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SIMULATION OF THE SENSE OF TOUCH WITH THE USE OF A SIMULATOR

The article presents a simulator used for interactive simulation of virtual overhead crane use and the results of studies performed to assess its functionality in simulating the sense of touch. The simulator was created using Virtual Reality techniques and is operated by two real steering panels. The prepared simulator was used for tests in which overhead crane operators and training instructors participated. The study enabled the authors to assess the usefulness of the simulator in the training of future overhead crane operators and the possibility to simulate the sense of touch. The results of tests showed that training with the use of the overhead crane simulator will improve the practical skills of future operators, and the simulator is a useful tool for staging possible accidents that cannot be performed in reality for safety reasons.

Keywords: overhead crane, simulator, accidents, virtual reality technique, the sense of touch.

1. INTRODUCTION

Virtual Reality technique, usually in the form of a simulator, enables us to not only immerse the user into a virtual environment, but also allows the trainee to personally participate in the simulated work process or in the staged accident. Simulators are used in the training of operators of, among others, wheeled vehicles [1, 5, 15], lift trucks [2, 12], locomotives, aircraft, as well as of operators of lathes [7], milling machines [10], spraying machines [17], welding machines [16] and cranes and lifts [4]. The use of simulators in training improves not only its attractiveness, but also operators' skills and knowledge of safe operation of the machines, as well as accelerates the training process and decreases the cost of the performed training courses. Research conducted by the French Association to Develop Professional

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Training AFT-IFTIM indicates that one hour of training using a car simulator combined with 4 hours of driving a real car is more effective than 8 hours of traditional, real car driving [11]. This fact was also acknowledged by research conducted by AutoSim AS (Tromsö, Norway) and SINTEF (Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology in Trondheim, Norway). These studies conclude that training using a simulator requires 40-50% less time, as compared to the traditional method of training, moreover it seems cheaper [11].

In 2008 a research team led by Villy Portouli [13] conducted research on the effectiveness of three training methods concerning the use of advanced systems supporting the work of a driver (meaning ACC systems, navigation, LDW and ABS). Three methods were chosen for the study: traditional, multimedia and simulator-based method. Results of this comparative study clearly demonstrated that the participants of the simulator-trained research group were more convinced that they can use these systems (particularly LDW and ABS systems), and that they do not need any additional training, compared to the other two groups. Hence, according to Villy Portouli, training of drivers using traditional methods is less effective than simulator-based training. This fact was also acknowledged by research conducted on a group of students from Iowa State University in 2010, where people trained using a simulator have 30-40% higher chances to receive a certificate of a professional welder than those who were trained only in a traditional way [16].

2. CHARACTERISTICS OF AN OVERHEAD CRANE SIMULATOR

The overhead crane simulator is a computer tool with VR software enabling the user to conduct an interactive simulation of the process of using the virtual overhead crane in an environment of a production-storage hall. Operation of the simulator is performed in the same way as it is done in case of a real overhead crane [8]. Moreover, while simulating the process of work, some typical accident situations which may occur during work are being staged in the simulator. The simulator consists of:

– a computer application of the virtual environment of a production-storage hall, where the process of simulation of virtual overhead crane operating is performed,
– a seat (Fig 1., point 1) for the user of the simulator,
– two real control panels to steer the virtual overhead crane (Fig. 1., point 2),
– an infohelmet (Fig 1., point 3) and a screen used for viewing the user’s actions taken in the virtual environment,
– a tracking system with motion sensors (Fig. 1., point 4) to register the position of hands and head of the user in the virtual environment.

Fig. 1. View of the overhead crane simulator: 1- seat of the simulator, 2- real panels to control the virtual overhead crane functioning in the simulator, 3- infohelmet, 4- motion sensor of the tracking system.

The simulator was made using Virtual Reality technique [3], which enables us to immerse the user (trainee) into a virtual environment of a production-storage hall. The user, transferred into the environment, becomes a virtual operator of an overhead crane controlled from the level of the cabin. Immersing a person in this environment is made by using the VR hardware such as the infohelmet and a tracking system with motion sensors.

The tracking system, together with the motion sensors placed on both hands of the user, allows to register their placement in space in the Descartes coordinate system, and then, after processing the data, it sends them to a PC unit. The simulator's real time user can observe his own actions during the interactive simulation of the process of using the virtual overhead crane. Operation of the simulator (control of the virtual overhead crane) is conducted with real steering elements placed on both control panels.

2.1. Use of the overhead crane simulator

After sitting in the simulator's seat (Fig. 2.) and putting both hands on the motion sensors of the tracking system, as well as the infohelmet on the head (with a sensor placed there), one may start using the simulator. The simulation starts after turning a key in the ignition on the left control panel.

Fig. 2. View of the simulator's seat after the user sits and wears VR hardware

The simulator allows the trainee to simulate performing tasks. These tasks consist of using the overhead crane equipped with an electromagnetic device and a hook. The overhead crane simulator user's task is transporting long bundles of metal rods from the storage hall to a truck and placing them inside (Fig. 3). Next, the user's task is transporting an empty basket from the storage hall (Fig. 4) to a placing field indicated by the instructor, situated in the production hall, and taking the full basket from one place and transporting it to an indicated place in the production-storage hall.

Fig. 3. View of a computer-generated image from the virtual environment during loading of the truck

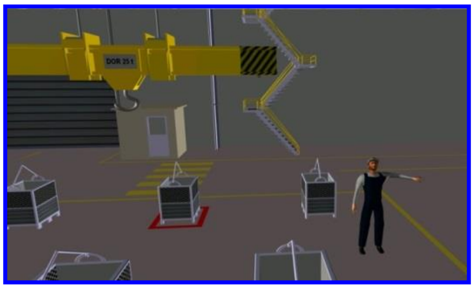

Fig. 4. View of a computer-generated image from the virtual environment during the process of picking up the basket with help of a rigger giving manual signals – movement to the right

2.2. Accidents initiated in the simulator

Using the virtual overhead crane may be connected with the occurrence of accidents resulting from work that includes picking up and transporting loads in the production-storage environment [9]. Such accidents are initiated in the moment when a mistake is made by a user of the tool or in the moment when an instructor initiates a situation which leads to the occurrence of the accident situation. The following accident situations are simulated in the simulator:

– hitting (with the transported load) an avatar of an employee working at a post or moving around the virtual environment (Fig. 5),

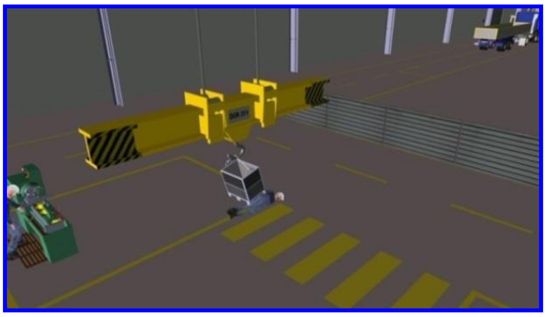

Fig. 5. View of a computer-generated image from the virtual environment during an employee being hit while passing a pedestrian crossing

– hitting a rigger with the load being picked up,
– hitting a rigger with the load transported on a too low level (e.g. post equipment, machine tool, production-storage parting fence etc.) or moving means of transport,

– destruction of the load resulting from detachment (of the basket off of the hook), or detachment of a long load of the electromagnetic tool.

2.3 Supervision of the simulation process

Use of the simulator of an overhead crane is conducted under the supervision of an instructor, who communicates with the user, explains how to perform a given task, comments on the mistakes during or after the simulation. In addition, during the simulation the instructor may interactively influence the process by initiating, from the level of the keyboard, situations leading to the occurrence of accident situations, such as the appearance of a passer-by on a pedestrian crossing or by a placing spot with the long loads, re-activation of buggies' movement on communication routes, etc.

3. USER TESTING

The simulator was tested to check its usefulness in training of future overhead crane operators. It was a test in which overhead crane operators (with at least 2 years of experience), training instructors and Safety of Work specialists took part. The tests on the simulator were conducted according to a prepared agenda [14]. The programme was composed of:

– teaching the trainee to interactively map chosen accident situations which may occur during use of the overhead crane,
– presenting the way of functioning of the overhead crane simulator,
– trial interactive simulation of the use of the simulator,
– basic interactive simulation of the virtual overhead crane user's work process, with a possibility to map accident situations,

Each of the participants of the training conducted three interactive simulations on the use of the virtual overhead crane. The first simulation allowed the participants to learn the functioning of the overhead crane simulator, e.g. steering the virtual overhead crane using real control elements, picking up and manoeuvring the loads. Then, the participant of the training began the basic interactive simulation of the process of using the overhead crane simulator, as well as mapping accident situations. Each of the participants conducted two interactive simulations using the overhead crane equipped with an electromagnetic tool and a hook. The task of the participants was to transport, in the safest possible way, a certain load to a place indicated by the instructor (Fig. 6.). The simulation lasted for about 15 minutes, and there was a 10 minutes break after each of them.

Fig. 6. A participant of the tests conducting an interactive simulation of using the virtual overhead crane

4. TEST RESULTS

Each of the participants answered questions included in a questionnaire, which concerned the assessment of functioning of the overhead crane simulator. The questions in the questionnaire were divided into the five following categories of assessment: comfort of conducting training, the simulator's control interface, interactive simulation of using the virtual overhead crane, training simulation functioning in the simulator and usefulness of knowledge acquired during simulator-based training.

The external equipment used in the simulator (the infohelmet, palm-bands with markers, the seat) did not cause any discomfort to the participants of the conducted test. The majority of the participants claimed that the equipment was comfortable and did not cause sweating of, for instance, the palms of the participants. The infohelmet enabled stereoscopic vision of the virtual environment, straight before the eyes of users of the simulator. Hence, 72.7% of the participants of the tests (Fig. 7) felt the environment was very realistic. It is also confirmed by research conducted by Juang et al. [6], which states that the participants felt the environment as more intuitive and realistic while using the stereoscopic view.

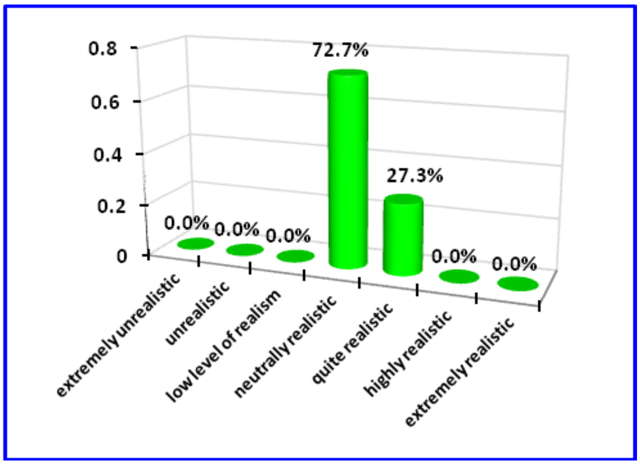

Fig. 7. Presentation of answers given to the questions concerning assessment of the realism of the simulation

A certain inconvenience which was observed during the use of the simulator was caused by the presence of third parties in the same room, who were observing the actions of the user of the tool. Another inconvenience was caused by fogging of the infohelmet screens resulting from sweating during the simulation, when, after a certain time, the participants were simply too hot; 54.5% of the participants agreed with this fact.

The time assigned for a trial simulation (Fig. 8) was, according to 72.7% of the participants, sufficient to learn the functioning of the steering elements of both real panels (Fig. 1 p. 2) and their peers in the virtual environment. The trial simulation allowed the participants to learn how to operate the virtual overhead crane (81.8% of the participants), which, as a result, enabled easy concentration on the task performed during the basic simulation (63.6%). The majority of the participants of the tests had no problem with identification of their identity in the virtual environment as well as the assigned tasks.

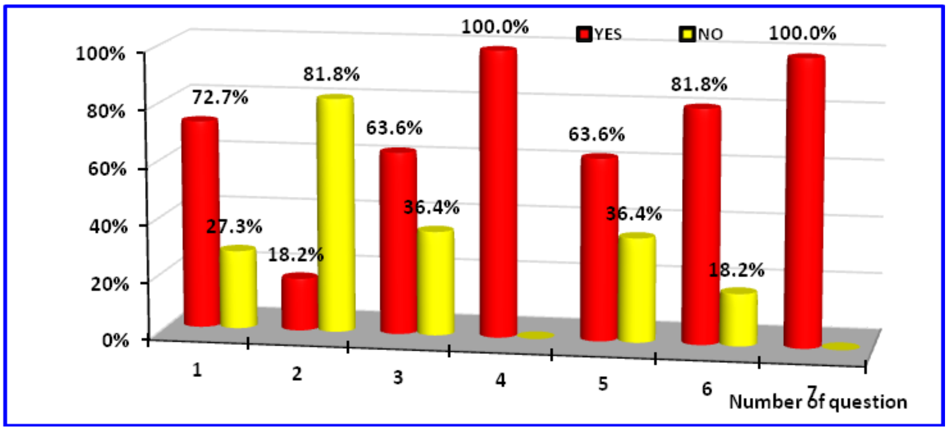

Fig. 8. Presentation of answers given to the questions concerning assessment of steering interface. Questions: 1. Time assigned for trial simulation was sufficient to learn the environment as well as the functioning of the steering elements of the overhead crane, 2. Learning how to operate the tool and how to use the virtual overhead crane was difficult, 3. After the trial simulation I could easily concentrate on performing the task during the basic simulation, without searching for steering elements of the tool, 4. After the beginning of the simulation I could easily realize who I am in the virtual environment and what my task is, 5. I needed little time to adapt to the interface of steering the virtual overhead crane, 6. Steering the overhead crane with the interface was intuitive, 7. Steering interface was easy to use.

Operating the simulator (carrying out an interactive simulation of the use of the virtual overhead crane simulator) is not extremely complicated and allows for its intuitive use. There are no difficulties while manipulating the elements of the overhead crane while picking up loads using the hook or electromagnetic device. During this simulation, accident situations were staged and, according to 81.8% of the participants, were very realistic. The occurrence of accidents depended on mistakes made by the operators of the virtual overhead crane. The participants claimed that personal participation in a given accident situation and its observation will reflect in an improvement of workers' understanding of accidents in the work place. Moreover, according to 90.9% of the participants, the interactive simulation fully involved their senses of sight and touch. The interaction with the environment was very good and caused no visible delays during the simulation. The interactive simulation of overhead crane use and actions performed during operation are in line with the professional experience of 72.7% of the test's participants. The majority of users indicated that they enjoyed the form of training using the overhead crane simulator (Fig. 9a), and 81% stated that it will be a good tool to complete traditional training of overhead crane operators (Fig. 9b).

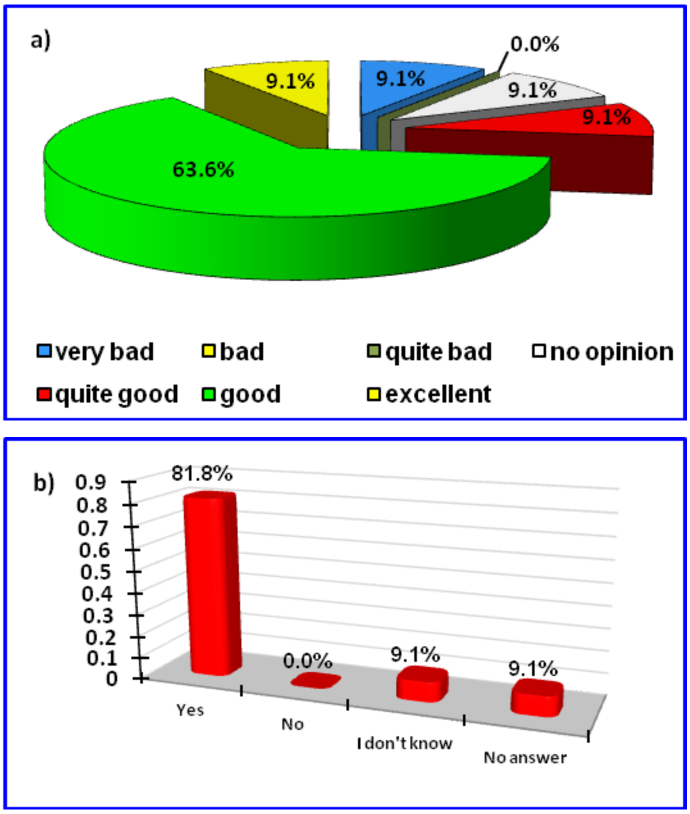

Fig. 9. Presentation of answers given to the questions concerning assessment of the form of training (a) and using the simulator in training of crane operators (b)

5. CONCLUSION

The simulator of the overhead crane, controlled by real panels, enables us to simulate typical work conditions in which the overhead crane operates. Using it for the training of overhead crane operators will enable them to directly learn about situations leading to accident situations during the use of the overhead crane as well as about consequences of their occurrence. In addition, such training will enable the creation of correct habits during manoeuvring loads in the work environment and shaping among the users correct behaviours concerning the use of overhead cranes. According to 69.7% of the participants of the conducted test, the knowledge acquired is useful and may be used in activities aimed at improving work safety at their enterprise as well as during training on occupational safety and health, e.g. during the presentation on overhead crane accident situations, which, for safety reasons, cannot be presented in real conditions.

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SYMULACJA WRAŻENIA DOTYKU NA PRZYKŁADZIE UŻYTKOWANIA SYMULATORA

Streszczenie

W artykule przedstawiono charakterystykę symulatora do interaktywnej symulacji procesu użytkowania wirtualnej suwnicy oraz wyniki z przeprowadzonych testów sprawdzających jego funkcjonalność w aspekcie symulacji wrażenia dotyku. Symulator wykonano w technice wirtualnej rzeczywistości VR i jest sterowany za pomocą dwóch rzeczywistych paneli sterowniczych. Tak opracowany symulator został użyty w testach z udziałem operatorów suwnic i instruktorów szkoleniowych. Test pozwolił ocenić przydatność wykonanego symulatora w szkoleniach przyszłych operatorów suwnic oraz w symulowaniu wrażenia dotyku. Wyniki przeprowadzonego szkolenia wskazują, że szkolenia z użyciem symulatora

suwnicy pozwolą na zwiększenie umiejętności praktycznych przyszłych operatorów, a także prezentowanie inscenizowanych zdarzeń wypadkowych, których ze względów bezpieczeństwa nie można prowadzić w warunkach rzeczywistych.