Overview of virtual worlds usage for student engagement

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ABSTRACT
This paper presents an overview of 3D virtual world systems used by universities around the world to increase student engagement. Using publicly available information from the universities websites, we classified the virtual world systems they have deployed according to the type of technology used, availability and level of immersion. Using this classification, we provide a high-level view of the currently used systems and the expectations set for them by their target audience, students and prospective students. The purpose of this paper is to analyse the state of the art in the field of virtual world systems used in universities, as a start point for further improvements in this field. We also present a set of emerging technologies used in this context: augmented world through personal smartphones and virtual reality helmets.

Author Keywords
Virtual worlds; education; student engagement

ACM Classification Keywords
H.5.1. Information interfaces and presentation: Multimedia Information Systems.

General Terms
Experimentation; Human Factors; Design;

INTRODUCTION

Over the last decades, 3D virtual world systems have evolved from crude simulations to full immersive experiences. With their increased popularity among young people and the appearance of affordable devices (personal computers and smartphones) that can render them, universities around the world are using 3D world simulations to increase student engagement.

Virtual world systems are 3D simulated worlds rendered on a screen using a computing device, video games representing the most common example. They range from simple, where the user can see panorama style pictures from fixed locations but cannot move through the world, to complex, in which the user can navigate through a fully simulated 3D environment.

The universities most commonly use these simulations for three purposes:

- **presentational**, by showing the campus and associated facilities to prospective students, for example in 3D virtual tours;
- **social**, as an online hub for students to communicate, for example multiplayer campus simulations where the students can post messages;
- **educational**, by simulating learning materials and experiments, for example interactive 3D courses;

History

The first virtual campus simulator used by a university was the one developed by the Nanyang Technological University in Singapore (NTU) since 1997 [1]. The system is no longer maintained, but at its appearance, it featured a full 3D simulation of the university campus and also interactive lessons for 3D modelling.

This system appears to be ahead of its time, as no other similar offerings have been developed until 2009 at other Asian universities [2], [3] and [4].

Because of high costs of development and maintenance, these types of fully immersive systems did not become widespread. As such, most public facing virtual world systems currently deployed by universities are 3D virtual tours available online [5], [6] and [7]. These tours are limited in scope and have lower production costs, as they only show 360-degree pictures and videos of the campus from fixed locations.

With the improvement of frameworks for developing 3D applications like Unity 5 [8] and Unreal Engine 4 [9] that allow the creation of fully immersive environments at much lower production costs, it is possible that improved campus simulations will be available in the near future.

In contrast to virtual campuses, 3D courses had a linear progress. Currently this type of courses are widely available and cover a variety of subjects, like DNA simulation [10] and surgery [11]. In addition, dedicated platforms exist to facilitate the development of 3D virtual classrooms [12].

CLASIFICATION OF VIRTUAL WORLD SYSTEMS

Considering student engagement, virtual world systems can be classified based on three characteristics:

- Used technology
- Availability
- Immersion

Type of technology

Developers have two options for simulating 3D worlds: static images/videos or interactive simulated 3D environments.

Static images and videos are made using a technique known as 360-degree spherical photography or virtual reality photography. Until recently, this procedure required expensive panoramic cameras, but with the appearance of digital cameras, a process known as "stitching" can be used, which uses multiple rectangular pictures and algorithmically unifies them to a single panorama [13].

Figure 1. 360-degree spherical photo projected on a flat surface

Users can view the produced 360-degree photo using any device, through a browser or a specialized application. One popular service that uses this technique is the Street View from Google Maps [31].

Interactive 3D environments are most commonly associated with video games. They use 3D models, textures and animations to render a virtual world on the user's screen.

Figure 2. Rendered 3D environment [16]

Creating 3D environments is usually more expensive than 360-degree photos or videos, as a team of artists has to create every required asset manually.

Through a technique known as photogrammetry, real objects can be used to generate 3D models and textures. This is especially useful for simulating places from the real world which are typically very difficult (time consuming and expensive) to model.

Availability

Availability refers to how easily users can access the virtual world and in general refers to the hardware, software and time requirements of the product.

From a **hardware** perspective, a system that can run on more devices is considered more available. 360-degree photographs can be rendered on any device and have low requirements. Interactive 3D worlds, on the other hand, need resources proportional to their visual fidelity. Displaying a realistic 3D environment needs much more computing power than displaying a single photograph.

From a **software** perspective, a system is considered widely available if it does not need the installation of additional software packages.

Web applications are a type of widely available software. A user only needs to access an URL in a browser and is instantly able to use their functionality.

Because of their low computing requirements, 360-degree pictures are readily accessible online.

Virtual 3D environments can also be made available online, but rendering them through a browser increases their already high requirements, as the browser abstracts underlying hardware and makes it harder for applications to use native instructions.

In recent years, this problem was alleviated through the introduction and improvement of WebGL [14], which allows applications to use the graphical pipeline available on hardware systems in direct manner. Also in this direction, WebAssembly [15] will help increase the performance of web applications with high computing requirements, but this is still a work in progress.

In general, rendering 3D environments requires installing software on the user's device. This process can be facilitated through software installers, like application stores.

Immersion

Immersion refers to the deep mental involvement of an individual in an activity [25].

Regarding virtual words, immersion denotes the system's ability to captivate the user, through both realism and interaction.

Realism is achieved mainly through visual and audio stimuli. It is not necessary for a virtual world to reproduce the real world in order for be immersive, but rather it has to be realistic and consistent. For example, 3D environments should not change the color palette very often, as an abrupt

change from bright colors to dark colors will break the user's immersion. Consistency is also important for sounds. Immersion can be broken if the same object makes different sounds in similar contexts.

In a 3D environment, a user can walk and interact with the surrounding elements. This creates immersion by allowing free exploration. Depending on the amount and quality of the available interactions, the system can become more immersive. Multi-user systems allow a multitude of interactions and this is the reason they are generally more attractive.

Exploring a 360-degree photo or a video is less interactive, mostly because of the restricted movement and underlying technology and as a result, these systems are less immersive.

Relationships between classification characteristics

Type of technology	Availability	Immersion
360-degree photos and videos	High (Easily available online)	Low to Medium (Low number of possible interactions)
Single user 3D interactive environment	Medium to low (Can be available online)	Medium to High (Free movement and high number of interactions)
Multi-user 3D interactive environment	Low (Harder available online)	High (Free movement and very high number of interactions)

Table 1. Availability and immersion based on type of technology used

EXAMPLES OF VIRTUAL WORLD SYSTEMS USED BY UNIVERSITIES

Virtual world systems deployed by universities generally fall into one of three broad categories:

- 3D virtual tours;
- 3D campus simulations;
- 3D courses;

Virtual 3D tours

Bonch-Bruevich Saint-Petersburg State University of Telecommunications Virtual Tour

This virtual tour [5] uses spherical photos and videos to help students and prospective students to explore the university's campus.

Most of the pictures are taken inside of the buildings and have a high resolution, enough to make small objects like electrical equipment easily distinguishable.

An interesting feature of this virtual tour is that it presents pictures taken in the laboratories and allows simple interactions with the objects inside them. For example, inside of the music laboratory, the user can click on instruments to make them play their specific sounds. This adds to a more interactive experience.

In addition, in some rooms, 2D videos that show students using them can be played, for example the fitness room. The videos look like being "projected" inside the room and rotate and scale accordingly as the user looks around the room.

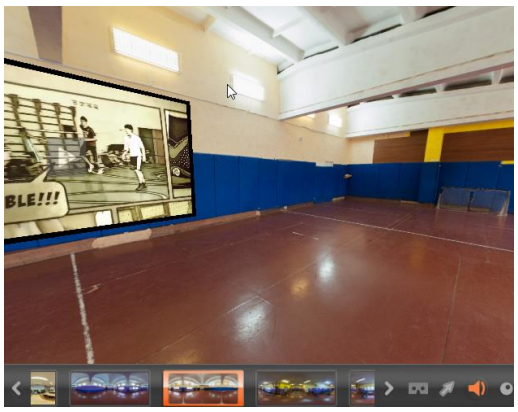

Figure 3. Saint-Petersburg University virtual tour interface with video being projected inside a 360-degree picture

None of the taken 360-degree pictures captures human activity. This helps with capturing high-resolution still pictures, but makes the experience less immersive.

The tour is made using the Kolor [17] platform, which helps creating panoramas, virtual tours and 360-degree videos.

Harvard University virtual tour

The Harvard University virtual tour [6] uses 2D pictures of various buildings and landmarks as a main feature of the experience.

This tour presents the entire Harvard campus, so unlike the previously presented one, it does not feature pictures of the student laboratories. Most pictures show outdoor places, except some that are taken inside large buildings, such as the student hall or the stadium.

Figure 4. Harvard University virtual tour interface with "virtual tour guide" on the right side.

The experience is centered on locations and the user's current location is displayed in a small map in the bottom left corner.

360-degree pictures and videos are also present, but are hidden away from the main interface. The user is noticed when such a view exists nearby his current location and he can open it in an overlay above the interface.

An interesting feature of this tour is the "virtual tour guide". This represents a cropped video of a Harvard student talking about the currently presented landmark, which adds to the user's immersion. The tour guide's narration is also displayed as scrolling text, which acts a subtitle.

As an augmentation to the online virtual tour, the users can download a virtual reality application to show the 360-degree pictures using a virtual reality helmet like Google Cardboard [18].

The application is powered by YouVisit.com [19], which helps creating virtual tours and 360-video presentations.

Eindhoven University of Technology virtual tour

The Eindhoven University of Technology virtual tour [7] is centered on 360-degree pictures of campus locations.

Unlike in the previous tours, in this one all the pictures feature human activity, as the application tries to immerse the user in the daily student life.

Some locations, for example parks, also feature sounds recorded near them, such as cars, birds and human voices, which also improves the user's immersion.

A "virtual tour guide" is also present in some areas as a student in the 360-degree picture, and the user can click on a "play" button to hear what the student is saying.

Videos are used prominently throughout the tour, as the user can click on various objects representing university projects or activities and see a detailed video about them.

Figure 5. Eindhoven University of Technology virtual tour displaying a "virtual tour guide" (female student) integrated in the 360-degree picture. The "Play" displays a video about the presented vehicle.

Probably the most interesting part of this tour is a 360-degree video of the 2016 inauguration. The user can see in first person how the students are entering the hall, and the dean giving a presentation for them. Although the experience is not interactive, it is engrossing, especially since during the video a student "talks" to the user, creating a feeling of presence.

This tour is developed by the university without using a third-party platform.

3D campus simulations

Virtual Campus of the Nanyang Technological University of Singapore

The Nanyang Technological University of Singapore virtual campus [1] is the first of its kind. It was developed starting with 1997 by the team of Associate Professor Alexei Sourin.

It featured a full 3D simulation of the university campus and interactive lessons for 3D modelling.

The system was implemented using the Virtual Reality Modelling Markup Language (VRML) [20], a standard file format for representing 3D interactive vector graphics. Web browsers supported this format at the time, using it to display complex 3D models.

The entire campus model is still available online and it can be explored using specialized software for rendering VRML files.

Figure 6. Nanyang Technological University of Singapore virtual campus. Snapshot of building interior.

3D UPB

The "3D UPB" project in an ongoing virtual campus simulation project at the Politehnica University of Bucharest [32].

The project was started in 2010, as an initiative to create a complex educational and social platform. It was designed as a Massively Multiplayer Online Game (MMOG) and was intended to be a real time replica the university's campus. The simulator is meant to be extensible, with added components such as social-learning, mobile learning and serious games [33], [36]. Also, it should be integrated with the web based e-learning platform used by the university [34].

The initial architecture for the project was based on the open source Open Simulator [35] platform as an application server, with a MySQL database for storage.

Since the development of Open Simulator has slowed down, the team behind 3D UPB is looking for alternatives, for example Unity 5 [8].

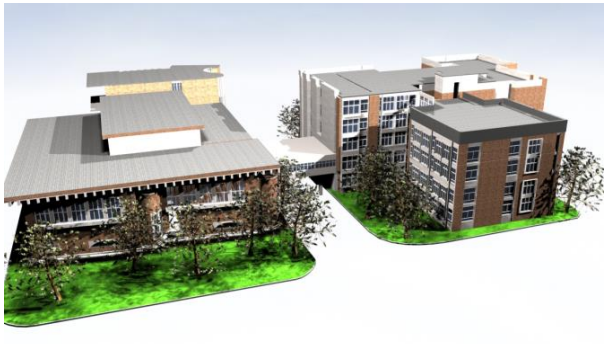

Figure 7. Render of the Faculty of Automatic Control and Computer Science buildings in 3D UPB

Virtual universities in Second Life

Second Life [21] is an online virtual world where users can socialize and interact with each other through their 3D virtual avatars. This application belongs to the massively multiplayer online role-playing game (MMORPG) genre.

At its peak, in 2013, this virtual world had 1 million regular users, but since then this number fell to about 500 thousand users. The large number of players inspired universities to build virtual campuses in this game, using the application's existing infrastructure to create "virtual social hubs" for their students [22].

The University of Hawaii built a virtual campus in 2010 [23]. The virtual space mimics the real university's campus but also uses some other unrealistic elements such as a space rocket museum.

Students have used as a social hub and as a place for 3D art exhibitions.

Figure 7. University of Hawaii virtual campus in Second Life.

Since Second Life as a platform lost much of its popularity, less students are currently using these virtual campuses but universities support them nonetheless.

3D courses

3D courses are widely available and cover a variety of subjects, like DNA simulation [8] and surgery [9].

Since some 3D courses can be used only in the universities laboratories, they can use the most advanced technology available.

A good example of this is the Bohemia Interactive Flight simulator, which puts the user in an actual cockpit, and uses a virtual reality helmet to render the 3D world and motion sensors to register the user input.

Figure 8. Student using a virtual reality flight simulator. [24]

EMERGING TECHNOLOGIES

Presently there are two main emerging technologies in the context of virtual worlds:

- Virtual reality
- Augmented reality

Virtual reality

Virtual reality is a computer-generated simulation of a three-dimensional image or environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment, such as a helmet with a screen inside or gloves fitted with sensors [26].

Recently two types of virtual reality devices became available to a wide audience:

- Expensive, high fidelity devices like the Oculus Rift [27]. These devices have their own high-resolution screen and display vivid 3D environments, typically video games.
- Affordable, low fidelity devices like Google Cardboard [18] (less than 50 dollars). These devices use a smartphone screen as a monitor and provide the necessary optics to make a head mounted display. They are useful for short virtual reality experiences, like 360-degree videos.

With the increased popularity of such devices, more users can experience virtual reality than ever before.

Among the presented virtual world systems used by the universities, only the one from Harvard [6] uses a form of virtual reality. The 360-degree images presented in the tour are also available in a smartphone application that can be used together with a Google Cardboard device.

We consider that in the near future more virtual world systems will use virtual reality devices, as they provide a high degree of immersion.

Augmented reality

Augmented reality is a technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view [28].

With this type of technology, developers can create parallel virtual worlds, for example video games where the users interact with real objects to see changes in the virtual environment.

Augmented reality is also used for educational purposes, as an informative overlay to the real world. A good example is the Star Chart [29] application, which shows a constellation map on top of a star system that the user is filming.

Figure 9. Star Chart application showing the Cygnus constellation [24]

Using augmented reality in university courses can increase student motivation [30], which is why we expect this type of courses to gain popularity.

CONCLUSIONS

Universities around the world use virtual worlds as a tool for student engagement.

The systems presented in this paper are successful at achieving one or more of their purposes: presentational, social and educational.

We consider that the presented virtual tours have proven useful for engaging prospective students, as they provide an easy way to see the university campus and surroundings.

Virtual worlds have not been as successful at engaging active students, as the cost of creating an immersive 3D environment that supports multiple users has been very high until recently. With the appearance of frameworks such as Unity 5 [8] and Unreal Engine 4 [9] that allow much lower production costs, we consider that improved campus simulations will be available in the next years.

Emerging technologies that increase user immersion, for example virtual and augmented reality, can also be approached for generating student engagement.

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