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LAUNCH OF THE IMMERSIVE 3D VISUALIZATION LABORATORY

Abstract: The paper presents the concept of Immersive 3D Visualization Laboratory, formed at the Faculty of Electronics, Telecommunications and Informatics of the Gdańsk University of Technology under the Gdańsk University of Technology Modern Auditoriums project. The basic unit of this laboratory will be a cubic CAVE (Cave Automatic Virtual Environment) supplemented with a spherical walk simulator. This device will allow the user unlimited walking, and even running, in a freely created virtual world. If the virtual world becomes a battlefield or a burning building, this device will be able to serve as an infantry soldier simulator or fire-fighter simulator. The opening of the laboratory will take place in mid-2014.

Keywords: virtual reality, CAVE, walking simulator, virtual training.

1. INTRODUCTION

The idea of virtual reality is not a recent one at all. Attempts to train pilots on training devices, which in today's nomenclature we would call flight simulators, were made during World War I. During World War II devices of this type were commonly used by the Allies to train aviators. Military history of that time has other examples of "less obvious" simulators. For instance, the Polish Naval Academy in Gdynia has a device for training shooting to surface targets that was constructed in 1927 (Fig. 1) [11]. Shell explosions on water surface are simulated there by means of metal bolts coupled to a keyboard, wherein the bolts are thrust out of an imitated water surface when the operator presses an appropriate key. The trainee observed whether the "explosion" occurred in front of the ship model and obscured it or behind the ship model.

But it was only the technology of the present times that allowed to create simulators that could make the simulation participant lose the impression of the artificiality of the exercise. Contemporary flight simulators or training devices, e.g. naval rocket and artillery sets (to be seen also in the Polish Naval Academy in Gdynia [4]), allow for a deep immersion in the simulated world. Obviously, immersion can most readily be achieved with simulators of technical devices (e.g. flight, tracked vehicle, gun), where large part of the simulated world comprises a copy of the simulated device (e.g. cockpit of an aircraft, vehicle cab, gun). It is much more difficult to simulate the world of a person that is outside of such "encompassing" devices, e.g. the world of an infantryman. Popular and inexpensive solutions that enable this type of simulation are walking simulators equipped with virtual helmets or head mounted displays (HMD). These devices, however, must be worn on the head and are often characterised by a lag in image generation, which is noticeable particularly during rapid head movements and causes fatigue. An example of such solution is the Virtusphere spherical walking simulator for training of hazardous occupation specialists (military, counter-terrorism units, police, fire fighters, etc.) [13].

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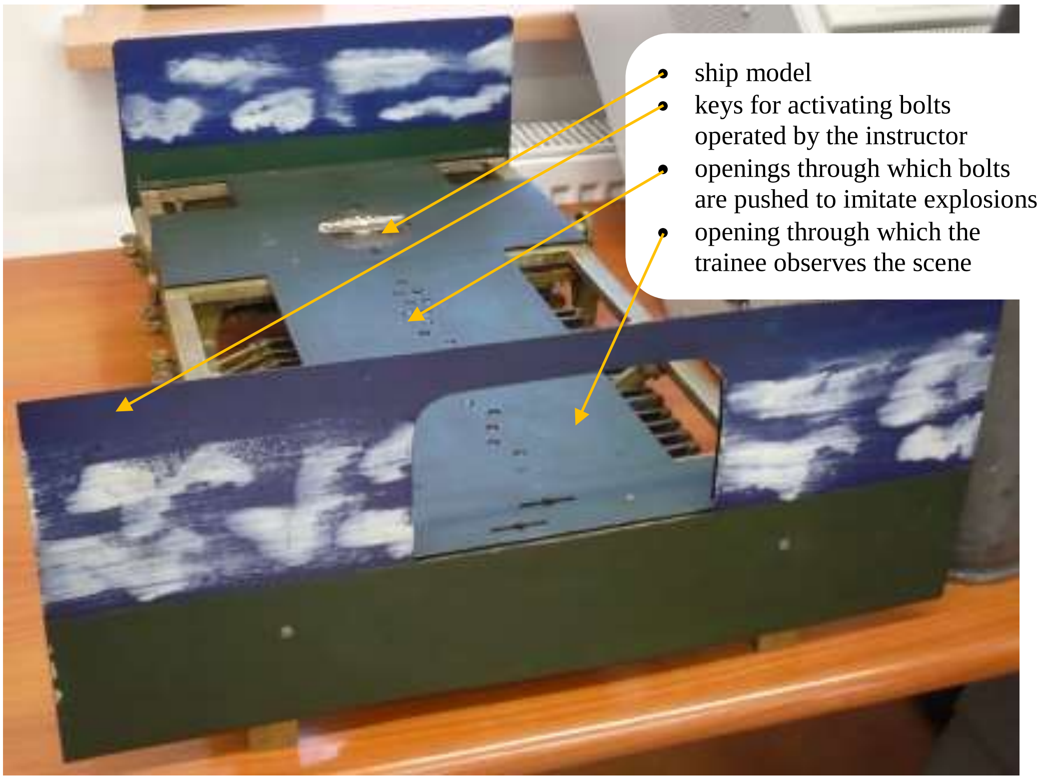

Fig. 1. A device from 1927 for training shooting to surface targets (photo by J. Lebiedź)

Spherical simulators are not the only equipment that enables simulation of march. There are other solutions that allow walking in place [5, 8]: omni-directional treadmill, omni-directional roller skates, movable tiles, slippery platform, etc. However, in most cases these are either expensive devices, or they only enable movements that are unnatural, or are ineffective (due to slow response alone). Only the last approach, particularly the Virtuix Omni version [12], seems to be a competitive solution with the spherical motion simulator.

Simultaneous simulation of any virtual space for several persons, although limited in walking range to a few metres, is provided by virtual CAVE (*Cave Automatic Virtual Environment*). The oldest device of this type in Poland is at the Faculty of Biomedical Engineering of the Silesian University of Technology in Gliwice [14]. In general, the virtual cave consists of a room comprising three, four, five or six screens forming a cuboid or a part of it, onto which images are projected to create a consistent all-round view of the created virtual world (Fig. 2). Persons inside this room can move within it, although this is usually insufficient, and therefore they are provided with an additional controller to enable moving in the virtual world without walking. Participants often wear 3D goggles to enable stereoscopic vision. To conceal corners of the room, images are generated from the viewpoint of the simulation participant, whose position is detected by means of special markers fitted to his or her 3D goggles.

Unfortunately virtual caves do not enable unrestricted walking. In mid 2014 an Immersive 3D Visualization Laboratory (LZWP) will be commissioned at the Faculty of Electronics, Telecommunications and Informatics of the Gdańsk University of Technology. It will contain a CAVE-type installation with the option to place inside it a spherical walking simulator. This will allow the trainee to benefit from the advantages of both devices without having to put on a virtual helmet. The next section explains the concept of LZWP, while the subsequent section describes the possible applications thereof.

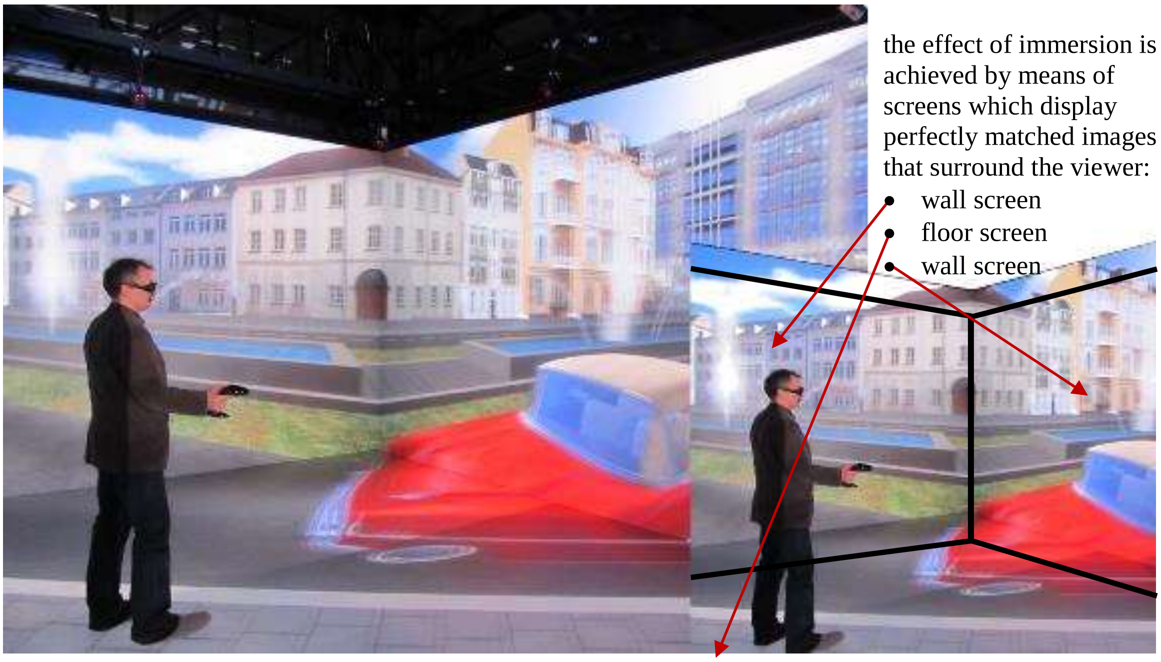

Fig. 2. An example of a virtual cave [10] **and its operating principle** (photo by A. Mazikowski)

2. CONCEPT

The Immersive 3D Visualization Laboratory will include a device enabling unrestricted walking within the defined virtual world. This device will simulate autonomous movements within a computer-generated scene. The impression of self-determined walking will be achieved by using a mechanism allowing to walk in any direction without the walker having to change his/her position (walking in place). This mechanism will have the form of a transparent sphere with the user inside rotating the sphere by his/her steps (like a hamster wheel). Visualisation will be effected by simultaneous external projection of a three-dimensional image onto all six walls of the cuboid room (CAVE) and will be supplemented with surround sound generation [6, 7, 9].

The major challenge of the project seems to be the mechanism for marching in place. It is assumed that to this end a rotary sphere with the user inside will be used - a spherical walking simulator (Fig. 3). A set of sensors for registering the rotation of the sphere corresponding to subsequent steps of the user will control the visualisation effected on the screens surrounding the sphere and the sound emitted from loudspeakers around the sphere.

Various methods of implementing the spherical walking simulator were considered at the stage of initial specifications. The first involved 3D image projection directly onto rotary matte-surface sphere (the sphere would be the screen). The user would enter the sphere (through a special hatch). In this case no CAVE installation would be necessary. But the authors have not come across this type of working solution anywhere in the world. The inspiration for this concept was an installation at the Warwick University in the United Kingdom [3]. During a visit to the site the system revealed its limitations. It comprised a rotary double-layer sphere suspended in a stream of air from a blower. Image projection was two-dimensional. The image on the sphere was created by one, rarely by two projectors. When two projectors were used, the researchers from Warwick encountered problems with the synchronisation of images from the two projectors resulting from the complexity of the border line, from various pixel sizes on the sphere (pixel size varies depending on the angle of incidence) and from vibrations and deformations of the sphere (indeterminacy of sphere position was estimated at at least several centimetres!). These problems could not be resolved, therefore one projector only was used most of the time.

Another considered solution, also unknown in the world, was to use a transparent sphere revolving inside another, static, matte-surfaced sphere that formed a projection screen. The Belgian company BARCO [1] has developed a method of joining images from a number of projectors over a static surface of a sphere and has even recently delivered to the Israeli army such a system comprising as many as 16 projectors. The user, after entering the sphere, gains an impression of the surrounding virtual reality. The cost of this, static only, solution greatly exceeded the budget planned for LZWP.

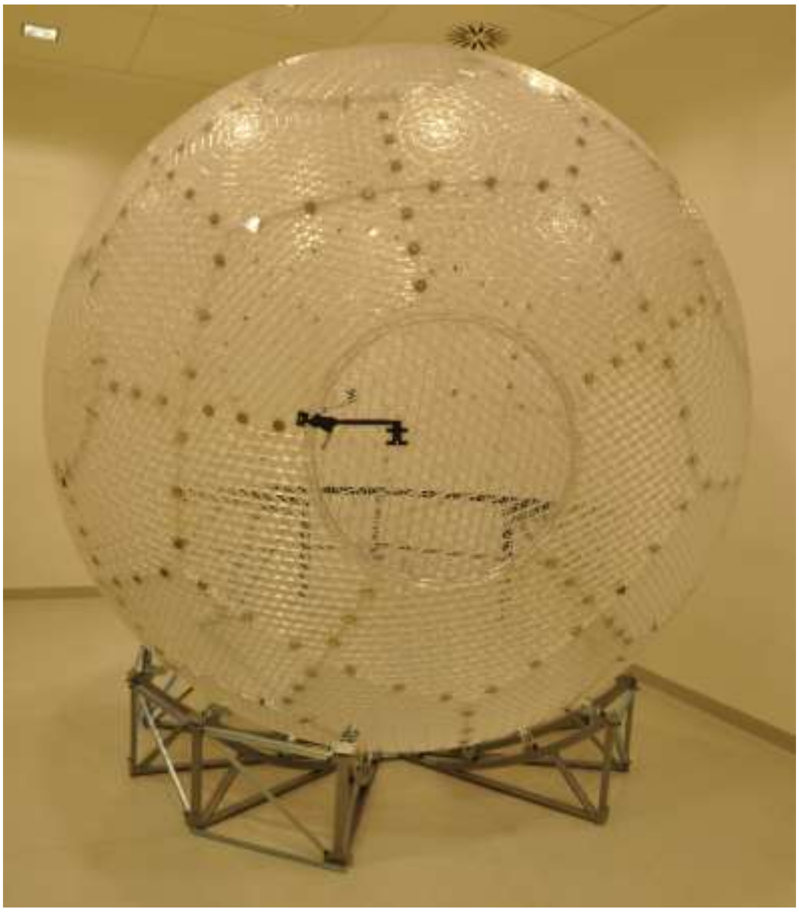

Fig. 3. Spherical walking simulator by Virtusphere [13] (photo by J. Lebiedź)

It was finally decided that the third concept, consisting in placing a spherical walking simulator in a cubic (or more generally, a cuboid) CAVE installation, would be implemented. Although the authors of this paper have not come across such a solution before, its implementation seemingly requires only the use of two typical devices: spherical walking simulator (e.g. Virtusphere [13]) and CAVE installation. Moreover, the spherical walking simulator, 3.05 m in diameter, would be removable from the surrounding enclosure of six screens (by opening one of the screens), so that the set of screens could be used as a traditional CAVE environment and the sphere alone could be used with a virtual helmet. It would then be also possible to place inside the cave an alternative motion simulator, e.g. a Virtuix Omni slippery platform [12].

There are several virtual CAVEs in the world. These installations differ in size and the number of projection walls: 3 screens, 4 screens (3 vertical walls + floor, e.g. [14]). 5 screens (with 1 wall missing or without ceiling, e.g. [10]) or 6 screens forming a complete cuboid. The cave at LZWP will have six acrylic walls-screens, 3.4 m by 3.4 m each (with glass-acrylic floor), including one moving wall to function as a door. This solution resembles aixCAVE (Fig. 2) of the RWTH Aachen University) [10]. Image displayed on a single wall will be generated by two Barco Galaxy NW-7 projectors at WXGA resolution (1920 × 1200). The images will be partly blended, so that the total resolution of image on one wall will be 1920 × 1920. Two alternative stereoscopic mechanisms will be applied: shutter glasses and colour filtering glasses (Active Infitec+ technology).

Image generation on screens (that is the projectors), determination of the position of the rotary sphere and simulation control will be handled by high-performance computers connected by fast InfiniBand glass fibre network and by Ethernet. Each projector will have its dedicated computer. Another computer will track the position of the user's head and will control surround sound generation. Still another computer will monitor the rotation of the spherical walking simulator.

Appropriate network infrastructure (of adequate throughput and minimum latency) will enable operation of the device under design with other simulators available, for instance, at the virtual reality laboratory of the Faculty, which include three vehicle simulators (four-monitor stations with driving wheels or yokes), virtual helmets and gloves, motion controllers (Kinect) and stereoscopic monitors. This will enable interactive distributed simulation of the virtual world using many diverse simulators, as well as hardware resources of the Academic Computer Centre TASK in Gdańsk for simulations requiring high computing power.

A dedicated building was erected to house the LZWP (Fig. 4). In addition to the main hall designed for the cave and the spherical walking simulator, the building will include several additional rooms (office, server room, control room, observation gallery, lecture room, etc.).

Fig. 4. LZWP building in the final stage of its construction (photo by J. Lebiedź)

The specifications of the individual subsystems for LZWP can be found in the Terms of Reference (SIWZ) for the delivery, installation and commissioning of equipment to be located in the rooms of the Immersive 3D Visualization Laboratory [2].

3. APPLICATIONS

At first sight the installation seems to be a device designed mainly to play computer games. Undoubtedly it will make playing more attractive, particularly in the case of games involving moving in a terrain (e.g. first person shooters). This device may also, using a computer network, allow to operate together with other simulators (walking or vehicle simulators) and enable thereby more people to participate in the game (multiplayer game).

But the project is not devised to play games only, but it is intended to train public services, such as the military or fire brigades, that provide homeland security. Virtual battlefields and virtual fires are much cheaper and safer than real training grounds. An infantryman can train here to not only operate together with colleague servicemen (several spherical walking simulators), but also with combat vehicles controlled by other trainees using other types of simulators.

The device under design can also be used to train industry specialists. Training of a ship or construction inspector requires several inspections to be carried out under the supervision of an instructor. As was the case before, virtual inspection of ships or buildings is less expensive and safer. Moreover, it is more efficient, as it enables to follow more scenarios.

Another potential application of the proposed solution is virtual tourism. After loading appropriate data, it will be possible to visit any place at any historical time. Both medieval Gdańsk, as well as ancient Pompeii will be within the abilities of a virtual tourist. Apart from that it will be possible to visit virtual expositions and museums or to virtually attend concerts and other artistic events. Virtual training sessions, consisting in wandering in a microworld (chemistry) or in the universe (astronomy), may be created.

Display capabilities of the simulator may also allow: designers (e.g. architects) – to demonstrate the future appearance of the objects they design and to visit them virtually, chemists – to view from the viewpoint of a free electron the structure of a protein they model, artists – to prepare three-dimensional artistic installations. It will also be possible to analyse this way the effect of the appearance of the surroundings on human behaviour and emotions. Presentation of various forms of packaging of an article on the shelves of a virtual supermarket or presentation of various designs of a signboard placed above the entrance to a virtual shop may help assess the attractiveness of the visual designs even before a prototype is made.

Medical applications are also plausible. The device, on the one hand, may be used to diagnose ailments of the locomotor system or to study the effort of a runner. It would, however, be more interesting to see the device used in the treatment of anxiety disorders, phobias (e.g. glossophobia, that is fear of public speaking) and obsessive-compulsive disorders (such as persistent hand washing), by the method of controlled exposure through systematic desensitization. Suppressing of response to negative stimuli would then be effected not through the patient's imagination or his/her real contact with those stimuli, but through exposition to virtual reality (for instance, in the case of glossophobia, to a virtual audience of defined size), that exposition being controlled by an expert (or, in future, by an automatic device that monitors patient's emotional state).

4. CONCLUSIONS

The Immersive 3D Visualization Laboratory will enable generation of dynamic all-round three-dimensional images and responding to the motion of the spherical walking simulator (marching or running) and to the movements of the user inside (position of the head or controllers, if any) or outside (if the spherical walking simulator is moved out of the cave). It will also ensure safe use and easy change of simulation scenario. Although LZWP is an extremely complex project, and its implementation covers various mechanical, optoelectronic and computer aspects, its functionality seems very promising.

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