Interactive Scientific Visualization in 3D Virtual Reality Model

Filip Popovski [1], Igor Nedelkovski [2], Svetlana Mijakovska [1],
Gorica Popovska Nalevska [3]

[1] *Faculty of Technical Sciences, SS Kliment Ohridski, Makedonska Falanga 34, 7000 Bitola, R. Macedonia*
[2] *Faculty of Information and Communication Technologies, SS Kliment Ohridski, Partizanska, Bitola, Macedonia*
[3] *PhD Researcher, Pande Kajzero bb, 7000 Bitola, R. Macedonia*

Abstract - **Scientific visualization in technology of virtual reality is a graphical representation of virtual environment in the form of images or animation that can be displayed with various devices such as Head Mounted Display (HMD) or monitors that can view three-dimensional world. Research in real time is a desirable capability for scientific visualization and virtual reality in which we are immersed and make the research process easier. In this scientific paper the interaction between the user and objects in the virtual environment are in real time which gives a sense of reality to the user. Also, Quest3D VR software package is used and the movement of the user through the virtual environment, the impossibility to walk through solid objects, methods for grabbing objects and their displacement are programmed and all interactions between them will be possible. At the end some critical analysis were made on all of these techniques on various computer systems and excellent results were obtained.**

Keywords - **Scientific visualization, Virtual reality, Real Time Interactions, Virtual environments, Computer design.**

1. Introduction

”Scientific visualization is the use of computer graphics to create visual images which aid in the understanding of complex, often massive numerical representations of scientific concepts or results [14].

The process of data visualization can be described as a sequence of fundamental processing steps like simulation, data selection, visualization and rendering [9]. There are several reasons in which virtual reality with immersing can provide a good environment for scientific visualization, [4][8]. Data are often high dimensional and presented in 3D volume. Visualization of this phenomena associated with these data often includes 3D structures. The shapes and relationships in the 3D structure are very important. Virtual reality can show these structures, providing a rich set of spatial and depth characters. Some researchers [3][5][6] have summarized four technologies which are crucial for VR: Displays, Rendering system with 20-30 f/s, Tracking system, Database for building virtual world. The sensation of space and depth is essential for every VR system. The human visual system interprets the depth in sensed images using both physiological and psychophysical cues [17]. Furthermore, interfaces for virtual environment follow quickly and intuitively exploring 3D volume which contain datas, allowing examination of various phenomena in different places in that volume. Scientific visualization is oriented in informative viewing of abstract quantities, rather than trying to present real objects in the real world. Therefore, the graphical requirements of scientific visualization are oriented on accurately displayed data. We can choose graphical representations that correspond to current technology. Because phenomena that are presented are artificial, the researcher can do research in virtual environments that are impossible or meaningless in the real world.

In many ways, the main impact of virtual reality technology on scientific visualizations consists of providing an intuitive interface for research data. To have maximum benefit, visualization in virtual reality can be integrated into computer management environment, providing a virtual laboratory where the researcher can immediately visualize the data and interactively manage the simulation.

2. Scientific visualization in virtual environment and techniques of interaction

Interaction is an essential characteristic of virtual environments [19]. About interaction techniques in virtual reality there are many research, but the question for truly intuitive and natural interaction techniques still endures. The interaction between users and virtual environments is complex. Users must be able to navigate through the 3D space, manipulate with virtual objects or control parameters of a simulation, and interact with the 3D GUI inside the virtual environment in a user-friendly way [2].

The interaction between user and objects in our virtual environment (VE) are in real time. For this to be possible, the movement of the user through the virtual environment, impossibility to walk through solid objects, methods for grabbing objects and their displacement are programmed and all interactions between them will be possible, which is shown in Figure 1. It is the virtual environment of real sport hall located in Skopje, Macedonia with all buildings around it. We made it in 3Ds Max and converted it in Quest3D VR.
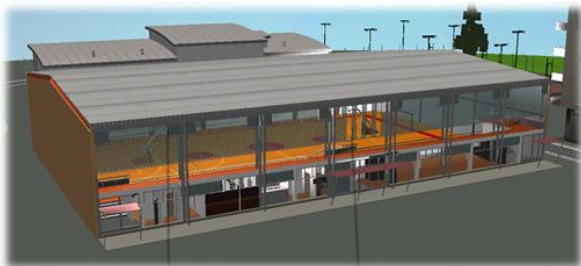

Figure 1. Virtual environment of real sport hall

At the beginning, we programmed movements of the user in virtual environment and inability to pass through solid objects. It applies to all solid bodies in which the user can not walk or run.
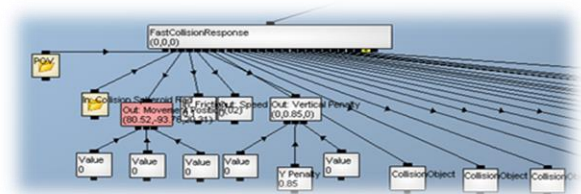

Figure 2. Object oriented programming in Quest3D and the impossibility of user to pass through solid objects

In this case the interactivity refers to the user and his inability to move through solid bodies like walls of buildings, fences or windows.
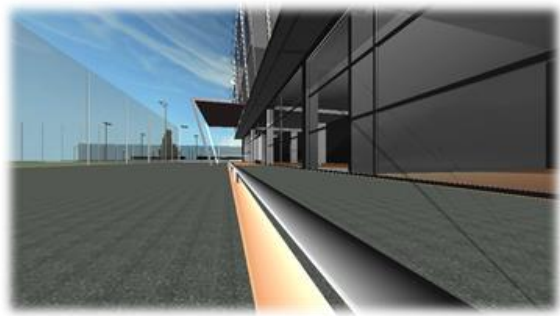

Figure 3. Visual view of interaction between the user and the outside fence

Next step is programming interactivity between the user and objects in the hall. The movement of the ball occurs according to the laws of physics and it is added a gravity force. Also it has been introduced the frequency of moving the ball up and down so the movements will be more realistic. Then we made programming for taking the ball in our virtual hands, running together with the ball and throw the ball in real time.
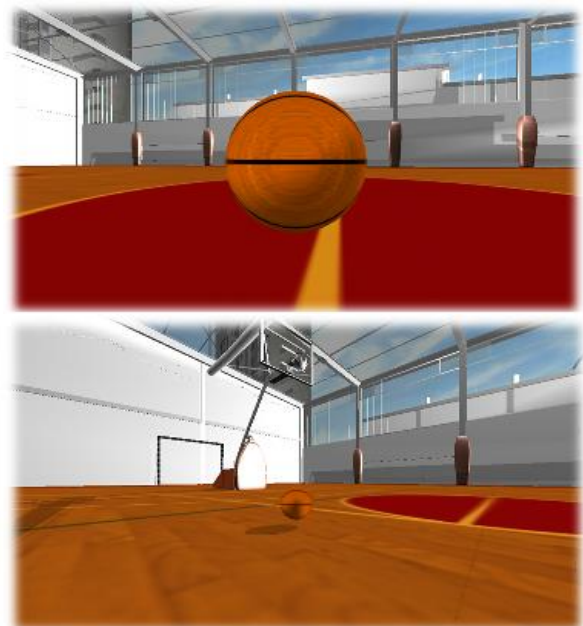

Figure 4. Techniques of interaction between user and the ball

There is also interaction between the user and the objects in the fitness center. The user can select any of the objects, such as bicycles, accept it and move it in all directions. For this purpose, we programmed bicycles benches that can be moved from one place to another.
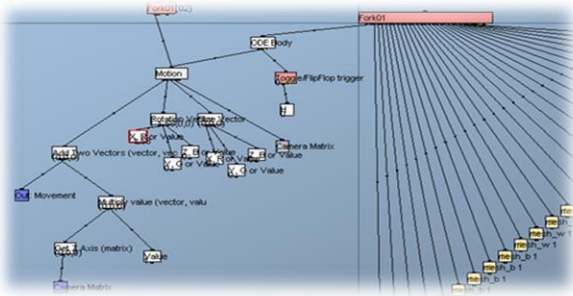
Figure 5. Programming for possibility to move the bike through the virtual environment

In this model was added the gravity force as well as special keys for accepting and putting bicycle in a certain place. The movements of the user and the bicycle with their shadows are in real time and according to the laws of physics.
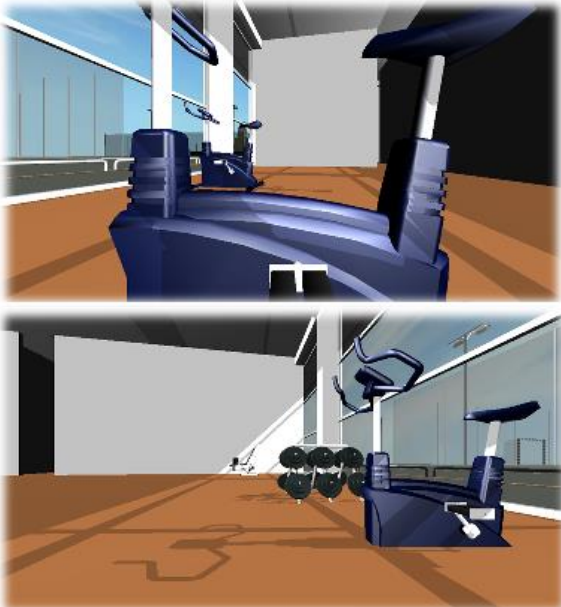

Figure 6. Techniques of interaction between user and the bike in fitness center

Very important characteristics in our virtual world are interactions with environment [7]. In our case it relates to the falling of sunlight on objects and sport hall and motion of their shadows, depending on the light source. When the sun moves from east to west, movements of the shadows are opposite of the light source.

Figure 7. Techniques of interaction with the environment in virtual world

3. Simulations in Real Time

In this part of the research there will be a visualized mechanical part of airplane or its engine created in 3Ds Max and will be put in a virtual environment. In this model there are visualized several processes such as the movement of each fin separately around the axis of symmetry and adding real sound of jet engine in a virtual environment.

The presence of the audio modality extends the realistic impression of the virtual environment. A variety of choices (e.g., different types of music, sounds on/off, environmental sounds, instructional and praising statements, airplane sound etc.) gives the user a sense of control and also involves him or her into it [13]. The primary goal of this model is to show the behaviour of jet engines in a virtual environment when they will start running. Firstly, there should be given options for moving each of the fins separately and then equal their speed and acceleration compared to the potentiometer in the window and the sound from the engine itself. With each movement of the potentiometer, the engine speed and the fins themselves will increase, and it will have stronger and sharper sound.

Figure 8. Interaction between user and objects in real time simulation

Presented model displays 25 frames per second. In extreme situations, it can speed up to 60 frames per second. Acceleration of the airplane motor has sound effects and motion blur view. This means that the user feels comfortable in our virtual environment.

4. Implementation of C++ codes for HMD and Motion Tracker

Many VEs are designed to simulate real-world scenarios, but the experience is constrained by the VR hardware used. For example, typical VR restrict the user's field of view, as compared to the real-world interactions. This can decrease the feeling of presence in the virtual environment, and the lack of expected sensory feedback may hinder a user's virtual movement performance [12]. If we want the user to be fully immersed in a virtual environment it is necessary to use additional hardware for virtual reality. Large and expensive VR systems, such as CAVEs and panoramic walls, are not affordable or suitable for the daily-use in real research work in many application areas [18][20][16]. What is required are ergonomic VR systems, with which the scientists can work longer than 30 minutes in their natural environment with stereoscopic 3D view. It presents different image content to each of viewer's eyes to create the illusion of visual depth [1]. Stereoscopic 3D imaging is similar to immersive virtual technology. Although virtual immersive technology allows a player to be engulfed in or feel as if they are actually present in a virtual world, 3D mimics by creating an illusion of visual depth for the user. [11]. In the configuration of our virtual environment there is a programmed support for HMD Vuzix Wrap 1200 DX-VR. Firstly the whole process was programmed to be viewed through stereoscopic projection. HMD contains a system for tracking the movement of the user's head Wrap Tracker and with it the sense of immersion is very good. For this purpose we programmed support in C++ for full equipment functionality. Now with this programming we can see and manipulate with graphical objects on the screen, but also we could touch and feel them. Research goes in a direction to make sensors for hearing, tasting and smelling [15]. Our codes in C++ are for stereo sound, to calibrate the movements of the sensor in zero position and tracking movement in all axes. In every codes in C++ are used prepared library data. Here only some of them will be presented.
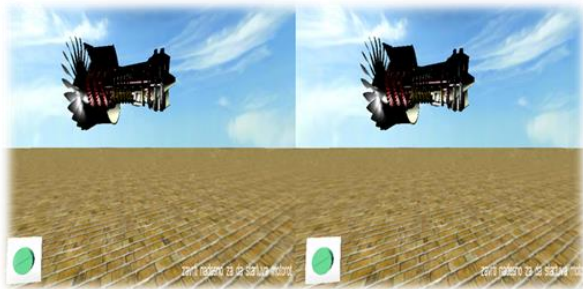

Figure 9. Interaction between user and objects in real time simulation

First programmed channel in C ++ is for adding stereophonic sound in a virtual environment in which the user feels real.

Figure 10. Channel for stereophonic sound

Next, we made programming channel for tracking movement of the user head through virtual environment. With each movement of the head in any direction simultaneously the view of the user changes in that direction. First we made programming code for calibrating tracker in the position in which the user is.

Figure 11. Channel for calibration of movement in all axes

Then we made programming channel for tracking of the user head in all directions, tracking in zero position, calibration of the movements in all directions etc.

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5. Results and Analysis

Scientific visualization is essential in interpreting data for many scientific problems. It transforms numerical data into a visual representation which is much easier to understand for humans [10]. Interactions between the user and objects are important characteristics in the virtual environment. Above all, these interactions are related to acceptance, displacement and movement of objects, their shadows, gravity force, accessible and impassable areas through which the user can pass. In both models interactions are in real time.

Speed of the user in the virtual environment is different, depending on the mode of viewing. Certainly it depends on the hardware components of the system, and also on the resolution. Different display resolution have different times of movement, both in Quest3D and in the executive version. In table 1, are given times of movement on 100 units in the same computer system at various resolutions at Quest3D (.cgr) and executable version (.exe).

Table 1. Comparing the times of movement at different resolutions in Quest3d and executable version

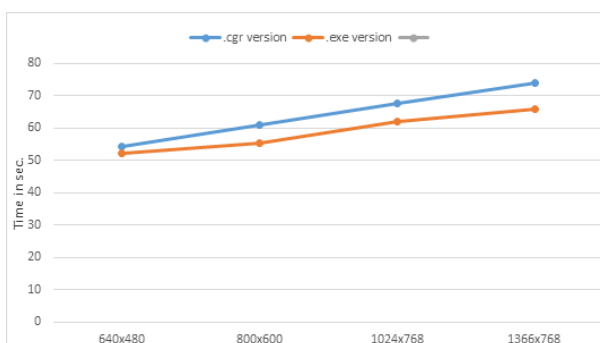| Resolution	.cgr	.exe
640x480	54,2 sec	52,1 sec
800x600	61,1 sec	55,3 sec
1024x768	67,5 sec	62,2 sec
1366x768	74,0 sec	66,0 sec

Figure 12. Dependence of the time of movement in virtual environment of the resolution in 100 steps of the user in Quest3D and executable version

In table 2 are given dependences of the interaction between the user and objects in a virtual environment from the performance of the computer system. From the table we can see that speed of interaction is better when working in the executive version of the software. First model that we made is sports hall and it contains more than 65536 polygons that contribute to the process of interaction and sometimes delay the executive version.

Table 2. Comparing the speed of interaction between user and objects in Quest3D and executable version

Category	.cgr	.exe
Delayed time of interaction	Rarely	No
Speed of the interaction	Good	Excellent
Performance of computer	High	Low

6. Conclusion

This paper gives some great results in the field of visualization in virtual reality .Performance of the system is very important characteristic when rendering is in real time.Interactions between user and objects in a virtual environment are real and with the laws of physics. It refers to the movements and acting force of gravity, the way of acceptance and placing objects, user interactions with solid objects and impossibility to walk through them, the sound effects that capture real feeling in the surrounding area. The lighting of the environment is another important characteristic with which the user can feel the real view of the environment. It refers to the fall of the external light on the objects in the virtual environment and its behavior. The increase and decrease of the intensity of light energy affects to the shadows and visibility in the virtual environment. Second model with airplane engine gives sound effect from the real engine and user can feel comfortable in virtual environment.

From the performed analysis it is concluded that this system works great on different computer systems with different performances. The quality of graphics and speed of rendering is excellent, while rendering is in real time with a minimum of 25 frames per second and can speed up to 60f/s. The work in the executive version gives better results at different resolutions. With additional hardware component Vuzix Wrap 1200 DX-VR this study leads us to a higher level in the field of virtual reality. Displaying virtual world is in HD resolution. Programmed codes in C ++ support system for tracking the movement of the user head in all directions with high level of immersion in which user will feel comfortable.

At the end we made model for interactive scientific visualization in 3D virtual reality that have user friendly interface; no need of expensive accessories for virtual navigation (HMD Vuzix Wrap 1200 DX-VR, Wrap Tracker) and cost under 1000 EUR.

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