Structure synthesis of visualization system for the adaptive training complexes

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Abstract. Classification of the problems that can be solved as a result of development of adaptive training complexes, components and technologies in the system of visualization is proposed. A problem formulation of the structure synthesis for visualization system of adaptive training complex is offered implying the possibility of solution of maximum number of the training problems. A scheme of connections is developed between the problems and technologies, concretization of the visualization components that allow solving of a certain set of tasks.

1. Introduction

Nowadays time-adaptive training complexes (ATC) are actively applied for the study of the staff in the sectors with high risks where significance of the human factor is especially high, where it is impossible to study at the really operating objects: transport, defense-industrial sector, missions on the eliminations of emergency situations, in medicine, in the power engineering and in similar areas [1, 2].

However, the requirements to the quality of visualization in each sphere of ATC applications are considerably different. In a number of sectors an accuracy of reproduction of the real processes should be maximal thus laying high claims to the hardware and software of the visualization system.

In this work the links between the problems solved during the training and components of visualization ATC system are studied that are used for solution of these tasks. The problem of structure synthesis for the system of ATC visualization is stated formalizing dependences between the functional requirements to the training simulator and the capabilities of its components. To solve this problem it is proposed to realize the scheme of correspondence between the problems of learning and the components of visualization system.

2. Analysis of the subject domain

Let us introduce some refinements for the terms and ideas applied in this subject domain.

ATC is a technical facility for training of the user intended for the formation of certain knowledge, skills and practices. With the use of this facility the system “man-computer” is realized just as its interaction both with a direct subject of the control and with the external factors. Thus, ATC term should satisfy the following criteria [1]:

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1) this model of the real system is in the basis of training simulator and to control this system it is required to have a human-operator;

2) this artificial environment follows strictly educational aims: first of all it is directed at the formation of the professional competences;

3) training simulator includes the components of visualization system for the interaction with the user or with an instructor.

Visualization system of ATC is a set of software and hardware components intended for the presentation of the studied object in the ergative system (or a system as a whole) in the form usable as for user’s perception as for the interaction of the user with ATC [2].

Taking into account of these latter specifications classification of the main problems was developed which can be solved using the developed ATC:

1) Theoretical training. It is realized, as a rule, in the form of interactive application with simple elements of interaction (manuals on assembly of a certain unit in the manufacture process, training of the operator of the chemical production for the management of industrial control).

2) Formation of gross and fine motor skills. The ability to handle various mobile technical means (combines, tanks, airplanes) can be related to the gross motor skills. Manipulations with specific tools (electrode holder of the welding unit, surgical scalpel) are related to the fine motor skills.

3) Psychological training. Training simulator imitates certain stressful situations while arising of contingency situations.

4) Physical training. Simulation of unusual physical impacts on the human (hydraulic imitation of zero gravity for the preparations of cosmonauts for a work in the outer space) [3].

5) Ability to orient oneself within the environment of the simulated system. The main task of visualization system is the implementation of the ability of free movement and free actions of the learning person in the simulated system.

Let us focus in more details on the visualization system. It includes a number of components and technologies of their operation. Different hardware tools are related to the components, which interact with the systems of input and output information of ATC:

- systems of motions tracking which make it possible to determine position of the head, eyes or hands of a man using gyroscopic or infrared sensors, special suites, gloves and so on;

- different game controllers allowing for attainment of more easy-to-use and realistic interaction with the simulated system (joysticks, alternate doublets of the control units for automobiles, airplanes and so on);

1) conventional systems for the output of graphical information such as monitors or projectors. In some cases, this function can be executed by smartphone display;

2) conventional systems for the input: keyboard and computer mouse;

3) functional units allowing to control construction and mode parameters of the simulated object, completely realizing the functions and parameters of the original, for example, a complete analogue of the control panel board for the technical system;

4) systems for creation of the physical impacts providing acquisition of additional skills such as adaptation to physical exercises, muscle memory;

5) units for the direct realization of visualization technologies (headsets and rooms of reality (VR), glasses of augmented reality (AR) and mixed (MR) reality;

6) simulators of specialized tools – different means of the imitation of the instruments for the development of fine motor skills.

Thus, the components of visualization systems realize the process of mapping for different modes of operation and parameters of ergative systems for vocational allocation in ATC in accordance with the chosen models and algorithms using the impact on the sense organs of a human with the use of different means for the information output. To implement software of the system various means for creating of 2D and 3D graphics are employed, for example, widely used development tools and graphics platforms of Unity3D, DirectX, UnrealEngine, OpenGL and some others [4].
3. Problem definition
It is necessary to find a set $C$ of the components in the visualization system and a set of technologies for their implementation providing possibility of solving for the maximal number of of the learning tasks stated before the training complexes:

$$f (C, T) = Z \rightarrow \text{max}$$
where $f$ is a function realizing the choice of components and visualization technologies and determination of the list of tasks solved with their use; $T = \{ t_j \}$ – set of visualization technologies; $t_j = \{ f_{ajm} \}$ – certain technology; $f_{ajm}$ – certain functional capability; $Z = \{ z_i \}$ – set of problems; $z_i = \{ ft_{in} \}$ – certain problem of learning; $ft_{in}$ – one of the functional requirements to ATC.

The main links between the tasks and technologies can be formalized as a set

$$R^1 = \{ r_{ij}^1 | z_i \rightarrow t_j \}$$

i.e. each of the functional requirements $\{ ft_{in} \}$ in each of the task $z_i$ corresponds to one of the functional capabilities $\{ f_{ajm} \}$ of technology $t_j$. To solve the task $z_i$ it is required that the intersection of sets $\{ ft_{in} \}$ and $\{ f_{ajm} \}$ should be maximal one.

Concretization of the visualization components allowing to solve a set of tasks $Z$ is convenient to be represented in the form of a set

$$R^2 = \{ r_{jk}^2 | t_i \rightarrow c_k \}$$

characterizing the links between visualization technologies and certain examples of their implementation in the form of components.

Figure 1 represents component connection scheme of $R^1$, $R^2$ type for some set of tasks, technologies and visualization components. Consider an example of formalization of connections with this scheme: it is required to find a set of components of the visualization system for the training of the welder. The main tasks $z_i$ in this case are development of the fine motor skills and necessity of tactile contact of the trainee with the instrument. This set of the problems is compatible with a set if requirements to the technology $\{ ft_{in} \}$, which can be satisfied applying the capabilities $\{ f_{ajm} \}$: heal system imitator and VR technology (link $R^1$). Concretization of the aggregate components can be presented by the link $R^2$: the best component $c_k$ is an imitator of specialized instrument.

4. Conclusion

Statement of the problem of the structure synthesis for visualization system of ATC allows you preliminarily, at the design stage, to predict its training capabilities, determine cost characteristics and formulate the requirements to the algorithm for structure-parametric synthesis of visualization system, which includes the following stages [5]:

1) formalization of the structure for visualization system basin on classification of the components;
2) the choice of visualization technology with the account of a set of required competences;
3) technique for the components assessment for their choice by reduction of a set of possible alternatives;
4) optimization of structure and parameters for visualization system.

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