Revisiting Virtual Reality Training using Modern Head Mounted Display and Game Engines

Chad Jarvis Tyge Løvset Daniel Patel

Christian Michelsen Research AS, P.O. Box 6031 NO-5892 Bergen, Norway {chad,tyge,daniel}@cmr.no

ABSTRACT
Immersive Virtual Reality (VR) is an aid to mastering the spatial complexities of 3D data. Christian Michelsen Research (CMR) previously developed a virtual reality system for safety training using a large-screen and shutter glasses for stereo vision along with positional and rotational tracking. Building and maintaining a custom system has been expensive and time consuming. The recent availability of affordable and capable head mounted displays (HMD) along with powerful 3D game engines has created new opportunities for affordable immersive VR. In this paper we compare our custom made VR hardware system and 3D engine with a solution built on Oculus Rift HMD and the Unity 5 game engine.

Categories and Subject Descriptors

I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism – *Virtual reality,* I.3.7 [**Computer Graphics**]: Hardware Architecture:Three-dimensional – displays, K.4 [**Computers and Society**]: Human safety

General Terms
Algorithms, Measurement, Documentation, Performance, Design, Experimentation, Human Factors.

Keywords
Virtual Reality, Large models, Oculus Rift, Unity-5, Unreal Engine-4

1. INTRODUCTION
CMR has developed a VR system for safety training using a large screen display and shuttered glasses for stereo viewing including positional and rotational tracking along with a custom 3D engine.

Until recently, our experience with VR technology has been that custom 3D engines are time consuming to develop and expensive to maintain and that the VR hardware is either not advantageous enough or too expensive for VR to become mainstream.

However, the recent availability of affordable but advanced VR head-mount displays (HMDs), such as the Oculus Rift Developer Kit 2 (DK2) by Oculus VR [1] along with powerful 3D game engines, such as Unity 5 [2] and Unreal Engine 4 [3], has created a new interest in VR technology.

To test the potential of this new technology we have ported some of the functionality of our VR system into the Unity 5 game engine and used the DK2 for rendering and tracking.

In this paper we will discuss our previous experience with VR technology and then compare and contrast our experience with the new technology.

2. VR Training
HMDs have been used extensively for military training purposes [4] and are entering the public domain [5].

In 2004, CMR started development of a VR solution called VRSafety [6,7], funded by Statoil and Norsk Hydro for safety training and for planning structural changes in industrial models. Rendering and interacting with a 3D model of an existing or planned industrial environment makes it possible to move objects around for discussing structural changes, for navigation, to test out evacuation routes and to visualize simulated gas leaks and explosions. As spatial understanding and the sense of presence is important in these scenarios, we implemented this as a 3D immersive solution.

As a result of this work, a mode of operation has been developed whereby experts and non-experts can communicate relevant major hazard risk topics in a more efficient way by collaborative work practices utilizing VR.

2.1 VRSafety Hardware
Our immersive VR setup consists of a 4.6 m x 1.6 m screen, back projected by two slightly overlapping Barco Galaxy NW-7 projectors. The overlap is smoothed using edge blending resulting in a resolution of 2048x1600 at 120Hz. Stereo is achieved using active stereo shutter glasses from NVIDIA synchronized with the display through an infrared signal. Positional and rotational tracking of the glasses and of the pointing device is achieved with the IOtracker [8] system using reflective markers tracked by infrared emitting and receiving cameras positioned around the bevel of the display wall, see Figure 1. The application runs on a commodity PC with a powerful NVIDIA graphics card.

Figure 1 Our back projected screen with infrared cameras.

SIMUTOOLS 2015, August 24-26, Athens, Greece

DOI 10.4108/eai.24-8-2015.2261306

2.2 Custom made 3D Software Engine

VRSafety uses CAVELib [9] for projection setup, the IO Tracker library for tracking and OpenSceneGraph (OSG) [10] for rendering. On top of OSG we implemented navigation and our own event system for programming behavior into the virtual environment.

CFD (Computational Fluid Dynamics) simulations [4] were used to simulate gas leak and explosion scenarios inside the geometry. To visualize these results, we implemented volume rendering and isosurface rendering.

2.3 Experiences

Our VRsafety setup consisted of expensive hardware that required a custom made room solution with a small projector room behind the main visualization room. In addition, a calibration process was needed for the projectors and the tracking system. The setup was ideal for immersing several people together in the virtual environment and for having collaborative discussion sessions between experts from multiple disciplines. The work sessions did usually not produce motion sickness among the participants. Requests for added functionality was time consuming to implement due to the low-level custom made software platform. Also, in our particular setup, we only had the front wall projected, resulting in a lower degree of immersion than in a multiwall cave.

3. Head Mounted Displays and Game Engines

Several HMD developer kits are available such as the Oculus Rift DK2, the Sony Project Morpheus, and the HTC Vive. Each offers similar features such as six degrees of freedom and a wide field of view (FOV). The Sony Project Morpheus is geared toward the Play Station 4 game console whereas the others are designed for the PC. None of these HMDs exist as commercial products but each of them is expected to be commercially available in 2016.

Samsung has released a commercial HMD called Gear VR. However, it's aimed for the mobile market with more limited graphics hardware and it only supports three degrees of freedom.

The Sony Project Morpheus and the HTC Vive are available for select developers. We applied for a developer kit for the HTC Vive but did not receive a response. The Oculus Rift DK2 is not limited to selected developers and it was simple to purchase. For this reason and due to its support for the PC we choose the Oculus Rift DK2.

Additionally, we used the Unreal and Unity game engines because of their state-of-the-art features and liberal end user licenses. The Crytek CryEngine also offers state-of-the-art features but its subscription end user license agreement appears to be limited to only game development [11].

3.1 The Oculus Rift Device

The latest developer HMD from Oculus VR is the DK2. The DK2 has a resolution of 960x1080 pixels per eye. The first consumer version announced for Q1 2016 is expected to have a resolution of 1080x1200 pixels per eye.

The DK2 uses lenses to achieve a horizontal 90 FOV. This wide field of view is one of the major advantages of the DK2 compared to other HMDs.

The lenses, however, create two distortions: pincushion distortion and chromatic aberration. These distortions are corrected for by convoluting the image with a barrel distortion and distorting the red, blue, and green components of the image to cancel out the chromatic aberration.

Both the 3D position and angles of the DK2 is tracked. The position is measured by a stationary infrared camera observing at 60 FPS infrared (IR) emissions from an array of IR-LEDS on the DK2 whereas the angles are measured with an accelerator in the DK2.

3.2 Unity and Unreal Engine 3D Software

Unity 5 and the Unreal Engine 4 are multi-platform game engines. They provide advanced effects beyond those in our previous system such as a powerful scene editor for adding geometry, landscape shaping, and dynamic foliage and environmental effects. Additionally, all objects can be scripted for adding behavior to them.

4. Porting

To port our existing solution into the two game engines with oculus rift required us to consider the following aspects:

1) Pricing schemes and legal rights,
2) Porting of geometry models,
3) Implementing software functionality,
4) Interactivity and quality.

These aspects are discussed in the following subsections.

4.1 Pricing schemes and legal rights

Both game engines are reasonably priced with scalable fees according to either game revenue or development licenses used.

Unreal has a 5% royalty fee for revenues above 3000 USD per product per calendar quarter. It cannot be used for gambling-related activities, military with live combat, in nuclear facilities, or in critical aircraft software [12].

Unity has two licenses. With the personal license, products created with Unity can be used, distributed and sold without fees by entities earning less than 100,000 USD per year. Entities earning more must use the professional license which will per developer cost either 75 USD per month, or 1500 USD as a one-time fee [13]. Unity cannot be used for gambling-related activities.

4.2 Porting of Geometry Models

The geometry constituting the industrial model was originally in a CAD format, but was provided to us as an OSG Binary file (IVE) of 668 Mb. The geometry consists approximately of 5 million triangles.

Both game engines support the FilmBox format (FBX) [14], while Unity additionally supports Collada (DAE) [15]. Therefore we focused on converting the geometry to FBX. After investigation, we identified two geometry software packages which advertised the ability to convert from OSG exportable file formats to FBX. Sketchup Pro [16] could import DAE and export FBX, but in practice the software crashed. Blender [17] could transform both Autodesk 3ds Max format (3DS) [18] and DAE format to FBX, but Unreal failed to load the FBX file created both from 3DS and from DAE. It appears that Unreal's FBX importing is not suitable for large CAD files. Although, we were very pleased with the Unreal Engine editor and impressed with the visual realism of the Unreal Engine compared to Unity, due to the failure to import our model, we stopped using the Unreal Engine.

We then focused on the Unity engine. This engine successfully imported the FBX file, however, the original smooth shading had turned into flat shading. Loading the DAE format directly exported from OSG succeeded with smooth shading. Nevertheless, some issues needed to be addressed. All textures were lost during conversion but it was relatively easy to reassign the textures using the Unity editor. Many surfaces flickered due to overlapping surfaces. These were fixed also in the Unity editor by deleting one of the overlapping surfaces. See Figure 2 for an overhead view of the model in Unity.

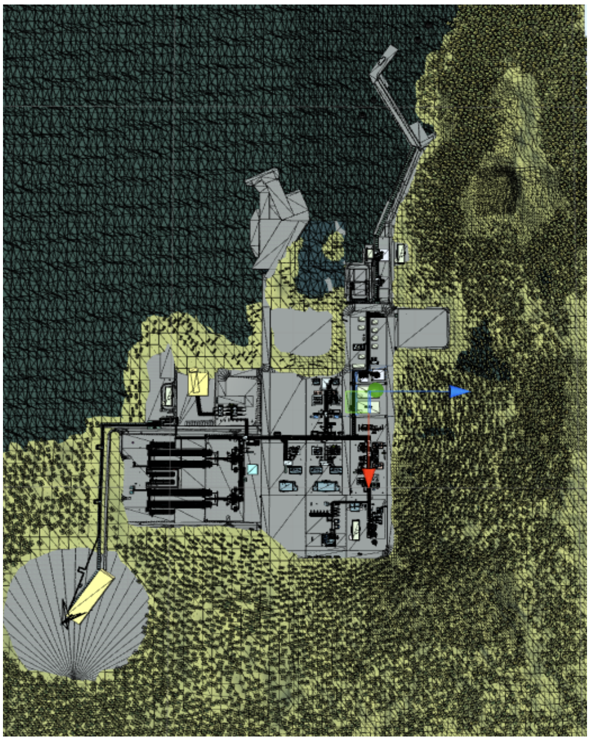

Figure 2: Top view of the industrial model in the Unity editor. The sea and the surrounding terrain with foliage were created in the Unity editor.

4.3 Implementing Software Functionality

Functionality such as navigation and collision detection was simply a matter of importing an asset and clicking a check box. Other functionality from VRSafety such as moving around objects in the scene have not been implemented, but by inspecting the game engine design and scripting functionality we realized that this would be trivial to do. However, showing gas scenarios will require more work. A volume renderer, an isosurface renderer, and an interface towards the CFD simulators needs to be implemented.

4.4 Interactivity and Quality

We ran our demo on a Nvidia GTX580, which was state-of-the art in late 2010. However, far more powerful cards can now be acquired. Rendering our scene in Oculus rift with the basic Phong shading model as used in our previous system resulted in interactive framerates at more than 70 FPS, which is the minimum recommended framerate for Oculus rift.

Unity supports several extensions for improved rendering quality, such as advanced shading models with shadow casting, and dynamic content such as animated objects. Adding too many of these features quickly degraded the framerate.

4.5 Added value using Unity

Compared to VRSafety which lacks an editor, Unity supports many advanced features that can be created easily within the Unity editor. Unity also has an assets store where one can purchase textures, models and effects.

Our original model was positioned inside a large sky-textured box for rendering the sky. It also included some geometry for rendering surrounding terrain. Unity supports several sky-models and allows for interactive terrain sculpting and adding of foliage. We removed the original sky and terrain and added these assets from Unity. In addition, we added an animated sea into the model. Using the interactive editor in Unity we were able to create surroundings that more accurately represented the original surroundings of the model. See Figure 2 for a top-down view and Figure 3 for a perspective view.

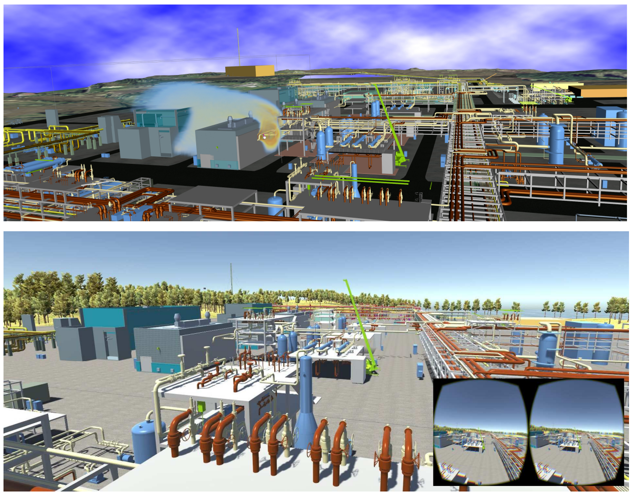

Figure 3 Top: VRSafety showing a gas leak. Bottom: Unity with trees, shadows and water in the distance. Bottom right inset: Stereoscopic rendering generated for the DK2.

5. The Immersive Experience

Those that have used the old system with a large screen and shuttered glasses found the experience with the DK2 far more immersive than our single back projected wall setup. Several people using our demonstration found it so immersive that they expected to see their hands and arms when they moved them. The lack of this reduce the immersive experience.

We did face some new challenges using the DK2. One major problem we faced is that the complex terrain we added along with shadows and a dynamic ocean can have a dramatic effect on the framerate particularly with rotational head movement. The large-screen display solution does not have update problems during rotational head movements since display and view direction is decoupled. The low frame rate not only damages the immersive experience but also contributes to motion sickness. The main author, after using the demonstration without pause for over 30 minutes, felt nausea for well over an hour after stopping the demonstration.

We are confident that with a more modern GPU along with a better understanding of the Unity engine, we can achieve a sufficiently high framerate. For now, we have created two version of our demonstration: one with a complex terrain and ocean and one with a simple terrain and no ocean.

Oculus VR has listed several factors which may cause motion sickness such as rapid acceleration (rapid head movements are a type of acceleration), low frame rates, lag, flicker, and the FOV. However, lowering the FOV is not an appealing option since a smaller FOV takes away from the immersive experience. To some degree, experience with the HMD may be necessary to overcome motion sickness (analogous to overcoming sea sickness on a boat).

Another challenge with the DK2 compared to the large-screen setup is that it blocks the view for the user. Thus, collaborative sessions where several users see each other and physically point at parts of the model is not supported. However, it may be possible to combine the DK2 with 3D scanning technology to incorporate virtual avatars of all participants in a satisfactory way.

Motion sickness and lack of collaboration are probably the two biggest challenges using the DK2. We have summarized the differences between our old system using a large screen and shuttered glass and the new one using Unity and the DK2 in Table 5-1 and Table 5-2.

Table 5-1 Comparing the software aspects of the solutions. "++" is better than "+", which is better than "-".

	VRSafety	Unity	Unreal
Importing large geometry	+	+	-
Visual editor	-	+	+
Rendering quality	-	+	++
Adding functionality	-	+	+
Pricing scheme	In-house	per dev. license	per sale

Table 5-2 Comparing the hardware aspects of the old and new solution.

	Large-screen VR	HMD VR
Hardware price	high	low
Motion sickness	low	medium
Interdisciplinary	yes	no

6. Conclusion and Future Plans

VRSafety has been a useful tool for training and safety assessment of industrial environments. The costs for developing and maintaining a custom 3D graphics engine along with the less advanced VR hardware, however, made it challenging to convince companies to pursue further investments.

The recent availability of inexpensive HMD with six-degrees of freedom tracking and a wide FOV along with the availability of advanced 3D engines have rekindled our interest in VR as a viable platform for immersive training.

Our initial experience using the DK2 device has been positive. Exploring the model of the industrial complex has never felt so immersive. Additionally, using Unity made it simple to reproduce many of the features we have in our custom 3D engine with much less effort and the visual quality with Unity is more realistic than with our 3D engine.

The major problem using the DK2 is the motion sickness. This is a serious issue which needs to be carefully addressed. This may be as simple as avoiding low frame rates and lag to more restrictive solutions locking the user to a fixed inertial reference frame such as the cockpit of an automobile. It remains to be seen how well future Oculus Rift devices will work for first person exploration and training.

7. REFERENCES

[1] Oculus VR https://www.oculus.com/

[2] The Unity 5 Engine http://unity3d.com/5.

[3] The Unreal 4 Engine https://www.unrealengine.com

[4] Virtual Reality Exposure Therapy for Combat-Related Posttraumatic Stress Disorder. A. Rizzo, A. Hartholt, M Grimani, A Leeds, M Liewer. IEEE Computer. Vol 7. Issue 7. 2014

[5] A Virtual Reality Training Tool for Upper Limb Prostheses. M. Bressler, Vienna University of Technology. Masters thesis. 2013.

[6] FAVEum Framework Architecture for Virtual Environments Applied to Urban Modelling .J. O. Erdal, T. Langeland, D. Patel, I. Eliassen. Next Generation 3D City Models, 2005.

[7] VRSafety Improved Safety and Risk Communication and Training using Virtual Reality. http://www.cmr.no/cmr_computing/doc/PDF%20files/flyers%20VRSafety.pdf

[8] IOtracker http://iotracker.com/

[9] CAVELib http://www.mechdyne.com/software.aspx?name=CAVELib

[10] OpenSceneGraph http://www.openscenegraph.org/

[11] CryEngine http://cryengine.com/get-cryengine/eaas-eula

[12] Unreal License. https://www.unrealengine.com/eula

[13] Unity License http://unity3d.com/legal/eula

[14] Fbx Format. http://www.sidefx.com/docs/houdini14.0/io/fbx

[15] Collada Format. https://www.khronos.org/collada/

[16] Sketchup. http://www.sketchup.com/products/sketchup-pro

[17] Blender Software. https://www.blender.org/

[18] 3DS Format. http://www.autodesk.no/products/3ds-max/overvie