Virtual Classrooms: Making the Invisible, Visible

Tongzhen Zhang [a,1], Vic Callaghan [b], Ruimin Shen[a], and Marc Davies[b]
[a] *E-Learning Lab, Shanghai Jiao Tong University, China*
[b] *Digital Lifestyles Centre, University of Essex, UK*

Abstract. In this 'work in progress' paper, we describe research into e-learning and virtual reality at Shanghai Jiaotong University (SJTU) and Essex University respectively. We use our experience to propose a novel virtualised learning model and architecture to support online learners and teachers to visualize important learning related information that has hitherto been invisible to users of online learning systems. The purpose of this work is to enhance the learners' experience (eg by introducing dynamic learning communities), and to help teachers by providing more efficient feedback tools to improve their teaching (eg by creating the notion of a 'virtual learner' to represent a group of similar ability learners). In undertaking this research we address challenges, such as learner community composition, virtual classroom construction, avatar modelling, collaborative Q&A machine interaction, etc and propose some novel solutions that will form our future research and experimental agenda.

Keywords. Networked classroom, intelligent answer machine, immersive learning, virtual reality, online learning

Introduction

The world is rapidly becoming a knowledge-based economy, where education offers a critical advantage in the race between individuals and nations to achieve better standards of living. As a result, an ever increasing number of young people want to receive higher education to raise their competitive advantages. In many countries, such as China, the competition for College and University places is fierce with only a relatively few people succeeding, due to the limited number and scale of colleges and universities. Can technology help solve this problem; most researchers agree it can and ideas range from Callaghan's futuristic view of personalised learning pods [1] to the application of existing e-learning technologies that people are using to overcome these obstacles [3]. e-learning enables a huge number of geographically dispersed people to share high-quality learning resources. In this model education can be anytime and anywhere. For example, to match their lifestyle, students might choose to, study at home or on the move (eg via their laptop or mobile phone) taking live lessons or recorded lessons. Due to its importance, much research has been undertaken on supporting e-learning environments. For example, Shanghai Jiao Tong University

[1] Corresponding Author: Tongzhen Zhang, 200240, E-learning Lab, Dept. of Computer Science and Engineering, Shanghai Jiao Tong University, Shanghai, China; E-mail: tzzhang@sjtu.edu.cn

Network Education College (SJTU-NEC) has designed and built an e-learning platform, serving some 20,000 learners, which we will describe in the following section

1. The SJTU Online Learning System and the Intelligent Answer Machine

1.1. Overview of the SJTU-NEC E-Learning System

SJTU-NEC has designed and built an e-learning platform which utilises two main learning approaches; live classroom broadcasting and web-based learning. Live classroom broadcasting exploits multi-casting technology for delivering real-time lessons (audio, lecture video, presentation video) to remote multi-modal receivers ('standard natural classrooms', home computer, IPTV, mobile phone etc) via broadband (ADSL), GSM, UMTS dial-up network and satellites. Web-based learning supports learners studying by two modes: lecture on demand and downloading archived material. The advantage of web-based learning is that learners can study at their own pace anytime and anywhere. To improve the learning experience, the web-based learning system is supplemented by various tools such as, fast content-based search engines which helps students to get the learning material they want quickly, an intelligent answer machine provide answers to frequently asked questions, a data analysis centre monitors and analyses the learner's progress (mining data from logs browsing history, questioning, assignments, examinations, etc). To provide a personalized learning service and to support collaborative learning activities (eg self-organizing learning communities), the SJTU uses the mined data to cluster learners according to their ability and subjects [4].

1.2. Living Lessons Based on the Standard Natural Classroom in SJTU-NEC

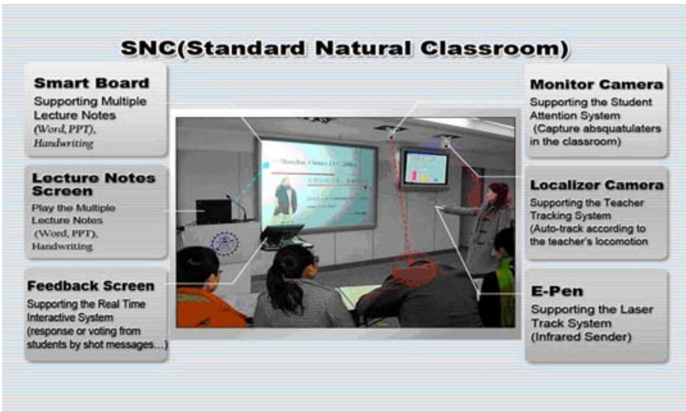

Figure 1. A standard natural classroom.

At Shanghai, after many years experience of regular and e-learning classes, we have concluded that systems modelled on traditional classroom environment benefits learners most. Thus, in our work on high-tech classrooms, we have made a lot of effort to retain the essence of a natural classroom; we call this a '*standard natural classroom*' (SNC). An SNC is shown in Figure 1 and contains a number of high-tech devices such as a camera to capture the lecturer’s location and face (for delivery to remote learners), a set of cameras to capture the students learning states, a large projecting screen for displaying the lecturer’s presentation (PPT), and smaller ones to present student or system related information to the teacher. A live learning environment comprises up to 4 elements: a local classroom, remote classroom, home environment and a mobile phone; Figure 2-3 illustrate a local and remote classroom, Figure 4-5 shows a home and mobile phone based learning environment [4].

Figure 2-3. Local lecture classroom and a remote concentrated classroom.

Figure 4-5. Remote-home learning and outside mobile phone learning.

1.3. The Intelligent Answer Machine (IAM)

Questions and Answers are a very important part of any learning activity. Unfortunately, the teacher can not be online at all times, and even when teachers are online, they can not resolve many questions (especially when they are teaching - online teaching session can have over 500 online learners!). In such circumstances, how can a learner get the timely response? SJTU-NEC have designed and built the IAM (Intelligent Answer machine) to solve this problem [5][6]. The IAM uses AI techniques to gather, parse and reason about its accumulated information. It can benefit both learners and teachers by giving the students timely responses while reducing the load on teachers by automatically answering recurrent questions. Below we introduce how the IAM works from the viewpoint of both a learner and a teacher.

1.3.1. A Learner’s View of the IAM

During the learning cycle, the IAM acts as an agent, responding on behalf of the teacher. In response to a particular question the IAM can offer a number of possible answers, each of which is ranked by the AI reasoning engine based on how well it matches the question. The learner benefits in various ways. First, the learner gets an answer immediately. Second, for more complex questions, the reasoning engine enables answers to be generated by mixing answers from the ranking list. Third, even when a learner poses a question in an imprecise way, the reasoning engine is able to provide its best answer match, which may or may not satisfy the learner. If the IAM is unable to find an existing answer, or when the learner is unsatisfied with the answer, the system can pass the question to the real teacher. Later, or in real-time, their teacher can answer the question, which then is both returned to the learner and added to the IAM knowledge bank. After several years of self-enrichment, the IAM, can answer the majority of the learners questions. In fact, according to recorded data in this system, the IAM matching performance has reached 90%, and, according a recent survey, the degree of learner satisfaction has reached 95%.

1.3.2. A Teacher's View of the IAM

During the traditional teaching procedure, an important part of teaching is to ask or answer questions. This helps a teacher to know how well students are understanding the lesson so they can adjust the lesson accordingly. However, because e-learning platforms can have huge numbers of students (500 or more) it can be impossible to deal with students on an individual basis, and hence the IAM provides a good solution. We have found that students tend to ask the same questions, and so, by logging the teacher's response, the answer machine gradually builds up a set of answers that allow it to answer questions without the need for the teacher to intervene. Only a few questions which learners never asked, or with no suitable answers, need to be passed to the teacher to answer manually. This can greatly reduce the workload of a teacher. Also, knowledge of the questions (type and quantity) that learners pose to the IAM, provides a valuable insight to the learners understanding of the teaching material, or the effectiveness of the teaching methods. For example, the IAM provides an insight into questions, such as, which issue is the hot question (poorly understood) etc.

1.4. The Merits and Shortcomings of Traditional eLearing

There are a number of shortcomings associated with online learning, in particular the isolation (loneliness) of remote-home learners, and a loss of mutual support (live interaction) between learners. It is well known that classmates can introduce both humour and knowledge into the learning procedure. How can a learner get the feeling of being in a classroom with other learners? From a teacher's view, they want to know more about the cyberspace classroom; how many learners are taking the lessons - how the learners distributed - how many learners understand what is being said - what are the questions are being asked? All this 'class knowledge' is very useful feedback to help a teacher to adjust and improve the lessons. Thus, to be effective, an online system should show this information to teachers, and encourage learners to pose more questions. Hence, the statistics relating to learners' questions provide a particularly useful teaching resource but raise the challenge of how this information can be provided efficiently. An intuitive idea we had to solve these challenges was to allow the students and IAM to take the form of avatars, which are all visible to each other. In this scheme the IAM would be given the appearance of an avatar-based teacher-assistant who would answer questions, thereby reducing the load on the teacher and the interruptions to the class. The shared form of an avatar conveys both a community of classmates and a feeling that it's a teacher who responds to the question. Below, we will describe a virtual-reality based learning model that implements all the above concepts, in particular, it uses the Shanghai intelligent Q&A machine (wrapped in the mantle of an avatar) to make the invisible Q&A based knowledge visible to the teacher and learners in an efficient way during the live lessons. It also embraces other concepts such as creating learning communities to enhance the students' social learning experience allowing more intuitive communication of meta-learning information.

2. Virtual Reality Technology

2.1. Overview of Virtual Technology

Virtual reality technology is well known for being used in computer games industry. In fact, it is also used for research into online education [10], and intelligent environments [8]. Perhaps the most powerful aspect that virtual reality technology can offer to online education is the ability to '*make the invisible, visible*'; Earlier we argued that whilst current online technology brings many significant advantages, by its limitations, it hides much of the information that is essential to teachers and learners for effective learning. Virtual and augmented reality allows this hidden information to be made visible. Also, virtual reality offers other side benefits such as enabling learners and teachers to customize their learning environment addressing issues of learner engagement thereby giving the student a sense of being a stakeholder in the learning process. Also, some learners might be regarded as 'shy' or perhaps overly reverent, which impairs their ability to ask questions and benefit from the learning process. The anonymity that virtual reality provides goes some way to overcome this.

2.2. The Essex iWorld and Tools

The iWorld is an extensive multi-building virtual environment and toolset that has been built to allow research and experimentation on different type of virtual reality application. It exists in both a RealXtend and Wonderland version [7][8][11][20]. The creator of the iWorld, Marc Davies, designed this toolset to further his own PhD research that is concerned with creating computer-controlled avatars that have behaviours akin to their human controlled counterparts. Although not directly connected to this work, there is a clear connection with the IAM artificial online avatar tutors we are proposing. The iWorld is a virtual reality system taking the form of an environment simulation containing multiple buildings outfitted with pervasive computing technology. At the core of this is a simulation of the Essex University iSpace, a full-size two-bedroom apartment located at the University of Essex which serves as a living-lab test-bed for pervasive computing research [9]. The current iWorld is built as a mixed reality intelligent environment, meaning the system consists of a virtual world linked to a real space. Changes made to devices in one world can be made to reflect in the other world or, alternatively, one reality may supplement the other reality. Figure 6 shows the views of a real iSpace which makes a perfect example of the environment our home learners may find themselves in and the iWorld is a perfect environment for building the virtual reality tools that we propose should augment existing e-learning system [2].

Building a completely bespoke virtual world from scratch would be a daunting prospect. Fortunately, modern computer games have attracted massive commercial investment which the model we are proposing can benefit from. In fact earlier versions of the iWorld were built by modifying off-the-shelf game technology, namely Electronic Arts' Sims [7][8]. However, more recently the work was ported to an open-source massive multiuser online (MMO) virtual world system, RealXtend (programmed mainly using C# and Python) which provides tools to build attractive world landscapes and realistic avatar models and Wonderland (Programmed in Java).

Figure 6. Views of the real iSpace.

Numerous open-source software packages are available to produce high-quality content for the iWorld: For example, bespoke objects can be created using Google SketchUp and off-the-shelf objects are available in Google 3D Warehouse (a vast online repository of 3D models created by people using SketchUp [11][12]. Figure 8 also shows a prototype virtual lecture theatre built within the iWorld, which could potentially be used for distance learning or other MMO meetings involving large numbers of people.

Figure 7. Views of the virtual iSpace.

Figure 8. Views of the virtual iWorld.

2.3. Virtual Learning

The Shanghai e-learning system forms the basis of our teaching infrastructure and functions as follows. At the start of an online learning session, learners log into the learning system that collects, monitors and analyses the learning activities (eg IAM Q&A) which produces statistics that are then, or later, used by staff to improve the learning programme. During the live teaching session the online learners (or their communities) are not visible to each other, or the teacher. The teachers have only a partial view of the online Q&A (eg questions that the IAM passes to the teacher). Thus a lot of valuable information in this e-learning system remains invisible to the educational stakeholders! The idea proposed by us in this paper it that this invisible e-learning information could greatly improve the learning and teaching experience, if it were made visible to students and teachers. Thus, in the following section we will propose a model that, principally, renders visible the invisible data captured by the IAM using avatars and other virtual reality components in a way that augments traditional e-learning and improves the learning and teaching experience. This then is the focus of the work we are proposing.

3. The Virtualised Learning Model

3.1. Using VR as a Solution to Visualise Online Meta-Learning Data

At the core of model is the idea that we will use an avatar to give the IAM (intelligent answer machine) an avatar based persona. In the virtual teaching environment we are proposing (Descartes[2]), the teacher and the learners appear as avatars, and thus interaction with the IAM takes the form of an avatar tutor (or teaching assistant). By using a virtual world, one aim is to let the learners get a more realistic feeling of being in a traditional classroom with the teacher and other classmates rather than just being an onlooker, In this way it is hoped the learners will have a stronger desire to engage with the teachers and other classmates and find the experience more satisfying and effective; The other aim is to provide the teacher with more timely and accurate feedback about the state of the learners and their learning so the teachers can adjust their teaching content and means in real-time. However, whilst the scheme promises the advantages we argue above, there are also a number of challenges that need to be overcome. For example, firstly, on the teacher's side, there will be several hundreds of online learner avatars that need to be crammed into a limited virtual world screen leading to a confusing mess of information. A similar situation also emerges at a learner's side. Secondly, as the system becomes more engaging to the learners, more questions will be posed to the teacher during the lesson time, which, if the questions are new to the IAM could result in more interruptions to the lecture while the teacher responds to the questions. To resolve the first challenge we propose to use a single avatar to represent not only one learner but a family of learners. We propose to link this representation to the concept of self-organizing learning community, and employ it to cluster learners into some communities, which have (at one level) a single avatar representation (at a lower level, they retain their individual representation). To resolve the second challenge we propose to integrate the intelligent answer machine into the virtual world, so it has its own avatar representation (and persona), acting as a teaching assistant supporting the teacher in the virtual world, and thereby reducing the load on the teacher and improving the experience of both the learner and teacher.

[2] Inspired from a play on the words "I AM" which Descartes famously stated as "*I think, therefore **I am***",

3.2. Forming Self-Organizing Learning Communities

The use of self-organizing learning communities has become an important principle in the provision of personalized and collaborative learning for e-learning [13] [14] [15]. Learners within a community usually share common features, studying in a community can overcome the loneliness and enable learners to share experiences and resources (to some extent), and even enable personalized instruction and services from the teacher (as there are fewer groups to deal with). In forming communities many clues are used such as trust awards [16], social presence [17] and knowledge points [18][19] to capture the common features and to form learning communities. Most community models use only each learner's primary feature, while Zhang [18][19] captures the multiple interests from knowledge points reflected in routine learning activities. This latter approach allows learners to be distributed to more than one community according to their multiple interests (one learner could belongs to several communities at the same time). All these models capture features and cluster learners dynamically and automatically into different communities (without any human intervention).

3.3. Visualising Learner Learning Communities

In a virtual world, too many learner avatars would confuse the teachers and learners. Thus the question arises, what is the proper amount of avatars and which avatars should appear in any person's world? We will discuss this in detail from both a learner's and teacher's viewpoint and use the notion of communities to settle this question.

3.3.1. Communities from the Viewpoint of a Learner

For learners, the system is intended to support them better by enabling other learners, and the IAM, to appear as avatars in a shared learning community, providing background communication and information that supports the teacher increasing moral support and inspiration for all participants. Thus a natural question is whom would the learner want to see in this virtual classroom? We are sure a teacher must be the most important person, but others such as good friends, or fellow learners (with a similar knowledge level or interest) might be beneficially grouped into a community. Communities might be defined by the teacher, the learners, the AI system or a mix of these. Regrouping can be fairly dynamic and can vary from small sub-groups to the entire class (eg when few learners are online, it is also a good choice to avoid being alone). In a few words, we can give the learner multiple choices to customize their own virtual classroom; apart from the teacher, friends could all be check boxes, while the community types can be a set of radio boxes. To identify different people in the virtual classroom, we can add labels (names) floating above an avatar's left shoulder and using different colours to indicate the avatar's community identity. Choosing 'interest' as a community membership can provide more opportunities to get effective help from others in the same community, while choosing the 'knowledge level' as the community membership can reduce effectively the potential frustration and gain more personalized instructions. As we know communities tend to be highly dynamic, a student's avatar might join or leave a community if the student's performance changes or the system allocates clusters differently. To make the automated communities relatively stable, we only update it periodically by analysing the learners' profiles and learning activities.

3.3.2. Communities from the Viewpoint of the Teacher

For the teacher, the virtual world is intended to support them better by improving the quality of the feedback. By improvement, we mean making more information available to them (the hidden IAM information) whilst at the same time simplifying the views, so teachers are only presented with the most relevant information for their current situation. In a little more detail we can imagine they might want to be given a view of all the learners online, to get an overall impression of the class, or maybe, just have a general view of the feedback from all learners so they can adjust the lessons appropriately. If there are only a few learners online, displaying all the learners with different avatars is viable, whereas, if there are several hundred learners, using a text format to present statistical information might be a better way. However given we are using virtual reality technology, a better choice may be to use a single avatar representing one community, with an 'interest' or 'knowledge level' label floating above the avatar's left shoulder. Alternatively, a third choice is to use a single avatar representing one community in which the 'learner's questions' float above the avatar's left shoulder. For all community avatars, the 'number of learners' floats above the avatar's right shoulder. To make the questions (knowledge points) more readily interpretable to the teacher, we propose to make avatars with questions, cross to the teacher's side of the virtual classroom. Thus, as the lesson progresses, and the number of questions (knowledge points) increases, more and more avatars appear in the teacher's side of the virtual classroom. After a quick look at the distribution of community avatars, a teacher can adjust the teaching to deal with the difficulties of the class. If we need to go beyond the usual Q&A exchanges with the IAM, we can get additional question information by two means: designing a client questionnaire on each lecture knowledge point (to let learners choose a 'clear' or 'unclear' option - with the default set to 'clear'). Alternatively, we can use the IAM to simply count the number of the learners who have posed a question to the teacher. The avatar of the community in question will change its text on the right shoulder, or even disappear when there is no avatar showing 'unclear' status (or no questions) about a given knowledge point after the teacher has given an extra explanation or answered the questions. Of course, like any class, there is limited time and it may not be possible to deal with all the questions in the class, so some may have to be dealt with offline.

Finally, the issue of how learners and teachers might use the system to assign and change communities will be a source of interesting research data. We intend to experiment with allowing learners and teachers' maximum freedom to do this, so we might learn the optimum types of community and community management.

3.4. Integrating the IAM into the Virtual Classroom

The IAM is a relatively independent subsystem in the SJTU-NEC learning system. How can this subsystem be supplemented with virtual elements to give it the feeling that it's a teacher rather than a cold machine, which is answering the question? To solve this we are proposing to make the IAM appear as an avatar with its own persona (probably customisable by the learner). Thus, this IAM based teacher assistant would be an avatar representation of IAM standing in the corner of the classroom ready to help. To illustrate this, imagine the following: a learner poses a question (raises his virtual arm), the 'teacher assistant' (an avatar) walks to the learner (another avatar), rising its right hand and displaying a window with a ranking list of the same or similar questions with their answers. If after the learner has scanned all the items and they still believe there is no answer, they can push the 'unsatisfied' button, and the question is passed to the real teacher (and fellow learners) to wait for the teacher's (or a fellow learners) answer. Only answers from the teacher (or learner answers approved by the teacher) are admitted permanently to the IAM. After this, the 'teacher assistant' avatar walks back to the corner in the virtual classroom (each learner can have an instance of their own 'teacher avatar', so learners have a virtually one-to-one teaching assistant). After the lecture has finished and the teacher has answered all the questions (which may not occur for some time after the lecture) the teacher's avatar will turn its face to the class, as if in a real classroom.

3.5. Bring It All Together- an Architecture of The Virtual Classroom

Based on the above discussion, Figure 9 shows the computational model we propose. On the left side is the learner's virtual world view, where the avatar of the teacher (Ta) and the avatar of the 'teacher assistant' (IAM) (Tsa) reside. La is an avatar of a learner, and Pla is the avatar of the first-person learner (enabling the learner to see themselves beside this avatar). Multiple lines, with arrowheads show the relationship amongst them. On the right side is the teacher's virtual world, where knowledge point avatars (K), or several Las representing different learning communities, just one learner, or TEXT provide statistics. In the middle of Figure 9, the blue lines with arrowheads, indicate questions being posed and the green lines with arrowheads indicate questions being answered. From this, we can see that learners can pose many questions to the IAM, which responds to the questions. The IAM also communicates learner's questions to the teacher, but obviously, most of the questions are resolved by the IAM with only few being passed to the teacher. Another route for questions and answers is the teacher asking direct questions of a learner.

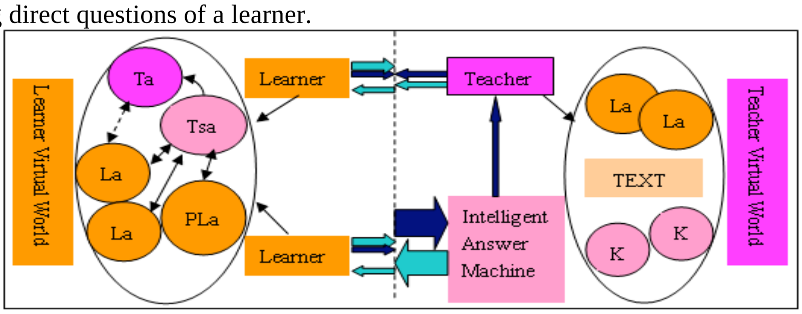

Figure 9. The architecture of the visual classroom.

Finally, there is the question of how to realise the physical design of the immersive learning ePod (educational pod). Some fascinating ideas were presented in the paper that inspired this work [1] but our task in this work has been to find a practical and affordable way to produce a home based immersive learning environment. Towards those ends Essex University has entered into a collaborative project with a UK based company, Immersive Display Ltd [2] that specialises in immersive virtual reality technology. At the time of writing (April 2011), this work is still underway but a conceptual design and an early proof-of-concept 'lash-up' is shown in figure 10.

Figure 10. Conceptual and Early prototype ePod work

4. Conclusions

In this work-in-progress paper, we have proposed a model and an architectural solution to the problem of helping online learners and teachers to visualize what has hitherto invisible meta-teaching information, with a particular focus on an e-learning component known as a 'intelligent answer machine'. We did this by describing well proven work at SJTU on e-learning and VR work at Essex University. In doing this, we presented a novel solution comprising a virtualised learning model and architecture. Although this research builds on well proven work there remains some challenges to the realisation of this vision namely:

- Dynamically assigning learners to groups, according to their use of the IAM and directed Q&A in relation to lesson knowledge points.
- Building a high-quality realistic 3D virtual world in which avatars of the teachers and learners may be visualised.
- Supporting representation of dynamic communities.
- Providing interfaces for the teacher and the learner, to communicate with each other (especially, for questioning and answering).
- Integrating the IAM into this architecture, so it provides appropriate information to the teachers, learners and teacher assistant avatar.
- Integrating this architecture into the immersive learning pod.

As the system is highly customisable by both the learners and teachers, once this architecture is implemented, in addition to studying the performance, the variable settings available to users will generate a lot of useful research data.

Finally, in this paper we have presented a case and high-level model for integrating traditional eLearning with immersive reality and intelligent systems (answer machines and avatars) in a novel way based on the metaphor of "*making the invisible, visible*".

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