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Training Simulators for Crane Operators and Drivers

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ABSTRACT

The article deals with the use issues of modern information technology for training purposes. In particular, use of simulation modelling to create a learning environment as close as possible to the real working environment. This helps speed up learning, make more practical, learn theoretical issues directly when mastering practical skills, and make the learning process more attractive and interesting for students. Moreover, a virtual working environment can be used for advanced training of employees, to improve their professional skills, master new technologies, train them to work on new and modernized equipment, assess their professional level, restore skills after a long break in the work and pass qualification exams. Information technologies can significantly reduce the cost of material support for training and eliminate dependence on large areas for staff training. To create an interactive virtual learning environment, modern gaming technologies, software modelling or, at least, simulation modelling of physical processes in equipment and the interaction of all components of the working environment, including the actions of the student, are used. It also allows testing employees in extreme working conditions and testing their skills when dealing with non-standard and emergency situations, without any real danger to the health of students. The proposed solution can be used to train students and trainees, assess professional skills of those already working in the conditions of special training centers and professional retraining colleges.

KEYWORDS

Crane simulator, Training of crane operators and drivers, Loading and unloading operations.

1. INTRODUCTION

Information technology has become an integral part of modern society. In this regard, the modern education system faces the difficult task of preparing a new generation for the existence and professional activity in the global information society. The additional working profession that students obtain during their studies at the university, will not only allow them to gain practical skills necessary when mastering their main speciality, but will also make them feel more confident in the labour market, and will also increase the likelihood of employment after graduating [1-3]).

Many institutions face problems reducing the effectiveness of acquiring practical skills of students [4, 5]:

- universities often have limited opportunities to provide students with equipment, materials and other means using which the student will acquire practical skills, having learned theoretical knowledge;
- the volume of practical training allotted for mastering the disciplines becomes very limited, as a result, the transience of the laboratory work prevents students from comprehending the research carried out;

- laboratory works using full-scale installations are associated with corresponding operating costs, these are usually electricity costs, and some of these works are dangerous for the students.

Purely theoretical and virtual study of modern technology and production engineering cannot provide the required level of training. When using simulators, practical experience is formed (Fig. 1), which, along with knowledge and skills in the working profession, serves as the basis for studying special disciplines and forming the professional competence of future bachelors [4, 6].

Figure 1: Training simulators for locomotive drivers, Ukrainian State University of Science and Technologies, Department of EDSD MBCSS

When working on a simulator designed in accordance with modern technical requirements, the student, using existing knowledge, gains experience very close to working in real conditions, and at the same time, the process of clarifying and consolidating his theoretical knowledge is underway. It is important that when performing the tasks set by the instructor based on practical experience and real operating conditions, students have to be creative. As a result, not only the skills of working with equipment or a habit of actions according to the necessary algorithm is formed, but also logical and imaginative thinking, the ability to solve non-trivial problems based on the learned theoretical information is developed. Thus, when working on simulators, the processes of obtaining practical and theoretical knowledge come as close as possible. Training technologies activate the student's cognitive processes without limiting their freedom of action in finding the right solution [7-9].

The following advantages of using simulators (even compared to working on real laboratory benches) can be noted:

- intensification of learning without losing the quality of mastering the material;
- the possibility of conducting laboratory works by the frontal method (all students perform one work simultaneously), which significantly increases the effectiveness of this type of training;
- the possibility of a wide change in the conditions of the experiment;
- the possibility of simulating and safe study of extreme and emergency modes of equipment operation;
- the possibility of relatively easy and quick modification of elements of the equipment under study to the latest industrial designs;
- substantial energy saving compared to the use of real laboratory stands, saving of training areas, reduction of capital, operating and other costs are provided.

The most effective way of learning is through practical exercises performed by a specialist (operator or crane driver) in the presence of colleagues. This method makes each specialist consciously participate in the learning process, so the material that is planned for study is learned better. If one of the participants is unsure in his/her knowledge or makes technical errors in solving the task, as directed by the instructor, other participants are engaged in the class [4, 5, 10].

Thus, it is the task of mastering practical skills that is one of the most difficult tasks in the process of education and training of specialists. Due to the rapid development of computer and information technology, it became possible to solve this problem through the use of multimedia training simulators or modelling tools.

2. ANALYSIS OF THE LATEST RESEARCH

The process of training operators and drivers of special equipment takes a fairly long period of time and requires considerable financial costs. The development of computer technology and related technologies makes it possible to create modern interactive learning tools. In the field of training operators and drivers of special equipment, such tools include training simulators. Such simulators can be made for any types of special equipment and for any real industrial enterprises where operators will work after training. In addition, the use of simulators will allow simulating various abnormal and even emergency situations that may occur in real working conditions. This will teach operators to make quick and correct decisions to avoid serious consequences in a real situation. This aspect of the use of simulators cannot be overestimated because in real conditions it is impossible to create such situations intentionally. Moreover, the use of simulators will significantly reduce the training time for future specialists by intensifying the training process, which will reduce the cost of training.

Although the virtual environment is widely used when designing, planning and training in many industries, its benefits in training operators of handling equipment at the operational level have yet to be explored. Simulating the crane vibration and the sensation of vibration in the crane simulation system increases the user's interactivity level, so that users feel like they are operating a real crane [11].

Training using a virtual reality overhead crane simulator may be of more value in simulating some of the cognitive load (adequate load on working memory) required during training to perform crane operations in various types of noise [12, 13].

Virtual reality overhead crane simulators are used to investigate some critical aspects of heavy load handling in industrial environments. Studies of the effects of various industrial noise on overhead crane operators and their physiological responses have shown that noise influences the tilting maneuvers and excessive vibrations. High-frequency noise is the worst condition for maneuvering and affects heart rate changes, and the highest increments occur under the influence of modulated noise [14].

Virtual crane simulators are widely used to teach and demonstrate swinging suppression skills. The work of Sasaki [15] describes a ship crane simulator developed using a rotary crane model. Active Joystick is developed as a working interface for the simulator, representing the ideal work with joystick information. Using the crane simulator, the operator can acquire the skills needed to suppress load swinging by experimenting with sway angles [16].

The study by Zemánek[17] tested the method of boom ends control in forwarders. Intelligent Boom Control (IBC) only partially improves forwarder operator's productivity over standard hydraulic crane control. The obtained results justify this statement only with the operators without training. The work productivity increase of more than 25% occurred in the beginning of operators using the IBC system thanks to the increased number of simultaneous hydraulic crane movements and to a more appropriate choice of the end part track of the hydraulic crane.

The research of crawler cranes operating with full load in order to determine the risk of overturning is presented in the work by Doci[18]. Boom motion of crawler cranes is accompanied by heavy oscillations caused by the load swinging, which pass to the boom and other parts of the crane. This phenomenon can create problems with stability, load drop and crane overturning. The main focus is the study of dynamic stability, overturning moment and forces in some parts of the crane.

The mobile jib crane is one of the most widely used types of construction equipment. However, over the past decade, the number of accidents, including casualties and deaths, has increased. Mobile cranes overturn due to excessive loads, strong winds, or lack of proper ground pressure [19-21]. The mobile crane overturning stability test is divided into the following steps: lifting conditions test, mobile crane selection, and ground contact stability test. Preventing accidents involving crane overturning offers significant benefits in terms of protecting the lives of operators and reducing the risk of damage. To reduce such cases a dynamic simulator of mobile cranes based on the overturn limit data [21], automatic design algorithms for ground stability of mobile cranes [18, 22], a monitoring system that can predict the moment of overturning and send a warning signal [23] have been developed.

An experimental method to study the behaviour of tower cranes in strong winds exposed to disturbed shear flow induced by the surrounding buildings has been proposed in the work of Voisina[24]. Wind tunnel tests on a tower crane model are described.

3. DESCRIPTION OF THE SIMULATORS FOR TRAINING OF OPERATORS AND DRIVERS OF CRANES

A paper should contain title, names and affiliations of authors, abstract, list of keywords, paper body, acknowledgement and references.

The simulator is designed to train operators and drivers of special equipment (handling equipment, tractors, bulldozers, excavators, front loaders, cranes, mining dump trucks, drilling machines, etc.) to perform routine maintenance in compliance with the safety requirements and actions in non-standard and emergency situations, that may arise in real work [4, 25, 26].

The simulator is used for the following purposes:

- Initial training of young professionals. Familiarization with the management and control elements and the procedure for preparing special equipment for work.
- Training to control mechanisms and machines during operation.
- Training how to act in abnormal and emergency situations that may occur in real work. This unique feature of the simulator will allow operators to develop the skills of quick and correct actions to avoid serious consequences during the real work.
- Learning to interact with other process-related equipment operators.
- Assessing the qualification level of operators after the long breaks in work.
- Training of operators to control modernized or new types of machines and mechanisms.

The surrounding panorama of the real operation site of special handling equipment (Fig. 2) is reproduced on the basis of modern 3D virtual modelling tools, supplemented by an audio system designed for audio support, which increases reliability and brings the learning environment as close as possible to the real working environment [5, 8, 27].

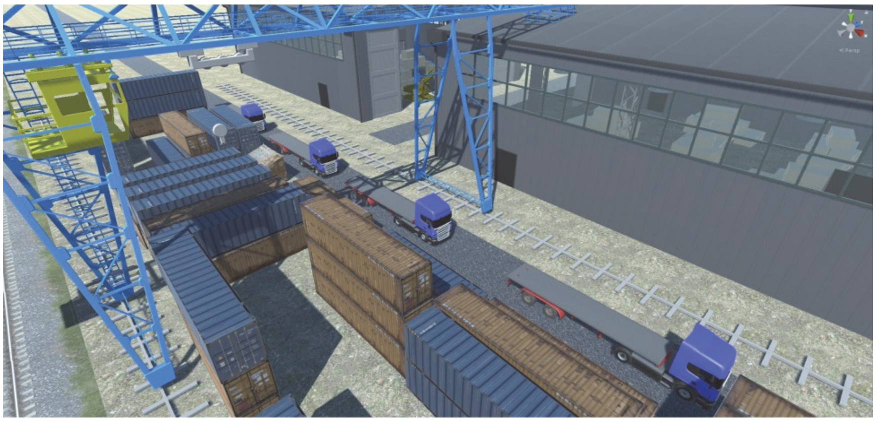

Figure 2: General view of the 3D panorama of the simulator

The simulator allows professionals to train in a virtual environment based on real physical models and real equipment (Fig. 3).

Figure 3: General view of the 3D panorama of the simulator during unloading operations

This includes:

- bending/twisting the crane boom;
- stability and risks of overload/overturn;
- encounter with obstacles on the working site and crane boom;
- vertical and horizontal load swinging, which is realized due to the simulation of the load suspension system operation close to the real.

The simulator consists of an operator's workplace equipped with a computer, where a panorama of the real working environment is displayed (Fig. 4). At the request of the customer, the workplace of the operator or driver can be placed on a moving platform designed to simulate vibrations close to the operational ones. The crane vibration simulation and vibration sensation in the crane simulation system increases the level of user interactivity so that users feel like they are operating a real crane. The simulator is made for a real enterprise and for a specific model of special equipment, and it can also be configured to work with software for simulating the operation of mobile, tower cranes or lattice boom cranes [28-30].

The simulator can be equipped with a second display mounted below the main display for tower crane configurations (Fig. 5). The second display can be reconfigured to switch between mobile and tower mode.

Figure 4: General view of the overhead and gantry crane simulator

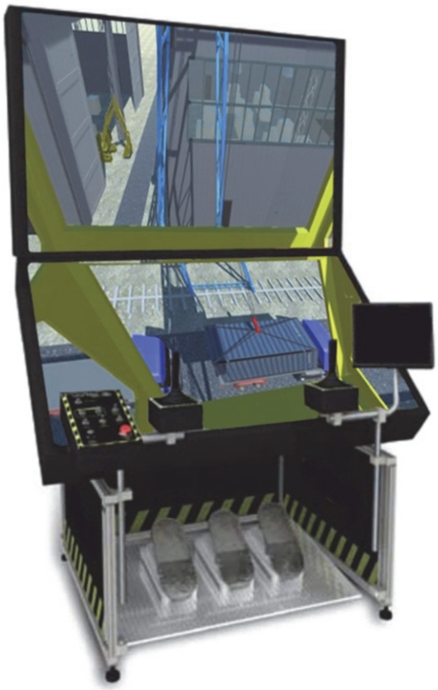

Figure 5: General view of the tower crane simulator

Each module of the training complex is designed for visual and interactive work with the student and assessment of his/her qualifications. The simulator curriculum contains a sequence of tasks that start out simple and then progress to more complex ones. They provide an opportunity for periodic knowledge checks during the training period and certification of the operator upon completion of training [4, 5].

Upon completion of work on the simulator, the results are being formed and stored in the database of each operator for further analysis and determination of the student's training level.

This gives instructors the opportunity to evaluate specialists after each use of the simulator in order to achieve their training goals faster:

- the assigned task is completed and completed at the scheduled time;
- time spent in load swinging;
- collision of the load or a crane hook with the equipment of the operation site;
- rough handling;
- dragging the load and pulling the sling from under the load, while the load is on the sling;
- time spent in a state of prolonged reflection (anxiety);
- contact with power lines (if any).

All simulators are manufactured according to the specific wishes of customers and are supplied with the operating instructions and methodological materials for their use for the real needs of the customer. In addition, classrooms or remote classrooms for online learning can be made on the basis of student workplaces.

4. CONCLUSIONS

Due to the obvious advantages of using simulators, their application field is constantly expanding. Today, they are common in the places where training on a real system or object is accompanied by the serious technical difficulties or serious material costs. Thus, the more virtual models correspond to real objects, the better the simulator contributes to the assimilation of material and the acquisition of practical experience. The use of such training complexes will reduce the purchase value of classrooms and the cost of their maintenance and service.

The presence of simulators in higher educational institutions will allow not only research and development work, but also create conditions that provide advanced socialization, self-determination and professionalization of future specialists at manufacturing enterprises.

The described approach to training crane operators and drivers will make it possible to use individual training or training in small groups of 2-3 people. This, in turn, will provide an opportunity to increase the number of hours of practical training for each student and increase the capacity of training centres. Such a complex will also be indispensable during the study of theoretical issues related to the arrangement of operated, modernized and new equipment. In this case, the student will have the opportunity to combine the study of theoretical issues with the practical application of the acquired knowledge. In addition, there is the possibility of simulating non-standard and emergency situations and training personnel to act in such conditions without real danger to their health and life. A virtual environment that is as close as possible to real operating conditions will help acquire and improve practical skills of orientation in the working environment, which will reduce the adaptation time when starting a real work. Another important advantage of training complexes is the ability to use them to assess the qualifications of specialists after a long break in work, or to decide whether the qualifications of an operator or driver correspond to the specifics of work in certain conditions.

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