Aleksandar Ivanov

EDUCATIONAL AR/VR SYSTEMS FOR MILITARY PROJECTS

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CONTENTS

1 INTRODUCTION

Developments and improvements in computing technology have allowed for vastly improved immersion when consuming digital media. The most notable examples of such technologies are Augmented reality and Virtual reality. The immersion these technologies offer can be used to create educational systems that have more benefits than traditional digital education systems.

In this thesis project I will be comparing the difference between AR(Augmented reality) and VR(Virtual reality) in the context of educational software. Different implementations and physical devices will be compared and analyzed. A device and a technology will be chosen to create a prototype educational application for Observis Oy related to the company's Situational Awareness System(SAS).

The SAS product has a steep learning curve which raises the need for a more efficient educational tool. The goal of the project is to pick the most suitable technologies and implement such a tool. Advantages and disadvantages of AR/VR need to be considered over more traditional digital educational tools. The future prospects of these technologies are also of interest to the company. VR and AR have grown in popularity and market share over the recent years as the technology has improved(Figure 1).

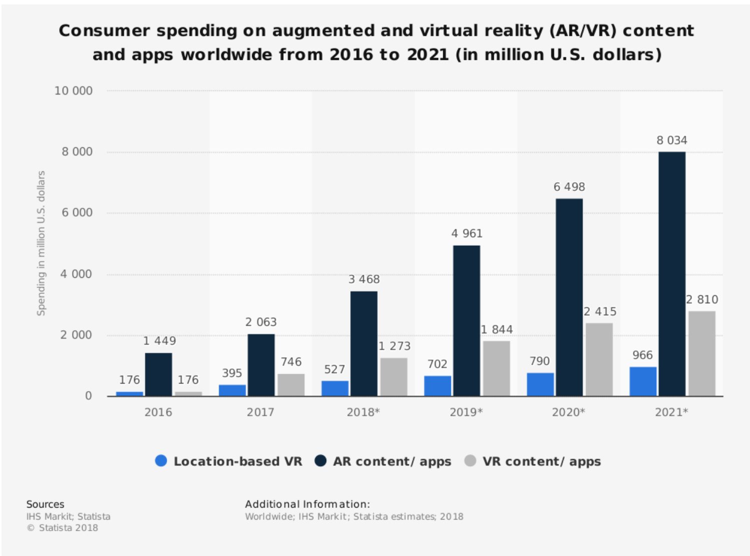

Figure 1. (*Consumer spending on AR/VR worldwide 2016-2021*, 2018)

2 AUGMENTED REALITY AND VIRTUAL REALITY

Augmented reality and Virtual reality are technologies that offer a different view and experience to the physical world. They leverage similar kinds of technology and both aim to provide an enhanced and enriched experience to the user. Both technologies are a part of the general area of mixed reality (Figure 2). However they have different goals and are essentially different in terms of user experience.

Figure 2. Reality-Virtuality Continuum (Paul Milgram et al. 2007)

2.1 Augmented Reality

Augmented Reality can be described as the technology that bridges reality with virtual environments. Real life objects are transformed or replaced with virtual equivalents. Information can be added or removed to the real environment. Key aspects of AR(Augmented Reality) are the ability to run in real time, be interactive, three dimensional and combine real with virtual information(Figure 3). AR is most commonly used with the sense of sight, but it can potentially be used with other senses such as hearing, touch, smell, taste, temperature etc. Augmented Reality can be considered as the next step in graphical user interfaces(GUI) evolution (Mullen and Mullen, 2011). Its current state is comparable to command line interfaces and 2d interfaces in the 1980's and 1990's. It is a vision of future computing and a field that is under research.

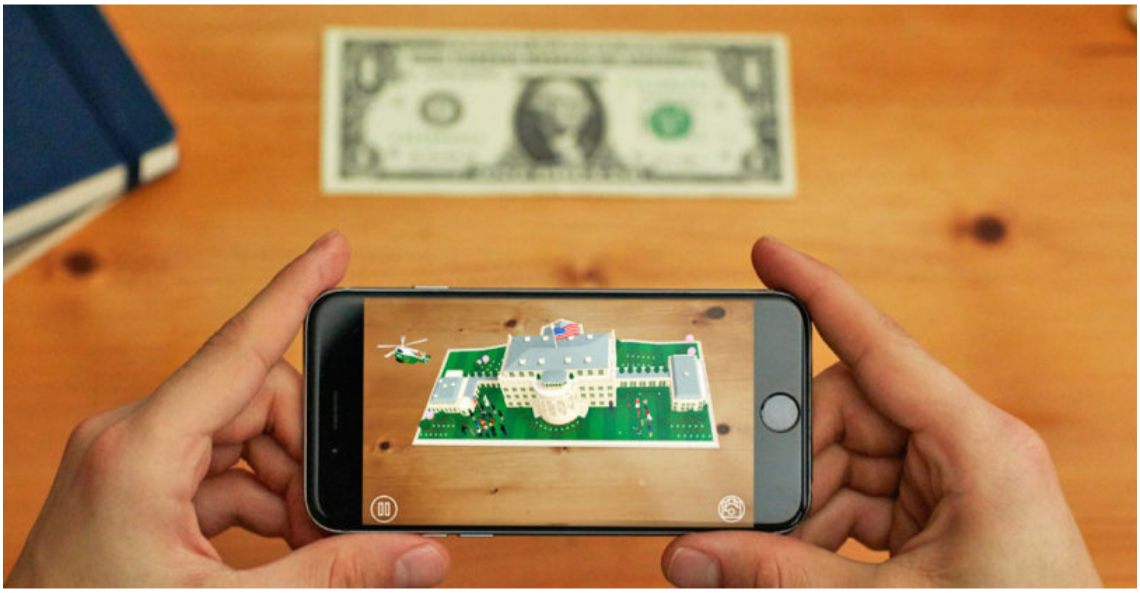

Figure 3. Mobile Augmented Reality application (*AR experience of the White House*, 2016)

Augmented Reality has higher technological requirements compared to VR which has lead to the slower maturity of AR. AR enabling technologies have been developed throughout the history of which the Optical see-through has become the most popular(Microsoft HoloLens, Google Glass, Intel's Vaunt). Optical see-through is achieved by using opaque displays on which virtual overlays can be rendered. The resolution of the real world is left intact as it passes through the screen. Benefits of this approach include power fail safety, which allows users to still see the real world even during a power outage, cheaper production costs of the used displays, no parallax effect that irritates the user's eyes. Disadvantages are the reduced visibility and brightness through the opaque lenses, limitation of the field-of-view, requirement of additional tracking sensors such as cameras, gyroscopes and accelerometers. Due to the lack of maturity of other AR enabling technologies only Optical see-through techniques will be considered throughout this work (van Krevelen and Poelman, 2010).

2.1.1 AR for training and education

Augmented Reality provides new paths to conveying information. Learning experiences are more contextual by connecting and embedding information with the real world in real time. These approaches are already being utilised by Boeing.

Mechanics in the company use AR goggles that aid repairs with embedded textual instructions, illustrate different steps of the repair and help users identify the required tools for a repair. Consequently training resources are reduced and transfer of information between workers is greatly improved (Johnson et al., 2010).

Learning through doing is another approach in which AR shines. Mistakes and errors made during the learning experience have no real consequences. This provides for more authentic learning experiences which cannot be achieved easily or cost effectively otherwise (Kipper et al., 2013).

2.1.2 AR Challenges

An AR framework has basic requirements to accomplish a combination of the real and virtual world. The four main requirements are sensing, tracking, interaction and displaying(Figure 4). Sensing refers to capturing environment events and recognising markers or other objects of interest. Tracking handles updating the viewing direction and position of the user relative to the real world. Tracking is an important component of AR as even a slight tracking error can cause misalignment between the virtual and real world objects (Wang and Dunston, 2007). Registration refers to how the digital information is being delivered to the user. The registration can be achieved through different methods for different senses: videos, audio, haptic feedback, scent, etc.

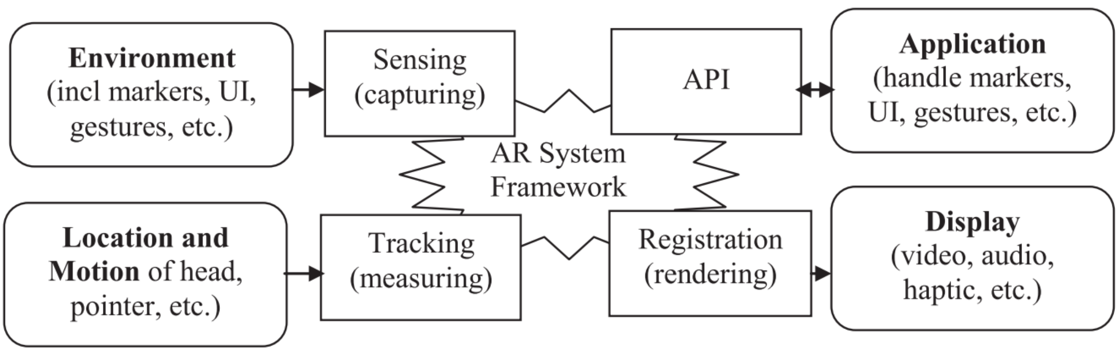

Figure 4. Augmented Reality framework (van Krevelen and Poelman, 2010)

As most developing technologies AR has many challenges that need to be overcome before it can be widely adopted. The challenges of AR arise from the framework requirements and they can be separated in five groups (Figure 5).

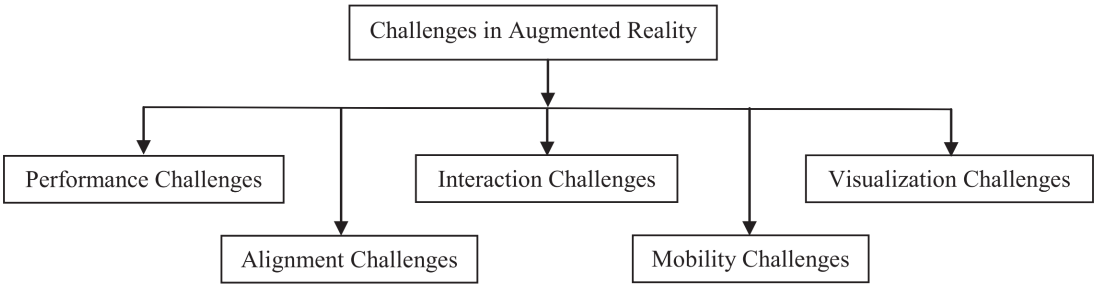

Figure 5. Augmented Reality challenges (Rabbi and Ullah, 2016)

Performance challenges arise from the need of real time processing. AR tasks such as marker detection and virtual object rendering are computationally intensive and this slows down performance. Alignment challenges come from the complexity of tracking the users movement and registration of real life objects. Any errors in those methods can cause misalignment between the rendered objects and real view.

Interaction challenges are concerned with the interaction between users and virtual or real objects. User interfaces need to be intuitive and unobstructive for the best experience. Mobility challenges refer to the need of portability for AR systems.

2.2 Virtual Reality

Virtual Reality in the broadest sense is the method or technology of substituting a physical environment with a virtually perceived environment. The Oxford dictionary gives a more detailed definition: ”The 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”. This is typically achieved by using an HMD with integrated motion tracking and a built-in or external rendering unit. The requirements of VR are same to those of AR with the exclusion of environment sensing (Figure 4). The virtual environment is entirely digitally constructed, thus eliminating the need for sensing as all environmental events are native to the system. It is achieved with a Virtual Reality headset that has different views for each eye, accomplishing depth perception (Figure 6).

Figure 6. HTC VIVE Pro headset (*HTC VIVE Pro review*, 2018)

Interaction with the environment isn't necessary for a VR experience, but it increases the possibilities and usability of a VR system. Different approaches to user interaction offer various degrees of immersion and limitations. Motion tracked controllers, hand motion tracking gloves, pointer centered to the viewport, headset location tracking in 3D space and sekeletal motion tracking are common approaches.

2.2.1 VR Challenges

VR challenges can be categorized in the same way as AR challenges (Figure 5). Performance is a very important factor in keeping the VR experience immersive for a prolonged period of time. High resolution picture rendering at a high freamerate in real-time is taxing even for the highest end of current GPUs. Lower framerate or lower resolution picture can cause dizziness, eye tiredeness and overall dissatisfaction. Alignment challenges arise from the difficulty of tracking in real-time. Users' view, location or controllers can become misaligned with the virtual environment, breaking the immersion and interactability. Interaction challenges come from the current hardware limitations on interacting. Tactile feedback, hand interaction and free movement in the 3D space are all possible individually, but combining them at the same time is not yet achievable.

Mobility challenges arise from the need of portability for VR platforms. Common solutions rely on tethering to a machine that handles the rendering and power supply. However portable VR backpacks and headsets are starting to emerge (*HP Z VR Backpack Overview*, 2018). Visualization can be difficult due to the complexity of the physical world. Keeping proportions, lighting, textures, view depth, field of vision and other visiual perception aspects can be challenging.

2.2.2 VR for education and training

VR has many prospects for use in education. Learning can be promoted by interacting with objects and the environment in a virtual world. Similarly self-paced exploration can improve the users' ability to understand a given topic. Learning through doing is even more prominent with VR than AR. Scenarios that are hard or impossible to create with traditional approaches can be executed in a virtual environment for the fraction of the cost. Users that are physically apart can be in the same virtual environment. Professors or specialists don't need to travel to remote locations to train people.

2.3 Hybrid approaches

Hybrid approaches to VR and AR can be used to improve on some of the imposed drawbacks by the techologies. These approaches include using physical objects or combining different sensors. Such a drawback for VR is the lack of tactile feedback or realistic hand interaction with the environment. This becomes a problem when training pilots as they get accustomed to the feel of the virtual environment and are unable to perform tasks as quickly in the real environment. Feedback from the cockpit instruments is essential as well as the ability to use them with peripheral vision. One solution to this problem has been developed by NLR with the use of a hybrid approach. IR depth sensors and a camera feed are used to map the pilots hand in the virtual cockpit. Mockups of the flight instruments are 3D printed and are mapped to the virtual environment with tracking markers. This allows for a much more natural feel of the flight instruments and offers better training results (van Gimst, 2018).

3 PROJECT USE CASE

Observis Oy is developing a product for situational awareness in different environments called ObSAS. This product is a software system running on multiple devices with multiple purposes. Low level software that communicates with various sensors and devices, Server software that summarizes the data and handles automatic actions and the User software that allows users to interact with all components of the system. The environment the software can be integrated into vary a lot and so does the complexity of the various applications associated with the product.

The end use for the product is usually civil defence or shelter management. High reliability and availability are crucial requirements for the final product as human lives can be put in danger by improper operation of the software or misuse by the users. Training is becoming necessary to ensure proper use of the software and other components of the situational awareness system. So far traditional training approaches have been used. Power slides including pictures of the software, textual description of individual components and narration from the training personnel.

3.1 Current training approach

Current training is done on customers premises in two parts - theoretical and practical. The theoretical part takes place in a classroom with teaching tools such as whiteboard and projector provided by the customer. A group of 20 people is trained during the theoretical part with the use of powerpoint slides containing screen captures of the software. Additionally the software enabled in simulation mode is displayed and used in front of the trainees. Devices such as latops, external hard drives, cameras are not allowed during the training to avoid redistribution of confidential information.

The second part of the training involves practical use of the system. In the Sassi Project case it takes place inside a reconnaissance vehicle with a group of 3 to 4 people. Real life devices are used with the software. Test sources are used to trigger devices alarms and cable disconnecting is used to test failure states.

Feedback from the customer in the Sassi project has been positive, although there have been complaints from the trainees about the translation of the materials, but still overall positive feedback has been received. According to Jukka Härkönen(an employee from Observis who conducts the training) the trainees with better English language skills have managed to attain more knowledge from the training. Trainees who were familiar with a previous version of the software have had no problems adjusting to the differences in the new version of the product. Some trainees however have not been able to fully prepare for the use of the software and require further internal training conducted by the customer.

3.2 Future goals

Regardless of the good customer feedback there is room for improvement of the training. Streamlining of the training can reduce the time required to create training materials and the amount of staff needed to conduct the training. Another future goal of the training is to be able to experience more lifelike situations and more complex scenarios resulting in better preparedness for critical situations. Misunderstanding caused by a language barrier is something that should be avoided in future training.

Innovation in every aspect of the product is welcomed from the customers. The market has been stagnant and competing companies have been refusing to innovate due to the various risks involved with doing so. Observis is willing to take those risks to set itself apart. A survey and analysis of Virtual reality technologies is of interest to the company.

3.3 Defining the application specifications and requirements

The primary goal of the training application is to provide a better view on the future prospects of using mixed reality for training. A secondary goal is to offer a training platform for better understanding of the ObSAS software to trainees. Furthermore finding other suitable AR/VR use cases for the current Observis projects can also be a positive by-product of the research.

A particularly sophisticated requirement of the system is the maintenance procedure. Measurement devices and sensors require periodic maintenance and inspection to remain in good operating condition. Neglect of these requirements can lead to faulty readings over time, device breakdown or even failure to recognise threats. The maintenance involves physical interaction with a measurement device that is guided by an instructional document. Software use is also required during the procedure to mark used parts and add additional notes. It is not possible to practice all maintenance procedures during training because of the time constraint. Consumables are often needed for the maintenance which can increase the cost of training. For the above-mentioned reasons implementing a training scenario that involves conducting a maintenance in a mixed reality environment would be of great benefit.

One particular device that requires maintenance is Environics ChemProDM. The device is a Chemical Warfare Agents(CWA) and Toxic Industrial Chemicals(TIC) detector that is targeted for vehicle use(Figure 7). Typical installation includes 2 modules: ChemProDM detector and Remote Alarm Unit. A maintenance training scenario for this device is a great candidate for a mixed reality application. Initial installation and testing are also interesting use cases that can benefit from a training application.

Figure 7. ChemProDM and modules (*ChemProDM Chemical detector for mobile and vehicle applications*, 2018)

Other devices included in ObSAS are Thermo SVG2 radiation sensor, Meteo IRDAM MAWS 5060 weather sensor, Infinicon Hapsite ER chemical analyzer. Basic knowledge of those devices is a great benefit when using the system, however it is not required of the users. The user can be familiarized with the devices during training. The knowledge attained can be helpful if on field repairs are required.

3.3.1 CBRN defense

CBRN is an acronym for Chemical, Biological, Radiological and Nuclear. CBRN defense is the field of detecting, reducing the impact of or avoiding the threats of CBRN agents. In recent years the threat of CBRN attacks has increased due to technological development and increased willingness of terrorists to obtain and use such agents (Carter, 2014).

ObSAS provides possibilites for early detection of CBRN attacks. Gathering as much information possible about the attack can help with planning impact reduction strategies. ObSAS allows for the gathering and analysis of such data: chemical threat identification, air spectrum analysis, radiation measurement, geographical location and meteorological conditions. A vehicle with an ObSAS installation can safely cover and inspect a large area. Communication channels can be used to share and collect data from various CBRN sources. A more clear picture of threats can be established that way.

CBRN considerations such as decontaminating equipment and clothes, medicine administration, evacuation radius require training and practice.

3.4 Comparing VR and AR in the project context

AR and VR differ not only in hardware but also in software development kits. It is rarely the case that an application written for one of the platforms can be seamlessly ported to the other. Therefore the two technologies need to be compared in regards to the current project. To keep the scope of this thesis narrow a single technology will be used to implement a training application.

AR hardware such as goggles, glasses and headsets are generally very portable and self-contained. This makes it easy to transport the required hardware during training or installation tirps. The initial setup of the training environment could be more tedious with AR. If real life devices need to be tracked, markers have to be placed and calibrated. Immersion may be sacrificed due to the narrow field of view (*Microsoft HoloLens Device Specifications*, 2018), smaller color space, low luminosity and lower computing power. Another downside is the inability to emulate real life scenarios such as being inside a moving vehicle or simulating an environment that is completely different from the one the user is in. For example it is impossible to simulate night missions if the user is in a brightly lit room. For these reasons AR is restricted by the environment it is being experienced in.

The easability of use of AR headsets is one important benefit. While VR headsets require a tether cable, external computer and even base stations in some cases, AR headsets can be used as they are, independently. 3D modelling isn't as big of a requirement compared to VR as it is enough to create models only of the objects the user interacts with, not the full environment the user is in. This can reduce development time significantly.

VR shines in implementing a completely independant environment. The only limit to what can be recreated is imposed by the hardware performance and development time and skills. VR allows for spectating and recording users' interaction with the environment. This can be used to analyze their experience and improve the software further. Giving suggestions and guiding during the training is also possible. A multi-user environment is also possible and trainees and teachers can be in the same environment even if they're physically far apart.

Price difference is very small between VR and AR if the most advanced frameworks are being considered. An AR headset with the development pack such as Microsoft HoloLens is priced at 3000$ (*Buy Microsoft HoloLens*, 2018). And a VR headset such as HTC Vive Pro is priced at 1500€ (*Buy HTC VIVE Pro*, 2018) with VR capable laptops priced starting from 1500€. Similarly prices of development kit licenses are not far apart either. This makes the decision between the two based entirely on the features they provide, driven by the requirements of the use case they're aimed for.

3.5 Selection of mixed reality framework

The main benefit of AR over VR in this project is the portability and ease of use it offers. In terms of what training can be implemented VR offers a lot more possibilities. Battery limitations are also reduced or avoided which enables long training sessions. Good multiplayer support and additional peripherals(such as gloves and controllers) are in favor of VR too. The portability of AR is not a crucial feature for this project and the usability it offers over VR are not sufficient enough to place AR as a more suitable platform in this project. A conclusion to this chapter is that a VR framework is a more suitable choice in the context of creating a training application for the ObSAS system.

4 PROJECT IMPLEMENTATION

This chapter will describe the various stages of developing a VR training application. Concepts such as 3D computer graphics, 3D modelling, game engine and tracking will be defined. Source code used in the development of the application will be provided and explained.

4.1 Researching VR hardware and software

The most notable VR headsets available on the market are Occulus Rift and the successor to HTC VIVE, the HTC VIVE Pro. Widest software and peripheral support is offered to these headsets, so other options would not be considered. The main difference between the two is that HTC VIVE Pro has higher screen resolution and pixel density (Figure 8). Occulust Rift has lighter controllers, but requires at least 3 or even 4 sensors in some cases for decent room tracking. In contrast HTC VIVE Pro offers a wider tracking area with just 2 tracking sensors (*HTC VIVE Pro vs Occulust Rift*, 2018). Both options are pretty good options, but HTC VIVE Pro is more suitable and offers more because of the better graphics.

Category	**HTC VIVE Pro**	**Occulus Rift**
Display	Dual Amoled 3.5"	Dual Amoled 3.54"
Resolution	1440x1600(2880x 1600)	1080x1200(2160x1200)
PPI	615	461
FOV	110 degrees	110 degrees
FOV	90Hz	90Hz
Connection	USB-C 3.0 DisplayPort 1.2	HDMI USB-A 2.0 USB-A 3.0

Figure 8. HTC VIVE Pro vs Occulus Rift specs

VR hand and finger tracking is a great addition to the immersion of the VR experience. More intuitive interaction with the virtual environment is possible. Many gloves are available as prototypes on the market. Some feature resistive finger feedback and texture and shape simulation (*VRGluv*, 2018). A large portion of such gloves are in the prototyping stage and can only be preordered. The Noitom hi5 gloves however are available as a purchasable product, even though they're missing the aforementioned features.

These gloves achieve full finger tracking by using 9 inertial measurement units on each glove. The VR headset controllers are strapped on the gloves to provide absolute tracking (Figure 9). Vibration feedback is also supported by the hardware and software API (*HI5 VR Glove business edition*, 2018).

Figure 9. Noitom HI5 VR glove (*HI5 VR Glove business edition*, 2018)

The Noitom hi5 gloves are compatible with HTC VIVE Pro and offer SDKs for the most popular game engines (Unreal Engine and Unity). These gloves will be used in the project to achieve better immersion and quality of training.

4.2 Game engines

A game engine is a software framework aimed at simplifying and streamlining the production of games. At the core it provides a 3D or 2D rendering engine, generic physics engine, sound, animation and other features that assist game creation but do not directly specify the game's behavior. If used successfully a game engine can produce a higher quality game with less resources and in less time. An engine isn't required to build applications as all the features can be implemented from the ground up without the need for reusability or modularity, but that takes significantly more resources than using already existing tools (Lewis and Jacobson, 2002).

Despite having the name game engine, such engines have many other applications besides making games. They can be used for pretty much any graphical application. Simulation applications, training applications, VR and AR applications of any kind, presentations, cinematography can all benefit from using a game engine. Using a game engine is suitable for this project because of the time constraint and limited resources available.

One popular game engine is Unreal Engine, created by Epic Games Inc. It is widely adopted and offers a large selection of plugins, addons, libraries and assets that aid development. Unreal Engine supports various VR and AR platforms including HTC VIVE Pro and Hi5 vr gloves. This engine will be used to develop the training application.

4.3 Application Objectives

4.4 Implementing basic scene with objects

4.5 Tracking and interacting with the virtual environment

4.6 Creating a context for training

5 ANALYZING THE MIXED REALITY TRAINING APPLICATION

5.1 Future possibilities for development and improvement

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