Models of the Dialogue "Human - Computer" for Ergonomic Support of E-Learning

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***Abstract*—The article deals with the processes of human-computer interaction in e-learning. It demonstrates the necessity of taking into account the human factor in the organization of learning processes, using information systems. The principles of the description of interactive dialogue using the apparatus of functional networks are justified. Models of typical dialogue structures were built**

Keywords— Ergonomics, human-operator, e-learning, an algorithm of activity, self-control, optimization of activities.

I. Introduction

Last years have been associated with a fundamental change in the education system both for children and adults [1-3]. E-learning, distance learning, and blended learning are widely introduced [4-7] using both computers and a wide variety of mobile devices [3-7]. The information environment of modern universities and firms allows for continuous access to information training resources [1-7]. However, despite the obvious successes of e-learning, there are significant problems related to the consideration of the “human factor” and the adaptation of automated systems to human characteristics [8-13].

The main problem tasks of e-learning are [10-13]:

- organization of intelligent interfaces,
- construction of the convenient dialogue interaction between a man and an information system.

From the earliest times of using computers, scientists have tried to simulate the dialogue "human-computer" [9, 12-16].

Modeling and optimization of dialogue systems have become in fact one of the central tasks of cybernetics and ergonomics [14-16]. Unfortunately, most of these developments are unsuitable for predicting possible outcomes for on-line interaction on the basis of objective quantitative indicators, considering reliability of both a human and a computer.

The solution of the central task of the “HUMAN-COMPUTER” interaction problem – designing an effective dialogue based on quantitative indicators – became possible after the creation of a unified methodology for modeling human-machine systems (HMS). Anatoly Gubinsky's functional-structural theory of ergotechnical systems (FST ETS) has become such a methodology [17-19].

A generalized structural method (GSM), which became the core of the FST ETS, from unified methodological positions, allowed creating a language that could be described in a single model:

- machine operation,
- the activity of a human-operator.

Such a model allowed solving the following tasks, arising during the development and improvement of the HMS:

- description of the processes of human-machine interaction,
- performance evaluation,
- optimizing HMS.

At the same time, specific factors of the working environment, information model, parameters of technical equipment and a person are taken into account.

The presence of such a model has caused great interest in its possible use for modeling interactive systems. Many studies within the framework of the FST ETS are devoted to such research, for example [18-25]. However, these studies were carried out mainly in relation to the systems of automated control and information processing.

The observed today “booming interest in e-leaning”, the problems of intelligent agents to manage ergonomics of a dialogue [10, 11, 20], and the need to improve adaptation mechanisms put the task of the development of dialogue models in e-leaning on the nowadays agenda.

Thereby, it is necessary:

- to study the possibility of using approved (in systems of technological type) apparatus for modeling human-machine interaction to manage complex interaction processes in e-learning,
- to develop a theory of dialogue modeling, taking into account all the features of e-learning.

II. Statement of the Task

The tasks of the research are:

1. Analyze the specifics and features of the dialogue in modern progressive systems in e-leaning.

2. Evaluate the possibility of using existing models of the FST ETS to simulate a dialogue.

3. Identify the elements of the dialogue, which models need to be improved.

4. Suggest an approach to the description of the identified structures of the dialogue characteristic of modern e-leaning systems.

5. If necessary, supplement the FST ETS model library with new typical functional structures (TFS).

6. Check in practice the applicability of the developed models for dialogue description.

III. Results

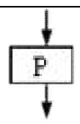
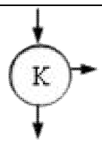
A. Principle of the Description of Human-Computer Interaction in E-Learning

The FTS ETS [17-19] proposed a number of typical functional elements (TFE) to describe the activities of the operator:

- starters,
- finishers,
- working operations,
- control operations,
- diagnostic operations.
- alternative,
- and others.

A full description, designation and TFE models are given in [17,18]. Our experience of simulating conversational interaction in e-leaning proves the possibility and efficiency of using these "building blocks" for most of the research tasks of modular learning systems [20]. With a modular approach to learning, the educational material is divided into separate blocks-modules. Modules can be either informational or controlling (Table I).

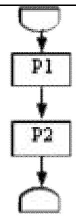
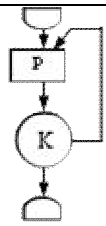
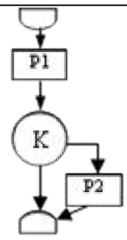
TABLE I. TYPICAL ELEMENTS OF EDUCATIONAL ACTIVITIES

Dialogue element	Type of TFE (by [17, 18])	Designation of TFE (by [17, 18])
Work on the training module	Working	
Self-monitoring of learning outcomes	Functional control	

When undergoing the information module, a certain amount of knowledge is absorbed. With the undergoing of the control module, the quality level of acquired knowledge is determined. Depending on the chosen learning strategy, the structure of the student's activity may differ, when studying the material.

The learning process is carried out, as a rule, as follows: A person is presented with a certain portion of learning information (LI). To determine the quality of assimilation of a portion of LI, he exercises self-control. According to self-control results, the subsequent action in the system is determined. In the simplest case, the elements of such activity are described with the help of TFS, known from FST ETS [17, 18]. Some examples are given in Table II.

TABLE II. SOME TFS AND THEIR COMPARISON WITH THE STRUCTURES OF THE EDUCATIONAL PROCESS

Name of TFS	Comparison with educational structures	Diagram	Performance
Sequential execution	Sequential execution of training modules		1. The probability of a correct answer (during final testing) to a randomly selected question 2. Mathematical and runtime variance
Cyclic FS "Working operation with operation control without restriction on the number of cycles"	Work with the training module with self-control and repetition of training.		1. The probability of the correct answer (during the final test) to the randomly selected question 2. Mathematical expectation and runtime variance
Working operation with functional control and revision without cycle	Work with the training module with self-control and additional training		1. The probability of the correct answer (during the final test) the randomly selected question. 2. Mathematical expectation and and runtime variance

The benefit of converting dialogue models to well-known TFS [17, 18] is baseds on:

- unification,
- possibilities of using existing [17, 18] mathematical models for dialogue assessment.

The use of these models in the technology of "intellectual agent" [20] allowed us to predict on-line the results of training activities and answer questions like "WHAT IF?".

B. Meaningful Analysis of Dialogue Interaction in E-Learning And Identification of New Typical Structures of the Dialogue

Substantial progress in interactive learning systems, including the expansion of self-diagnosis capabilities, changing the learning path, interrupting learning and moving to another level led to a qualitatively new interconnection between the functional elements in the dialogue structures In the works [1, 10, 11, 20] it is indicated that the possibility of flexible control over the level of the quality of education and the multivariance of learning paths have significantly increased in modern systems.

Analysis of a large number of real e-learning systems allowed us to reveal ***a tendency to increase the degree of interactivity.***

Modern modular systems provide a variety of opportunities for changing the learning path. Among the main trends, there is the combination of opportunities:

- works with elements of training modules,
- self-control of the achieved level of learning quality,
- determine the need for re-training the training module: in full, in incomplete (with diagnostic tools available),
- return (if necessary) to: training module, a fragment of the training module,
- conducting the final ("test" or "examination" control).

The main problem we encountered when trying to describe real systems was:

- the need to make a decision on the direction of continuing the dialogue, depending on the fulfillment of a certain condition,
- implementation of this solution.

The simplest example of this problem situation is the need of:

- analysis of the achieved quality level (based on self-control results),
- depending on certain conditions: achieved quality level, motivation, resources, availability of diagnostic tools.

Transition to:

- next module,
- return to the full study of the current module,
- additional study of a certain fragment of the module,
- etc.

Thus, a new generation of "student-computer" systems has essentially new logical-functional connections between the elements of the dialogue. Such connections cannot be described by existing standard structures [17-19, 21-25].

The need for new TFS is associated with the additional possibility of choosing alternative ways of the dialogue, depending on the results of self-diagnosis.

Thus, as we see, in the dialogue model, the relative frequency of decision-making procedures, which can be described by ***alternative operations*** within the FTS ETS, increases.

This situation of choosing the path of the dialogue can be modeled by introducing an alternative operation with 3 outputs (Fig. 1.)

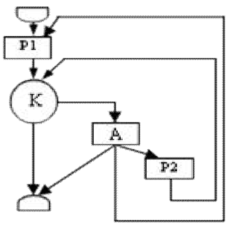


Fig. 1. Cyclic TFS with a 3-alternative choice according to the results of self-control (legend according to [17])

Examples of special cases of this structure (2-alternative cyclic TPS) are shown in Fig.2.

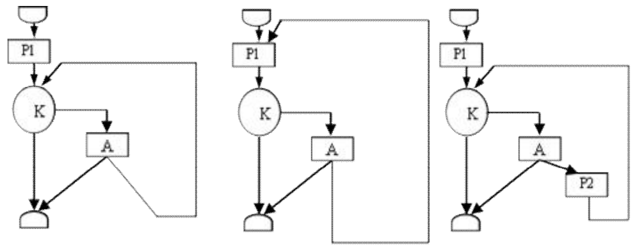


Fig. 2. Examples of cyclic TFS with a 2-alternative choice according to the results of self-control (legend according to [17])

Obviously, there may be other typical structures associated with the ability to control the process of changing the dialogue path.

However, at present the TFS data can be accepted as new models for expanding the TFS library of the FTS ETS [10–13] and sufficiently satisfy the requirements of the e-learning practice.

C. Mathematical Models for Evaluating the Dialogue Indicators

For models describing the typical structures of dialogue interaction in e-learning, models for evaluating indicators have been developed [20]:

- probability of a correct answer (during final testing) to randomly selected question, expectation time of execution, runtime variance,
- likelihood of timely execution for given allowable learning time,
- predictive assessment of the quality of learning activities (100-point scale, 4-point scale, arbitrary scale).

D. Approbation

The developed models are used to build a computer program "Intellectual agent-manager for managing dialogue in e-learning" (Fig. 3).

CONCLUSION

A formal description of the man-machine interaction algorithms in e-learning systems is a necessary condition for the possibility of modeling and optimizing the activities of operators.

It is convenient to carry out the description of the dialogue in the e-learning system by using the apparatus of functional networks of the functional-structural theory of ergotechnical systems.

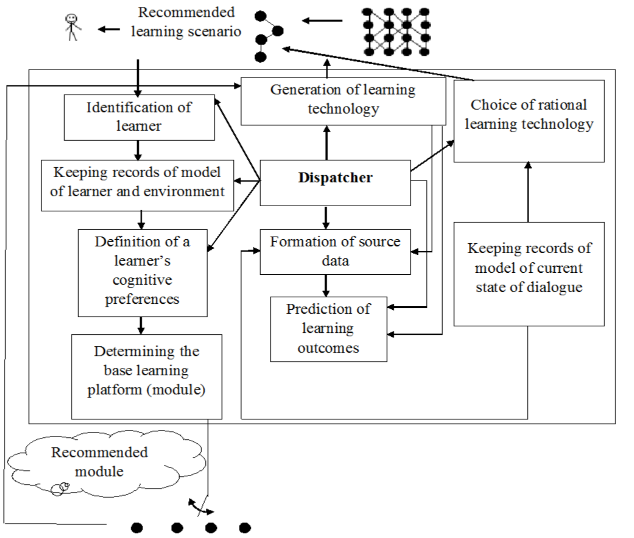


Fig. 3. Basic functional blocks and principle of agent-manager functioning for e-learning.

The logic of the process of dialogue interaction in e-learning can be described with the use of 2 well-known typical functional units (working and control) and 18 well-known typical functional structures.

To simulate e-learning with a developed system of self-diagnostics of the learning process, it is necessary to introduce new typical functional structure with the use of an 3-alternative operation and a working operation of the "refinement" type. It was shown how this structure can be transformed with the use of 2-alternative operations. Three possible options for such structures were developed.

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