PhD dissertation on

Virtual reality techniques, relational databases and field techniques in the construction and use of machine simulators

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ABSTRACT

The analysis of the literature on the subject and the author's own experience unambiguously indicate the beneficial influence of the use of simulators on the quality and effects of training of machine users thanks to, among others, the possibility of extending their programmes by training of responses to potentially dangerous situations. Limitations to the use of simulators can be both the cost of purchasing them and the unavailability on the market of products tailored to specific programme requirements. The solution may then be to design and construct a simulator on their own and develop software to support the analysis of the effects of using it by trainees. This subject is addressed in this dissertation.

The dissertation provides general methodological guidance (supported by experience) allowing to follow the simulator construction process step by step, from the beginning of the project until its completion, and the development of a relational database and its application to enable the recording of data from the simulation processes and their subsequent analysis. The discussed indications are illustrated by the examples of solutions used in the development of overhead crane and lathe simulators, modifications to a lift truck simulator, and the creation of a relational model of the information structure associated with the training of machine operators using such simulators.

The methodological indications covered four main areas (stages) of building a simulator or application, i.e. organisation of work, design of the product, its execution, and verification of correct functioning. In the first, 'organisational' area, organisational and human resources are identified as well as the components of the implemented project in the context of the main objective assumed. Operations carried out at this stage also allow for a preliminary estimate of the cost of implementing individual tasks and the entire project. In the second, 'design' area, methods of performing individual tasks influencing project implementation are presented. At this stage, it is important to gather sufficient knowledge to properly design the simulation process scenario to cover the actual issues and problems associated with the operation of the machine. The knowledge gathered also makes it possible to formulate assumptions for the project and to define actions to be taken to achieve a satisfactory effect. In the third, 'execution' area, activities aimed at product development in accordance with the adopted assumptions and a specific scenario are presented. The fourth area involves the verification of the activities carried out, i.e. checking the finished product or the result of the implemented project in terms of compliance with the main objective. Following these methodological guidelines, a simulator of a gantry crane controlled from the cabin and a simulator of a combined lathe (lathe-milling-drilling machine), as well as a relational database and its application designed to support the analysis of training results were developed. The developed products underwent verification in terms of their functionality and usability by 71 participants.

The verification related to the crane simulator was aimed at determining which version – stationary or portable – has a greater impact on the realism of the simulation and which is a better tool to support the training of crane operators. Research has shown that operating the portable version, equipped with VR goggles, allows the simulation to feel more realistic than using the desktop version of the simulator, where the screens are arranged in SEMI-CAVE technology. This result was also corroborated when conducting usability evaluation of the simulator in both versions and in a pilot training conducted at a training centre outside the Central Institute for Labour Protection.

The verification of the lathe simulator was intended to compare two methods of simulating the sensation of touch, with the assistance of which interaction can be carried out with controls and with objects of the virtual reality environment. The first one enables virtual controls to be felt and operated with real controls, while the second allows virtual controls to be felt and operated in a virtual environment using a VR glove with force feedback, without the need for real controls. For this research, a VR glove was developed that allows users to feel the sensation of touching virtual objects (including virtual controls) while gripping and operating them in a virtual environment. The research conducted has shown that both methods provide a high degree of realism and precision in the simulation of the use of virtual machines, however in the opinion of the respondents participating in the research, the touch sensation simulation method using a VR glove with force feedback has a greater impact on the realism of simulating the operation of a virtual machine, including the operation of controls, also increasing the precision and reducing the time of performing control tasks on the simulator.

The dissertation also presents the results of the verification of the previously mentioned relational database and its application. The purpose of the verification was to verify the functionality and ability to support instructors supervising the training process using the simulator in the analysis of errors made by its participants. The verified application allows for the recording and storage of data from simulation processes carried out on the simulator, and their subsequent analysis in terms of comparison and evaluation of training processes in relation to different sessions performed by the user on the simulator. It also allows to obtain statistical information, e.g. in terms of the number of sessions carried out, the number of dangerous situations that occurred or mistakes made by users in individual or all training sessions in relation to sessions held at different times of the day, etc. The verification performed showed that the developed application is a functional and easy-to-use tool for storing information from the simulation process and conducting analysis of the collected data. It may also be a useful tool to support the work of the instructor supervising the training process conducted with the use of the simulator with respect to the analysis of mistakes made by trainees, or verification of their skills and progress in training.

The research has shown that simulators made on the basis of methodical guidance formulated in the dissertation, using the technique of virtual reality, are a good tool for supporting the training process, while the created relational database and its application allow for the introduction of additional elements of analysis, such as verification and evaluation of the conducted training processes, learning about the psychophysical characteristics of individual employees, or monitoring their progress. Nevertheless, it should be noted that currently simulators and computer applications can support the training process, extend its scope, but they cannot replace traditional training, related to the operation of the machine.