

Inspiration from VR Gaming Technology: Deep Immersion and Realistic Interaction for Scientific Visualization

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Abstract: The computer gaming industry is traditionally the moving power and spirit in the development of computer visualization hardware and software. This year, affordable and high quality virtual reality headsets became available and the science community is eager to get benefit from it. This paper describes first experiences in adapting the new hardware for three different visualization use cases. In all three examples existing visualization pipelines were extended by virtual reality technology. We describe our approach, based on the HTC Vive VR headset, the open source software Blender and the Unreal Engine 4 game engine. The use cases are from three different fields: large-scale particle physics research, X-ray-imaging for entomology research and medical imaging with ultrasound computer tomography. Finally we discuss benefits and limits of the current virtual reality technology and present an outlook to future developments.

1 INTRODUCTION

During the last two years there was a huge progress in the development of virtual reality (VR) hardware, mainly driven by the computer game industry. Now there are several VR devices available with high quality at moderate prices. High quality means: high-resolution displays, precise head tracking and lightweight hardware. Each property is required to achieve a high level of immersion. Scientific visualizations can benefit from this development in several ways: produce a realistic impression of the magnitude of objects and dimensions, free viewpoint navigation and natural interaction. On the other hand, the high immersion has the risk to produce simulation sickness (see Section 3.1). Furthermore, as the eyes of the users are covered by the VR HMDs (head mounted display), it is not possible to use conventional control devices like keyboard and mouse. These limitations require alternative means for navigation and interaction.

In this paper, we present the extension of three visualization use cases by VR technology from the

fields of particle physics, biology and medical imaging. We describe the used software and hardware configurations. The workflow from traditional to VR visualization is discussed as well as the benefits of several aspects of the new visualization devices with current technology.

2 VR SETUP

The typical VR development and showcase setup consists of a VR headset, a graphics workstation and manipulator devices. Currently there are basically two high-end developer VR HMDs available on the market, the Oculus Rift and the HTC Vive. The PlayStation VR is only available for gaming consoles. Google VR and its various clones have a too low quality in display resolution and computing power and are not considered here. However, it will shortly be discussed in Section 4. In our setup, we use the HTC Vive, as it is the only one providing spatial-tracked hand controllers, which we regard as essential for control and interaction in VR

applications.

The basic HTC Vive system consists of the HMD, two hand controllers and the lighthouse stations. The display resolution is 1080 x 1200 pixels per eye at a frame rate of 90 Hz. The lighthouse stations track an area of 5 m x 5 m from two opposing corners to avoid occlusion of the sensors. The hand controllers provide buttons, track pad and trigger. After a short calibration step the chaperone system, invented by HTC, will become active to protect the user from collisions with the surrounding: When approaching the border of the tracked area, a fence-like structure will be faded into the virtual scene to alert the user.

In contrast to HTC's recommendations to use a NVIDIA GeForce GTX 970 or higher, we were able to run the HTC Vive headset with a GTX 680 at satisfying performance. The GTX 580 didn't support the HTC Vive.



Figure 1: The HTC Vive headset and one of the two hand controllers. The controller provides a round track pad (left side of controller), the grab trigger on the opposite side and three buttons.

3 OBJECTIVES

In all our use cases we visualize 3D surface meshes of different levels of abstraction. The traditional way to display is rendering them on a 2D computer display and to interact with keyboard and mouse. In this way we lose stereoscopic viewing and natural interaction. With 3D displays, we get a better spatial perception, but hardly an impression of real dimensions of objects, surroundings or locations, simply because of the defined viewing angle, limited by the size of the display or the projection.

From VR technology we expect to overcome these drawbacks: the field of view is not limited, the user can turn its head to arbitrary directions. Manipulation of objects is transferred into the virtual environment. Appropriate objects represent the

hands of the user, movements of the hands are tracked by the hand controllers and displayed in the virtual world. Thus a user can just grab virtual objects, turn them and inspect them almost like in the real world.

3.1 Deep Immersion and Navigation in a Particle Physics Experiment

The goal of the KATRIN experiment is to measure the mass of the neutrino particle (KATRIN, 2005). It is a large-scale research facility, spread over several buildings. Its beamline length is 70 m. There is a large interest of the public in visiting and viewing the experiment site. However, KATRIN has temporary and permanent closed areas due to hazards like high voltage, low temperature or tritium, so a visit is not always possible. To alternatively provide at least a virtual visit of the experiment, a virtual visit of the whole *KATRIN setup* had been constructed in a game-like environment (Bergmann, 2014). The main objective of the 'game' is to give the player a realistic impression of the real size of the experiment.

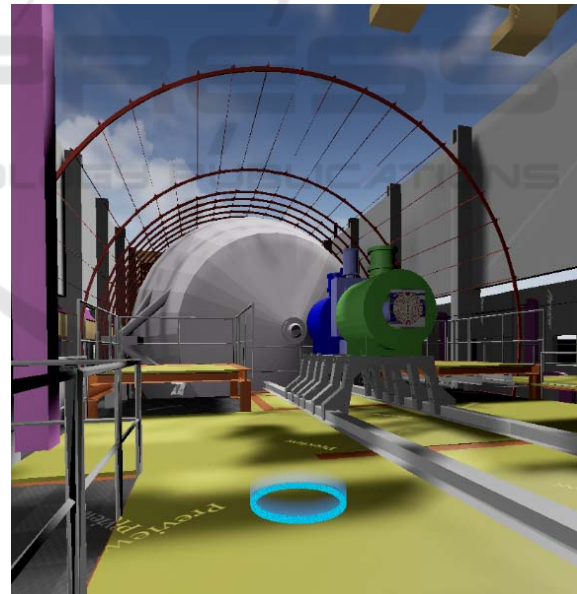


Figure 2: A virtual visit on the KATRIN detector platform. In the foreground the target gizmo (light blue circle) pointing to the next teleport location.

Our first use case of applying VR technology is the *KATRIN game*. The game and its geometry is freely available under a CC license. The game has been developed with the open source software Blender (Blender, 2016) and originally runs under the Blender game engine. Blender does currently

not support any VR hardware, so we decided to use the Unreal Engine version 4 (UE4) game engine, which is also freely available. Only for commercial applications Epic Games Inc. charges a royalty (Epic, 2016).

The conversion from Blender to UE4 is straight forward using FBX as geometry format. However, lights, sounds, animations, interactions and controls need to be adapted manually for the UE4 environment. Mainly the collision system requires a substantial effort and is still under construction. Blender may use just the meshes itself for collision detection. UE4 is highly optimized for game performance and allows only simple and convex collision geometries. Complex meshes need to be subdivided and remodelled.

Controls and animations can easily be implemented using the UE4 *Blueprint* visual programming system. In the beginning we took over the common WASD control scheme from single player games: basically controlling the viewing direction using the mouse and walking forward by pressing the W key. However, in tests we found this control scheme may result in simulation sickness. If the visual impression of walking does not agree with the proprioceptive impression, the brain will respond with sickness. This experience was at that time common to VR developers. Epic Games Inc. collected some recommendations in its *Virtual Reality Best Practices* (Epic, 2016) and recently brought to public VR Templates for the Unreal Engine. Instead of walking through the virtual world, the player *teleports* through the world. Teleporting is executed as follows: using the head or hand motion the player points to a location, visualized by a target gizmo or icon, and initiates the teleportation by pressing a button on the controller. Before the teleport the display fades to black and fades back after. This way, the player does not see a quick movement of the viewpoint and a sudden change of the surrounding. We adapted this scheme and got positive feedback from first users.

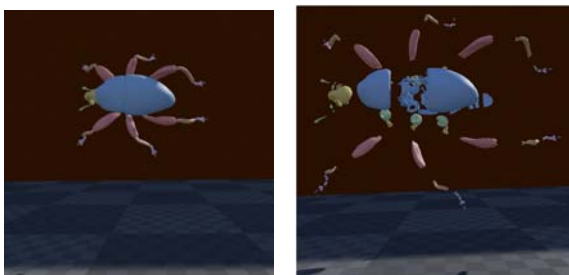


Figure 3: 3D view (left) and 3D explosion drawing (right) of the weevil *Trigonopterus vandekampi*.

For the extension of the KATRIN game, our main objective was to achieve a realistic immersion and get an impression of the real size of the experiment. Our investigations proof, that VR is able to fulfil this requirement. Wearing the VR headset, the player has a realistic feeling to be part of a virtual world. The position and motion head tracking is precise enough and the visual response so fast, that there is no discrepancy to the real world.

3.2 VR Interaction with a 3D Model of an Insect

Our second use case comes from entomology. X-ray micro-tomography is a powerful technique to resolve internal structures of opaque objects with a spatial resolution in the micro meter scale. Again analysing complex 3D structures is challenging with standard displays. We use the geometry meshes of a snout beetle (weevil, *Trigonopterus vandekampi*).

The main physiological properties have been segmented (van de Kamp et al., 2014; Tan Jerome, 2017). In general, the 3D meshes are the means to investigate the objects in detail and in this use case we wanted to find new ways to facilitate successive investigations.

We implemented a virtual lab, where we placed two models of the weevil. Both can be grabbed using the virtual hand and the controllers, the first as one single object, the second consists of single segmented objects, each of which can be grabbed and moved around individually. To get a better overview, the second specimen can be transformed into a '3D explosion drawing' of its individual segments (see Figure 3). All 76 segments can be picked up, moved and inspected from all sides.

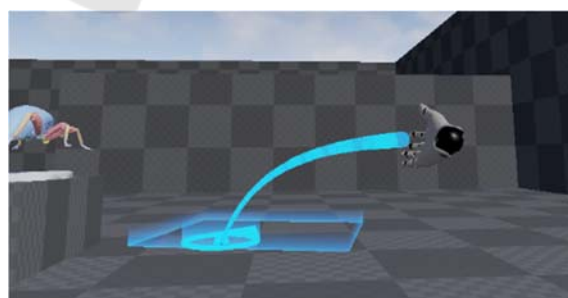


Figure 4: The teleporter in the entomology virtual lab.

For navigation in the virtual world, the navigation scheme of a new VR Template provided with the UE4 is used. A new teleport location is selected with the hand controller, and during this process, a blue line or arc is displayed (see Figure

4). In this way, it is also possible to teleport behind smaller obstacles. Further, the outline of the chaperone mesh is displayed and can be turned using the track pad on the controller. The trigger (see Figure 1) is used to grab and hold objects.

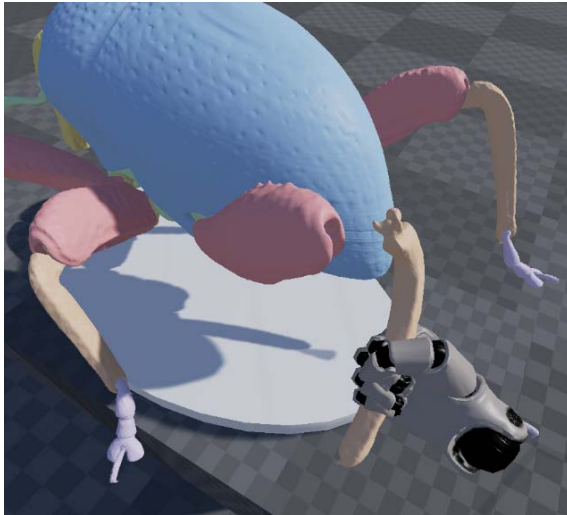


Figure 5: Grabbing and investigating the beetles leg in detail. As visual feedback of the user hand position a robot hand is displayed in the virtual world by the UE4 VR blueprint template.

3.3 Combining 3D Imaging and Projections for a Medical Application

The objective of the project *Ultrasound Computer Tomography* (USCT) is to establish a new imaging methodology for early breast cancer detection (Ruiter et al., 2012 and 2013). In this use case we combine 3D meshes and the according image slices. The images were taken from an artificial mamma phantom containing hidden inner structures to simulate tumour tissue of differing physical properties. The images result from the reconstruction process and the mesh is produced out of a segmentation-processing step.

Our setup for this third use case has the objective to give the spectator a spatial impression of the object. Therefore, it is placed on a table and ‘mounted’ onto a frame. A second frame is movable into one direction, like a slider, and can be moved through the 3D model using the hand controller. Depending on the position of the ‘slider’ the according image slice is displayed on a large polygon (see Figure 6). To browse through the images, we use a UE4 *FlipBook* Blueprint to select the according image with respect to the slider

position.

This application is currently under development. Plans are to make the image slice movable and to provide meta information belonging to the data set. To investigate the inner part of the 3D mesh, arbitrary cutting planes would be helpful.

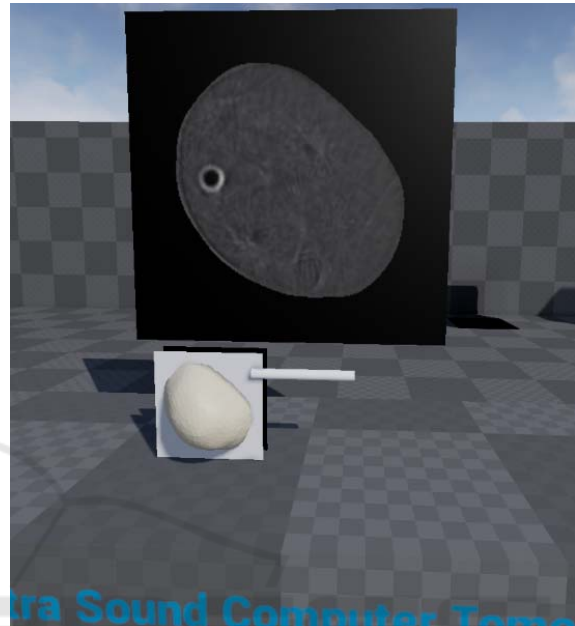


Figure 6: A virtual USCT image viewer: segmented 3D mesh in the foreground, the original image slice behind the table in the background in poster size.

4 CONCLUSION AND OUTLOOK

Our question was: Do scientific applications benefit from VR gaming technology? We used the HTC Vive VR headset and controllers in three use cases, which we implemented using the software Blender and Unreal Engine 4 game engine.

VR provides some traps. It is essential to avoid simulation sickness. On the other hand, there are so many new possibilities. The amount of immersion is simply impressive. If the goal is to show the user realistic impressions of objects or locations, VR is the method of choice.

VR can help in investigating 3D mesh models. We developed and implemented some ideas like the 3D explosion drawing. The obvious next step is to implement constraints to the joints of the single segments – then we could investigate, how the weevil moves.

For navigation and interaction in virtual reality environments alternative techniques need to be developed. Traditional control using keyboard and

mouse is not possible, as the VR headsets cover the eyes of the users. One solution for navigation is the *teleport navigation*, which additionally helps to avoid simulation sickness. Tracked controllers simplify the investigation of virtual objects like the insect. In 2D applications, a spectator usually needs to learn complicated combinations of mouse movements and keyboard buttons to select, pan, rotate and scale objects to be able to investigate it from all possible viewing directions. With tracked controllers, only the trigger is necessary to grab and select an object, afterwards it can be turned and moved around by moving the hand like in real life. This kind of interaction ability may increase the usability and user-friendliness of visualization systems.

On the other hand, complex or ‘special’ interactions need new types of user interfaces. In our use cases, we implemented a *virtual button* to convert the 3D beetle mesh into a 3D explosion drawing and a *virtual slider* to browse through the tomography image stack. And the teleport indicator acts like a virtual pointing device. Current VR games and applications are using various additional ways to implement virtual control elements like virtual menus, buttons, laser pointers etc. In general, virtual control elements are necessary to provide additional interaction abilities and we expect to have common ‘best practices’ in the near future. We recommend mimicking real world interaction schemes in the virtual reality environment to simplify the learning process of the VR system users.

An open issue is actor/player collision in VR environments. The player can easily move its hands or head into or through virtual obstacles like objects and walls. In traditional 2D applications, the rendering engine can just prevent such movements. In VR applications, this could destroy the immersion or even could result in simulation sickness.

Some visualization systems are designed to support collaborative work of a team of e.g. domain scientists. Using a single VR headset isolates the active user from the remaining team. In our VR application use cases the images inside of the VR headset are mirrored on a separate monitor, so team members are able to follow the user -passively- in the virtual environment.

It is planned to extend the beetle VR use case to a ‘virtual museum’ and present the virtual specimen of other insects, too. In order to provide numerous visitors the VR experience, it would be interesting to have cheaper devices, maybe based on smartphone headsets. As already mentioned, the Google VR

device family has too low image quality and no controllers. However, recently Googles *Daydream View* VR headset became available, providing high quality displays and one tracked hand controller, and we are planning to investigate its usability for our use cases.

The VR headsets in conjunction with tracked controllers are powerful new tools for visualization of higher dimensional objects. In the near future, we expect further developments of VR software, higher resolution HMDs, more accurate tracking, more natural 3D controllers and multi-user VR systems. We are just at the beginning. But the current technology is already sufficient for serious and exciting scientific visualization.

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