# Virtual Reality Laboratory for Distance Learning

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*Abstract*—**This paper describes authors' research in developing collaborative virtual reality classrooms for laboratory and distance learning. The proposed platform was developed to facilitate the implementation of virtual reality labs that can be used by students, locally or by remote access from any device.**

*Index Terms*—**Collaborative, distance learning, virtual reality, virtual worlds.**

## I. Introduction

The multi-user virtual environment (MUVE), also known as the virtual world or metaverse, is a 3D environment with a server-client architecture that enables a wide number of users to travel in the virtual space and to communicate synchronously. MUVEs were initially used to refer to multi-user video games, but the term has recently been expanded to include networking media and virtual communities.

The most well-known MUVE platform is Second Life, but similar platforms from the same generation are OpenSimulator, Project Wonderland and There. Despite the fact that technology has advanced significantly since Second Life's introduction, most organizations still continue to use it for distance learning due to the simplicity of creating and integrating the content.

As Kay and Fitzgerald (2008) [1] point out, Second Life simulations span a broad variety of practices, including computer programming using the Linden Lab (LSL), art and music programs, theatre and performing arts, teaching and practice, policy, commerce, architecture design and modeling, community planning, artificial intelligence and literature studies. This broad spectrum of practices was also supported by the Eduserv study (2008), which was based on feedback from educators from computer programming field and engineering field.

Online learning environments yield instructional outcomes that are superior to conventional classrooms, according to studies. Students in virtual classes spent 50% more time participating in groups than their peers in regular classes [2].

A research undertaken at Queensland University of Technology in Brisbane, Australia [2] illustrates how virtual environments are used in higher education in Australia and New Zealand. Automatic tutorials displays and exhibitions, interactive exhibits, role-playing games and simulations, historical and archeological reconstructions, treasure hunts and quests, cultural immersion for language learning, and creative writing are among the activities present in the virtual worlds created by developers. The simulations cover a wide range of disciplines, including early childhood education, in areas including physiotherapy, public health, health care, pharmacy (Fig.3), nutrition, health, medicine, biotechnology, social work (Fig.1), occupational therapy, project management, journalism, construction, communications, community services, elderly care, arts, criminology, languages, multimedia and business.

Sports, interviews, guest workshops, reading events, gatherings, talks, thoughts, simulations, constructions, and scenarios and role-playing games (Fig.2) are just a few of the activities. The educators are collaborating with other universities through interactive seminars, courses and virtual public relations offices when collaborating with students on design projects.

The results of a 2007 New Media Consortium study of Second Life educators (based on 209 responses) reveal some of the benefits and drawbacks of using Second Life for education. Because of the limited sample size of 209 respondents and the one-year study period in a constantly changing setting, these findings should be regarded as suggestive rather than definitive (NMC, 2007).

One-third of residents use multiple avatars, causing identification problems. Rich encounters, meeting new friends, widening networks, and group generosity were the most productive activities (45%), accompanied by "educational activities, teaching / learning in Second Life" (28%). The worst Second Life experiences were attributable to technological problems / use of Second Life (36%). 58 percent, on the other hand, said they were widening their professional network and collaborating further.

Fig. 1. Second Life Campus.

The use of role play for creative expression (65%), as well as scenario-based modeling and training exercises, were the most common responses when it came to Second Life's educational potential (57%). Only 29% thought Second Life had a lot of promise for teaching complete courses. Second

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Life is presented as a captivating and engaging site, rather than one that is straightforward to use or practical. The survey's findings also point to the need for appropriate mentoring and assistance with navigation as well as accessing and using audio and video. Built-in speech contact is feasible, which is essential for successful language learning, but the standard isn't perfect. Participant organizations are willing to adopt restrictive policies and procedures for platform users. These proposals would have a detrimental impact on the exchange of resources with other educators (the material would be closed), as well as the euphoria that characterizes so many Second Life experiences. The study's most cited positive points were the expression of imagination, the potential for teamwork it provides, and the strength of social presence.

Fig. 2. Role playing simulation.

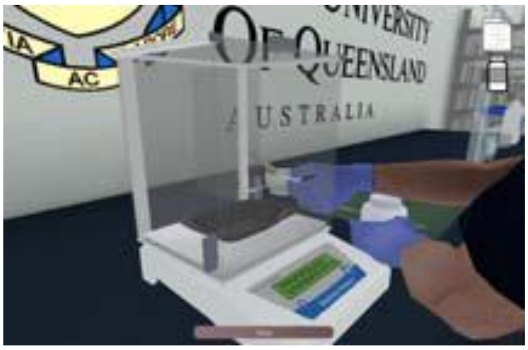

Fig. 3. Virtual lab at University of Queensland.

One of the features of Second Life is the ability to socialize using different egos [5]. This style of socialization will result in deep emotional bonds with the avatar, as well as a rich role-playing experience. For others, the diversity of cultures can be overwhelming, but it can also become a significant part of their lives. Avatars may also inspire people who are actually oppressed by society because of their physical presence or skills.

Usability issues caused by insufficient internet connectivity, hardware efficiency, and poor audio communication caused by latency are still some of the obstacles to using Second Life or other Unity-based virtual worlds.

## II. The 8agora Platform

In this research a novel approach was taken in order to implement a modern and feasible platform for distant learning.

The platform was developed to facilitate the implementation of virtual reality labs that can be used by students, locally or by remote access from any device (computer, tablet, smart TV or game console) (Fig. 4). The architecture of the application for MUVE is client server, multiple servers can be used for content, and from the client application installed on the laboratory computers it will be possible to access these servers preferentially depending on the desired applications. On each computer in the laboratory will be installed a remote desktop application, which will allow a remote access in a web browser, from any type of device, only by accessing the IP address of each computer in the laboratory. The remote desktop application will also stream bidirectional audio.

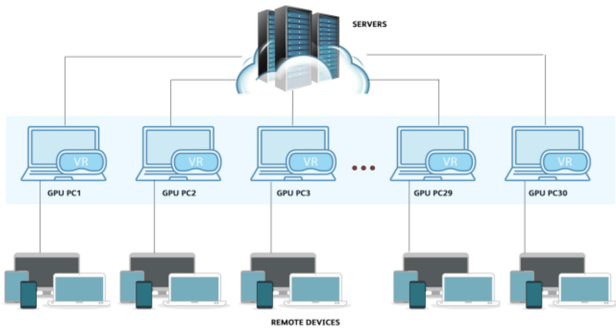


Fig. 4. VR laboratory architecture.

For the proposed MUVE the 8agora platform was used. The 8agora application was developed in C++ and have a large API library exposed to JavaScript, in this way one has a flexible and easy to extend platform. Supported script types are Client Entity Scripts, Interface Scripts, Avatar Scripts, Server Scripts and Assignment Client Scripts.

The content of a domain can be managed and edited directly from the client interface if the authenticated user has editing rights on the connected domain. From the editing interface (Fig. 5), the user can import 3D models, create 3D shapes, particles, web entities, zones, lights, texts, and materials. The 3D models can be imported in FBX, OBJ or GLTF format and can include baked animation. The models must be textured using PBR (physical based materials). To reduce the drawcalls (number of calls to the graphics API to draw objects), and improve the user experience, for complex objects it is better to use atlas textures and low poly meshes. The application includes a powerful physics engine to run simulations, based on Bullet (https://pybullet.org), which simulates collision detection, soft and rigid body dynamics. For each object can be defined physical parameters from the editing interface such as: grabbable, triggerable, cloneable, collides, dynamic, linear velocity, linear damping, angular velocity, angular damping, bounciness, friction, density, and gravity.

The objects can be locked/unlocked, hided/unhided, parented to a different object, and each entity can have assigned scripts and server-side scripts and can hold in json format different user preferences.

All kind of objects (3D models, images, java-scripts) can be hosted externally on different web servers and included in the simulation as a link or can be uploaded and stored on the domain server ATP (entity library).

The main advantage to store the assets on an external server is that you can use the same library on multiple domains for different simulations, the assets stored on the ATP, being visible only in that specific domain.

8agora include a low latency, high quality surround audio streaming application that allows a great immersive communication experience for users.

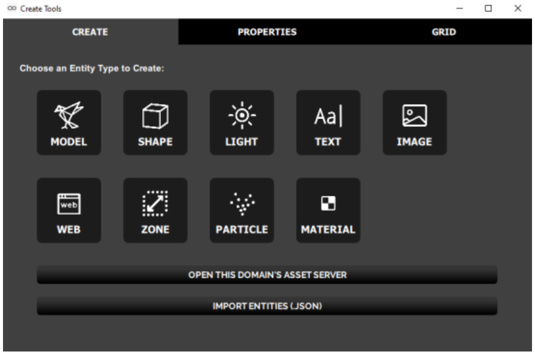


Fig. 5. Editing interface.

Fig. 6. Example of a conference 3D space.

In Fig. 6 is presented am example of a conference 3D space.

To enable proper teaching activity, several collaboration tools and applications have been developed and integrated (Fig.7), such as: text chat, video streaming, video conference, slide show, screen sharing, automated machine translation using text-to-speech, surveys, whiteboards, tele-prompts, web page display, automatic speech-based transcription, video sync presenter, a Wikipedia bot which are answering to student questions and a user activity monitoring system.

For the evaluation process a Quiz application was included which based on real time users' answers enlarge or shrink the student's avatars, in this way being possible to see their performance in a funny and interactive way.

An NPC (non-playable character) was also included as a bot, using speech to text, NLP and text to speech. This NPC can respond to students' questions and even to have a decent conversation on different topics such as general, philosophy, music, art, literature. Its knowledge base can be extended on demand.

The Text Chat program is written in JavaScript and Node.js, and it helps users to connect synchronously and asynchronously, as well as send and receive files, and it saves messages in a folder for later viewing. Based on web connections, the program will view interactive video material and images.

Video conferencing is a multi-user WebRTC-based JavaScript technology that enables audio-video collaboration between VR users or between VR and the real world. The software also helps you to share your screen and videos on YouTube and Vimeo.

Fig. 7. The presenter application interface.

A WebRTC JavaScript module that enables instant translation of up to 200 different languages using the Google API. The presenter would speak in his native language, with the translation serving as text for each recipient in their chosen language.

The WebRTC online broadcasting technology enables live streams in the virtual reality context, as well as broadcasts from the virtual reality environment to the Web and from the virtual reality environment to the outside world.

Screen sharing software that allows the user to view live PC displays in VR and link to a remote desktop.

The user tracking system tracks traffic, usernames, dates, access times, and instructional materials gathered in detail.

The slide show program helps users to import JPEG images and then play them on a large screen in a timed slideshow or manually using the previous and next buttons.

Since the simulation is run on the client side, a socket Node.js video synchronization program has been implemented to enable shared viewing of videos. This application records user experiences (video source shift, replay, pause, fast forward, scroll, jump to a particular frame) and transmits them to remote users. The videos seen in the simulation are thus synchronized across all participants, as if they were all watching the same display screen.

The GOTO application can be started from client interface, by pressing the GOTO button. When a user starts the client application, is redirected to a training zone, where information regarding the controls, navigation and functionalities are presented. If the user is not logged in, it will not be able to visit any domain. After authentication on the platform, with his credential, based on the whitelisted domains defined by the identity manager administrators, the GOTO menu will be populated with links to all these domains. By clicking on a link, the user is teleported to the specific location of that domain.

Fig. 8. The classroom.

The GOTO application includes other functionalities like enlisting users to a company, loading custom scripts for each user and loading the personal avatar of user. The application checks continuously the authentication status of the user and if the user is logged in, will request from the identity manager application based on username, all the specific data for the user like whitelisted domains, the list of custom scripts, the user's real name, if is guest, avatar mesh location.

Multiple simulations can be developed and exported from a server. The administrator can load different simulations on a server depending on the applications (fig. 8 and 9). Multiple domains servers can be also used and the users from the client applications can access each server from the GOTO application. A good practice will be to make all these archives of server content for different simulations available for other institutions, in this way the community shared content will help to achieve a higher level of adoption for this technology.

The users can use the GPU computers in the lab in VR (with glasses) or desktop mode, or they can connect to these computers from any device by a web based remote desktop application. This application installed on each GPU computer in the lab use the GPU to accelerate the video streaming of the desktop, also support the bidirectional low latency audio streaming and capture the user actions from keyboard and mouse. If the user is using a touch device (smartphone or tablet), a D-Pad script is automatically enabled and allows the navigation inside the platform using a touchscreen joystick.
Using all this tools, the teachers and students can be part to an immersive collaborative experience from remote places using modern pedagogical methods and gamification.

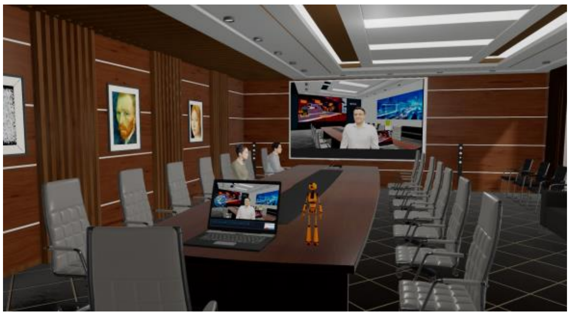

Fig. 9. The meeting room.

The 8agora platform allows rapid content development and easy action scripting, to create any kind of simulations for teaching purposes. However, to achieve the greatest learning experience there are some rules and guides that need to be taken in consideration.

## III. The Guidelines Used for Platform Design

Rules and guides considered during the platform design and development:

1) The visceral and relational mechanisms need not be ignored. To stimulate the initial desire and positive feelings the artistic intuition should be used.
2) To alleviate user dissatisfaction and improve user behavior, one should use both constructive and negative feedback.
3) Make sure consumers have an emotional reaction to the conclusion of a VR session because at the end this is what they are most likely to recall.
4) Make the user interfaces intuitive in order to grasp the nuances by using the simplest conceptual construct possible to obtain the desired outcome.
5) To assist the user in forming quality conceptual models and making explicit decisions, including practical prompts, suggestions, and constraints.
6) VR developers should be careful about the shades they choose, since haphazard color decisions may have unexpected implications.
7) To provide a sense of where the sound is coming from, combine binaural cues with head orientation.
8) When precise timing is critical, use music, and when precise position is critical, use visuals.
9) When creating worlds and experiences, consider personal space, action space, and perception space.
10) Important stimuli should not be held near the eyes.
11) Masking will allow the second stimulus to perceptually delete the previous stimulus if two items or sounds become too close together over time.
12) The order and pacing of events is very important. Changing the order may have a huge effect on the context.
13) Include enough distance cues and keep them aligned with one another to preserve height, form, and location constancy.
14) Users are unable to remember or recall incidents precisely because they are in their field of vision. To get someone's attention, use facts such as a vivid / vibrant object or a spatial sound.
15) Concentrate on cultivating and perfecting a wonderful, pleasurable, demanding and satisfying experience.
16) Instead of focusing on all the information, concentrate on conveying the story's main points. These key points should be always noted by the users. Their minds will fill in the blanks of their own tale for the non-essential points.
17) Use real-world metaphors to show people how to communicate and to explore the virtual world,.
18) Focus on intense feelings, deep engagement, huge stimulation and an escape from life to construct a convincing narrative.
19) Instead of focusing on technologies, concentrate on the experience.
20) Instead of focusing on photorealism, consider authenticity.
21) Reduce the complexity of the history and spatial geometry. The focus should be on fundamental geometry and interactive objects.
22) Make sure the scaling of the geometry is consistent. Include recognizable objects in normal sizes that are convenient for the user to view for practical encounters.
23) Color may be used to emphasize feelings. Bright colors that stand out will draw people. To show use or switch off use, change the color of such items.
24) To create a sense of reality and appearance, use ambient sound effects.
25) Use music to elicit feelings.
26) Place landmarks in strategic positions to assist users in preserving their position and navigational guidance in

the virtual world. To aid navigation, use visual railings.

27) Make it easier for users to customize their own avatars.
28) Use limits to add realism (do not let users walk through walls, for example).
29) When flying long distances or across continents, when reliability is important, or when motion sickness is a concern, use teleportation.

## IV. Conclusion

The implementation of e-Learning based on the 8agora platform was tested both using the computers in the laboratory and the remote connections on different devices and the user experience was exceptionally good. In the case of remote access, latencies in the range of 40-95 milliseconds were noted, depending on the internet connections from different providers, including 4G networks. Such latency makes sound delays and the interface's response to user commands almost imperceptible.

By using the tools integrated in the platform for collaborative work and content sharing, it was possible for a wide variety of courses on different topics to be held exclusively in the virtual environment.

As future research is intended to integrate hardware accelerators for remote streaming based on NXP processors. These accelerators will allow an even better user experience in case of remote access.

It is also planned to design and build a dedicated hardware platform for such simulations, based on AMD Ryzen processors, which will have a low price and will allow the use of the platform at maximum quality.

## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

All authors had equal contributions in: the literature review, analyzing the data, writing the paper and approving the final version.

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