STUDIA UNIV. BABEŞ–BOLYAI, INFORMATICA, Volume **LIX**, Number 2, 2014

AUGMENTED REALITY WITH INTERACTIVE INTERFACES

MARTIN VARGA, BRANISLAV SOBOTA, FRANTIŠEK HROZEK, AND ŠTEFAN KOREČKO

Abstract. The Augmented Reality (AR) merges a real world and a virtual environment. A virtual object is added into a real world in order to improve or to add more information for an observer. AR is computer-generated data integration with the real world, which among others can be done with computer graphics rendering on a real-time footage. The paper presents a concept for design of augmented reality system, which uses two head-mounted displays (HMD). Two users can see the same virtual scene in own real environment via HMD. Proposed system also allows users to change 3D objects in AR scene directly using data gloves. We develop this interactive AR system in our virtual-reality laboratory (Laboratory of Intelligent Interfaces of Communication and Information Systems - LIRKIS).

1. Introduction

The Augmented Reality (AR) merges a real world and a virtual environment. A virtual object is added into a real world in order to improve or to add more information for an observer. AR can be used for many things, such as displaying a mobile directions to head-up display, in the medical field, the AR may help doctors to insert information on a patient's medical record (such as x-ray result from the patients), or to reconstruct the old buildings and historic as reality which can be seen at present time [4], [11] , [12]. AR in the architecture merges virtual designs with real construction sites, and enables new types of interactions that enhance the design process [1]. Behzadan et al. developed a hardware and software framework for visualization of construction processes (e.g., machinery placement) for construction sites [2].

Received by the editors: August 15, 2014.

2010 *Mathematics Subject Classification.* 68U05, 97R60.

1998 *CR Categories and Descriptors.* I.3.7 [**Computer Graphics**]: Three-Dimensional Graphics and Realism – *Virtual reality*; I.4.8 [**Image Processing and Computer Vision**]: Scene Analysis – *Tracking*.

Key words and phrases. Augmented reality, data gloves, head-mounted display(HMD), interactive interfaces.

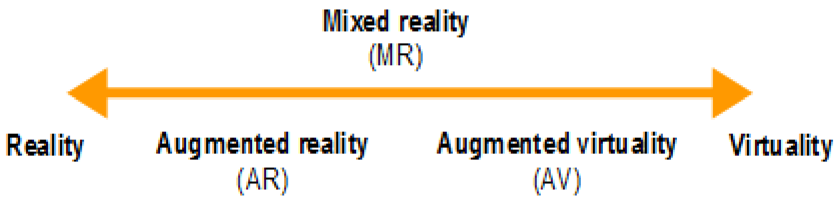

Figure 1. Milgram's definition of real to virtual world transition (reality-virtually continuum)

The article[13] discusses about the combination of networked video and augmented reality visualization. Visualization can give remote users a good working level of tele-presence with both the visualization and the remote room, and adequate sense of social presence though the visualization of the facial expressions of the remote users. The paper [10] discusses about the use of a wearable device for visualization and control Drone through head positions and gestures performed by the operator wearing a Google Glass.

Our proposed system can assist with interior designing or train new employees in the manufacturing process.

Augmented reality and augmented virtuality systems are quite similar and they belong under mixed reality definition. A goal of mixed reality system is to merge real world with virtual one into a new environment where real and virtual (synthetic) objects exist together and interact in real time. Relationship between mixed reality, augmented reality and augmented virtuality is defined by Fig.1 [3], [5].

According to the method how virtual objects are aligned with real scene image there are two systems use:

- **Marker systems** special markers are used in a real scene. The markers are then recognized during runtime and replaced with virtual objects.
- **Markerless systems** processing and inserting of virtual objects is without special markers. Additional information is needed, for example image (e.g. photo (semi-markerless system (articles [8] [9]))), face recognition, GPS data, inertial and electromagnetic tracking devices (articles [4], [6], [7]), etc [4].

2. Visualization Engines

In general, the purpose of graphics, or visualisation, middleware is to support loading and displaying of scenes to be visualised. It also defines data format for the scenes and provides processing of user input. It can also have additional functionality such as support of special effects and physics and come with integrated environments for scene development and scripting. Nowadays there are several open source solutions for VR and AR systems (e.g. OpenSceneGraph, OGRE or Irrlicht).

2.1. **OpenSceneGraph (OSG).** - Scenes are represented by a data structure called scene graph that arranges the logical and often also spatial representation of the scene. It uses OpenGL for rendering. OSG directly supports parallel computation thanks to the fact that the scene graph supports multiple graphics contexts and the cull and draw traversals have been designed to cache rendering data locally and use the scene graph almost entirely as a read-only operation [16].

2.2. **Irrlicht.** - Irrlicht [17] is a fairly lightweight 3D engine. For 3D rendering Irrlicht uses both mainstream application program interfaces Direct X and OpenGL as well as its own software renderers. One of the advantages of the engine is that it doesnt require any 3rd party libraries to be installed and configured separately, so it is quite easy to install and execute.

2.3. **OGRE.** - As in the case of Irrlicht, OGRE [18], [19] is only a rendering engine, so support for audio, physics and other features have to be added in the form of 3rd party libraries. It supports Direct X and OpenGL. This extendibility is supported by its highly modular plug-in architecture. ORGE supports only its own .mesh format. Fortunately, export to it is available in 3D editors (i.e. in Blender). To support input VR devices the Virtual Reality Peripheral Network (VRPN [20]) can be used.

3. Input and Output interfaces

3.1. **Head-mounted display.** A head-mounted display (HMD) is display device, worn on the head or as part of a helmet that has a small display optic in front of one (monocular HMD) or each eye (binocular HMD). Based on how a user sees mixed reality there can be two types of systems:

- **Optical see-through** systems where the user sees real world directly and computer generated objects are added to this view. This category of systems usually works with semi-transparent displays (see Fig.2).
- **Video see-through** where captured real world image with added virtual objects is displayed to the user. This is usually realized via camera display system [4].

FIGURE 2. The user with HMD display (nVisor ST 60)

3.2. **Electromagnetic tracking device.** Electromagnetic spatial measurement systems (see Fig.3) determine the location of objects that are embedded with sensor coils. When the object is placed inside magnetic field, voltages are induced in the sensor coils. These induced voltages are used by the measurement system to calculate the position and orientation of the object. Electromagnetic device usually composed of two parts (Magnetic field source and sensor) [4].

Magnetic field source -The Source is the device which produces the electro-magnetic field and is normally the reference for the position and orientation measurements of the sensors. It is usually mounted in a fixed position to a non-metallic surface or stand, which is located in close proximity to the sensors [4].

Sensor(s) - The sensor is the smaller device whose position and orientation is measured relative to the Source. The azimuth, elevation, and roll angles that define the current orientation of the sensor coordinate frame with respect to the designated reference frame [4].

3.3. **Data glove.** Data glove is device, which serves for capturing mechanical and gestural information from a hand. Various technologies are used for capturing this information. These technologies can be divided into two categories: technologies that determine the shape of the hand and position tracking technologies. Various types of bending sensors are used for shape determination (both hand and fingers). The three most common types of bending sensors are conductive ink-based, fiber-optic based and conductive fabric/thread/polymer-based [14]. Position tracking devices are used for sensing hand positon and rotation in 3D space [15].

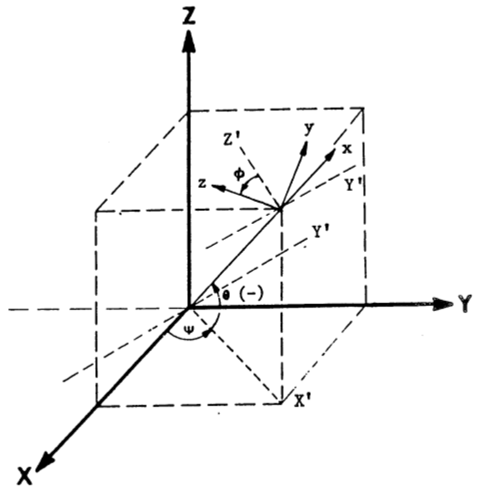

FIGURE 3. Reference frame of system Polhemus Patriot. Legend: X,Y,Z - alignment (reference) frame, x,y,z - rotated sensor coordinate frame, ϕ - Azimuth, θ - Elevation, ψ - Roll

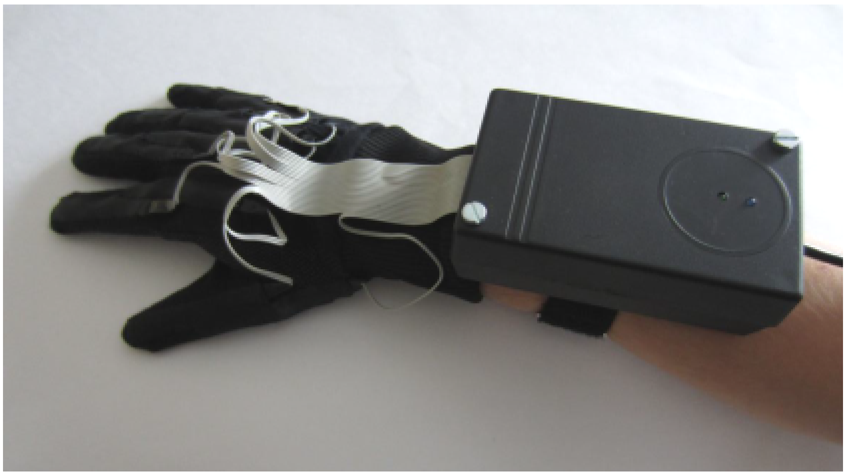

FIGURE 4. Data glove

Data glove (see Fig.4) which will be used in proposed AR system has five embedded bend sensors which allow accurate measurement of finger movements. Resolution of the finger sensors is 10 bits and sample rate is 25 Hz. For sensing both hand movements and orientation (roll and pitch) is used embedded 3 axes accelerometer. Measured hand acceleration is from -2g to 2g

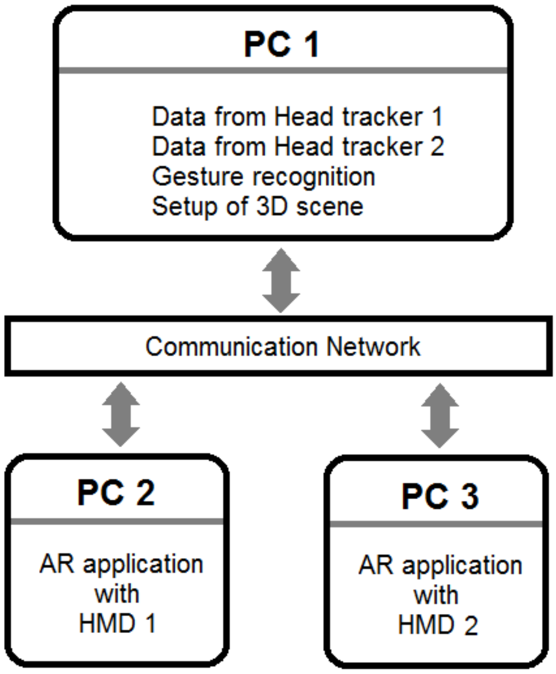

FIGURE 5. The architecture of the AR system with two HMDs using electromagnetic tracking system and data gloves.

and hand orientation resolution is 0.5. DG5 VHand 2.0 can be connected to PC by USB or Bluetooth [15].

4. System with two HMDs

Design of proposed AR system with two HMDs using magnetic tracking is shown in Fig.5. This system uses three computers. The first computer is intended for data collection from head trackers and data gloves. Data from data glove is used for gesture recognition. Gestures are used for interaction between a user and AR system (e.g. to change position of a 3D object in the virtual scene). The first computer (PC1) sends data (positions and orientations from head tracker 1 and 2 and actual position of 3D object in the virtual scene) to PC 2 and 3 via network. AR applications for AR visualization of 3D object (Fig.8) are running on the computer 2 and 3. Head-mounted displays are connected to PC 2 and 3 separate.

4.1. **Head tracking.** Polhemus PATRIOT (Fig. 6) is used for head tracking in our solution. PATRIOT provides dynamic, real-time measurements of head

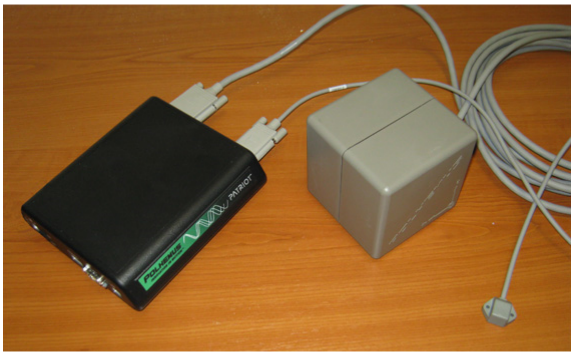

FIGURE 6. Polhemus PATRIOT consists of three main parts (System electronics unit, magnetic field source and sensors).

position (X, Y and Z Cartesian coordinates) and orientation (azimuth, elevation and roll). PATRIOT can update data continuously, discretely (point by point), or incrementally. Sensor is located on the top of head-mounted display and it measures correct position and orientation of user's head. The origin of the virtual scene coordinate system is identical with the origin of the magnetic tracking system (magnetic field source). Polhemus collects data from both users (their position and orientation in 3D space). This device is connected to computer PC1.

4.2. **Gesture recognition.** If the user makes a gesture, software will evaluate this gesture and set a new position to a 3D object. PC1 sends this new position of the 3D object to PC2 and PC3, where the 3D object with new position is displayed into views of users. System recognizes two basic gestures (Fig.7):

- *fist gesture* - user grasps a virtual object and sets a new position
- *open palm gesture* - user releases the virtual object.

Only one user can manipulate with a virtual object. So, if one user takes the virtual object (fist gesture) the second user will not be able to manipulate with this object. The first user is owner of this virtual object in this moment. After the user releases the virtual object (open palm gesture), it becomes available to all users.

5. AR APPLICATION WITH HMD

System of augmented reality consists of three main components: *Initialization, Pose estimation* and *AR visualization* (see Fig.8). The component *Initialization* sets virtual 3D scene which was created using 3D models in OBJ format (OBJ format is a simple data-format that represents 3D geometry alone namely, the position of each vertex, the UV position of each texture

FIGURE 7. Gestures with data glove (left - fist gesture and right - open palm gesture).

coordinate vertex, vertex normals, and the faces that make each polygon defined as a list of vertices, and texture vertices). This component also sets data about user's view and its position in real environment from PC1.The next component sets transform matrix of view (*Pose estimation* component) and the last component (*AR visualization*) displays the virtual scene in the real world using head-mounted display.

5.1. **Initialization.** This virtual scene is composed from 3D objects which were created in the stand-alone software. The users are able to locate 3D object in the virtual scene and change position of 3D object using data gloves (send PC1). Next step is detection of user's head position for correct aligment of virtual scene with user's view.

5.2. **Pose estimation.** This component is next step after determination of user's position in real space with electromagnetic tracking device. Every virtual world has virtual camera which captures virtual scene. In this step the user's view must by aligned with virtual camera. That means the transformation matrix (M) of view is set. Determination of matrix parameters is needed for correct aligment of the virtual scene into the real world. The OpenGL uses 4x4 matrix for transformations.

$$M = M_1 * M_2 * M_3$$

The M_1 in formula corresponds with the initial transformation of a scene (identity), M_2 is transformation caused by calibration and M_3 is application of virtual (left or right) camera's position and orientation.

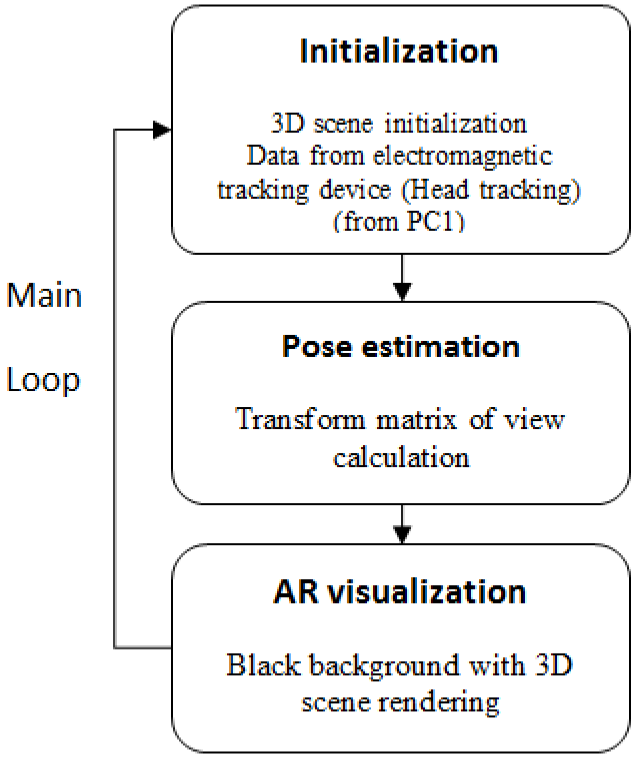

FIGURE 8. The architecture of the AR system using electromagnetic tracking device and the visualization of virtual scene (using head mounted display).

5.3. **AR visualization.** The system is implemented on MS Windows platform. AR application uses 3D models in OBJ format and for rendering is used OpenGl libraries (see Fig.8 section *AR visualization*). For displaying was used head mounted-display nVisor ST60 (see Fig.2, Fig.10). This HMD use optical see-through technology to create illusion of three dimensional objects in the real world. For displaying is used Liquid crystal on silicon (LCOS) technology. Displaying resolution is 1280x1024. Weight of this HMD is 1300 g. Rendered image of virtual scene created by application is displayed using HMD. Black background is not displayed and the user sees real world augmented with virtual scene. To create stereoscopic vision, application renders two images which are side by side (see Fig. 9). One image is for the left eye and another one for

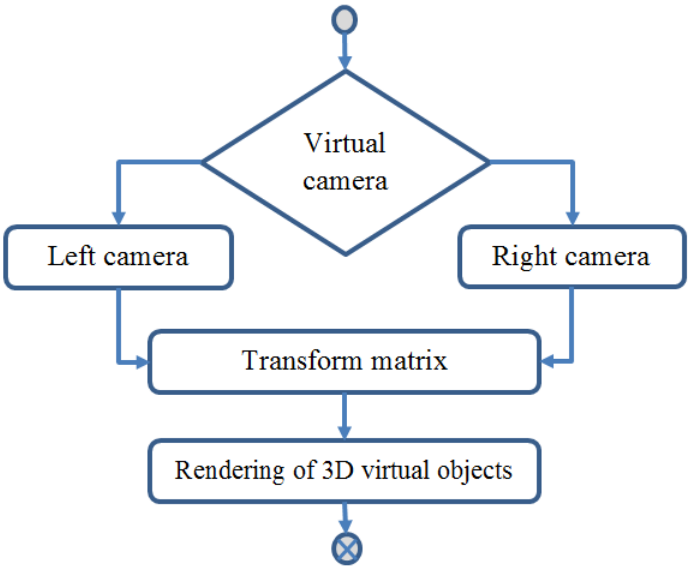

FIGURE 9. Rendering of virtual scene

the right eye. In the Fig.10 are the users with head-mounted displays which can manipulate with a virtual object using data gloves.

5.4. **Summary of proposed system.** The system uses a distributed architecture for augmented reality. Applicability of the proposed system:

- *shared augmented reality* - system allows connectivity to an unlimited number of users with HMDs
- *modern interface for human-computer interaction* - controlling the virtual reality using a data glove
- *position tracking of users* - using electromagnetic tracking system

Extensibility of the proposed system:

- *artificial intelligence* - each virtual object in the scene can be controlled by a separate intelligence module (avatar)
- *simulation of physical effects* - the use of advanced physical cores

6. Conclusion and Future Work

The proposed system for two head-mounted displays, presented in the paper, was constructed at the DCI FEEI TU of Košice (Department of computers and informatics, Faculty of electrical engineering and informatics, Technical university of Košice) in the LIRKIS (Laboratory of Intelligent Interfaces of

FIGURE 10. The users with head-mounted display can manipulate with a virtual object using data gloves (illustration)

Communication and Information Systems). Advantage of this solution is that two users can see same virtual scene and they can change position of 3D objects in the virtual scene. Users can interact with the virtual scene using hand gestures. Currently system recognizes two basic gestures: drag (fist gesture) and drop (open palm gesture). The interactivity with the data glove is in real time. Accuracy of gesture recognition will be the next subject of examination. Application displays virtual objects into users view using HMD. Frame rate for rendering (low poly virtual objects) is less than 15 fps (computer configuration: Intel Core i5 2.6GHz, 8GB RAM, Nvidia GeForce GTX275). Frame rate is low because the scene must be rendered in high resolution (2560x1024). Disadvantage of this system is interference of magnetic tracking with metal objects and other magnetic fields. Future work will be focused on the localization of user's head position and orientation with a 3D inertial motion tracker.

Acknowledgement

This work is supported by KEGA grant project No. 054TUKE-4/2013: Application of virtual-reality technologies for handicapped persons education and this work is also supported by KEGA grant project No. 050TUKE-4/2012: "Application of Virtual Reality Technologies in Teaching Formal Methods".

References

[1] Wang, X. and M.A. Schnabel, *Mixed Reality in Architecture, Design, and Construction* 2008: Springer-Verlag New York Inc.

[2] Behzadan, A.H. and V.R. Kamat, *Enabling smooth and scalable dynamic 3d visualization of discrete-event construction simulations in outdoor augmented reality* Proceedings of the 39th conference on Winter simulation (WSC 07), 2007: p. 2168-2176.

[3] MILGRAM, P., KISHINO, F, *A Taxonomy of Mixed Reality Visual Displays* IEICE Transactions on Information Systems, Vol. E77-D, No. 12, 1994, pp. 1321-1329.

[4] M. Varga, Z. Dudlakova, *Markerless augmented reality using head tracking device* POSTER 2013 17th International Student Conference on Electrical Engineering : May 16, 2013, Prague. - Prague : Czech Technical University in Prague, 2013 P. 1-5. - ISBN 978-80-01-05242-6

[5] HROZEK, F., VARGA, M., et al. *Augmented reality application in parallel computing system* 7th International Workshop on Grid Computing for Complex Problems, Bratislava, Slovakia, 24 26 October 2011,stav Informatiky SAV, 2011, pp.118-125,978-80-970145-5-1.

[6] M. Varga, P. Ivank. *Markerless augmented reality using electromagnetic tracking device* SCYR 2013, Proceedings from conference : 13th Scientific Conference of Young Researchers : May 14th, 2013, Herany, Slovakia. - Koice : TU, 2013 S. 156-159. - ISBN 978-80-553-1422-8.

[7] M. Hovanec, M. Varga, et al. *Inovatvne trendy a vzie v ergonmii vyuitm rozrenej a virtulnej reality* Aktulne otzky bezpenosti prce : 25. medzinrodn konferencia : trbsk Pleso - Vysok Tatry, 06.-08. 11.2012. - Koice : TU, 2012 S. 1-7. - ISBN 978-80-553-1113-5.

[8] M. Varga, *Markerless augmented reality using head-mounted display* POSTER 2012 : 16th International Student Conferenece on Electrical Engineering : May 17, 2012, Prague, Czech republic. - Prague : Czech Technical University in Prague, 2012 P. 1-5. - ISBN 978-80-01-05043-9

[9] M. Varga, *Markerless augmented reality using SURF method* SCYR 2012 : proceedings from conference : 12th Scientific Conference of Young Researchers : May 15th, 2012, Herany, Slovakia. - Koice : TU, 2012 S. 173-176. - ISBN 978-80-553-0943-9

[10] Teixeira, Joao Marcelo; Ferreira, Ronaldo; Santos, Matheus; Teichrieb, Veronica, *Teleoperation Using Google Glass and AR, Drone for Structural Inspection* Virtual and Augmented Reality (SVR), 2014 XVI Symposium on , vol., no., pp.28,36, 12-15 May 2014.

[11] Y. Ariyana, A.I. Wuryabdari, *Basic 3D interaction techniques in Augmented Realitye* System Engineering and Technology (ICSET), 2012 International Conference on , vol., no., pp.1,6, 11-12 Sept. 2012.

[12] B. SOBOTA, et al., *Rieenie loh spracovania rozsiahlych grafickch dajov v prostred paralelnch potaovch systmov* 2012, Editan stredisko TU, Koice, ISBN 978-80-553-0864-7

[13] Hong Hua; Chunyu Gao; Biocca, F.; Rolland, J.P., *An ultra-light and compact design and implementation of head-mounted projective displays* Virtual Reality, 2001. Proceedings. IEEE , vol., no., pp.175,182, 17-17 March 2001

[14] Hrozek, F. *Data glove as input device for computer* Journal of Information, Control and Management Systems, vol.8, no.4, pp. 329-334, 2010, ISSN 1336-1716.

[15] Hrozek, F., et al. *Virtual Reality Technologies in Education* Veda pre vzdelanie - Vzdelanie pre vedu 1 : 2. ronk medzinrodnej konferencie : 20.- 21.10.2011, Nitra, Slovakia. - Nitra : UKF, 2011 S. 315-319. - ISBN 978-80-8094-973-0

[16] Jianzhong Zhou; Liwu Pan; Mingtao Ge *Virtual visual simulation of urban lakes based on OpenSceneGraph* Consumer Electronics, Communications and Networks (CECNet), 2013 3rd International Conference on , vol., no., pp.723,726, 20-22 Nov. 2013

[17] Zhigang Xie; Ming Xu; Zhenxiang Cai; Ningbo Qiao *The design and implementation of three-dimensional virtual experiment system based on graphics engine* Education Technology and Computer (ICETC), 2010 2nd International Conference on , vol.4, no., pp.V4-477,V4-480, 22-24 June 2010

[18] Gregory Junker *Pro OGRE 3D Programming* Aoress, ISBN-13: 978-1-59059-710-1

[19] Pengqi Gao; Datao Yang; Ming Shen; Xiaozhong Guo; Huanhuan Yu; You Zhao; Zunyi Xu *Space situation simulation and visualization based on OGRE* Fuzzy Systems and Knowledge Discovery (FSKD), 2011 Eighth International Conference on , vol.4, no., pp.2566,2569, 26-28 July 2011

[20] Russell M. Taylor, at al. *VRPN: a device-independent, network-transparent VR peripheral system* VRST '01 Proceedings of the ACM symposium on Virtual reality software and technology, Pages 55-61, ISBN:1-58113-427-4

Department of Computers and Informatics, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Slovakia

E-mail address: Martin.Varga@tuke.sk
E-mail address: Branislav.Sobota@tuke.sk
E-mail address: Frantisek.Hrozek@tuke.sk
E-mail address: Stefan.Korecko@tuke.sk