Increased of Efficiency in the Automated Training of Fuelling Machine Operators Using Iterative Simulation Learning

Rustam Abubakirovich Fayzrakhmanov and Ivan Sergeyevich Polevshchikov

Department of Information Technologies and Computer-Based Systems, Perm National Research Polytechnic University, Perm, Russia

Abstract: This article is to consider the current problem of training of fuelling machine operator. One of the most important features related to the training of fuelling machine operators is an objective assessment of learner learning skills during the learning and the formation of the control actions to improve the efficiency of the learning process using assessment results. The disadvantages of existing approaches to training of fuelling machine operators were identified: traditional teaching methods, using of electronic simulators and computer simulators. The principle of mathematical models of iterative learning in relation to training on computer simulators of fuelling machines was demonstrated. The principles of adaptive management of a process of the training task accomplishing by learner was formalized. An algorithm for management of the learning by learner taking into account the possibility of the learning process managing by the instructor has been developed. The practical significance of this study consists in the fact that the study results were applied to the creation of a computer simulator of specific fuelling machine developed within the framework of scientific-research project no. 2010/293 on August 19, 2010 by Department of Information Technologies and Computer-Based Systems, Perm National Research Polytechnic University for OAO “Motovilikhinskiye zavody” (Perm, Russia) and possibility of implementation to creation of a computer simulator of gantry crane within the scientific-research project of the research Department of Information Technologies and Computer-Based Systems.

Key words: Fuelling machine • A computer simulator • Interactive learning • Adaptive control • The absorption coefficient

INTRODUCTION

The Problem of Training of Fuelling Machine Operators:
The problem of training of fuelling machine operators is relevant because this work is significantly time-consuming and related to the motion of loads and essential in many sectors of the Russian economy [1].

One of the most important features related to the training of fuelling machine operators is an objective assessment of the level of abilities and skills of learner during exercise [2], as well as the formation the control actions to improve the efficiency of the learning process based on the assessment results.

The traditional training method of fuelling machine operators is practical tasks on the real equipment. This method of learning has a number of disadvantages like an absence of objective estimation of abilities and skills of learner. During the training, the instructor subjectively assesses the quality of the exercise based on his own professional experience and provides the instructions to the learner. The instructor can use only simple measuring instruments (such as a stopwatch and a ruler) or some parts of equipment.

In order to eliminate the significant disadvantages of traditional training of fuelling machine operators, the researchers of the Department of Computer Technology and Automated Control of the Perm Polytechnic Institute (now the Department of Information Technologies and Computer-Based Systems (DITAS) of Perm National Research Polytechnic University (PNRPU)) in 1971 began the research work aimed to create the electronic simulators for crane-operator. An important advantage of training on electronic simulators compared with traditional training methods was an ability to use some objective measures of learning quality (such as the time of the task learning, the accuracy of the load installation, etc.) assessing the

Corresponding Author: I.S. Polevshchikov, Department of Information Technologies and Computer-Based Systems, Perm National Research Polytechnic University, Komsomolskiy prospekt 29, Perm, 614990 Russia.
abilities and skills of the learners [3]. However, it was very difficult to implement complex data delivery of learner’s performance on the simulator using facilities and equipment existed in 1971.

In present, due to the widespread of personal computers related with their low cost and extended possibilities, scientific-research work to create a new class of simulators for fuelling machine operators – computer simulators are performed at the DITAS (PNRPU).

The questions of mathematical modeling of physical processes [4], 3D-modeling [5], the hardware development [6], testing of learners’ knowledge [7] were considered in details within performed scientific-research work. The type of quality indicators used by learners performing the tests on computer fuelling machine simulators and possibility of assessment of the current level of learned skills by learners has also been investigated [8]. In study [2], we have considered some features of adaptive control of learning process using the computer simulator in terms of professional pedagogy, however, there were no proposals for a formalized representation of these data. The experience of abilities and skill assessment in professional training presented in studies [9-17] was investigated.

Thus, the question of required actions to improve the efficiency of the learning process using the data on current level of learning of knowledge by learner remains unsolved.

Using an Iterative Learning Models: The study [8] demonstrates the use of the fuzzy-set theory to determine the key indicators of the quality of performed tasks included into exercise (the time of task performance, the accuracy of the load installation, etc.) based on single parameters, absorption coefficient, which is a comprehensive estimate of exercise performance.

However, it is known that the formation of skills of the learner at the required level requires the repeated performance of exercise in strictly repetitive conditions. This process, called iterative learning is described in details in the study of D.A. Novikov, the corresponding member of the Russian Academy of Sciences [18]. Absorption coefficient proposed in study [8] does not reflect the characteristics of the iterative learning process, which can improve the efficiency of the learning process by their control.

Due to the constancy of external conditions, it is possible to qualitative description of the iterative learning as the dependence of the absorption coefficient on the number of attempts to perform the exercise. These dependencies are the learning curves and approximated by the exponential curves [18].

We introduce some clarifications. The results of study [8] allocate the following types of absorption coefficient:

- Absorption coefficient of particular quality parameter during performance of the specific learning task;
- Absorption coefficient a particular learning task;
- Absorption coefficient a particular exercise.

To describe the changes of absorption coefficient of any of these types in the course of multiple performance of any exercise by particular learner and relying on existing mathematical models of iterative learning [18], we used the following dependence:

\[ K = 1 - e^{-\gamma n}, \]  

where \( n \) – the number of attempts to perform the exercise from the learning begin; \( K \) – absorption coefficient after performed exercise by \( n \) times; \( \gamma \) – the speed of learning, i.e. the rate of change of the learning curve, which is non-negative constant.

The speed of learning is individual for each learner and reflects the performing of a particular exercise by particular learner. The variable of learning speed depends on numerous factors: complexity and properties of a learning system (i.e. the learner), external environment, learning method, etc. [18].

This simple dependence (1) reflects only general tendency of the learning process, but due to weak formalizability of management of learning process on a computer simulator, this dependence is significantly convenient.

The experts can determine the necessary number of attempts to perform the any exercises. For example, the study [2] indicates approximately 5-10 attempts during learning process of crane-operator of gantry crane.

We introduced the following definitions:

- Total absorption coefficient is the value of coefficient of exercise absorption in general or specific learning task or single quality indicator that must be achieved in the time of transition to the next exercise and determined by experts.
• Intermediate absorption coefficient is the value of coefficient of exercise absorption in general or specific learning task or single quality indicator that must be achieved after performance of exercise by \( n \) times.

Knowing the number of attempts recommended by the experts and Total absorption coefficient using a formula (1), the required learning speed can be calculated as following:

\[
\gamma_{req} = \frac{\ln(1 - K_{total})}{n_{rec}}
\]

(2)

where \( \gamma_{req} \) – required learning speed; \( K_{total} \) – the total value of the absorption coefficient; \( n_{rec} \) – recommended number of attempts to exercise performance.

Then, calculated speed of learning using formula (2) was used for determination of direct intermediate absorption coefficient:

\[
K_{int} = 1 - e^{-\gamma_{req} n}
\]

(3)

where \( K_{int} \) – intermediate value of the coefficient of absorption; \( \gamma_{req} \) – required speed of learning; \( n \) – number of attempts of exercise performance by learner.

Adaptative Management of the Learning Task Performance: As mentioned above, some features of an adaptative management of learning process on computer simulator from pedagogical point of view were indicated in [2].

It should be noted that providing of prompts to learner is important element of adaptative management of learning process. There are types of prompts during task performing and after. Using the results presented in study [2], we can conclude that the prompts should appear in the beginning of task learning (usually at the time of any error) and then, with the gradual absorption of exercise, only after performed task and showed educational videos.

This requirement provides the motivation of the learner for quick skill development and self-control of the quality of their work. In the fact, the prompts during computer simulator trainings are managing effects. We have several suggestions to formalize this requirement

Some learners before the first particular test performance, before each learning task, the learner watch the educational video demonstrating the right performance of a task.

During task performance, the learner obtain the prompts – signals of any modality (tactile, audio, visual) [2] in real time about the moments of the motor actions in accordance with the algorithm of optimal control of any device of fuelling machine (for instance, a crane) that should be considered by learner as a command to task performance. There are few types of the prompts, for example:

• Arrows on the screen show the direction of the crane motion;
• Highlighting of some buttons and levers on the control panels;
• Audio and visual signals on emergency situations (for example, a collision of any transported cargo with any parts of fuelling machine); and etc.

During task performance, the appearance of any prompt will occur only if the absorption coefficient of quality indicator corresponding to this prompt is less than the intermediate:

\[
Pods_{qlt.ind} = \begin{cases} 
0, & \text{if } K_{qlt.ind} \geq K_{int}. \\
1, & \text{if } K_{qlt.ind} < K_{int}. 
\end{cases}
\]

(4)

where \( PODs_{qlt.ind} \) – variable that takes the value 0 or 1 depending on the presence or absence of prompt corresponding to a particular quality index; \( K_{qlt.ind} \) – achieved by absorption coefficient of quality indicator; \( K_{int} \) – intermediate value of the absorption coefficient of quality indicator calculated by the formula (3).

The proposed formula (4) corresponds to the requirement of early learning of task by learner, the prompts must appear during task performance [2]. Thus, the prompts during task performance will appear if the absorption coefficient of quality indicator does not correspond to the intermediate level.

After the task performance, the learner watches a video fragment containing a repeat of the learner’s task performance with indication of the errors, i.e. the prompts. The duration of the video fragment must be extended proportionally to the absorption coefficient of the learning task (i.e. the learner’s task performance is worse the video fragment is slowed):

\[
Y = \begin{cases} 
0, & \text{if } K_{learn.task} \geq K_{total}. \\
(2 - K_{learn.task}K_{norm}), & \text{if } K_{learn.task} < K_{total}. 
\end{cases}
\]

(5)
where $K_{\text{total}}$ – absorption coefficient of learning task achieved by the learner; $K_{\text{ind}}$ – the total value of the absorption coefficient; $T_{\text{norm}}$ – duration of video fragment shown before first task performance.

The prompts appearing during video fragment demonstration are provided to the learner according to following principle:

$$Pods_{\text{qlt.ind.}} = \begin{cases} 0, & \text{if } K_{\text{qlt.ind.}} \geq K_{\text{total}} \\ 1, & \text{if } K_{\text{qlt.ind.}} < K_{\text{total}} \end{cases}$$

(6)

where $Pods_{\text{qlt.ind.}}$ – variable that takes the value 0 or 1 depending on the presence or absence of prompt corresponding to certain quality indicator; $K_{\text{qlt.ind.}}$ – achieved by absorption coefficient of quality indicator; $K_{\text{total}}$ – the total value of the absorption coefficient.

The proposed formula (6) corresponds to the requirement that the prompts should appear only after the task performance during video fragment demonstration [2] with gradual learning of the task. Prompts during the educational video demonstration will be available if the total absorption coefficient does not correspond to recommend by the experts.

Thus, the principles of the prompt appearance listed above, ensure the motivation of the learner for fast training of skills of self-control of the quality of own work, formation of internal model of actions performed in real conditions [2]. This is stipulated by the fact that the learner will not receive the prompts in real conditions and he must control his actions by himself.

The Algorithm of Management of the Learning Skill Acquisition by Learner: Summarizing the results obtained above, we have composed the algorithm of management of the learning skill acquisition by a learner during certain task performance on a computer simulator (Fig. 1).

The blocks learned a skill at the required level and The instructor general control actions require separate explanation. Management of learning process is largely determined by the instructor on these steps. We have introduced the following designations: $K_{\text{learn}}$ – the current absorption coefficient of exercise, $K_{\text{total}}$ – total absorption coefficient of exercises and $K_{\text{int}}$ – intermediate absorption coefficient of exercise. In this case, the following variants are possible:

- $K_{\text{learn}} \geq K_{\text{total}}$. If this result is confirmed by the after several times exercise performance (i.e. if appropriate skill is formed) then the exercise can be considered as acquired and a learner performs next exercise.

CONCLUSION

Thus, the following tasks of the learning process were solved in the present study:
Shortcomings of existing approaches to training of fuelling machine operators were highlighted.

The principle of implementation of mathematical models of iterative learning applied to the training on computer simulators of the fuelling machines is shown.

The principles of adaptive management of exercise performance process by learner were formalized.

An algorithm of management of the skill learning process taking into account the possibility of managing of the learning process by the instructor is developed.

The practical significance of this study consists in the fact that the study results were applied to the creation of a computer simulator of specific fuelling machine developed within the framework of scientific-research project no. 2010/293 on August 19, 2010 by Department of Information Technologies and Computer-Based Systems, Perm National Research Polytechnic University for OAO “Motovilikhinskiye zavody” (Perm, Russia) and possibility of implementation to creation of a computer simulator of gantry crane within the scientific-research project of the research Department of Information technologies and computer-based systems.

Acknowledgments

This work was financially supported by the Ministry of Education and Science, Russian Federation (contract no. 13.G25.31.0093) within the framework of Russian Federation Government resolution no. 218 “On measures of state support for the development of cooperation in Russian higher education institutions and organizations implementing complex projects on high-tech production”.

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