Virtual reality technologies as an interface of cognitive communication and information systems

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***Abstract*— This paper describes research, development and teaching applications in area of parallel, distributed and network computing systems for solving computational processes in the processing of graphics data and virtual reality with a primary focus on information systems, intelligent interfaces, including the development of network communication environments, allowing searching and quality access to distributed multimedia resources (knowledge stocks) and services and their use in creating and delivery of new knowledge and services including the development of online platforms to access to multimedia content. Main part contains description of infrastructure of laboratory for systems of scanning and visualization of input/output data for management of information systems in the context of cognitive communication human-computing system in its parallel, distributed or networked implementation environment. Special attention is devoted to description of research and development of new flexible and intelligent interfaces of systems based on virtual reality technologies designed to work in the following areas: systems for a scanning and a creation of input data (tracking systems, 3D scanning, modeling, simulation), visualization engines for rendering the outputs in various forms and controlled using higher level languages for easy handling of objects, including script handling and interfaces for database systems for storing large data and information (graphical and non-graphical).**

***Keywords*— virtual reality technologies, 3D interfaces, virtual reality systems**

I. Introduction

Laboratory of intelligent interfaces of communication and information systems (LIRKIS) is the laboratory for research, development and teaching applications in area of parallel, distributed and network computing systems for solving computational processes in the processing of graphics data and virtual reality with a primary focus on information systems, intelligent interfaces, including the development of network communication environments, allowing searching and quality access to distributed multimedia resources (knowledge stocks) and services and their use in creating and delivery of new knowledge and services including the development of online platforms to access to multimedia content.

LIRKIS organization structure:

- Computer Graphics and Information Systems Interfaces Laboratory (LAGRIS)
- Computer Network Laboratory (LPS)

LIRKIS laboratory work on the projects that deal with:

- software evolution by language adaptation (project APVV SK-SI-0004-08, coordinator full prof. Ing. Ján Kollár, CSc.)
- security in the distributed computer networks (projects NIL-II-021 and VEGA 1/0026/10, coordinator prof. Ing. Liberios Vokorokos, PhD., on project NIL-II-021 cooperate Technical University of Kosice with the Norwegian University of Science and Technology in Trondheim)
- large graphical data processing in parallel, distributed and network computer systems (project VEGA 1/0646/09, coordinator assoc prof. Ing. Branislav Sobota, PhD.)
- behavioural categorical models for complex program systems (project VEGA 1/0175/08, coordinator full prof. RNDr. Valerie Novitzká, CSc.)
- development of videoconference archive system AVE and user applications for EVO system (project APVV-0732-07, coordinator associate prof. Ing. František Jakab, PhD.)

II. Virtual Reality Technologies in Laboratory

LIRKIS (LAGRIS) is laboratory for systems of scanning and visualization of input/output data for management of information systems in the context of cognitive communication human-computing system in its parallel, distributed or networked implementation environment. Special attention is devoted to research and development of new flexible and intelligent interfaces of systems based on virtual reality technologies designed to work in the following areas:

- systems for a scanning and a creation of input data (tracking systems, 3D scanning, modeling, simulation)
- visualization engines for rendering the outputs in various forms and controlled using higher level languages for easy handling of objects, including script handling
- intelligent robust database systems for storing large data and information (graphical and non-graphical)
- parallel, distributed or network systems implementation environments

Virtual reality (VR) technologies in LIRKIS (LAGRIS) are: 3D scanners, augmented reality, position tracking, data gloves, head mounted displays, 3D displays, 3D printers and touch screens.

A. 3D Scanners

A 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance (i.e. color). The collected data can then be used to construct digital, 3D model useful for a wide variety of applications.

The 3D model acquisition process consists of two stages: 3D scanning and data processing.

There are several types of 3D scanners, which differ in the technology used for obtaining a data. They can be divided into two main categories: *contact* and *non-contact* scanners.

Contact scanners require a physical contact with the object being scanned. Although they are usually very precise, they are also much slower (order of 10^3 Hz) than non-contact scanners (order of 10^5 Hz). A typical example of a contact 3D scanner is a coordinate measuring machine (CMM).

Non-contact scanners use radiation to acquire required information about objects. They are of two basic types: *passive* and *active*. The main advantage of passive scanners is that they are cheap as they do not require so specialized hardware to operate. To scan objects, they only use existing radiation in its surroundings (usually visible light). In contrast, active scanners are equipped with their own radiation emitter (usually emitting laser light). While the latter are considerably more expensive, they are also much more accurate and able to scan over much bigger distances (up to few km) [1].

3D scanner in laboratory

This scanner is Leica ScanStation 2 (Fig. 1) from Leica Geosystems. This scanner use for scanning method called „time of flight". Scanning range is up to 300 m and scanning density is up to 1 mm. More about Leica ScanStation 2 at manufacturer's webpage [2].

Fig. 1. Leica ScanStation 2

B. Augmented Reality

Based on how a user sees augmented 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.
- *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.

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

- *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. photography (semi-markerless system)), face recognition, GPS data, etc.

C. Position Tracking

Position tracking serves for sensing user's position and rotation in 3D space. Position tracking devices are divided into these categories (depending on technology used for position and rotation tracking) [3]: mechanical, magnetic, ultrasonic, optical and inertial trackers.

Each one tracking technology has its advantages and disadvantages. For example, magnetic trackers do not suffer obscuration problems, but they are sensitive to environmental magnetic fields and ferromagnetic materials in the workspace.

Position trackers in laboratory

First position tracking system is Polhemus PATRIOT (Fig. 2). This tracking system has 6 degrees of freedom and for tracking position and rotation this system uses magnetic tracking. Parts of this system are: control unit, source of magnetic field and sensor. More about this tracking system at manufacturer's webpage [4].

Fig. 2. Patriot tracking system parts (from left to right): control unit, magnetic field source, sensor

Second position tracking system is InterSence IS-900 SimTracker. This system has also 6 degrees of freedom but for tracking position and rotation is used inertial-ultrasonic hybrid tracking technology. Parts of this system: MicroTrax devices (head and hand tracker, wireless transmitter, wand – see Fig. 3) and SoniFrame. More about this tracking system at manufacturer's webpage [5].

Fig. 3. MicroTrax devices (from left to right) – wand, hand tracker, head tracker, wireless transmitter

D. Data Gloves

Data glove is device, which serves for capturing mechanical and gesture information from the hand. Various technologies are used for capturing this information from the hand. These technologies can be divided into two categories: *determining the shape of the hand* and *position tracking*.

For determining the shape of the hand and fingers are used various types of bending sensors. The three most common types of bending sensors are conductive ink-based, fiber-optic based and conductive fabric/thread/polymer-based [6].

For sensing the hand position and rotation in the 3D space is used position tracking.

Data glove in laboratory

This data glove is DG 5 VHand 2.0 (Fig. 4). Data glove has five embedded bend sensors for sensing the finger movement. For sensing hand movement and orientation (roll and pitch) is used 3 axes accelerometer. More about this data glove at manufacturer's webpage [7].

Fig. 4. Data glove DG5 VHand 2.0

E. Head Mounted Displays

A head mounted display (HMD) is a display device, worn on the head (or as part of a helmet), that has small display optic in front of one (monocular HMD) or each eye (binocular HMD). HMD are used in virtual reality and augmented reality applications. Another classification of HMDs is based on how the user sees real world. This classification divides HMDs into two categories: *immersive* and *see-through*. See-through HMDs have two subcategories: *video see-through* and *optical see-through*.

For sensing HMDs position and orientation is used position tracking.

HMD in laboratory

This HMD is nVisor ST60 (optical see-through) (Fig. 5.). For displaying is used Liquid crystal on silicon (LCOS) technology. Displaying resolution is 1280×1024. Weight of this HMD is 1300 g. More about this tracking system at manufacturer's webpage [8].

Fig. 5. HMD nVisor ST 60 from NVIS

F. 3D Displays

3D displays allow information presentation in three dimensions. There are several technologies for 3D displaying and each technology has its advantages and disadvantages.

3D displays can be divided into [9]:

- Holographic displays
- Volumetric displays
    - Swept-volume displays
    - Static-volume displays
- Stereoscopic displays
    - Passive
        - Anaglyph
        - Polarized stereo
        - Infitec (**In**terference **fi**lter **tec**hnology)
    - Active
    - Autostereoscopic
        - Parallax barrier
        - Lenticular lens

3D displays in laboratory

This display is autostereoscopic 42" 3D display Philips WOWvx (Fig. 6). Resolution of this display is 1920×1080 but real resolution in 3D is 960×540 and. Optimal watching distance is 3 m. 3D image is created using 2D-plus-depth method. This method create 3D image using 2D image and depth map. More about this 3D display and 2D-plus-depth method at manufacturer's webpage [10].

Fig. 6. Autostereoscopic 3D display Philips WOWvx

3D displaying system in laboratory

This system uses passive stereoscopic technology based on Infitec technology. Parts of this system are:

- pair of projectors with Infitec filters and glasses,
- special projection screen,
- mouse or "space mouse" for navigation in 3D scene,
- rendering cluster consisting from three PCs with cluster version of SuperEngine

Fig. 7 shows projection screen, glasses and projector pair used in this stereoscopic system.

Rendering cluster currently supports scenes rendering up to 5 million polygons. Rendering performance of this cluster can be extended by adding other computers to cluster.

Fig.7. Parts of stereoscopic system: screen, glasses and projectors

G. 3D Printers

3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layers of material. 3D printers are generally faster, more affordable and easier to use than other manufacturing technologies. 3D printers offer developers the ability to print 3D models for visualization, testing or direct parts creation.

3D printer in laboratory

This 3D printer is ZPrinter 450 (Fig. 8). Maximum dimensions for printed model are 203×254×203 mm with printing resolution is 300×450 DPI and layer thickness between 0.089 - 0.102 mm. More about this 3D printer at manufacturer's webpage [11].

Fig. 8. ZPrinter 450 (left) and 3D model printed by this 3D printer (right)

H. Touch Screens

A touch screen is an electronic visual display that can detect the presence and location of touch within display area. Touch screen has two main attributes. First, it allows user to interact directly with what is displayed. Secondly, it allows controlling without requiring any intermediate device that would need to be held in the hand.

There are thee types of touch screens, which differ in technology used for sensing finger position [12]:

- resistive touch screens – use resistivity
- capacitive touch screens – use capacitance
- infrared touch screens – use infrared light

Touch screen in laboratory

This touch screen is Microsoft Surface (Fig. 9). The diameter of this touch screen is 30" (76 cm) and designed is as conference table. For sensing touches Microsoft Surface use five infrared cameras that can sense up to 50 touches at the same time. More about this touch screen at [13].

Fig. 9. Microsoft Surface

III. Systems Based on VR Technologies

At LIRKIS (LAGRIS) we currently work on several systems that use or combine together VR technologies presented in previous section. Three of them are:

- Drawing system
- Augmented reality system
- VR system for interaction with virtual scene

A. Drawing system

This system consists from drawing application and data glove (DG5 VHand 2.0). For drawing are used data sensed from data glove (hand gesture and glove movement). Fig. 10 shows drawing in this system using data glove.

Drawing system can be used in education, medicine (rehabilitation after stroke) or robotics (drawing application must be switched for application that control robot and then robot hand or entire robot can be controlled with data glove).

Fig. 10. Drawing with data glove using drawing system

B. Augmented reality system

This system combines together Microsoft Surface and HMD nVisor ST 60 (Fig. 11). Surface is used for displaying 2D markers. Displayed markers are recognized by augmented reality system and through HMD user sees 3D objects placed over these markers. Surface touch screen allows user easy interaction with 3D objects through 2D markers.

This augmented reality system can be used in cognitive education, products presentations or architecture.

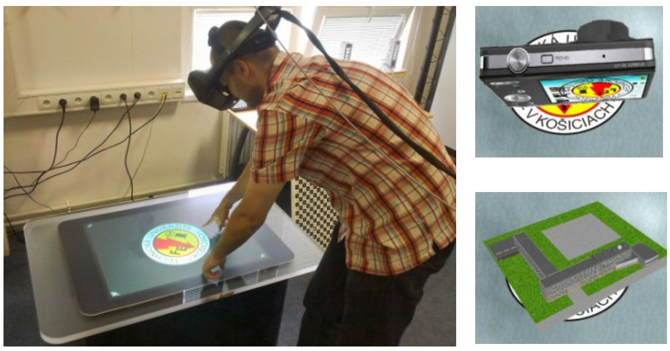

Fig. 11. Augmented reality system (left) and examples of user views (right)

C. VR System for Interaction with Virtual Scene

This VR system combines several VR technologies which allow easy interaction with virtual scene (Fig. 12).

These technologies are:

- Position tracking - IS-900 SimTracker - serves for user tracking and navigation in virtual scene
- Data gloves – DG5 VHand 2.0 - serves for interaction (grabbing, moving) with virtual scene content
- 3D displaying system – passive stereoscopic system using Infitec technology - serves for displaying of virtual scene

Virtual scene for this system can be created with 3D modeling application or 3D scanner.

Fig. 12. User working with VR system through interaction with virtual scene

IV. Conclusion

Information and cognitive communication systems that use as interface VR technologies can be used in education (virtual training systems), architecture (building presentation), medicine (surgeon training) or robotics (controlling robots, for example telerobotics).

Knowledge and experiences earned in LIRKIS laboratory about VR technologies can be used at the Technical University for:

- creation of 3D models, virtual scenes, simulations, visualizations of data output from parallel applications with photorealistic support (Faculty of Electrical Engineering and Informatics)
- creation and visualization of technical products models from all areas of industry with focus on car industry (Faculty of Mechanical Engineering)
- creating complex and spatially extensive models of objects and their complexes (Faculty of Civil Engineering)
- creation of flight simulators and virtual simulations of airspace (Faculty of Aeronautics)
- visualization and calculation of geological deposits, 3D models creation of rock structures and chemical elements (Faculty of Mining, Ecology, Process Control and Geotechnology and Faculty of Metallurgy)
- visualization/animation creation of buildings, urban complexes, designs of industrial products (Faculty of Arts – architecture, industrial design)
- creation of graphics representation of economical analysis and mathematical functions (Faculty of Economics)

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