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WORLD OF PHYSICS

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Executive Summary

A research on the State of the Art in 3D Virtual Reality Worlds and frameworks is deemed very important for the work to be conducted in the scope of the World-of-Physics project. The aim of the report is to serve as an introduction to the 3D Virtual Worlds, tools and frameworks available, identify the strengths and weaknesses of each one of them and select the most appropriate one to be used within the World-of-Physics project.

List of abbreviations

Abbreviation	Definition
3DVW	Three Dimensional Virtual World
MMOW	Massively Multiplayer Online World
VW	Virtual World
VE	Virtual Environment
"in-world"	An action taking place within the 3D virtual world
NPC	Non-Player Character (aka Bot) is a computer controlled Avatar that can be programmed to have certain behaviour as part of a virtual world simulation or activity
IM	Instant Message (private message)
SL	Second Life
AW	Active Worlds
OS	OpenSimulator
OW	Open Wonderland
OC	Open Cobalt

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1. Introduction

A virtual world or massively multiplayer online world (MMOW) is a computer-based simulated environment in which many users create a personal avatar and simultaneously but independently explore the virtual environment and participate in various activities, as well as communicate with others.

A generally accepted definition of virtual world does not exist, but they do require that the world be persistent; in other words, the world must continue to exist even after a user exits the world, and user-made changes to the world should be preserved [2, 3]. While the interaction with other participants is done in real-time, time consistency is not always maintained in online virtual worlds.

Numerous 3D Virtual Worlds exist, aiming for various purposes, from socialization and leisure, to more formal approaches such as commercial and education oriented.

1.1. Definition

"A virtual world is a digital environment (usually graphical, usually 3D) completely delivered over the Internet or Intranet, where users are represented by Avatars, interact with each other, interact with and effect their environment in a persistent manner, have no more restrictions placed on them than they can expect in the real world, can decide from a wide range of actions, or even inaction, can build and create within the world, without having to master additional tools, can use the world for a wider variety of different purposes" [2].

Many definitions of VW exist in the literature, all of which have the following characteristics [3, 4]:

- Shared space between multiple users
- Graphical user interface – the virtual environment

- Real-time interaction between users
- Interaction with the virtual environment and with digital content within the virtual environment
- Persistence: it is guaranteed that the VW, its objects, as well as user interaction effects will exist even after the user has left the VW
- User communication through text and/or voice
- Networks of people formulate forming social groups
- User avatars: a digital representation controlled by a human in real time to interact within the VW
- Networked computers (servers) that manage all the data

2. Virtual Worlds and Education

The above characteristics of the 3DVWs could potentially transform these environments to "educational virtual environments". An "educational virtual environment" is defined as an environment that is based on a certain pedagogical model, incorporates or implies one or more didactic and learning objectives, provides users with experiences they would otherwise not be able to experience in the physical world (or in a classroom) and redounds specific learning outcomes [5].

Therefore, a growing interest in learning and teaching within 3DVWs is observed and a large number of schools and universities own such VWs for educational purposes, most of the times by projecting their campuses to the VW. 3D educational VWs are mostly used as safe simulation environments and virtual classrooms.

Compared to other e-learning technologies, 3DVWs use immersive 3D experiences, allowing the learner to freely wander through the learning environment, explore it, obtain sense of purpose, act, make mistakes, collaborate and communicate with other learners, and by that provide him/her with a full understanding of a situation [2]. The most important and unique features that 3DVW technologies offer is the sense of immersion, i.e. the impression of "actually being in there" and the sense of presence, i.e. the feeling that the person is an entity of the virtual world that interacts with other entities in the same way as in a real physical environment.

Moreover, the anthropomorphic avatars enhance the sense of presence. 3DVWs occupied by human-like avatars could enhance collaborative training activities such as games and simulations. In addition, immersion and interaction with virtual objects can enhance learners' interest and engagement to the learning tasks and help them to develop a stronger conceptual understanding, depending on the content [6, 7].

A very interesting statement however is that the simple use of highly immersive technologies alone could not be effective unless it is coupled to specific design strategies [8].

3. Virtual World Platforms

Virtual World platforms are the tools for creating highly immersive 3D interactive online environments that can be either replicas of existing physical places, or even imaginary places. They can represent places that are impossible to visit in real life due to restrictions such as cost or safety. There exist proprietary and open-source VW platforms. In the following of this section we will describe the most important and popular proprietary and open-source VW platforms.

3.1. Proprietary Platforms

3.1.1. Second Life

Second Life (SL) - www.secondlife.com (2003 by Linden Lab) is the most popular VW platform and the largest active community.

Figure 1: Second Life

Most important Features:

- 3D graphical environment
- Fully customizable avatars
- Built-in voice and text communication
- Includes a social network, groups, as well as information and object sharing
- Includes in-world virtual currency (Linden Dollars (L$): 2500L$=10.09USD
- Has an enormous market: users are able to build objects and goods and write scripts in-world
- Registration and basic usage is free but there is an option of paying a monthly fee for virtual land to build a home and become ‘residents’ (however, large building projects require the purchase of a large piece of private land - or an

island)

- Private land can be accessible only to specific group members
- Many learning organizations from all around the world are augmenting their current curriculum with virtual learning modules of SL, or even conductung classes and educational programs in SL

Figure 2: Second Life (Myths, Mystics and Elements of Nature, www.secondlife.com)

Architecture

- Client – Server
- Client or 'viewer': open-source, free, runs on many platforms
- Server: owned & hosted by Linden Lab

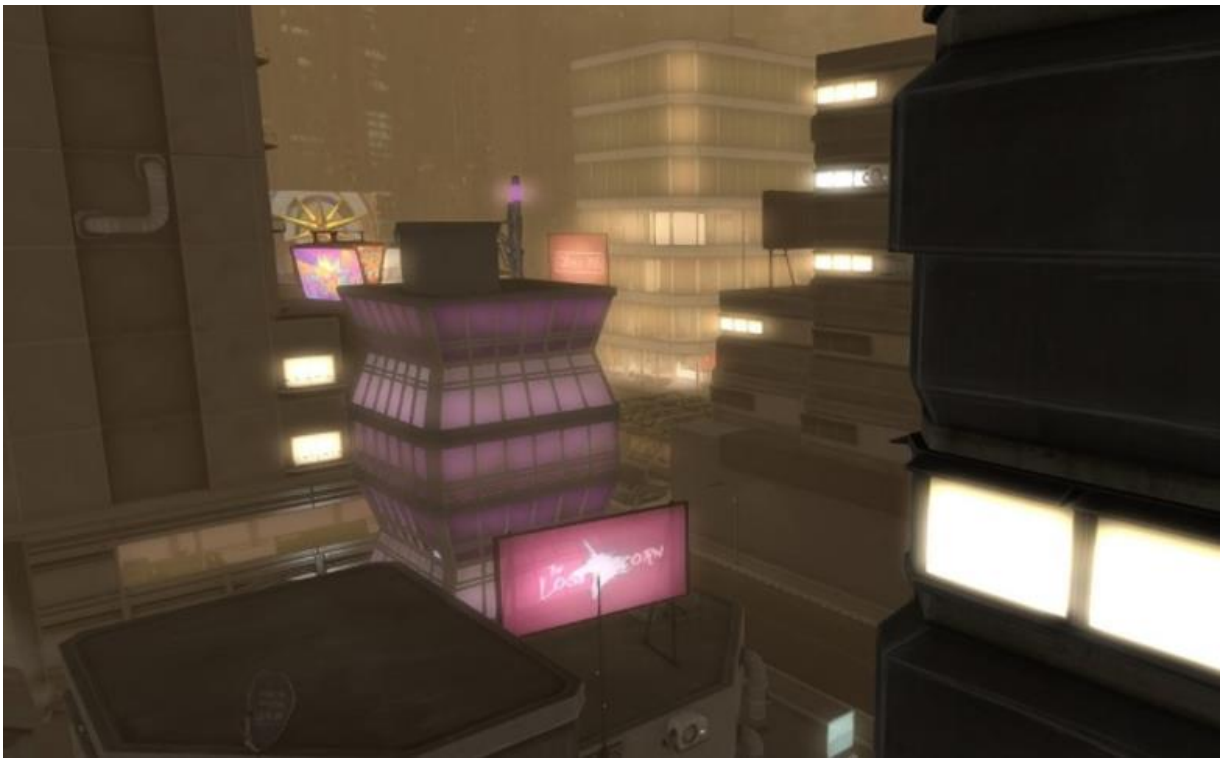

Figure 3: Second Life (SR Redemption, www.secondlife.com)

Technical Characteristics

- Physics engine: Havok 7,
- Communication methods: Vivox, Inc. built-in voice, text chat and IM
- In-world scripting: Linden Scripting Language (LSL)
- Built-in 3D building tool
- Fully customizable avatars
- Image, video, audio file upload
- Web pages and media on virtual objects
- Groups and full user profiles
- Region backup and upload for landowners
- In-world economy
- Restriction in access and building rights
- Terrain modification

- Head Up Displays (HUDs)

3.1.2. Active Worlds

Active Worlds - www.activeworlds.com (1997) is similar to SL in functionality. There is a “tourist account” for free usage, however paying a small monthly fee buys "citizenship": "citizens" have a unique name, unrestricted access to the VW, avatar customization, object building, access to social networking and communication features such as voice chat, Instant Messaging (IM) and file sharing.

Figure 4: Active Worlds

For more control and privacy over environments, private firewall-protected Universes

are available usually for enterprise and educational purposes. These Universes are separate worlds from the main world and their cost varies. A separate set of worlds and a community for educational projects with over 80 organizations also exists under the name “Active Worlds Educational Universe”.

Figure 5: Active Worlds, Horizon City (www.activeworlds.com)

Architecture

- Client – Server
- Client: free only for Windows
- Server: free for Windows & Linux

Figure 6: Active Worlds, Cobalt City (www.activeworlds.com)

Key Characteristics

- Physics engine: NVIDIA PhysX
- Support modeling programs (Truespace, Blender, Studio Max, Google Sketchup, Collada, etc) & import of custom created 3D models
- Library of over 6000 models
- Basic scripting system (for basic object interactivity)
- Active Worlds SDK (C/C++ and Visual Basic/COM versions), for development of in-world applications
- Built-in VOIP, text chat, IM
- File transfer
- Built-in 3D building tool
- Avatar customization
- Development of NPCs
- Heads-Up Display

- Office documents display tools
- Ability to restrict access and building rights

Figure 7: Active Worlds, Yeti City (www.activeworlds.com)

3.1.3. Jibe

Jibe - http://www.hypergridbusiness.com/2011/09/reactiongrid-tests-jibe-on-android-opensim-upgrade/ is a 3D VW developed by ReactionGrid Inc. An important aspect of Jibe is that the developed VWs can be embedded in webpages and accessed from mobile devices. VWs can either be either hosted by ReactionGrid Inc., or deployed on private servers. Jibe requires the installation of the Unity web plugin with Android and iOS support under development.

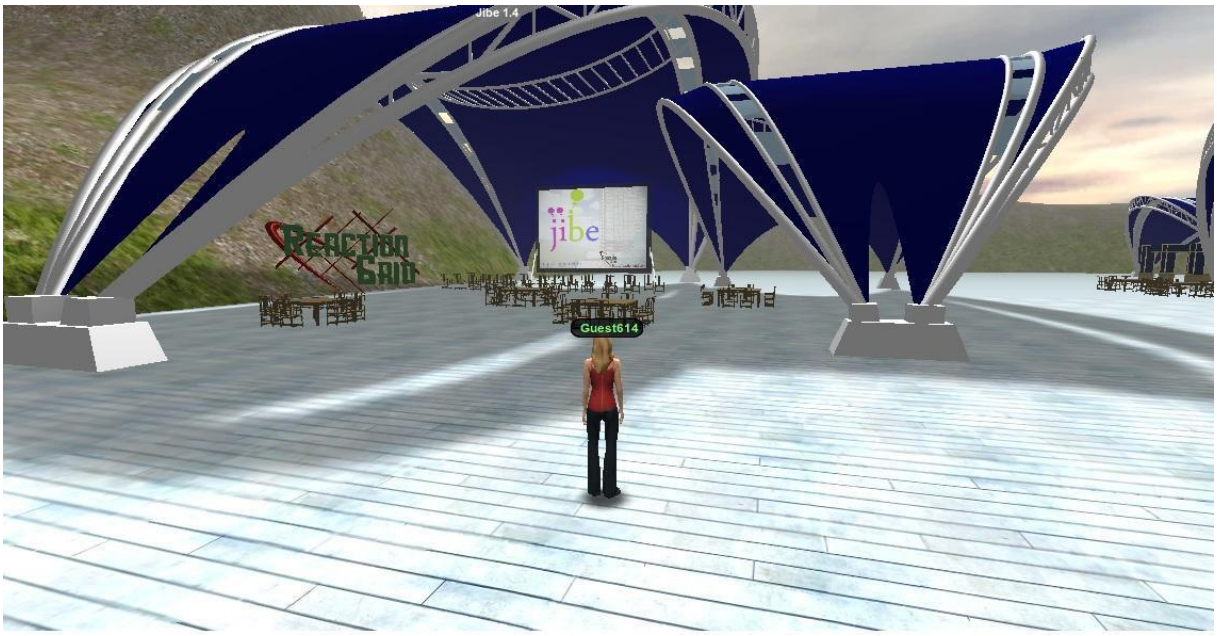

Figure 8: Jibe

The Unity 3D editor must be used to build a Jibe VW. The outcome is a professional development environment with professional quality graphics, physics and sound. Jibe supports creating 3D objects, as well as importing 3D models from Maya, Blender, and other platforms.

Architecture

- Frontend: Unity 3D
- Backend: SmartFox Server
- The exists a middleware layer for the communication between backend and frontend and user database communication

Key Characteristics

- Up to 100 concurrent users
- NVIDIA PhysX Physics Engine
- Free Unity 3D editor for world creation

- Scripting in C#, JavaScript or Boo for enabling object interactivity
- Web-plugin for browser based virtual worlds
- Windows and Mac standalone version
- Option to convert Jibe world into Android mobile app (additional charge)
- Group and private chat
- Import mesh files from Sketchup, Maya and more
- Sit, teleport scripts, animations
- Dynamic Slideshow System
- User Registration System with Database & Password Reset Forms
- In-world event tracking system - logins and in-world events are logged to a database
- Vivox Voice

3.1.4. Unity

Unity – unity3d.com/unity is not a VW platform; rather, it is a 3D professional game development tool which can also be used to create suitable training simulations and educational 3DVWs. It can be accessed through a client or a web based player.

Figure 9: Unity

Unity can be used to develop a game along with its user interface without the need to program. The development of single-player games/apps requires only to download and install Unity but the features and properties of the developed training environment depend mostly on the ability to use the content creation tools.

The Unity Asset Store is a Unity global marketplace which provides content such as character models, landscape painting tools, game creating tools, audio effects, visual programming solutions and scripts for free or low cost. Unity evolves with the latest mobile (iOS, Android), desktop (PC, Mac, Linux), Web (web player, Flash) and

console (Wii U, PS3, Xbox 360) technology.

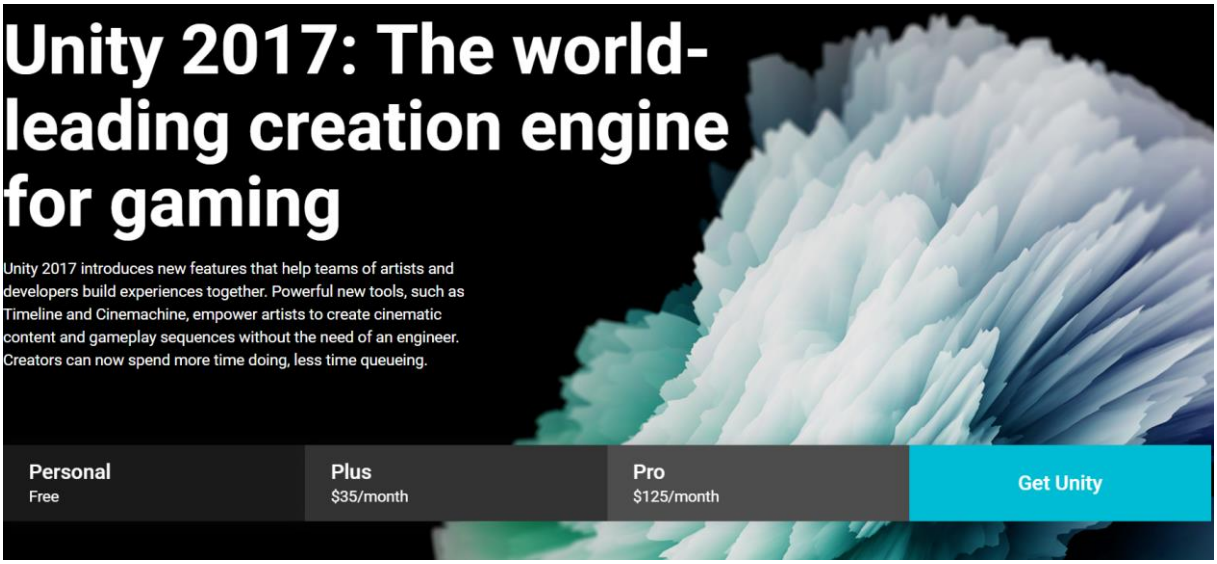

Figure 10: Unity Official Website (unity3d.com/unity)

Key Characteristics of the free version

- NVIDIA PhysX Physics Engine
- Audio 3D
- Multiplayer Networking
- Mechanim: complete animation system for characters and objects
- Professional graphics
- Single-Click game deployment to any platform
- Web-browser integration
- Scripting API (supports JavaScript, C# and Boo)

Figure 11: Unity (unity3d.com/unity)

3.2. Open-source Platforms

3.2.1. OpenSimulator

OpenSimulator, Opensim - www.opensimulator.org (2007) is a free, open-source, 3D application server for the development of multiuser 3DVWs. The VWs are accessible through various open source clients. Moreover, VWs can be private or public. OpenSimulator is based on C# and is easily extensible through external modules.

Figure 12: OpenSimulator

OpenSimulator's history is interesting: it started as an open source server to Linden Lab's Second Life open-source client. In this manner, the architecture of OpenSimulator is heavily influenced by that of Second Life, allowing the user to produce similar highly detailed 3D graphical environments at low cost, or at no cost provided that the hardware/software and the building/scripting/technical skills are offered for free. Furthermore, the avatars are fully customizable and resemble those of Second Life.

Figure 13: OpenSimulator (opensimulator.org)

The in-world communication is based on chat and IM. Free voice service with lip sync is currently provided by Vivox Inc., after request. An important feature of OpenSimulator is Hypergrid. Hypergrid is a protocol that allows hyperlinking between Opensim VWs and supports seamless avatar transfers among these worlds.

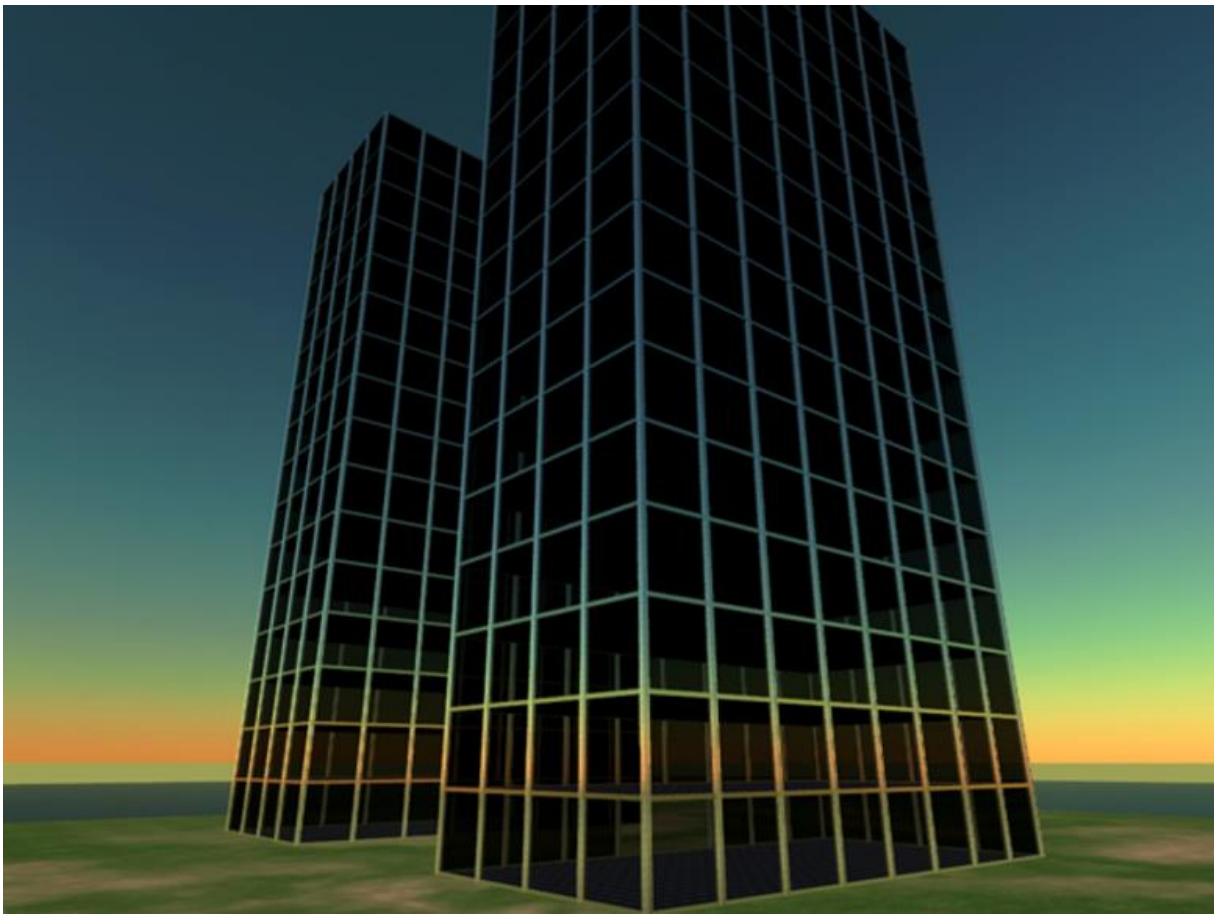

Figure 14: OpenSimulator (opensimulator.org)

The aforementioned and the freedom to anyone of owning, building and configuring the VW have made OpenSimulator quite popular among the educational and science community.

Figure 15: OpenSimulator (opensimulator.org)

Architecture

- Client – Server
- Client ('viewer'): open-source, multiplatform, free downloadable
- OpenSim Server: open-source, multiplatform, free downloadable

Figure 16: OpenSimulator (opensimulator.org)

Key Characteristics

- Physics engine: OpenDynamics (ODE)
- Text and IM communication in-world. Voice not built-in: through external free modules: Vivox, Freeswitch, Mumble
- In-world scripting: Linden Scripting Language (LSL), OpenSim Scripting Language (OSSL), C#
- Built-in 3D building tool
- Hypergrid protocol
- High quality fully customizable avatars
- Image, video, audio file upload (free)
- 3D COLLADA format meshes upload (free)

- Web pages and media on virtual objects
- Region and avatar inventory backup and upload
- Access and building rights restriction
- Groups and full user profiles
- Terrain modification
- Bots (or NPCs)
- Head Up Displays (HUDs)

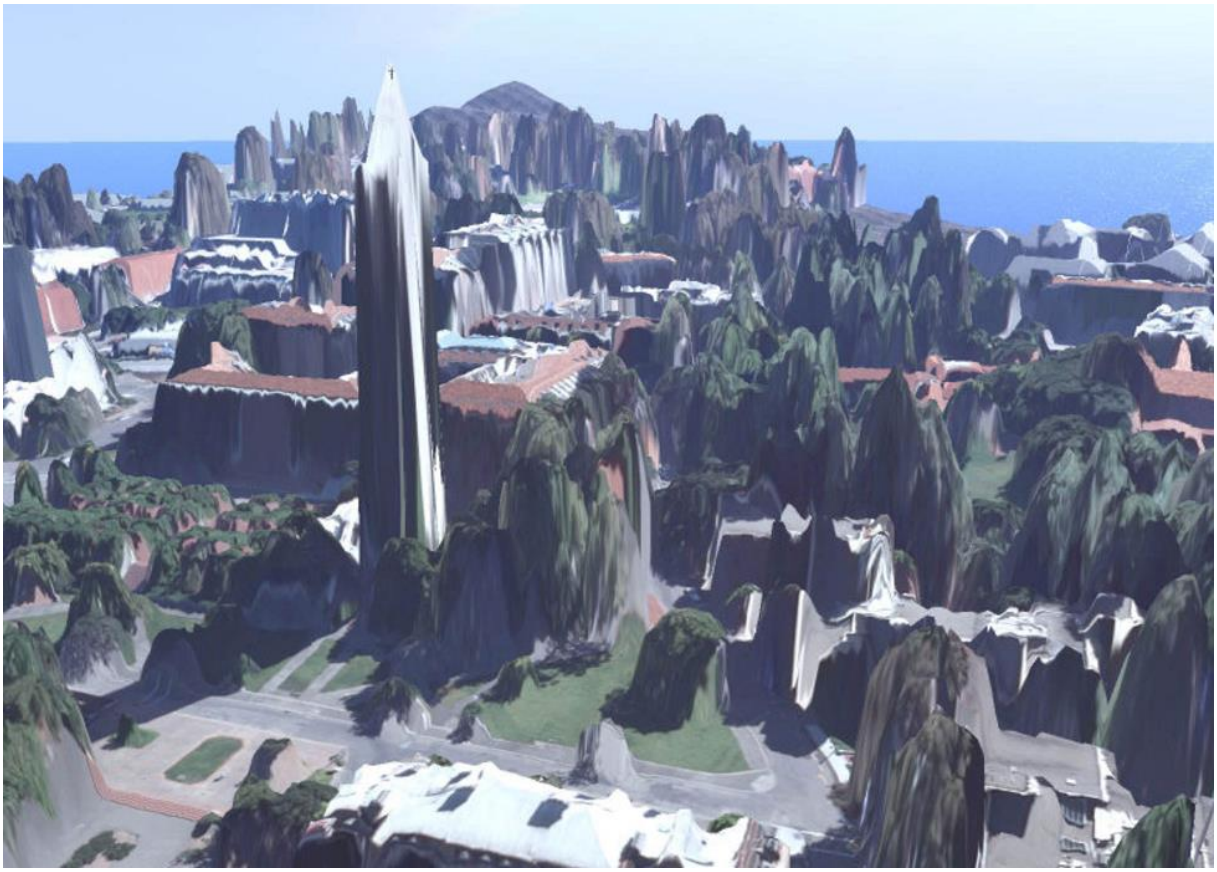

Figure 17: OpenSimulator (opensimulator.org)

3.2.2. OpenWonderland

OpenWonderland, OW - www.openwonderland.org is an open source Java toolkit for creating 3DVWs. OW is in early stages of development: the graphics are rather simplistic but other features of the platform are comprehensive. The toolkit allows the creation of modules that can extend the client or the server functionality-wise. Moreover, customized, special-purpose VWs can be created.

Figure 18: OpenWonderland

Examples of the external modules that have been created by different developers (can be found in Module Warehouse) are: Authentication system, webcam viewer, writable text/HTML poster, collaborative text editor, and more.

Figure 19: OpenWonderland

A distinct feature of Open Wonderland is easily embedding existing content. There is an enormous list of document types that can be dragged and dropped into the world. Moreover, any content within the Google 3D Warehouse can be imported. Open Wonderland does not offer in-world 3D building; 3D objects can be imported from Maya, Google SketchUp, Blender, etc.

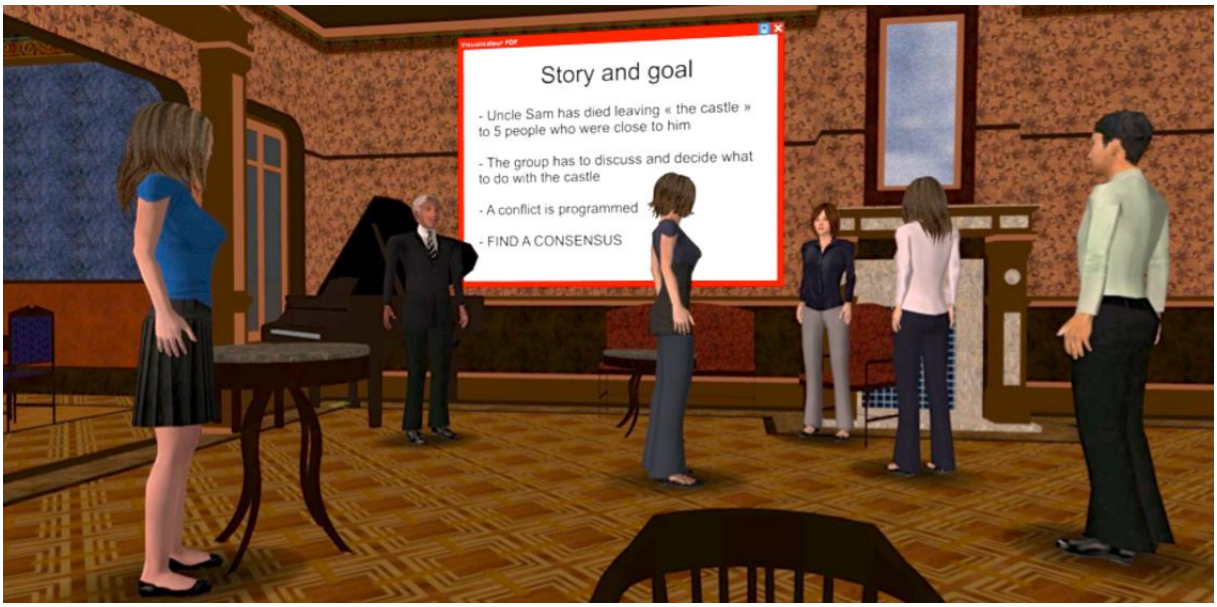

Figure 20: OpenWonderland (www.openwonderland.org)

Within OW Vws, users can communicate with high-fidelity, immersive audio, share live desktop applications and collaborate in an education or business context (simulations, meeting rooms, mixed-reality worlds, etc.).

Architecture

- Client – Server, both provided free, open-source

Key Characteristics

- Scripting in Javascript, PHP, Groovy, JRuby, Java, Jython
- In-world embed scripts in 3D models
- In-world run Open Office, Firefox, NetBeans, etc.
- Shared application framework (whiteboard, PDF viewer, sticky notes, etc.)
- Screen sharing
- Drag-and-drop content

- High quality immersive audio
- Telephone integration
- Webcam viewer, video player, audio recorder
- Group and private text chat, private voice chat
- Portals ("teleport") creation to locations on same server or on different servers
- LDAP plug-in for connecting to existing LDAP authentication systems

3.2.3. Open Cobalt

Open Cobalt, OC - www.opencobalt.net/ is an open source VW browser and toolkit for creating VWs. OC uses peer-to-peer architecture instead of the client-server schema. Peer-to-peer technology enables users to access OC VWs on LANs, intranets, or across the Internet without the need to access remote servers. In this manner anyone is able to host an OC VW for free.

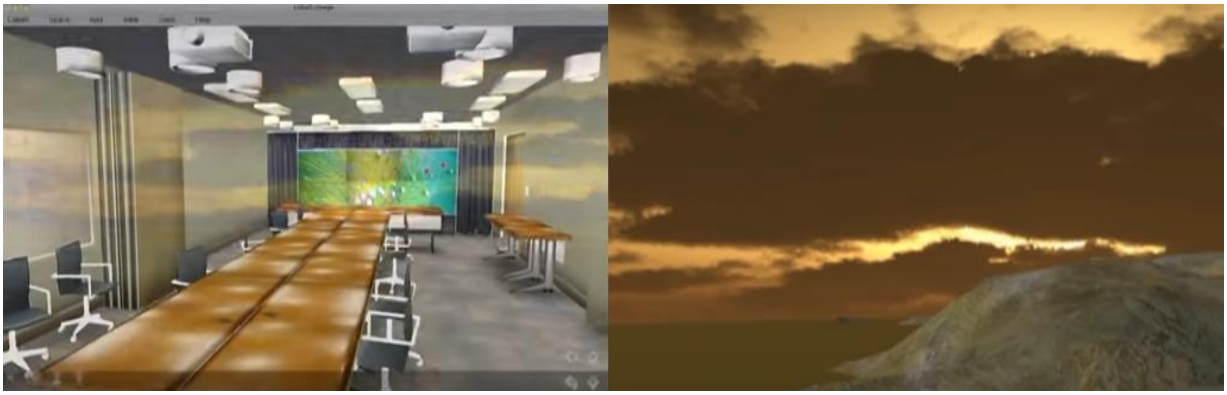

Figure 21: Open Cobalt

Open Cobalt‘s peer-to-peer technology through which interactions within VWs are conducted constitutes a great differentiation from other commercial multi-user VW platforms such as Second Life, where in-world interactions are done through central servers. The biggest advantage is that users of OC can set up VWs and interact with

other users without any hosting fees, licensing or virtual land lease costs.

Figure 22: Open Cobalt (http://www.opencobalt.net)

OC allows users to hyperlink their VWs and form large distributed networks of interconnected collaboration spaces. It also allows the set-up of public or private 3D virtual workspaces that feature integrated web browsing, voice chat, text chat, and access to remote desktop applications and services.

However, OC lacks 3D content creation tools in-world. It provides the infrastructure for world creation, navigation and collaboration, while it supports content created in open source applications such as Sketchup or Blender.

Architecture

- Client: Open Cobalt Browser (free and multiplatform)
- No Server: Peer-to-peer technology instead

Key Characteristics

- "Squeak" for in-world and system scripting

- Navigable 3D hyperlinking between virtual worlds
- Enterprise directory access (LDAP)
- Text chat, in-world voice chat (through VoIP)
- In-world web browsing (via VNC)
- In-world annotations (text and audio)
- Collaborative document sharing/editing
- Save/restore virtual worlds
- Access to remote applications (via VNC)
- Basic end-user content creation and editing
- 3D objects, mesh, texture, media (audio, videos) import
- Avatar selection from custom avatars

4. VW Platform for the World-of-Physics project

In the context of the World-of-Physics project, there is a need for a 3DVW environment and platform that will is technically mature, as well as immersive that provides a sense of presence to the users. Immersion and sense of presence do not only refer to the quality of graphics that must be high; they also refer to avatar personalization and easy, straightforward in-world interaction.

In addition, VWs used for educational purposes might need to include programming capabilities in order to provide interactive objects and special functionality such as bots (NPCs) that will be able to support the scenario requirements, as well as

mechanisms to track the user's performance and provide feedback and recommendations.

We have identified a number of VW platform selection criteria that are in accordance with the World-of-Physics project goals:

1. Cost-free and open-source
2. Allow the development of fully customizable and multiuser VWs to simulate various scenarios
3. Good system stability
4. Straightforward server configuration and parameterization in order to fully control the VW and the usage rights at will
5. Self-hosting possibility
6. Reasonable hardware and bandwidth requirements
7. User-friendly, free downloadable, multi-platform client software
8. High-quality 3D graphics and human-like fully customizable avatars to support immersion and sense of presence
9. The platform must be popular regarding educational projects, while a large, active and supportive community of developers should exist

Based on the first criterion, the platform of choice must be open-source and free. Based on the features and the functionality of the open-source platforms presented in Section 3 of this report, OpenSimulator seems to be the best option for World-of-Physics. OpenSim is more mature and fulfils all the aforementioned requirements. In addition, OS's compatibility to SL, the most popular 3D virtual world platform for educators worldwide, as well as its open and modular design, makes the OS platform ideal for educational institutions and enterprises that need to have full control and maximum flexibility on their 3D simulations, while the VWs offer graphics of similar quality to Second Life, similar functionality and similar building possibilities as Second

Life but with significantly reduced cost - or no cost at all.

Furthermore, there exist two very large and active educators' and developers' communities for OS, which is a major advantage especially for developers not so experienced in this field. Although OW and OC platforms present interesting features, they are still in earlier stages of development and evolve in slower rate in comparison to OS. They are also supported by smaller community of developers, especially the OC platform.

5. Client Software - Viewers

For 3DVW platforms that are based on a client-server architecture, such as OpenSimulator, a client software or Viewer is needed. The aim of the viewer is to handle the connection and communication with the server and offer to the user the appropriate interface to access the 3DVW environment.
A number of viewers exist for this purpose. The viewers below can be used with OpenSimulator [9] and are equipped with both a grid selector and a grid Manager, meaning that they enable selection between many grids, including a grid or region on localhost (local PC). There is also an appropriate user interface that allows modification or addition of connection settings to these grids.

- **Alchemy Viewer** (https://alchemyviewer.org/pages/about.html): Alchemy is an experimental Second Life™ viewer striving to be at the forefront of stability, performance, and technological advancement in the open-source metaverse

viewer field. It is always based on the latest release code from Linden Lab, and is currently in active development with new features, bug fixes, and performance optimizations.

- **Cool VL Viewer** (http://sldev.free.fr/) - the oldest of all actively maintained, OpenSimulator is fully supported: The Cool VL Viewer (formerly known as "Cool SL Viewer" is a third-party viewer for Second Life® and OpenSim grids. Cool VL Viewer focuses on high UI coherency from one version to the other while staying in sync with Linden Lab's official viewer features, high stability and reliability, and a high reactivity to new patches and bug fixes provided by the Open Source community. The Cool VL Viewer is also kept fully OpenSim-compatible.

- **Hippo Viewer** (http://hippo-opensim-viewer.soft112.com/): Hippo OpenSim Viewer is a free software application currently available in English and it was last updated on 2010-04-30. The program can be installed on Linux Vista WinXP. The Hippo OpenSim Viewer is a modified Second Life viewer, targeted at OpenSim users. It allows building up to a height of 10,000 m, scaling prims up to 256x256x256 m and other exciting features. More specific OpenSim features are under development.

- **Firestorm viewer** (http://www.firestormviewer.org/about/) is the most widely used viewer on Second Life. OpenSimulator is fully supported with its own version. Firestorm Viewer is based on the Linden Lab V3 LGPL code base and has an enormous number of features, options and interface customization choices, including a look similar to its predecessor Phoenix Viewer. Firestorm is developed for Windows, Linux and Mac OS X operating systems.

- **Kokua** (http://wiki.kokuaviewer.org/wiki/Kokua/Downloads): this viewer is for OpenSim grids. Features:

  - The Visual Outfit Browser will let you create, pick and manage outfits from a gallery

  - Media content is handled with the VLC plugin on Windows, while the macOS version still uses QuickTime

  - Media content on Linux remains with Gstreamer, but can be switched to VLC by editing skins/mime_types_linux.xml

  - You can upload and play back sounds of up to 60 seconds

  - The macOS version now use a gamma of 2.2 which improves tonal range of the scene.

  - You can test and adjust voice microphone and volume without an active session

  - Almost complete localization of the viewer to German

  - Added functionality in support of the OpenSim Export function

- **Radegast Metaverse** (http://radegast.org/wp/) Client Light-client based on the libopenmetaverae project. Opensimulator is fully supported.

- **Singularity** (http://www.singularityviewer.org/) - A Snowglobe-based viewer with many current features backported. The most widely used viewer for OpenSimulator. OpenSimulator is fully supported. The Singularity Viewer is an exciting client for Second Life and OpenSim. It engages the latest and greatest available technology and is compatible with future Second Life changes and features.
- **Lumiya viewer** (http://lumiyaviewer.com/) - A Second Life and OpenSimulator viewer for Android.

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