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Introducing VR technology for increasing the digitalization of SMEs

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Abstract: One main discipline of Industry 4.0 (I4.0) is Virtual Reality (VR), which could contribute to increase product quality, decrease design and production costs and reduce the time needed to go from product concept to production. However, most of VR deployments are not very familiar to SMEs. There are various software applications that could be used to create Virtual Environment with specific scenarios usable for training SMEs' employees. This article presents two main VR platforms for the realization of virtual environments suitable for training users in the operation of LPWAN in Industry 4.0 workplace. It presents the main technological aspects of Virtual Reality, the available technologies, their potential, and their limitations for supporting the VR developers in creating VR environments that produce reliable/feasible simulations of a specific use case scenario. It presents how promising is the adoption and realization of VR into Industry 4.0.

Keywords: Virtual Reality, SMEs, Industry 4.0, VR Use case Scenarios, VR Software Platforms.

1. INTRODUCTION

Virtual Reality (VR) has the ability to create and integrate all kinds of environment, and redesign, retest, and refine them in a virtual computer-based framework. Virtual Reality is the main discipline for introducing the visualization part of Industry 4.0. The scope of Industry 4.0 is to overlay a simulation on a real-time production line that can investigate any related phenomena. The use of Virtual reality for training and learning purposes (Matsas *et al.* 2018), (Hutabarat *et al.,* 2016), (Makarova *et al.,* 2015) and (Nemec *et al.,* 2017) has attracted great interest from the research community. Various VR deployments are proposed to help users complete specific tasks (Carruth, 2017), (Gamlin *et al.,* 2017), (Zhang *et al.,* 2017) and (Seth *et al.,* 2011). VR is the main discipline of Industry 4.0 that could provide new solutions and more efficient opportunities for a revolutionary new manufacturing training and simulation environment.

1.1 VR technology in SMEs

VR integration technologies are used for simulating the real world dynamically, and for pretending any physical presence in places in the real world, as well as in imaginary worlds, without the limitations of the real world (Gandhi *et al.,* 2018). VR is a helpful technology in achieving rapid understanding and decision-making by visualization and experience (Choi *et al.,* 2015). VR is not merely for visualisation purposes; instead, it offers improved methods of interaction especially in real engineering problems (Hamid *et al.,* 2014). Organisations invest in VR facilities because they consider VR as a strategic and well-defined approach for supporting them to make decisions in product design (Berg *et al.,* 2017). An SME can use VR technology for creating believable environments for effectively measuring people's decisions about realities that have yet to exist and for predicting future outcomes.

Gavish et al. utilized an experimental study and their results show that using VR for simulating training tasks can reduce the number of unsolved errors, and thereby their potential undesired consequences. They indicated that VR platforms have a significant advantage over the traditional training because of their focus on enhancing the cognitive understanding of the tasks (Gavish *et al.,* 2013). Darmoul et al. present a VR robotic cell and their study in shows that VR can save a lot of time and cost during product design and development, and it can provide a risk free and injury free environment for teaching and training (Darmoul *et al.*, 2015).

SMEs could adopt VR technology for utilizing evaluation and testing procedures (Buttner *et al.,* 2017). Furthermore, SMEs could use VR for simulating real-time movements so that to decrease the potential cost and risk of physical implementation (Liagkou *et al.,* 2018). SMEs could use a VR environment for training their employees and simulating safety scenarios that can minimize SME safety concerns (Gavish *et al.,* 2018), (McGrath *et al.,* 2017), and (Parlangeli *et al.,* 2000).

However, most of VR deployments are not so familiar to SMEs (Moeuf *et al.,* 2017). On the other hand, there are various software applications that could be used to create Virtual Environment with specific scenarios usable for training SMEs' employees in any new technology. One issue in adopting VR technology is the technical features of the available VR platforms such as OpenSim and Second Life VR (Christopoulos *et al.*, 2013). VR platforms can also be based on open software (Calvo *et al.*, 2017).

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1.2 Outline

In this work, the authors present the main VR technology's limitations for creating VR application environments, and present an exploitation of two basic VR software platforms for training users in the operation of a communication protocol. They asses the technical aspects of VR platforms for simulating realistic VR Wolds and gaining effective training results for the operation of Low-Power Wide-Area Network (LPWAN) in Industry 4.0 environment (Chatzigiannakis *et al.,* 2018).

The authors, based on a well-defined use case scenario (Liagkou *et al.,* 2018 a), implement it in two different VR platforms so that to illustrate the technological and implementation factors that have to be considered for building a VR simulation training environment. The scenario is implemented in two VR platforms, OpenSim (OpenSim, 2018) and Unity (Unity, 2018). Here, we demonstrate the major issues that have to consider for the integration of virtual reality applications into OpenSim or Unity and summarize the technology factors that have to manage in order to select one of the two VR training platforms.

2. VR PLATFOMS

There are various software platforms that SMEs could use to create Virtual Environments usable for training their employees in Industry 4.0 aspects. (Němec *et al.,* 2017). Unreal Engine 4 and Unity 3D are two main tools that have been used to develop VR Game like applications. Some other widely applied platforms for implementing and providing VR solutions are Second Life and OpenSim, which have been used for years to create virtual worlds for education and learning. Both OpenSim and Second Life platforms are easy to install and maintain (Christopoulos *et al.,* 2013). Second Life environment has been upgraded into a new platform named Sansar, which is able to provide improved immersion but it required higher computer requirements.

2.1 Technical Implementation of VR applications

Here, we are designing, developing and presenting the scenario by using the OpenSimulator and Unity 3D environment.

The first implementation is based on the OpenSimulator server, where the client uses the Firestorm viewer. We use OpenSimulator native tool to design and create the 3D objects. The developed scripts in VR Training environment are created by using the Linden Script Language (LSL). LSL is a native scripted language developed and used in the OpenSimulator server. The VR training environment can be accessed by a set of URLs in the virtual reality server, and when users click on the link at their browser they are teleported to the specific locations of VR environment.

The second Virtual reality application is built in WebGL Unity Project. The WebGL build option allows Unity to publish content as JavaScript programs that use HTML5 technologies and the WebGL rendering. Unfortunately, till today only a few web browsers support WebGL, and most of the mobile devices are not supported by Unity WebGL. Actually, Mozilla Firefox browser supports all the utilities of WebGL.

We created the 3D objects for the VR training environment via importing, the already created collada files, into the Project's asset. The VR training environment can be accessed by iframe and when users through the browser navigate on a VR training game. The developed scripts in VR Training environment are created in Unity Project by writing scripts in C# Language.

In general, Unity 3D application requires more coding compared to OpenSimulator application. Thus, creating a Unity VR application requires the collaboration of professional designers and programmers. Moreover, the user's computer requirements for both applications are similar. The OpenSim VR platform's performance is affected by network issues, thus there are required high bandwidth and little latency . Moreover, OpenSim's VR application performance is similar to simulator issues, like the number of scene objects, the number of textures, and the number of scripts. Unity application consists of assets in the Unity3d file that is delivered to the client, and it's a standalone, fully interactive environment, and has no simulation issues.

3. EVALUATION OF THE TWO VR TRAINING ENVIRONMENTS

The above briefly presented two platforms have been used to implement a 3D game/training environment for a specific case study. The case study under investigation is referred on how to learn and understand the security level for every action and the potential security flaws related to LPWAN protocol. Both training environments were designed in such a way that the user has to pass through different rooms/areas for concluding the 3D scenario.

In this work, the authors do not provide the detailed description of the implemented use case scenario but they study the main technology aspects of Unity and OpenSim VR platforms for helping an organisation to oversee the technical aspects, in order to build a VR simulation training environment adapted to its needs.

3.1 Scene Composition and Connection Issues

The basic difference between the two VR environments is the VR scene composition. In OpenSim application, the avatar can be teleported in various areas inside the VR environment. On the other hand, the Unity VR application is composed of individual scenes connected by teleport portals.

For any organisation who wants to implement an online accessible VR environment that would consist of several scenes, then the Unity could provide a better VR online experience, without latency issues. OpenSim's performance for a VR environment with a lot of scene objects, textures, and the number of scripts encourages network issues. In contrast, Unity could decompose the general scenario to several individual scenes for providing a more on-line stable VR experience. Unity can establish a decent connection with end users, since it only requires the installation of Unity 3D plugin and it is accessible via a URL, but this plug-in is not compatible with mobile operating systems. For a VR environment accessible via mobile users, then OpenSim has better compatibility.

3.2 VR Realistic Graphical Representation

The VR graphical representation in Unity has higher quality than the OpenSimulator application, because Unity's objects and animations are more realistic (see Figures 1 and 2). Moreover, Unity application uses physical laws, ragdoll animations, lighting factors, and audio. The two implemented VR training environments include a common visualized path, so that the user may be able to understand the basic security parameters of Lo-RaWAN network. The Unity VR application provides a more engaging VR experience to users, since it includes objects that interact with the avatar, and these objects are using physical laws, ragdoll animations, lighting factors, and audio. Figure 2 shows a VR scene where a user can construct a packet for sending it via LoRaWan, and the implemented scene has higher representation quality than the similar scene in OpenSim (Figure 1). Whendesiring a high quality graphical representation of VR environment, then, Unity has better realistic tools.

Fig.1. Packet Construction in OpenSim

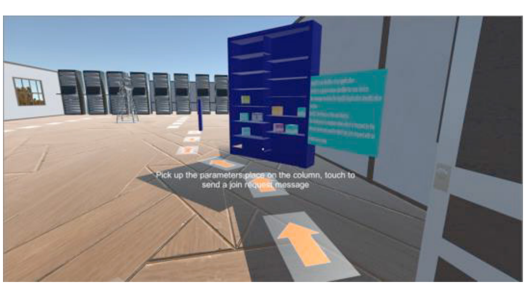

Fig. 2. Packet Construction in UnityGetting A Key

3.3 Usefulness

Unity application has a more user friendly VR environment, without confusing menus or keyboard commands or other distractions (see Figures 3 and 4). In case an SME needs to build a VR training environment for users that are not familiar with IT technology, then Unity could provide a more convenient VR environment for them.

Fig. 3. Sample Navigation Environment in Unity

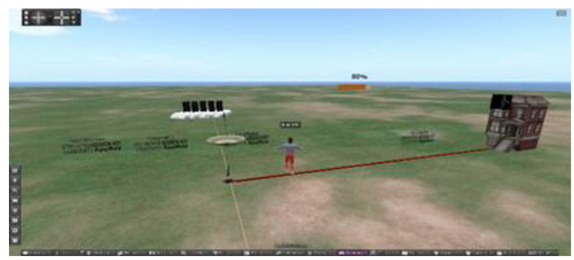

Fig. 4. Sample Navigation Environment in OpenSim

3.4 *Experiential VR Challenge*

In both VR applications the avatar can walk, talk, sit, chat, and interact with objects. In OpenSim application, the avatar interacts by clicking on the desired objects. Figure 5 shows the avatar constructing a package by clicking on the selected packages. In Unity application, the avatar can perform several actions on the animated objects, and it can also interact with other animated entities/characters. The packet construction in Unity application helps the user to understand what information is broadcast by LPWAN protocol for joining the network by using a more interactive and experimental experience, since the avatar can select, pick, and place the correct packages from a pile of packages (Figures 2 and 6). In both VR applications, the avatar constructs an encrypted packet in order to understand the use of each key for performing different actions, like encryption and sign.

Fig. 5. Selecting Objects in OpenSim

Fig. 6. Selecting Objects in Unity

Figure 7 visualizes how the generated keys are used to encrypt all further message payloads in OpenSim application. Figure 8 shows how the avatar, by walking in front of network components, is able to perform actions; e.g., key by checking the stump and unlocking the lock.

Fig. 7. Sending a Packet in OpenSim

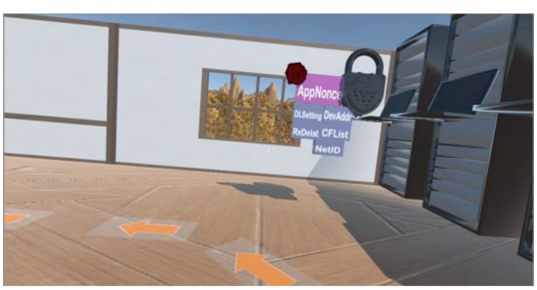

Fig. 8. Sending a Packet in Unity

Unity VR environment provides several actions to the avatar and simulates the real life scenarios in a more realistic way. A Unity user can unlock the encoded package by putting his graphical object of key into the lock and watching it being unlocked (Figure 9).

Fig.9. Unlocking the lock in Unity

Moreover, a Unity user can connect his device (i.e. a smartphone or a refrigerator) like he does in everyday life (Figure 10).

Figure 11 shows Unity's application avatar interacting with another character who steals a user's transmitted package, to illustrate the replay attack.

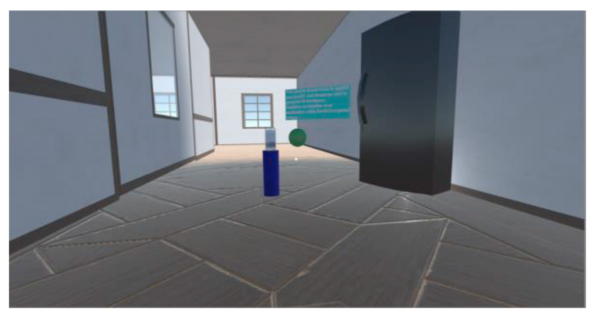

Fig. 10. Connecting a device in Unity VR application

Supposing that an SME wants to represent a use case scenario that needs various interactions with objects and with other characters, the Unity could provide a wider range of character actions and roles.

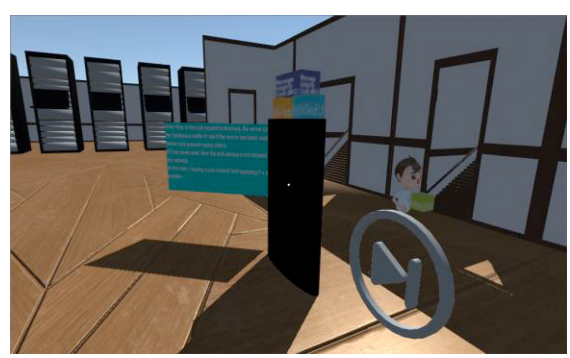

Fig. 11. Interacting with characters in Unity application

3.5 Multiplayer VR Environment

Here both applications utilize a single player VR training environment. If the SME would like to develop a multiplayer VR training environment for sharing collaborative experience of employees, then OpenSimulator could easily provide a multi-user shared collaborative environment. On the other hand, Unity requires extensive development, as it needs to add complementary features for that purpose. Furthermore, if an SME would like to run a simple VR training environment and not a full-featured multi-user shared collaborative environment, then the SME could just embed the Unity player on their website.

4. DISCUSSION AND CONCLUSIONS

Tables 1 and 2 summarize the main technology factors that an end-user such as an SME has to take into consideration in order to select one of the two VR training platforms.

The basic license is free and supports an unlimited number of users, depending of concurrent user connections on the server. The development of a specific use case scenario in OpenSim has lower cost than a Unity VR application, since OpenSim is an open source platform. However, Unity has a limited number of free 3D items that are available from the Google Warehouse or the online mesh stores, and a Unity developer has to build or buy 3D objects, thus increasing the cost of VR application.

Moreover, if somebody would like to contribute to editing/updating the VR environment, then OpenSimulator could simply provide at the same environment procedures for editing/updating and participating/viewing the VR world. In contrast, editing/updating VR environment and using it are completely different situations in Unity. An SME employee could easily make a few modifications by rearranging objects in the VR environment by using OpenSim. The same modification in a Unity VR environment must be done by a programmer to write a script in C#.

The two VR implementations utilize a single user training scenario, where Unity application provides a more realistic experience as it is not affected by network communication. Unity uses client-side physics, thus the quality of the VR experience depends on the application and has no relation to user actions.

Unity application has a decent connection with end users, since it only requires the installation of Unity 3D plugin and it is accessible via a URL. But if the end-user uses a mobile device, then the OpenSim has better performance. Unity application builds a more user friendly VR environment, without confusing menus or keyboard commands or other distractions. Moreover, the avatar can walk, talk, sit, chat, and interact with other animated objects and entities.

The VR experience in Unity VR application has higher quality than the OpenSimulator application, because Unity's objects and animations are more realistic. Unity application uses physical laws, ragdoll animations, lighting factors, and audio. Unity VR application provides a better VR engaging experience, with interactive objects and good graphic design and sound design.

The basic difference between the two VR environments is the VR scene composition. In OpenSim application, the avatar can be teleported in various areas in the VR environment. On the other hand, the Unity VR application could be decomposed into individual scenes connected by teleport portals. The development of a scenario with various levels and phases in Unity application can be utilized by walking/flying from one scene to another.

Table 1. OpenSim Technology key points

Advantages	Disadvantages
OpenSimulator could easily provide a multi-user shared collaborative environment	Not so realistic VR experience
Open source platform.	It's affected by network communication
Easily edited/updated VR environment	It's affected by simulation
VR environment can consist of a more structural sequence of scenes.	It's affected by simulation issues

Table 2. Unity Technology key points

Advantages	Disadvantages
More realistic VR experience	Unity has a limited number of free 3D items
It's not affected by network communication	Not an Open source platform
It's not affected by simulation issues	Modifications/Adaptations require a lot of effort
VR experience has no relation to user actions.	SME must cooperate with a programmer
Easily accessible via Internet	WebGL not supporting mobile devices
User friendly VR environment	
More Interactive and Experiential VR environment	

The presenting scenario has been evaluated by a number of SMEs' employees and we have collected their feedback on how the implemented virtual reality applications helped them to increase their comprehension of the provided security level at an LPWAN network.

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