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A Mixed Reality Teaching and Learning Environment

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Abstract. This work in progress paper describes collaborative research, taking place on three continents, towards creating a 'mixed reality teaching & learning environment' (MiRTLE) that enables teachers and students participating in real-time mixed and online classes to interact with avatar representations of each other. The longer term hypothesis that will be investigated is that avatar representations of teachers and students will help create a sense of shared presence, engendering a sense of community and improving student engagement in online lessons. This paper explores the technology that will underpin such systems by presenting work on the use of a massively multi-user game server, based on Sun's Project Darkstar and Project Wonderland tools, to create a shared teaching environment, illustrating the process by describing the creation of a virtual classroom. We describe the Shanghai NEC eLearning system that will form the platform for the deployment of this work. As these systems will take on an increasingly global reach, we discuss how cross cultural issues will effect such systems. We conclude by outlining our future plans to test our hypothesis by deploying this technology on a live system with some 15,000 online users.

Keywords: Hybrid learning, online education, eLearning, mixed reality, learning technology, smart classrooms, cultural engagement.

1 Introduction

The world is witnessing radical changes as information technology alters how we communicate with each other and the machines that serve us. The arrival of the Internet and mobile phones has spearheaded these changes making possible the vision for "anyone, anytime, anyplace" communication, accelerating the pace of globalisation, as services become affordable international commodities.

Education is such a global service. Ron Perkinson, the Principal Education Specialist for the International Finance Corporation (part of the World Bank Group)estimated

* Alphabetical ordering.

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that the value of the global education market in 2005 was a little over US$2.5 trillion with the private higher education market being worth over $400 billion worldwide (about 17% of the overall education market). In 2005 the international student population worldwide was 115 million, growing at a rate of approximately 15% per annum, with about half of this increase being due to China [1]. Education is becoming increasingly important in modern knowledge-based economies [2] where learning is rapidly becoming a life long process.. The focus of this paper is to examine how emerging technology might address this challenge. To these ends we describe a state-of-the-art network education college in Shanghai that delivers real-time online education to almost 20,000 students. We discuss a parallel online phenomenon, the rise of massively multi-user game (MMUG) servers. We contend that network education and MMUG technology share a common computational framework and that the massive investment in games technology could be synergistically exploited to provide cost effective forms of educational service. This paper seeks to explore this hypothesis by investigating the use of MMUG technology in the form of Sun's Project Darkstar and Project Wonderland platforms, to create a shared teaching environment. We illustrate the process by describing the creation of a virtual classroom. In addition, the international dimension of such global education services poses significant culture-based challenges for developers, and providers—another issue we seek to explore.

1.1 Related Work

1.1.1 Online Learning Systems

The rapid evolution of information technology has led to new ways of learning and education. eLearning has been promoted by most education institutions and numerous corporations to facilitate better learning and teaching environments. Products such as WebCT (www.WebCT.com) and Blackboard (www.Blackboard.com) have been in use for the past few years. Many online colleges such as the UK Open University (www.open.ac.uk), the Hong Kong Open University (www.ouhk.edu.hk) and the Network Education College Shanghai Jiao Tong University (www.nec.sjtu.edu.cn), have developed and deployed their own eLearning platform and infrastructure to provide adaptive and efficient eLearning services. Today, eLearning becomes heavily learner-centred, emphasizing pervasive and personalized learning technologies [3]. As both the traditional classroom learning and web-based learning offer strengths and suffer from limitations, it is now a trend for eLearning systems to combine the strengths of the two into blended learning [4].

1.1.2 Online Games

The computer games industry is the primary user of virtual worlds which vary in complexity from a basic simulation such as a chess board, to a complex virtual environment the size of a country, continent, planet or universe.

The latest generations of computer games consoles have been designed for broadband internet connectivity, allowing traditional offline game genres (such as racing) to be updated so players can challenge opponents online from anywhere in the world. The success of online gaming has led to a new genre of online social communities (for example Second Life) where a user can log-in to the virtual world "seeing" and "interacting" with other users, without any of the mission-based objectives or tournaments found in traditional online computer games. Second Life (secondlife.com/) has expanded to the point where businesses have been established in the virtual environment, with real-world money being exchanged for products and services traded within the virtualised space. Traditional Universities are also beginning to offer services in online virtual worlds; for example, Harvard Law School, has set up a simulated court room in Second Life where students can practise their advocacy skills whereas Edinburgh University uses it to deliver an MSc course on elearning [5]. Currently (2008), over one hundred higher education institutions are listed on the Second Life site with many enthusiastically pursuing the vision for a globally networked virtual classroom environment (secondlifegrid.net/how/education_and_training). Another notable example is Sun Microsystems' MPK20; a virtual meeting environment for supporting Sun's business activities (research.sun.com/projects/mc/mpk20.html).

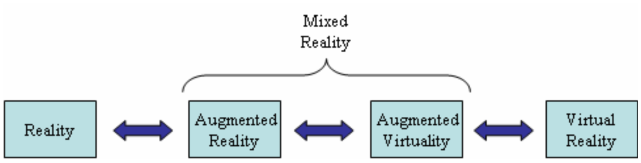

Fig. 1. Milgram's Reality-Virtuality Continuum

More advanced approaches are exploring the area connecting the real-world with a virtual environment. Collectively known as Mixed Reality, this term can be broken down further using the Reality-Virtuality Continuum [6] into: a) Augmented Reality, where the system consists of virtual components being added to a real-world environment [7]; and b) Augmented Virtuality, where real-world features are added to a virtual environment [8]. Such technological advances underpin our vision to bring innovative mixed-reality solutions to remote education environments.

1.1.3 Cultural Issues - Models in Designing Culturally Sensitive Instruction

Teaching is, by its very nature, a profoundly cultural act. Challenges associated with any cross-cultural interaction, such as the misunderstandings that arise from the assumptions we unknowingly make also influences teaching and learning [9]. As Pai & Adler have argued, culture and education are inextricably related; so much so, in fact, that, in a sense, they "define" each other. "The processes of teaching and learning are influenced by the core values, beliefs, and attitudes, as well as the predominant cognitive and communication styles and linguistic patterns, of a culture" [10].

With the increasing global outreach of online programs and courses, there is a great need to design and deliver online learning that can be engaging to a culturally diverse audience. Several models have been suggested that could assist those creating online instruction, each illuminating important considerations. Thomas, Mitchell, and Joseph [11] suggested adding a cultural dimension to the widely used ADDIE (Analyze, Design, Develop, Implement, and Evaluate) instructional design model. This cultural dimension would have three aspects: intention, interaction, and introspection. The intentional attribute of learning would encourage the designer to consider and make their cultural bias explicit. The interaction parameter would involve the collaboration of designer, subject matter expert, and end user throughout the model phases to facilitate the melding of culture into the end product. Finally, introspection on the part of designer ensures that he or she is considering his or her own thoughts, beliefs, attitudes, desires, and feelings toward the cultures represented in the instruction.

Edmundson [12] proposed the Cultural Adaptation Process model, which ideally helps to categorize course complexity and culturally adapt materials for particular learner groups based on the type of content, instructional methods, and media used. Henderson's [13] [14] "multiple cultures model" emphasizes the importance in sustainable learning outcomes of including elements from both the learner's own culture and those from the emerging global academic or training culture (from industry, government, or higher educational institutions).

Cultural factors are also a factor for the underlying technology. For instance, differing cultures and political groupings may react differently to the potentially invasive nature of the technology raising issues such as how privacy might be compromised by the sensing and monitoring aspects of these systems [15].

2 Sun's Project Darkstar and Project Wonderland

Sun's Project Darkstar is a computational infrastructure to support online gaming (www.projectdarkstar.com) [16]. Project Wonderland[1] is an open-source project offering a client server architecture and set of technologies to support the development of virtual and mixed reality environments. A noteworthy example of this is Sun's MPK20 application; a virtual building designed for online real-time meetings between geographically-distributed Sun employees.

In more detail, Project Wonderland is based on several technologies including Project Looking Glass to generate a scene, and jVoiceBridge[2] for adding spatially realistic immersive audio. The graphical content that creates the visible world as well as the screen buffers controlling the scene currently use Java3D. Additional objects/components to Wonderland (such as a camera device to record audio and video seen from a client), make use of other technologies such as the Java Media[3] Framework. Graphical content can be added to a Wonderland world by creating objects using a graphics package such as Blender or Maya. Project Wonderland provides a rich set of objects for creating environments, such as building structures (such as walls) and furniture (such as desks) as well as supporting shared software applications, such as word processors, web browsers and document presentation tools.

Thus, for example, a virtual whiteboard can be drawn on by one or several users, PDF documents and presentations can be viewed. A user is represented as an avatar augmented with the user's login name. A user can speak through their avatar to others users in the world via the voice-bridge and a microphone and speaker, or use a dedicated chat window for text-based messages. The scene generated by Wonderland can be viewed from first-person or several third-person perspectives.

[1] lg3d-wonderland.dev.java.net
[2] jvoicebridge.dev.java.net
[3] java.sun.com/products/java-media/jmf

Fig. 2. Sun's MPK20 Environment

3 The Shanghai e-Learning Platform

3.1 Overview

The Shanghai eLearning platform (Figure3) developed at the Online College of Shanghai Jiao Tong University delivers fully interactive lectures to PCs, laptops, PDAs, IPTV and mobile phones. The core of the platform includes a number of "smart classrooms" distributed around Shanghai, the Yangtze River delta, and even in remote western regions of China such as Tibet, Yan'an, Xing Jiang and Nin Xia.

The smart classrooms (Figure 4) are equipped with numerous smart devices/sensors and specially developed software. For example, the touch screen of the room displays presentations (such as PowerPoint), while also acting as a whiteboard for handwriting. The lecturer can write on materials projected on the screen using a laser E-Pen. To optimize the video quality, a pan-camera automatically follows the lecturer as he/she moves around in the classroom. RFID (Radio-frequency identification) tags are used to identify and track students. Another tracking camera is mounted in the front of the classroom and it captures students' attention status by recognizing the blink frequency of their eyes.

During the class session, lecturers can load their pre-prepared PowerPoint and Word documents and write on the whiteboard (even when they are away from the whiteboard). The students can also write individual notes to the lecturer's handwriting window. All these live lecture scenes can be recorded and archived for later access. Using this environment, the teacher can move freely, demonstrate his or her body language, and interact with learners as naturally and easily as in a traditional face-to-face classroom.

Currently, the Network Education College has about 17,000 Students; 99% of them are working professionals who attend the University part time. The large number of students in this College and its expansive course delivery systems make it a perfect place to test our mixed reality technology: MiRTLE.

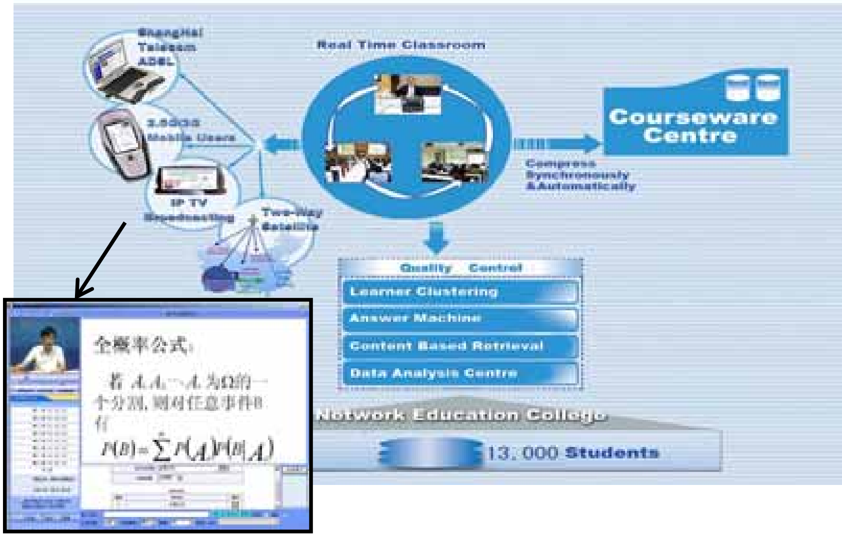

Fig. 3. The SJTU eLearning System Architecture (inset - Option 1 display)

3.2 The eLearning Platform in Use

Figure 3 illustrates the architecture of the SJTU eLearning system, which includes mobile phone broadcasting and a classroom management sub-system. Classrooms are connected to two servers (broadcasting and management) either through CERNET (China Education and Research Network) or cable network providers. Mobile phones can use the General Packet Radio Service (GPRS) network.

The teachers use the presentation station to teach in their usual ways. At the same time cameras and microphones capture the live scenes of the classroom. A recording system records all these media components: audio, video, handwriting, and any programs or documents shown on the computer. Students can view these live online, or they can download them for later viewing. If a student uses a mobile phone to connect to a class, the teacher periodically receives a screenshot of the student's mobile device so that the teacher can monitor the student's progress and the students can send SMS messages to the teacher. Students' messages are displayed on a screen that the teacher can view. Frequently asked questions are answered automatically by a computerized answer machine [17] and for more special cases teachers can provide oral explanations or reply via SMS text messages. In addition students can participate in polls and class activities initiated by the teacher. A computer analyses the poll results and immediately displays them to the teacher so that they may adjust or improve the lecture. To improved the efficiency of the system further, matching algorithms are employed to assemble student groups of similar attainment and ability [18].

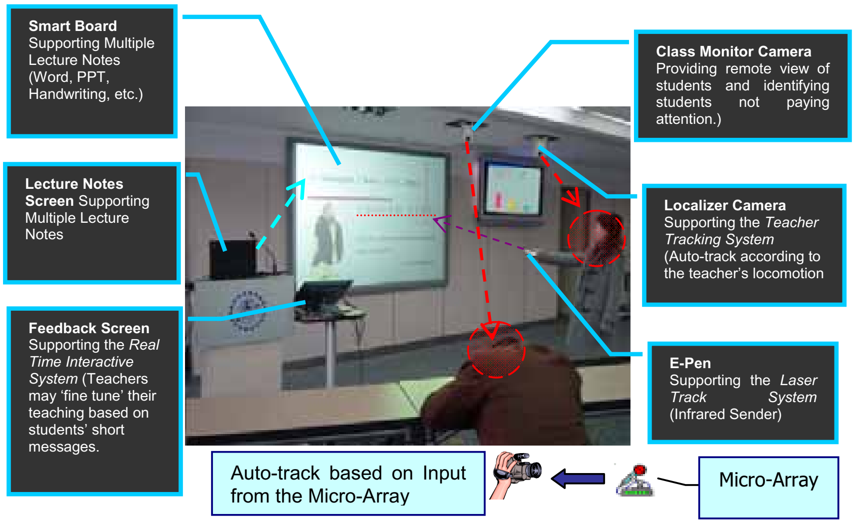

Fig. 4. The Technology of a Smart Classroom

When connecting to a live class, students have four options:

1) text, audio, and a small video of the real-time classroom,
2) video of the instructor only,
3) enlarged display of the course material shown at that time, and
4) a close-up display of the instructor's facial expressions and their body language.

We have found that 85% of the students prefer option (1): text, audio, and video (see Figure 3). Previous surveys with several samples of students in Shanghai NEC all reveal their preference to study alone, by listening to the archived recordings of live class sessions [19]. In theory, the text, audio, and video mode (option 1 above) can create a better context for learning as its closer to the feel of being in a real classroom with the teacher. Our current work on MiRTLE seeks to use mixed reality to reinforce this sense of a learning community further.

4 MiRTLE

The objective of the MiRTLE (Mixed Reality Teaching & Learning Environment) is to provide a mixed reality environment for a combination of local and remote students in a traditional instructive higher education setting. The environment will augment existing teaching practice with the ability to foster a sense of community amongst remote students, and between remote and co-located locations. The mixed reality environment links the physical and virtual worlds. 'Where students are distributed across geographically dispersed locations the hybrid learning environment allows an

Fig. 5. Lecturer view of remotely located students

Fig. 6. Student View of Lecture

increase in teaching productivity by enabling teachers to deliver only one lecture to all students rather than duplicate lectures which incur time and travel costs

Our longer term vision is to create an entire mixed-reality campus but in this paper we describe our first component in this process: a mixed-reality classroom. In the physical classroom the lecturer will be able to deliver the lecture in their normal way but they will have the addition of a large display screen mounted at the back of the room that shows avatars of the remote students who are logged into the virtual counterpart of the classroom (see figure 5). Thus the lecturer will be able to see and interact with a mix of students who are present in the real world or the virtual world whilst delivering the lecture. Audio communication between the lecturer and the remote students logged in to the virtual world is made possible via the voice bridge mentioned earlier. Two additional items of equipment located in the physical world are a camera placed on the rear wall of the room, and a microphone situated in the centre of the room—these combine to provide a live audio and video stream of the lecture to the virtual world.

From the remote students' perspective, they log into the MiRTLE virtual world and enter the classroom where the lecture is taking place (see figure 6). Here they see a live video of the lecture as well as any slides that are being presented, or an application that the lecturer is using. Spatial audio is employed to enhance their experience such that it is closer to the real world. They have the opportunity to ask questions just as they would in the physical world via audio communication. Additionally a messaging window is provided that allows written questions or discussion to take place.

A means by which a student can feedback their emotional state to the lecturer is also being investigated [20] [21] [22] together with the use of Sun's Small Programmable Object Technology[4] (SPOT) as a means of interfacing between physical and virtual worlds. The MiRTLE world has been developed using open source tools. Blender has been used to create the objects that populate the world. These objects are then exported to the X3D file format for use in the world. The platform employs a client-server architecture and to aid ease of use and to ensure that users receive the current version of the client Java Web Start Technology[5] has been employed. A short video showing an early Mirtle prototype is available on YouTube[6].

[4] www.sunspotworld.com
[5] java.sun.com/products/javawebstart
[6] http://www.youtube.com/watch?v=FYS6YzgPujc

5 Multicultural Aspects

With the increasing global outreach of online education, designing online learning that can be engaging to a global audience is critical to its success. Recent studies have found that students learn better when they are socially, cognitively, and emotively immersed in the learning process [23]. Social presence is about presenting oneself as a "real person" in a virtual learning environment. Cognitive presence is about sharing information and resources, and constructing new knowledge. Emotive presence is about learner's expression about their feelings of self, the community, the learning atmosphere, and the learning process. Learners' cultural attributes affects how they perceive an online learning setting and how they present themselves online, cognitively, socially, and emotively [24] [23] [24]. Therefore, it is essential that cross-cultural issues in online learning be more critically examined [10]. With the increasing global outreach of online programs and courses, there is a great need to design and deliver online learning that can be engaging to a culturally diverse audience.

For this paper, we are interested in learning how learners from different cultures present themselves online, either through learning interactions or avatars. Further, we will explore how culture affects student learning in educational online games. There is still a dearth of research in this area**.** In the new millennium, one of our main challenges is to learn to live with difference. [19] assert that "within the broader filed of education, online education may well have the greatest potential for enabling people to develop tolerance and learn to live with difference." Of course, the condition is that "this potential will only be realized if we as researchers and developers take issues related to culture more seriously." This assertion grounds a "call to action" and emphasizes the power that online learning environments can have to better prepare all of us for operating in a global environment.

6 Bringing It Together

In this paper we have described three areas of our research; *eLearning*, *mixed-reality* and *cultural diversity* in education. Whilst these areas are individually successful and productive, our plans are to bring these together. The way we have chosen to do this is to use the SJTU eLearning platform as the educational delivery platform. In particular, we are focusing on the SJTU smart-classroom which the MiRTLE simulation will be developed to model as closely as we can. Sun Microsystems are providing two Darkstar servers for the project, one of which will be located at the SJTU eLearning laboratory and will serve out MiRTLE. A server will offer a forward looking camera view of the smart-classroom (that is, from a student's position, towards the teacher), together with a number of simulated instances of the smart-classroom (each instance being a particular student's environment and view). The Darkstar server will be interfaced the existing smart classroom servers and processors, enabling Darkstar-based students to access the full range of educational media available in the smart-classroom. To access the system students will need to use the Internet (broadband or GPRS) to log into the Sun Darkstar server in Shanghai which will create an avatar representation of them (which they will have previously selected as part of customising their account). We are planning to use this customisation as one of the vehicles to explore the effects of cultural diversity by providing a rich set of operational modes which will reflect social preferences. For example, students will be able to create environments in which they are isolated or highly social avatars. Likewise the amount of personalised information available to other online students will be under their control, as will some of the options for interaction with lecturers and other students. Currently, we are still debating the ways we will integrate the three strands of our collaboration and this discussion is offered as by way of providing an insight to some of the issues that have arisen. Finally, although this is a long-term collaboration, in which the results will emerge over a period of years, we plan to deploy an initial experimental prototype during the summer of 2008 which we hope to report at ICHL08.

7 Conclusions and Further Work

In this paper we have described 'work in progress' aimed at augmenting online eLearning systems with mixed reality technology which we argue will counter the isolation of remote network-based learners, engendering a sense of community and social presence which Wang has shown can improve student engagement and the overall learning experience. At the heart of our vision is the hypothesis that a mixed reality version of the smart-classroom, with avatar representations of teachers and students, will help the social environment that Wang's work has shown can improving student engagement in online lessons.

Thus an important component of this work is the mixed reality environment and, to these ends, we have described how we are applying an online games server, based on the Sun's Project Darkstar and Project Wonderland tools, to create a shared virtual classroom which will be based at the Shanghai NEC. We have discussed that, not only does Wang's findings drive some of our objectives, but that the technology itself will form a vehicle to advance the cultural insights into the design of eLearning systems which are becoming increasing global in reach and nature. Looking further into the future, we recognise that other human qualities can play an important factor in learning performance and, as part of the social space, we are integrating some of our work on emotion monitoring and mediation, as part of this experimental framework. Thus, whilst we are aiming to use this work for shorter term deployment of mixed-reality technology on the Shanghai NEC system, we are also seeking to create a framework for much longer term research addressing more speculative and less understood aspects of remote education, such as the role of culture and emotion. We look forward to reporting on these as our research progresses.

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