

# Using 3D Graphics for Learning and Collaborating Online

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## Abstract

*Today, the use of e-learning is common place. E-learning courses are now becoming prevalent on the Internet. They offer students great flexibility as well as a wide range of subjects. Traditionally the majority of these courses provide learners with text-based material and allow them to contact the course tutor via email. Virtual Reality (VR) has a lot to offer the e-learning paradigm. 3D virtual worlds can give people a sense of belonging and, as they mimic the real world, they are a natural way to access information. This paper describes CLEV-R, a collaborative learning environment with Virtual Reality. This environment uses VR and multimedia to deliver learning material to students in a stimulating and motivating manner. By using a suite of communication tools, students can learn, collaborate and socialise on line.*

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## 1. Introduction

The use of computers and technology in education has been increasing steadily. This is particularly noticeable in the last decade and today several institutions have been established with the primary goal of providing online courses using the Internet [CCV05], [DTI05]. The material provided through these portal websites is often text based with few pictures and little to stimulate the student. This can ultimately lead students to leave such courses as is evidenced by the high dropout rate among on-line courses [Ren02]. Communication with the tutor and among the students does not take a natural format; it generally involves e-mailing tutors and posting messages to forums or message boards. The response to such queries can be slow with students possibly having to wait long periods of time for a response. These communication tools are in no way adequate for students to collaborate on group work or projects. Students are forced to work alone, which leads to a sense of isolation [HH98]. It has been shown in universities and other centres of learn-

ing that social interaction plays a very important role: students can learn as much from one another in informal discussions as they do from a tutor during a lecture [KM98]. Traditional e-learning systems with the poor communication options they provide have no facilities to address the social needs of students.

In order to address these issues we are developing CLEV-R, a Collaborative Learning Environment with Virtual Reality. CLEV-R is a multi-user environment, which uses VR to deliver learning material to students in a stimulating manner. Course material can be presented using a variety of media including animation, video and audio. The interactive 3D environment provided by CLEV-R is a motivating way for students to learn. Each student enrolled in a course is represented on screen and can see the representations of other currently connected users. Therefore feelings of isolation or loneliness can be removed. This sense of belonging and community is further enhanced through a rich set of communication controls, which not only enable students to collaborate on group work but also brings a social aspect to the on-line learning environment. This e-learning environment augmented with VR can be used as an accompaniment to the classroom or as a stand-alone distance education so-

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lution. In both cases CLEV-R can undoubtedly enhance the students learning experience.

The remainder of this paper is organised as follows: Section 2 details some previous work that has been carried out into the use of VR in education. The system architecture and technologies used are discussed in Section 3, before a full system outline in section 4. An extension of the system to mobile devices is presented in section 5 and optimisation techniques for greater efficiency are discussed in section 6. Evaluation methods of the system are outlined in section 7 and finally some future work and conclusions are given.

## 2. Related Work

E-learning is an area very much in vogue at present and is receiving a great deal of attention from the research community. Improving current on-line learning systems is at the forefront of this research. In recent years, the use of virtual environments has been explored as they can enhance the users' learning experience. Two such projects that have researched this issue from the point of view of online training are EVE [BGT03] and INVITE [BTT01]. The Intelligent Distributed Virtual Training Environment (INVITE) developed a detailed system specification for the development of a collaborative training environment using VR. However due to insolvency of the project partners, research never reached a development stage and so no evaluation was carried out. EVE, the Educational Virtual Environments platform, offers a multi-user training environment in which users can share certain applications in order to work together. In a similar vein, VES [BFK\*99] is a multi-user platform using VR where the target audience is European secondary schools. In VES, schoolbook publishers provide themed multimedia learning material in addition to traditional classroom material. The multimedia material is available via a 3D environment and it is here that students can put into practice and reinforce theories learned in class. Another area in which VR is used within learning is the use of animated 3D characters to assist students [Nij00], [RJ97], [RJ99]. Jacob [Nij00] is a 3D agent in a virtual environment, which helps students solve the towers of Hanoi problem. By following the directions of Jacob the user learns how to solve the problem on their own. VR in simulations is extremely useful for demonstrating complex tasks. For example, STEVE [RJ97], [RJ99] has been developed for use in naval training. Here, individuals or groups of students are guided around a VR simulation of a vessel as a 3D character demonstrates the use of certain machines on board. The student then has the opportunity to practice using the machinery in the VR environment.

CLEV-R can be differentiated from the systems described above as it provides an interface to a more general 3D learning interface. Unlike some of the systems described above, CLEV-R is not limited to a specific learning task, instead various types of courses can be run simply by uploading appropriate material. While CLEV-R is aimed at undergrad-

uate students to accompany traditional lectures as well as facilitating distance learning, it can easily accompany any educational course both in secondary and primary schools. One of the key distinguishing features of CLEV-R is the social interaction provided. E-Learning systems often put all their emphasis on the learning material and fail to address the social needs of students when in fact many studies have shown the significant role social interaction plays in learning [LK02], [RN02]. A lack of communication between users in online learning can cause some to become unmotivated to complete a course or to undertake another online course in the future. It can lead to a feeling of isolation on the students' part [HH98] and the benefits of collaboration with others [KM98] are not realised. CLEV-R recognises the importance of social learning and by providing a host of communication tools, these social needs of students are dealt with.

## 3. System Architecture

The CLEV-R system is built using a client-server architecture, illustrated in figure 1. This allows multiple users to connect to the same location where they can access learning resources.

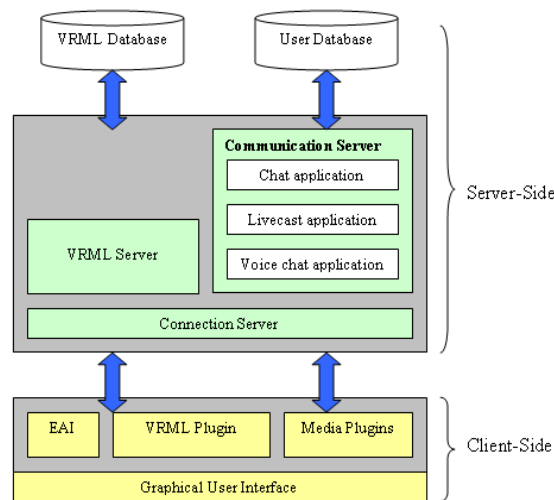


Figure 1: The System Architecture.

Databases containing user information and learning material are stored on the server side of the application. The servers are responsible for user management and they must also ensure that all connected users are presented with a consistent and up-to-date view of the 3D environment. The media communication server is responsible for transmitting live voice and web cam feeds to appropriate users of CLEV-R. It also manages text communication in the environment supporting both public and private messages. The client-side of CLEV-R consists of a web browser enabled with relevant plug-ins and is responsible for presenting the system to

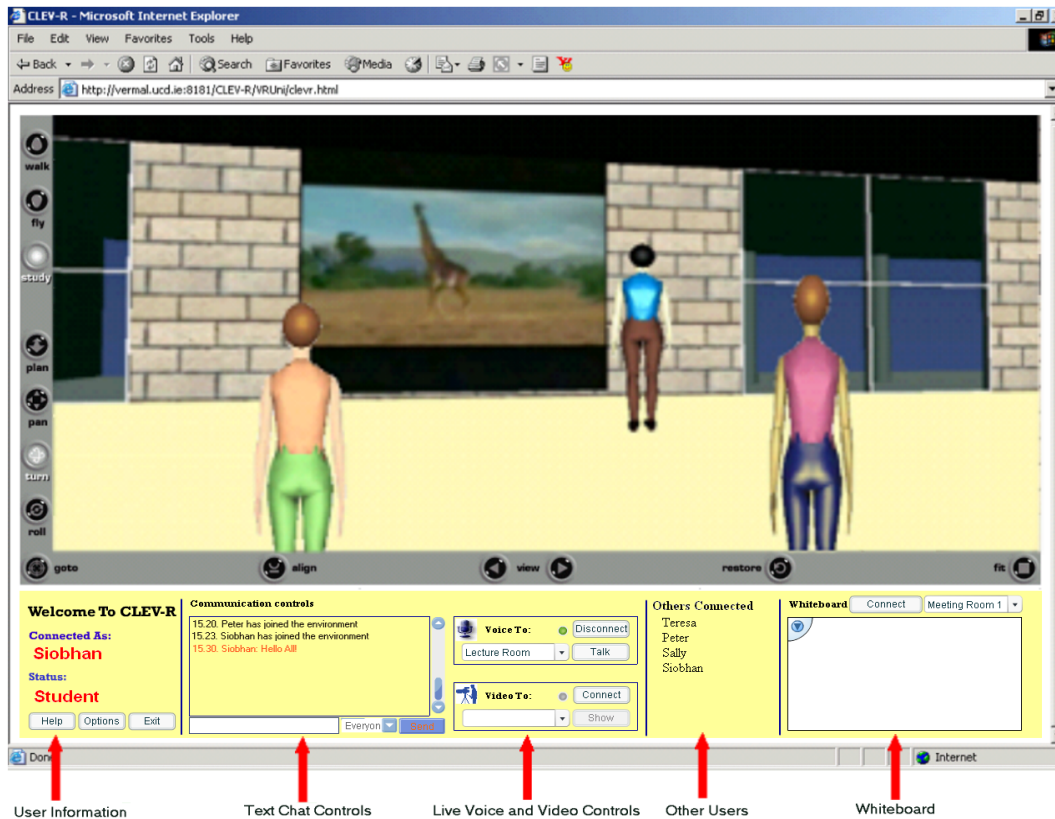


Figure 2: The CLEV-R Interface showing the 3D Environment and Communication Controls.

users. It allows the user to access learning material through a 3D interface and to interact with the 3D environment and other users of the system. It also sends local changes in the environment (e.g. changes of the current presentation slide, upload of a new file) to the server so all connected clients are informed of the change.

### 3.1. Technologies

The 3D environment of CLEV-R is manually developed using the Virtual Reality Modelling Language (VRML). This language was developed in 1994 [VRM05] and has since become the standard for transmitting 3D data over the Internet. The small file size makes it an efficient means of sending 3D information. In order to view the 3D data, the client needs an appropriate VRML viewer. This viewer acts as a plug-in to a web browser and provides controls for the user to navigate within the 3D environment. Many VRML plug-ins are freely available on the Internet [PG005], [BT005]. During the development of CLEV-R, we are using the Cortona plug-in by Parallelgraphics [PG005]. VRML is compatible with Java and interaction between the two is achieved using a set of Java classes known as the External Authoring Inter-

face (EAI) [VRM05]. In CLEV-R the EAI is responsible for actions which take place in the environment and informing the server of local changes that have occurred. The Graphical User Interface (GUI), is a combination of a Java Applet and Flash movies. The Applet is used to control the user's character in the environment while the Flash movies are responsible for the voice and text chat communication in CLEV-R.

### 4. System Description

CLEV-R is an online learning environment. However, unlike traditional web-based learning systems, it uses VR along with a rich suite of communication tools to enable collaboration and reduce the sense of isolation that users often experience during online learning sessions. The interface shown in figure 2, is subdivided into two segments; the upper section displays the 3D environment while the Graphical User Interface (GUI) on the lower panel allows access to communication controls. The 3D environment in which the users are immersed mimics a real university. It consists of a central courtyard or common area, surrounded by classrooms, meeting rooms and social rooms. As a user navigates within the virtual environment, they can trigger certain events by

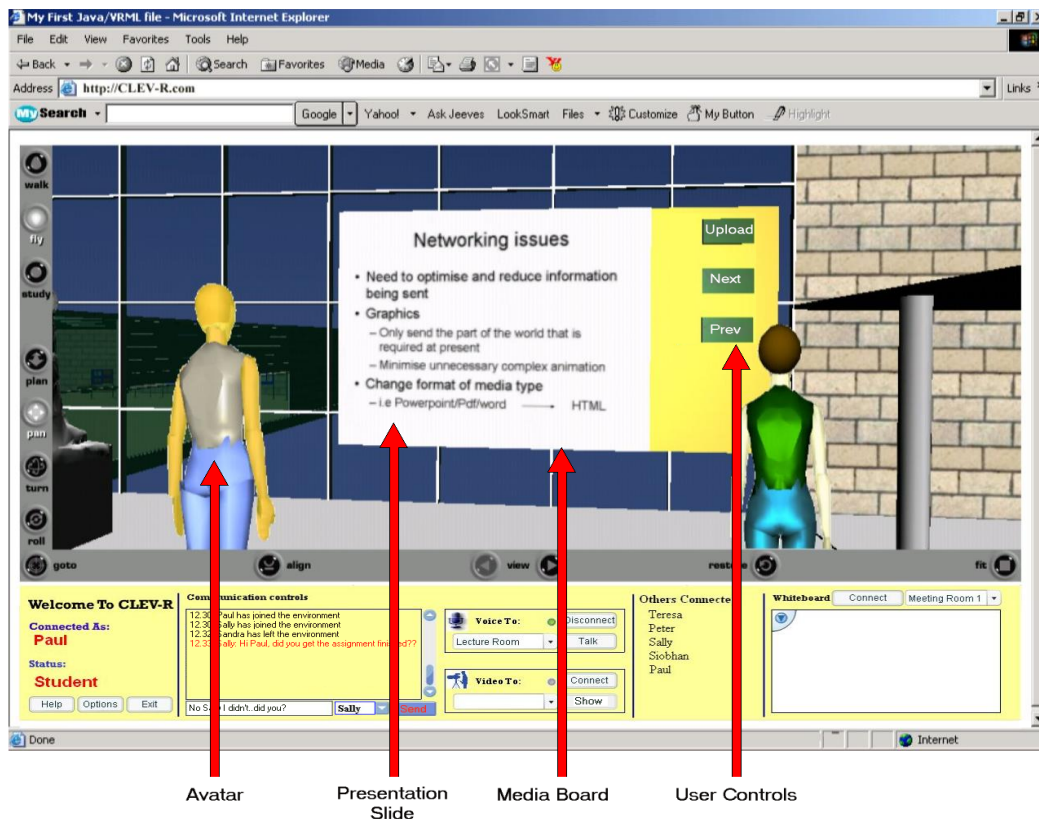


Figure 3: An online lecture within the CLEV-R environment.

clicking on objects and by their proximity to certain features. For example, a movie may start to play as a user approaches a media board or a user can change the current lecture slide by clicking a button. The virtual rooms, communication controls and user representations are detailed below.

#### 4.1. Communication Controls

The communication controls segment of the GUI provides the tools necessary for interaction with the environment and collaboration with other users. It is divided into a number of panels. The first panel on the left, gives personal information about the connected user and allows access to supporting help files ("User Information" in figure 2). The centre panel ("Text Chat Controls" and "Live Voice and Video Controls" in figure 2) is concerned with communication. A text-chat facility enables students to 'talk' to selected users or groups using text messages. This panel also facilitates video and voice communication where users can transmit live feed from their web cam or microphone to a selected location. The third panel lists other students currently in the environment, while the final panel provides a whiteboard. As there are a number of whiteboards in the 3D environment, the user

must specify on which whiteboard in the environment their drawing is to be placed.

#### 4.2. User Representation

Upon registering for a course each student and tutor is required to select a character to represent them in the VR environment. This 3D character, known as an avatar, is the user's on-screen persona for the duration of a course. The avatar, as shown in figure 3, can be personalised. For example, clothes and various hairstyles can be selected from a library of styles available to each user. This personalisation helps users recognise each other in the VR environment, as well as recognising users' individuality. Within the VR environment users can not only direct their avatar to different locations, they may also control their characters actions. For example, a student can direct their avatar to raise its hand to ask a question or even nod its head in agreement with a point that is being made. This form of interaction increases the sense of immersion and belonging felt by students while using the environment.

### 4.3. Lecture Room

The lecture room is at the heart of the university. This room facilitates synchronous learning and provides several features to enable a tutor to present learning material to a number of students simultaneously. A media board is provided, where the lecturer can upload both audio and video files (See figure 3). Where appropriate the lecturer also has the option of streaming live video of him or herself into the lecture room. This can be used for demonstrating more practical aspects of a course, or as a video conferencing tool for guest speakers. Lecture slides, such as powerpoint presentations as well as notes can also be displayed. The tutor controls the slide show and when the tutor changes the current slide, it is changed in the worlds of all connected students. The tutor can also use the streaming audio facility to provide live audio commentary to accompany the presentation and address any questions raised by students. The lecture room also contains a whiteboard where the tutor can demonstrate certain points or make notes for the class to see.

### 4.4. Meeting Rooms

As one of the main focuses of CLEV-R is collaboration, it is very important to provide an area for this collaboration to take place. While the entire environment can be used for collaboration, designated areas of the environment provide additional functionality for groups of students to meet and work together. The meeting rooms provide a similar set of tools found in the lecture room. Students can use audio and text messages to communicate their ideas with each other. A round table allows students to upload their own material to the room for discussion. Each student can bring slide-shows, animations and media clips to the table for discussion and viewing by the entire group. Again live video can also be streamed into this room via a student's web cam if it is felt it will aid with the discussion.

### 4.5. Social Rooms and Common Area

Social interaction is a key component of CLEV-R and to this end nominated areas of the 3D university have been designed for social interaction. While students can use these areas to discuss the course they are attending, they can also use them for social purposes. In a similar way to the meeting rooms, small numbers of students can gather together to share their experiences and stories as well as photos, pictures and movies. A centrally located courtyard serves as a common area; its role is primarily social. It is an informal setting in which students can chat and build rapport with others. Here users can talk informally about the course material. Students can display their project work on special notice boards, which are provided; others can then peruse these posters at their own pace. Students can place ads for upcoming events, items for sale and so on, in designated areas provided in this common area.

### 5. Mobile CLEV-R

Mobile devices are becoming more and more widespread and so we are exploring the use of these devices in education. The use of mobile or wireless devices is termed mLearning within the research community and much work is currently being carried out to determine the effectiveness of these devices for education [MLe05], [Mob05]. We are developing a mobile version of CLEV-R that will provide "anytime-anywhere" access to learning resources. We feel that this will provide the opportunity for people on the move to work through course material and to communicate with course tutors and other users in real time when they cannot be stationed at a fixed location. mCLEV-R will be especially useful for revision and will be of great benefit for users on their way to an examination in particular.



Figure 4: The 3D Graphics on a PDA.

Mobile devices have certain limitations when it comes to developing any application for them. Small screen sizes with low resolution make it difficult to ensure an application looks well and displays all necessary information. Limited memory for running applications and also for storage means applications need to be light weight. Their inexpensive and convenient nature however, makes them the ideal target for a learning application and once mCLEV-R has been developed we feel it will be of great benefit to any mobile user.

In a system like CLEV-R where mobile devices such as Personal Digital Assistants (PDAs) connect to a server and deal with transfers of lots of different sorts of information, a new thin-client version needs to be developed. This new version will provide a subset of the functionality available in the full-scale system. We envisage mobile students accessing

course material, chatting with other users of CLEV-R and attending online lectures. However, their interactivity with the system will be somewhat restricted. They will not be able to fully participate in interactive group meetings nor will they experience movie files from lectures or live camera feeds from within the VR world. They may however, download these files to their device using links from the 3D environment and then display them using a relevant application.

In the desktop version of CLEV-R, the EAI allows user interaction with the 3D environment and dynamic changes in VR world content to take place. These classes are currently not supported for mobile devices however Parallelgraphics offer an alternative through the VRML automation [Aut05]. This set of interfaces allow an external environment to access and manipulate objects in a VRML scene loaded in Cortona and so we plan to explore its use for the mobile version of the system.

As shown in figure 4, a scaled down version of the 3D environment has been developed for mobile devices. Presently, this environment is displayed using the pocket Cortona VRML plug-in provided by ParallelGraphics [PG005]. Learning material can be displayed on presentation boards and mobile users are aware of all other connected users of the system. They can currently communicate with these through a text-chat facility.

## 6. Optimising Graphics

We aim to make our system available to users with both broadband and dial-up modem connections. In order to ensure that the system runs with greatest efficiency for all connection types, the 3D graphics can be optimised. Firstly, we can ensure that the 3D VRML environment is developed optimally. For example, complicated objects and textures that may achieve a great sense of realism and prove attractive for a user connected via broadband would prove time-wasting and painstaking for a dial-up modem user to download. These complicated structures can be simplified greatly for the users with a lesser connection speed by specifying different Levels Of Detail (LOD) for the object and using VRML's switch node or could indeed be removed altogether. LOD allows us to specify varying degrees of detail depending on how close or far from the object we are [ANM96]. The switch node allows us to decide at runtime which object version should be downloaded and built in the client's browser. VRML also provides visibility and proximity sensors which can limit complex animations from occurring. Visibility sensors can be used to only activate an animation if it is happening in line of sight from the user, while proximity sensors can trigger animations when the user is close by.

Another method of providing greater efficiency is to limit the amount of graphical information sent to the clients. Only parts of the 3D environment visible to the user at any one

time need to be downloaded and rendered. By spreading out the download and rendering of the environment across the users learning session, they can begin their learning experience much sooner than if the whole 3D environment was downloaded on connection. Also it saves the user from downloading parts of the environment that they never use. This is particularly beneficial for users using a dial-up modem to connect since the download and rendering of the 3D world causes a bottleneck for these clients. Much previous work has been carried out in relation to the distribution of large VRML datasets on the Internet [BC05], [ZBR04].

A VRML file defines a scene graph of all the objects in the 3D world. Parent nodes are defined and other objects that are dependent on them are referred to as child nodes. For example, the position of a presentation board in a lecture room would be dependent on the location and orientation of that room. This scene graph structure can be stored in a database and can be sent out to a user in different segments. The Potential Visibility Set (PVS) of an object in the 3D environment is a set of all other visible objects from any given position. It must also be stored so that no gaping holes are displayed in the 3D model.

The optimising module of CLEV-R is responsible for querying this database to see what objects are currently in view. It must first calculate the view frustum of the client and then query the database for objects in this space. Use of bounding boxes together with the scene graph structure in the database makes this querying process efficient. If the bounding box of a particular parent node is nowhere in the current field of view, then none of its children will be either and so these nodes do not need to be checked. The result set from this query will contain all objects in the current view frustum and will be sent for display in the client's browser. Shapes that are no longer in view will be removed and marked as "not downloaded" in the database for future queries. Use of proximity sensors in the VRML world can increase efficiency of this technique by forewarning the server when a user is about to move to a new room for example. The optimising module can begin to query the database for objects in the new location before they are requested.

## 7. Evaluation

Final preparations are now taking place to begin user trials and an evaluation. The target users for the first trial have been selected from students within a university. The trial will involve users accessing the CLEV-R system and attending a number of synchronous lectures. Students will also be given group tasks and projects to do using the tools provided in the CLEV-R environment. After completing the course, students will be required to complete a questionnaire, a segment of which is shown in fig 5. The results of this will identify problem areas both from a technical and usability point of view.

This study will also highlight additional features that may

<b>Question 11 Personal File Share/Personal File Upload</b>				
<b>A. Did you use the upload facility for personal files such as audio or picture files?</b>				
YES/NO				
<b>B. Please rate the usefulness of this facility</b>				
1	2	3	4	5
<b>C. How many people viewed your files?</b>				
1	2	3	4	>5
<b>D. Please state in how many sessions you used this tool?</b>				
1-3	4-6	7-10	>10	
<b>E. Did anyone else share personal files with you?</b>				
YES/NO				
<b>Question 12 File Share/Personal File Upload</b>				
<b>A. Did you use the upload facility to share and display course material such as power point slides?</b>				
YES/NO				

Figure 5: Excerpt from evaluation questionnaire for CLEV-R.

be added to the CLEV-R system. A further facet of the study will entail students undertaking a similar course with similar tasks in a traditional text based learning system. This comparative study will yield some interesting feedback with regards to the true benefits of CLEV-R over traditional learning systems. These preliminary evaluations will pave the way for a full scale evaluation at a later date. In addition to the measures outlined above, the full scale evaluation will involve splitting a group of test users; half will par-take in a course using a traditional e-learning system while the others will do the same course using the CLEV-R system. A common exam at the end of the courses will be given and the results from each group compared. These results should yield information about the educational value of using a VR environment for learning.

## 8. Conclusions

This paper described CLEV-R, an e-learning environment using VR. CLEV-R takes a novel and modern approach to address some of the issues and problems with existing e-learning systems. Each user, represented on screen by a character becomes immersed in a 3D university. Learning material is delivered through the medium of VR. On-line lectures are enhanced with the addition of multi-media, animations and live video. These enhancements help to stimulate and motivate students. Collaboration on group and project work is also possible using designated areas and special tools within the environment. CLEV-R recognises the importance of social learning and so provides various means for students to socialise and interact while using the VR environment. CLEV-R promises to improve the usability of online learning and enhance the students learning experience. To keep

up to date with new technology developments, we are also extending CLEV-R to mobile devices.

## 9. Future Work

The system is currently in its development phase. At present a prototype system has been developed and is ready for preliminary testing. Results from the first phase of user trials will be used to make any amendments necessary to improve performance and usability. Feedback regarding user representations and learning content within the VR environment will also be examined and suggestions about improvements to these will be evaluated. For example, some users may prefer to be represented in the environment by a live web cam stream rather than a 3D avatar. Future work in the development of CLEV-R will include continued research into mobile learning and implementation of a lightweight mobile client. Ensuring that the system runs efficiently is an important part of our work and so the optimising methods outlined above will be fully incorporated.

A further enhancement of CLEV-R is the use of Intelligent Software Agents (ISAs) as described in [MMBM05]. We have proposed the conceptual design of an agent-based architecture for CLEV-R; the agents monitor students, assist with carrying out everyday tasks and make recommendations about learning material. We are currently re-structuring our architecture to include intelligent agents. The use of ISAs will make the students time online more productive.

## 10. Acknowledgements

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