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MULTI-MODAL INTERACTION FOR 3D MODELING

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Abstract: *The actual usability of a Virtual Environment (VE) depends to a large extent on the multi-modal interaction interfaces. A multi-modal interaction system combines visual information with many interaction methods to provide flexible and powerful dialogue approaches, thus enabling users to choose single or multiple interactions. This paper is a review of existing multi-modal interaction interfaces and multi-modal interaction applications for 3D modeling. Also, several conclusions are drawn that form the fundaments for future research that will be undertaken by the authors within development of new multi-modal interaction systems for 3D modeling.*

Key words: *virtual reality, multi-modal interaction, virtual environment, haptic devices, 3D modeling.*

1. Introduction

Virtual reality (VR) allows and at the same time demands new ways of user interaction with the virtual environment for visualizing and manipulating three-dimensional objects [15].

In computer based 3D modeling virtual models of real or fictional objects are created through computer aided design. The rendering of these models is usually done through real images in order to represent their properties.

Many research activities focus on 3D modeling inside a VR system, thus increasing the immersion feeling. In the past years the number of applications that require a fully multimodal interaction with the virtual environment has steadily increased [25].

Multimodal interfaces are expected to be easily learnt and used by the user, and also preferred in the majority of applications. A multimodal interaction system makes simultaneously use of several input and output information channels of the human body for interfacing with the computer [37]. Senses like sight, hearing, touch, balance are used in multimodal interfaces, and commands are given through voice or gestures which involve movement of different parts of body like fingers, hands, head, eyes or mouth. Multimodal interaction systems generally allows a greater flexibility in transmitting commands, i.e. several ways of performing an operation are possible through different interaction devices [3].

The great interest behind multimodal interaction systems study is highly supported by the goal of providing a more transparent, flexible, efficient, and at the same time natural human-computer interface.

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First, this article analyzes the most important interaction devices used in 3D design and their corresponding interfacing manners. Furthermore, an overview study of current multimodal interfacing systems is presented. In conclusion, fundamental avenues for future research in development of innovative multi-modal interaction systems for 3D modeling are proposed.

2. Multi-Modal Interfaces

The current trend is to develop virtual reality applications by using 3D multimodal interfaces, which are natural for human users for most of the tasks, as they leverage the motor and sensory skills that we use every day.

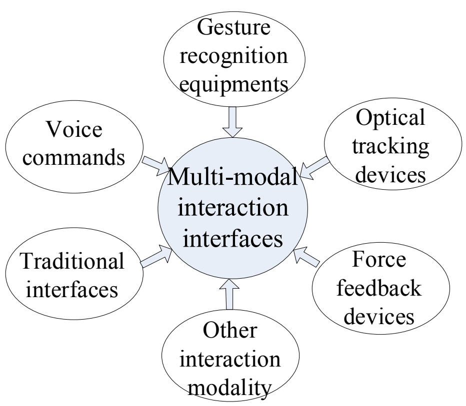

Fig. 1. *Multi-modal interfacing main interaction ways*

Figure 1 shows the main interaction ways of multimodal interfaces used for 3D modeling.

2.1. Devices for Interaction with Virtual Environments

Interaction devices with virtual environments transmit user commands and provide feedback information to the user. They allow users to communicate with the computer system and to implement various interaction techniques [19], [36], [38]. Depending on applications [33], [13] various interaction methods can be used, and information can be sent and received on multiple sensory channels [8]. Interaction devices with Virtual Environment can be divided into the following:

2.1.1. Interaction devices for desktop workspace

A multimodal interface based on Virtual Reality technologies [14] provides an alternative to the traditional interfaces that uses 2D display, keyboard and mouse [29].

Similar with the above presented devices applications with 3D Virtual Environments make use of the following devices: 3D mouse, joystick, and steering wheel:

• Mouse and keyboard

The *Keyboard* is a traditional desktop 2D interface which is used for transmission data to activate various commands of CAD systems [10]. The disadvantages of this device are:

- The keyboard is designed for using simultaneously both hands; hence it is rarely used in combination with other devices, the user having to move the hand a lot.
- It is very difficult to be used in immersive CAVE systems because the user is in standing position [7].

The *Mouse* is the common used device for 2D operations. In CAD applications [6], the mouse is used to activate commands, to create and/or to modify entities, and to navigate in virtual environments. Its suitability for virtual immersive applications is quite restricted, since it requires a planar or close to planar surface [23].

• 3D Mouse

The traditional two-dimensional mouse was replaced by the 3D-mouse [16], which allows a more natural movement. Because it encompasses six degrees of freedom (DOF) [1], it is specially designed for interaction in virtual environments. Its main uses in computer aided design applications are manipulation of 3D models and navigation inside the virtual environment. The main drawback of the 3D mouse comes into play when precise manipulation of virtual objects is needed. To perform high accuracy movements with a 3D mouse extensive practice is needed.

• **Force feedback and tactile feedback devices**

Haptic devices offer force feedback [31] [32] and tactile feedback thereby enabling the user to feel the movement and touch the interacting objects, respectively. This allows an even more realistic interaction with the virtual environments. The most popular devices on the market are the force feedback joystick [16], [21] and steering wheel [18]. Games are the main applications in which they are used and seldom can be found in 3D modeling applications; even they have an almost affordable price.

Fig. 2. *Force feedback and tactile feedback devices*

A haptic device used in 3D virtual applications is SensAble Phantom depicted in the left picture from Figure 2. It is composed from a mechanical robotic arm with joints and a pen-shaped end-effector as manipulator. The arm follows the handler movement and it is capable of developing a comparable force with the one applied to the handler. The limited workspace and the impossibility of grasping virtual objects are the weaknesses of the Phantom devices [28]. These can be overcome by the use of Cybergraps [23], [24], a haptic device attached to the hand which provides independent force feedback for each finger. Thus, the user can feel the shape and size of virtual objects. For texture, temperature, or small oscillatory movements (vibrations) sensing, the CyberTouch tactile feedback device can be used.

2.1.2. Gesture tracking devices

To discover real object information such as users' hands position and orientation a tracking system is needed. In immersive virtual space, user's avatar hands will follow the real hand movement. The tracking system allows even a more intuitive interaction for control, visualization, selection and handling of virtual objects. However, they require calibration, involve high costs and may have cables that obstruct the user. According to the functionality principles of 3D these tracking devices are commonly found in existing systems:

• **Mechanic tracking devices**

The tracking system [34] is formed of several rigid mechanic links connected by joints. The tracked object is placed at one end of the kinematic chain and its position and orientation can be computed with a high degree of accuracy at any time knowing the joints' angles and their lengths. The workspace has a limited range and the mechanical structure imposes certain movement restrictions. Apart from these constraints, the complexity and the wear of the mechanical system have also to be counted as disadvantages.

• **Electromagnetic tracking devices**

This type of equipment is formed by a static magnetic emitter which generates a magnetic field and several magnetic receptors attached to the tracked object [17]. By triangulation the position and orientation of the object can be determined. The small sensors can be easily attached to the hand or head and they provide a high precision, but a slow response time. In addition, the system is susceptible to electromagnetic interferences from other operating devices or metal objects in the workspace.

• **Optical tracking devices**

Another method to establish the location is by measuring the light waves reflected by sensors mounted on the tracked object. Such devices commonly use infrared emitters, cameras and reflectors making them insensitive to visible light perturbations. They provide high accuracy [39], and a large wireless workspace, expandable with addition of more cameras. On the other hand they still are very expensive.

2.1.3. Gesture recognition equipments

User's hand gestures recognition is done mainly using gloves equipped with sensors. The sensors can measure the angular displacement of the phalanges, or alternatively the contact between fingers [34]. This interaction method allows using both hands for modeling process in a natural and easy way, but it requires prior learning of the supported gesture language.

2.1.4. Voice commands recognition

Voice commands can successfully replace other types of input control devices such as mouse or keyboard. The hardware required is very simple, consisting of only a microphone that can be placed virtually anywhere in the workspace, without having the user to carry it all the time. Voice command recognition can speed up the interaction process when used in combination with other interaction devices [2]. For example, if the user has its hands occupied he can simply say the command. On the negative side, the system needs prior training to obtain the users' accent and pronunciation parameters. Also, is very sensible to background noise and not very accurate.

3. Multimodal Interaction Systems

During last few years multi-modal interaction technologies have gained momentum in industrial applications due to the advantages that virtual reality can offer. Current systems allow the user to modify and manipulate 3D CAD models in intuitive and close to reality ways.

Multimodal interaction is more and more popular for VR applications. For instance, in [30] and [20] multimodal key elements are presented, such as semantic environment representation and semantic interaction description. These studies allow the user to interact more precisely with the scene (for instance, respecting the object geometry and equilibrium). Such interactions require fine grain knowledge of the whole scene, including interaction paradigms available for each object.

Plenty of efforts are made to improve multi-modal system interaction. Virtual reality technologies offer an interaction alternative by providing an interaction metaphor [15] in the 3D immersive environment. An interaction task in a virtual environment that includes an information exchange between the user and the environment, essentially a dialog between the user and the environment, is called an interaction metaphor. When the user performs an action the system reacts by initiating the corresponding process. Current systems combine and assemble the interaction metaphors in order to create new metaphors which present the user in logic way the operations to be performed. These metaphors constitute additional embedded components of the interface which trigger the necessary processes during the system use. The major problems in current 3D modeling systems are related with the use of interaction devices and the associated interaction metaphor [11]. It is therefore vital to develop new interaction metaphors that will help improve the creation and manipulation process of 3D models.

One of the first multimodal interaction systems [6] built in 1976 uses a Head Mounted Display (HMD) and a sensors glove for real-time editing of bi-cubic surfaces. Because of limited video processing resources from that time the surface was only rendered as wireframe. It was a considerable breakthrough for the time when commands were only transmitted through keyboard.

A different multimodal interaction system [4] conceived in 1992 uses also a HMD for virtual reality immersion. Modeling commands are transmitted using a two-buttons spherical device with integrated 3 DOF motion tracking sensors. The user can create and manipulate 3D primitives, but with a coarse accuracy.

A 6 DOF interaction device which enables objects manipulation in the tri-dimensional workspace is proposed in [22], but lacks precise dimensioning for created model. Another innovative method for 3D surface creation is suggested in [34]. A sensor glove and a 6 DOF motion tracking system allows easy polygonal surface creation by simply moving the hand in the workspace. Still, it exhibits the same problem as the previous method, the lack of precise dimensioning. Thus, both are suited only for prototype sketching, not for design and editing.

The optical tracking mechanism in [12] also has 6 DOF which can be used for creating 3D primitives, curbs and parametrical surfaces in an immersive environment. It uses a library for generating the models' geometrical parameters, and the user can visualize the models in real-time. However, 3D geometries modifying is not permitted with this system.

The 6 DOF interaction system from [5] uses only one projection screen for visualization and supports only direct creation of two-dimensional geometries; 3D entities are obtained through extruding.

A system for generation and evaluation of CAD models is described in [26], [27]. Selection, navigation and manipulation of objects is made by tracking the user hands with a 6 DOF optical tracker, but the creation of the 3D models is done exclusively using classic 2D interaction devices.

In [35] is proposed a multimodal system for part assembly, and claim that with multimodality the user does not need other devices besides his/her natural modalities. On the other hand, in [9] is recently proposed a multimodal architecture for CAD applications, which addresses flexibility issues and makes a multimodal system adaptable to different interactive contexts (i.e. desktop vs. VR, and so on.).

A multimodal interaction system that combines gesture recognition with voice recognition is presented in [2]. The low precision of the system is enhanced in [15], presented in Figure 3, by using a haptic rendering interface with force feedback for the hands.

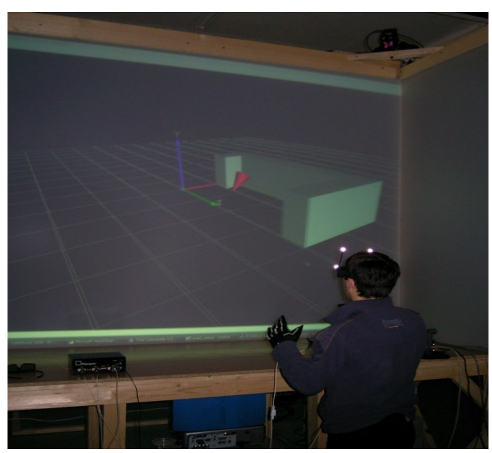

Fig. 3. *Multi-modal user interface*

4. Conclusions and Future Works

A study of current available user-computer interaction methods for 3D computer modeling was performed. Each interfacing device with the virtual environment has its own strong and weak points that propagate and affect the overall quality of the multimodal interfacing system that incorporates them. Thus, the creation and editing of virtual 3D models is impaired to a certain extent by interaction devices.

This study proves that interaction with the virtual environment should be improved so that the user can concentrate on the actual modeling of 3D objects, not on activating certain functionalities of the design software. Fundamental modeling techniques can and should remain the same. However, the interaction interface and the corresponding methods need careful enhancements to ease the designer work, and thus increase the productivity.

One avenue for future research on this line is the user work posture during the modeling activity. He must have a comfortable and ergonomic body posture which will not tire him after prolonged activity. In addition, the interaction devices must follow the same constraints and make use of natural body movements that don't provoke physical or mental stress.

We will propose and run experiments that mimic real working conditions to evaluate the effect of different interaction devices and based on that results we can propose improvements to multimodal interaction interfaces used in 3D modeling or novel efficient and easy to use designs for them.

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References

1. Biermann, P., Jung, B., et al.: *A Platform for Multimodal Assembly in VR*. In: Proceeding of VRIC'02, Laval, France, 2002, p. 73-81.
2. Boeck, J., Raymaekers, C., Coninx, K.: *Aspects of Haptic Feedback in a Multi-modal Interface for Object Modeling*. In: Journal Virtual Reality, Springer London **6** (2004) No. 4, p. 257-270.
3. Bourdot, P., Convard, T., et al.: *VR-CAD Integration: Multimodal Immersive Interaction and Advanced Haptic Paradigms for Implicit Edition of CAD Models*. In: Journal Computer Aided Design **42** (2010) No. 5, p. 445-461.
4. Butterworth, J., Dacidson, A., et al.: *Dimensional Modelar Using a Head Mounted Display*. In: Proceedings of the Symposium on Interactive 3D Graphics Cambridge, Massachusetts, 1992, p. 132-138.
5. Cappello, F., Ingrasia, T., et al.: *Towards a Fully Integrated CAD System in Virtual Reality Environment*. In: Proceeding of Virtual Concept, Playa del Carmen, Messico, 2006, p. 121-128.
6. Catmull, E., Clark, J.: *Recursively Generated B-Spline Surfaces on Arbitrary Topological Meshes*. In: Computer-Aided Design **10** (1978), p. 350-355.
7. Choi, S.H., Cheung, H.H.: *A Cave-Based Multi-Material Virtual Prototyping System*. In: J. Computer-Aided Design and Applications (2006), p. 557-566.
8. Conti, F., Khatib, O.: *Spanning Large Workspaces Using Small Haptic Devices*. In: First Joint Eurohaptics Conference and Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, IEEE Computer

Society Washington, DC, USA, 2005, p. 183-188.

9. Convard, T., Bourdot, P., et al.: *Managing Deformable Objects in Cluster Rendering.* In: Proc. of 4th International Workshop on Computer Graphics and Geometric Modeling, Atlanta, USA, 2005, p. 290-207.
10. Cruz-Neira, C., Sandin, D.J., et al.: *An Immersive and Collaborative Visualization System for Digital Manufacturing. The Cave Automatic Virtual Environment*. In: Commun. ACM **35** (1992) No. 2, p. 64-72.
11. Dellisanti, M., Fiorentino, M. et al.: *Flexible Multimodal Architecture for CAD Applications.* In: Proc. of Eurographics Italian Chapter Conference, 2007, p. 113-118.
12. Fiorentino, M., de Amicis, R., et al.: *A Space Design: a Mixed Reality Work - Space for Aesthetic Industrial Design.* In: ISMAR'2002, Darmstadt, 2002, p. 86-94.
13. Frisoli, A., Bergamasco, M., Ruffaldi E.: *Advanced Haptic Systems for Virtual Reality.* In: Product Engineering (2008), p. 145-168.
14. Girbacia, F., Runde, C., et al.: *An Interactive Multi Wall Projected Virtual Environment for Virtual Reality Based Design and Manufacturing Simulation.* In: 12th International Conference on Machine Design and Production, Turkey, 2006, p. 633-646.
15. Girbacia, F., Talabă, D.: *An Approach for Integration of Virtual Reality Technologies.* In: Proceedings of Computer Aided Design, Advanced Study Institute on Product Engineering: Tool and Methods on Virtual Reality, Chania, Creete, 2007, p. 277-289.
16. Hara, M., Matthey, G. et al.: *Development of a 2-DOF Electrostatic Haptic Joystick for MRI/fMRI Applications.* In: Proceedings of the IEEE International Conference on Robotics and Automation, Kobe, Japan, 2009, p. 4238-4243.
17. Ikits, M., Brederson, D., et al.: *An Improved Calibration Framework for Electromagnetic Tracking Devices.* In: Proceedings of IEEE Virtual Reality Conference, Yokohama, Japan, 2001, p. 63-70.
18. Iván, E., González, I.E., et al.: *Eyes on the Road, Hands on the Wheel: Thumb-Based Interaction Techniques for Input on Steering Wheels.* In: ACM International Conference Proceeding Series, Proceedings of Graphics Interface, Montreal, Canada, Vol. 234, 2007, p. 95-102.
19. Jimeno, A., Puerta, A.: *State of the Art of the Virtual Reality Applied to Design and Manufacturing Processes.* In: The International Journal of Advanced Manufacturing Technology, Springer **33** (2007) No. 9-10, p. 866-874.
20. Latoschik, ME.: *A User Interface Framework for Multimodal VR Interactions.* In: Proc. of the IEEE 7th International Conference on Multimodal Interfaces, Trento, Italy, 2005, p. 76-83.
21. Li, W.H., Liu, B., et al.: *A 2-DOF MR Actuator Joystick for Virtual Reality Applications.* In: Science Direct Sensors and Actuators **137** (2007), p. 308-320.
22. Liang, J., Green, M., et al.: *A Highly Interactive 3D Modeling System Computers & Graphics.* In: 3rd International Conference on CAD and Computer Graphics, Beijing, China **18** (1994) No. 4, p. 499-506.
23. Magnuson, C., Rassmus-Gröhn, K.: *Non-Visual Zoom and Scrolling Operations in a Virtual Haptic Environment.* In: Proceeding Eurohaptics 2003, Dublin, Ireland, 2003, p. 111-120.
24. Magnusson, C., Rassmus-Gröhn, K., et al.: *Navigation and Recognition in Complex Haptic Virtual Environments*

- Reports from an Extensive Study with Blind Users. In: Proceeding Eurohaptics 2002, Edinburgh, UK, 2002, p. 461-476.
25. Navarre, D., Palanque, P., et al.: *A Formal Description of Multimodal Interaction Techniques for Immersive Virtual Reality Applications.* In: Human-Computer Interaction (2005), p. 170-183.
26. Neugebauer, R., Weidlich, D., et al.: *Perspektiven von Virtual - Reality Technologien in der Produktionstechnik - VRAx®.* In: Chemnitzer Produktion-stechnisches Kolloquium CPK 2004, p. 75-100.
27. Neugebauer, R., Weidlich, D., et al.: *Virtual Reality Aided Design of Part and Assemblies.* In: Proceedings of Virtual Concept'2006, Canncum, Mexico, 2006, p. 15-20.
28. Nikolakis, G., Tzovaras, D., et al.: *CyberGrasp and PHANTOM Integration: Enhanced Haptic Access for Visually Impaired Users.* In: Conference Speech and Computer, St. Petersburg, Russia, 2004, p. 507-513.
29. Oh, J.Y., Stuerzlinger, W.: *Moving Objects with 2D Input Devices in CAD Systems and Desktop Virtual Environments.* In: Proceedings of Graphics Interface (GI), Canadian H-man-Computer Communications Society, 2005, p. 195-202.
30. Pfeiffer, T., Latoschik, ME.: *Resolving Object References in Multimodal Dialogues for Immersive Virtual Environments.* In: Proc. of IEEE Virtual Reality Conference, Trento, Italy, 2004, p. 35-42.
31. Picon, F., Ammi, M., et al.: *Case Study of Haptic Methods for Selection on CAD Models*. In: Proceeding of IEEE Virtual Reality Conference, Reno, NE, 2008, p. 209-212.
32. Picon, F., Ammi, M., et al: *Haptically-aided Extrusion for Object Edition in CAD.* In: Proceeding of 6th EuroHaptics International Conference. Lecture notes in Computer Science, Madrid, Spain, Springer **5024** (2008), p. 736-44.
33. Richard, E., Tijou, A., Richard, P., Ferrier, J.L.: *Multi-Modal Virtual Environments for Education with Haptic and Olfactory Feedback.* In: Virtual Reality **10** (2006) No. 3-4, p. 207-225.
34. Schkolne, S.: *Drawing with the Hand in Free Space.* In: Leonardo Journal (2002), p. 371-375.
35. Touraine, D., Bourdot, P., et al.: *A Framework to Manage Multimodal Fusion of Events for Advanced Interactions within Virtual Environments.* In: EGVE '02, Proceedings of the Eurographics Workshop on Virtual Environments, Eurographics Association, 2002, p. 159-168.
36. Turk, M.: *Gesture Recognition*. In: Stanney, K.M. (Hrsg): Handbook of Virtual Environments. Design, Implementati on and Applications (2002), p. 233-237.
37. Weidlich, D., et al.: *Virtual Reality Approaches for Immersive Design.* In: International Journal on Interactive Design and Manufacturing, Springer **3** (2009), p. 103-108.
38. Youngblut, C., Johson, R.E., et al.: *Review of Virtual Environment Interface Technology.* In: Institute for Defense Analyses: IDA, 1996, p. 3186.
39. Yuan, C.: *Creating Virtual 3D See-Through Experiences on Large-size 2D Displays*. In: Proceedings of IEEE Virtual Reality Conference, Lafayette, LA, USA, 2008, p. 237-238.