach to develop virtual entities that provided students access to core content, communication- and service tools, and a collaborative virtual study environments. These tools aimed to train students in spatial sciences theory. An online education portal provided access to a variety of learning tools (Fig. 3). The following list provides an overview:

1. **Development of core content tools:** The core tools provided course learning content to students including the following media: (a) reading material in form of Adobe pdf format; (b) Power Point slides narrated with lecture notes; (c) digital lectures recorded in Adobe Connect; (d) Flash animations; (e) quizzes; (f) library of ArcGIS video clips (step-by-step instructions to explain spatial

Figure 3. Snapshot of the online education portal that facilitates access to learning tools



functionality of ArcGIS software); and (g) hyperlinks to access Internet resources on GIS. Almost all of these tools, except for quizzes, are student-centered and focus on information delivery.

2. **Communication tools:** We provided students with a variety of communication tools that aimed to engage students in exchange of information, reflection, and discussion. A mix of synchronous and asynchronous communication tools were used to accommodate students' diverse preferences to interact with the instructor and teaching assistants. Our tools included: (a) message board; (b) chatrooms facilitated by Adobe Connect; (c) bulk emails (shared with all students); (d) self-reflective emails (shared between students and the instructor); and (e) phone.
3. **Service tools:** The online education portal contains a variety of service tools that guided students through the course including: (a) calendar; (b) checklist that listed all required tasks (e.g. reading assignments, lectures, GIS assignments, etc.); (d) grading tool; (e) event viewer that listed all important class events; and (f) upload and download functions for course material, assignment reports and a final project.
4. **Tools/methods that stimulated collaborative work:** To engage students in discussions numerous techniques were used: (a) focus questions for chat sessions; (b) provocative comments posted by instructor and teaching assistants on the message board; (c) student-corner that provided photographs, profiles and contact information for all students in class; and (d) student peer-evaluation of GIS projects.

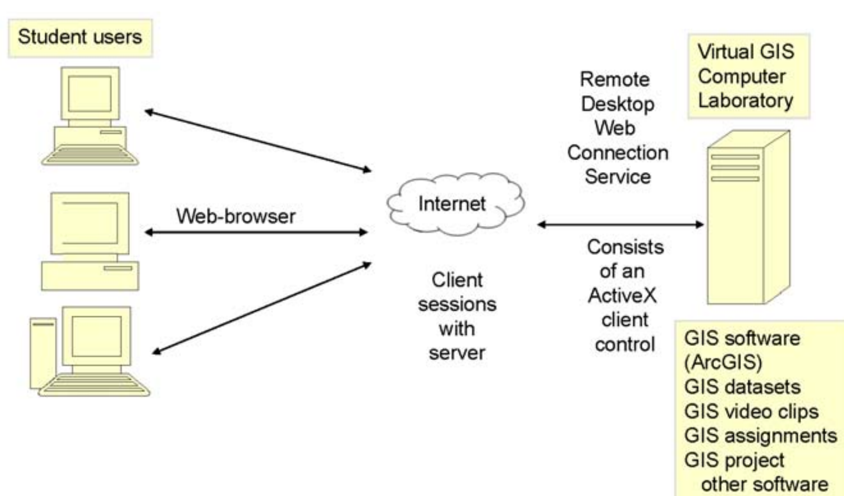
Implementation of the Virtual GLS Computer Laboratory

The lab component of the GIS course required the solving of traditional and topical GIS problems and aimed at stimulating higher order problem solving skills using real-world spatial datasets. Each of the GIS assignments addressed one specific GIS topic (e.g. map projections, raster-based operations) using real-world GIS datasets and focused on specific land resource issues (e.g. land use change analysis, carbon sequestration, characterization of the spatial distribution and variability of total soil phosphorus in a wetland ecosystem). Detailed step-by-step instructions supported by snapshots of the GIS-based spatial operations were provided to students to guide them through the assignments. At the end of each assignment students had to answer 2-4 questions closely related to what they just learned. To answer these questions, students employed their GIS knowledge to solve problems with new datasets.

We adopted a hybrid virtual architecture that provided distance education students access to the ArcGIS 9.1 software and spatial datasets to conduct the GIS assignments and to work on an independent and/or group project. Figure 4 shows the architecture of our virtual GIS computer laboratory. Currently up to about 250 students can work simultaneously in the virtual computer lab. The only limitations to this system are hard drive space and memory. Students access the virtual computer lab using a Windows terminal server application through a web browser. The virtual GIS computer lab uses the Remote Desktop Web Connection service provided by the Windows XP Professional operating system. Remote Desktop Web Connection consists of an ActiveX client control and sample web pages. ActiveX controls are reusable software components that can quickly add specialized functionality to web sites, desktop applications, and development tools. ActiveX controls are used for developing programmable software components used in a variety of different software tools. The ActiveX client control provides virtually the same functionality as the full Remote Desktop Connection client, but it is designed to deliver this functionality over the Web. When embedded in a web page, the ActiveX client control can host a client session with a server, even if the full Remote Desktop Connection client is not installed on a user's computer. In essences, the Remote Desktop Web Connection allows students to access a remote computer (server), via the Internet, from a local machine using a web browser.

Using Microsoft Remote Desktop as a group appliance has had several drawbacks in practical

Figure 4. Architecture of the Virtual GIS Computer Laboratory



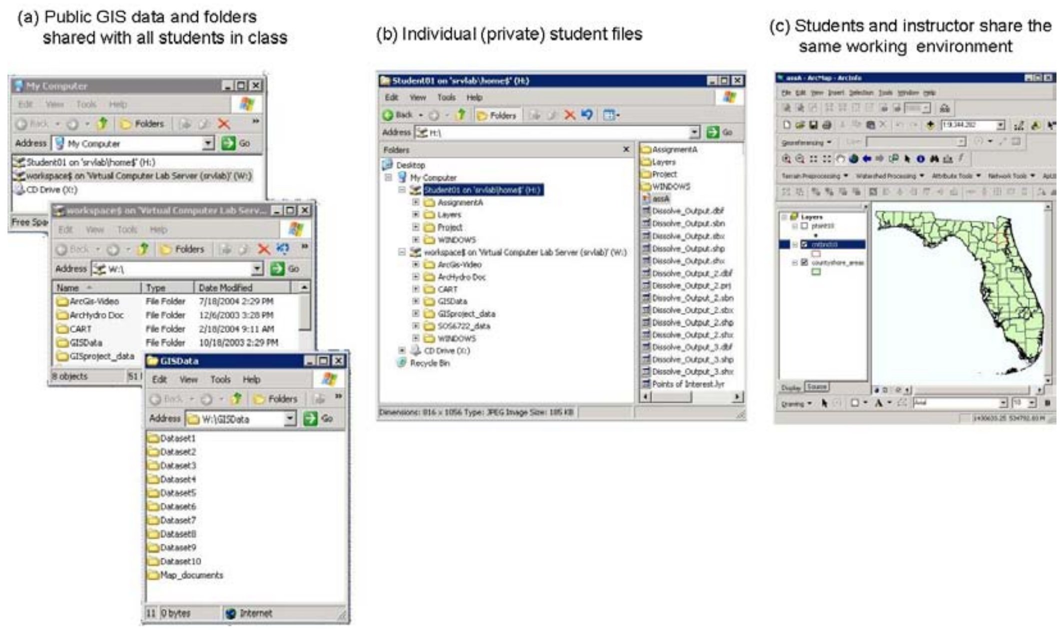
use. The first of which is the lack of upgradeability. Servers were built to handle network traffic and file sharing, but not for multiple users logged in simultaneously. The second constraint is related to usage because the speed of Remote Desktop applications decreases as the number of users increases given a fixed set of hardware configuration (i.e., processor speed and memory). Virtual Desktops, which are essentially an image of a computer, take a whole new approach for shared computing. They are hosted from a Storage Area Network (SAN), which is essentially a group of computers that share the same storage, processors and memory. The software on the SAN will read this image and allow you to connect to it as if it were an independent computer. The SAN is able to maintain a large number of desktops without compromising usability. The software manages the virtual desktops by having a single image of a computer and simply making copies of it for multiple users. The advantages of using a Virtual Desktop Machine over a Remote Desktop server are numerous. All user data is saved to a shared storage area, so if a desktop begins to show problems, it can be deleted and a new desktop can be created in its place at the touch of a button. Also, software management is simplified by only having to maintain one computer. All the Virtual Desktop Machines are copied from the single image. In addition, the Virtual Desktop Model is much more cost effective and flexible from an IT standpoint.

The virtual GIS computer lab differs from Learning Management Systems (i.e. Blackboard or WebCT Vista), and chat software such (i.e. Adobe Connect or Elluminate) in that it provides access to expensive software (i.e. ArcGIS), spatial datasets and public and private workspace (files and folders) on the server. In addition, the virtual lab provides a secure learning environment that enables students to learn complex, multi-step geospatial operations.

Constraints and Benefits

Our versatile virtual learning entities provided students with core content and service tools that were used extensively by students throughout the course. A survey conducted in 2003 and 2004 in which 27 distance education students replied (out of 34 enrolled students) ranked the GIS assignments conducted in the virtual computer laboratory highest (4.7) followed by Power Point slides (3.6), reading material (3.6), digital lectures (3.5), ArcGIS video clips (3.3), quizzes (3.0) and hyperlinks (3.0), on a Likert scale ranging from "5 = extremely useful" to "0 = not useful at all". While some students have text or visual learning styles, others have auditory learning styles. Thus, we used a variety of contextualizations for virtual entities customized for different learners. For example, the same learning material about one specific topic was provided in form of reading material, Power Point slides, a Flash animation and a digital movie to reach students with different learning styles. Such a liberal virtual learning environment gives students freedom to focus on those media/tools they respond to best. Gardner (1983) asserts that humans learn through many different cognitive styles ranging from bodily-kinesthetic, interpersonal, intrapersonal, linguistic, logical-mathematical, musical and spatial. This suggests that the most effective instructional media should engage multiple types of learning styles. Zerger et al. (2002) argued for a self-learning multimedia approach for enriching GIS education. Such a student-centered approach is liberal in the sense that students make choices when, how much, and what to learn. They do caution, however, that self-learning modules are designed to complement rather than replace existing traditional approaches in the classroom. Marion and Hacking (1998) examined the relative merits of the Internet in education and argued that the evolution of the Internet provides the opportunity to build a more constructivist learning environment. We agree that a virtual approach

Figure 5. Student view of public and private files in the virtual GIS computer laboratory



to learning GIS and spatial sciences is important because these disciplines evolve rapidly and textbooks are often outdated within a short amount of time. Our core content tools can be easily updated because they are organized in form of learning objects using a hierarchical set-up.

We also promoted a flexible approach to interacting with students. While some students extensively used the public message board and chatroom sessions other students preferred to communicate with the instructor or TAs on a one-to-one basis using self-reflective emails and phone conversations. Students appeared to be highly motivated to participate in group activities fostered through the virtual learning environment. They were encouraged to become involved in a peer-evaluation of their classmates GIS projects. Almost all students participated in this process. Hardwick (2000) notes that shifts towards collaborative models remove the common competitive paradigm inherent in education and we saw this to be true in the distance education courses described in this chapter.

Since students only needed the Internet to access the virtual GIS computer laboratory, no physical presence on-campus was required. Such an implementation is ideal to teach GIS and spatial sciences to distance education students that were traveling and/or engaged in other professional activities during the duration of the course. A major advantage was that students, teaching assistants and the instructor had 24/7 access to the virtual GIS computer laboratory. Complex spatial GIS operations could be performed with the same speed in the virtual GIS computer laboratory when compared to local computers. In addition, students were not required to purchase and install expensive GIS software on their local client machines. Other benefits included a reduction of the need to download and upload large GIS files because almost all such data files needed for the assignments were made available on a public folder in the virtual GIS computer laboratory. For the GIS project, students were able to use a web browser to download spatial datasets into their individual folders in the virtual GIS computer laboratory.

Public folders in the virtual GIS computer laboratory provided access to spatial datasets and assignments and generic folders were shared by all students, teaching assistants and the instructor (Fig. 4). We constrained the access (read, write, execute permissions) to individual (private) student folders (Fig. 4). This method did not permit the students to share their GIS output from assignments with each other, which reduced the risk of plagiarism. The teaching assistants and the instructor had unconstrained administrator access to all files and folders in the virtual GIS computer laboratory. This is important for troubleshooting and providing student support in real-time for complex spatial operations. Because the virtual GIS computer laboratory is a collaborative learning environment, the students and instructors were able to share the same view of GIS files and projects simultaneously. This facilitated collaborative student-student and student-instructor interactions independent from a geographic location.

The Remote Desktop Web Connection provided a high-encryption ensuring security to the server. Remote Desktop works well over the Internet, because only the keyboard input, mouse input, and display output data are transmitted over the network to a remote location. However, to ensure optimized viewing of maps and graphics, a high-speed Internet connection between the client and server machine provided the best solution. A benefit of the Remote Desktop set-up was that client computers shared a clipboard that allowed data to be interchanged. Sala (2003) described similar examples of hypermedia modules for distance education and virtual universities that provide interactivity for learning while many other learning tools are still limited to display data and instructional material. For example Hays et al. (2000) presented a tool that was limited to display earth science data. In contrast, Barak and Nater (2002) developed a web-based fully-interactive learning environment to introduce students to minerals and molecules. Thai and Upchurch (2002) presented a synchronous experimental machine-vision virtual laboratory to engage students in hands-on assignments. Almost all authors emphasize two critical elements that engage students in learning activities namely “interactivity” and “hands-on tools”.

While most students felt comfortable performing tasks in the virtual GIS computer laboratory others were challenged by the highly-interactive computerized online environment. Overall, 3.6% of students found that it was very easy, 24% found it easy, 17.4% somewhat easy, 27.6% moderately easy, 16.9% difficult, and 10.5% found it very difficult to perform tasks in the virtual GIS computer lab.

A complete overview of the survey can be found in Grunwald et al. (2005). The response time of numerical geospatial operations conducted in the virtual GIS computer laboratory was no different than the same operations conducted on a local PC. When asked if the GIS technology used in this course improved the learning outcomes, students unanimously answered “Yes.” The assessment of student interaction included the following responses: (i) 100% of students used the virtual GIS lab (no drop outs); (ii) on average, 85% of students submitted biweekly self-reflective emails throughout the course; (iii) the instructor received about 2-3 emails daily from distance education students; (iv) email traffic was generally higher in the evening hours and weekends; and (iv) on average, 650 messages were posted on the message board in a given semester.

Five years of teaching in distance education mode has enabled us to identify some limitations with the current virtual GIS computer lab design. To ensure fast display a high-speed Internet access is required. Though broadband availability is greatly expanding in the U.S., it poses limitations to students at remote locations in developing countries. In our course students from 5 different U.S. states and from South America were enrolled to receive advanced instruction in spatial sciences and GIS that was previously unavailable. At lower bandwidths the display of large, complex maps slows down. The hard drive and memory of the server machine needs to be designed for peek usage (e.g. simultaneous work in the virtual GIS computer laboratory before assignment and project deadlines). Other limitations included a major time commitment to develop the virtual learning environment that required content development, programming and extensive testing. Despite some of the limitations mentioned above, our virtual learning environment has greatly improved GIS and spatial sciences instruction at the University of Florida.

CONCLUSION

Our innovative architecture for the virtual GIS computer laboratory is simple, affordable and versatile in design. It provides a flexible, collaborative virtual learning environment for distance education instruction. A hybrid approach was used to complement virtual entities of core content, service and communication tools with a virtual GIS computer laboratory. The overall response from students using the virtual GIS computer laboratory was overwhelmingly positive. Some students, that were less computer-literate, indicated that it was somewhat difficult for them to perform tasks in the virtual computer laboratory. Instructors and teaching assistants noted that the virtual learning concept facilitated to oversee students work and interact with students. Despite our positive experience with our virtual learning environment, we caution that a balanced team of members from different disciplines is required for successful implementation. Our team comprised two faculty members teaching GIS and spatial sciences, a computer programmer and network specialist.

Although the virtual computer laboratory was designed for one specific GIS / spatial sciences course, it has the potential to be instrumental in courses that make use of software packages a/o simulation models (e.g. hydrologic and water quality simulation models, statistical software). The virtual computer lab concept has also been adopted by IFAS at UF to teach on-campus computer-mediated courses. This indicates that emerging technologies do not only improve distance education instruction but also on-campus courses that might eventually develop into blended/hybrid or online courses.

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Chapter XIX
A Changed Economy with Unchanged Universities?
A Contribution to the University of the Future

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ABSTRACT

Individualised open and distance learning at the university continuing education and post-graduate education levels is a central issue of today. The advanced information and communication technologies together with several applications offer new perspectives, such as the so-called virtual university. Simultaneously, to gain market share, several organisational arrangements are emerging in the virtual university field, like consortia arrangements and joint venture initiatives between and among institutions and organisations. The dynamically changing social and economical environment where we live claims for new approaches to virtual and flexible university continuing and post-graduate education, such as the concept of Agile/Virtual University proposed by the authors. However, the implementation of this concept (and of other similar concepts) does not rely just on basic information and communication infrastructure, neither on dispersedly developed applications. Although absolutely necessary as support, the added value comes from the higher-level functions to support individualised learning projects. The implementation of the Agile/Virtual University concept requires a framework and a specific supporting environment, a Market of Teaching Resources, which are discussed in the article.

INTRODUCTION

In the fast-changing and strongly competitive business environment we live, a confluence of factors such as (1) the economic globalisation and integration, (2) the impact of technological developments, (3) the growing demand for sustainable development and (4) the emerging work systems are having a strong impact on organisations, on society and on individuals.

Advances in information technologies (IT) are now one of the major driving forces of change. IT is an essential infrastructure for competitiveness of other economic sectors, and the basis for trade, provision of services, production, transport, education and entertainment (ACTS, 1998). IT is transforming organisations into global networked structures, with processes extended through continents, creating markets and systems not just global and distributed, but virtual, in a new perspective of a global, networked and knowledge-based economy.

The fast evolution of IT is creating a huge role of opportunities, and simultaneously of challenges to organizations and to society. Organisations of every stripe try to respond to the challenges by adapting their strategies and activities; that is, restructuring to align themselves to the new requirements of the changing economy, where every sector of society will systematically use IT. These technologies support concepts as distributed systems, computer supported cooperative work, telework, electronic commerce, electronic marketplaces, virtual manufacturing, concurrent engineering, some forms of distance education, and many others.

Distance education (Web-based) seems to be a contribution towards the democratisation of learning access in particular in the domain we are concerned with - the university continuing education and post-graduate education.

According to several authors, (Evans & Nation, 1996; Khakhar & Quirchmayr, 1999) the most relevant advances in distance education over the past three decades have been in the university sector, where Open Universities represent an attempt to establish fully integrated distance-teaching systems.

However, the new approaches to learning, such as flexible and distance learning, are still at an immature stage. Although some of these concepts have existed for several years, there is not yet a clear understanding of the way these approaches will evolve and become useful and common practices.

Another concern is that systems conceived to provide integrated standard off-the-shelf learning solutions are less efficient when compared with dedicated systems. Providers of units of learning, primitive or complex[1], can be integrated in completely individualised (customised/tailored) flexible Web-based networked learning projects, which in turn can be agilely and dynamically adjusted to either the performance of the providers or to the learner evolution or changing requirements. This corresponds to a new structure of learning for each individual (learner) while, at the same time, each provider (teacher) can specialise himself in focused units of learning, and get economies of scope by providing - with high quality - this same unit in several different learning projects. This concept requires an environment to cope with several concerns, such as assessment, accreditation, quality assurance, trust, and so forth, such as the Market of Teaching Resources here proposed, and must be mediated by a broker.

IT innovations are stimulating the growth of markets for educational services and the emergence of for-profit competitors, which could change the higher-education enterprise (Goldstein, 2000).

In this contribution, we introduce the Agile/Virtual University (A/V U) concept, as an integrated set of providers of units of learning that is integrated to respond to an individualised need. The product provided by the A/V U is an *individualised learning project* (a continuing training/education course). These providers can be universities, university teachers and individuals (independent teachers), organised and managed by either a higher-education enterprise or a university itself, in a specific environment proposed by the authors as a *Market of Teaching Resources*.

The paper discusses the challenges to the university of the future, introducing the concepts of individualised learning project and Agile/Virtual University in the second section, and the new roles of the teacher and of the individual in the third section. In the fourth section it is introduced a framework conceived to implement the A/V U model and, in the fifth section, it is introduced the Market of Teaching Resources as an enabler of A/V U. The sixth section concludes the article.

BACKGROUND: Enabling Technologies, Frameworks And Applictions

Internet enabled and enhanced communication, publishing and collaboration for individuals and organisations over a worldwide computer network. Initially, restrictions in bandwidth, storage capacity and processor power limited interactions over the Internet to text-based applications and technologies (Looms & Christensen, 2002). Today interactive applications and media-rich content are possible due to several infrastructure and standards, such as the XML (the W3C *Extensible Markup Language* Standard) for document structure, the SOAP (the W3C *Simple Object Application Protocol*) as a specification for computer communication and MPEG (the *Motion Picture Experts Group* standards) for video compression and delivery, which allow one to package, delivery and present learning contents in new ways. But a new generation of needs emerged regarding the specificities of e-learning, which claimed for specific standards, frameworks and approaches.

In this section we introduce some concepts and review the main developments and contributions regarding standardisation in the e-learning domain.

The Concept of e-Learning Objects

Several different definitions of *e-learning objects* can be found in literature, and other terms are used seemingly interchangeable in place of *e-learning objects*. In this paper, Wiley's definition is adopted. Other terms proposed by Cisco (2001) are *educational objects*, *content objects*, and *training components*. According to Wiley, a learning object is a "reusable digital resource to support technology-supported learning" (2000).

Cisco defines a learning object as a "(…) granular and reusable chunk of information that is media independent" (2001, p.5). Learning objects allow instructional designers to build small or elementary instructional components that can be reused in different learning contexts, deliverable over the Internet. They represent reusable units of learning content that can be consumed or studied within a single learning session or a predefined period of time, organised in larger units such as classes or courses, if desired. At CEDAR (Centre for Economic Development and Applied Research), an e-learning object is defined as a small piece of text, visual, audio, video, interactive component, and so forth, that is tagged, and stored in a database (Muzio, Heins, & Mundell, 2002, p.24).

The first generation of e-learning systems focused essentially on the management and measurement of training process, delivering inflexible courses, adding little or no value to the learning process (Ismail, 2002). According to the author, with whom we agree, these e-learning systems (learning management systems) were not designed to help organisations to collect, organise, manage, maintain and reuse instructional content.

In their current situation, learning technology standards do not support interactive learning objects properly, as widely accepted (Hanish & Straber, 2003). Today, it is recognised the need to move towards producing database-driven reusable learning objects, and that they should conform to relevant standards, some of them to-be-developed.

The Virtual University Concept

In recent years the definition and application of open and distance learning has been evolving in parallel with the arrival of newer and intelligent technologies (Commonwealth of Learning, 2003). According to a Commonwealth of Learning evaluation report on virtual education (Farrell, 1999), the label virtual is widely and indiscriminately used and it is frequently used interchangeably with other labels such as open and distance learning, distributed learning, networked learning, Web-based learning, and computer learning. Another Commonwealth report (Farrell, 2001), clarifies that open and distance learning embraces any or all of the concepts and practices of open learning, flexible learning, distance education, online learning and e-learning, and virtual education.

To gain market share in the lifelong learning market, several organisational arrangements are emerging in the university virtual learning, and are the result of partnerships between institutions or businesses and institutions, joint venture initiatives between and among institutions and organisations, consortia arrangements, and so forth. Examples of emerging models include: for-profit university initiatives (Dirr, 2001), consortia and alliances of universities or of high schools (Dirr, 2001), the open school, broker-type organisations (Farrell, 1999), and corporate-university joint venture (American Federation of Teachers, 2001). Simultaneously, complementary institutions that do not provide instruction directly emerge in the virtual university field. Examples include institutions authorised to provide services as quality assurance, award credentials, learning assessment, learning records and so forth, and broker-type organisations, designed to broker programmes from individuals and institutional providers.

The definition proposed by the Commonwealth of Learning for the concept of virtual education institution (Farrell, 2001), consists of an institution involved as provider of learning opportunities to students, using information and communication technology to deliver its programmes and courses and provide tuition support, and is the result of alliances/partnerships to facilitate teaching and learning to occur without itself being involved as a direct provider of instruction. We accept this definition and use it as a basis to the proposal of the new concept of Agile/Virtual University.

There are still few examples of virtual educational institutions, namely of virtual universities. Besides several valuable examples like the Michigan Virtual University (http://www.mivu.org/) and the University of Phoenix (hppt://www.phoenix.edu/), we still can say that most of the developments towards virtual universities are experimental, and many times still do not address the needs of their potential clients. The market for virtual university learning is being fragmented (as the markets for all sorts of goods and services), with niche learners, each time more demanding, rather than mass clientele, and this market is becoming more and more competitive even in a world-wide scale, with global providers acting through strategic partnerships.

Standardisation and Interoperability Efforts in the e-Learning Domain

E-learning standardisation is currently a vital concern and a continuously evolving process that, according to several authors (Anido et al, 2003) will last for years until a clear and generally accepted set of standards is developed.

From the perspective of integrability there are significant efforts towards standardisation at two levels: (1) Specification of data models and information models involved (specification of the format, syntax, semantics of data concerning learners, course structures, educational contents, etc., to be transferred among platforms); (2) Specification of architectures, software components and interfaces (for managing the information models, i.e., for managing learning objects in online environments) (Anido et al., 2003).

Several contributors towards the development of standards for education-related systems can be enumerated, such as IEEE's Learning Technology Standardisation Committee (LTSC), The National Institute of Standards and Technology (NIST), the IMS Global Learning Consortium, Inc. (Open Specifications for Interoperable Learning Technology) (IMS, 2004d), the Aviation Industry CBT Committee (AICC, http://www.aicc.org), the US Department of Defence's initiative Advanced Distributed Learning (ADL, http://www.adlnet.org).

Several projects should also be mentioned: the Alliance of Remote Instructional Authoring and Distribution Networks for Europe (Ariadne, 2004), PROmoting Multimedia Access to Education and Training in EUropean Society (PROMETEUS), Gateway to Educational Materials (GEM), Getting Educational Systems Talking Across Leading Edge Technologies (GESTALT), and the Information Society Standardisation System are some of the most relevant.

Specifications that have already been released by IMS[2] include: IMS Digital Repository Interoperability model (first draft approved in August 2002) (IMS, 2003b), Content Packaging (IMS, 2003a), Learner Information Packaging (IMS, 2003d), Metadata (in May, 2004) (IMS, 2004a) and Question and Test Interoperability (last public draft in June, 2004) (IMS, 2003e, 2004b, 2004c) and Learning Design (IMS, 2003c) -- this last can be considered as an integrative layer to some of the above-mentioned specifications. IMS project groups are in the process of improving specifications for competency, accessibility, learning design and digital repositories.

SCORM (Sharable Content Object Reference Model) project, an ADL (Advanced Distributed Learning) initiative based on the CMI specification of the Aviation Industry CBT Committee, is a model for content exchange between different learning management systems. The purpose of SCORM is to achieve accessibility, interoperability, durability and reusability within SCORM compatible content (ADL, 2002).

Another field that is waiting for developments is the educational metadata one. Metadata (*data about data*) provides descriptions, properties, information about objects (in our case, learning objects) to characterise them in order to allow its manipulation and management. Many efforts can be listed, including almost the entire above list of projects and initiatives, but we are still waiting for generally accepted recommendations and standards (Dodds, 2001). LOM, the IEEE Learning Object Metadata (IEEE 1484.12.1—2002) is a major contribution that specifies the syntax and semantics of learning object metadata (Hodgins, 2002).

The ability to search repositories is fundamental to provide access and delivery content from distributed repositories. The Open Archive Initiative (OAI) is a technical and organisational metadata framework designed to facilitate discovery of content in distributed repositories, specially directed to peer-reviewed information (scientific papers) (Lagoze & Van de Somple, 2002).

The growing interest over Web services is based on the potential for a combination of XML, the Web, the SOAP and WSDL specification and some to-be-defined protocols. Web services are designed as standard reference architecture to promote integrability.

Brokerage for Educational Systems

Efficient searching and selection of educational content is a key feature of distributed Web-based educational systems. Traditional technology (search engines and directories) could be used to search the Web for educational content; however, it is easy to conclude that these do not cope with our requirements.

The role of third party intermediaries, linking different parts of a value chain, has been covered extensively by researchers in economics and business, and the question seems to be whether the future will hold a place for intermediaries, given that new technologies facilitate direct links between market players, such as manufacturers and end-consumers of products, or businesses and their suppliers.

In the e-learning environment, brokerage will support the match between offer and demand of learning objects. The GESTALT project proposes a brokerage service for educational resources, named Resource Discovery Service, within a pool of registered providers of educational contents (GESTALT, 2003). In Anido et al. (2003) it is described a proposal for a Domain CORBA facility for educational brokerage that defines the software services needed in an intermediation framework for learning objects, using the OMG's[3] *Interface Definition Language* (IDL). IDL is not tied to any specific environment or platform.

Frameworks and Applications Under Development

It is a generalised concern the provision /delivery of effective and efficient access to information /learning contents /learning objects, communication teacher/ facilitator—learner, provides also improved learning opportunities.

In Ismail (2002) it is proposed an e-learning systems framework, specifying a learning system's architecture for pedagogical development and systems integration, based on the Learning Technologies Systems Architecture (Architecture and Reference Model Working Group, IEEE) developed by IEEE and other standards organisations such as Aviation Industry CBT Committee, IMS Global Learning Consortium and the Advanced Distributed Learning Network. This framework allows organisations to envision and craft their e-learning systems while maintaining interoperability with third party applications and content (Ismail, 2002).

In Ong & Hawryszkiewycz (2003), the authors propose a framework for integrating personalisation and collaboration in a virtual learning environment, in a learner-centric approach, where learners are expected to actively engage in the learning process to construct their own learning and instructors play the role of facilitators, guiding the learning process.

Lin et al. (2001) propose a framework for designing and developing agent-based online learning systems, integrating software agents and learning objects.

The contributions of Anido et al. (2002) address the interoperability problem due to the proliferation of online learning systems, proposing CORBA as the technological supporting infrastructure.

Academic institutions such as the University of Calgary [CAREO System (CAREO, 2002)] or the Technical University of British Columbia [POOL Project (Richards & Hatala, 2001)] have developed and deployed Distributed Learning Objects Repository Networks (DLORN) using peer-to-peer protocols.

The peer-to-peer (p2p) model is not new and despite its problems in the beginning of its use in the academia - generalized copyright violation and uncontrolled usage of the computational resources and the institution bandwidth, which are used in entertainment and non productive activities (Vilano, 2005) - a strong interest and curiosity in academic environments for such applications is rising (Schoder & Fischbach, 2003). Projects like Edutella (Nejdl, 2002), Comtella (Vassileva, 2004) and especially Lionshare (LionShare Team, 2004), and developments like Elena (Kieslinger & Simon, 2004; Rivera et al., 2004), bring p2p to the arena of large scale sharing of resources in the academic world.

A New Context and New Concepts

The convergence of information technology developments, together with instructional and pedagogical developments, is creating opportunities for new paradigms of learning and teaching. New concepts of post-graduate university education and of university continuing education will emerge, where new roles for individuals and institutions will be available, and where new requirements will constringe.

According to Hicks, Reid, & George (2001), universities are asked to provide for a larger and more diverse cross-section of the population, to cater for emerging patterns on educational involvement in order to facilitate lifelong learning and to include technology-based practices.

In this section, we discuss a new concept of networked virtual Web-based learning and teaching environment, where universities or providers make their units of learning[4] available to learners in a market of teaching resources (i.e., mediated by a third party), under the format of individualised learning projects.

The Agile/Virtual University and Individualised Learning Projects

The emergence of virtual institutions is directly linked to the development of, and access to, information technology and communications infrastructure, and is contributing to overcome the socio-economic and geographical disadvantages in acquiring skills and knowledge.

Many people believe that IT will introduce structural changes to the universities, both in the organisational domain and in the research and learning domains. While university administrative activities have been transformed by IT (e.g., student and faculty communications), other higher education functions have remained more or less unchanged, like teaching for example, which in many cases still continues to follow a classroom-centred, seat-based paradigm (National Research Council, 2002). This report by the National Research Council warns academe against "complacency in the fast-paced technological developments from virtual universities" (Kiernan, 2002).

As in earlier periods of change, the university will have to adapt itself to this changing economy, while protecting its most important values and traditions, such as academic freedom, a rational spirit of inquiry and liberal learning (National Research Council, 2002). In this changing economy, adaptation to change means to identify challenges and opportunities, and to reshape roles and activities, in order to align the university missions with the new requirements of society. Scholarly communities will shift from physical campus to virtual and globally distributed and networked structures.

One of the most widely discussed areas in recent business literature is that of organisational network structures as the basic principle to achieve flexibility and responsiveness in a highly complex environment (Bradley, Hausman, & Nolan, 1993; Byrne, 1993; Davidow & Malone, 1992; Handy, 1995; Miles & Snow, 1986). If, in the business domain, flexibility and responsiveness are the main competitiveness requirements to strategically align business with a more global, networked and demanding market, we are convinced that the same applies in the services domain, specifically in the domain of university education.

We agree that universities should strive to become learning organisations, much along with the well-known concept of Senge (1990), self examining and self-improving the services; however, besides the recognised need to shift, the university of the future will not stand alone! It will consist on an agile network or partnership of providers of teaching units, configured in learning projects, designed and redesigned to dynamically respond to the needs of each individual.

But the strength of the university of the future will be in the fast response, high quality, dynamics/agility and customisation, to closely meet the learner's needs and expectations, which are traduced in an Individualised Learning Project.

In our understanding, the concept of virtual university as presented in the literature and as we have introduced in the second section does not respond to the requirement of dynamics that we want to address. We understand the university of the future as a dynamically changing structure that works as a university. The university of the future is the Agile/Virtual University.

The A/V U concept is defended by the authors as an agile and virtual entity, integrated from independent providers of learning units (in principle university teachers, but also other independent teachers), existing solely to dynamically respond to a learning opportunity or need, traduced by an individualised learning project. After the conclusion of that learning project, the A/V U dissolves itself. During its lifetime, the A/V U can be subject of reconfiguration (changing or adapting its physical structure) in order to keep aligned with the learning project. Reconfigurability dynamics is a main requirement of this model, in order to be closely aligned with the learner's needs and expectancies. An A/V U is expected to have integration and reconfiguration capability in useful time.

This way, a leaning project, viewed as an integrated set of units of learning designed to meet learner requirements, can show its maximum efficiency and effectiveness.

A/V U reconfiguration implies the search and selection of new providers and can be the result of unpredictable changes in the environment (learner) or as a requirement of quality and competitiveness improvement, or even be due to un-accomplishment of responsibilities of a given provider. An A/V U can have as many instantiations (physical configurations) as required (reconfigurability) in order to align the Individualised Learning Project with the learner requirements.

Two main requirements are identified in the implementation of the A/V U model: (1) permanent alignment with user (or learner) needs and (2) reconfigurability dynamics. In order to respond to these requirements, the implementation of the A/V U model requires an environment covering the whole process, from the design of the Individualised Learning Project until the creation and reconfiguration of the A/V U responding to the project, assuring trust, accreditation, efficiency, quality, assessment, and so forth.

The concept of a Market of Teaching Resources consists of an electronically delivered intermediation service (with different degrees of automation), mediating offer and demand of teaching resources (or units of learning) to dynamically integrate in an A/V U and "brokers" (consultants, knowledge support). In this "virtual" environment, offer corresponds to *teaching providers* (providers of units of learning) that make their skills and knowledge available, as potential servers/partners for A/V U integration, and demand corresponds to *learner*, the individual looking for an individualised learning project to satisfy his needs. The Market of Teaching Resources intends to provide participants (learners/teachers) with access to a larger pool of learning/teaching opportunities (both offer and demand sides).

Teachers, Learners, Brokers and ... A Market of Teaching Resources

A new entrant in the emerging university education market is the teaching provider (who can be a university teacher or a certified trainer/teacher), motivated to create learning opportunities for anyone who is interested.

Specialisation is becoming a mark to those new teachers that need to make their skills and knowledge available to a global market, to integrate strategic and dynamically reconfigurable partnerships—A/V Us -- according to individualised learning projects. These teachers can be reached through institutions providing market access to teaching units, such as the Market of Teaching Resources.

The several providers of units of learning are subscribed to the Market, and form a graph where links between units of learning represent all the identified meaningful/possible combinations of units of learning in Learning Projects (*Figure 1*). An A/V U instance represents a physical structure of a set of integrated teaching providers, and reconfigurability along a learning project lifetime corresponds to the changing physical structures, as represented in *Figure 2*.

In the emerging context of *learner pulls, versus market push*, we assist to a shift from "knowledge providers to knowledge seekers" (Porter, 2000). The learner commands the process of course delivery, in such a way that a single university or educational institution could not answer. The proposed A/V U model empowers the individual/learner.

The agility and virtuality of this model is assured by the existence of a Market of Teaching Resources and by a human broker.

The presence of the broker in the Market of Teaching Resources is justified with the answer to questions such as: how does the learner locate the teachers; find the units of learning that fit its needs or draw an individualised learning project. Brokers are tailors that use the Market of Teaching Resources to design Individualised Learning Projects and to integrate/reconfigure an A/V U that is able to provide that project.

New Challenges Towards the Agile/ Virtual University Model

It is to recognise that the development of this new virtual educational models brings in change

Figure 1. Global domain for selection of teaching providers, globally distributed, organised according to units of learning

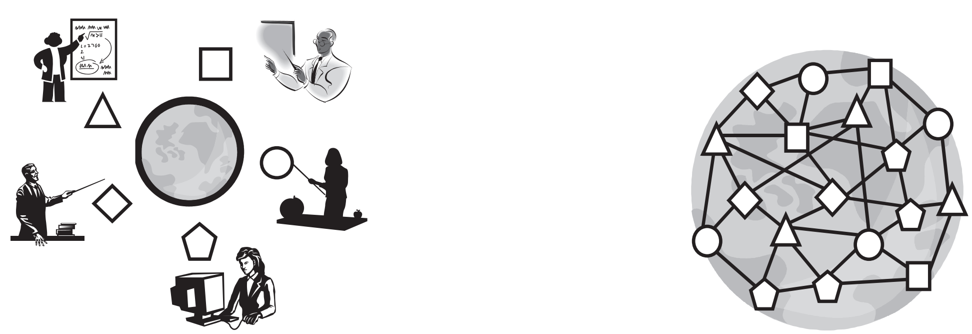
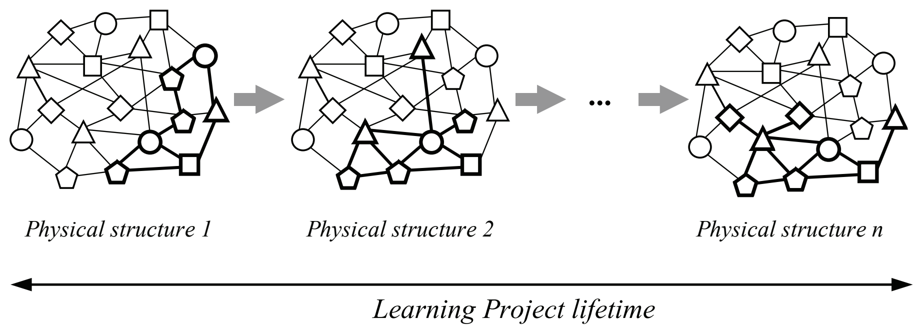


Figure 2. The Learning Project lifetime



forces in several domains: trust, quality and curriculum relevance to labour market needs, are some of the main requirements for the success of the A/V U model.

Specific regulations, legislation, accreditation, recognition of degrees and curricula, consumer protection, and cultural sensitivity are urgent concerns to promote, in order to allow this step further towards the development of liberalised agile and virtual learning concepts and the materialization of a new sort of organisational supporting environments (of which the proposed Market of Teaching Resources is an example). It would be out of our scope to highlight all of them, but some challenges associated to the emergence of these learning concepts involve:

- Certification of providers of units of learning, in a world-wide basis;
- Recognition and wide acceptance on the definition of units of learning, content, duration, objectives, supporting learning materials, and so forth. Recognition of units of learning between different institutions, by the attribution of units of credit and possibility of transfer, and so forth;
- Accreditation of brokers and all sorts of third parties intermediating offer and demand;
- Accreditation of institutions like the Market of Teaching Resources;
- Assessment and quality assurance of units of learning and of learning materials of support;
- Assessment of skills acquired by the individuals/learners;
- Maintenance of a learner profile, comprising goals, learning history (learning units studied or successfully completed), learning performance and preferences;
- Standardised design processes to support the definition of individualised learning projects[5].

Besides the legal aspects and the supporting legislation that this model would require, the Market of Teaching Resources should offer an environment responsible by assuring trust, assuring the implementation of rules and laws, quality assurance, counselling and management of the learning path of the individual, assuring the interface with the providers of teaching committing them to accomplishing the contracted roles, and so forth.

The Agile/Virtual University Framework

The implementation of the A/V U model and its requirements requires a framework covering all processes in a learning project. The two basic properties, implicit in the designation A/V U, are virtuality and agility. Together with integrability and distributivity we have the four basic properties of the A/V U model[6].

The framework proposes that the A/V U model requires an enabling environment to cope with the intrinsic requirements of the model (the Market of Teaching Resources) and the Broker, acting through the Market, as the enabler for agility and virtuality. The Market of Teaching Resources together with the Broker offers the support to the A/V U model.

In this section, we discuss the meaning of these four properties in the A/V U model and how are they implemented. But let us first introduce briefly the concept of hierarchical system, a basic concept to understand our framework.

A Hierarchical System Model

The A/V U framework is based on a hierarchical system model as a global view of a learning project. The underlying formalisation is the theory of hierarchical multilevel systems by Mesarovic, Macko, & Takahara (1970). In hierarchical multilevel systems, a system S is specified as:

$S: X \rightarrow Y$

where X is the set of outside *stimuli* and Y is the set of responses. Both X and Y are representable as Cartesian products, that is, X and Y are assumed as a families of sets such that:

$X = X_1 \times \ldots \times X_n$

and

$Y = Y_1 \times \ldots \times Y_n$

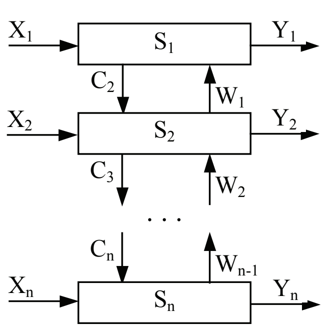
representing the ability to partition the input *stimuli* and responses onto components.

Each pair of (X_i, Y_i), $1 \leq i \leq n$, is assigned to a particular level of a system S_i, represented as a mapping, as in *Figure 3*. C_i is the result of level S_{i-1} and passed to level S_i, while W_i is the result of level S_{i+1} and returned to level S_i, until we reach level 1.

Basic Properties of the Agile/Virtual University Model

The properties of the Agile/Virtual University model include: integrability, distributivity, agility and virtuality, which are introduced in this section.

Figure 3. A hierarchical multilevel system



Integrability

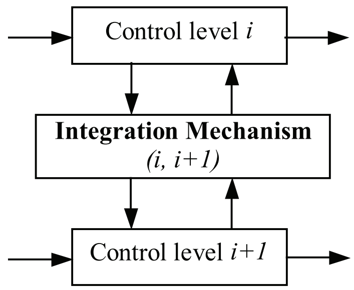
One of the most important requirements for the A/V U is the capability for efficient access to heterogeneous candidate teaching resources and their efficient integration in the A/V U. By "heterogeneous" teaching resources we mean that under the technological perspective, their supporting systems (applications and platforms) may work/operate internally in their own specific, proprietary language, that is, they may not conform to the same standard(s). Portability and interoperability among heterogeneous systems, as well as extendibility, reconfigurability, and longevity, are characteristics of the so-called *open system architecture*.

Integration is primarily the task of improving interactions among the system's components using computer-based technologies with the following goals (Vernadat, 1996):

1. To *hide underlying heterogeneity and distribution* of functions, data, knowledge and functional entities to business applications and users, therefore ensuring portability;
2. To *facilitate information exchange and/or sharing* among applications, and
3. To *provide an open environment*, that is, an *interoperable "plug and play" environment* in which new components can be easily added or connected, updated or removed, for integrated enterprise operations.

Although the definition of distributed system refers the computer application domain (hardware and software), the same problems occur for components and processes integration, requiring some integration mechanism for the distributed systems. In this framework the integration mechanism assured by an "Integration Mechanism" (IM), represented in *Figure 4*, where *Control level i* corresponds to the learner and *Control level i+1* corresponds to the teaching provider.

Figure 4. Elementary structure for an integrated and open hierarchical multilevel system control

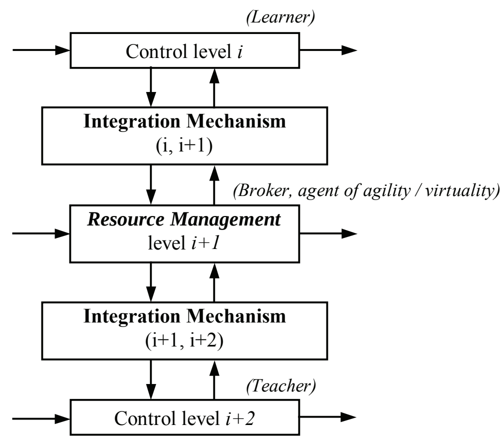


The integration mechanism functions[7] represent the required interface or translation functions between control levels and resources management levels, to assure integrability between the participants. The environment supporting the A/V U model (such as a Market of Teaching Resources) must assure integrability between the participants (teachers, learners and agents of agility and of virtuality), as represented in *Figure 5*. At this moment, this property is dependent of the developments in the domain of standardisation already mentioned in the second section.

Distributivity

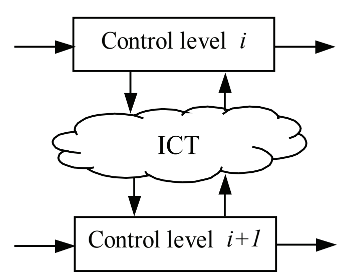
In the context of the A/V U framework, the distributivity concerns the geographical dispersion of teaching providers (see *Figure 1*). It is important to consider spatial distribution of the A/V U components, because the A/V U requirement for reconfigurability, as a part of flexibility, implies the search of new teaching resources, to be allocated to the task to be performed, in order to satisfy new or changing circumstances. To obtain the best combinations of resources, it is desirable that as many as possible teaching resources providers concur to the integration of the A/V U. This requisite implies that the candidate providers are globally distributed and inter-connected using information and communication technologies (ICT), to enable the negotiation capability, the integration of the A/V U and the delivery of the contracted units of learning in an efficient, effective and real-time way. ICT enables the efficient access to remote providers distributed geographically, all over the world (see *Figure 6*).

Figure 5. Integration mechanisms between levels of the A/V U framework



We are not concerned with the implementation of the distributivity characteristic, as this is assured by the ICT infrastructure. The definition presented is oriented to a spatial distribution of the A/V U elements and not to distributed management or distributed software applications. A distributed structure does not imply a virtual structure. We may say that distributed structures are an intermediate step on the development and implementation of the virtual structures concept.

Figure 6. Elementary structure for a distributed hierarchical multilevel system control

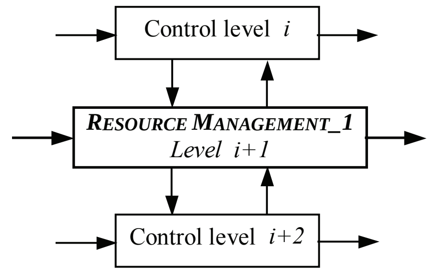


Agility

The competitive foundations of agile manufacturing or enterprise are continuous change, rapid response, quality improvement, social responsibility and total customer focus (Kidd, 1994). An agile company is one capable of operating profitably in a competitive environment of continually and unpredictable changing customer opportunities (Goldman, Nagel, & Preiss, 1995). *Agility* is the capability for *fast adaptability* or *fast reconfigurability* in order to respond rapidly to the market (or customer demand) changes. We consider the same meaning for these concepts, in the context of the A/V U model.

As the A/V U implies interactions between various independent teaching providers, it will be required to control and manage inter-provider organisational configuration. It is essential to be able to define domains of responsibility for configuration management, which reflect organisational policy and permit limited configuration management facilities to be offered, or to be contracted. A/V U agility must be carried on by some "organisation configuration manager:" the *resource manager* or *broker*. The *Market of Teaching Resources* is a domain for configuration management, subscribed by a set of providers, to which a particular access control policy applies.

Figure 7. Elementary structure for an agile hierarchical multilevel system control



The "organisation configuration management," that is the agility function, is presented by the *"Resource Management_1"* level, and implemented by the *broker* (*Figure 7* and *Figure 8*). *Control level i* corresponds to the *learner* and *control level i+2* to the *providers of teaching units* (A/V U participants); *control level i+1* corresponds to the *broker*.

Figure 8. Agility in the A/V U model - operation scheme

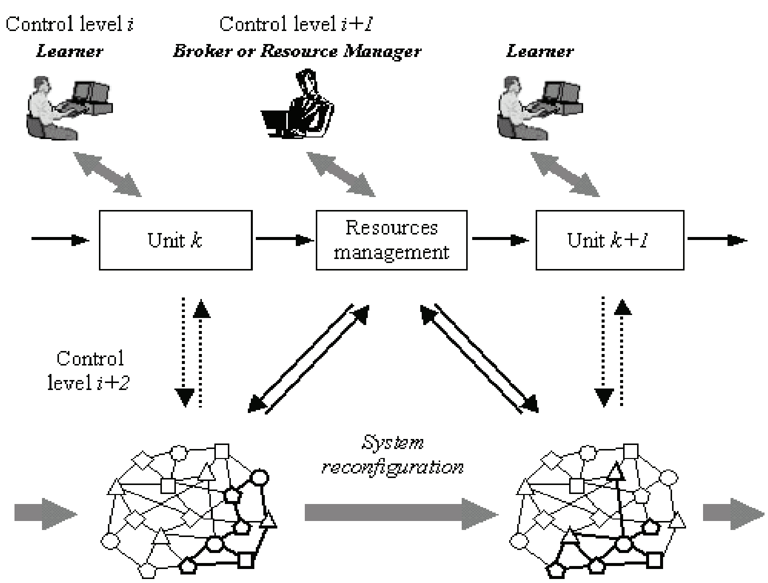


Figure 8 represents a scheme of the A/V U elementary structure operation. It is important to notice that the structure proposed provides the reconfigurability between two units of learning (by the unit of learning it is meant a set of processes carried on by a single provider and without interruption). When the unit is concluded, the broker can reconsider the organisation structure and act with the objective to adapt it (to reconfigure it). The broker is the principal agent of agility. Reconfigurability between two units can also be a request of the learner: reconfigurability can also be the result of a demand of the learner to change its learning project, and the Market, together with the broker, can agilely respond to that demand.

Virtuality

In the specific organisational structure between A/V U participants (teachers) and brokers, the learner is not aware of the mechanisms used to communicate with, activate, or store the server object, let objects discover each other at run time and invoke each other's services.

Virtuality makes possible the transition from one A/V U physical structure (instance) to another in a way that the learner is not affected by the system reconfiguration nor aware of the reconfiguration - the underlying service structure and reconfiguration process are hidden.

To implement the "virtuality" in the A/V U it is proposed the introduction of some organisation configuration manager, that is, the *broker*, similarly as for the concept of agility. The *organisation configuration management*,that is, the function that provides virtuality, is presented through the *Resource Management_2*, implemented by the *broker* (*Figure 9* and *Figure 10*).

In *Figure 10* it is presented a scheme of the A/V U elementary structure operation. It is important to notice that the proposed model hides the physical structure from the learner; that is, the elements of one instance of the A/V U are not seen

Figure 9. Elementary structure for a virtual hierarchical multilevel system control (Putnik, 2000)

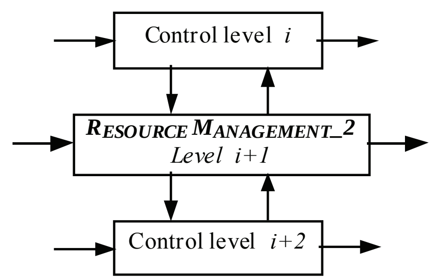
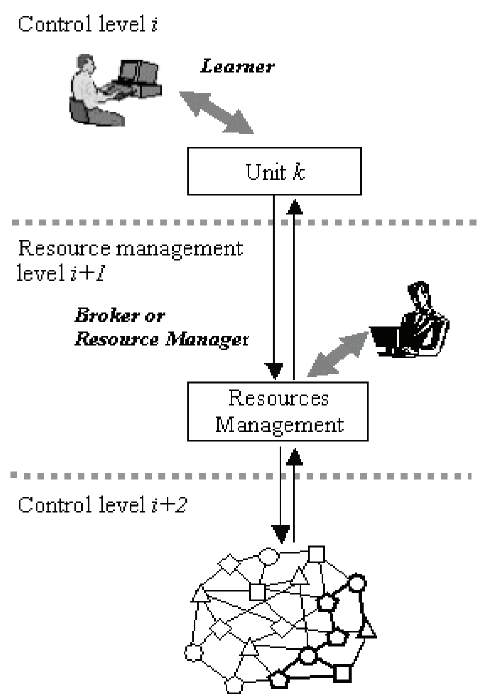


Figure 10. Virtuality in the A/V U model - operation scheme



by the learner. When the broker reconfigures the A/V U, it is without intervention of the learner.

The underlying physical structure of the A/V U can be hidden to the learner. The broker must provide the transition from one physical structure to another in a way that the learner cannot be affected by the system reconfiguration.

The main motivation for the application of the three-level hierarchy model is the learner's lack of time or of knowledge to supervise the teacher/provider, or to monitor its own learning project. But even in the case the learner has both the required time and knowledge, in order to identify a reconfiguration need (substitution of any provider) it is necessary to perform reconfiguration in parallel[8]. In the agility scheme, as previously defined, the delivery of the unit of learning and the A/V U reconfiguration are still performed in a sequence.

A Market of Teaching Resources for Individualized Global Networked Web-Based Learning

The implementation of the proposed concept of A/V U requires the ability of (1) flexible and almost instantaneous access to the potential teaching resources providers to integrate in a learning project, negotiation process between them, selection of the optimal combination and its integration; (2) design, negotiation, monitoring, management and performance evaluation functions independently from the physical barrier of space; and (3) minimisation of the reconfiguration and integration time.

The learner must have a correct idea of its needs and requirements, so that the Market can traduce them into a learning project. This learning project must be clear and consistent, as it will be the basis to the task performed by the Market of searching, selecting and integrating the teaching resources providers in a virtual university able to respond to the learner requirements.

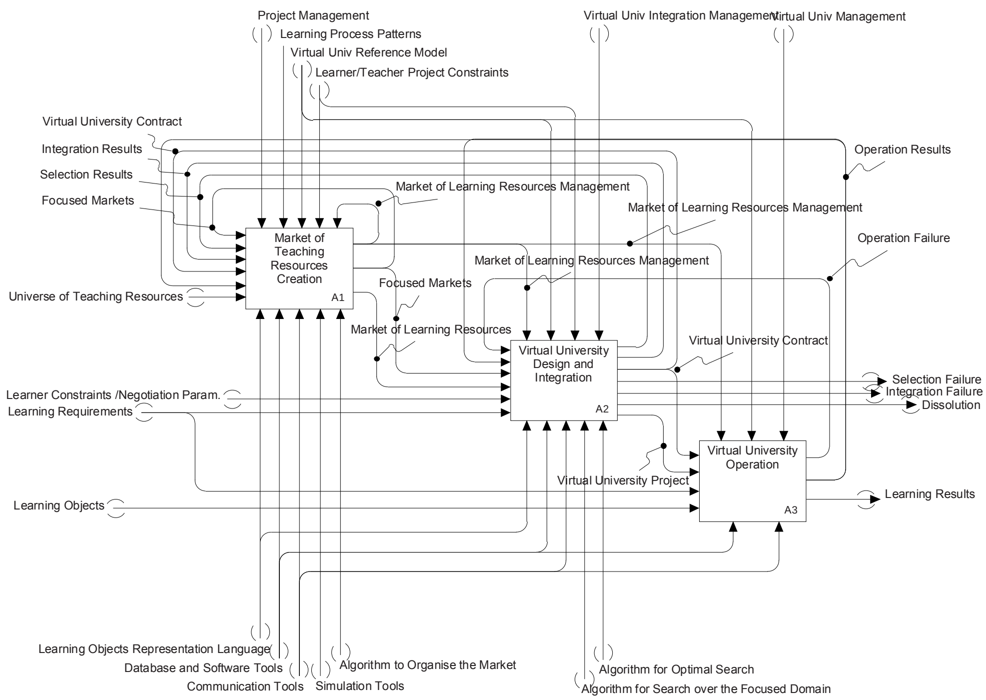
The service provided by the Market is supported by: (1) a knowledge base of teaching resources and results of the integration of resources in previous projects, (2) a normalised representation of information, (3) computer aided tools and algorithms, (4) brokers and (5) a regulation, that is, management of negotiation and integration processes. It is able to offer (1) knowledge for resources search and selection and its integration in a virtual university, (2) specific functions of operation management of the virtual university, and (3) contracts and formalising procedures to assure the accomplishment of commitments, responsibility, trust and deontological aspects.

Market of Teaching Resources: the Process Structure

The overall functioning of the Market of Teaching Resources is represented in *Figure 11*, using an IDEF0[9] diagram. It consists of the creation and management of the Market of Teaching Resources as the environment to support *Virtual University Design and Integration* and *Virtual University Operation*, offering technical and procedural support for the activities of identifying potential teachers, qualifying teaching resources providers and integrating the Virtual University, as well as coordination and performance evaluation mechanisms.

- **Process A.1.—Market of Teaching Resources Creation and Operation:** This process corresponds to the creation and operation (management/ maintenance) of the environment proposed, from the technological aspects—such as the creation of databases and development of software tools, implementation of communication systems–- up to the definition and permanent adaptation and updating of the managerial aspects, such as regulation and rules, criteria for selection, management and brokerage procedures, organisation of the Market, commitments definition, evaluation, and so forth, including the performance of the Market itself in order to improve the Market organisation.
- **Process A.2.—Virtual University Design and Integration:** This process consists of three main activities—Virtual University

Figure 11. IDEF0 representation of the global process for the Market of Teaching Resources Creation and for Virtual University Design, Integration and Operation



Request, Teaching Resources Selection and Virtual University Integration. Virtual University Request consists of treating the request presented by learner (or client), and involves the design of the learning project configuration/reconfiguration and the specification for teaching resources selection and negotiation (Virtual University Project) that matches the learner requirements. Teaching Resources Selection involves the search for the eligible resources providers to participate in the Virtual University to be created/reconfigured, negotiation among them and then selection of the "best" combination of resources to be integrated in the structure. The re-design or reconfiguration of a Virtual University, implying the substitution/integration of new resources is considered also in this process, as well as the dissolution of the Virtual University. Integration consists on formalising the structure (contractualisation) and on the establishment of procedures regarding the integration of the participants and the implementation of management and evaluation techniques. Process A.2. is detailed in *Figure 3*.

- **Process A.3.—Virtual University Operation:** The service provided by the Market controls the operation of the integrated Virtual University, tracking the performance of each resource provider, and restructuring the structure (reconfiguring the Virtual University) whenever necessary along the learning project lifetime. The operation results are of interest to keep actualised historical information concerning the performance of the resources providers, to be taken into consideration in future selection processes, and to adjust the management and monitoring procedures.

Virtual University Design and Integration

In this section we focus on the process of Virtual University Design and Integration (Process A.2.), detailed in *Figure 12*, discussing the alignment between (1) the client of the *Market of Teaching Resources*, (2) the entities involved in a Virtual University integration, that is, candidate providers and (3) learning projects.

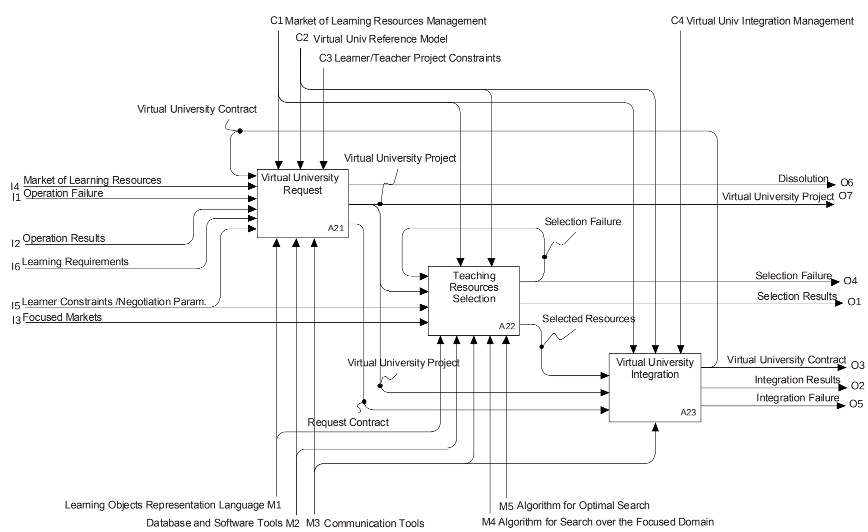
To keep the dynamics of the Virtual University model, the optimal combination of resources to integrate should be obtained almost in real-time. The complexity of the resources selection in general means that a compromised domain size (as a base for the solution space construction) should be used for each resource search. For each search, the *Market of Teaching Resources* proposes a *Focused Domain* (composed by *Focused Markets*), reasonably dimensioned, to allow a good match at a limited time.

The first step of the Design and Integration process is the design of the Virtual University, that is, the Learning Project, as a result of a Learner Request for a Learning Project (Process A.2.1.), which means (1) the translation of the specification parameters provided by the client and traducing its needs (input flow "Learning Requirements") into *Normalised Teaching Resources Selection Requirements* and (2) the translation of the specific learning constraints defined by the client that will determine the process for search of potential resources providers (input flow "Learning Constraints/Negotiation Parameters") into *Normalised Negotiation Parameters*.

The Teaching Resources Selection process (Process A.2.2.) takes place in three phases: (1) eligible resources identification, (2) negotiation, that is, identification of candidate resources and (3) final selection or identification of selected resources for integration. The process corresponds to visiting all the elements proposed by the focused domain, in order to identify negotiation parameters (availability, time to respond to the demand, or time to offer the resource, and costs), and perform an optimal search algorithm considering the client's negotiation parameters and subjected to the client project constraints (time to complete the product, cost, etc.).

Virtual University Integration (Process A.2.3.) consists on the formalisation of the structure that

Figure 12. IDEF0 representation of Process A.2.—Virtual University Design and Integration



will provide teaching: establishing procedures, normalising processes, interoperability, responsibilities and commitments. While selection means to check availability and to find the best resources that meet the requirements, integration means effective allocation and formalisation of the partnership.

CONCLUSION

We highlighted the emergency to reshape the virtual university continuing education concepts. This article discusses the necessary evolution of continuing university education to face the changing economy and introduces a framework for a new concept of university virtual education—the Agile/Virtual University model. It is also included a high level specification of an environment to cope with A/V U called a Market of Teaching Resources.

The model traduces a challenge to the traditional way we conceive the university structural organisation and the delivery of services to the society; the concept of the university of the future brings in serious implications and urgent concerns and, as such, must be faced with determination.

The structure of the university of the future can be founded upon knowledge and concepts developed and under development in other domains, like the domain of the virtual enterprises, in order to accelerate the implementation of the university of the future and to take profit from concepts and advances already achieved and validated or under validation. The model introduced in this paper is part of a wider research project under development at the University of Minho, addressing the Agile/Virtual Enterprises organisational model, whose validation the authors intend to undertake also in the university continuing education field.

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ENDNOTES

1. Complex units of learning are understood as meaningful combinations of primitive units. The concept of *e-learning object* (introduced in the second section) corresponds to the concept of primitive unit of learning.
2. Documents available at IMS (http://www.imsglobal.org/specifications).
3. OMG (Object Management Group) is an open membership, not-for-profit consortium that produces and maintains computer industry specifications for interoperability.
4. To the authors, a unit of learning can be an e-learning object or a combination of e-learning objects, constituting a chapter or a module in a subject or a course.
5. This is not a new concern in a "learning-on-demand" environment. A consortium of around 600 institutions has been joining efforts towards the identification of standards since year 2000 (Porter, 2000).
6. This framework is based on the BM Virtual Enterprise Architecture Reference Model (BM_VEARM), conceived by Putnik (Putnik, 2000; Putnik, Cunha, Sousa, & Ávila, 2005). The BM_VEARM is a reference model for enabling the highest organisa-

tional/structural reconfigurability dynamics and operational inter-enterprise dynamics of Virtual Enterprises. As the A/V U concept shares some of the properties of the Virtual Enterprise organisational model, the BM_VEARM is adapted to suit the specific requirements of the A/V U model.

7 The integration mechanism functions (represented in *Figure 5*) are not levels of the model.

8 This is the main principle of the concurrent or simultaneous engineering model.

9 IDEF stands for ICAM DEFinition methodology (ICAM—Integrated Computer-Aided Manufacturing). IDEF diagrams illustrate the structural relations between two processes and the entities present in the system. The processes (represented as boxes) transform the *inputs* into *outputs* (respectively the left and the right arrows of a process), using the *mechanisms* for the transformation (the bottom arrows of a process) and constrained by *control information or conditions* under which the transformation occurs (the top arrows).

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Chapter XX
Rationale, Design and Implementation of a Computer Vision-Based Interactive E-Learning System

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ABSTRACT

This article presents a schematic application of computer vision technologies to e-learning that is synchronous, peer-to-peer-based, and supports an instructor's interaction with non-computer teaching equipments. The article first discusses the importance of these focused e-learning areas, where the properties include accurate bidirectional interaction and low cost hardware; system portability and versatile vision technology are emphasized. In the subsequent sections, we present some results aiming to achieve these goals. In particular, we highlight the most recent advancements in the interactive PTZ camera control from both the instructor and remote student. We also illustrated how these results have successfully addressed the challenges.

INTRODUCTION

In recent times, there has been an increase in the research activities aiming to apply computer vision (CV) technologies to various automated e-learning multimedia systems.

In this article, we will discuss our progressive work in Intelligent Video Detection Agent (IVDA), which is a scheme of hardware design and computer vision software algorithms to assist e-learning systems that are *synchronous*, *peer-to-peer based* and an instructor uses *non-computer based teaching equipment*.

Before we present our prototype system, we need to explain the importance of these three properties, and illustrate how it differs from the other existing CV e-learning systems' focuses.

Synchronous e-Learning

In synchronous e-learning, the video and teaching multimedia are exchanged between the students and instructors in real-time, creating a highly interactive teaching and learning environment. Synchronous e-learning provides the students with instantaneous feedbacks and provides the instructor with a platform from which to monitor and adapt to student's activities (Soreanu & Saucan, 2003).

Computer vision technologies are used in various synchronous e-learning systems to replace many manual, laborious and time-consuming tasks, which made real-time automated camera control and instantaneous multimedia authoring possible.

Peer-to-Peer e-Learning

E-learning application can be classified according to its participant numbers, into peer-to-peer (P2P) and institutional ones. In P2P e-learning, there is usually one instructor and one student. Both participants can be of a variety of types, including home-based computer users. The learning can be both formal and informal.

Our work is focusing on P2P e-learning, since it allows for various types of participants, more importantly, the average computer users to take part in either or both the student and instructor role. It is an inexpensive learning platform and many studies can be identified to argue its advantages, such as literature in Jokela (2003) and Fletcher (2004).

However, the widespread of P2P e-learning participants also means that there will be additional considerations that need to be taken into account when designing computer vision software to support it. These considerations include:

1. The CV software must be able to intelligently assist the instructor when he works alone.
2. The CV software must adapt to standard equipment of an average computer user.

Non-Computer Based Interaction

In the current synchronous e-learning applications, the instructor and student(s) usually communicated via standard computer interfaces, using chat window, computer whiteboards, sharable text and drawing pads, for example (Deshpande & Hwang, 2001).

However, many researchers have argued that e-learning cannot replace traditional learning altogether. In a similar argument, Liu & Kender (2004) mentioned that, based on a recent survey carried out at University of South Carolina, students consider traditional blackboard presentation as "essential" and "indispensable."

Therefore, allowing the instructor, at least, to use traditional teaching equipments and video-capturing and streaming such information to student in real-time becomes a compromise solution between modern technology and traditional pedagogy.

However, most of the operator-less instructional video-capturing is achieved through the use of static camera(s) without computer vision processing. While this method is sufficient for some applications, the crude streaming suffers from an uninteresting presentation of teaching materials and is dependent on the instructor's verbal instruction and remote student's visual perception to determine what the student should pay attention to. In addition, the instructor is required to constantly check the streaming video results, such as the position of his/her body with regard to the camera view, or the size of his/her whiteboard writing. This constant distraction makes uninterruptible teaching difficult during a synchronous e-learning session.

For this reason, computer vision has played an important role in detecting classroom events and transforms many probabilistic video signals into deterministic information. This information includes the instructor's body movements, gaze, gestures, teaching objects and whiteboard writing changes. Based on this information, computer vision has made possible for automatic camera control, real-time event detection and instantaneous multimedia synchronization.

For the interested readers, please refer to Xu & Jin (2005) for more detailed discussion on the importance of these three focused e-learning areas.

Hardware and Software Challenges

Having stated in the introduction the importance of employing computer vision technologies in e-learning applications that are *synchronous*, *P2P based* and instructor *using non-computer teaching equipments*, we have deduced the four main requirements associated with these types of e-learning systems, namely:

- *Bidirectional interaction (Requirement R1)*
- *Low cost hardware (Requirement R2)*
- *Higher system portability (Requirement R3)*
- *Versatile CV technology (Requirement R4)*

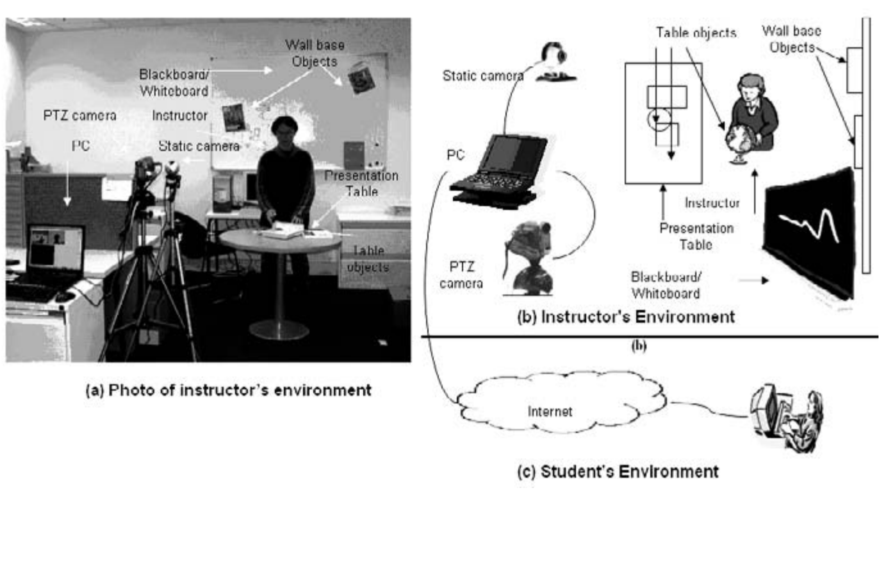
Following on from these requirements, in this section we will present the challenges when designing IVDA's hardware system and computer vision-based software algorithms to address them.

Hardware Challenges

A typical P2P instructor's room is depicted in *Figure 1*, which is also used as a testing environment for some of our experiments.

This environment setup mimics a typical P2P instructor's room. *Figure 1b* is a diagrammatic illustration of the physical placements of the camera system, PC and teaching objects in relation to the instructor. In *Figure 1c*, we show the student's environment. The settings are simplified to just a standard PC.

Figure 1. A typical peer-to-peer e-learning instructor's room



In order to achieve the low-cost hardware requirement (*Requirement R2*), the following challenges are addressed in our hardware design:

Hardware Portability

A system that can easily be ported and installed from one instructor's room to another is beneficial to the low-cost requirement, since a highly portable camera system can be shared among different users and hence more cost effective.

For this reason, in our work, the permanent fixture of any hardware in the instructor's room is clearly prohibitive. Instead of ceiling mounting the camera(s), which is common among the other learning systems, we have placed static and PTZ camera on a tripod(s) at an eye level, shown in *Figure 1a*. This design has also introduced additional software issues, such that computer vision algorithms must recover quickly when accidental camera relocation occurs during a real-time session. This is discussed in software challenge section.

Additional equipment

We have grouped the additional equipment used in our work into *reusable* and *e-learning specific,* see Table 1.

The reusable equipment includes a consumer camcorder and its tripod, which can be reused as a household appliance or can be easily borrowed.

Our goal is to minimize the remaining e-learning specific hardware cost to be less than $200. We argue that this amount would make our system hardware accessible to most ordinary e-learners. In our project, we have used two items of e-learning specific equipment. The first one is a mechanical pan, tilt, zoom (PTZ) camera base, Eagletron PowerPod (TrackerPod, 2005), which cost $179 a piece. This item has been commercially available since 2004. The second equipment is a standard laser pointer, which cost $20 each. The total cost for these two pieces of equipment have added up to $199. In *Table 1*, we have itemized the prices for all the equipment used.

Monocular Vision

Our prototype system uses single Web cam for most of our CV detection results, apart from close-up streaming.

Two or more video capture devices provide stereovision, which can bring about many new applications into e-learning. However, many stereovision techniques are sensitive to camera position changes when a camera system is placed on a portable tripod instead of ceiling mounting. At the same time, multiple camera streams processing on single PC can also degrade the real-time performance.

Computer Vision Software Challenges and Goals

Given the hardware constraints listed in the previous section, the majority of our work is obviously attempting to develop and apply CV software algorithms to adapt to these hardware challenges, while achieving the four requirements stated in the beginning of this section.

Table 1. The hardware cost in USD

	standard Pc hardware	r eusable Hardware (Household Appliances)	E-learning Specific
standard function	1 Laptop ($1,299) 1 Logitech web cam ($89)	1 Sony Camcorder ($599) 1 Camera Tripod ($20)	1 Eagletron PTZ camera Base ($179) 1 Laser Pointer ($20)
Total:	$1,388	$619	$199

Methodology for Student-to-Instructor Communication

In order to facilitate accurate bidirectional interaction *(Requirement R1),* we have provided student-to-instructor communication, allowing the student to interact with the instructor's environment by controlling the PTZ camera remotely. As a result, the student is able to view a close-up writing on the whiteboard or a teaching object without interrupting the instructor.

Automation, Intelligence and Versatilities in Instructor's Room

In terms of vision versatilities *(Requirement R4),* we have developed several functions to facilitate intelligence and automations in detecting instructional video events.

IVDA is primarily for research purpose instead of product development. Therefore, instead of designing a system that can perform a quantitative set of existing computer vision functions, we are focused on incorporating state-of-the-art CV algorithms, which have not yet been applied extensively to e-learning. These algorithms are also supporting non-computer teaching as much as possible *(Requirement R3).*

Adaptive to Inexpensive Processors

We stated previously that many P2P instructors are home-based. For this reason, when we design the software system, we aim to customize computational computer vision algorithms to suit the user's PC processor, instead of making the assumption that the hardware, such as fast and multi-processor computers, are always available to apply the technology (such as Shi et al., 2003). Therefore, in our experiments, we aim to achieve as much computer vision throughput as possible, without significant degradation to the visual processing results.

System Portability and CV Robustness

The system portability requirement *(Requirement R3)* is achieved through both the hardware and software design. Because we do not permanently install the cameras to the room, the relocation of the cameras during a live session is not always preventable. Such relocation may occur unintentionally, as the instructor may accidentally touch the camera tripod, or trip over the wires as he moves around. It can also be deliberate, such that instructor may feel the initial placement of camera does not cover certain scenes, therefore he/she may reposition the camera for a better angle during a live and informal e-learning session.

These practical challenges have prevented us from employing some computer vision algorithms where re-training or recalibration is required when camera position is changed. The techniques that fall into these categories have included background subtraction and camera calibration using reference images.

Script-Based Customizing Interface

When system is ported from one application to another, instructor will have different requirements. These requirements can be formulated into rules, which govern the camera control and multimedia syntonization. In our work, we have provided the instructor the ability to program these rules through a simple scripting interface (Xu et al., 2005).

RELATED WORK

The CV based e-learning systems have started to emerge since the late 1990s, and it has been an active and growing research field since then. In this article, we will present only the analysis of the existing works where we extracted the information on both their applications (and relevance to our work) and the CV technologies being used.

For the interested readers, please refer to our survey paper (Xu & Jin, 2005) for a more detailed summary.

Application Areas

Automatic Camera Control

The majority of the existing works in vision-based e-learning systems have focused on automatic camera control using single or multiple PTZ cameras to simulate human video shooting. The recent works are found in Onishi & Fukunaga (2004), Onishi et al. (2000a), Bianchi (2004), Wallick et al. (2004), Rui et al. (2003), Itoh et al. (2003), Ozeki et al. (2002), Ozeki et al. (2004), Kameda et al. (2000), Kameda et al. (2003) and Shimada et al. (2004).

Our work also incorporates a PTZ camera. As we have noticed that, although capturing video data from a static camera alone is enough for detecting many vision events, however, it cannot provide a sufficient streaming result for close-up writing and objects far away from the camera. However, our work differs from these approaches, where in order to satisfy our low-cost requirement, we have used a low-cost and low-precision PTZ base compared with single-purpose and expensive PTZ camera used in exiting works.

Media Synchronization Based on Event Detection

Some of the current works also focus on instantaneous multimedia synchronization based on events captured from classroom. The work that falls into this categories include Franklin (2001), Chiu et al. (2000), Kim et al. (2004), Mukhopadhyay & Smith (1999), Shi et al. (2002), Wallick et al. (2005), Shi et al. (2003) and Shimada et al. (2004).

In IVDA, automatic multimedia synchronization is also being studied where functions such as object recognition subsystem and synchronization events scripting are proposed to facilitate this functionality.

Other Applications

There are also many other applications of computer vision technologies in e-learning. Some of these examples have included biometric identification for automatic lecturer's login (Shi et al., 2003); apply student's gaze information for lecture feedback evaluation ((Suganuma & Inaki, 2004)) and augmented reality in e-learning (Liarokapis et al., 2002). Currently, we feel these types of work are less relevant to P2P e-learning.

c omputer Vision t echnologies u sed

We have reviewed the computer vision technologies used in the existing e-learning systems. Note that a complete survey of this kind is difficult, since many literatures are focusing on the learning system aspect, and the CV algorithms are often lack in detail. However, some of these technologies used can be intuitively deduced from the results they achieve.

Most of the works have used human tracking for instructor and students, face tracking, hand tracking (Ozeki et al., 2002; Itoh et al., 2003; Ozeki et al., 2004), background subtraction (Heng & Tan, 2002), gesture recognition, (Flachsbart et al., 2000; Franklin, 2001) color and motion segmentation, (Shi et al., 2003; Shimada et al., 2004), and template matching (Chiu et al., 2000; Suganuma & Inaki, 2004), as well as many other computer vision and statistical analysis techniques.

Differences to Our Work

Although many factors can be learned from the existing systems, there are also a number of differences, which prevent some of these methods from being applied for our purpose:

CV Robustness and Portability

We feel that some of the existing systems have not been designed with sufficient system portability, even though they have reported impressive results under certain environments.

For example, Wallick et al. (2004) used a simplistic algorithm to track the speaker, where weighted vertical columns of the video frame difference is used to locate and update the instructor's head position. Theoretically, this method can not achieve high robustness in tracking under environments where the instructor is not the only moving object.

Similarly, in CABLE project (Shimada et al., 2004), the authors used a three skin color area assumption by K-means to search the face and hands region, the author then use the Hough transform to detect a circle based on the fact that faces is approximately in a circular form. The system then classifies the other two regions to be "hands." In our experiment, this method has poor robustness when instructor is wearing cloth that has color similar to the skin.

Ozeki et al. (2004) have used a skin colour model for Asian skin types, since their work is focused only on Japanese TV-learning broadcasting.

We argue that despite the high performance in their local environments, much of the system adaptability and portability are in question when CV algorithms in these works are ported from one P2P instructor's room to another.

In addition, most of the current systems have used ceiling-mount camera systems, for example Shi et al. (2003), Itoh et al. (2003) and Ozeki et al. (2004). These methods hence prevent the hardware to be portable between the instructors' rooms.

Expensive Hardware

Many existing applications that have used multiple computer vision algorithms were relying on expensive hardware to achieve their versatilities. An example of such system is Shi et al. (2003). This system is comprised of seven computers and eight video cameras.

In addition, every automatic camera control algorithm employed in the existing e-learning system has used commercial or industry PTZ cameras, where the average price for the commercial models is around $1,000 USD, let alone the industry models. These commercial PTZ cameras can not be reused as a household appliance and are unlikely to be affordable by most home-based e-learners.

From our analysis, most of the current systems have given us the impression that their primary focus is to apply different hardware to suit the CV technology, whereas in our work, we are aiming to customize the CV technologies to suit a low-cost hardware implementation.

Interactive E-Learning: Control Low-Cost PTZ Camera

During an e-learning session, there are many objects in the instructor's room that need to be captured in close-up, such as whiteboard writing, the instructor and the teaching objects. This is commonly achieved using computer-controlled automatic pan-tilt-zoom (PTZ) cameras.

In contrast to current approaches, in our work we have used a low-cost, low-precision PTZ camera base to achieve automatic camera control in order to satisfy our low cost requirement *(Requirement R2)*. Our contribution in this area has been a sophisticated and novel software control scheme to compensate the low-precision hardware disadvantage.

In order to also meet the requirement for accurate and effective bidirectional interaction *(Requirement R1)*, we allow the PTZ camera to be controllable by an instructor as well as from a remote student. The control from an instructor is by drawing a virtual ellipse using a laser pointer over an object or a part of the whiteboard. Student control is by specifying the areas of viewing though computer interface with a single mouse drag operation.

PTZ Camera Hardware

Past Approaches

As described previously, the use of a single-purpose, professional PTZ camera conflicts with our low-cost requirement. For this reason, we have employed an alternative PTZ base, Eagletron (TrackerPod, 2005), which has been available since 2004. This device is cheap and can perform computer-controlled panning and tilting operations. In addition, it is designed to work with a household video camera[1], in which its optical zoom-in can also be software controlled[2].

The PTZ base costs USD$179. We have used it in combination with a video camera (Sony HC42E, USD$599). Although the overall camera system has only reduced the total cost marginally compared with a commercial single-purpose PTZ camera, we argue that our approach is far more economical to home-based e-learners. This is because the attached camera can be reused for household video shooting and easily borrowed from others.

Camera Configuration and Specification

Since we have already used a single static Webcam to achieve most of our e-learning vision results, therefore, it is natural to use an additional PTZ camera in conjunction with this static Webcam. The two cameras are placed sufficiently close at eye level as shown in *Figure 2*.

This approach of using a combination of static and PTZ camera is common among e-learning camera control schemes, such as the ones used in Bianchi (2004), Wallick et al. (2004) and Onishi et al. (2000b). Its appropriateness to e-learning is obvious, since all the areas of interest, including the instructor, whiteboard and teaching objects are naturally in the same part of the room facing and within the view of a static camera. When a PTZ camera is in action, it would have a narrower view, and hence it is relying on the static camera to capture the other events. We itemize our customized camera system's specification in *Table 2*.

Figure 2. PTZ and static camera configurations

Table 2. The specification for our customized camera system

Eagletron PowerPod + Sony HC42E	Resolution Pixels (video)	Optical Zoom	Pan-Tilt Speed
	690,000	12x	Pan: 160º, Tilt: 110º.

Challenges for Controlling Low Precision Camera Base

Despite the low-cost advantage and the sufficiency in its panning and tilting ranges, the major setback from using this device is its low mechanical precision level; mainly due to the external joints between the base and the attached camera (commercial single-purpose PTZ cameras have mechanical integration internally).

Shown in *Figure 3*, by performing a +5 and –5 panning steps, the camera shows that it is slightly off-centre to the original square drawn.

The minimum steps (the step size) in pan and tilt is close to one degree interval compared with 0.07 degree interval in Sony EVID100 used in e-learning applications such as Wallick et al. (2004). In addition, this PTZ camera base does not send a feedback signal to a PC for its status during and after a movement. Therefore we can not synchronize the current video frame feature easily with its mechanical operation.

Due to these factors, our challenge is to design computer-vision algorithms adapting to the base's mechanical imprecision. In addition, these factors have forced us to perform camera control semi-passively based on the camera's video feature rather than using 3-D coordinates.

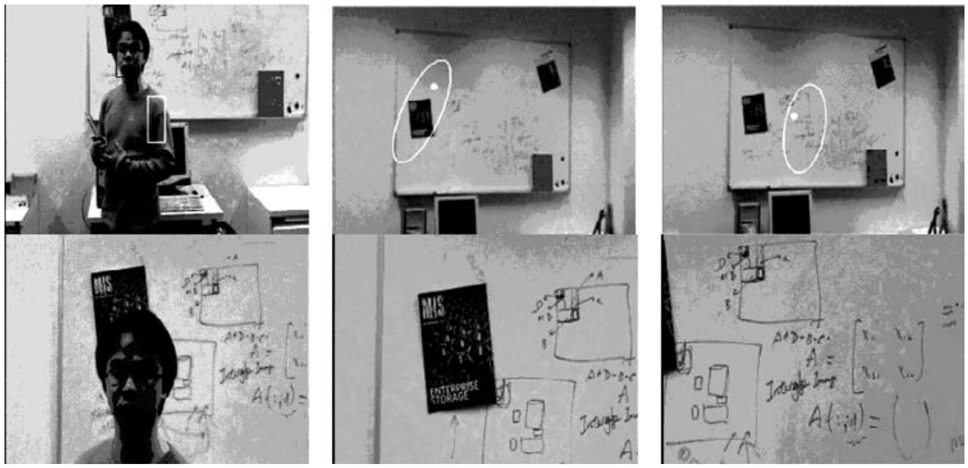
PTZ Camera Control Algorithms

In our work, we need to zoom into the *instructor*, the static teaching objects placed on the wall (the *wall-based objects)* and the *whiteboard writing.*

The results of these three types of track and zoom operations are shown in *Figure 4*. In *Figure 4a*, the top screen capture shows when the instructor is first detected, and the bottom screen capture is after the instructor's face has been automatically zoomed in. In *Figure 4b*, the top image shows the detected virtual ellipse drawn by an instructor using a laser pointer over a wall-based teaching object, and the bottom image is the screen capture after the camera zooms in accordingly. In *Figure 4c*, the images are similar to those of *Figure 4b*, except the object-in-interest is the whiteboard writing.

Figure 3. PTZ camera's mechanical imprecision: Notice that after +5 and -5 pan operations, the dark gray rectangle's position is shifted slightly towards right with respect to the book

Figure 4. Track and zoom results: (a) instructor (b) teaching objects (c) the writings



Track and Zoom to the Instructor

Placing the PTZ camera zoom onto a fast-moving instructor all the time is not possible with our low-precision camera base. Accurate and fast tracking of a moving person involves stereovision to estimate the 3-D locations of the person. For example, IBM's person tracking project, (Connell et al., 2004) has used a pair of distant static cameras for wide stereo baseline triangulation to estimate the 3-D position of a person. Then, a PTZ camera can zoom onto the person in real-time. In addition, since our PTZ camera view is not consistent after movements (shown in *Figure 3*), even if there are two static cameras available to us (and calibrated without considering accidental camera relocation issue stated previously) and the 3-D position of the instructor is estimated correctly, the PTZ camera can not mechanically pan and tilt to the desired coordinates accurately.

Despite its hardware limitation, we have achieved robust track and zoom operation using the algorithm show in Algorithm 1.

The only difference compared with a real-time instructor tracking using precision camera (Kameda et al., 2003) is that, in our work, we have only allowed the zoom-in operation to occur when an instructor's face is confined to a small movement for a five-second period. This time interval is to allow the PTZ camera to converge its mechanical movements, which then places instructor's face in the center of its view prior to its zoom-in operation.

We argue that such confinement does not introduce a significant degradation in instructional video presentation. We have observed that, unlike the surveillance video tracking, during an e-learning session, the instructor's upper body and face do not move all the time. They usually remain relatively stationary for a period longer than five seconds, particularly when the instructor is explaining something (which is also the most appropriate time to zoom into the instructor's face). We would re-track the instructor once he/she began to move more rapidly.

The mechanical convergence subroutine used in the above algorithm is discussed in the subsequent sections. The face detection is based on the well known Haar-like features using Adaboost training (Viola & Jones, 2001) while tracking face after detection is using mean-shift color tracking (Comaniciu et al., 2003), which is also used in many parts of IVDA.

Algorithm 1. Instructor tracking and zoom procedure

```
WHIle  ()
    Detecting face in static camera
    IF (Face detected)
       Normalize PTZ camera's position
       Track face in PTZ camera
    IF (Face is tracked)
       c all Start Pan-Tilt Mechanical convergence (by
        colour)
        IF (Tracked position changed is > Allowable
             Position Threshold)
              r estart Pan-Tilt Mechanical convergence
                 subroutine (by colour)
        end  IF
        else
              r estart Instructor tracking and zooming
               procedure
        end  IF
   end  IF
end  WHIle
```

Estimating PTZ Camera Direction From Static Camera View

When the PTZ camera is in its normalized position, it contains a similar view to the static camera, as they are placed close together as shown in *Figures 2* and *4*. Therefore, if the face detection succeeds in the static camera, then it also means that the face can be detected in the normalized PTZ camera view. However, this approach also means that the PTZ camera's mechanical convergence always starts from its normalized position.

In our work, we have also experimented with a method to control PTZ camera's pan and tilt movement initially by static camera information. As a consequence, when the tracking subject becomes more stationary, PTZ camera's mechanical convergence can start from a direction closer to the subject.

To achieve this, we have measured and recorded the sizes of detected faces in the static camera across different depths. During real-time, the size of detected face is then used as depth information for triangulation. A similar monocular tracking approach is also found in Cheng & Takatsuka (2005).

Although this method can not robustly place PTZ camera exactly into the direction of the instructor's face, it achieves our purpose where in most of the time the instructor's face is included in the PTZ camera view even though the face may not be at the centre. It then allows PTZ camera's mechanical convergence procedure to begin when the static camera detects the instructor's movements is slowed.

In *Figure 5*, we have shown the tracking result based on this technique. The first seven screen captures shows PTZ camera's movement controlled by detected face sizes in static camera view. During this time, the instructor has large movement and PTZ camera is not exactly pointing into the direction of instructor's face, but contains it within its camera view. In the last screen capture, instructor remains stationary for a five-second period to allow PTZ camera to complete its mechanical convergence.

Figure 5. PTZ camera movement controlled by static camera view

Zoom-in to Wall-Based Teaching Objects and Whiteboard Writings

Unlike face detection, which can be achieved automatically by the vision system, the zoom-in operation for static objects such as the teaching equipment and whiteboard writing requires user specification. The region can be specified by the instructor, using a laser pointer drawing a virtual ellipse over the subject, as shown in *Figure 6a*.

The system then detects the locations of the laser pointer virtual ellipse region. The laser pointer detection algorithm is based on a spatio-temporal training/detection using integral image features; its technical details are not discussed in this paper. The remote student can also specify the region using GUI interface to the instructional video, shown in *Figure 6b.*

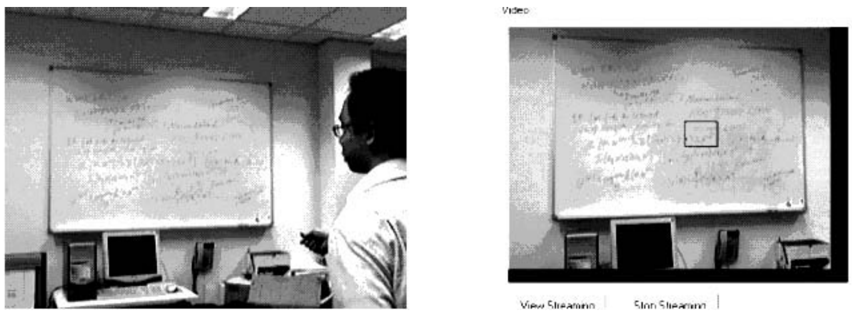
There is a major difference between white-board writing and teaching object in terms of PTZ camera control. For whiteboard writing, the selected area has very similar color distributions to its neighboring regions. For this reason, we can not control the PTZ camera by tracking its color features. Instead, we have used a classic Kanade-Lucas Thomsi (KLT) tracking method by Shi & Tomasi (1994), where a set of "stable features" are used to track displacements between video frames using optical flow method. The track and zoom algorithm for static objects and whiteboard region is shown in Algorithm 2.

Implementations

PTZ Camera's Mechanical Convergence

Before the zoom-in operation takes place on either type of object, the PTZ camera needs to pan and tilt until the selected region/object is in its centre. One important part of our contribution lies in our semi-passive, gradual mechanical

Figure 6. Two interaction methods to specify the zoom-in region



(a) Instructor draws a virtual ellipse over a whiteboard writing region by a laser pointer

(b) remote student specifies the region by GUI selection

Algorithm 2. Track and zoom to teaching object and whiteboard writing

```
WHIle ()
    Detecting laser pointer in static camera
    IF (laser pointer is detected)
        Normalize PTZ camera
        Detecting virtual ellipse drawn by laser pointer
        Segmenting Video frame
        Check colour feature of object inside virtual
            ellipse drawn
            IF (without distinct colour)
                call Start Pan-Tilt Mechanical
                    convergence (by optical flow)
            else IF (with distinct colour)
                call Start Pan-Tilt Mechanical
                    convergence (by colour tracking)
            end IF
    end IF
end WHIle
```

convergence control algorithm. This algorithm allows the low-precision PTZ camera base to perform "*centering*" operation using the selected region/object as a reference.

When precision hardware is used, the correspondence between the camera's angular motions in relation with the amount of changes in its camera view can be estimated using stereovision techniques. Then the centering can be controlled using triangulation of the 3-D coordinates. However, as we have pointed out before, such measure is unachievable from our imprecise hardware. Therefore, our semi-passive control algorithm is the only effective measure to achieve centering.

Tracking is performed on the selected/detected region using either mean-shift tracking (by colour) (Comaniciu et al., 2003) or KLT (optical flow). By accurately tracking the selected region while continuously updating the position of PTZ camera's current centre view, its mechanical movements can effectively be converged, such that the selected region and the centre of camera view will overlap.

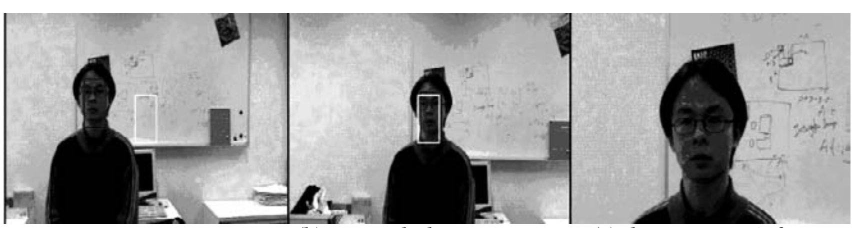
Algorithm 3. The mechanical convergence procedure

```
WHIle ()
    Update location of the object
    IF (pan and tilt are both less then 1 unit of
          movement) And
        (Location of selected window is close enough to
        the center view) t Hen
        PTZ camera is mechanically converged
        c all Zooming operation
   end IF
    Calculating its current direction towards center view
   IF (Last horizontal or vertical move is same direction
          towards center view)
       Current Move = same direction and length of last
       movement
       Update last move
   else
        Current Move = Opposite direction, Length – 1
                              Unit
        Update last move
   end IF
        Stop sufficient time (by estimating its movement
        length)
end WHIle

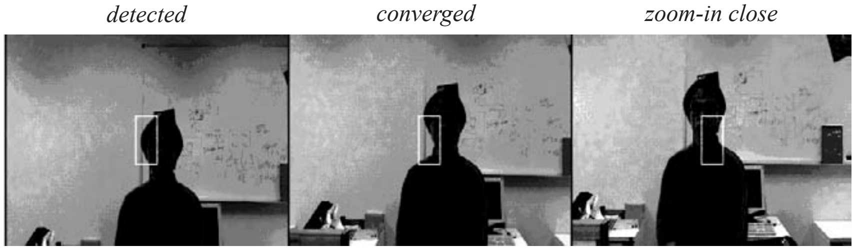
COnCURREnTl Y:
     Move camera according to "Current Move"

COnCURREnTl Y: (either)
     Track selected objects (by color) at every frame
     Track selected whiteboard writing (by optical flow)
      at a given interval
```

Figure 7. Result of the mechanical convergence by tracking colour when



(a) the instructor is first detected *(b) pan and tilt operation is converged* *(c) the instructor's face is zoom-in close*



(d) Image sequences captured from the PTZ camera, while it performs pan and tilt operations

The algorithm works in a simple harmonic motion style, such that it begins with larger movements. When it is getting close to an object or has "passed" over the object, its motion becomes slower and in a reverse direction. The algorithm is depicted in the Algorithm 3.

We recall that the PTZ base has no feedback signal. Therefore, in our work, both colour tracking and optical flow have to take place concurrently with the camera movements.

In *Figures 7* and *8*, we have shown the video sequence capture results using the above algorithm (by tracking colour and optical flow respectively). Notice that the initial movement is larger, and then it becomes slower and in a reverse direction when the object (in blue) "passed over" the centre view (in white). This procedure usually takes up to a maximum of five seconds before it converges.

PTZ Camera Centering

By Tracking Color

The tracking-by-colour algorithm is based on mean-shift tracking (Comaniciu et al., 2003), which can be executed in real-time and is particularly robust when a camera is moving. We have verified its tracking robustness under different PTZ camera movements, and noticed only under extremely large pan and tilt operations noticeable degradation is seen.

The initial face detection algorithm in *Figure 7* is based on the Haar-like features training/detection (Lienhart & Maydt, 2002). We have also changed the detected face from a square to a rectangular region to improve its tracking performance.

By Tracking Optical Flow

Although mean-shift based tracking using color feature resulted in both accuracy and efficiency and is invariant to depth of the specified object, it however is not appropriate for tracking whiteboard writing for the reason stated earlier.

Therefore, for whiteboard writing, we have used optical flow to control its mechanical convergence and centering procedure. Optical flow is a common technique in computer vision. The algorithm calculates for a given point $[u_x, u_y]^T$ in image I_1, a point $[u_x + \delta_x, u_y + \delta_y]^T$ in image I_2 that minimizes $\hat{\imath}$:

Figure 8. Result of mechanical convergence by tracking optical flow

(a) The top image shows the specified writing area; the bottom image shows the zoom-in result

(b) a series of images captured from the PTZ camera while it performs pan and tilt operations, with the optical flows shown in red

$$\xi\left(\delta_x,\delta_y\right)=\sum_{x=u_x-w_x}^{u_x+w_x}\ \sum_{y=u_y-w_y}^{u_y-w_y} I_1\left(x,y\right)-I_2\left(x+\delta_x,y+\delta_y\right)$$

By using the algorithm stated in Algorithm 3, and replacing mean-shift tracking by optical flow techniques, we have obtained the results shown in *Figure 8*.

The red arrow indicates the direction of motion from the "stable" points between the frames. These "stable" features are generated according Shi & Tomasi (1994). The white arrow is the direction of the PTZ camera's motion, calculated by averaging the feature displacement from areas containing similar depth to the board regions.

Automatic Switching Between Mean-Shift Tracking and Optical Flow Tracking

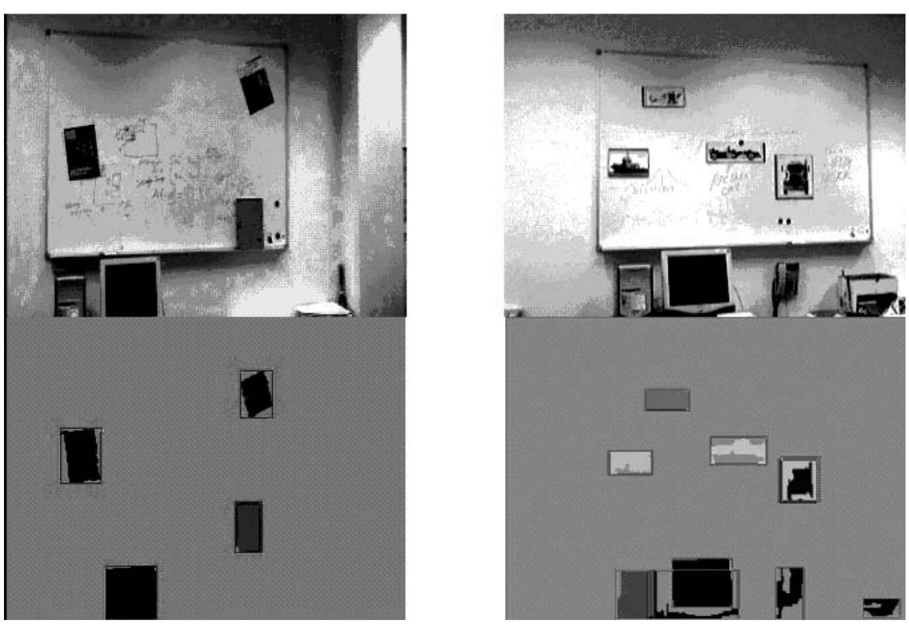
As stated above, we have used tracking either by mean-shift (color feature) and KLT (optical flow) for PTZ camera movement control. In order to automatically detect which of these two techniques to apply, as soon as the instructor selects a region using the laser pointer, we perform a color segmentation routine using mean-shift based segmentation (Comanicu & Meer, 2002) (*Figure 9*) on the current video frame and test it against the instructor's selection coordinates. If the selection contains a region of distinct color feature, then mean shift tracking scheme is adopted, otherwise, optical flow method is used.

In our earlier attempt, we developed such detection scheme based on the location of whiteboard (that is, optical flow is used for selection within the whiteboard). However, we have realized that such a scheme would constrain the instructor from placing teaching objects inside of the whiteboard area, which is often required.

Bidirectional Interactions: Control PTZ Camera from Remote Student

To achieve accurate bidirectional interaction *(Requirement R1)*, in our work, apart from the

Figure 9. Two segmentation results: the top image is the captured video frame and the bottom image shows segmented regions, with bounding rectangle indicating the co-ordinates of object with "distinctive" color



instructor directing PTZ camera using a laser pointer, we also allow the student to override the PTZ camera controls remotely, as shown in *Figure 6b*. As a result, the student is able to choose a close-up view of the instructor room without disturbing the instructor.

A simple implementation analogous to student's manual control of a security camera via a GUI interface over the Internet is insufficient and different to our approaches. There are two reasons:

1. Remote-controlling a PTZ camera manually takes time, particularly when camera base has low precision. During synchronous e-learning such manual effort diverts the student's attention from his/her normal learning for a longer than necessary time.
2. The PTZ camera is operative in most of the time according to events occurring in the instructional video events. A student's request to control the PTZ camera may need to be queued and processed a short time later.

Therefore, once the remote student has selected the region by drawing a rectangle over an area using GUI interface, no more action input is required from the student until the enlarged video stream is shown on student's PC. The rest of the operations are handled by the vision system.

The same PTZ camera control algorithm stated in the above sections is also used to process the student's request. There is an additional factor we need to consider:

Scheduling PTZ Camera Between Instructor and Student

In order to handle a situation when student is requesting the PTZ camera while it is in action, we have designed a camera control scheduling. In our current work, we have associated each PTZ camera's operation with a *minimum* and *normal* allowable time. When a PTZ camera is in action, the student's request to PTZ camera is queued until the *minimum* time associated with the current action is expired.

In our future work, we will use an XML approach for this scheduling. The syntax may also allow the instructor to specify the priorities to each PTZ camera's operation, to decide whether the current operation can be immediately terminated or to have a shortened operation time. E-learning cinematic effects in PTZ camera may also be incorporated.

Results, Discussions and Conclusions

In this article, we have identified and stated the importance of our focus areas in e-learning, which are *synchronous*, *peer-to-peer based* and the instructor uses *non-computer teaching equipment*. We have also illustrated the properties which these types e-learning systems exhibit and the challenges we face when designing a computer vision-based system to support these properties, which are *accurate bidirectional interaction*, *low hardware cost*, *system portability* and *versatilities in vision algorithm*s.

We present each hardware component used in IVDA. We emphasised on their portability setup and inexpensiveness to reflect the low-cost requirement. We have described in detail the camera control algorithms used in IVDA, where we presented methods to control a low-cost, low-precision PTZ camera base. In this work, we have proposed several novel methods, including a semi-passive mechanical convergence control algorithm to encounter its mechanical imprecision. The control algorithm also makes automatic selection of colour-base or optical-flow base method as reference object tracking. We have also proposed PTZ camera control by both student and instructor, where instructor control is by specifying the area of interest using a laser pointer, and the student does so by a computer interface. We also subsequently touched on the topics in camera scheduling. All these efforts are made to address the four properties we have stated.

There are also many other multimedia sub-components constitutes IVDA. These sub-systems include the individual teaching object recognition (Xu & Jin, 2006) and teaching multimedia scripting (Xu et al., 2005). These combined efforts have enabled us achieving all the properties we have specified in the introduction.

The aim of our work in IVDA is also to setup an illustration by example, which, by presenting current challenges and solutions we have encountered, we hope to encourage more researchers to also consider these factors when designing vision-based automated e-learning systems. We hope there will be more progressive studies in this field, which in turn can accelerate the transfer of computer-vision technologies from laboratory into people's everyday teaching and learning experiences.

Currently, most of our IVDA e-learning work is from a technical, particularly computer-vision design perspective. Although some usefulness evaluation analysis was made, we have yet to perform thorough pedagogical studies into the impact of IVDA system will have on different types of peer-to-peer e-learning instructors and students. Future work is also focused on collecting such information.

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ENDNOTES

1. Currently available to most Sony and Canon camera
2. For a Sony camera, we have controlled its optical zooming through LANC interface, for a Canon camera, optical zooming can be controlled via ZR command set.

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Chapter XXI
Supporting Learners' Appropriation of a Web-Based Learning Curriculum

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ABSTRACT

This article presents an approach and tools that can help learners appropriate a Web-based learning curriculum and become active participants in their learning. The approach is based on a detailed modeling of the curriculum and intends to equip the learners with different computer-based tools facilitating a multiple point of view perception of the curriculum, while promoting self evaluation and self regulation of the learners' curriculum performance. The proposed architecture is generic and can be used in the context of an already existing Web-based learning system. We define what we call "appropriation," describe our approach, present different tools that have been implemented, and present the findings from the first experiments.

INTRODUCTION

Learners utilizing Web-based learning curricula, distance learners in particular, often face problems related to the curriculum (i.e., the components of the curriculum and how these components are related one to the other) and how the curriculum corresponds with their personal wills and objectives. This problem, that we will call the "appropriation problem," is closely connected to autonomy and motivation issues.

It is well known, even from educational research that focuses on the early school years, that the student's participation in his learning process in terms of motivation and independent learning (Wang & Han, 2001) is very important. Independent learning involves student's meta-learning (meta-control) in a framework of goal driven learning (Ram & Leak, 1994). Meta-learning from an educational pragmatic point of view occurs with a student's self-reflection and self-evaluation of his own performance in relation to his goals, to the other students' performance, and to the tutor's evaluation of his performance. Meta-learning also continues after reflection/evaluation and encompasses the regulation phase. In the regulation phase, self-regulatory mechanisms are set up to change behavior taking into consideration cognitive and affective factors as well as environmental factors, such as group dynamics, class structure and interaction with the tutor (Pajares, 2002).

The transition of the meta-control of the learning process from the tutor to the learner has been discussed for a long time. Some researchers have found that the transfer from traditional guided learning to an autonomous learning is not easy for teachers or students (Grow, 1991). A major difficulty for the learners to become autonomous is setting goals and making plans for their learning (Kelly, 2002). According to Sinista (2000), technologies are able to make it smoother by arranging intelligent support for learning-related activities. Examining the issue of technology integration into traditional education from the tutor's and students' perspectives, researchers Anand & Zaimi (2000) mention that being accustomed to extensive tutor guidance can make learners feel abused when they are thrown into a self-directed activity all of a sudden, and the tutors then become unable to fulfill their goal to create independent learners. The researchers tried to involve their learners into an evaluation of Web-based learning materials by asking them their opinions and suggestions. This involvement affected the attitude of the students, made them collaborative and opened the door of independent learning for many of them. In addition, Forcheri et al. (2000) identified three steps in the transition using technology: a need, identification of an objective, and a strategy for attaining the goal. Sinista (2000) mentions that during the learning process, apart from the typical learning activities that are necessary for the learner to acquire knowledge, he (the learner) also performs control, evaluation and monitoring functions. She calls these activities meta-learning activities and proceeds to elaborate on them in detail. For Fischer (Fischer et al., 1993; Sumner et al., 1997) such types of reflection are difficult and a human coach/teacher or a design critic can help the learner to identify the breakdown situation (these breakdowns can happen due to missing knowledge, misunderstandings about the consequences of actions, wrong self-efficacies or any reason that hinders the learner from attaining his goal) and prompt the learner to reflect. Fischer in his work chooses the computational critic to provide some of this support when humans are not present.

The objective of the exploratory research presented in this article is to study how a learner can be helped to appropriate a Web-based learning curriculum by proposing different computer-based tools dedicated to this issue. In order to explore this question we have constructed a model for appropriation based on three dimensions (perception, evaluation and regulation) and have designed different tools (the Saafir architecture) that address these dimensions: first, perception tools that allow learners to browse a detailed model of the curriculum from different points of views. Second, evaluation tools that allow learners to annotate the different items of the curriculum, to indicate a level of achievement and to propose syntheses of the annotations. Third, regulation tools that promote peer-to-peer help and allow us to introduce some control issues, such as deadline warnings. The preliminary experiments suggest that such functionalities do result in a better understanding by the learners of the curriculum and better motivation. These results pave the way towards further experiments, which will allow for more detailed analyses of the respective use and impact of these tools, a continued refining of the tools implemented thus far, and the designing of new ones.

This article is organized as follows: the second section presents the research questions that address this work and the methodology, the third section presents a conceptualization of the appropriation issue and the overall approach, the fourth section presents examples of tools that we have designed according to this conceptualization, the fifth section presents the implementation approach, the sixth section presents some findings from the experiments realized so far, and the seventh section summarizes the work and its perspectives.

As a general objective, in the context of in Web-based learning curricula, supporting learners' transition to self-directed learning must be addressed by both technological means and human tutor means. In this article we address technological means. This does not mean we exclude human tutors, but that we explore, as a research question, the type of support that can be proposed by technological means. In the sixth section, when we present the experiments, we will describe the human tutor role in the learning context created by these tools. Considering technology, we have studied what tools could be proposed to learners in order to help them gain an understanding of the curriculum and their process within the curriculum, as opposed to approaches such as intelligent tutoring systems that fully direct the learning of the students (Fischer & Scharff, 1998).

GENERAL ISSUE: Supporting Appropriation

Definition

We define appropriation as the process of a learner to make a curriculum his own, giving it a sense of relevancy to him personally. The overall objective of this research is to study how a learner involved in a Web-based learning (WBL) systems context can be helped in reaching this desirable state by equipping him with dedicated computer-based tools that he can use to facilitate the appropriation of the curriculum. Appropriation is a notion that is not limited to the WBL context; however, we believe that when developing a WBL system it should be given particular attention as it is directly related to autonomy and motivation, two known major issues for WBL (Linard, 2000).

The appropriation notion is often referred to in WBL and distance learning contexts, as it is considered to be a prerequisite and/or desirable state to reach. However, this notion remains vague and is not associated with an operational definition. In this article we will refer to appropriation in the general sense used in the literature (Bourdages & Delmotte, 2001; Garland, 1994; Henri & Kaye, 1985; Karsenti, 1999; Paquette et al., 2002) and, in particular in Jouet (2000)), considering that a learner has appropriated a curriculum if he is aware of the curriculum structure and contents; and is aware of how he can best utilize the curriculum, its resources, and its activities according to his personal objectives. In other words, a learner that has appropriated a curriculum is not a passive consumer but an active participant of his learning.

Shifting from a structural and/or administrative conceptualization of the curriculum to a conceptualization in terms of addressing a personal objective is a key issue for appropriation. In the context of WBL, an active participant who has appropriated a curriculum should, for example, be capable of drawing relationships or possibly making connections between a given pedagogical resource such as an online document, his participation on an online forum, and the resources available to him for communication with other learners or a tutor, all as means to achieve his plan and address his personal objectives.

Research Questions

The definition we have proposed does not allow for a straightforward assessment of criteria to decide if a learner has appropriated a curriculum or not. In this research, we will not attempt to propose a more precise definition and a list of criteria with respect to this concept of appropriation. We think that this would be premature in the current understanding of the appropriation notion, in particular in a WBL context. Rather, we will consider this general definition as a direction to go towards and consider the following questions:

- What means can be proposed to a learner working with a WBL system to progress towards appropriation? This aspect of the work has been conducted in order to suggest tools that can help learners develop their appropriation of the curriculum.
- How do learners react and use such means? This aspect of the work has been conducted to identify some learners' behaviors in respect to the proposed tools.

This article is therefore essentially oriented on engineering issues (proposing innovative tools related to appropriation issues). The model and tools that have been elaborated and the first analyses we made are a step forward in the direction of both (1) a better understanding of the appropriation notion and coming up with the notion's formal definition that allows us to measure it and (2) an understanding of what types of tools can be proposed for this purpose and how they are used.

In this research we focus on supporting learners in order for them to appropriate the curriculum on their own. This does not mean that we think that tutors should not be active participants in the appropriation process. On the contrary, we believe that learners should construct a personal study plan and then discuss and negotiate it with human tutors, as well as evaluate and regulate their progress with those tutors, and this is what was achieved during the experiments. However, we believe that (1) in many cases, while it is not a desirable situation, there is lack of tutoring and therefore, developing an understanding of what can be achieved by proposing specific tools to the learners without involving tutors, is interesting and pertinent per se, and (2) this understanding is a necessary boot-strap step toward a later study on how the appropriation issue could be supported by coordinating the respective potentials and roles of tools and tutors. It should be noted that this is not an assumption that we should just "add" a human tutor to the system. The tools proposed to the students will have to be re-analyzed in respect to the role of the tutors. Addressing this coordination issue is, however, anticipated while what can be done to help students to appropriate the curriculum on their own has not been studied.

Methodology

We analyzed literature related to the appropriation notion and to WBL, and we elaborated a general model for appropriation. Then, we designed and implemented an integrative architecture (the Saafir architecture) that proposes different tools based on this model. This architecture has been tested in two contexts at a university level: first, in an explanatory context where using the tools was made possible but not mandatory for learners; second, a context where using the tools was mandatory. We then analyzed how much the tools were used (by analyzing the logs) and how the learners felt about these tools (by administering questionnaires).

The two contexts we have used are very different and the analyses we made have the unique objective of providing empirical ideas for this exploratory research. Therefore, the analyses do not follow a controlled data comparison methodology. Here again, we believe that designing functionalities to support appropriation in the context of WBL is a domain in its infancy that requires a better understanding before allowing controlled experiments.

SUPPORTING APPROPRIATION: General Approach

Issues Related to the Appropriation Notion

The appropriation notion can be related to different characteristics that have been identified in the literature:

- **Motivation with respect to the curriculum:** A learner can involve himself in a Web-based curriculum with different kinds of personal objectives, such as acquiring a targeted competence, obtaining a degree or sharing knowledge with other learners (Carré, 1998). Making explicit one's motivations is an important issue in order for a learner to appropriate a curriculum. This is a very personal issue, which can eventually be investigated by administering to the learners an attitudinal questionnaire or interview. Apart from that though, a WBL can help learners to address such an issue by providing the requested data, that is, a comprehensive view of the curriculum and its description at a detailed level. The fact that learners can be concerned with different objectives and that these objectives can evolve during a session can be tackled by: (1) presenting the learners with different descriptions of the curriculum according to predefined prototypical objectives or (2) presenting a structural view (i.e., in terms of modules, sub-modules, etc.) as almost all systems do, but, differently from these systems, also proposing means for learners to perceive the same information from different perspectives (addressed competence, etc.) according to their objectives. This second approach, which is more flexible, is the one we have adopted in this research.
- **Motivation with respect to the tasks:** Making explicit if and how a given pedagogical activity that is proposed to learners is useful in order to attain an instructional objective. Questions such as the following are addressing important issues related to the curriculum appropriation (Viau, 1994): What are the required capacities to address a task? What is the degree of control of the task or sequence to be achieved? What are the consequences of achieving, or not, a proposed pedagogical activity? Answers to these questions should be explicit and available to the learners.
- **Time management:** Making learners explicitly manage time issues is of crucial importance. Time management is a spiral process (Paquette et al., 2002): elaborating a learning plan (scheduling actions), acting in a process guided by the plan, adapting the plan to the effective actions and unexpected events. A plan is not a constraint, but a resource for action (Bardram, 1997). Time management can therefore be related to two different issues: (1) planning activities and (2) regulating activities, which includes, if necessary, a re-planning process.

- **Autonomy:** An autonomous learner is a learner that is conscious of his strength, his objectives, his learning tasks (etc.) and also other surrounding persons (Deschênes, 1991). The autonomy concept comes in hand with different competences such as: adopting a learning strategy, establishing priorities, scheduling actions, selecting necessary resources (materials, numerical, or human) in order to achieve one's learning objectives, examining and criticizing one's actions, measuring one's progress or diagnosing one's difficulties (Paquette et al., 2002; Garland, 1994).
- **Self-regulation:** Self-regulation has been initially defined in Zimmerman (1986) and Zimmerman et al. (1996). Following Karoly (1993), "self-regulation appears to be the stable element attempting to guide behavior along a specific path to a directed aim or goal. However, apart from procedural, epistemic and conceptual divergences in various models of self-regulation, basic volitional factors, such as goal setting, self-monitoring, activation and use of goals, discrepancy detection and implementation, self-evaluation, self-con-sequation, self-efficacy, meta-skills, boundary conditions, and self-regulation failure, characterize the process of self-regulation."

Towards Tools to Support Appropriation

The basic functionalities of a WBL system are to make available pedagogic documents and activities descriptions (downloadable documents, on-line quizzes, exercises, etc.), communication tools (forum, chat, white-boards, etc.), tutoring services and administrative interactions (registering learners, etc.). These basic ingredients can be mixed in different manners, from purely delivery mechanisms to more pedagogical approaches such as collaborative activities. Our point is not to be innovative at this level, but to work out how a given WBL system can be enhanced to support the appropriation issue.

The previously described analysis allows us to define general specifications. The system should not impose a unique point of view but allow learners to have different points-of-views on the curriculum. The different activities proposed by the WBL system should be described in detail making explicit issues that often remain implicit, such as the addressed competence of the different activities. The relationship between the activities and/or other learning objects (documents, forum, etc.) should be highlighted. Time management should be promoted and supported. Reflective activities such as analyzing and regulating one's activities should be proposed and supported.

It can be supposed that a WBL system proposing such issues would help learners (as individuals) to appropriate the curriculum by supporting issues such as:

1. Understanding the structure and the content issues of a curriculum.
2. Developing an explicit understanding of the reasons why one does enter the curriculum (as a side effect of considering explicitly the details of the curriculum).
3. Identifying the learning objects that are related to one's personal objectives or how to tackle activities in a way that matches one's interests.
4. Planning one's itinerary in the curriculum.
5. Evaluating and regulating one's itinerary in the curriculum: examining and criticizing one's actions and the way one's personal plan is being performed, adapting one's plan and actions to unexpected difficulties or emergent events.
6. Contacting useful persons (other learners, tutors).

Proposed Model: Perception, Evaluation and Regulation

On the basis of the previously proposed approach of appropriation we propose to conceptualize appropriation on the basis of three dimensions: perception, evaluation and regulation.

- Perception is related to the awareness and understanding of the structure and details of a curriculum. Supporting perception is a key issue that addresses points 1, 2, 3, 4 & 5. Perception can be supported by making explicit the different curriculum issues, both in terms of structural and organizational issues (modules, activities, precedence links, etc.), and in terms of content (pedagogical objectives of an activity, prerequisite competences, competences to be obtained, etc.).
- Evaluation is related to awareness of how curriculum activities are performed. Supporting perception is a key issue that addresses point 5. Evaluation can be supported by encouraging the learner to annotate his activities, for example, stating to what extent a task is achieved and/or typing free text as "meta-level" notes.
- Regulation is related to the fact that a learner manages (at a meta level) the way he performs the activities. Supporting regulation is a key issue that addresses points 4, 5 & 6. Regulation can be supported by facilitating awareness of the progression, by encouragements to consider at an explicit level planned and effective advancement or connecting learners that encounter similar problems.

It can be noted that this three-dimension model helps in conceptualizing the appropriation issue and specifying computer-based tools, but that these dimensions are of course not independent nor disconnected.

Some of the features proposed by classical WBL systems can be analyzed according to these three dimensions. For instance, WebCT (WebCT, 2005) proposes some perception issues, such as the « goal » item of a module, evaluation and regulation issues such as the curriculum calendar feature (time-management issues); the connection statistics; the personal events editor; or the annotation editor. A WBL system such as Explor@ (Explora, 2005) proposes advanced functionalities that can also be considered as supporting appropriation, such as highlighting a learner's itinerary in respect to that of other members of the group or the personal feedback of the system. The appropriation issue is, however, not considered as an issue, per se, and if some of their functionalities can be useful for appropriation there is not any notion of appropriation involved in the pedagogical foundations of the system's design.

If one comes back to the notion of self-regulation, we see that the model we propose is not dealing in detail with all the elements of self-regulation. Actually the model is proposing a perception of something very specific: an online course curriculum presented in a very detailed ontology, aiming for the student's better understanding of what the specific course curriculum entails (knowing in depth what are the objectives, competences, activities and deadlines, as well as how all these components are related to each other) and helping him put together this understanding with his interests so that he can spend his labor on work that interests him and/or is going to prepare him for the field he wants to specialize in. If he accepts the curriculum, then the designing of a personal plan that will help him go through with the course, a plan that includes material and/or human resources and/or personal adjustments is necessary. Evaluation is related to how well the student has done within this plan and an editor that allows him to annotate his progress supports the evaluation. Regulation is related to fixing errors or failures of his performance and a tool that allows a learner to present his planning as rules and generates a warning according to these rules supports the regulation. With respect to the definition of self-regulation by Karoly (1993) we can see that the model (and the implemented tools) support the following aspects of self-regulation: goal setting (creation of one's own study plan); self-monitoring and self-evaluation (annotations tools, advancement synthesis, specific tools for rules and discussions); self-efficacy (students have the feeling of contributing to their learning, cf. results of the experiments); self-regulation failure (revision of the plan, by oneself or with the tutor, cf. results of the experiments).

Modeling the Curriculum

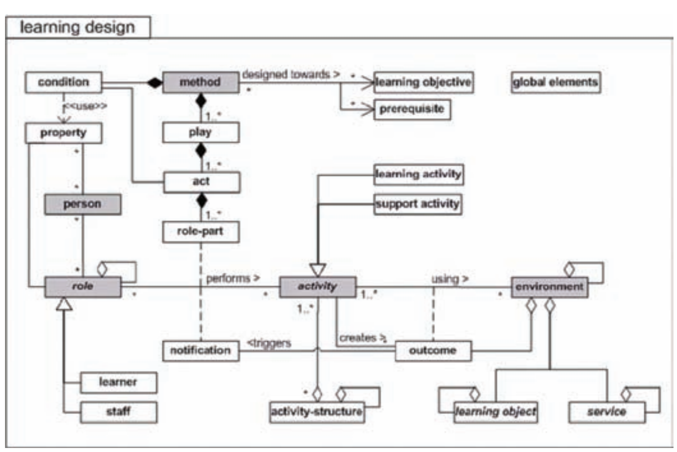
In order to allow learners to perceive and understand the curriculum notions in detail and to allow some actions related to these notions (e.g., associating an annotation to a given activity) it is necessary to define a fine-grained modeling of the curriculum. This model must denote the structural features of the curriculum (e.g., the fact the curriculum is hierarchically structured in modules or the different activities and sub-activities) and the content features (e.g., pedagogical objectives, prerequisites or addressed competences of an activity).

We believe that such a modeling requires a two-step process: (1) defining a meta-model (i.e., the means that will allow constructing a model of the curriculum under study or, in other terms, an ontology: the notions that can be used to describe the curriculum, the links, etc.) and then (2) constructing with the teachers a model of the studied curriculum by utilizing the meta-model notions. This consists of presenting each teacher (in the generic sense of: each responsible authority of the top-level objects of the modeling, e.g., a module or an activity) with a description form (structured following the ontology concepts) to be completed.

It is important to note that such a two-step process requires an effective cooperation of the pedagogical staff. Although the description of a module or the ontology itself can be modified at any time, such changes are time consuming and cognitive consuming tasks. The modeling can be defined by some hierarchical manager (for a curriculum or a set of curricula) and imposed on everyone, but we advocate to some extent, at least, a collaborative elaboration of the modeling by a group consisting of different curriculum managers and teachers or tutors. The experiences we processed demonstrated very clearly that the curriculum modeling is a key stage of the process and that it required time and cooperation.

Considering the notions used to model the curriculum, the IMS-Learning Design (IMS–LD)

Figure 1. Learning Design conceptual model (IMS project, 2003)



proposal is an interesting basis. LD is based on work by the Open University of Netherlands on EML (Koper, 2001) and different other standards as the pedagogic resources meta-data standard LOM (LOM, 2005). The LD objective is to allow the description of different kinds of learning approaches in a formalized way that facilitates abstraction, reuse, and interoperability.

Considering the appropriation issue, the interesting part of LD is the A level (see *Figure 1*). This level proposes a set of notions that can be used for conceptualizing and describing curriculum notions. We believe that a particular interest of LD is that it proposes an activity centered point of view. Activities link the roles and the environment notions, the environment being composed of learning objects and services. Activities can be separated as learning activities (oriented by the learning objective) and support activities (performed by staff members to support learners). Activities can be structured in an activity structure, that is, a structure corresponding to a group or a sequence of activities. An activity can be associated with a maximal duration. LD also allows describing the learning objectives to be addressed and the prerequisites.

Figure 2. An LD model of a module (simplified)

<u>*Informal description of the module*</u>

The Module « Journalism vs. Literature » addresses one pedagogical objective: understanding the similarities and the differences between journalism and literature. The prerequisites are: (1) Ability to detect and explain a journalism work and (2) Ability to detect and explain a literary work. The activity « Journalism vs. Literature Activity » is composed of two sub-activities « Read URLs referring to the differences and similarities of literature and journalism writing » and « Given two different works, decide which is a novel and which is journalism ».

<u>*LD modelisation:*</u>

```
<imsld:learning-design identifier="JvsL" level="A">
  <imsld:title>Journalism vs. Literature </imsld:title>
  <imsld:learning-objectives>
    <imsld:item>
    <imsld:title>Understanding the similarities and the differences between journalism and literature</imsld:title>
    </imsld:item>
  </imsld:learning-objectives>
  <imsld:prerequisites>
      <imsld:item>
        <imsld:title>Ability to detect and explain a journalism work </imsld:title>
      </imsld:item>
    <imsld:item>
      <imsld:title> Ability to detect and explain a literary work</imsld:title>
    </imsld:item>
  </imsld:prerequisites>
  <imsld:components>
    <imsld:roles>
      <imsld:learner identifier="learner"> </imsld:learner>
    </imsld:roles>
```

continued on following page

Figure 2. continued

```
    <imsld:activities>
      <imsld:learning-activity identifier="Read">
        <imsld:activity-description>
          <imsld:title>Read URLs referring to the differences and similarities of literature and journalism writing </imsld:title>
          <imsld:item identifier="I- Read "/>
        </imsld:activity-description>
      </imsld:learning-activity>
      <imsld:learning-activity identifier="GiveWork">
        <imsld:activity-description>
          <imsld:title>Given two different works decide which is a novel and which is journalism </imsld:title>
          <imsld:item identifier="I- GiveWork"/>
        </imsld:activity-description>
      </imsld:learning-activity>
      <imsld:activity-structure identifier="JvsLActivity" number-to-select="2" structure-type="selection">
        <imsld:title>Journalism vs. Literature Activity</imsld:title>
        <imsld:learning-activity-ref ref="Read"/>
        <imsld:learning-activity-ref ref="GiveWork"/>
      </imsld:activity-structure>
    </imsld:activities>
  </imsld:components>
  <imsld:method>
    <imsld:play>
      <imsld:act>
        <imsld:role-part>
          <imsld:role-ref ref="learner"/>
          <imsld:activity-structure-ref ref=" JvsLActivity"/>
        </imsld:role-part>
      </imsld:act>
    </imsld:play>
  </imsld:method>
</imsld:learning-design>
```

Figure 2 presents an example of a module LD modeling (taken from our second experiment).

An LD modeling proposes a comprehensive view of a curriculum and its different activities. When using LD to model the curricula however, we encountered three minor problems. Firstly, interactions with the teachers highlighted that it was useful to model a « competence » notion (capacities in relation to some content) and an « objective » notion (objective in respect to a situation or an activity), notions that LD does not distinguish. Secondly, objectives, prerequisites and competences are not categorized very precisely in LD. This limits the accuracy of the information that can be proposed. In particular, it is interesting for a learner to understand what type of issue an objective is about, for example, to dissociate theoretical and pragmatic issues or discovery oriented and investigation oriented activities. Thirdly, activities and modules are not associated with beginning and ending dates in LD (which is information that differs from total duration). This lack of precision for describing temporal aspects limits the capacity to support time management issues (e.g., being warned that time is running short for a given activity), which is central for learners not only to achieve the tasks they are supposed to, but also to construct and maintain a global control of their progression.

In order to respect the issues that the teachers wanted to model we had to extend LD basic model. A detailed description of this can be found in Rasseneur et al. (2004). We do not claim that this extension of LD solves all problems. We have elaborated this model in the context of our experiments, and we believe that this model has to be further analyzed in the context of different experiments before reaching certain stability. Note that the tools we propose are linked to this modeling but can easily be modified if the modeling evolves.

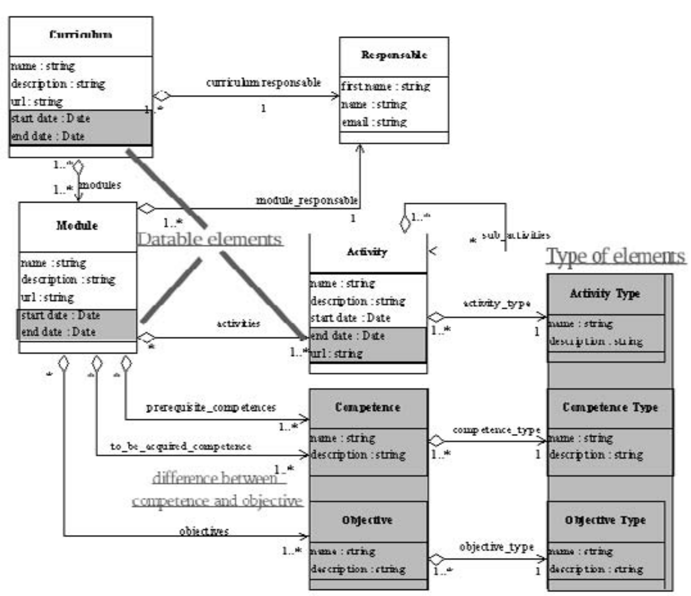
Examples of Tools to Support Appropriation

In this section we present different examples of tools that can support appropriation:

- Perception support: tools that support learners in their awareness and understanding of the curriculum structure and contents.
- Evaluation support: tools that support learners in evaluating their itinerary by annotating their actions and offering synthesis of their advancement.
- Regulation support: tools that support learners in regulating their itinerary by offering some feedback on their itinerary.

These tools are but a possible operationalization of the general approach previously described here. They have been implemented in the so-called Saafir architecture but could be integrated in any WBL system. Therefore, we dissociate: (1) the description of these tools and exemplifying

Figure 3. Meta-model for describing a curriculum currently used in Saafir



snapshots that illustrate how they are implemented in the Saafir architecture (this section) and (2) the description of the Saafir architecture itself and the process for using it (the fifth section). The usability of the tools will be discussed in the sixth section.

Example of Tools to Support Perception

Although the contents of a curriculum are generally identical for all the learners, each of these learners has his/her own history, interests and background knowledge. Each of these learners probably already has mastered some of the addressed competences and can therefore, focus on some others. Thus, it appears interesting to allow every individual learner to construct an individualized perception of the curriculum content and how he/she intends to proceed.

Following Deschênes (1991), we dissociate three aspects of a module that can be sources for learners' autonomy and appropriation : (1) structure, (2) content and (3) interaction aspects:

- **Structure-based appropriation:** A curriculum is based on a set of structures (e.g., modules, activities and exercises) regulated by features such as agendas or assessment procedures. Providing structure-based views allows learners to define/structure their objectives and plan their work. While some of them organize their work according to the curriculum structure, others organize their work differently (e.g., by competences), but use the structure view to deal with the curriculum planning or its assessments procedures.
- **Content-based appropriation:** A module generally addresses a set of domains and sub-domains and/or competences. It therefore, it appears interesting to propose different views of the curriculum (e.g., add to the view by modules a view by addressed competences, this competence view being accessible through the module structure and more transversally at the curriculum level) that will allow every individual learner to construct an individualized perception of the curriculum content.
- **Interaction-based appropriation:** WBL implies different types of interactions between different participants (learners, groups of learners, tutors, curriculum manager, etc.). These interactions are, in particular for distance-learners, of key importance, and it is therefore necessary to provide learners with a comprehensive understanding of the interactions that could/will take place. As an example, distance learners usually look forward to exchange with other learners through collective activities, but are also very worried about the fact they can appear as incompetent (or not at peer level). This prompts some of them to organize their work in order to appear at their best within these activities.

These different points of view are complementary and not exclusive. Learners usually adopt a predominant point of view (that can be one of the prototypical views described here above or an idiosyncratic view), but in all cases a single view is insufficient; it must be complimented by other points of view.

The perception functionalities implemented in Saafir allow different views according to the different ontology notions. The different ontology notions correspond to the way a curriculum is usually described. As an example, the view by module allows browsing the curriculum descriptions as a set of modules (see *Figure 4*). However, using the ontology notions, it becomes possible to make this view much more detailed than usual presentations, as every module is further described by different items such as the pedagogical objectives to be reached, the prerequisite competences, the different courses or the proposed pedagogical

Figure 4. View by module

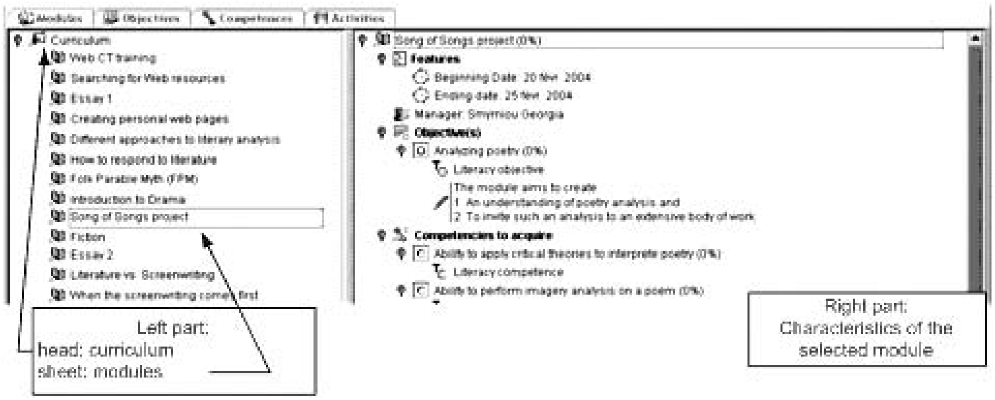
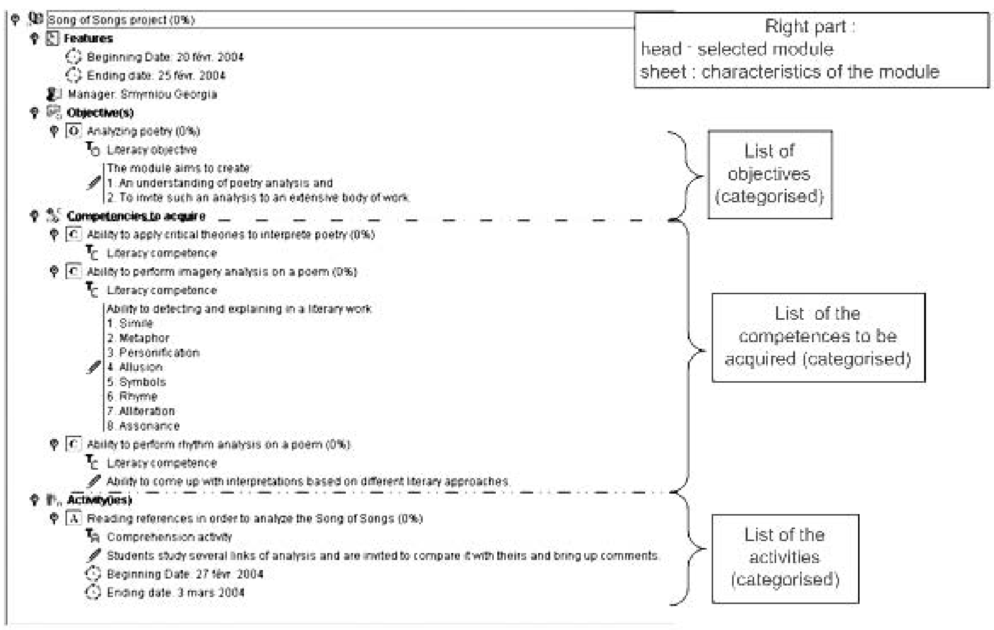


Figure 5. Detailed description of a module

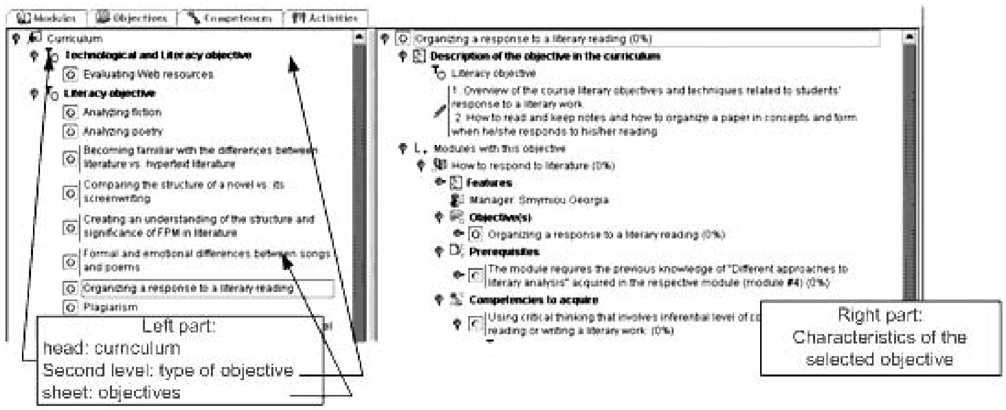


activities (see left part of *Figure 4* enlarged in *Figure 5*). The view by objectives (see *Figure 6*) lists and structures the different objectives of the curriculum and links them to the concerned modules (there is usually a 1-n relation between a module and a set of objectives related to the module topic, but very often a same objective is addressed by different activities that can eventually be related to different modules; in such cases this view is particularly pertinent). The views by competences or by activities propose alternative perceptions. Using a different ontology, other views could be proposed.

These different views are accessible as sheets (see upper part of *Figure 4*) and the learner can shift from one to the other. This allows scenarios such as:

browse the curriculum as a set of modules; focus on a given competence related to this module and

Figure 6. View by objective



select this competence; shift to the competence-view in order to understand how this competence takes place in the set of competences to be acquired and if it is related to some other module or activities or to prerequisite; discover that it is related to a particular activity and then shift to the activity view to analyze (etc.).

Example of Tools to Support Evaluation

Within this research project we are concerned by self evaluation, that is, how a learner can manage the way he achieves the different actions he is supposed to achieve (according to his individual plan and/or the teacher prescriptions), which will eventually lead him to a regulation phase (Deschênes, 1991). Evaluation here is therefore subjective and addresses the objective of helping the learner to perceive and manage his actions (which is different and does not replace an assessment by a teacher who intends to give marks). Evaluation is probably a phase that could be a mixed initiative by the learners and the tutors. However, coherent with our methodology, we study here what can be done to support a learner who is taking charge of his learning process.

The approach we propose to support evaluation is based on annotations and synthesis of annotations.

The Annotation Tool

An annotation is a piece of text that can be attached to an object and is separated from that object (Baldonado et al., 2000). Following Azouaou & Desmoulins (2005), we have defined an annotation as being composed of (1) episodic slots (e.g., name of the author or date of creation or modification) and (2) semantic slots that can be used to describe issues related to the object. This semantic slots can be pre-structured (e.g., proposing a slot denoting to what extent an activity has been accomplished) or unstructured (open text). An annotation tool is composed of a module for creating or modifying annotations, a module for browsing annotations, and a module to store annotations (Denoue & Vignollet, 2000). Within Saafir we propose tools that allow a learner to attach an annotation to any of the items corresponding to instances of the ontology notions (modules, activities, etc.). We have adopted a semi-structured format. An annotation is composed of:

- Episodic slots (date, author) that are created by the system.
- An assessment slot that allows a learner to indicate, using a progress bar, to what extent he feels he has completed the corresponding task.

Figure 7. Edition of an annotation

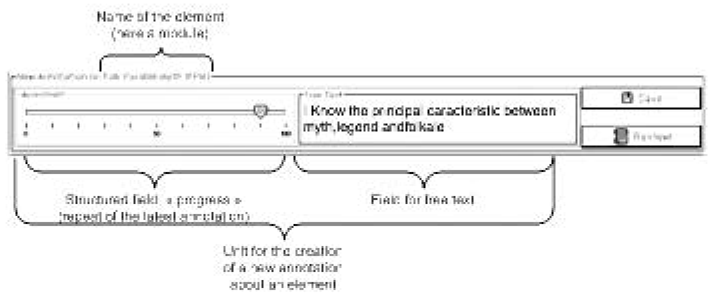


Figure 8. Visualization of an annotation

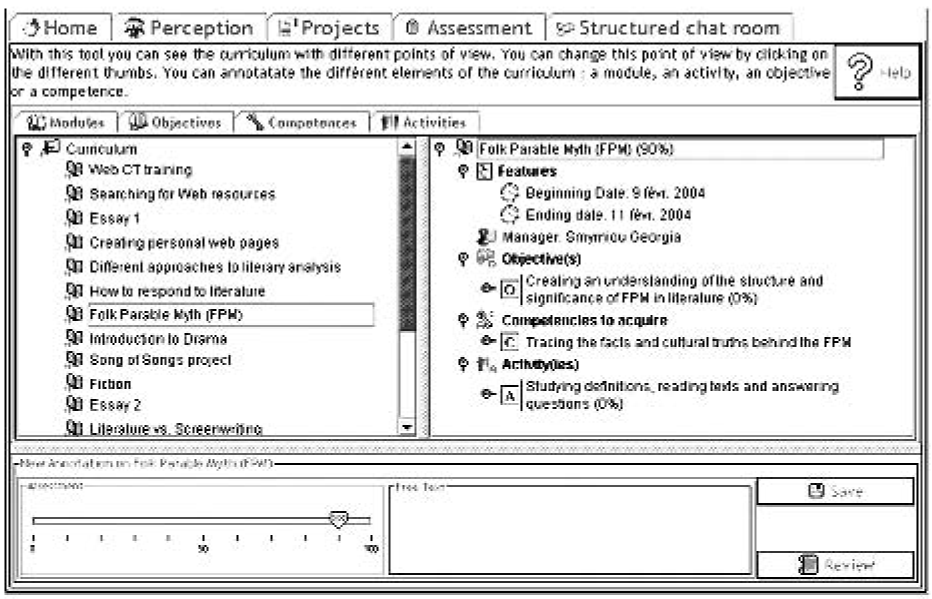
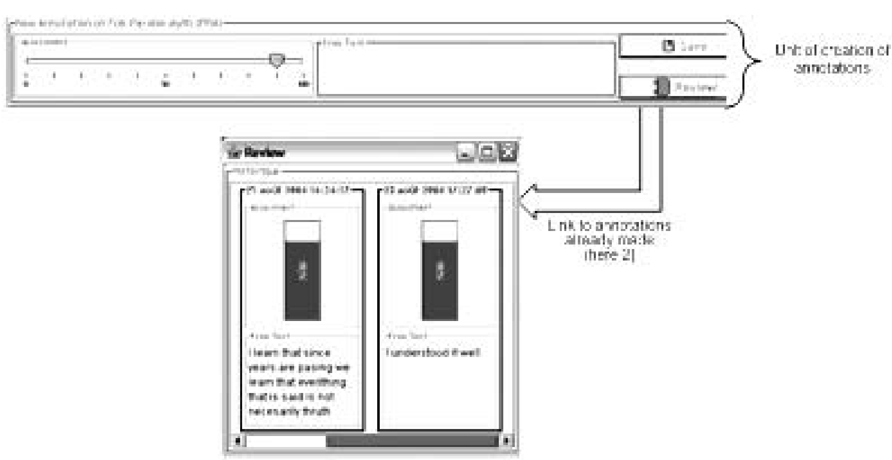


Figure 9. Visualization of the annotation history



- An open-text slot allowing a learner to indicate any pertinent information.

Figure 7 presents the annotation editing tool and *Figure 8* how a learner can browse the curriculum and, by selecting an item, visualize the attached annotation.

An important point is that annotations are cumulative: modifying an annotation does not destroy the preceding data and the learner can visualize the history of the annotation (see *Figure 9*).

The annotation structure we have used so far is minimally structured. We believe that, given a particular context, it can be advantageous for teachers to elaborate an annotation structure that will make learners question themselves in a way that is particularly pertinent, given the context or the curriculum. In other words, we do not think that it is pertinent to implement a fixed generic set of predefined slots, but rather that these slots should be contextually defined by the teachers and/or the learners themselves. Note that this is already possible in our system as the learner can structure the annotation by defining slots that can help him to denote some specific information (e.g., "To do list," "Relation to the A project," or "To be confirmed by John the tutor"). However, this has not been tested yet.

The Evaluation Tool

The evaluation tool proposes syntheses of the annotations. As with the perception tool, the learner can browse the curriculum through the different ontology notions (modules, activities, etc.). When the learner selects an item, the tool presents the data that is attached to this item (see *Figure 10* and details in *Figure 11*):

- Personal information: last assessment links to the last annotation and the different previous ones (history of the annotation).
- Group information: lower, upper and average progression of the other learners (anonymously).

Providing information on the other learners of the group is known as being an important issue in WBL (Dufresne & Paquette, 2000). Note that this information is, however, pertinent only if all learners "play the game" and record their progression on a regular basis.

Figure 10. Evaluation tool

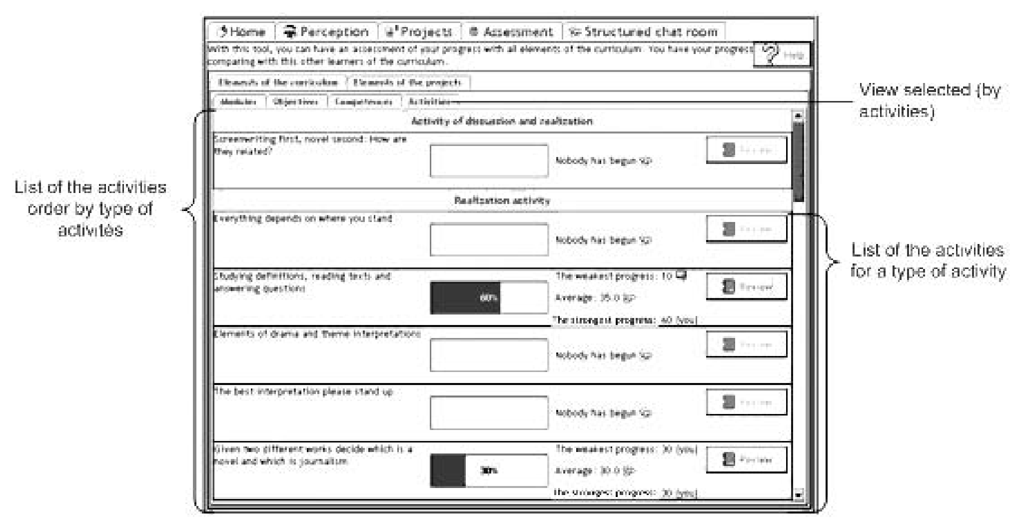
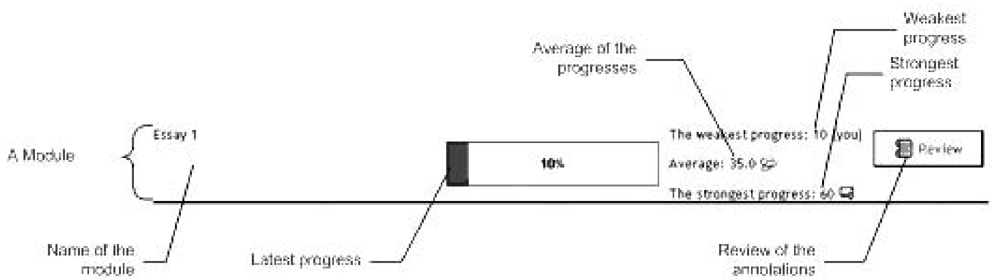


Figure 11. Detail of the evaluation tool interface



Example of Tools to Support Regulation

Regulation consists of identifying difficulties in one's progression and, eventually, reconsidering and/or repairing one's plan (Deschênes, 1991). This is certainly one of the most difficult issues to be tackled by learners on their own. However, different types of support can be proposed, from non-intrusive to more pro-active means.

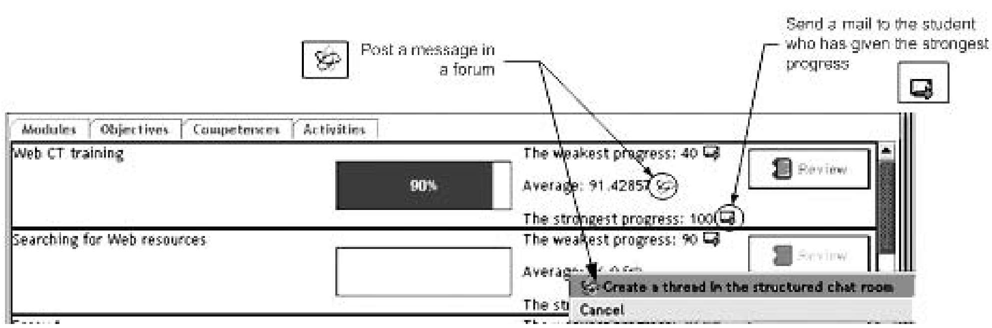
The evaluation tools, previously presented, can be considered as a first implicit support for regulation.

Another strategy to support regulation is to promote peer-to-peer interactions. As an example, it can be helpful for a learner to know about learners who share similar situations. In Saafir we have implemented a light strategy that provides learners with means to contact learners who are at a similar level of advancement (e-mail) and/or the entire group (forum; see *Figure 12*). More sophisticated (and semantic-based) strategies could be imagined, as analyzing the learners' production and linking learners with similar difficulties, but this requires domain-dependent analysis tools, which is not within the scope of our approach.

We have also elaborated a pro-active strategy based on automatic warnings. This strategy originates from the learners themselves, who explained that one of their major difficulties was the time management issue, most commonly, awareness of the deadlines for delivering their different works. We conceptualized this requirement as the fact that learners wanted to make explicit and externalize some regulation issues (in this case, time management issues). We generalized this requirement and implemented a tool that allows learners to define rules that must be respected (e.g., delivering an exercise before a particular date).

The Saafir warning tool allows learners to create rules following a premises and conclusions

Figure 12. Promoting peer-to-peer help



format. The premises allow denoting predefined constraints related to the ontology notions (module, activity etc.) such as, comparison of the beginning or ending date of an item with the current date, or comparison of the level of achievement of an item with a given value or the lowest/best/average level of the group. The conclusion is a text (typically a reminder) that can be composed from the dates, associated progressions (etc.) related to an item. Rules are also associated with a level of importance (green/orange/red). This allows definition rules such as: "If the activity A ending date is in less then 3 days and the level of advancement is less that 50%, then Print 'Urgent: A must be finished;'" "If the average level of advancement for Activity A is more than 20% above mine, then …" or "If my level of advancement for Activity A is within the lowest 10%, then …".

The editor allows a drag-and-drop construction of the rules (see *Figure 13*).

When the premises are respected, the text is presented to the learner when he connects himself to the system (see *Figure 14*).

Example of an Integrative Tool: Project Management Tool

The distance-learning literature highlights the importance for distance learners to adopt a formative project (Carré, 2001), that is, make explicit one or several high-level objectives that the learners identify as goals. Within such a framework, learners

Figure 13. Rule editor

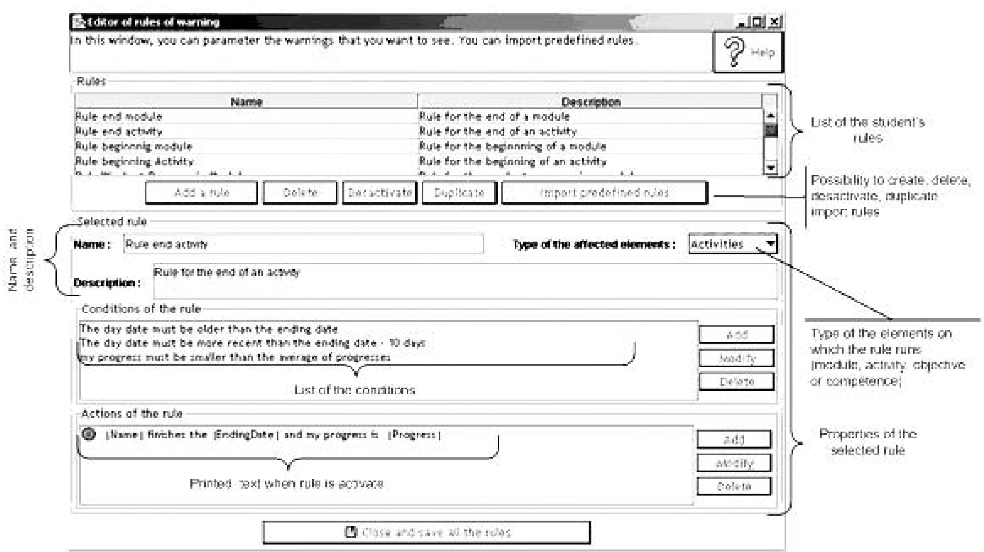
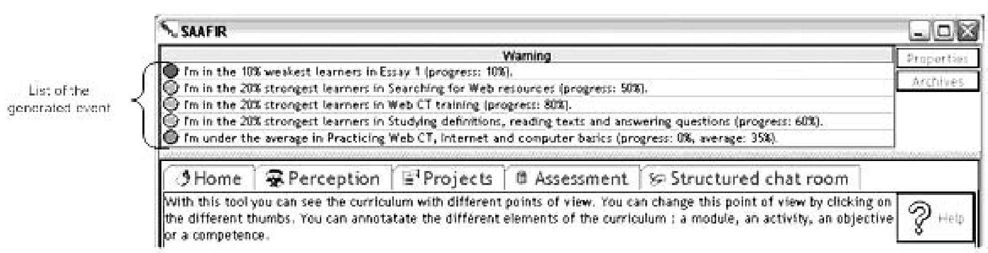


Figure 14. Warnings



identify the curriculum elements that are related to these objectives and can help them achieve it, and learners recognize how these elements are related to one another. Identifying such projects denotes a form of appropriation of the curriculum and helps in regulating one's itinerary within the curriculum.

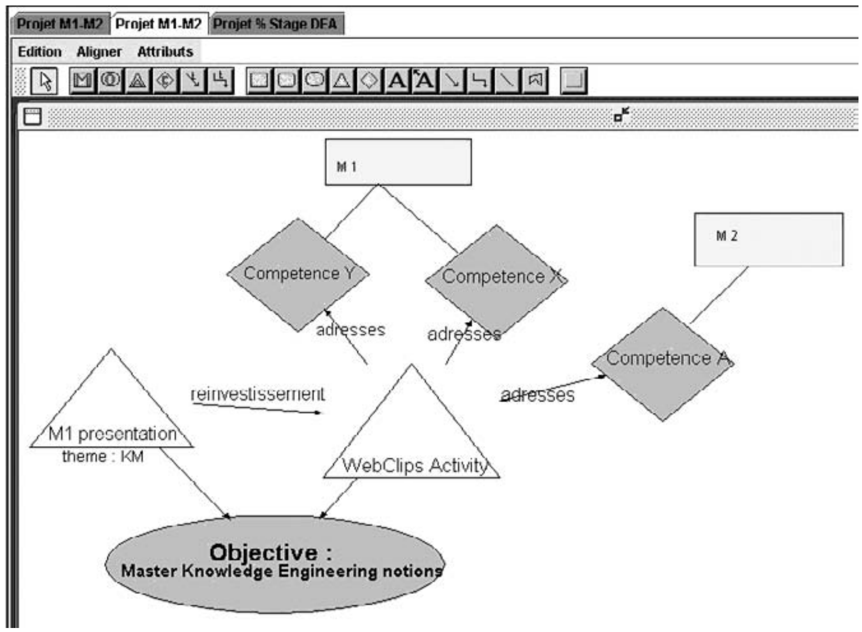
Such a project is a prospective point of view, that is, is similar to a plan. The fact that a learner identifies such a project does not mean he will necessarily work out the corresponding features following this plan. A misunderstanding would be that we want the learners to bury their activity in a predefined intangible plan. A project is a means for a learner to understand what the curriculum suggests and thereby, to organize his work and a resource to carry it out, nothing else [for a similar use of plans as resources, see Bardram (1997). However, although not mandatory, such projects are key issues in helping learners in their appropriation of a curriculum.

As an example, the master's degree curriculum in computer science that has been used as a first experimental field to test Saafir proposes theoretical modules, individual works and activities. These different modules, works and activities are interrelated. For instance, the M1 module addresses the domain "knowledge based systems and knowledge engineering" from a theoretical point of view. This corresponds, in the distance-learning Web site, to a set of PDF files to be downloaded and worked out. Learners are also supposed to prepare, as an individual work, an oral presentation on some subject related to the course, a subject they can propose themselves. One of the curriculum activities is also related to this domain (the "Web Clips activity"), in which learners must develop a toy knowledge-base system, here again on a subject they can propose themselves. These different features can be further related to different other modules such as the human-computer interfaces course and activities. We have learned from the successive promotions of this curriculum that distance learners have great difficulties in managing all these heterogeneous features and often give up, unable to face this apparent complexity. One of the staff pedagogical objectives is therefore to help learners to articulate the different curriculum features, and to perceive how the different items (and their underlying domain notions, competences, and constraints) can be interrelated in different ways. This can be obtained by encouraging learners to construct individual projects such as:

I know that there are at present many job opportunities in the knowledge management area; in order to develop my competence for this domain I will focus my M1 (Knowledge Engineering) presentation on this domain. Within the bibliography collected for this presentation different examples of ontologies are provided, and I could attempt to use one of these for the knowledge-based system I have to develop in the Web Clips activity. This will make me address competences X and Y from the M1 course (and competence A from the M2 - human-computer interfaces - course), and therefore for this M1 course the remaining competences to be addressed separately will be W and Z. As M1 course agenda is [...], I will organize things as follows: [...].

This example highlights that a module generally addresses different competences (domain competences, transversal competences such as analysis or synthesis) and proposes different activities (resources, exercises, etc.). This introduces complexity and although a module is generally presented with many explanations about what the learners are supposed to do, learners generally develop misconceptions. However, it also introduces flexibility in the way learners can work out the modules, and this is recognized as a key advantage of distance learning, that must be emphasized. Highlighting this flexibility helps learners in constructing individual projects that

Figure 15. A project editor (tentative interface)



articulate the different modules and items, whilst taking also into consideration their own objectives and motivations.

Managing formative projects is an example of a high-level task that can be supported by combining some of the tools we have presented: perception tools help in understanding the different elements of the curriculum and their links, annotation tools help in managing complex tasks, and so forth.

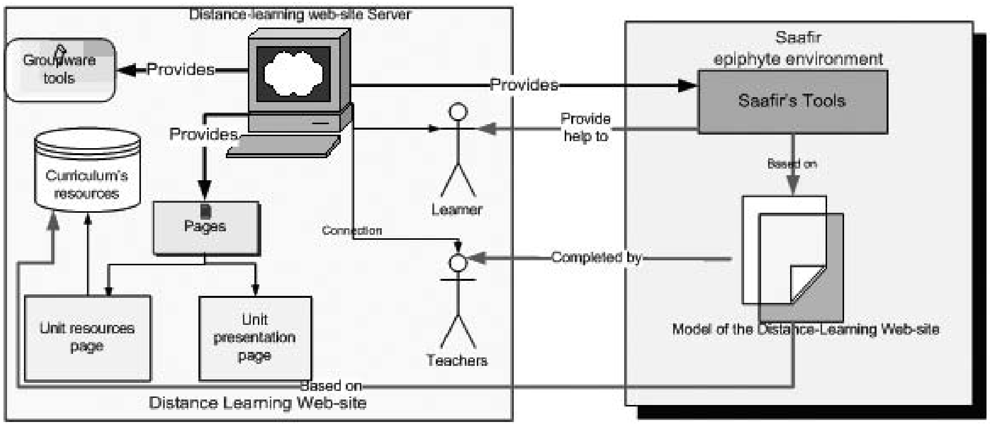
We believe that asking learners to design formative projects is a powerful means to help them in appropriating the curriculum. However, such an abstract task is far too difficult for most learners. This task is more likely feasible if supported by tools. In this case, it could be proposed to learners to edit (through a graph tool) a model of their project, this task being further supported by the perception and then evaluation tools. *Figure 15* presents a snapshot of a possible interface for a formative project editor. How much are learners capable of building formative projects on their own and/or with the help of tutors and how should this be implemented (asking each learner to define a project from scratch, proposing different prototypical projects to be used and/or customized) is however still to be studied.

SAAFIR: IMPLEMENTATION Architecture

As said before, our work does not aim to implement yet another WBL platform but to extend the capacities of current platforms. Therefore, the approach we have adopted in the Saafir project consists of the development of an epiphyte system, that is, a system that is associated to another (the host system, in our case the WBL Web site) without modifying or parasiting it (Paquette et al., 1996).

The Saafir architecture is a generic system that analyzes and manipulates an ontology-based model of the curriculum and not the Web site data directly (see *Figure 16*). This approach is known as "knowledge level reflection" (Reinders et al., 1991). The idea is that it is difficult to grasp the WBL data (the modules and their descriptions, etc.)

Figure 16. General architecture



from the implementation of the curriculum within the WBL, as some issues of the curriculum might be lost or denoted at a too low-level of abstraction. Rather, building or re-engineering a model dedicated to the appropriation issue enlarges and facilitates what can be done at a meta-level. Another advantage of this approach is that it can be used to apply our approach to already existing WBL curricula/platforms without the necessity to modify them. In such a case, it is only necessary to build an abstract model by a retro-engineering process. Note that this approach is not specific to the educational objectives addressed in Saafir: it can be used in different contexts that require enhancing an existing Web site with dedicated tools (Richard & Tchounikine, 2004).

Using Saafir tools thus requires modeling the curriculum according to the used ontology (see the third section). This additional work is the price to pay for (1) having the capacity to make learners understand the details of the curriculum and (2) constructing tools that are independent from the WBL platform and can thus be used on the top of existing commercial platforms.

Within the context of this research study, we have used an ontology dedicated to the appropriation issue and, with feedback from teachers, have constructed the curricula models "by hand" from the curricula original descriptions. This is manageable for a research project but is probably too expensive for ordinary settings. This issue is to be addressed by model transformation techniques, taking advantage of the fact that second-generation WBL platforms are now more often based on the use of explicit models of the platform and the curricula using (for instance) UML or XML dialects. This allows the consideration of the creation of "bindings" that can fill part of the appropriation-focused ontology from the platform-focused and/or the curriculum-focused ontologies and meta-data, while teachers have only to complete features that are specific to the appropriation issue and are not present in (or can not be automatically retrieved from) the already available data, if any. From a technical point of view, the necessary techniques already exist, for example UML transformation (via MOF) or XML binding techniques.

USABILITY AND USAGE: FIRST FINDINGS

As explained in the introduction, the first objective of this exploratory research was to work out the means that can be proposed to a learner working with a WBL system to progress towards appropriation. We have presented in the fourth section different tools that appear pertinent to this issue. The second objective was to understand how learners react to and use such means. We present in this section the first findings on this issue.

We have tested the approach and part of the tools proposed in the fourth section in two different settings. The first experience aimed at providing input for our iterative development. We have tested the Saafir tools for two consecutive years in a context local to the system designers, using the feedback from the learners to guide the creation of new tools and/or the refinement of the existing ones. The second experience took place in a completely independent setting and was piloted by a person who had no connection with the Saafir team and was just interested in the potential impact of Saafir on a learners' given curriculum.

In the sixth section we propose a summary of what was learned from these two settings, emphasizing the second one. Let us recall that these experiences were aimed at providing empirical ideas for this exploratory research and therefore that the analysis does not follow a controlled data comparison methodology. Here again, we believe that designing functionalities to support appropriation in the context of WBL is a domain in its infancy that requires a better understanding before allowing controlled experiments.

Case 1: Exploratory Open Use

The context is a master's degree in computer science of the University of Le Mans in France. This curriculum was followed by 16 learners the first year and 19 learners the second year, half of them being distance learners (in France and abroad). The learners were informed that they could use Saafir in order to have a better understanding of their curriculum (open use and not mandatory use). The tools offered were: perception tool, annotation tool, and evaluation tool. The WBL that was used was an ad-hoc Web site proposing different resources such as HTML or PDF files. The data was collected by questionnaires and debriefing sessions.

This setting did not test our system in its targeted general context of use as (1) learners were computer science students and therefore had no difficulties in using the environment (from a computer science point of view) and (2) the curricula was related to technology-enhanced learning and learners therefore had a specific interest for such tools. This experience, related to the designers' proximity, was therefore limited to a first understanding of the tools of perception and usage in order to iteratively improve them (ergonomic issues, residual bugs, etc.). These two years of experience allowed us to draw the following list of conclusions:

- Modeling the curriculum according to the adopted ontology was a non-trivial and engaging task for the educational team. As a side effect, this modeling helped teachers (as individuals) and the pedagogic team (as a group) to develop a better understanding of the curriculum (implicit links or constraints between modules, etc).
- All the learners used the tool, at least by way of curiosity. All face-to-face learners spent a few hours browsing with the perception tool, testing the other tools, and then did not use them anymore, while distant learners used it on a regular basis. This suggests that such a tool does play a specific role for distance learners, which is fulfilled in some other way for face-to-face learners. The debriefing sessions suggested that face-to-face learners do not feel that they need such a support because they are unconsciously confident in the fact they will be aware of what they need to be aware of by interacting with their teachers and peers, which is the implicit usual tropism. It would be interesting in follow-up research to study this point.
- The perception tool is by far the tool that is the most used (80% of the total amount of

time). The capacity to shift from one view to another was extensively used. A negative side effect of the perception tool was that some learners felt they had too much information at once (all the details of all the courses and activities of the curriculum).

- The annotation tool was mainly used to indicate the level of advancement; few advanced comments were defined.
- The assessment tool, and in particular the fact that it allows one to compare one's advancement with that of the others, was of great interest to the distance learners. However, the learners were disappointed to discover that the tool appeared to be unusable because only few learners did use it. At the debriefing it appeared that the learners who wanted to use the tool formed a coherent group and shared a certain type of implications in the curriculum. This suggests that group-based tools such as the ones that compare the learners' advancement with that of the others' must be used in coherent groups, that is, groups that may have the same willingness and motivation in the curriculum and to use the tools.
- The warning tool was developed after the first year of debriefing, and the first prototype was proposed in the second year. The system was initialized with a set of predefined rules implementing the curriculum deadlines. Some learners defined additional rules in order to be informed that an event (e.g., document to be sent to a teacher) was coming soon. This suggests that this "externalization" of the regulation seems interesting, although, here again, if not for all students at least for some of them. We, however, do not have enough data to draw some conclusions. Moreover, it must be remembered that the learners were computer science specialists. Analyzing these types of advanced tools (warning tool, project tool) requires some specific research actions.

Finally, it can be highlighted that the learners proposed numerous ideas for improving the proposed tools or adding new ones. For instance, a large consensus of learners suggested the addition of a chronological view that would help them to deal with time management issues. As another example, they proposed that the assessment tool should calculate the level of advancement of an item by the level of advancement of its sub-items, using "some kind of formula," this principle is used in Després & Coffinet (2004). They also suggested that a "learning companion" could mediate some information. Although this was a particular context, this makes us optimistic about the acceptability and the interest of learners in terms of using tools that make them reflect on the curriculum and their itinerary at an abstract level. This also suggests a tool-kit approach (proposing a set of tools that learners can use or not; or, eventually, adapt to their interest and practice) rather than an integrated all-in-one approach.

Case 2: Using Saafir to Increase Learners' Motivation

This section reports on the findings related to the use of Saafir for intermediate English learners at the University of Puerto Rico Mayaguez (UPRM) campus. This setting corresponded to our targeted general context of use: basic users in a basic domain (nothing to do with computers), already existing curricula, and students encountering appropriation problems. We describe the research and its outcomes in detail below.

General Context

Professors' experience teaching English in Puerto Rico for more than 11 years has shown that learners in college did not fulfill the requirements of the Puerto Rico Department of Education, which wants them by the end of their schooling to be bilingual. Learners' motivation to learn English is of the functional kind (e.g., to gain job advancement), rather than the integrative kind (e.g., to become members of the North American society) (Vargas Batista, 2005; Caratini-Soto, 1997). Despite that, a survey administered to the English composition learners showed that when learners have to deal with the courses of their own fields of study even functional motivation fades away.

Although the learning of a foreign language can be considered as being easy to self-direct and self-monitor, the UPRM team that works on the English composition issues faces problems, some of which are quite general, such as (Sully, 1995) low motivation and interest of students, no clear or realistic idea as to what is expected of them (Cooke, 1991), students' poor mechanical skills (in this case: spelling, punctuation, creating paragraphs, using references and organizational skills such as how to organize ideas and paragraphs together, how to use transitional devices, how to do prewriting, writing and revisions) and also, more specifically, students' inability to choose a topic (in this case, something to write about that gives enough material to develop an essay), students' poor style and reasoning ability (giving a personal color to their essay and creating arguments) and a lack of good language skills that relate to writing (reading, listening, vocabulary).

In terms of low motivation mentioned above, different reasons have been identified from the same survey, such as the concentration courses have priority and English becomes another subject not as "real" and "urgent" as the concentration courses; learners feel English is politically imposed on the educational system of Puerto Rico; poorly thought-out planning and teaching methods are used in schools before they entered college; a lack of daily use of English is taking place in Puerto Rico since Spanish is the primary language that covers the everyday needs of the speakers. Two other issues can be highlighted. First, the official course catalogue is succinct and brief, and cannot include the exact content, competencies, requirements, and deadlines of each course. The result is that professors have learners who choose English core courses (in our case composition, intermediate level) for a particular semester without knowing the curriculum. The way most used by students to gather more insight about the curriculum is by talking to students who have already taken the course about their experiences. This type of information, of course, is usually very subjective. Thus, when they enter the courses their expectations may not match what they encounter. The conflict between what was expected and what is actually given creates a decline in their motivation to learn. Second, course materials are pre-determined by the professors. This top down method does not leave enough freedom for the learners to choose chapters of the curriculum based on their interests or to bring new chapters to it, thus having a voice in the curriculum building. Curriculum building actually could be an incentive to increase students' motivation and thus the learners can direct their own learning (Lamy & Goodfellow, 1999; Brandl, 2002; Stepp-Greany, 2002; Strambi & Bouvet, 2003; Martens et al., 2004)). This being what they would prefer to do as it is obvious from the high scores they gave to the questions assessing their attitudes in relation to being able to choose which chapters of the curriculum they would like to work on and bringing their own materials to the curriculum building.

The survey, including the above variables, was administered to incoming intermediate English students in the UPRM in 2002 and it was also given at the end of the semester without any significant results between the two groups. It seems that students' motivation was as low exiting the course, as it was when they entered it. The following patterns specifically were scored equally high at the beginning and the end of the course:

- Students' willingness to spend a small amount of time studying for the course (90%)

- Priority is given by the students to courses of their field and the grade in English is only important to them
- Students' attitude toward English as being politically imposed on them (due to Puerto Rico's association with the U.S.) was turning them off (85% of the learners). The 85% of the learners also mentioned that if they had to choose a foreign language, it would not be English as they were familiar with it since pre-K. (Despite that, the English of many learners in Puerto Rico is not good.)

Integration of Saafir

In 2003 it was decided to integrate Saafir experimentally in the curriculum. The objective was to make learners have detailed information about what was taught to them and to make learners become participants of the curriculum building by constructing a module they wanted to be taught and by having the freedom to bring in materials that interested them.

Professors liked the fact that learners would have the opportunity through Saafir to evaluate themselves and the course, and they wanted to compare the students' evaluations with their own. Professors thought that students participating in what they were being taught would result in an increase of their motivation. By having an electronic curriculum instantly available to them, learners could decide if the course matched their workload for the current semester or not, and also they could know down to the last detail what the course was about, since the curriculum was described with as much detail as possible in terms of objectives, competences, modules, activities and dates. The professors' motivation to work on the project was high at the beginning, but due to the amount of work involved, from the twelve (including those who taught Intermediate English the particular semester during which Saafir was used, and those who had taught in the past but did not teach when we were experimenting with Saafir, as well as those who were interested in Intermediate English but usually do not teach it), three continued.

The profile of the Puerto Rican students who participated in the experiment consists of the following demographics: they are 17-18 years old; first year undergraduate students; the majority of being interested in the science curriculum of the University, particularly engineering, biology, chemistry, and pre-medicine; and they come from high schools with teacher centered environments.

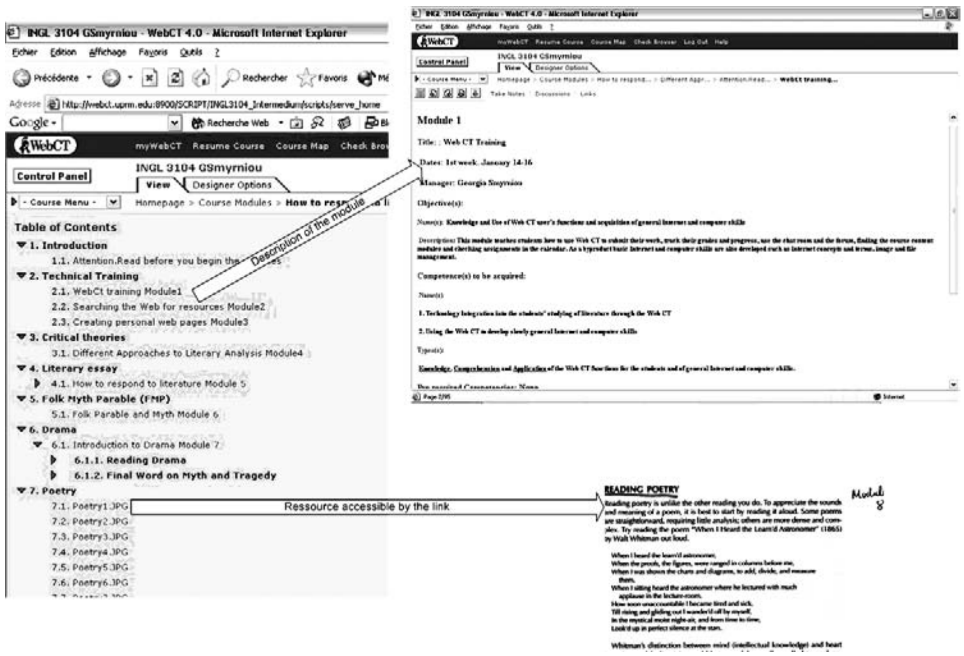
In addition, in our program, we have found that students can do well in their e-learning in the sense that students are able to follow instructions independently, the turnover of the assignments is higher when submitted online and student participation in discussions is higher in online sessions than in class.

In general, students do not have extensive knowledge of the English course curriculum (in this case, composition), nor is it extensively provided for them online before registration. All students utilize office hours for one–to-one counseling and guidance, and they seem to value this face-to-face discussion with the tutor more than an online interaction, particularly if their grade is in trouble.

From a technical point of view, the courses within the Intermediate English Curriculum were delivered using WebCT©. A link in WebCT homepage connected with the Saafir (see *Figure 17*), while one more link connected with a virtual trip presentation regarding how to use Saafir. Due to the fact that students had come up with additional questions, apart from those explained in the virtual trip, a manual was also written up and linked in WebCT.

As explained previously, the role of the tutor was not left to a tutor-less teaching machine. As put forth in the research questions of this article, we believe that a student's study program, along with the evaluation and regulation of his/her progress, should be developed and discussed with

Figure 17. The curriculum in WebCT



human tutors. In the case of the UPRM experiment, Saafir was projecting the curriculum model, but the course modules, the work groups, and the synchronous and asynchronous communication was done in WebCT with meetings of students and instructor [instructors, professors, teaching assistants (TAs) are all considered tutors]. Thus, the curriculum was not a passive database; the tutor was monitoring questions and giving prompts while the students could exchange work and give feedback on each other's work in the discussion forum. Students' progress was monitored continuously by observing interactions (student to student and student to teacher) and assignments. Also, the tutor wrote and published in WebCT platform the manual "How to Use Saafir;" prepared the students to use Saafir; gave the students hands-on training in how to actually use it; guided the students in how to write their own course modules and objectives in the curriculum that would match their interests; monitored students' use of Saafir with online observation of students' interactions and assignments, and with face-to-face interviews, (see section six), which included fielding questions about the use of its tools and communicating them to the Saafir team, monitoring students' attitudes about using Saafir, monitoring the effect of its use on students' motivation to learn and improve their composition skills and offering counseling in terms of students' evaluations of their achievement compared to the achievement of other students and the tutor's evaluation of the students.

First Experience, General Findings

This section presents how Saafir was used in a one-year pilot study and the lessons that were learned.

Students are not motivated to learn English and they stayed with the course mostly for the credits. For the pilot study, two sections of Intermediate English learners were randomly chosen, for a total of 20 learners. When Saafir was introduced to the students and during the sessions familiarizing the students with the tool, through discussions we found: first, that the perception tool was helpful in the sense that learners could have all the information of not only the general course, but also of the specific sections, even before registering for the course with a specific professor. To that extent, it was more detailed than the course catalogues. Secondly, we found that the annotation/assessment editor was considered useful because it allowed learners to use simple text for the evaluation of the modules, the particular professor, the curriculum, and their progress. Contrary to the University server, which had the course information posted as a continuous text, a format which tended to tire the students who tried to read it, causing them to give up, Saafir did not lose the students because of its navigability by clicks on the links to different parts of the curriculum (objectives, activities, and competences). Thus with Saafir, there was more of a chance that the student would actually read the curriculum. The same goes for WebCT. In WebCT the curriculum was given also as a database, making the learners who tried to read it as tired as the University server did, leading them to quit reading. With Saafir the curriculum was posted and linked in the system automatically.

Questions at the beginning and end of each module regarding the activities, competences, and objectives of the module as described by Saafir helped learners have an idea of what was happening in terms of class content, and how to evaluate the module and the class in Saafir. Also, the learners evaluated their progress while they had the chance to be warned about upcoming deadlines of the curriculum in terms of activities (assignments due). At the end we invited the learners to tell us what modules they wanted to see in the curriculum that were not there and how they would integrate them in the current curriculum, even if they had to modify or to take out any current ones. We also asked them to state those modules in the same detail that we had stated the course modules in Saafir's ontology. This would give them the opportunity to participate in curriculum building by going through the experience of writing curriculum modules with material they would be interested in, and viewing them in the broader picture of the whole curriculum. We were hoping that in this way the motivation to learn would increase. The modules had to be checked and discussed with their professors.

What we observed in this phase was that learners evaluated the modules using the annotation editor in the modules but not in the other windows, such as competences, objectives and activities, as they found that they could do it all in the modules editor. It may have also been because the teachers did not insist on different windows' assessment and they used the modules editor as a catchall.

Teachers thought that the same happened with the e-mailing of the learners. The assessment window gives the possibility for the learners to e-mail other learners of different or same levels of assessment in a particular module, activity objective, or competence. The learners did not do it because teachers did not insist, since the focus was to use the annotation tool, and also because the Saafir learners knew that they were participating in an experiment and they would be graded in terms of evaluation and curriculum building, not in terms of cooperation with the other learners. Thus cooperation did not happen inside Saafir. The WebCT chat or threads in WebCT forum were the meeting places used by the learners.

In terms of cooperation, there was a reservation on the part of the teachers to use the e-mail. The learners could compare assessments anonymously, thus the learner would not know with whom he/she was communicating while he/she would be able to send them e-mails. Teachers felt that for a constructivist approach to learning, knowing each other virtually and having the feeling of membership would be very important. Though information could be exchanged anonymously it would be hard to create a community of learning (virtual classroom group). The other option would be not to use anonymity, but by law in the UPRM one learner's grades/levels cannot be reported to another, even if they are self-evaluations. Since in the Saafir the self-evaluations take place in each student's personal account, which is password protected, the issue of privacy creeps in if the content of the account is revealed to another account holder.

During this phase of our investigation, which lasted a semester (a total of 32 times online teaching/learning), we used action research, the nature of which is qualitative (Dick, 1999). The ways to collect data under this kind of research, in order to examine students' opinions/attitudes about Saafir and the level of their motivation with and without using Saafir, involved students-tutor interviews, students' evaluations in the Saafir, and a discussion blog period (Kern et al., 2004). The interviews and the blog period were run at the middle and end of the semester.

The blog showed how the learners felt about Saafir and if they were ready to proceed with the curriculum-building phase. It indicated that students would have preferred Saafir to be used as a study program tool (choosing the chapters they wanted to concentrate on and entering their own materials in the curriculum) rather than an evaluative tool, though they mentioned that they felt good that some of their own opinions about the course and themselves were heard and considered.

Regarding the interviews (Warschauer, 2000) that took place at the end of the semester, they showed that learners believed that the evaluations and the freedom to use their own modules had made them to want to participate more in the course because their needs and preferences could be heard (Oldfather, 2000). Also that the curriculum was not departmental wisdom thrown at them but a negotiation of institutional goals, learners' preferences, and instructor's ability to manage and counsel the learners' objectives and such preferences. The fact that they saw how a curriculum was divided in detail made them informed course consumers, instead of course consumers based on instinct and/or the experiences of other learners who had taken the course In order to get the evaluations from Saafir annotations, we used an administrator's site that brought up all the evaluations from the different students' accounts

Second Experience: Questionnaire-Based Analysis

This section presents the lessons learned from the second year experience.

Procedure

Forty-two learners (two sections) were selected randomly to use Saafir. Another forty-two learners of similar demographics made up the control group where Saafir was not used and it was a traditional face-to-face interaction class. Six learners from the Saafir group and four from the control group dropped the course for health, family and transportation reasons.

Regarding the class, it was taught partially online through WebCT. In general, the composition courses are traditional face-to-face classes or hybrid classes [in which case, the majority (75%) of the work is done online] using WebCT. From past experiments we had come to the conclusion that WebCT itself is not a self-motivating/meta-control tool (Smyrniou, 2004) but rather a communication tool and the role of the teacher, even when WebCT is used, is important. This is the reason the Saafir was examined in comparison with a face-to-face control group to check motivation and not another hybrid section without Saafir. The class ran for a semester and the time that the students spent on learning varied from minimum of 1 hour to a maximum of 5 hours per week with the majority of the students falling between 1-2 and a half. The hours moved to three and five as they started writing the course modules (see results).

Regarding Saafir's functionalities, all the elements of Saafir were used, with the exception of three: deadline warnings for the activities of the modules, learners' e-mail, and projects in the form that Saafir defines them. The reason for not using the deadline warnings was that WebCT was flashing the corresponding info even before the learners would enter the course and as soon as they would just log in. The "flashes" were links that learners had to click for the info to pop up. Thus, Saafir would duplicate the work. The projects option was not used because they were literature essays, not long individual or group projects that the engineering departments usually require from the learners. Thus, Saafir's concept of projects did not pertain to the nature of the course. The learners received six extra points for their work in Saafir. Regarding the e-mail, it has been already discussed in the pilot study (see above). In addition, the WebCT e-mail was sufficient for the students to communicate without the danger of any rating of students' performance to be given out either anonymously or namely. There was not any special need for the functionalities to be tested one at a time, as students, after some initial explanations, were able to use the tools quite well.

In terms of instruments for data collection, we continued as in the pilot study before to use a qualitative approach (Madison, 2001), this time involving questionnaires and Saafir evaluations. Learners had to keep notes on their progress in Saafir and evaluate themselves and the course modules, as well as the course in general. These learners' evaluations were compared with the professor's evaluations of the students. One week (called counseling week) before the deadline to drop the course, the learners would come to the professor's office to discuss the similarities and the differences between the two evaluations.

The learners also had to write modules that they would like to be included in the course. The learners' virtual groups in WebCT would decide with forum meetings which ones should be included in the curriculum and those were taught during the semester. The modules had to be written in detail and based on Saafir's ontology.

In addition, similar surveys were given to learners using Saafir and those in the control group upon entering and exiting the course. The survey for the entering students of the control and experimental group, as well as the exiting students of the control group, called for students' personal opinions on how their motivation to learn English (particularly composition) was affected in general, by course expectations; by the quality of information given to the students by the counselors and the course catalogue, or by teaching methods they encountered in the past; by their own beliefs regarding how useful English is in their jobs, citizenry and field of study; by the political imposition of the English; as well as by the ability to choose materials from the curriculum according to their interests or by the opportunity to bring materials to the curriculum (this is the survey that we always give to the students and it has helped us form an idea through the semesters about the students' attitudes). Also, for the exiting students of the control group questions specifically about their course expectations, and their levels of motivation were asked, as well as an invitation was extended to them to suggest any changes they would like to make to the course so that their motivation could be raised.

The survey of the exiting students of the experimental group gave information on the above variables and additionally on: students' opinions on the use of Saafir and its functionalities (perception and evaluation and general ease of use); students' opinions on the course using Saafir and if it motivated them to learn; students' opinions about building their own course modules based on Saafir's ontology.

We analyzed the data by looking for themes, patterns, and big ideas. Then we coded the data according to the themes found. This procedure was followed for all those questions that invited students' open-ended comments. Special attention was paid to those items with the highest frequency. We also paid attention to the high frequencies of the multiple-choice items. Last but not least, we watched for any unusual comments or behaviors that might be connected with the tools, motivation, and course attitudes of the students. The analysis of the data followed the qualitative pattern we had established since the pilot study, with the exemption of only one inferential test (which was run to confirm and triangulate the pattern we had established in our qualitative analysis of the data), between the results of the entering and exiting students of the control group and the entering and exiting students of the experimental group. This inferential test was a test of significance applied on the same variables of the entering versus exiting group of students, in one case within the control group and in another within the Saafir group. Then the results—qualitative and inferential—were compared.

Results

From the survey given to the entering students of both groups (experimental and control) we found that in terms of motivation, the results were exactly the ones reported in the sixth section under "context." The survey results from the entering students (control or experimental group) did not show any significant differences. Also, none of the students of either group had ever been part of any curriculum building in any UPRM courses. Regarding what they would like to see changing in the course; they mentioned more participation, fewer assignments and more discussions of topics they were interested in. The majority of students' expectations about the course did not match with what the course was all about. Regarding the time they were spending to learn and study, they mentioned they would not dedicate more than one to two hours maximum, as the course was not part of their field area only being taken to help their GPA (Grade point average. See also the sixth section above). These results were compared with a similar survey given to the learners at the end of the semester (see below).

From the survey given to all learners at the end of the semester we found the following:

- While the counselors' ability to orient students right in the course curriculum, along with the quality of the information provided by the course catalogue and the decrease in students' motivation due to previous school methods that tried to teach them composition were scored very unfavorably by the exiting students of both groups, 98% of these learners liked the fact that they could write their own modules of interest and give them to their group members in WebCT for review; that each group voted which one would be taught in class; that they would then submit them to teachers for inclusion in the curriculum, and that at the end of the semester these modules were taught as part of it. But they mentioned that while the Saafir electronic curriculum had helped them to build the modules, they found it hardly an easy task. One learner mentioned that it was as difficult as the computer graphics course he was taking. From the same learners 85% noted that while their respect for the course increased through the difficulty they experienced in writing the modules, the grades they received in their concentration courses were still more important to them. Also, contrary to the entry survey where the majority of the students wanted to do the minimum, in this (exit) survey 96% of learners mentioned that the time they had to put into finding materials and contributing to the class had increased, but it was a "creative time" and because of that, the motivation to participate offset the usual complaints between credit versus required work. The students did not perceive the six extra points we gave them as an incentive for using Saafir as an extreme reward for the work involved. Despite that, they were not belligerent about it.
- In addition, 98% mentioned that they would enjoy contributing materials to the cur-

riculum and working with the professors in curriculum building.

- The same amount of learners mentioned that they could understand better through the Saafir curriculum what the professors intended to do in each module, and that they would like to see other courses being provided electronically, since it is an easy way (a "click away" as they mentioned) to understand what was going on in the course. In addition, they mentioned that it is preparing the students well for what is expected in the course and in a way it taught them how to write curriculum modules. Looking at the control group, we found that learners did not have as firm a grasp on the details of where the course was headed as the Saafir group did.
- The questions referring to attitudes toward English regarding its use in PR, its contribution to the students' field of study, or job or citizenry and its image as a politically imposed language scored in both exiting groups as being unfavorably associated with their learning of English, though a few students in the Saafir group mentioned that it makes sense to learn it if you go to work in the United States or study (42%).
- Regarding what they would like to see changed in the course, the non-Saafir exiting group mentioned more interaction in the groups and fewer assignments. The Saafir group, by introducing their own modules, gave us a pretty good idea as to how the curriculum, in terms of topics, has to be revised. They clearly asked to continue the students' involvement in the curriculum.
- For the questions or part of the questions of the survey that lent themselves (they were not open ended) to a test of significance, we discovered that there was not a significant difference between the two groups. The differences in terms of students' motivation seem to come in when new variables, such as construction of modules or a detailed electronic curriculum comes on stage (see above) or self-evaluations/regulation, are introduced (see below).
- As far as the Saafir's functionalities are concerned, the following results were gathered: it was very easy to use Saafir (87%) and as the open ended comments mentioned, it became almost intuitive; they found it very easy to evaluate themselves in any of the four parts of the Perception function (modules, objectives, activities, competences); they liked the tracking of the progress, as 96% of the learners mentioned that they liked having their Saafir evaluations being compared with the professors' evaluations (as was found in the first survey, too) and then being given counseling time at the professor's office. This kept them informed throughout the semester and helped them to make a decision when the administration's deadline came up regarding dropping or going along with the course. In terms of what they would like to see changing in Saafir, they mentioned the following:
- First, some students mentioned that it would be a good idea if after every evaluation is done a check mark could be put as a reminder where the student left off the time before. It would be easier for the student to track his evaluations if he had only one part of the perception to work with, for example, modules. But since there are four (modules, objectives, competences, activities) it can be confusing where he stopped.
- Second, for some students putting all buttons in one language—English or French—would be an idea and make the program become faster and shorter (-Kbytes).
- Third, that the program stores only one evalution by event and that it have many colorful icons to associate things (sometimes the evaluations were saved more than once).

- Fourth, for security reasons some students would like to implement an option that helps them change the passwords.
- Fifth, coming from three students was the thought: "I think that not everyone has the facilities of accessing a computer with Internet and downloading the program Saafir because the program has certain specifications. I personally tried to download it into my laptop but I don't know why it didn't allow me to do it" and "Maybe if it can come with an online manual of trouble shooting it would help."

Regarding learning, the final exam showed that the grades were distributed equally between the control and the Saafir group. If somebody defines learning based on grades and final exams, then we did not have any difference between the groups (control and experimental). The difference is in the quality of learning and the understanding of the structure of the course between the two groups, along with the creativity of the learners that went into actual curriculum building, which helped them to learn. This creativity was obvious in the Saafir group but not in the control group. Summarizing, if learning is defined along the lines of motivation, experience with the course structure, and use of creativity, then the Saafir group had an advantage.

In terms of Saafir and faculty we found that the use of Saafir helped the professors to see where our curriculum needs revision based on learners' evaluations in Saafir and on the learners' writing of modules. It also helped to discover how learners' needs, starting with learners' learning disabilities that were never reported, up to learners' personal issues that came up through the counseling week interviews, changed the way it was decided to evaluate learners (particular deadlines for emergencies were established as well as a definition of what is an emergency in the course; also instructions were given in the course syllabus as to how the American Disability Act protects the learners who suffer from learning disabilities and how and where on campus they have to report them). On the other hand, we did encounter the issue of how to change the dates of the activities if something should go wrong and either some modules had to be skipped or the deadlines to be changed (as happened due to an all campus strike). Due to a regrouping of materials to adjust them to time that had been left, the students would see different dates and modules from the ones taught during the face-to-face interaction. This issue was resolved by gaining access to the particular site from where we could change those dates. Some professors mentioned that it would be nice if in the future, instructors could have control also in order to change some of the activities as the course proceeds if better materials came up that are more relevant than the ones that have already been entered in the Saafir.

Two major features can be outlined concerning the functions of the developed tools. First, students have an opinion on the tools, not only in terms of "it is useful or not," but in terms of how the tools could be adapted to fit their needs. This means that students learn that appropriation tools can be useful to them and actively reflect on the utility of the tools and propose ideas pertinent to their own usage. This is an interesting side effect. Second, students have different proposals, which at times are contradictory. This is coherent with our theoretical premises: appropriation of a WBL curricula concerns both appropriation of the curricula and of the technological issues, and it is coherent in that students who are appropriating the WBL curricula are required to adapt the tool to their own individual needs. The conclusion that can be drawn from this is that an architecture that proposes appropriation tools should not be one-in-all but composed of building blocks that students can use or not, and that these blocks should be customizable by each student.

CONCLUSION

In this article we have suggested that appropriation is an important issue to be considered in the context of Web-based learning. We have proposed a general definition of the concept of appropriation and explored how it is possible to design computer-based tools that manipulate an explicit model of the curriculum in order to help learners to perceive the curriculum from different points of view, to annotate, to evaluate, and to regulate their itinerary.

The experiments conducted thus far demonstrate that such tools do provide an added value service. In particular, the second experiment in Puerto Rico suggests that Saafir helped with learners' motivation and curriculum participation. In addition, as a consequence of using Saafir with the English learners, the pedagogic team of the course was challenged to refine its curriculum description.

We have proposed in the fourth section, examples of tools that can be useful to support appropriation. At this point, further research must take place: the basic tools (perception, annotation) must be further tested in different learning environments; the complex tools (project editor, warning editor) must be evaluated in terms of usability and then be tested in real learning contexts; and many other tools could be designed and implemented. It is also necessary to work out if it is possible to propose an ontology (the one we have used so far or a variant) that is both sufficiently generic and precise enough to be used in any setting or if a preferable strategy is the construction of an ontology that is context-dependent (customized according to the curriculum, the public, or the objectives). This latter case would then require addressing issues (such as an automatic customization of the tools to accommodate the ontology of different curricula). In both cases, it would be interesting to study how the ontology based modeling of the curriculum (which is a task that is difficult for teachers to address) can be supported, including potential bindings with standards such as IMS-LD.

From a more general point of view, this exploratory research opens different questions to be examined, in particular:

- Can/how can the appropriation of a curriculum by a learner be measured?
- Can the effect of using/not using tools such as the one presented in this article be measured?
- Can using such tools be interesting enough to learners and to such a degree that they use them on a volunteer basis, or is making this usage mandatory a better strategy?
- How can the support proposed by such tools and the support proposed by human tutors be articulated?
- Can we propose an architecture that students can adapt to their needs, selecting the tools they want to use and then customizing these tools?

We believe that the research presented in this article and the different researches that we suggest above can contribute in enhancing WBL platforms with tools that can avoid some of the appropriation, autonomy and motivation problems that learners face and that contribute to the pedagogical and learning difficulties currently associated with Web-based learning.

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Chapter XXII
Development of a Web-Based System for Diagnosing Student Learning Problems on English Tenses

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ABSTRACT

In the past decades, English learning has received lots of attention all over the world, especially for those who are not native English speakers. Various English learning and testing systems have been developed on the Internet. Nevertheless, most existing English testing systems represent the learning status of a student by assigning that student with a score or grade. This approach makes the student aware of his/her learning status through the score or grade, but the student might be unable to improve his/her learning status without further guidance. In this paper, an intelligent English tense learning and diagnostic system is proposed, which is able to identify student learning problems on English verb tenses and to provide personalized learning suggestions in accordance with each student's learning portfolio. Experimental results on hundreds of college students have depicted the superiority of the novel approach.

INTRODUCTION

The advance of computer and Internet technologies has significantly affected the style of tutoring and learning (Kuo & Chen, 2004). Many educational institutions all over the world have started to develop and deliver Web-based courses on the Internet (McCormick, 2000).

English has been the most popular language for the past decades, probably due to its systematical grammatical structure. Even though English has such positive characteristics, learning it has always been substantially difficult for ESL/EFL (English as Second/Foreign Language) students. Additionally, English tenses play an important part in explaining the temporal background of English sentences. Nevertheless, EFL learners in general often omit or misuse them. These errors can significantly alter the intended meanings, especially in higher-level communications. Moreover, EFL learners' confusion about English tenses seemed to be the most significant reason for their learning obstacles.

Experts of language education have recommended that the best way to learn English is to establish a good study environment and practice it through various approaches, thus making it a satisfying learning experience (Wang & Lin, 2004). From this viewpoint, an e-learning environment seems to be a good solution to improve a student's English learning performance.

Most existing e-learning systems for English courses evaluate and represent the learning status of a student with a score or grade, which merely makes the student aware of his/her learning status through the score or grade, but the student might be unable to improve his/her learning status without further guidance. In this article, an intelligent English tense learning and diagnostic system is proposed by employing artificial intelligence (AI) technologies, which is able to identify student learning problems on English verb tenses and to provide personalized learning suggestions in accordance with each student's learning portfolio. Furthermore, some experimental results are given to demonstrate the benefits of the novel approach.

RELEVANT RESEARCH

In recent years, many researchers have attempted to make use of computers to help ESL students in learning English (Chan et al., 2001). Through implementing computer-mediated education, many advocates emphasize its positive aspects and the English learning tutoring systems, which are computer-based, that have been developed by numerous academic research groups (Wang & Lin, 2004). For example, Tsou et al. (2002) applied the ideas from computer-assisted learning (CAL) and language learning to the development of a multimedia Web-based English abstract word learning system. An experiment on thirteen commonly encountered abstract words at the elementary school level has demonstrated the benefit of applying the system. Recently, Yang et al. (2005) proposed a Web-based interactive writing environment designed for elementary school students. The environment includes several writing themes to encourage reading comprehension, creativity and problem-solving skills of students.

In addition to the examples mentioned above, there exist innumerably splendid and elaborate works devised by researchers around the world (e.g., Park & Shirai, 1998; Brett & Nash, 1999; Li, 2000; Wintergerst et al., 2003; Itakura, 2004; Ruthven et al., 2004; Coniam & Wong, 2004; McDonald, 2004). Moreover, the issue of applying information technologies to the improvement of English learning efficacy for those who are not native English speakers has attracted researchers from various fields regardless of educational circles, such as linguistics and computer science.

Meanwhile, the computer has evolved into a tool that can improve the accuracy, efficiency, interface, and feedback mechanism of online tests (Ho & Yen, 2005). Many researchers have attempted to inject information technology into computer-assisted learning (CAL) for further diagnosis on how well students learn, or where they are having difficulties during the learning process. For instance, Virou et al. (2000) created an intelligent multimedia tutoring system for the passive voice of the English grammar. The main focus of the tutoring system is on the student's error diagnosis process, which is performed by the student modeling component.

In 2001, Virvou & Tsiriga (2001) created the Web PVT (Web Passive Voice Tutor), an adaptive Web-based intelligent computer assisted language learning (ICALL) system that aims at teaching non-native speakers the passive voice of the English language. The system incorporates techniques from intelligent tutoring systems (ITS) and adaptive hypermedia to tailor instruction and feedback to each individual student. Furthermore, it is capable of detecting misuse and performing ambiguity resolution of passive voice based on the long-term student model. One year later, Fox & Bowden (2002) presented GRADES (GRAmmar Diagnostic Expert System), a diagnostic program that detects and explains grammatical mistakes made by non-native English speakers. GRADES performs its diagnostic task, not through parsing, but through the application of classification and pattern matching rules. This makes the diagnostic process more efficient than other grammar checkers. GRADES is envisioned as a tool to help non-native English speakers learn to correct their English mistakes, and it is also a demonstration that grammar checking need not rely on parsing techniques.

The study of new methods for diagnosing learning problems has also attracted the attention of researchers from computer and education fields. Hwang (2003) developed a network-based testing and diagnostic system that provides learning suggestions for each student by analyzing answer sheets and the relationships between subject concepts and test items. Furthermore, to assist the teachers in providing the relationships between subject concepts, some methodologies and tools have been proposed (Tseng et al., 2004; Hwang, 2005).

Research Archtecture and Design

In this section, we shall demonstrate our novel approach to diagnosing student learning problems in learning English tenses.

Classification of Tenses in English Grammar

In diagnosing student learning problems on English tenses, it is an important issue to classify the associated grammatical concepts (e.g., *articles*, *quantity words*, *countable nouns*, *uncountable nouns*, *verbs*, and even *sentence patterns*) of English by defining its grammatical category. By means of referring to various English grammar bibles, consulting English experts on grammar teaching, and grouping relevant English concepts into grammatical categories, we bring out a systematic categorization of English grammar by proposing fourteen tense-related concepts of English grammar in this study. *Table 1* shows the name and the instance of these concepts.

In the tense category, four patterns (i.e., simple pattern, progressive pattern, perfect pattern, and perfect progressive pattern) and two adverbs (i.e., time adverb and frequency adverb) that might affect the variation of verbs in a clause are taken into consideration.

Identification of Online Learning Performance with Fuzzy Approach

We attempt to identify each learner's online performance and provide corresponding learning suggestions based on the fuzzy approach. *Fuzzy*

Table 1. English tense category

Category		Concept	Instance
Tense	C_1	Present Simple	*The earth* **is** *round.*
	C_2	Past Simple	*I* **graduated** *from Harvard last year.*
	C_3	Future Simple	*I* **will be** *the winner.*
	C_4	Present Progressive	*Kent* **is reading** *that best-selling biography.*
	C_5	Past Progressive	*They* **were dancing** *when the teacher came in.*
	C_6	Future Progressive	*Two days later, I* **will be driving** *a new car.*
	C_7	Present Perfect	*I* **have seen** *that movie twenty times.*
	C_8	Past Perfect	*Jerry* **had studied** *a little English when he came to the US*
	C_9	Future Perfect	*I* **will have perfected** *my English by the time I come back from the US*
	C_{10}	Present Perfect Progressive	*I* **have been studying** *English since 1987.*
	C_{11}	Past Perfect Progressive	*He* **had been driving** *all day before he went to class.*
	C_{12}	Future Perfect Progressive	*By the time you leave, you* **will have been living** *in Rome for six months.*
	C_{13}	Time Adverbs	*The plane landed five minutes* **early**.
	C_{14}	Frequency Adverbs	*I* **always** *brush my teeth before I go to bed.*

Set theory was proposed in the mid-sixties by Zedah (1965), and was extended later to include *fuzzy logic* (Zedah, 1973), a superset of conventional (Boolean) logic that has been developed to handle the concept of partial truth. Fuzzy sets (or vague sets) generalize the notion of crisp sets (Gau & Buehrer, 1993); that is, an element could be in a set with a membership degree between 0 and 1.

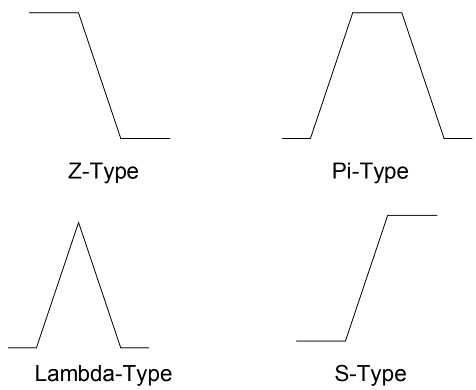
The source of fuzziness in "if-then" rules stems from the use of linguistic variables (Zadeh, 1971). Concept understanding degree, for example, may be viewed as a numerical value ranging over the interval [0, 100%], and a linguistic variable that can take on values like "high," "not very high," and so on. Each of these linguistic values may be interpreted as a label of a fuzzy subset of the universe of discourse $X = [0, 100\%]$, whose base variable, x, is the generic numerical value concept understanding degree.

Each linguistic value is defined by a membership function, which helps to take the crisp input values and transform them into degrees of membership (Ngai & Wat, 2003). A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value, or degree of membership, between 0 and 1. The function itself can be an arbitrary curve whose shape can be defined as a function that suits the particular problem from the point of view of simplicity, convenience, speed and efficiency (Kalogirou, 2003). In practical application, four standardized MFs are constantly used: Z-type, Λ-type (lambda), Π-type (pi), and S-type, as shown in *Figure 1*.

Fuzzy rules serve to describe the quantitative relationship between variables in linguistic values. These IF-THEN rule statements are used to formulate the conditional statements that comprise fuzzy logic (Kalogirou, 2003). In the following, we shall present the fuzzy approach for identifying online learning performance in detail.

- Definition of the Linguistic Variables

Figure 1. Four standardized membership functions



Related linguistic variables and the membership functions to measure the status of learners shall be defined in this section, including *individual's relative learning achievement*, *concentration*, and *patience*. As the system will eventually provide a five-scale remedial learning suggestion, these linguistic variables are designed to have five linguistic values, as shown in *Table 2*.

The linguistic values of the output linguistic variable $RLAsc(S_i,C_j)$, for example, are between *Grade 1* to *Grade 5*, where *Grade 1* represents the lowest achievement degree and *Grade 5* represents the highest achievement degree.

Moreover, in order to know whether the learner was concentrating on the online learning materials, as well as to forbid them from daydreaming, gossiping, browsing irrelevant Web pages, or even playing games, we designed a concentration windows (CWs) mechanism. Learners were asked to make responses to these pop-up windows (click to close) during the learning progress (Hwang, 1998). The system kept track of the time when CWs popped open (*CW_jumpingTime*) and were closed (*CW_closeTime*), as well as whether the CW was valid (*CW_valid*). Whether a CW is valid is defined as:

CW_valid= true if (CW_closeTime - CW_jumpingTime) ≤ CW_autoCloseTime,

where the setting of the parameter *CW_autoCloseTime* is considered to be one of the functionalities that the role teacher can use. For example, suppose the auto-close time of CWs (*CW_autoCloseTime*) is set to 8 seconds, the CWs will close themselves automatically after the eighth second if the learner did not respond to it. In contrast, the system will

Table 2. Linguistic variables and values used in the study

Linguistic Variables	Definitions	Linguistic Values
Input		
LAsc(Si,Cj)	Learner S_i's individual learning achievement toward a certain concept C_j.	*Low*, *Medium*, *High*
$ALAc(C_j)$	The learning group's average learning achievement toward a certain concept C_j.	*Low*, *Medium*, *High*
$concentration(S_i)$	Learner S_i's response rating toward the concentration windows during the learning progress.	*Grade 1~5*
$pageBT(S_i)$	Learner S_i's average browsing time to the learning materials.	*Short*, *Moderate*, *Long*
Output		
$RLAsc(S_i,C_j)$	The S_i's relative learning achievement toward a certain concept C_j compared with the learning group.	*Grade 1~5*
$Patience(S_i)$	Learner S_i's patience rating performed during the learning progress.	*Low*, *Medium*, *High*

also record valid responses when the learner clicks the close button on the window within the time span.

Hence, we are able to know a learner's concentration degree *concentration*(S_i) through the following mathematic formula:

$$concentration(S_i) = \frac{\sum_{i=1}^{nCW} cw_i}{nCW},$$

where cw_i is the *i*-th concentration window ($cw_i = 1$ if $cw_i \in$; $cw_i = 0$, otherwise), *nCW* is the total number of concentration windows that popped up during the learner's learning progress, and represents the set of concentration windows to which the learners responded validly.

In spite of *concentration*, *patience* was also adopted to measure the learner's ability to continuously engage in the learning progress, which could be calculated by comparing the learner's individual and learning group's average browsing time on learning materials. We have

$$pageBT(S_i) = \frac{\text{Total time the learner } S_i \text{ spent on browsing the materials}}{\text{Total number of learning materials that learner } S_i \text{ browsed}}$$

and

$$pageABT = \frac{\sum_{i=1}^{nStu} pageBT(S_i)}{nStu},$$

where *nStu* is the total number of learners who participated in the study.

Consequently, by mapping the rules, the grade of *patience* can be met and the appropriate learning suggestion will be provided to the learner.

- Definition of the Membership Functions

In this study, we assume that the input and output fuzzy numbers are in triangular forms and these forms approximate human thought processes. That is, three membership functions: Z-type, Lambda-type (triangular), and S-type are used. Related membership functions of input and output linguistic variables are defined as follows:

Learning Achievement: $LAsc(S_i, C_j)$ and $ALAc(C_j)$ (1)

Generally, most examinations are assessed using a cut-off point of 60 percent to judge whether a learner passed or failed. This rule of thumb is also adopted in our study. We use 60 points as the minimum criterion for determining whether a learner/learning group understands enough of the concept. Hence, the membership function of learner S_i's learning achievement degree toward the concept C_j is defined as follow:

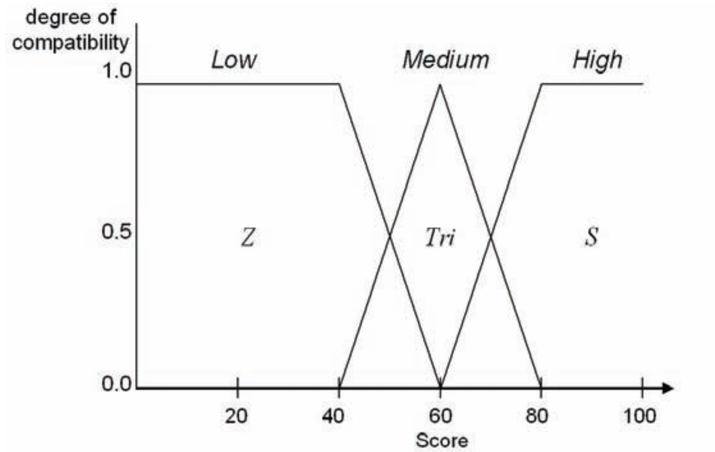
$$\begin{cases} Z(x;0.4,0.6) & \text{;Linguistic Term is } \textit{Low} \\ Tri(x;0.4,0.6,0.8) & \text{;Linguistic Term is } \textit{Medium} \\ S(x;0.6,0.8) & \text{;Linguistic Term is } \textit{High} \end{cases}$$

The graphical representation of membership functions is shown in *Figure 2*.

Online learning behavior: $RLAsc(S_i, C_j)$, $concentration(S_i)$ and $patience(S_i)$ (2)

For the learner's relative learning achievement degree, valid response ratio toward CWs (concentration) and the patience manifested during the process of material learning, we split them into five grades: *Grade 1~5* (*Grade 1* represents the worst performance; *Grade 5* represents the best performance). Based on these grades, the system renders the learner with the individualized learning suggestions. The Membership Functions are as follows:

Figure 2. Membership functions to model learning achievements



$$\begin{cases} Z(x;0,1/6,2/6) & ;\text{Linguistic Term is } Grade\ 1 \\ Tri(x;1/6,2/6,3/6) & ;\text{Linguistic Term is } Grade\ 2 \\ Tri(x;2/6,3/6,4/6) & ;\text{Linguistic Term is } Grade\ 3 \\ Tri(x;3/6,4/6,5/6) & ;\text{Linguistic Term is } Grade\ 4 \\ S(x;4/6,5/6,6/6) & ;\text{Linguistic Term is } Grade\ 5 \end{cases}$$

Page browsing time: $pageBT(S_i)$ (3)

This variable represents the average Web page browsing time of student S_i in comparison with the average time of all of the students. The range of $pageBT(S_i)$ is limited between 0~2×*pageABT*, where *pageABT* is the total average time the whole learning group spent on the learning materials. The membership functions are defined as follow:

$$\begin{cases} Z(x;pageABT/2,pageABT) & ;\text{Linguistic Term is } Short \\ Tri(x;pageABT/2,pageABT,3pageABT/2) & ;\text{Linguistic Term is } Moderate \\ S(x;pageABT,3pageABT/2) & ;\text{Linguistic Term is } Long \end{cases}$$

- Definition of the Fuzzy Rules

Fuzzy reasoning model plays an important role in our system for diagnosing learning performance. For learners, it provides indispensable assisted information. Thus, the establishment of fuzzy rules is critical to analysis and concerns the correctness of inference results. There are twenty-four rules defined in our study, as shown in the following:

$\tilde{R}_1$: IF $LAsc(S_i,C_j)$= *Low* AND $ALAc(C_j)$= *Low*
THEN $RLAsc(S_i,C_j)$= *Grade 3*

$\tilde{R}_2$: IF $LAsc(S_i,C_j)$= *Low* AND $ALAc(C_j)$= *Medium*
THEN $RLAsc(S_i,C_j)$= *Grade 2*

$\tilde{R}_3$: IF $LAsc(S_i,C_j)$= *Low* AND $ALAc(C_j)$= *High*
THEN $RLAsc(S_i,C_j)$= *Grade 1*

$\tilde{R}_4$: IF $LAsc(S_i,C_j)$= *Medium* AND $ALAc(C_j)$= *Low*
THEN $RLAsc(S_i,C_j)$= *Grade 4*

$\tilde{R}_5$: IF $LAsc(S_i,C_j)$= *Medium* AND $ALAc(C_j)$= *Medium*
THEN $RLAsc(S_i,C_j)$= *Grade 3*

$\tilde{R}_6$: IF $LAsc(S_i,C_j)$= *Medium* AND $ALAc(C_j)$= *High*
THEN $RLAsc(S_i,C_j)$= *Grade 2*

$\tilde{R}_7$: IF $LAsc(S_i,C_j)$= *High* AND $ALAc(C_j)$= *Low*
THEN $RLAsc(S_i,C_j)$= *Grade 5*

$\tilde{R}_8$: IF $LAsc(S_i,C_j)$= *High* AND $ALAc(C_j)$= *Medium*
THEN $RLAsc(S_i,C_j)$= *Grade 4*

$\tilde{R}_9$: IF $LAsc(S_i,C_j)$= *High* AND $ALAc(C_j)$= *High*
THEN $RLAsc(S_i,C_j)$= *Grade 3*

$\tilde{R}_{10}$: IF $concentration(S_i)$= *Grade 1* AND $pageBT(S_i)$= *Short*
THEN $patience(S_i)$= *Grade 1*

$\tilde{R}_{11}$: IF $concentration(S_i)$= *Grade 1* AND $pageBT(S_i)$= *Moderate*
THEN $patience(S_i)$= *Grade 2*
$\tilde{R}_{12}$: IF $concentration(S_i)$= *Grade 1* AND $pageBT(S_i)$= *Long*
THEN $patience(S_i)$= *Grade 3*
$\tilde{R}_{13}$: IF $concentration(S_i)$= *Grade 2* AND $pageBT(S_i)$= *Short*
THEN $patience(S_i)$= *Grade 1*
$\tilde{R}_{14}$: IF $concentration(S_i)$= *Grade 2* AND $pageBT(S_i)$= *Moderate*
THEN $patience(S_i)$= *Grade 2*
$\tilde{R}_{15}$: IF $concentration(S_i)$= *Grade 2* AND $pageBT(S_i)$= *Long*
THEN $patience(S_i)$= *Grade 4*
$\tilde{R}_{16}$: IF $concentration(S_i)$= *Grade 3* AND $pageBT(S_i)$= *Short*
THEN $patience(S_i)$= *Grade 1*
$\tilde{R}_{17}$: IF $concentration(S_i)$= *Grade 3* AND $pageBT(S_i)$= *Moderate*
THEN $patience(S_i)$= *Grade 3*
$\tilde{R}_{18}$: IF $concentration(S_i)$= *Grade 3* AND $pageBT(S_i)$= *Long*
THEN $patience(S_i)$= *Grade 4*
$\tilde{R}_{19}$: IF $concentration(S_i)$= *Grade 4* AND $pageBT(S_i)$= *Short*
THEN $patience(S_i)$= *Grade 2*
$\tilde{R}_{20}$: IF $concentration(S_i)$= *Grade 4* AND $pageBT(S_i)$= *Moderate*
THEN $patience(S_i)$= *Grade 3*
$\tilde{R}_{21}$: IF $concentration(S_i)$= *Grade 4* AND $pageBT(S_i)$= *Long*
THEN $patience(S_i)$= *Grade 5*
$\tilde{R}_{22}$: IF $concentration(S_i)$= *Grade 5* AND $pageBT(S_i)$= *Short*
THEN $patience(S_i)$= *Grade 2*
$\tilde{R}_{23}$: IF $concentration(S_i)$= *Grade 5* AND $pageBT(S_i)$= *Moderate*
THEN $patience(S_i)$= *Grade 3*
$\tilde{R}_{24}$: IF $concentration(S_i)$= *Grade 5* AND $pageBT(S_i)$= *Long*
THEN $patience(S_i)$= *Grade 5*

For example, $_2$ is concerned and mainly expresses that the learner's individual concept achievement degree is low and the learning group is medium. Consequently, we would consider the relative concept achievement degree of this learner to be *Grade 2*, and provide the equivalent learning suggestion to him. Moreover, from $_{10}$ to $_{24}$, there are fifteen fuzzy rules defined for enumerating distinct patience grades based on linguistic variables $concentration(S_i)$ and $pageBT(S_i)$.

Implementation of a Fuzzy Expert System for English Tense Diagnosis

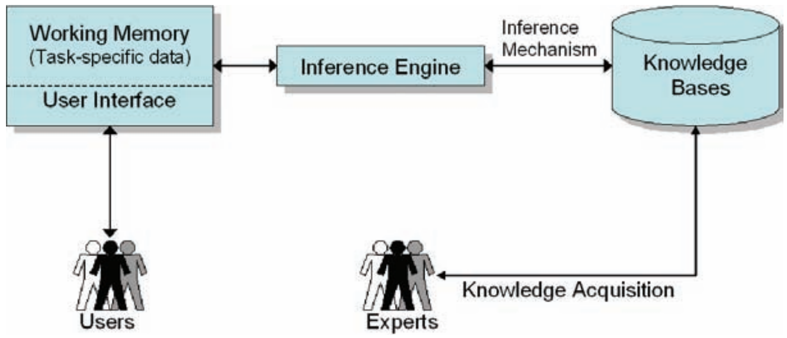
ET-DES (English Tense Diagnosis Expert System), a Web-based diagnosis expert system focusing on the verb tenses of English, was built to evaluate EFL students' learning performance and to render personalized learning suggestions. An expert system is a computer program in which the knowledge of an expert on a specific subject can be incorporated in order to solve problems or give advice (Jackson, 1990). It usually consists of a knowledge base (KB), an inference mechanism, an explanation component, and a user interface (Nebendahi, 1987). *Figure 3* shows the basic architecture of a fuzzy expert system. Individual components are illustrated as follows.

Expert system shell packages give users the opportunity to develop an expert system-based decision aid that is geared toward their specific needs while assisting users who do not possess technical expertise in computers. In our study, we adopt DRAMA to serve the core of fuzzy reasoning. DRAMA is an expert system shell developed by CoreTec Corp.

System Architecture and Functionality

ET-DES accommodates three roles: learners, teachers, and system administrator. The users

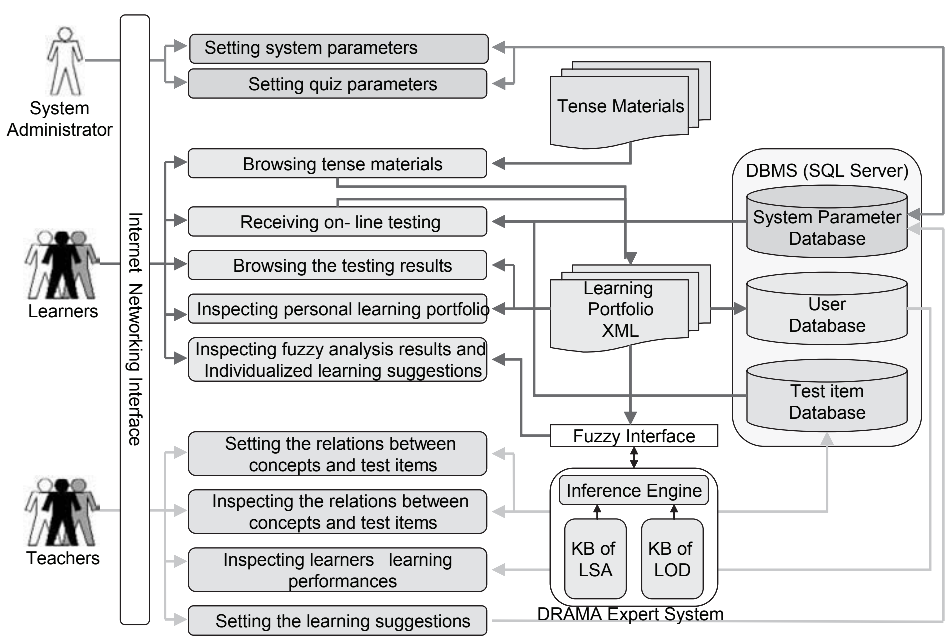
Figure 3. Architecture of an expert system



of different roles logs into the system via the same user interface. ET-DES will identify the user privilege and guide the user to different main pages based on their IDs. *Figure 4* depicts the architecture of ET-DES, where KB of LSA represents Knowledge Base of Learning Statue Assessment, while KB of LOD stands for Knowledge Base of Learning Obstacle Diagnosis.

From the perspective of technique, ET-DES is developed on a 3-tier architecture: in the client-tier, the users access the system through Internet browsers (e.g., Microsoft Internet Explorer); in middle-tier, Tomcat 4.0.4 is used as the Web server, in coordination with J2SDK1.4., and JSP (Java Server Pages) is used to write programs of various functions, such as parameter transmissions among Web pages, data computations, database accessing, learning portfolio recording, and DRAMA expert system invocating. On the user-tier, the client language JavaScript is employed to check user's input, preventing any possible error from happening. Moreover, SQL Server 2000 is

Figure 4. Architecture of ET-DES



employed to maintain the databases, including the item bank, user's individual information, the relationships between concepts and test items, and so on.

User Interface Design

A registered learner logging into the system is first shown a system operation instruction describing the characteristics of the system and its functions (see *Figure 5*). The following sub-sections demonstrate the functions of the interfaces for learners in accordance with the operational sequences.

Browsing Tense Materials

As shown in *Figure 6*, the screen is divided into two: concept material selection buttons are on the left; the content of the materials is shown on the right. By clicking on these buttons, learners can select any specific tense material to browse.

To detect if the learner paid attention to the subject materials, the system pops up some con-

Figure 5. Learner interface for system operation instruction

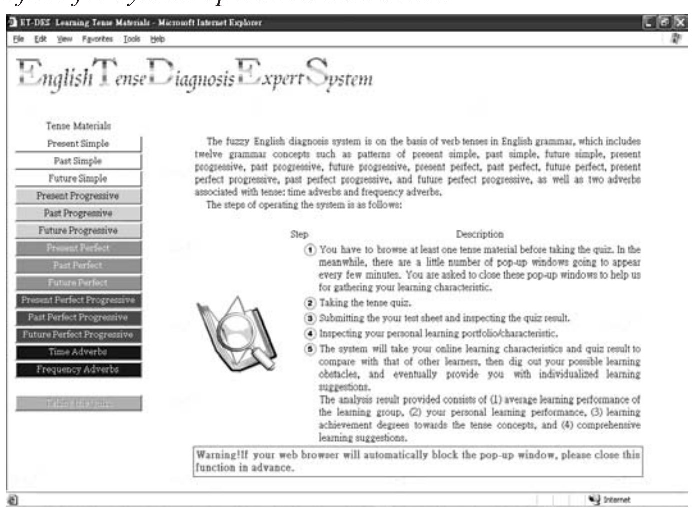


Figure 6. Learner interface for learning the tense materials

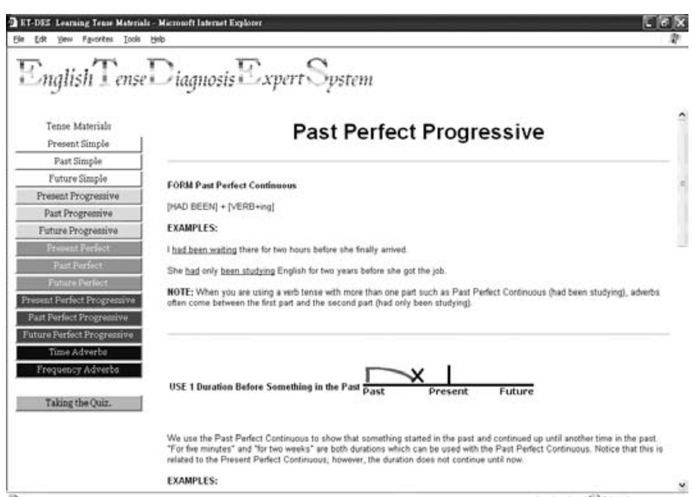


Figure 7. Concentration window

centration window (as shown in *Figure 7*) and asks the learner for a response. If the learner does not respond to the concentration window within the predefined period of time, the windows will automatically close.

Receiving Online Testing

This part of the system provides learners the opportunity of self-evaluation. The test is designed in the form of multiple-choice questions with four answer choices and all concepts included in the test alternatives are limited to the tenses of English grammar. *Figure 8* shows the user interface for conducting a test.

Browsing the Testing Results

Via the user interface depicted in *Figure 9*, learners can browse the list of relevant concepts, the correct answer, and his/her own answer for each test item. Moreover, there are two "supplements" given to the learner, providing the learner the opportunity of improving his/her learning performance. One is the magnifying glass icon, which can display, the original question accompanied with the four possible answers, another is the question mark icon, which provides detailed explanation to every test item.

Browsing Personal Learning Portfolio

Figure 10 shows the user interface for presenting a learner's learning portfolio. The presented information includes the Web pages that have been visited, the time the leaner entered and exited those Web pages, the concepts learned, and so forth.

Figure 8. Learner interface for taking the tense testing

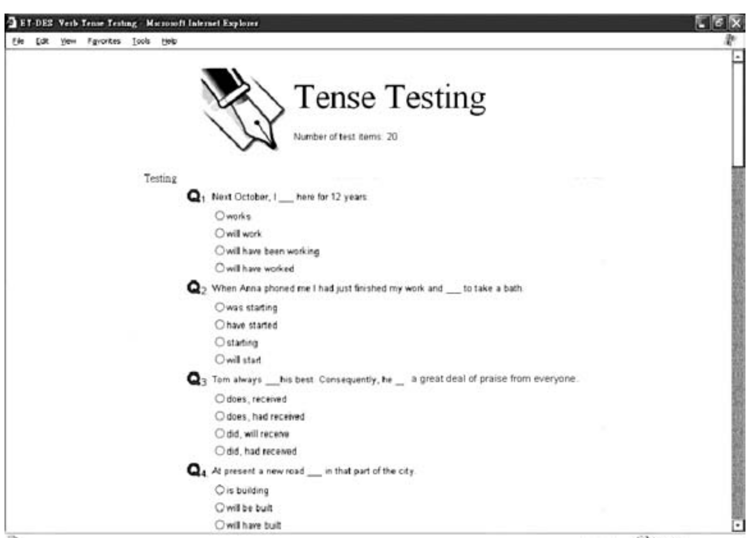


Figure 9. Learner interface for inspecting the testing result

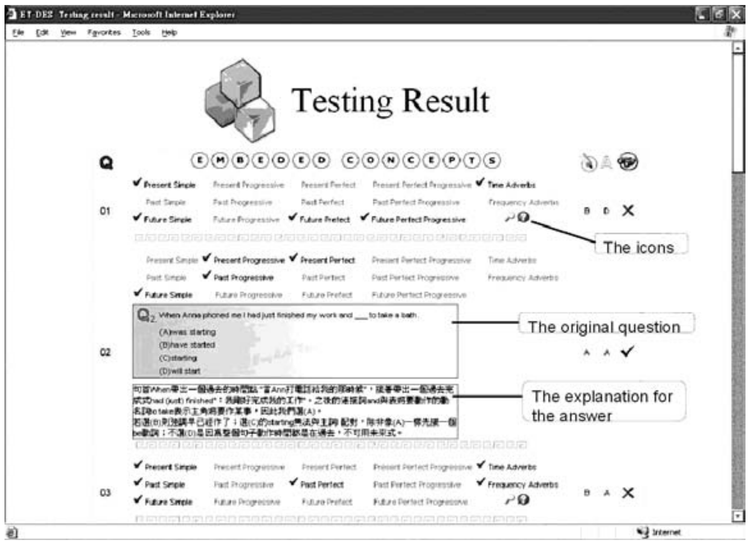
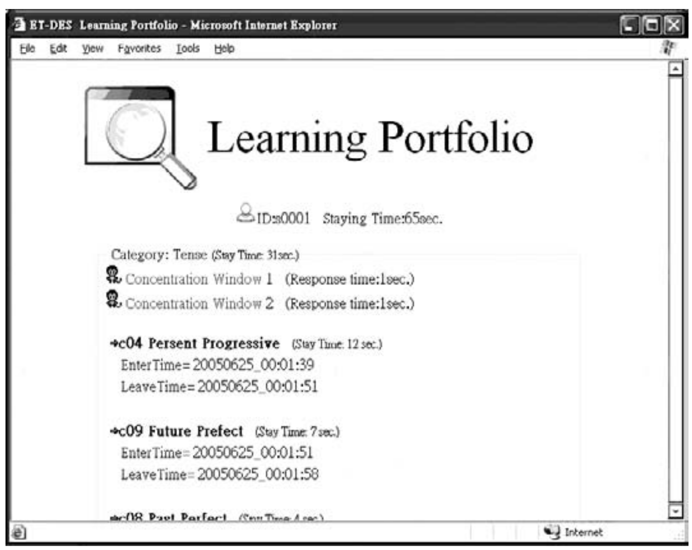


Figure 10. Learning portfolio of individual student



Browsing Analysis Results and Individualized Learning Suggestions

After comparing a learner's individual learning performance with that of the learning group by invoking the DRAMA expert system, ET-DES presents the diagnosis results, which are displayed in a horizontal bar chart, together with the percentage value (see *Figures 11-15*).

The information contained in the learning diagnosis results are depicted as follows:

- **The average learning achievements of all participants:** such as average score, browsing time, concentration window response time, concept understanding degree, and so forth, are shown in *Figure 11.*

Figure 11. Average learning performance of the group

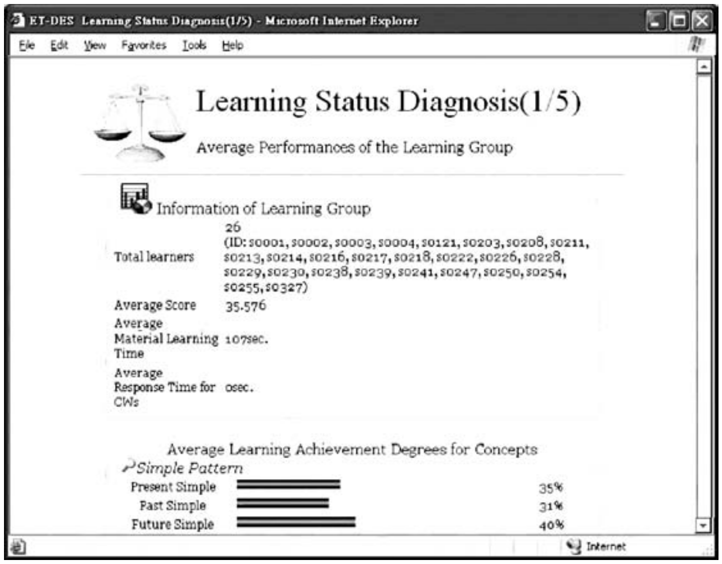
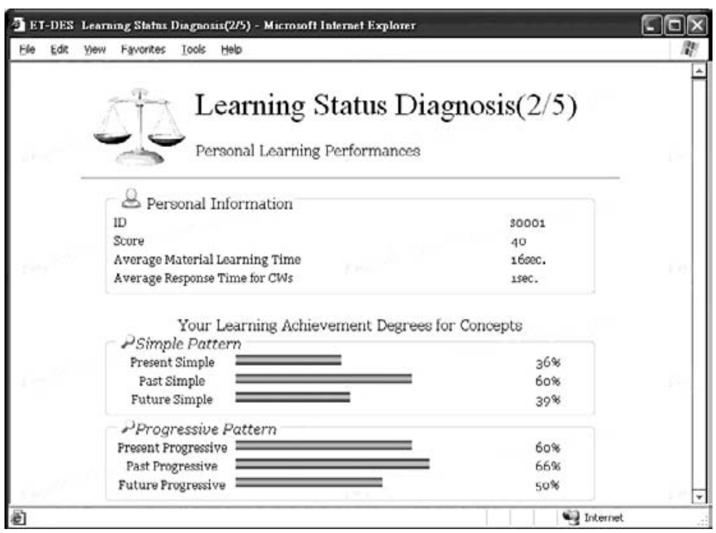


Figure 12. Personal learning records



- **The online behaviors of learners:** such as a student's score for the testing, total staying time, response time, learning achievement of each tense concept, and so on, all are provided on the Web page as shown in *Figure 12*.
- **The summarized information on learning achievements:** (as shown in *Figure 13*) is used to compare and highlight the learning achievement of the individual and the group for every concept to be learned.
- **Personal information on learning achievements:** (as shown in *Figure 14*) reveals the learning levels of fourteen English tense concepts and the corresponding learning suggestions.
- **Evaluation of the learner's online behavior:** includes patience and the comprehensive learning suggestions (as shown in *Figure 15*). The summarized learning suggestion consists of two parts: first, it provides a clear

Figure 13. Comparison of the student's individual and the learning group's learning achievement

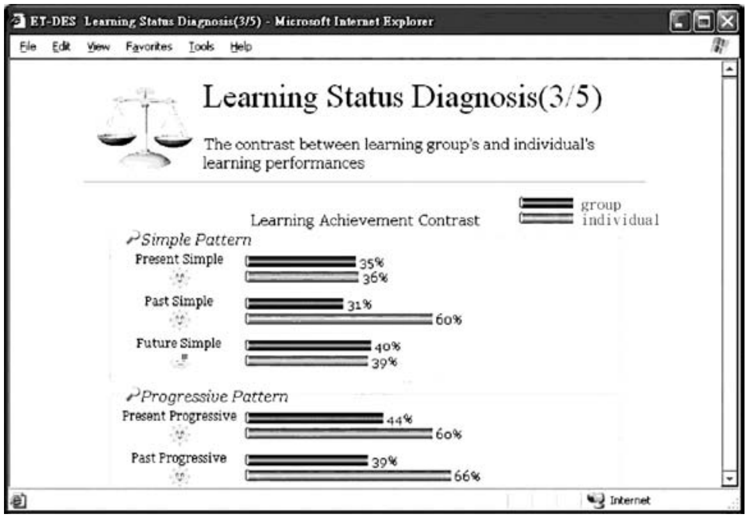
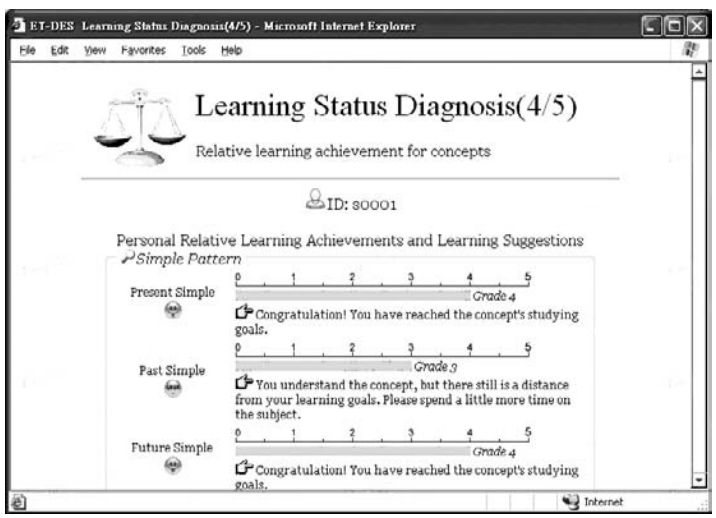


Figure 14. The student's learning achievement degrees and the corresponding learning suggestions



learning guidance for the learner (a list of the concepts the learner needs to improve and a brief conclusion of the learner's understanding degree), informing the learner of his/her strengths and deficiencies; second, it draws an integrated comment of the learner's level of concentration and patience. These suggestions are followed by concrete suggestions for advancement.

Experiment and Analysis

To evaluate the performance of ET-DES, an experiment was conducted at National Chi Nan University in March 2005. Two hundred and fifty-seven undergraduate students participated in the experiment. Initially, the system developer gave the participants a brief orientation about the purpose of the experiment and the operations of

Figure 15. Learning suggestions based on the student's individual learning perfor-

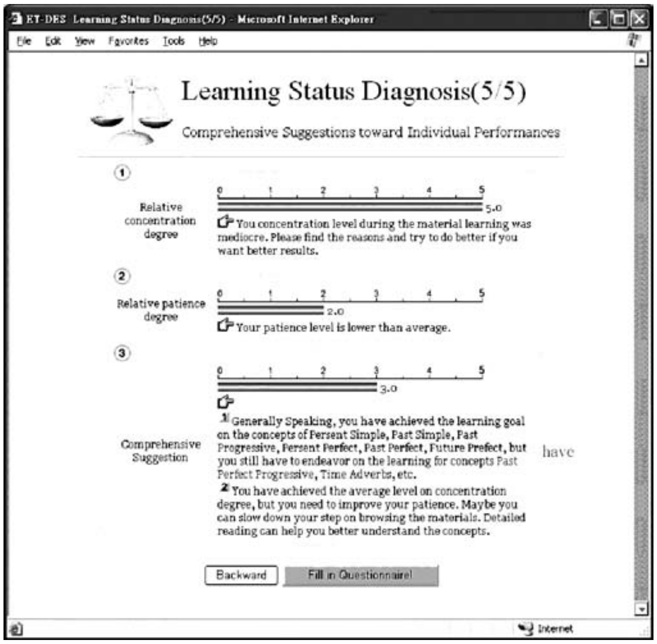


Table 3. Statistics of questions of four facets

Issues	Options					Mean	S.D.	Satisfaction (4+5)
	1	2	3	4	5			
Facet 1 - SYSTEM								
1. System Function Grading (1=VP, 2=P, 3=N, 4=G, 5=VG) [a]	5 (2.2%)	4 (1.8%)	69 (30.9%)	124 (55.6%)	21* (9.4%**)	3.6816	.7605	145(65%)
2. System Interface Grading (1=VP, 2=P, 3=N, 4=G, 5=VG) [a]	4 (1.8%)	8 (3.6%)	49 (22%)	130 (58.3%)	32 (14.4%)	3.7982	.794	162(72.7%)
3. System Operation Difficulty Grading (1=VD, 2=D, 3=N, 4=E, 5=VE) [b]	6 (2.7%)	5 (2.2%)	39 (17.5%)	132 (59.2%)	41 (18.4%)	3.8834	.8246	173(77.6%)
4. System Operation Flow Smoothness Grading (1=VP, 2=P, 3=N, 4=G, 5=VG) [a]	14 (6.3%)	34 (15.3%)	41 (18.4%)	105 (47.1%)	29 (13%)	3.4529	1.0931	134(60.1%)
Facet 2 – MATERIAL								
1. Material is easy to understand? (1=SD, 2=D, 3=N, 4=A, 5=SA) [c]	5 (2.2%)	40 (18%)	75 (33.6%)	86 (38.6%)	17 (7.6%)	3.3139	.931	103(46.2%)
2. Material typesetting is good? (1=SD, 2=D, 3=N, 4=A, 5=SA) [c]	3 (1.4%)	8 (3.6%)	80 (35.9%)	111 (49.8%)	21 (9.42%)	3.6233	.7617	132(59.22%)
Facet 3 - QUIZ								
1. Test items of the testing are easy? (1:SD, 2:D, 3:N, 4:A, 5:SA) [c]	26 (11.7%)	86 (38.6%)	77 (34.5%)	24 (10.8%)	10 (4.5%)	2.5785	.9827	34(15.3%)
2. The test items can gauge your understanding degree for tenses? (1:SD, 2:D, 3:N, 4:A, 5:SA) [c]	6 (2.7%)	18 (8.1%)	58 (26%)	121 (54.3%)	20 (9%)	3.5874	.8648	141(63.3%)
Facet 4 – DIAGNOSIS RESULT								
1. Learning Achievement of Concepts (1:SD, 2:D, 3:N, 4:A, 5:SA) [c]	4 (1.8%)	13 (5.8%)	57 (25.6%)	122 (54.7%)	27 (12.1%)	3.6951	.8255	149(66.8%)

continued on following page

Table 3. continued

2. Concentration Degree (1:SD, 2:D, 3:N, 4:A, 5:SA)[c]	8 (3.6%)	27 (12.1%)	65 (29.2%)	78 (35%)	45 (20.2%)	3.5605	1.0547	123(55.2%)
3. Patience Degree (1:SD, 2:D, 3:N, 4:A, 5:SA)[c]	6 (2.7%)	21 (9.4%)	66 (29.6%)	95 (42.6%)	35 (15.7%)	3.5919	.9536	130(58.3%)
4. Comprehensive Learning Suggestions (1:SD, 2:D, 3:N, 4:A, 5:SA)[c]	4 (1.8%)	4 (1.8%)	41 (18.4%)	135 (60.5%)	39 (17.5%)	3.9013	.7647	174(78%)

Frequency (Percentage**)*

[a]*VP:Very Poor, P:Poor, N:Neutral, G:Good, VG:Very Good*

[b]*VD:Very Difficult, D:Difficult, N:Neutral, E:Easy, VE:Very Easy*

[c]*SD:Strongly Disagree, D:Disagree, N:Neutral, A:Agree, SA:Strongly Agree*

the system. The participants were asked to fill in a questionnaire after using the system. This questionnaire was composed of four facets: the system, the learning material, the test items of the quiz, and the diagnosis result. The choice of each question is based on a scale of 1 to 5. *Table 3* shows the statistical results.

Table 4 shows that the participants have a positive attitude toward the facet of SYSTEM (Mean = 3.704), indicating that the functionality, interface, difficulty of operation, and operation flow smoothness have been well accepted by the participants (S.D.=0.1867).

When considering the facet of MATERIAL (Mean = 3.4662), based on the statistical results of "*Material is easy to understand*" (Mean = 3.3139) as well as "*Material typesetting is good*" (Mean = 3.6233), we conclude that there is room to improve the quality and content of learning materials in our system.

For the question "*The test items can gauge your understanding degree for tenses?,*" the mean value is 3.5874, reflecting a positive agreement. That is, the students tend to believe that the system is helpful in improving their learning performance.

For the facet of DIAGNOSIS RESULT, approximately seventy percent of the students agree or strongly agree that the provided diagnostic information (grades and corresponding learning suggestions) of "Learning Achievement of Concepts" is helpful for their learning, as shown in *Figure 16*.

Additionally, other provided information about the diagnosis results such as concentration, patience, and comprehensive learning suggestions are also well accepted by the participants with a high rate of acceptance, as shown in *Figure 17.*

Consequently, the question "*If possible, are you willing to take other relevant system assis-*

Table 4. Statistics of each facet

Facets	Options									
	1	2	3	4	5	Mean	S.D.	Min	Max	Satisfaction(4+5)
SYSTEM	29 (3.3%)	51 (5.7%)	198 (22.2%)	491 (55%)	123* (13.8%**)	3.704	0.1867	0.7605	1.0931	614 (68.83%)
MATERIALS	8 (1.8%)	48 (10.8%)	155 (34.8%)	197 (44.2%)	38 (8.5%)	3.4662	0.2198	0.7617	0.931	235 (52.69%)
QUIZ	32 (7.2%)	104 (23.3%)	135 (30.3%)	145 (32.5%)	30 (6.7%)	3.083	0.7134	0.8648	0.9827	175 (39.24%)
DIAGNOSIS RESULT	22 (2.5%)	65 (7.3%)	229 (25.7%)	430 (48.2%)	146 (16.4%)	3.6872	0.1539	0.7647	1.0547	576 (64.57%)

tances in the future?" has a high mean of 3.6061 and a standard deviation of 0.7344; therefore, we conclude the system has been well approved by the experiment participants.

Conclusion and Future Works

In this article, we designed and implemented a Web-based English Tense Diagnosis Expert System named ET-DES, which is capable of finding out the tense-related concepts that the learners failed to learn and rendering personalized learning suggestions by invoking a fuzzy approach. To sum up, with the assistance of the system we proposed, EFL students have better opportunities to enhance their learning efficiency of English tenses by aiming at those concepts that were diagnosed to be deficient. Currently, we are planning to conduct a long-term experiment on college English courses by applying ET-DES. The learning portfolios of the students will be analyzed at the end of each semester to find out the efficacy of our novel approach; moreover, the performance of the system can also be improved based on the experimental results and the suggestions from the learners.

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Chapter XXIII
Inhabited Virtual Learning Worlds and Impacts on Learning Behaviors in Young School Learners

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ABSTRACT

The paper outlines a new paradigm and its underlying rationales for implementing networked learning environments that is emerging from new technologies such as multi-user platform, virtual worlds, virtual learning community, and intelligent agents. The proposed paradigm of the networked learning environments is described as inhabited virtual learning worlds (IVLW), which is a shared learning space in 3-D format and populated with avatars that are the representations of learners who are geographically dispersed around the world. The virtual learning worlds are also composed of objects such as intelligent agents and learning materials. A pilot system is created based on the discussed rationales of inhabited virtual learning worlds. A preliminary empirical study focusing on the selected learning behaviors in young learners also has been conducted with the pilot system. The results of the empirical study and suggestions for enhancing the pilot system are discussed in the closing section of the article.

INTRODUCTION

There is much discussion pertaining to the potential of information technology to transform strategies of learning and create a learning society that values the principles of knowledge economy. However, the potential has yet to be realized due to a lack of sound networked learning paradigm and rich digital content. Furthermore, after decades of endeavors by the researchers and practitioners in the field, the search for a profound pedagogy for the application of Internet in education continues (Concord Consortium, 2002). It is obvious that there remains a great deal to be learned about networked learning or virtual learning, especially in the issues of designing networked learning environments and digital learning content.

After much hype for several years in the field of education, especially at K-12 levels, networked learning has come to redefine itself for reality. To date, there exists no clear evidence that Internet or information and communication technology has brought significant "added values" to conventional education or learning approaches (Lin, 2001a). It seems that a sufficient and sound networked learning environment has not revealed yet.

In addition to a lack of qualified digital content, the existing networked learning environments or Web-based learning platforms function more as an information warehouse than as a learning space. Above all, most Web-based networked learning environments currently available are in a teacher-centered or information delivery paradigm. This paradigm of networked learning usually discourages learning engagement and creates strong student isolation. This type of learning is passive and unable to engage student in active learning. Online students may find it difficult to follow the learning tasks and to monitor their progress (Lin, 2001b). Learning community and learning supports that are needed for motivating learning in online learning are completely missing in the teacher-centered or information delivery model. Hence, learner engagement of learners is absent. A new paradigm in designing networked learning environments that is different from the existing Web-based teacher-centered or information delivery paradigm is needed. Based on the current study in the field and advent of new information technologies (Concord Consortium, 2002), one solution is the incorporation of inhabited virtual learning worlds with the support of intelligent agents.

The fundamental rationale for inhabited virtual learning worlds (IVLW) is creating a shared and immersive learning space that is in 3-D format and populated with avatars where they can pursue collaborative learning activities and form a vibrant learning community (Vlearn3D, 2002). Avatars, the representations of learners in the space, can talk, walk, move, gesture, point within the IVLW and interact to each other or with objects in the IVLW, which contributes to intense social and intellectual interactions. Furthermore, IVLW can be seamlessly integrated with existing Web pages and teleported to other learning resources. The features thus extend the accessibility of information to avatars in the IVLW (Lin, 2002).

According to Gilbert's definition, an intelligent agent is "software that assists people and acts on their behalf" and it could make "computer systems easier to use by allowing people to delegate work back to the computer" (Gilbert, 1997). Research on intelligent agents has mushroomed in the past few years. There are two conflated areas of the research on intelligent agents currently (Isbister, 2005). One focuses on the use of artificial intelligence (AI) techniques to create software that performs information filtering and other autonomous tasks such as computing or searching for learners. Intelligent agents of this sort, referred as autonomous agents, may or may not display any explicitly anthropomorphic features. The other focuses on the agents acting as an interface metaphor that assists the learner in interacting with the system or environments. The latter, also known as interface agents, may or may not incorporate new AI techniques. The essential function of interface agents is to act as effective bridges between a learner's goals and expectations and the system's capabilities. The agent metaphor is used to make the interface more intuitive and to encourage interactions that might be difficult to evoke with a traditional graphic user interface (GUI). Usually, an agent of this sort has its own unique anthropomorphic character and figure.

Creating learning community and providing learning supports are the two most essential pedagogical issues for the success of a networked learning environment (Lin, 2001b). In light of resolving these two issues, the combination of inhabited virtual learning worlds and intelligent agents constitutes some of the most appealing solutions.

The Significance of Inhabited Virtual Learning Worlds

Based on the results of networked learning studies (Lin, 2002; Concord Consortium, 2002), the current practice of Web-based learning pedagogy that focuses on publishing learning materials on the Internet could be replaced and transformed by the application of virtual reality technology. To achieve a success in networked learning, it is important to create virtual learning worlds that combine the strengths of 3-D spatial learning, immersion, high learner telepresence, immediate visual feedback, and interactivity.

As postulated by Damer, Gold, Marcelo, & Revi (1999), inhabited virtual worlds have distinguished themselves from a 3-D graphical space by infusing simulation of living systems and therefore can play an important role in community building in cyberspace. The persuading features of a virtual learning world are that it could transform the networked learning environments into to a 3-D shared learning space and the learners in the shared space could be represented with avatars. An inhabited virtual learning world also provides the common playground for human creativity for all the intelligent agents that are associated with learning. Ultimately, the significance of 3-D shared learning space is that it could help to promote interpersonal interaction among learners via spatial dimensions with the sense of immersion and build up learning community with its analogy to the social bond that would engage learners in learning activities. In essence, the virtual learning worlds could provide a shared learning space for inhabiting avatars that are analog to the physical social circumstances (Costigan, 1997; Concord Consortium, 2002).

The Significance of Avatars

Avatar is the representation of learners in the virtual learning worlds with characters or icons. Avatar embodies a type of intelligent agent and inhabits the virtual learning worlds representing individual learners. In other words, avatar is the resident of IVLW and is part of the virtual learning worlds.

Many researchers have asserted that people learn best through the medium of human relationships (Concord Consortium, 2002). This is the reason that current Web courses in the field emphasize the implementation of features such as student-to-student interaction or teacher feedback. The claim suggests the importance of learning community building in networked learning environments. However, some researchers assert that the richest communication occurs when people are physically face-to-face, which the most sophisticated technology for connecting people with audio and video cannot surpass (Costigan, 1997). Nonetheless, recent research has also found that the use of avatars in immersive 3-D worlds could provide a higher sense of telepresence than other conferencing systems (Chou, 1999). The question then is: which communication scheme is the best choice for learning community building?

Walther (1996) classified three types of computer-mediated communication (CMC): impersonal, interpersonal, and hyperpersonal interaction. Different types of interaction are appropriate for various purposes. Impersonal interaction can be fostered in anonymous commenting, brainstorming, and for equal participation without knowing the individual's status. Interpersonal interaction contributes to a community of practice and establishes a more healthy relationship among the online learners. Hyperpersonal interaction could increase learner satisfaction and enrich learning experience. According to Walther (1993), computer-mediated communication (CMC) is no less impersonal than face-to-face communication. Different types of CMC systems could contribute to or constraint learner interaction. Therefore, CMC systems should be selected for the purposes that each system could provide the best capacity.

Online interpersonal communication for community building can be facilitated by CMC systems that include text-chat, audio conferencing, video conferencing and avatars in IVLW. Interpersonal communication relies heavily on both verbal and non-verbal cues. A quick comparison on the verbal and non-verbal capacities between different communication schemes could provide a good overview on how avatars can provide added values to community building and interpersonal communication.

In face-to-face communication, the communicators have relative positions, the abilities to point and gesture, and to use facial expression to convey meaning within a limited distance. In text-based chat, although the instant feedback allows quick interaction, the lack of visual and audio cues leaves many aspects of communication unfulfilled. In the audio conferencing mode, communicators are connected through audio without visual cues or shared space. In the video teleconferencing mode, the ability to use facial expression is still available, although there is no shared space, nor can one gesture in that shared space. In avatars-mediated interaction, although the ability to use facial expression is no longer available under the circumstances of current information technology, there remains a shared space and the ability to use gestures.

The comparison of the five communication channels suggests that without physical limitations such as size, distance, and time, the potential of avatars to convey messages beyond human capacity is very positive.

Furthermore, since the abilities to share a space and to gesture with relation to that space are important in communication, the amount and quality of information conveyed using an avatar should be similar to or greater than that of the face-to-face interaction (see Table 1). Hence, for the purposes of education or learning, the ability to share space and to have a presence whether real or virtual are more beneficial than the ability to see facial expressions in communication (Costigan, 1997). This indicates the value of avatars communication scheme in learning and education.

In addition, as the comparison in *Table 1* has highlighted that the use of avatars for interaction could be equal to or provide more advantages than face-to-face communication for the following reasons. First, avatars allow participants to interact with one another directly in a virtual environment, as much as face-to-face interaction does. Second, avatars provide learners with the ability to communicate nonverbally through position and gesture, which, again, makes it similar to face-to-face interaction. In video conferencing, interaction is possible only through the two dimensional screen, and nonverbal cues can only be observed from the image on the screen. Indeed, the space of interaction is not shared among participants of communication in video conferencing. Third, the sharing of space and immersion of learners are more important in education or learning processes than the ability to see and interpret facial expression.

In essence, avatars provide strong personal identity and telepresence to learners in networked

Table 1. The comparison of communication schemes

	Verbal interaction	Facial Expression	Shared Space	Gestures in the Shared Space	Physical Freedom
Face-to-Face	✓	✓	✓	✓	✓
Text-chat	×	×	×	×	×
Audio-conferencing	✓	×	×	×	×
Video Conferencing	✓	✓	×	×	✓
Avatars in IVLW	✓	?	✓	✓	✓

Legends ✓*: full support* **?***: limited support* ×*: unavailable*

learning environments. It is a necessary tool for learners to perceive their learning circumstances and help them gain the sense of belonging and ownership of the networked learning environments. Avatars allow learners to take residency in the learning environments with full immersion and strong engagement, which are the necessary ingredients for building a vibrant learning community.

The Significance of Intelligent Agents

In recent years, the research and application of intelligent agents have advanced by leaps and bounds. Intelligent agents, in addition to avatars, are proposed to provide imperative learning supports in customized and individualized manners for learners in IVLW. In essence, intelligent agents could provide all kinds of learning support and make adaptive learning possible in the networked learning environments. In other words, the roles of intelligent agents are to monitor learners' learning behaviors, to record learning processes, to understand learners' progress, and to assist learners in an adaptive fashion at any time. Thus, intelligent agents could increase the learning activities in the networked learning environments dramatically (Lin, 2001b).

In order to achieve the above-mentioned goals, we propose that an ideal networked learning environment should include these five intelligent agents: (1) learning companion, (2) moderator, (3) genie, (4) digital librarian and (5) evaluator (Lin, 2002).

Learning Companion

As the name implies, learning companion is an assistant or friend for every individual learner who would accompany the learner along the learning paths all the time. The roles of a learning companion in IVLW are to learn together with learners, provide support to them, interact with them and reduce their learning difficulties in a scaffolding manner. The learning companion would also suggest learning styles suitable for each individual learner respectively. For instance, Best Cyber Academy implements a learning companion—WuKong—and several studies already demonstrated that, with WuKong's assistance, the motivation and learning performance of learners in Best Cyber Academy were improved dramatically (Lin, 2001b).

Moderator

Collaborative learning activities and interpersonal communication are crucial tenets in constructivist learning and essential to networked learning. Some scholars have contended that providing moderating strategies is a key to the success of collaborative learning projects or activities (Roussos, Johnson, Moher, Leigh, Vasilakis, & Barnes, 1999). In practice, a moderator could direct the collaborative learning activities by tracking learning procedure and monitoring learning process. An experienced and intelligent moderator would guide learners to interact with other effectively and increase the quality of team works.

In a virtual learning space such as IVLW, the role of a moderator is essential in engaging learners in collaborative learning activities effectively. Even though deploying well-trained human moderators in IVLW is possible, the price could be high. It would be unrealistic or implausible to adopt the human moderator when the learning space is populated with crowded learners. Therefore, one best way to install moderators in IVLW is to utilize intelligent agents.

Genie

A genie acts as the mentor to learners in networked learning environments. A genie can examine and search the learner profile, understand the learning situation and difficulties, answer learner's inquiries, and provide learners with appropriate assistance. Genie is the opposite of learning companion in terms of tenderness and strategy of learning support toward learners.

Digital Librarian

Inquiry-based and project-based learning strategies are common for designing networked learning content or activities. Searching for resources in networked learning environments is one of the essential learning activities. However, searching tools such as search engines are not the best solutions for kids and the general public, nor are they suitable for learning purposes. A digital librarian is proposed to assist young learners and civilians alike for searching learner resources, filtering, and organizing information to suit individual needs and to automatically handle information overflow in the virtual learning space. Through the help from the digital librarian, learners can receive the information they really need in a just in time fashion and allow them to focus on learning tasks.

Evaluator

In networked learning environments, dynamic learning assessment is required from time to time for adjusting the learning paths or providing adaptive learning supports. An evaluator is proposed to conduct assessment on artifacts and learning performance to individual learners or groups. The evaluator can also provide input on assessment results to learner profiles. After evaluation, the evaluator could also provide immediate feedback or live online guidance to other intelligent agents such as moderator or genie.

Among these five intelligent agents, learning companion and genie are interface agents who are responsible for interacting with avatars directly. The other three agents (i.e., moderator, digital librarian, and evaluator) are autonomous agents who will process the information in the background of networked learning environments and support interface agents.

Implementation Issues

After analyzing the pedagogical values of IVLW, avatars, and intelligent agents for enriching the networked learning environments, the issues of implementation are the focus of this section. There are several essential features that are worthy of consideration when implementing the inhabited virtual learning worlds with intelligent agents.

Learner Profile

A learner profile is similar to a student model in expert systems, which represents each individual learner's learning behaviors and status dynamically. It is the essential ingredient for embedding intelligent and adaptive features into the networked learning environments. A learner profile is the heart of the brand new pedagogical approach of virtual learning.

Logging Mechanism

The logging mechanism in IVLW is essential and is designed to keep track of all the learning activities that happen on it. The data collected by the logging mechanism stored in log files is the primary resource for constructing learner profile and providing intelligence to the intelligent agents.

Spatial Dimension

A learner profile usually is composed of data of a specific learner's personal information and learning status and behavior. In IVLW, these data are not enough to characterize the learning model and social space of any individual learner. The data in learner profile should be transformed to 3-D spatial dimension in order to utilize the environments of IVLW. By including the data of 3-D spatial dimension, IVLW then has the opportunity to demonstrate the relationship among learners in it. In other words, conventional student model or learner profile holds the information of learners pertaining to their characteristics and learning status; nonetheless, spatial dimension could represent the relative relationship among learners in IVLW and provide information on patterns of learner interaction in a 3-D environment.

Virtual Interaction

Interpersonal interaction (i.e., the virtual interaction) takes place in virtual learning worlds that resemble the actual physical settings. Therefore, the virtual interaction in IVLW should combine the features of visual, gestural, and verbal communication. With these features, the learners in the virtual learning worlds would be able to apply the communication skills that resemble the tangible social interaction environments.

Archives

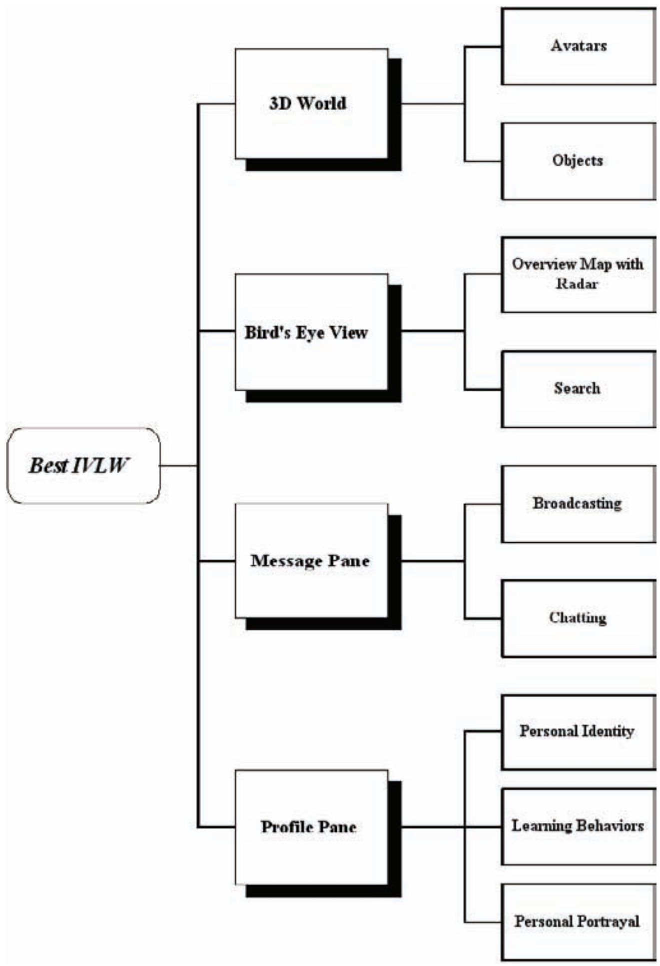
IVLW is a persistent learning world. For creating the sense of a learning community, there is a need to record the significant events or histories of the worlds for newcomers of the community. Archives of the historical events that have occurred in the worlds will do the job.

The Pilot System

The new paradigm of networked learning environments has been outlined and described as above. For fulfilling the framework and making it work, much effort has been directed to the design of the multi-users platform in 3-D format. A pilot system of IVLW with fewer features, entitled The Best Inhabited Virtual Learning Worlds (Best IVLW), has been implemented for usability analysis; Figure 1 is the architecture of the pilot system.

The architecture of the Best IVLW is drawn extensively from the technology of MUDs, which have existed for almost three decades and are a rich resource of reference about the structural aspects of virtual worlds (Vellon et al., 1998). Since the essence of the new paradigm is learning community of practice, the architecture emphasizes supporting the structural social mechanisms. To better facilitate the coordination of activity and the implementation of persistent world state,

Figure 1. The system architecture of Best IVLW



the Best IVLW chose client/server architecture over peer-to-peer. In addition, the architecture incorporates a very dynamic object model in the sense of software engineering in order to support the ability to add methods and properties to 3-D objects at run-time.

In essence, from technical point of view, the Best IVLW architecture possesses following features: (1) it is a distributed architecture metaphorically represented by 3-D virtual world that allows multiple users to interact in the shared space. (2) Objects in the virtual world are persistent over time. (3) It is extendable and scalable with run-time editing capability. It allows users to extend and make changes to it while it is running.

3-D World

The 3-D World provides a metaphor of the virtual shared learning space, which features avatars and objects such as learning materials and teleports. It is the primary component of the IVLW system.

The graphical presentation of the space allows a group of people to interact socially and see each other's actions and responses. The interface of the virtual world subsequently requires social functionality for avatars' talking and gesturing. The topology of the space is defined by "room" objects, representing discrete locations and which are interconnected by portal objects. There are also artifact and avatar objects in the world that configure "things" and people respectively.

Bird's Eye View

This is an overview map of the world with radar function that could spot the locations of the online avatars respectively. Learners could approach any avatar on the map by clicking it with their mouse. In addition, learners could also search for the current location of wanted avatar by keying the name in the search box in the map.

Message Pane

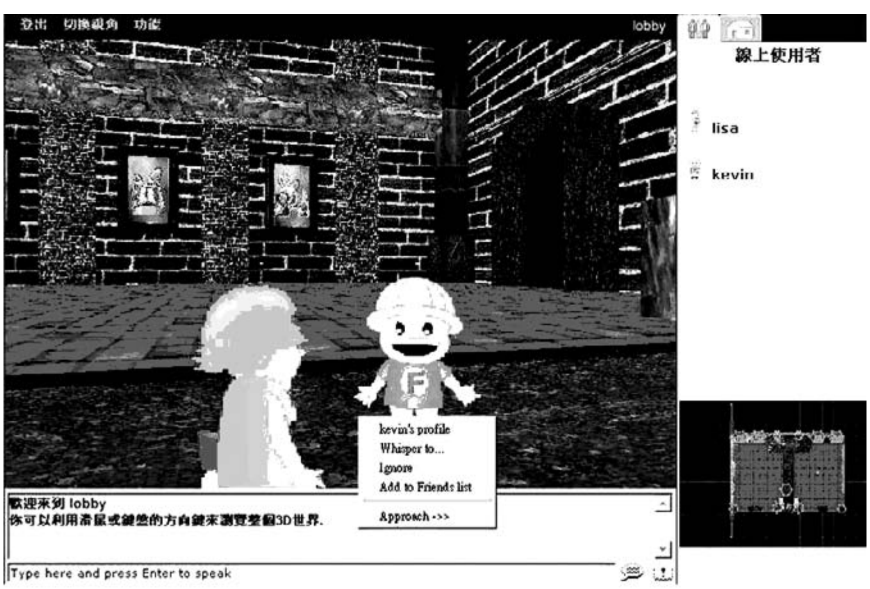
There are two kinds of message in the world. One is the interaction message generated by avatars and the other one is the broadcasting message initiated by the system. The message pane provides both functions of sending and receiving message in text format.

Profile Pane

Learners who are online are displayed with their icons of avatars and names in the profile pane. Learners could access anyone's learner profile as long as it is online by clicking on the respective icon of the avatar in the profile pane. There are twelve variables in the learner profile and they could be divided into three different categories.

1. **Personal identity:** The data in this category is static and associated with learner's personal identity information. It is composed of full name, gender, affiliate, and city pertaining to individual learners respectively.
2. **Learning behaviors:** The data in this category are dynamic and accumulated and are related to learner's learning behaviors online. The data are tracked and recorded by the system automatically. The data in this category are composed of frequency of login, frequency of upload (submitting artifacts), frequency of chatting, and charisma, which represent the learner's frequency of being included in other's friend list.
3. **Personal portrayal:** The data in this category is also static and associated with personal information. However, the values of variables in this category are editable to learners at any time. It is composed of

Figure 2. Interface of the best IVLW



hobby and interests, personal photo, and friend list.

Figure 2 is a screen shot of the interface of the pilot system.

A Preliminary Empirical Study

An empirical study is conducted with the pilot system to collect the experience of utilization of IVLW in learning and investigate the effects of learner profile on selected learning behaviors of elementary school learners. The independent variable is the presentation mode of learner profile, which has two values that are "click presented" and "collide presented." In "click presented" mode, the learner profile pops up on the screen when the avatar is clicked by the learner with mouse. As to the "collide presented" mode, the learner profile pops up on the screen when the avatar is collided by a controlled avatar. The system tracks and records four learning behaviors when learners are online, which are frequency of reviewing peer's profiles, frequency of chatting, frequency of reviewing its own profile, and frequency of modifying its own profile. These are the dependent variables that the study has focused on.

Research Questions

Since the Best IVLW is only a pilot system and the purpose of the preliminary study is to gain first-hand experience of utilizing IVLW in young school learners for setting the guidance of future studies, several practical research questions in the following are of primary concerns at the moment. What are the student feedbacks after using IVLW? What are the student attitudes toward the IVLW? In the Best IVLW, how do learners interact to each other? Does a learner profile play an important role in interpersonal interaction? Does a learner profile impact the learning behaviors?

Experimental Design and Treatments

There were 191 5th and 6th graders, from six different classes in two schools, who participated in the experiment during16 class periods respectively. They were guided to login to the Best IVLW in their computer labs respectively and asked to complete several project-based learning programs within 16 class periods. The project-based learning programs were implemented with interactive Web pages and were teleported in the Best IVLW. In the first eight class periods, the subjects had to click on the avatars with the mouse to access their peers' learner profiles. In contrast, the learner profiles automatically popped up when the controlled avatars collided with other avatars within a specific distance in the world in the later eight class periods.

Results

The quantitative data were collected with the logging mechanism of the Best IVLW and an online questionnaire. Statistical methods such as the frequency of distribution and z test were

Table 2. The frequency of reviewing peer's learner profiles in two treatments

Treatment in Learner Profile	Number of Subjects	Frequency	Mean	Standard Deviation	z
Click Presented	66	435	6.59	3.85	-2.568*
Collide Presented	66	510	7.73	4.71	

* $p < 0.05$

Table 3.The frequency of chatting in two treatments

Treatment in Learner Profile	Number of Subjects	Frequency	Mean	Standard Deviation	z
Click Presented	66	237	3.59	4.33	-3.177*
Collide Presented	66	319	4.83	4.98	

* $p < 0.05$

utilized to analyze data. There are only 66 subjects who completed the programs to the end of the experiment. The study accepts the 66 subjects as the sources of data analysis.

Frequency of Reviewing Peer's Learner Profiles

Table 2 shows the difference in frequency of reviewing peer's learner profiles between two treatments. The average frequencies of reviewing peer's learner profiles in Click Presented treatment and Collide Presented treatment are 6.59 and 7.73 respectively.

The z test indicates that the difference in the frequency of reviewing peers' learner profiles between two treatments is significant. The result implies that when subjects were presented with their peer learner profiles automatically, they did wish to know more about those with whom they interacted.

Frequency of Chatting

Table 3 shows the difference in frequency of chatting between two treatments. The average of frequency of chatting in Click Presented treatment and Collide Presented treatment are 3.59 and 4.83 respectively.

The z test indicates that the difference in the frequency of chatting between two treatments is significant. The result implies that when subjects were presented with their peers' learner profiles automatically, they intended to initiate interaction actively.

Frequency of Reviewing Its Own Learner Profile

Table 4 shows the difference in frequency of reviewing its own learner profile between two treatments. The average of frequency of reviewing its own learner profile in Click Presented treatment and Collide Presented treatment are 4.73 and 6.06 respectively.

The z test also indicates that the difference in the frequency of reviewing its own learner profile between two treatments is significant. The result implies that most of the subjects did care about the data presented in their own learner profiles.

Frequency of Modifying Its Own Learner Profile

Table 5 shows the difference in frequency of modifying one's own learner profile between two treatments. The average of frequency of modifying one's own learner profile in Click Presented

Table 5. The frequency of modifying its own learner profile in two treatments

Treatment in Learner Profile	Number of Subjects	Frequency	Mean	Standard Deviation	Z
Click Presented	66	98	1.48	1.66	1.093
Collide Presented	66	78	1.18	1.40	

Table 6. Responses to four Likert-style questions in questionnaire

Questions	5		4		3		2		1	
	N	%	N	%	N	%	N	%	N	%
A	13	19.7	26	39.4	19	28.8	6	9.1	2	3.1
B	7	10.6	25	37.9	25	37.9	6	9.1	3	4.5
C	17	25.8	26	39.4	19	28.8	2	3.0	2	3.0
D	21	31.8	28	42.4	17	25.8	0	0	0	0

treatment and Collide Presented treatment are 1.48 and 1.18 respectively.

Probably because subjects had already modified their learner profile in the first eight class periods, the z test indicates that the difference in the frequency of modifying one's own learner profiles between two treatments is not significant.

Responses in Questionnaire

An online questionnaire was presented to subjects at the end of the experiment. The questionnaire consists of five questions, four of them are regarding the subjects' experiences in using or attitude toward IVLW (using Likert 5-point scale), and one is a multiple-choice question regarding their suggestions for enhancement of the IVLW. The four Likert-Style questions are as following:

Question A: Do you like our 3-D world?
Question B: Does the 3-D world help you to communicate with others?
Question C: Does avatar make your chatting with others more interesting than merely through text box?
Question D: Is the information in learner profile helpful in making the acquaintance of others?

Table 6 shows the responses to these four questions. Referring to the Likert 5-point scale, answer 5 in the table represents the strongest degree of agreement or preference. In contrast, answer 1 represents the least degree of agreement or preference.

Based on the data in *Table 6*, most of the subjects indicate that: (1) they like the immersive 3-D learning space; (2) avatars accompanied with learner profiles do assist their communication with others; and (3) the quality of the Best IVLW is not quite acceptable.

Table 7 shows tabulated responses to the multiple-choice question regarding suggestions for future enhancement of the Best IVLW.

The responses in Table 7 could be characterized as revealing that information contained in the learner profile is sufficient at the moment to the subjects. However, the responses also indicate that

Table 7. Suggestions to the future enhancement of the IVLW

Answers	N	Percentage
Provide Costumes for Avatars	64	97.0
Provide More Sophisticated Virtual World	63	95.5
Provide Gestures in Avatars	59	89.4
Provide More Objects in the World	56	84.9
Provide More Roles and Selections of Avatars	55	83.3
Provides Voice in Avatars	53	83.3
Provide More Information in Profiles	37	56.1

a well designed virtual world, more functionalities and attractiveness in avatars, better customization of avatars, and rich content for exploration are all needed for meeting the promises of the IVLW.

Furthermore, only 34.6 % (66 out of 191) of the subjects completed the assignment in the experiment. This implies that the Best IVLW was somewhat amusing to learners in the beginning but of low relevance to their curriculum.

Although the pilot system of IVLW is far from acceptable and practical in terms of virtual learning space, the results of this preliminary study reveal that: (1) learners hold positive attitudes toward the 3-D virtual worlds and the utilization of avatars, (2) the presentation of learner profile in IVLW could have a significant impact on learners' learning behaviors and experiences. It seems that learner profile could trigger more communication among learners, which may result in better learning performance in terms of constructive learning. (3) Learners acknowledge that the enhancements of the quality of IVLW and the interactive functions of avatars are needed (i.e., more vivid look of avatars, voice communication function in avatars, personalized appearance of avatars, more virtual scenes and 3-D objects, and merging curriculum into the virtual worlds).

CONCLUSION

Based on the experience in the field of networked learning during these past two years, we found that telepresence, learning communities, and learning supports in networked learning are the top issues to be resolved before a full implementation of virtual learning in education. This article proposes a new paradigm of designing networked learning environments that abandons the current practice of Web-based teacher-centered or information delivery paradigms. The suggested approach is to create a virtual learning world that could provide a 3-D shared learning space as the residence of avatars, which are the delegations of individual learners in the learning environments. In practice, each individual learner will be represented with an avatar in the virtual learning worlds and supported by a variety of intelligent agents who also reside in the networked learning environments.

Through the use of avatars with learner profiles, geographically separated learners are simultaneously presented in the virtual learning worlds and the utilization of the visual, gestural, and verbal interaction are becoming available. These considerations are important to the fostering of a vibrant learning community and development of unique collaborative experiences to learners. The new paradigm utilizes the strengths of virtual reality: a combination of immersion, telepresence, immediate visual feedback, and interactivity.

With the proposed paradigm, it is possible to create a networked learning environment that not only resembles the real life school learning environments, but also augments the value of traditional education by removing its shortcomings and implementing the virtual learning space and extending in the new horizon of learning experience. It holds the high promise that the issues of learning communities and learning supports in networked learning could be resolved with the new paradigm of networked learning environments.

However, the preliminary study shows that it is never easy to claim the promise of the new paradigm. IVLW is an emerging learning environment and research on the field remains much needed. The enhancement of the pilot system, the Best IVLW, is currently underway based on the experiences gained from the empirical study and will be the test bed for further studies. In addition, several digital content projects designed with role play simulation and game genre are also in the phase of development (Lin, 2005). It is expected that more insights into this new paradigm of networked learning environments could be achieved with further empirical studies.

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Chapter XXIV
Research and Practice of E-Learning in Canada 2008

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ABSTRACT

Any view of e-learning in Canada must be informed by the uniquely Canadian feature of provincial jurisdiction over education. Therefore any investigation of e-learning in Canada must focus more on specific provincial initiatives in technologically enhanced learning rather than a Canadian overview. A distinctive "Canadian" model does not exist. The provinciality of Canadian e-learning serves to highlight the inability of Canada to sustain national strategies and focus as in other countries due to the fractious nature of federal/provincial relations in education.

INTRODUCTION

The vast majority of the population of Canada (36 million) lives in the south of the country within 100 kilometres of the U.S. border with scattered, remote, and characteristically small communities spread throughout the vast northern regions. The majority of the population in these remote regions are aboriginal, belonging to numerous diverse First Nations communities. Almost 25% of Canadians speak French as a first language and are mostly resident in the province of Quebec. Canada is an immigrant nation with major pockets of immigrants residing in communities within the major metropolitan areas. Thus, the Canadian context creates geographic and cultural as well as linguistic barriers that make it challenging for people to communicate effectively. These obstacles vary from province to province and in the far northern territories. E-learning technologies and practices are among the most powerful means of overcoming these barriers. However given the difference contexts, aspirations and resources of the different communities, this requires different e-learning approaches.

A principal characteristic of the Canadian experience with e-learning (and other forms of formal education) is the uniquely Canadian feature of provincial jurisdiction over education. Canada is the only country in the world that does not have a national department/ministry of education. Therefore, any investigation of e-learning in Canada must focus more on specific provincial initiatives in technologically enhanced learning rather than a Canadian overview. In the best sense, Canada's e-learning programming can be viewed as a patchwork quilt made up of interesting projects, programs and initiatives. In the worst sense it is a set of disparate and uncoordinated activities constantly struggling with and re-inventing solutions to problems solved elsewhere.

In this paper we first very briefly describe the major e-learning research programmes, delivery consortia and professional development programs with the objective of providing an overview of e-learning in Canada. We then extract particular trends we view as having future and ongoing impact on the development and support of e-learning in Canada.

e -LEARNING RESEARCH

High quality professional activity is always informed and inspired by quality research. The importance of research to practice is even more important when the field is under change and adapting to both disruptive and sustaining technological change. In this section we discuss major e-learning research initiatives, postgraduate training centres snd research puInterest at the national level in e-learning research is driven mainly through increasing concern over the development of Canada's "education industry". CANARIE, Canada's advanced Internet development organisation, has built and maintains the world's fastest Internet backbone, CANet4 that spans the country from east to west and includes isolated northern regions. This "supernet" links public and private research institutes, companies involved in research and development in information technology as well as higher education institutions. In order to stimulate use of this network, CANARIE funded both e-learning and ehealth initiatives from 1999 to 2004. The $29 million E-learning Program funded 29 cost shared projects and stimulated both development and testing of e-learning tools and content. One pan-Canadian programme was EduSource, which connected researchers in six provinces to build a prototype learning object repository (McGreal, Anderson, Babin, Downes, Friesen et al. 2006). The now defunct Tele-learning Network of Centres of Excellence (1995 – 2002) was a geographically distributed network of researchers and client communities from across Canada, who collectively researched the development, application, and evaluation of advanced learning technologies.

Most of the funding for academic research in Canada is provided through the National Research Funding Councils. The National Science and Engineering Research Council (NSERC) funded a 5 year pan-Canadian research project known as Lornet, a partnership of six universities across Canada that developed interoperability tools for e-learning based on semantic web tools, IEEE LOM, SCORM, and other standards.

The Social Science and Humanities Research Council (SSHRC) is responsible for funding educational research projects as one of many disciplines supported. A search of grants provided with e-learning as a major focus, reveals that only $900,000 was awarded by SSHRC for 21 scholarly projects during the past seven years. This compares rather unfavorably with the total of 3,420 projects it funded in all areas of education combined. With the end of the two national projects noted above and the tiny amount of funding provided by the research councils, most Canadian e-researchers are reporting being in the midst of a prolonged funding famine.

The Canadian Council on Learning (CCL) was established in 2004 with a 5-year, $95 million mandate to "to promote and support evidence-based decision-making in all areas of lifelong learning." CCL has established research clusters in five theme areas; Workplace, Adult, Health, Aboriginal and Early Childhood learning. CCL claims to support e-learning research across these themes and has funded a number of meta- analyses, literature reviews and reports on e-learning generally and specific applied research in related areas such as mobile learning (Cheung, McGreal, & Tin, 2007

A report commissioned for the CCL (Charpentier, Lafrance, Paquette, 2006) concluded that "Despite all this momentum . . . no [Canadian] e-learning strategy has yet emerged. They claim that Canada has never ventured beyond the first stage of ICT adaptation – implementing the infrastructure and carrying out research and pilot projects – unlike other countries surveyed where e-learning and content development are focused. Echoing a workshop report, they note that there is a lack of pan-Canadian coordination and persistent strategies with sustainable funding with few provincial or national action plans or policies. They particularly condemn the "almost total lack of support for R&D dissemination to communities".

Rossiter (2006) in his CCL sponsored report concludes that "other countries have moved forward more quickly and Canada has no clearly articulated strategy for the development of e-learning per se, while other national governments, including those with shared responsibilities for education, are moving forward with e-learning strategies." He gives Canada a grade of "promising work" because he believes that Canada's e-learning strategy functions only as a minor component of traditional learning approaches. He recommends that Canada should have a national "focal point" for bringing together the various jurisdictions. Abrami, Bernard, Wade, Schmidt, Borokhovsi et al. (2006) echo this sentiment, lamenting the fact that e-learning research has not been a Canadian priority. They recommend more emphasis on quantitative longitudinal research, focusing on learning impact.

Despite these federal initiatives, the provinces maintain their independence and continue to act autonomously, if not at cross-purposes. Even though the 10 provinces have constitutional responsibility for education, only one (British Columbia) has developed or sustained a long term e-learning research or development strategy.

Most of the major Canadian research universities offer doctoral level studies in education. Only a few however offer specialty programs in distance education, educational technology or e-learning. Concordia University and Téléuniversité du Québec (TÉLUQ) in Montreal offer the most well known residential Masters and Doctoral programs each of which has a focus on instructional design. Athabasca University has been offering a fully online Masters degree in distance education program since 1994 and has added a new Doctor of Education with a distance education focus in 2008. Other related distributed graduate programs are offered from the University of Calgary, University of British Columbia, Simon Fraser and Royal Roads University amongst others.

Critical to professional practice is dissemination or knowledge transfer from research to practice. Canada hosts three high quality, peer reviewed scholarly journals that focus on e-learning. Both the Canadian Journal of Learning and Technology and the Journal of Distance Education began as exclusively print-based journals and now publish in both paper and online. Both of these journals have been supported by professional development organizations and have made the move to open access publishing, without being forced to align with commercial and often high cost publishers. The International Review of Research on Open and Distance Learning (IRRODL) publishes exclusively online and has an International subscriber base of over 7,000. Another very significant Canadian contribution to research and practice is the Public Knowledge Project (PKP). PKP produces and distributes open source software for managing, reviewing and publishing manuscripts for online journals and conferences.

CONSORTIA

Due in part to the large geographic distances and relatively low populations, Canadian educators have often collaborated in the provison of e-learning and distance education. Generally these collaborations are designed to provide greater programming options to learners, and simultaneously to create economies of scale by sharing or reducing expenses and increasing the market for educational offerings. The next section of this report overviews some of the major national and provincial consortia.

Nationally, the Canadian Virtual University (CVU) consortium brings together the e-learning departments of twelve different universities in eight provinces into a common website. They pool their resources for collective advertising; accept course credits from each other; and work together to apply for funding for research and other projects. For example, the CVU received a grant in 2007 to create multimedia modules for a first year university calculus course.

The Canadian Armed Forces (CF) is among the national leaders in promoting e-learning through a Federated Centre of Excellence under the auspices of the Canadian Defence Academy. They launched an interim Learning Management System (LMS) solution in 2006, called DNDLearn that now has more than 20,000 active users. The Canadian Forces Direct Action project is focusing on developing simulations and games. The Navy and Airforce are also actively involved in promoting e-learning as a means of training a mobile workforce (Barr, 2008).

The first provincial initiatives can be traced back to the earliest province-wide distance learning network in Newfoundland - TETRA (Telehealth & Educational Technology Research Agency) in 1977; to the 1986 founding of Contact North/Contact Nord in Northern Ontario; and to the 1993 beginnings of the TeleEducation New Brunswick project. These uniquely Canadian networks began as audio and audiographic networks using simple teleconferencing and computing applications and evolved into online e-learning networks as the Internet matured and the World Wide Web appeared. These networks provide (or provided in the case of TeleEducation NB) e-learning sites and human support to different institutions delivering learning in their respective provinces.

There is considerable provincial activity in e-learning in several provinces, while others have comparatively very little. There is also a wide range of Canadian approaches depending on the level of education and the types of learning. The networks described above represent one approach. Other provincial networks have evolved to support the growing number of traditional universities that are offering programs or parts of programs over the Internet. In fact, the majority of courses offered in Canadian universities now have at least some component of either World Wide Web content and/or require some communications using email. Wikis and blogs are also used, but although growing, their deployment can be characterised as scattered depending on the enthusiasm of individual instructors.

This growing use of e-learning by institutions has stimulated the growth of collaborative networks or consortia, especially in the western provinces. The prairie province of Saskatchewan adopted a Technology Enhanced Learning (TEL) Action Plan in 1997, which led to the creation of Campus Saskatchewan, a partnership model for promoting inter-institutional collaboration "to achieve shared goals and priorities for the use of technology enhanced learning." Campus Manitoba shares a similar mandate in a neighbouring province along with Inter-universities North, which focuses on providing University level programming in the more isolated communities of northern Manitoba.

TRU with its open learning wing has appointed a Canada Research Chair in E-learning Practices (Friesen, Fisher, Tozer, Roberts, Hesemeir et al., 2004). This Chair was a leader in the development of the CanCore metadata implementation profile (. BC Campus is an online educational service in the west coast province of British Columbia that connects students and educators through a single access point to online learning resources Retrieved from at BC institutions. In addition BC Campus provides funds competitively for e-learning content development, maintains a repository for distribution of this electronic content and supports SCoPE an online professional development service and community. Unfortunately, BC Campus decided to implement a unique 'BC Commons' license, which restricts access to the majority of the course materials, which remain reserved for the exclusive use of BC postsecondary institutions.

eCampus Alberta is a consortium of fifteen colleges and technical institutes designed to stimulate and facilitate online learning in the western mountain province of Alberta. Alberta North is a complementary consortium serving institutions and learners through community access points in Alberta's northern region with partners in the Northwest Territories.

Alberta is a Canadian leader in e-learning with Athabasca University (AU), which has over 70,000 online course registrations annually. AU is Canada's only open university or single mode distance delivery institution. Previous open universities have been merged into traditional universities making them dual-mode. The former British Columbia Open University is now a department of the new Thompson Rivers University and Téléuniversité du Québec (TÉLUQ) is now formally a part of the Université du Québec à Montréal.

AU is leading Canadian efforts to promote the *Moodle* open source learning management system, holding the first Canadian Moodlemoot in 2007. AU is now implementing the open source content management system *Alfresco* and working with the Open University UK and others internationally to further develop and adapt these and other open source applications. AU is committed to open access by inaugurating Canada's first open access press: AUPress. In addition, AU is an internationally respected leader in mobile learning research, hosting the first North American Mobile learning conference and implementing a mobile accessible library and enabling mobile access to courses.

In Ontario, Canada's most populous province, the government has left the decision-making relating to e-learning to the different institutions, from which a few leaders and interesting initiatives have emerged. TV Ontario produces multimedia as well as televised learning content. The University of Waterloo has a long history of distance education and more recently has been the lead institution in the Co-operative Learning Object Exchange (CLOE), which is a collaboration between Ontario universities and colleges for the development, sharing, and reuse of multimedia-rich learning resources using a common repository. We previously mentioned Contact North/Contact Nord as a leading example of a collaborative e-learning network which also maintains community learning centres in over 100 rural communities. The Ontario Research and Innovation Optical Network (ORION) is an ultra high-speed fibre optic network that connects Ontario's research and education institutions to one another, and to partners and colleagues throughout Canada and around the world.

Quebec, Canada's only unilingual French-speaking province has supported the previously mentioned TÉLUQ as a leading open learning centre. At the community college level the CÉGEP à Distance supports distance education and e-learning. SOFAD (Société de formation à distance des commissions scolaires du Québec) produces adult distance learning courses. Canal Savoir (Corporation pour l'avancement de nouvelles applications des langages) is Quebec's principal provider of televised distance education courses from member universities, colleges and telecommunications partners. Thot provides a database of French language courses.

New Brunswick, Canada's only bilingual (French-English) province hosts distance education course offerings from the Université du Moncton a French-speaking university and from the English-speaking University of New Brunswick. The province is unique in Canada in hosting four private sector e-learning universities delivering graduate programs in Business or Psychology, Lansbridge University, Yorkville University and the University of Fredericton The US-based Appolo Group the parent company of the US-based Phoenix University has opened Meritus University in Fredericton. The province also hosts the training/mentoring department for Skillsoft, the largest e-learning company in the world. From Fredericton NB, mentors train workplace learners all over the world in skills such as project management, Microsoft professional, Cisco, Sun, Oracle and other certifications.

In addition to these Canadian universities, US universities are establishing campuses in several Canadian provinces and offering e-learning programming. Interestingly, the province of Ontario, Canada's largest province is allowing the opening of campuses of US universities, for example the University of Phoenix, and the DeVries Institute, while prohibiting any presence by Athabasca University, based in another province.

Newfoundland, as noted above, was the Canadian leader in postsecondary distance education, which began in Memorial University's Telemedicine unit. In 2008, the province has adopted Canadian owned Desire2Learn's Learning Management System in all public education including schools, colleges and universities. The Centre for Distance Learning and Innovation (CDLI) works in the K12 sector. Researchers have conducted surveys of DL teachers across Canada and synchronous communication with second language learners (Murphy,E. & Rodríguez-Manzanares, M., 2008a & 2008b).

Professional Development of e-Learning Practitioners

The rapidly evolving theory and practice of e-learning necessitates support for practitioners to aquire and maintain professional competencies. Perhaps most important of these competencies is the development of a professional network for friendship, advise, mentoring, information sharing and collaboration.

The Canadian Network for Innovation in Education (CNIE) was formed in 2007 through the merger of the Canadian Associaton for Distance Education (CADE) and the Association for Media and Technology in Education in Canada (AMTEC). CNIE supports technological and pedagogical innovations in learning, whether at a distance or in traditional settings. CNIE holds an annual face-to-face conference, monthly web conference sessions and publishes the peer reviewed Journal of Distance Education.

Le Réseau d'enseignement francophone à distance (RÉFAD) supports French language distance educators and researchers across the country.

The Canadian Institute for Distance Education Research (CIDER) is a research initiative coordinated from the Centre for Distance Education at AU. CIDER is an online, self-managed research community with a shared domain of interest in distance education research. Within this research community, Canadian and international members have the opportunity to engage in debates, explore research areas of interest, and disseminate research related to distance education.

Trends in e-Learning in Canada

It is evident from the Canadian e-learning description provided above that there are a wide variety of approaches to implementation in the different provinces. Nevertheless, e-learning is expanding as the vast majority of universities and community colleges continue to expand their e-learning options for the benefit of their students. The average Canadian university student now works part time (or full time) while studying and is demanding more flexibility in the course offerings. Significant trends in Canadian e-learning that should be watched include:

- The continued rapid growth in "blended learning" - the use of e-learning in various forms to enhance face-to-face courses offered by traditional universities;
- The development of common standards supporting the interoperability of learning resources in the form of learning objects;
- The implementation of technical standards and interoperability tools for instructional design and learning activities;
- The establishment of learning object repositories with content Retrieved from in common interoperable formats using XML;
- The development and implementation of more robust and people-friendly learning management and content management systems many of which are linking out to external web 2.0 services;
- The development and implementation of social software providing students with electronic tools and contexts for connecting, sharing and learning online;
- The growth in the use of open source applications, open educational resources and open access research publications;
- The continuing growth in the acceptance of "exchange" credits from other universities. First and second year courses credits are already accepted for transfer by nearly every university across Canada.
- The growth in the acceptance of Prior Learning Assessment and Recognition (PLAR) as more and more adults change career paths and continue lifelong learning;
- The growth in the use of mobile devices for learning, taking advantage of the interoperability of learning objects;
- The growth in the use of games for learning, taking advantage of the technical and pedagogical opportunities made Retrieved from by the video game consoles and applications;
- The continued growth of Athabasca University – Canada's Open University.

SUMMARY

It is evident that any view of e-learning in Canada must be informed by the uniquely Canadian feature of provincial jurisdiction over education. As was noted in the introduction, Canada is the only country that does not have a national department/ministry of education. Therefore any investigation of e-learning in Canada must focus more on specific provincial initiatives in technologically enhanced learning rather than a Canadian overview. A distinctive "Canadian" model cannot exist (unless one views disparate models as evidence of a uniquely Canadian archetype!). The provinciality of Canadian e-learning serves to highlight the inability of Canada to sustain national strategies and focus as in other countries due to the fractious nature of federal/provincial relations in education.

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