Enhancing interaction of CAVE systems with regards to disabilities

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Abstract. *Article deals with the possibilities of interaction in virtual reality (VR) systems with application to disabled persons. Using these technologies and appropriate learning methods can improve, accelerate and facilitate the learning of disabled children. For this reason, further development is directed to extend the interaction in VR systems (specifically CAVE LIRKIS). There are many inputs and interaction options such as keyboard, mouse, gyroscope sensors, EEG and others. Due to needs of handicapped people, their flexibility of movement it is necessary to consider the applicability of input devices. The MYO armband was selected as the first and most suitable device to work on further development of interaction in the virtual environment.*

Keywords

CAVE, disability, handicapped persons, HCI, natural user interface, virtual reality

1. Introduction

Currently, the field of virtual reality (VR) and its application in the world is highly up-to-date. It is prerequisite, that VR technologies in the future development will allow better integration of people with disabilities into the information society. VR system is typically based on subsystems that can be affected or affect human perception. Therefore using VR technologies is natural. Given the scale and complexity of the problem and the performance of current technologies, its logical to use parallel and distributed solutions (e.g. CAVE systems). Very important fact of using VR is to deceive the user's perceptions that the virtual world is real. In this case it is important to achieve high level of immersion and to provide real object behaviour in virtual environment (VE). Increasing the level of interaction between user and VE improves the immersion. Rapid development of various VR devices has a positive effect on the expansion of the immersion level. Immersive virtual reality (IVR) is associated with achieving a more realistic interaction between user and VE. The impact of immersion is important to achieve a more realistic interaction of user and VE. This interaction is provided by virtual reality interfaces (VRIs). VRIs differ from physical to application interfaces and graphical interfaces.

In this case it is necessary to consider the factor of people disability. Currently, all of factors depend on the disability type (mental, physical), the age of the person when the disability was acquired. Therefore, it is important to focus only on a certain range of human disabilities. This choice enables effective and faster integration of disabled people into society [14].

2. Immersive VR environment

Immersion provided by CAVE systems is more natural than HMD and other VR technologies. CAVE systems create more interactive environment for many people who operate in the same VE. Unlike HMD, people who work in CAVE in the same 3D scene do not require their own avatars. All of users communicate close to each other in real time and CAVE's physical space.

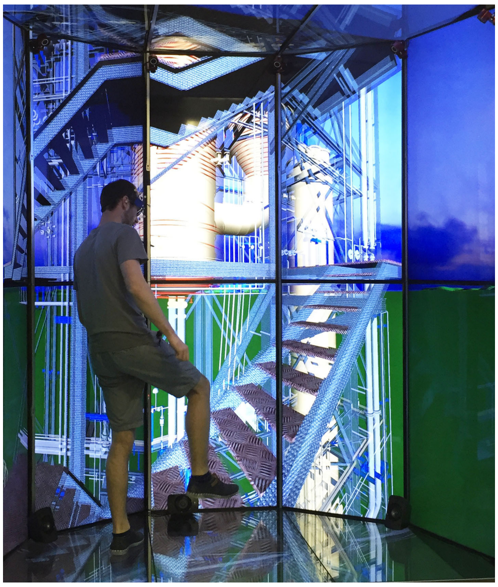

Fig. 1. Fully immersive environment in LIRKIS CAVE

One of the unique CAVE in Central Europe is the LIRKIS CAVE [4] at the Technical University in Košice.

The LIRKIS CAVE increases the level of immersion with various VR technologies. Main properties of the LIRKIS CAVE (Fig. 1) are cylindrical shape with 20 LCD screens, distributed cluster rendering, full perspective stereoscopic VE and OptiTrack motion tracking system. The cluster performance depends on seven computers, one of them is the master and six others are slaves. The master computer sends global data and commands to every slave through network. Finally, each slave renders final VE to LCDs outputs.

A similar visual experience is also achieved by HMD. Unlike CAVEs, HMDs does not require a lot of physical space and they are much more available [7]. Another advantage is lower system requirements than computer cluster. The problem is in the representation of users in VE. In this case it is necessary to create avatars and implement their behavior. Complex gestures and movements of avatars in VE represent many complications. One of them is the difficulty of achieving a real natural interaction between users. The most complicated is the situation when the user wants to describe scene object with his hands to other users. Using HMD is difficult to deploy a large number of users in one virtual environment.

3. VR interfaces

Each VR system works with different interfaces that enhance its usability. The most typical are VR controllers for manipulation with 3D objects [2]. The communication between them and VE is provided by interfaces, which distribute data between controllers and VR system. VR interfaces are divided into different categories depending on their usage, technology and scalability for VE. The basic categories of the VR consist of primary interaction through graphic natural user interface, haptic, and sensory interfaces.

3.1. Natural user interfaces (NUI)

Graphic VR interfaces used in VR environments are widely applicable as sophisticated immersive add-ons for any types of 3D scenes. In terms of usability, they are often called as natural interfaces which create intuitive interaction between user and VE [18]. Including their usability, they can be applied in different areas where user operates in a VE. In common use, NUIs are adaptable for every VE with possibility to combine them with other perception such as auditory and tactile.

An example of a NUI used in VRS is a gesture-based user interface in the space. Body or sign language belongs to known means of communication among people. VRSs can have the ability to capture, recognize, and respond to the stimulus of such communication. VRSs can have the ability to capture, recognize, and respond to the stimulus of such communication. It uses tightly bound and freely bound hardware (e.g. depth projectors and cameras, such as Microsoft Kinect) [12].

3.2. Haptic interfaces

The use of haptic interfaces is closely related with tactile perception. The main functionality of them is to transfer I/O data through different types of connections (via USB, Bluetooth, and Wireless). Haptic experiences contain gesture recognition and motion [19]. It is simple to use application layer for reading gestures but also difficult to process gesture recognition without any analysing of input data from device.

3.3. Sensory interfaces

Sensor interfaces represent a comprehensive approach to data acquisition. It is important to use complex algorithms and process a large set of input data. Sensors are usable for different needs of NUI or haptic interaction in VE. Data analysis of sensors values is difficult [3] because there are many cases in which a defined gesture must be recognized.

In the LIRKIS CAVE [5] there were created several VR interfaces to extend NUI and haptic commands (Fig. 2). The main structure of software equipment consists of several parts. The first part called Control Center (CC) provides dataflow with commands to all of slaves computers. The second part named Video Renderer supports 3D VE rendering of final scene to LCD screens. The next one is support of external I/O devices with external tools and applications implemented in C#. Their focus is to read data from peripheral devices and send them to socket trough cave TCP/UDP interface. However, external applications are independent of the LIRKIS CAVE and are compatible with any other VR systems.

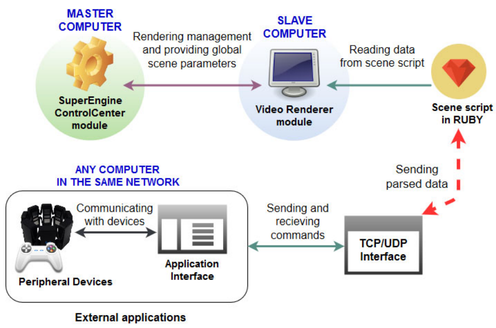

Fig. 2. Current software equipment in LIRKIS CAVE

4. Disabled children and VR technology

The World Health Organization (WHO) definition of disability being "*any restriction or lack of ability to perform an activity in the manner or within the range considered normal for a human being*" [1].

Therefore, the process of educating people with disabilities requires (except for ordinary aids) also extra aids which compensate for their health disadvantage. These include also some algorithms and technologies of virtual reality. In this way, it is possible to accelerate, improve and facilitate the teaching of handicapped people [14]. This is also confirmed by the cooperation Pavol Sabadoš special boarding school in Prešov and LIRKIS laboratory. One of the outputs is e.g. the speech recognition application (KPI-CGRS) using Microsoft Kinect device. It was comfortable for children and well received by educators. The educators have been extensively using the learning mode in order to teach the tool new gestures (Fig. 3). During their first encounters with the tool the children had showed their natural playfulness but after some time they got used to the tool and have been working with it without significant problems. The practical experience showed that it could be suitable to alter some features of user interaction via MS Kinect. For example, the "push" movement, representing confirmation ("OK") when using MS Kinect, was hard to perform by some children.

Fig. 3. Interactive school desk (left) and KPI-CGRS application in special pedagogy classroom (right)

Cooperation with handicapped children directly in the lab has been beneficial not only for them but also for the development of the application itself [15]. During the development of user interface including touch interface, the method has been applied of repeating processes of designing, testing and result evaluation. An interactive school desk has been developed at LIRKIS (Fig. 3), which uses a 24-inch touch screen LCD. The desk was used in education of children using special symbolic-text method [9], [13] with multiple handicaps, including cognitive, and the size of the display has been found sufficient [16]. Testing was carried out on a sample of 820 disabled students with different type of disability [10].

Next version of the desk is shown in Fig. 4. An application named "*Skladačka*" was created for this desk and is enriched with the ability to display 3D models using mixed reality technologies. The desk has an upper camera and two displays placed above each other. The bottom screen is touched and, if necessary, replaces the keyboard and mouse (these can also include). The computer is placed on the side of the desk. The application can also be used without a cam-

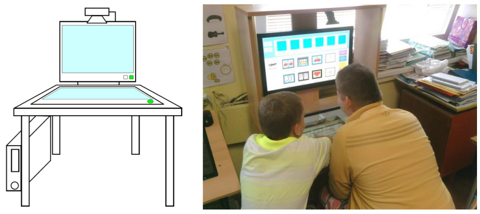

Fig. 4. Interactive school desk using mixed reality technology (left) and children working with the application in the classroom (right)

era (with only one monitor), but visualization of the symbols will not be possible. The application is responsive and adjusts the display even when monitor resolution is smaller than FullHD [17].

5. CAVE system and enhancing interaction

It has been shown that VR technology in combination with the right application methods is helpful even for persons with disabilities [16]. Because of this aspect, it is necessary to have a well designed user interface (NUI), which includes the collaboration of professionals from different areas, such as physiotherapists, health workers, architects, designer etc. Virtualization of such environment has proven to be appropriate due to lower costs and faster introduction of new knowledge into functional modifications [12].

A person in the virtual environment can interact with the 3D scene in different ways. In addition to standard inputs, a mobile application to control the virtual scene is currently available for the LIRKIS CAVE. This extends interaction capabilities using an infrared sensors (OptiTrack) that detect the position of the user's head in the CAVE [6]. Conceptual model is shown in Fig. 5.

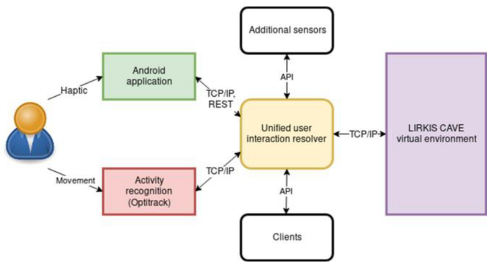

Fig. 5. User interface of the CAVE system with a mobile application extension

It is also possible to use gyroscopes, muscle tension sensors, or EEG devices to monitor human brain activity [8]. Each device meets a certain level of interaction for a specific deployment method. A significant shift in development are a devices that does not restrict a person in physical activity or creates a limited space to control the virtual environment

[11]. These devices are therefore suitable also for disabled people.

One of the latest innovative devices for controlling a three-dimensional scene through muscle tension is the MYO armband. MYO contains several modules for more accurate sensing muscle tension and hand position. The device is currently used in several scenes in LIRKIS CAVE [4], as can be seen in Fig. 6. Control is supported by a gyroscopic chip, accelerometer, and muscle tension sensors. The advantage of the device is simple calibration, market availability and the possibility of using the device without the physical connection with another device. Communication takes place on the basis of data transmission via Bluetooth technology and therefore restricts the motion activity to a minimum. The control of the scene with hand gestures is comparable to data gloves. On the other hand, MYO binds to the user's limb much easier and faster. It can also send the same gesture types (in view of data stream) when controlling a scene or by using the ability to create gestures.

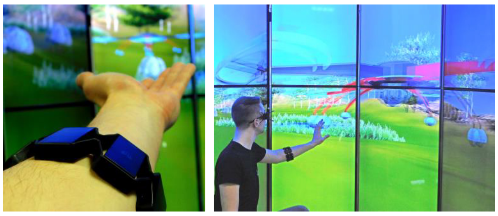

Fig. 6. Using the MYO armband in the LIRKIS CAVE system

6. Conclusion

Development of controls for VR systems enhances communication between the user and virtual reality systems. Innovative systems are more accessible to users, which contributes to the improvement of technology. They are also available for testing and training in rehabilitation activities which are focused on fine motor skills of a disabled people. Cooperation of the Pavol Sabadoš special boarding school in Prešov and LIRKIS laboratory has shown the VR systems, combined with the typical learning methods, which can accelerate, improve and facilitate the teaching of handicapped children.

Given this fact, enhancing interaction in VR systems (e.g. CAVE) could create additional possibilities for using the system to help disabled people. Current focus consist of enhancing the interaction in LIRKIS CAVE using MYO device for simple controlling of the scene with hand gestures. Further effort will be aimed on recognizing gestures and connection MYO with the OptiTrack infrared sensor, which enable the VR system to detect the position of not only the user in the VE but also the movement of his hand(s). Subsequently it will be possible to apply this type of interaction e.g. to train fine motor skills or on rehabilitation of disabled people in cooperation with the Slovak Academy of Sciences, Institute of Measurement Science.

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About Authors. . .

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