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ANALYSIS AND COMPARATION OF MODELS FOR INTERACTIONS IN VIRTUAL ENVIRONMENTS

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ABSTRACT

Scientific visualization is the use of computer graphics for creating visual images that help in understanding the complex, often large number of representations of scientific concepts or results. That kind of numerical representations or groups of data, can be result in numerical simulation of computer fluid motion, molecular dynamics or engineering in general, reading (recorded) data in geological, meteorological or astrophysical applications.

In this paper are analyzed 6 models for interactive scientific visualization and was made their comparison in terms of features that they offer and the price for their implementation. The purpose of the analysis is to obtain guidance for developing own model for interactive scientific visualization adapted to circumstances in research centers in Republic of Macedonia, which means to be optimized for effective results by using cheap equipment no more than 1000 Euro.

Key words: Virtual reality, Virtual environments, Scientific visualization, Computer design, Techniques of interaction.

1. INTRODUCTION

The idea of inserting a man in some imaginary the world is very old. Needs for visualization unrealistic, but yet sufficiently realistic environments occurs in the middle of the twentieth century.

First registered attempt that has similarities with modern devices was constructed by Morton Heilig (1926-1997) and was named Sensorama. It was a motorcycle simulator that had a wide range of stimuli that simulate. For visualization of images it used video projection and for sound it used appropriate audio of motorcycle. It was interesting that this device simulated vibration and even the smell of overheating tyre. In 1960 was designed the first device with built-in display that bring on the head (HMD), and in 1977's was constructed first Data Glove. The early nineties of the last century marked the development of various devices and software for virtual reality. Today, the applications for virtual reality technology provides good solutions in the implementation of complex visual requirements.

2. SCIENTIFIC VISUALIZATION IN VIRTUAL REALITY

2.1 Scientific visualization

"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 (McCormick, 1987)."

Such numerical representations, or datasets, may be output of numerical simulations as in Computational Fluid Dynamics (CFD), Molecular Dynamics (MD) or engineering in general, sensing (recorded) data as in geological, meteorological or astrophysical applications. 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. The process of data visualization can be described as a sequence of fundamental processing steps :

- **Simulation:** results of numerical simulations (or data sensing / measurement) are the input of the visualization pipeline.
- **Data selection & filtering:** relevant regions of the raw data are selected, then filtered and enhanced. Techniques such as: i.e. enrichment & enhancement, data cropping, down-sizing, noise filtering, segmentation and feature extraction can be used.
- **Visualization mapping:** the processed data have to be mapped / transformed into graphical primitives such as points, lines, planes / surfaces (triangle meshes), or icons, and their properties such as color, texture or opacity.
- **Rendering:** finally, the graphical primitives are rendered as images, which are then displayed on the screen.

2.2 Virtual reality

Virtual reality can be defined in many ways, which all come down to the definition of a significant relationship between human and computer. It can be described as a simulation that computer graphics applies for creating a world with realistic view and that synthetic world is not static, but responds in some way to the reaction of the user and modify the environment in real time. Interactivity and its effect contributes to a strong sense of Immersion - including in the environment in which is the user. He can see and manipulate with graphical objects on the screen, but also could touch and feel. Studies go in that direction to make sensors for hearing, taste and smell.

In this paper, we refer to the concept of immersive Virtual Reality, which gives the user the psycho-physical experience of being present in a virtual environment consisting of interactive (virtual) objects. This experience is achieved by a proper integration of VR hardware (3D displays and spatial interaction devices) with a responsive computer-generated 3D environment.

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. Through the use of artificial depth cues in computer graphics, these spatial sensations can be simulated. In Immersive Virtual reality the stereo display and head tracking are used to also provide the binocular parallax and motion parallax, respectively.

2.3 Scientific visualization in virtual reality

Visualization in a technology of virtual reality is a graphic representation of the virtual environment in the form of images or animation and can be displayed with various output devices such as monitors, LCD projectors, TVs and similar devices that can display three-dimensional world.

Visualization on desktop workstations produces static or animated images. Interaction with the visualization pipeline is usually provided via 2D user interfaces (keyboard and mouse). Visualization in virtual environments produces interactive virtual objects instead of images, see Figure 1. These virtual objects are present in the VE, and can have customized look and behavior. The objects may be directly selected (touched) and manipulated by the user. The proper employment of immersive Virtual Reality techniques and VEs can revolutionize the way the data are visualized and how people operate visualization environments. Instead of displaying 3D worlds inside of computer monitors with conventional 2D interaction, the scientists can now see these 3D worlds in the same space where they can naturally interact with the virtual objects.

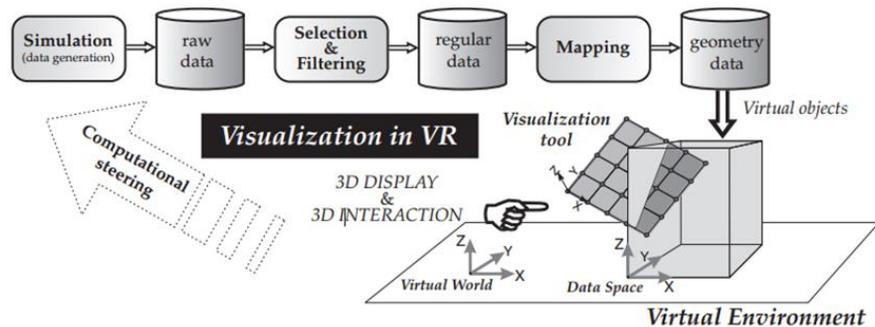


Figure 1. Visualization pipeline integrated with a responsive Virtual Environment

3. MODELS OF INTERACTION IN VIRTUAL ENVIRONMENTS

Interaction is an essential characteristic of virtual environments. Much has been published about interaction techniques in VR but the quest for truly intuitive and natural interaction techniques is still going on. Interaction between users and virtual environments is complex. Users must be able to navigate through 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. In this paper are processed several models of interaction in a virtual environment and each of them has special tools and equipment.

M. Rorke, S. Bangay, P. Wentworth (2000) with the help of Rhodes University implemented the system with a magnetic tracker and simple device with four switches called virtual stick. There was worked on some problems related to interaction in immersive virtual reality and was given recommendations on how is best to deal with them. Their research showed that most applications for virtual reality belong in the field of spatial realization and there is a very little effort to allow users to direct manipulation with objects. The main reasons for this are listed haptic force feedback, equipment for monitoring, precision of devices, etc..

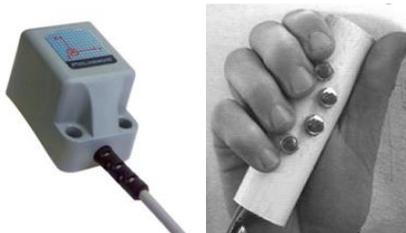


Figure 2. Magnetic Tracker and Virtual Stick

D. Bowman (2001) proposes a systematic study of the design, evaluation and implementation of techniques of interaction in VE. He designed an effective and efficient interaction techniques in VE. Most of them belong to three categories: point of view in motion, selection and manipulation. For each of these tasks there are many proposed interaction techniques.

The motion is part of a bigger task of navigation that includes real movement and decision process of the desired direction and aim of the movement. Three main components are involved in this technique and they are direction, speed and conditions which a user begins, continues and ends with the movement.

Selection refers to specifying or selecting an object for a specific purpose, while manipulation refers when the user touch the objects with the virtual hand and manipulate with them. Two basic techniques of selection and manipulation are presented. The first is ray casting, while the second is arm extension. In a ray-casting technique a light ray emanates from the user's virtual hand. To select an object, the user intersects the object with the light ray and performs a "grab" action usually by pressing a button. She can then manipulate the object using the light ray. Arm-extension techniques allow the user to reach far away objects by providing a means to make the virtual arm longer than the user's physical arm. This can be accomplished by various mapping strategies, button presses, etc. The user then selects and manipulates the object as with the in-hand metaphor: touch the object with the virtual hand and manipulate it with hand movements.

M. Koutek and F. Post (2001) presented a model of spring based tool for user interaction with virtual worlds, that will provide more realistic feel to the manipulation with objects in virtual environments. This tool using a spring attaches to objects and help in manipulating with them. This tool gives the user a feeling of weight or mass of the objects and can get natural visual force feedback during manipulation. When the user take some object, spring will expand proportionally to the weight of the object. Also, acceleration and deceleration of the movement will effect on the visible length of the spring.

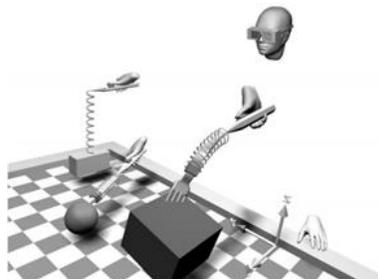


Figure 3. Spring-based manipulation tool

J. Kjeldsov and J. Stage (2003) describe and evaluate tools for developing software applications for virtual reality. Their goal is to compare and discuss the importance of classic styles of interaction for tools that are used in development of applications for virtual reality. The focus is on the process of developing actual virtual reality applications and comparing the potential of development tools based on a command language with one tool that is based on direct manipulation. The first category can be characterized as a classical programming approach, since the creation and manipulation of the virtual world and the objects in it is specified in a command language. One of the most widely used binary libraries for developing 3D virtual worlds is CaveLib. The second category of tools for developing virtual reality applications can be characterized as a graphic representation and direct manipulation approach. One of the few professional tools in this category is dvMockup.

L. Vogelmeier and others (2006) developed an application for virtual reality and it was cockpit using virtual prototypes. For this application it is essential to ensure, that the deviation of the real human body from its virtual representation is within a defined margin. Another important feature for cockpit development is the provision of haptic feedback. Both requirements could not be satisfied using commercially available tools, so they needed to develop their own methods. In the beginning they concentrated their activities on a precise representation of the human body. For this purpose they designed easy-to-use calibration methods for the measurement of the tracking sensor positions at the human body. In addition they developed a new kinematic model, which was able to compensate for inaccuracies, which arise from differences between the virtual and the real skeleton. In order to provide haptic feedback they built a flexible Mixed Mock-Up system, parts of which can be adjusted by the user during the VR session. For each method it is necessary to put special unit called LRU (Line Replaceable Unit). It is a box with electronics for complex engineered system that speeds up the operation.

P. Boudoin and others (2008) proposed a new multimodel for 3D interaction. It is a model for increasing the realness and the easiness of the interaction in virtual environment called Fly Over and is especially devoted to the navigation task. The purpose of this model is to give a sense on the user that moves naturally and easily in a virtual environment. This model offers possibility that all 3D navigation devices can be replaced with a simple pointing device called Fly Over.

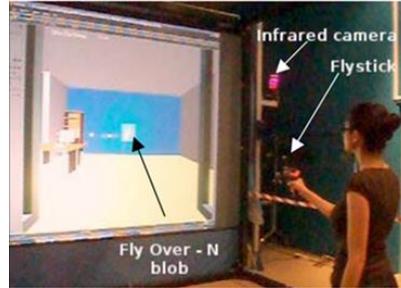


Figure 4. Experimental setting with the use of Fly Over on the semi-immersive platform. Users navigate by moving a Flystick in their hand, which position is computed by two infrared cameras.

4. ANALYSIS OF IMPLEMENTED MODELS FOR INTERACTION IN VIRTUAL ENVIRONMENTS

Model of *M. Rorke* is easy to use and provide tools to overcome the problems with haptic force feedback. But it also offers some alternative solutions to overcome problems in virtual environment.

In the model of *D. Bowman* none of the described techniques not provided optimum usability. In general Ray Casting technique is better choice than the Extended Arm technique which requires greater precision and manipulation with objects. However these techniques and research gave their contribution to the interesting and complex virtual applications such as Architectural Walkthrough and Gorilla Exhibit.

M. Koutek and F. Post designed tools to produce realistic visual force feedback. From the performed testing for manipulation in virtual environment with group of people, spring based tool is easy and intuitive to use. The results show that the behavior of the objects is a natural and predictable in most virtual environments. Synthetic models which are using the spring based tool look and feel surprisingly real. Approximation of the mechanics seems good enough to create illusion of weight and substance.

From the performed study of *J. Kjeldskov and J. Stage* is showed that implementing a virtual reality application using a command language tool and a direct manipulation tool required efforts in terms of time that are comparable. The command language tool, however, resulted in faster implementation during the most essential phases of the implementation process and thus outperforms the direct manipulation tool on a larger scale. The direct manipulation tool on the

other hand resulted in fewer errors. While the empirical results from the comparing shows that command language tool is simply superior to direct manipulation tool and is a three times faster in the implementation of the primary application. In further investigation direct manipulation reveals a number of more specific issues, which may have negatively influenced the performance of dvMockup.

On the model of *L. Vogelmeier* problem areas for examination were haptic force feedback, having a good motor skills, movement of the user and his visual perception, visual quality, etc.. They made five methods for examining the interactions in the model.

The first method was to use a Data Glove for interaction in combination with a contact simulation. Visualisation was provided by the data helmet and no haptic feedback was available. The contact simulation ensures that, if a collision between the LRU and the aircraft structure occurs, a compensation movement is calculated. If a collision occurs and the real hand continues to move, the positions of the real hand and the virtual hand do no longer correspond. This positional difference is visualised by the introduction of a second virtual hand in a wireframe look which represents the position of the real hand.



Figure 5. Holding a Ball with Two Virtual Hands; the Opaque Hands Show the Positions of the Virtual Hands, the Wireframe Hands Show the Positions of the User's Real Hands. They are, in contrast to the virtual hands, able to penetrate the ball.

The second option was to skip the contact simulation and to utilise a real size model of the LRU made of polystyrene. It was provided with an additional tracking sensor, so that the movement of the real LRU and its virtual representation matched. The user was wearing two datagloves, they were visualised by two virtual hands. So the user was able to see and also feel the LRU.

The third method applied an active force feedback device (FFD), which comprises a robotic arm,

the joints of which were controlled by electric motors. The FFD allowed to provide a force on to the user. The range of the robotic arm was comparable to the range of a human arm. A mock-up of the LRU was mounted at the end of the FFD arm. The contact simulation linked to the FFD made sure that, in case of a collision between LRU and aircraft structure, the respective force is transmitted to the user.



Figure 6. User Working with the Force Feedback Device

The fourth interaction method was to use a Space Mouse to control the movement of the LRU in combination with a contact simulation. The visualisation was stereoscopic on a desktop monitor. The Space Mouse allowed the user to move an object in all six degrees of freedom.



Figure 7. Space Mouse

The last method was to use a Flying Mouse for the control of the movement of the LRU in combination with a contact simulation. The visualisation was done in a four Side Cave System. The Flying Mouse has the form of a handle; it contains one or more triggers and a tracking sensor to pick up its position and orientation in space. By pressing a trigger, the virtual LRU is tied to the Flying Mouse and is moved according to the movement of the Flying Mouse. With the Flying Mouse it was much easier to control the LRU than with the SpaceMouse.



Figure 8. Flying Mouse

Model of P. Boudoin is based on two main ideas. First, all basic 3D interaction tasks may be turned into a simple pointing task. Second, the 6D space of the user (3D position and 3D orientation) may be seen as a set of hyperspaces in which a separate pointing task may be applied. Due to these ideas, Fly Over may be utilized the same way with various 2D, 3D or 6D devices. The generic model has been applied to a 2D navigation task and has been compared to the gaze-steering technique. Preliminary qualitative results shows that Fly Over generates smoother trajectories and is well accepted by the users.

5. COMPARATION

Overview of the characteristics of processed modes is shown in Table 1, while the cost of each individual model are shown in Table 2.

Table 1. Overview of the characteristics of the considered models

Author	Dim	FF	Using			Looking to			TA
			HMD	VH	VS	VD	CV	CK	
M. Rorke and others	3D	-	X	-	X	X	-	-	10 min.
D. Bowman	3D	-	X	X	-	X	-	-	1 hour
M. Koutek and F. Post	3D	X	X	X	-	X	-	-	3-8 hours
J. Kjeldsov and J. Stage	3D	-	-	-	-	X	-	-	2-10 hours
L. Vogelmeier and others	3D	X	X	X	X	X	X	X	24-72 hours
P. Boudoin and others	3D	-	-	-	X	X	-	-	1 hour

Legend:

Dim - Dimensions

VD - Virtual

Display

FF - Force Feedback

CV - CAVE

HMD - Head Mounted Display

CK - Cockpit for Virtual Reality

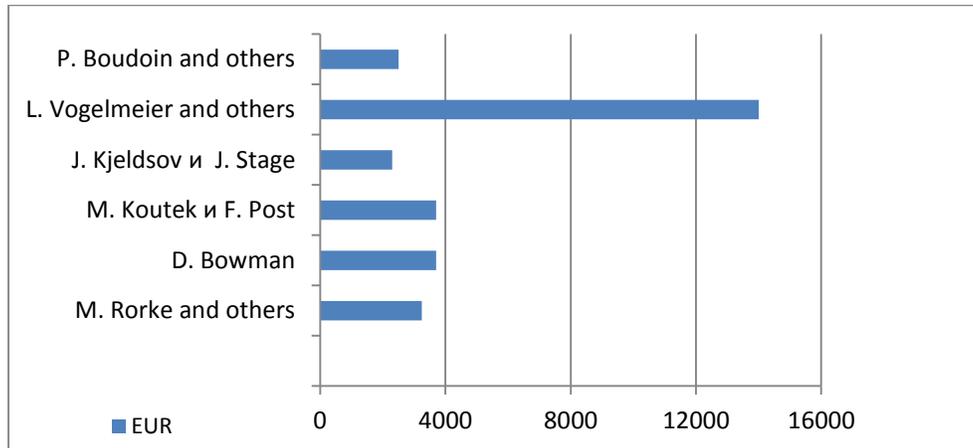
VH - Virtual Hands
of Adjustment

VS - Virtual Stick
no

TA - Time

X/- - yes /

Table 2. Overview of costs



6. CONCLUSION

From the performed comparison all models related to 3D virtual environment. Also, in each of these models user view is directed to the virtual display or virtual workbench, with the exception of the model of L. Vogelmeier which included also cockpit for virtual reality. In most models is used HMD and equipment appropriate for each model. But an important characteristic is that only two models had force feedback in contact with objects in the virtual environment. Another important element in these models is a time of adaptation by the user. From performed analysis model of M. Rorke is the easiest for using and can be used after 10 minutes of exercise. All models have a similar price in the market which is around 3000 EUR excluding model of L. Vogelmeier which is very expensive due to the complexity of the system and the high performance it has.

At the Faculty of Technical Sciences in Bitola in progress is development a model for interactive scientific visualization that will be based on the following principles:

- User friendly interface;
- Using open source libraries;
- Using normal computer monitor or LED TV;
- Unexpensive accessories needed for virtual navigation (HMD, trackball, virtual stick).

The same model compared with analyzed is expected to have the following advantages:

- To enable work on any computer that supports CAD software who can run interactive scientific visualization;
- It will be a low cost of about 1,000 EUR;
- It will give a contribution to the field of interactive scientific visualization as a tool for a large number of users which are not specialized in the field of engineering technology and virtual reality.

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