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Virtual Reality Lab in Education of Automation

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ABSTRACT: *This paper deals with possibilities of usage of Laboratory of Virtual Reality in Control with focus on education in area of control and dispatching of underground mine technological processes.*

Many particular tasks were solved in Institute of Economics and Control Systems. In the moment new Lab is available, so the first steps are to utilize existing programs and systems for education with new hardware components. This way we want to achieve new dimension in applying virtual reality in teaching of control systems.

1 WHAT IS VIRTUAL REALITY (VR)?

Virtual Reality is generally a Computer Generated (CG) environment that makes the user think that he/she is in the real environment.

The virtual world is hosted on a computer in the form of a database (e.g. terrain database or environment database). The database resides in the memory of the computer. The database generally consists of points in space (vertices), as well as textures (images). Vertices may be connected to form planes, commonly referred to as polygons. Each polygon consists of at least three vertices. The polygon could have a specific color, and the color could be shaded, or the polygon could have a texture pasted onto it. Virtual objects will consist of polygons. A virtual object will have a position (x, y, z), an orientation (yaw, pitch, roll) as well as attributes (e.g. gravity or elasticity).

The virtual world is rendered with a computer. Rendering involves the process of calculating the scene that must be displayed (on a flat plane) for a virtual camera view, from a specific point, at a specific orientation and with a specific field of view. In the past the central processing unit of the computer was mainly used for rendering (so-called software rendering). Lately we have graphics processing units (GPUs) that render the virtual world to a display screen (so-called hardware rendering). The GPUs are normally situated on graphics accelerator cards, but may also be situated directly on the motherboard of the computer. Hardware rendering is generally much faster than software rendering.
The virtual environment (also sometimes referred to as a synthetic environment) may be experienced with a Desktop VR System, or with an Immersive VR System.

With Desktop VR a computer screen is normally used as the display medium. The user views the virtual environment on the computer screen. In order to experience the virtual environment, the user must look at the screen the whole time.

With Immersive VR the user is 'immersed in' or 'surrounded by' the virtual environment. This may be achieved by using a Multi-Display System or a Head Mounted Display (HMD). Immersive VR Systems provide the user with a wider field of view than Desktop VR Systems.

With Multi-Display Systems the field of view of the user is extended by using several computer monitors, or projectors. When using projectors, the image may be front-projected or back-projected onto the viewing screen. Many simulators utilize three screens (forward view, left view, right view) to provide an extended field of view. The configuration where the user is surrounded by projection screens is sometimes referred to as a cave environment. The image may also be projected on a dome that may vary in shape and size. With a multi-display system the user may look around as if in the real world.

A Head Mounted Display (HMD) consists of two miniature displays that are mounted in front of the user's eyes with a headmount. Special optics enables the user to view the miniature screens. The HMD also contains two headphones, so that the user may also experience the virtual environment aurally. The HMD is normally fitted with a Head Tracker. The position (x, y, z) and orientation (yaw, pitch, roll) of the user's head is tracked by means of the Head Tracker. As the user looks around, the position and orientation information is continuously relayed to the host computer. The computer calculates the appropriate view (virtual camera view) that the user should see in the virtual environment, and this is displayed on the miniature displays. For example, let's assume that the virtual environment is the inside of a car, and that the user is sitting behind the steering wheel. If the user looks forward, the head tracker will measure this orientation, and relay it to the computer. The computer would then calculate the forward view, and the user will see the windscreen, wipers and bonnet of the car (the user will obviously also see the outside world, or out of window view). If the user looks down, the computer will present a view of the steering wheel. The orientation information may also be used to experience stereo and 3-D sound. If the user looks straight forward, he/she will hear the engine noise of the car. The volume and phase will be equal for the right and left ear. If the user looks to the left, the volume of the engine noise will be higher in the right ear and lower in the left ear. Trackers that only track the orientation (yaw, pitch, roll) are referred to as 3 degree of freedom, or 3 DOF trackers, while trackers that also tracks the position (x, y, z) are referred to as 6 DOF trackers.

Objects in the virtual world may be manipulated by means of a Data Glove. A data glove measures the flexure (bend) of the user's fingers. The user may grab a virtual object and put it at a different spot. The user may also throw the object. The position (x, y, z) and orientation (yaw, pitch, roll) of the user's hand is measured with a 6 DOF tracker. If it is a force-feedback data glove, the user will also be able to deform the virtual object, and feel the object (e.g. a tennis ball) resisting the deformation.

In order to navigate (e.g. walk or fly) in the virtual world, a Space Controller is used. The space controller could be a normal joystick, or a computer mouse. For example, when the mouse is moved forward, the user moves forward in the virtual world, when it is moved to the left, the user moves to the left, etc. Force-feedback joysticks or mice could provide haptic cues to the user, e.g. when the user moves into a virtual wall. Normal joysticks and computer mice are usually used in Desktop VR Systems. In Immersive VR Systems we normally use baseless joysticks as space controllers. This enables the user to leave the desktop and to interact with the virtual world while standing up.

It is also possible for different users to share the same virtual world. This is normally achieved by connecting the host computers to a computer network. Each user's host computer broadcasts the position and orientation of the user in the virtual world. The users may therefore 'see' each other in the virtual world. In fact, users will see representations, referred to as avatars, of each other in the virtual world. They will be able to interact; working together or competing. The sharing of virtual worlds is generally referred to as 'shared virtual worlds', or as 'networked virtual reality'.

Sight and hearing are the main human senses currently used to experience virtual worlds. Touch (as in tactile- and force-feedback) is becoming more commonplace. Smell dispensers are entering the marketplace, enabling the user to smell the virtual world as well. Taste dispensers will follow soon. [1]

2 VR LABORATORY CORE EQUIPMENT

The principal objective of the current project is a development of VR laboratory for controlling of technological processes. The laboratory will provide for students' purposes concerning exercises of VR modeling for concrete workplaces of which realizations by other means would be either impossible or too costly.

The existing virtual technology scenery, which has been realized by students in the framework of their scholarly projects, represents high didactic value tools whose potentials can be fully utilized only by employment of specialized HW. It is this gear that represents VR laboratory basic equipment.

The equipment will also provide for communication of VR technology scenery with actual material modeling, and PLC systems that already operate in the existing laboratory. By employing the new facilities, students will be able to realize a kind of control system synthesis as well as their actual interaction with the material environment.

Also exercises, which have not utilized this technology for their implementation as yet, could be worked out. Realizations of potential interest geological models are assumed, concerning their full 3D rendering, and possibilities of material interaction, as well as 3D representation of environmentally detected and pre-processed information, inclusive networking with GIS systems, and extending teaching of GIS courses.

Practical operations increasingly employ VR technologies for concrete task implementation, especially in environments of impaired visibility or that are either harmful or dangerous for humans. They find their employment also in situations of either too small or too big dimensions that are difficult for human movement or orientation. Working in the laboratory will provide for an experience accumulation that might be useful for students solving problems of practical systems.

Illustration figures are presented in following subchapters.

2.1 Workstation Dell Precision 650

Dell Precision 650 is a highly scaleable, expandable dual-processing workstation. Including the latest Intel® Xeon Processors, dual-channel memory and top of the range graphics capabilities, the 650 is perfect for those requiring extraordinary performance.

Features: Outstanding dual-processor performance with Intel® Xeon Processors up to 3.20GHz with 1MB L3 cache (we have 2x3.06GHz) * Microsoft Windows XP Professional operating system * Up to 4GB dual channel DDR 266MHz SDRAM memory (we have 2GB) * 533MHz system bus * Up to 584GB of internal U320 SCSI storage, including an integrated, high-performance RAID 0 controller (we have 300 GB ATA) * Ideal system for graphics-intensive, or compute-intensive, applications like advanced engineering, 3D visualization, and scientific analysis * Innovative clamshell chassis featuring Dell's QuietCase acoustic environment provides easy access to system interior and supports tool-less upgrades and maintenance of key internal components * Workstation-class tower chassis offering excellent scalability and expansion possibilities.

2.2 Head Mounted Display HMD 800 stereo

The 5DT Head Mounted Display (HMD) offers the user affordable quality, high resolution (SVGA), a crisp image and superior sound quality packaged in a sleek, comfortable and extremely light headmount design. The HMD provides for user configurable immersion levels. Other features are adjustable top/back ratchets, a mounting base for head trackers and a flip-up mode for reality checks. SVGA, PAL and NTSC input signals are accepted.

Features: Affordable duality * Adjustable top/back rachets * Mono or stereo models * Cable organizer * Mounting base for head trackers * Crisp SVGA image * Extreme comfort * User configurable immersivity * Lightweight * Flip-up mode for reality check * High quality headphones

2.3 Head Tracker InterTrax2

The InterTrax2 is the smallest high performance head tracker in the world. Designed to bring 3D to life for design, game play, and web visualization, the InterTrax2 is a fraction of the weight and size of earlier products with greatly improved performance. The InterTrax2 will change your view of motion tracking forever.

The InterTrax2 motion tracker delivers extremely fast, smooth, orientation data via the serial or USB port of a PC. Your imagination is the limit to the fully immersive 3D experiences you can explore with the InterTrax2 and an HMD (Head Mounted Display).
With InterTrax2, the physical flexibility in the real world is duplicated in the virtual world where users can look up, down and around through 360 degrees as they explore and interact with their environment.

Features: Increased functionality and accuracy * Priced for consumers, performance for Professional * Available standalone or bundled with headsets * Simple connection to all personal display device * Available with USB or Serial Interface * Compatible with Playstation2, PCs and workstation * USB PS2 middleware and SDK available * 3 DOF (degrees of freedom) angular tracking * Sourceless operation * Exceptional speed & accuracy * Zero jitter, high stability * On board processor performs sophisticated attitude compensation algorithms * Compatible with most 3D applications * Simple to connect via an RS-

232 or USB port * Tracking not affected by nearby objects * Attaches easily to HMD (Head Mounted Display)

2.4 Data Glowe DG 5Wr

The 5DT Data Glove 5 measures finger flexure (1 sensor per finger) and the orientation (pitch and roll) of the user's hand. It can emulate a mouse and can be used as a baseless joystick. The system interfaces with the computer via a cable to the serial port (RS 232 - platform independent). It features 8-bit flexure resolution, extreme comfort, low drift and an open architecture. The 5DT Data Glove 5-W is the wireless version of the 5DT Data Glove 5. The wireless system interfaces with the computer via a radio link (up to 20m distance) on the serial port (RS 232). Right- and left-handed models are available. One size fits many (stretch lycra). A USB adapter is available.

Features: Affordable duality * Extreme comfort * Open architecture * Mouse emulation mode wired version only * Right/left-handed versions * VR program drivers * Animation program drivers * 8-Bit flexure resolution * One size fits many * Built-in tilt sensor * High update rate * Bundled software * Low drift * USB adaptor available

2.5 3D Desktop Digitizing System MicroScribe2

In developing the MicroScribe™ G2 system, it was Immersion's goal to provide graphic artists, animators, video game developers, industrial designers, engineers, and scientists a 3D digitizer with the best combination of functionality and affordability. The result is a highly refined product that looks and feels at home on the desktop while providing the performance of a precision industrial instrument. The USB port provides both a high speed data connection and power for the system, producing a highly portable digitizing solution when combined with a laptop computer. The MicroScribe G2 system is constructed from the highest quality components using precise aluminum housings, lightweight graphite links, and state-of-the-art electronics to provide years of trouble-free digitizing. The mechanical arm is carefully counter-balanced to allow effortless manipulation.

Features: Workspace 50" sphere * Accurancy 0.38mm * Footprint 6"x6" * Compatible software: 3DS Max, Light Wave 3D, Autodesk Viz, Pro/ENGINEER, AutoCAD, CADKEY * Immersion software: MS Utility Pack, SDK * interface RS-232 / USB 1.1.

This equipment represents items needed for purposes of developing a VR Laboratory. Currently putting in operation of individual peripheral units, their functional verification, and system integration are in progress.

2.6 Software

Installations and configuration of SW means that the Institute of Economics and Control Systems, Unit for Mining Automation, have at their disposal for 3D scenery modelling and rendering. Especially Microsoft products are involved, as made accessible by MSDN AA programme, i.e. development environment on a .NET platform, but also Autocad Map 6, 3D Studio MAX produced by Autodesk company that are accompanied by supportive and exporting modules, as well as other SW means from freeware groups.

3 REALIZED VIRTUAL SCENES AND PROGRAMS

The Institute has a lot of program products at their disposal that were developed in the past and that are ready to be employed by a VR Laboratory. These products' themes cover a wide range of underground mining subjects from visual renderings of excavation through mining workplaces configurations up to modeling and simulations of mining technologies.

3.1 Visualization using VRML

VRML (the Virtual Reality Modeling Language) has emerged as the de facto standard for describing 3-D shapes and scenery on the World Wide Web. VRML's technology has very broad applicability, including web-based entertainment, distributed visualization, 3-D user interfaces to remote web resources, 3-D collaborative environments, interactive simulations for education, virtual museums, virtual retail spaces, and more. VRML is a key technology shaping the future of the web. VRML is described similar to HTML as fully hypertext descriptor of 3D scene. Its main characteristics are: text format * simple 3D objects description * standard for WWW environment * support from graphics subsystem and WWW browsers suppliers.

Basic building blocks of a VRML world are shapes. Primitive shapes are standard building blocks (box, cone, cylinder, sphere and text). Appearance of each shape can be controlled; color, opacity and material can be defined. For text information a text object can be defined, when billboard is used, text can be read from any direction. Placement of each shape is defined with its own coordinate system. Nodes like billboard and anchor have built-in behavior. It is possible to create own behaviors to make shapes move, rotate, scale, blink, and more. Animation changes something over time: position, orientation, and color. Animation requires control over time: when to start and stop and how fast to go. It can be sensed when the viewer's cursor: is over a shape, has touched a shape or is dragging atop a shape. It is possible to trigger animations on a viewer's touch or enable the viewer to move and rotate shapes.

Complex shapes are hard to build with primitive shapes. Terrain, machinery etc. are building out of atomic components - points, lines and faces. By default, there is one light in the scene, attached to your head. For more realism, multiple lights (Suns, light bulbs, candles, flashlights, spotlights, firelight) can be added to the scene. Lights can be positioned, oriented, and colored. Lights do not cast shadows.

Shapes form the foreground of your scene. You can add a background to provide context. Backgrounds describe sky and ground colors, panorama images of mountains, cities, etc. Backgrounds are faster to draw than if shapes are used to build them. Sounds are important supplement of displayed information. It can be triggered by viewer actions. Sounds can be continuous in the background or emitted from a location, in a direction, within an area.

Different types of worlds require different styles of navigation - walk, fly, and examine shapes. The navigation type can be selected; the size and speed of the viewer's avatar can be described.

3.2 Examples of realized 3D sceneries

Visualization of underground working places (Fig. 6): This part focuses on methods of presentation of an underground mine technologies. It shows usage of platform independent VRML client for presentation of static and dynamic information about technological process. Bi-directional interactions between client and process information database are solved.

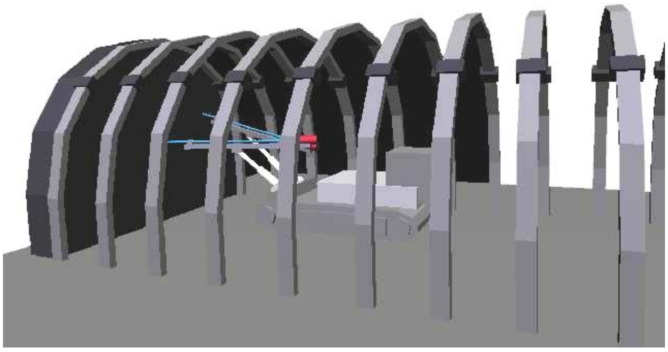

Figure 6a – Roadhead with wagon drill

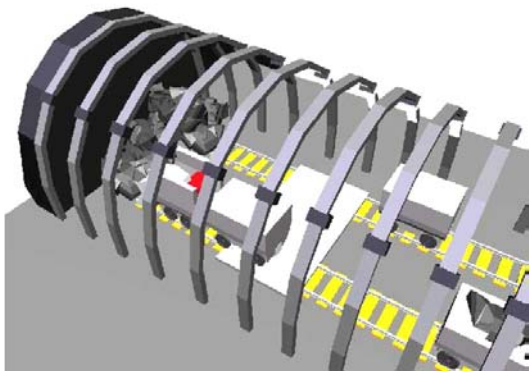

Figure 6b – Roadheadwith loader and rail transport

Database supported visualization of underground technology and equipment (Fig. 7): This program allows user to design his own technological scene from equipment stored in database. Objects with all properties are immediately put into virtual scene and displayed. Position and orientation can be set.

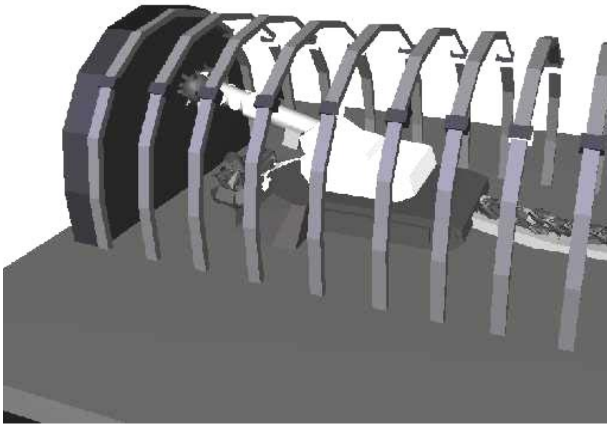

Figure 6c – Heading machine

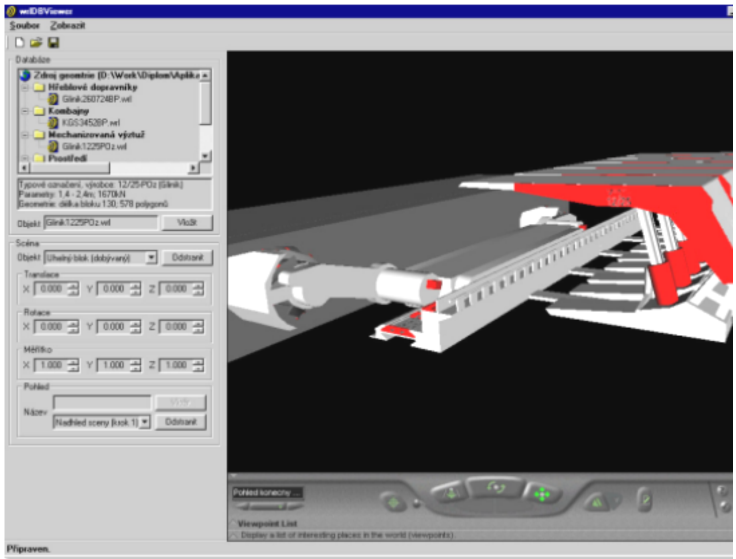

Figure 7 – Technology scenery development from equipment databases

Visualization of underground mine topology (Fig. 8): Based on analysis of technological process of underground mine database structure was designed. This is skeleton for storing of all information about any underground mine. This skeleton can be modified in any direction. Data in this "static model" of underground mine are used for visualization in VRML environment. This way it is possible to simplify and unify users front-end for all kinds of tasks.

All designed scenes can be interactively displayed in full view or in any detail view, so user can recognize every important part of installed equipment, its stage, technical parameters and other information. If producers of mining equipment will supply VRML model of their real products, everybody will be able to place it into VRML scene and learn everything about it.

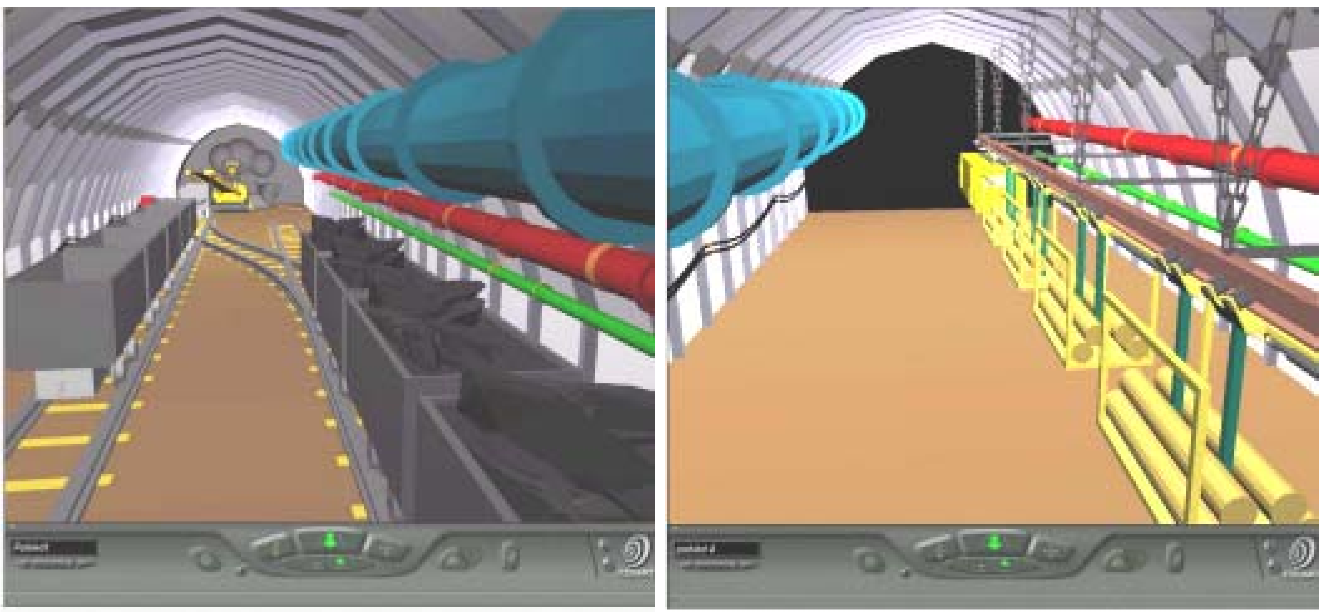

Figure 8a, b – Examples of underground technology scenery

Visualization of simulation model (Fig. 9): This software model concerns control of coal mining technological processes for continuous miners by means of virtual reality technologies. In accordance with VRML97 specification, static and especially dynamic properties for VRML scenes have been employed. The DrillControl application represents a principal module, which enables real time interactive control of continuous miner on the coal face, observing alarm and system information, as well as load trends for both driving mechanisms of the mining drums.

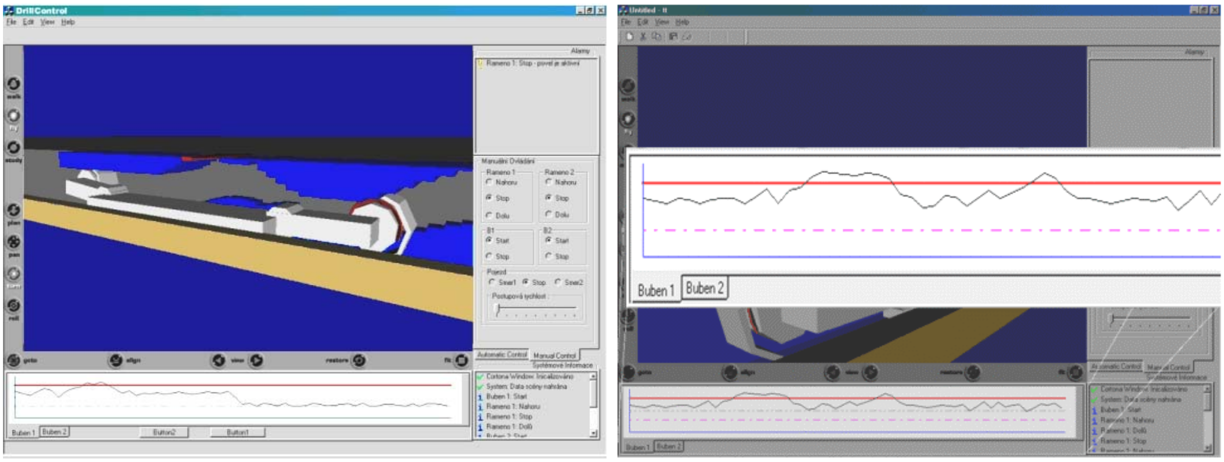

Figure 9a, b – Virtual scenery for continuous miner simple simulation

4 CONCLUSION

Implementing the project of VR Laboratory will provide for unique utilization of the state-of-the-art gear at the Institute. Many obstacles will be removed that have hampered realizations of virtual technology scenery. The obstacles concern mainly the magnitude of scenery object present, as well as its resolution power.

Figure 10 – Virtual Reality Lab

The Institute's Unit has already tested most of the realized VR technology sceneries and applications, and the knowledge acquired corroborates these assumptions.

The VR Laboratory facility will provide for further investigation concerning utilization of VR means for control of technology processes. It will also enable extending of possibilities for already existing sceneries and simulation modeling.

Partial extension of rendering possibilities in under development that concerns projected VR. For the time being with a single projector, but final solution would employ a stereoscopic back projection.

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