ISSN 2278-3091
Volume 9, No.3, May - June 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse230932020.pdf
https://doi.org/10.30534/ijatcse/2020/230932020

Improving the structure and modelinteraction of information processes on distance learning

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ABSTRACT

This article presents a systematic approach to the development of an adaptive distance education system. The main subsystems and elements are determined and the structural and functional model of the system is presented. A distinctive feature of the proposed structure is the presence of a module for the creation and correction of the curriculum. This module allows not only to build up a curriculum before starting training, but also to make changes to the curriculum in the learning process using network planning methods. The developed functional model reflecting the process of interaction of system components, the conversion of input to output.

Key words: distance learning, learner model, immutable data, mutable data, labor market.

1. INTRODUCTION

A modern direction in the field of e-learning systems is learning systems with an adaptive approach. The main feature of these systems is the adaptation of educational material to the individual characteristics of the learner. Adaptability is a property of a system that characterizes its ability to change under the current state of the external environment or input parameters. In learning, adaptation involves the individualization of the contents of training courses and test items designed to control knowledge for each learner. Adaptation can take place according to various parameters, for example, according to the volume of the proposed material or the form of its presentation. The task of adaptive learning systems is to optimize the educational process by providing the learner with educational material in the most preferred form. The result of this approach is to improve the quality and effectiveness of the educational process.

2. THE STRUCTURE OF THE ADAPTIVE SYSTEM ON DISTANCE LEARNING

The construction of an adaptive training system must begin with the development of the structure of this system. The previous chapter described the basic requirements for the system under development. Based on the analysis of these requirements, the developed system is representable from the point of view of a systematic approach, taking into account the input and output parameters of the system, the behavior of system components in the learning process.

The general structure of the adaptive distance learning system is presented in Figure 1.

Learner model formation subsystem

This subsystem is intended for the formation and correction of the learner's model. The formation of the model occurs when a new user is added to the system. Correction of the model occurs at the end of each stage of training. This subsystem includes the following elements:

A learner model is a set of learner's characteristics, measured during the system's work with the learner, and determines the degree to which he learns knowledge on the subject being studied and how to present educational information. The value of these characteristics changes during the operation of the system. The learner's model is the main component of the system by which adaptation is implemented.

The base of personal test items is a set of test items designed to determine the individual characteristics of the learner and to form a model of the learner with their account. Personal test items are elements of psychology. With their help, it is possible to determine the most preferable method for the presentation of information for a particular learner, optimal for the assimilation of the didactic volume of educational material in one lesson, etc. The results of personality tests allow you to determine the initial values of the learner's model used in the adaptation of educational material. These values will be adjusted during the training.

The base of the model's parameters is a set of various characteristics of the learner that correspond to the model of the learner that can be used in the process of adapting the training material. From the characteristics contained, they will be selected suitable for a particular learner.

*The testing block*is designed to determine the personality characteristics of the learner. The determination of personal characteristics is necessary for the further creation of the learner's psychological profile and determination of the parameters used to adapt the training material to the individual characteristics of the learner. This block uses test tasks from the personality test database described above.

In the model formation block, a model of a particular learner is created. Based on the results of the learner performing personality tests from the database of model

parameters, suitable parameters are selected and their values are set. At the initial stages of training, the model is inaccurate, in the future, the parameters of the learner's model are constantly adjusted, thereby achieving high accuracy of adaptation of the training material.

The model correction block is used to adjust the values of the adaptation parameters of a particular learner after he passes the test control of knowledge at the end of the training [1-2]. The training material offered to the learner is adapted based on the parameters of the model formed by the results of personality testing. It should be noted that personality testing may not accurately determine certain adaptation parameters. Based on the results of testing the knowledge gained during the training process, these parameters can be clarified and their value corrected in the model.

The training planning subsystem

The training planning subsystem is designed to determine the goals of training and the formation of training elements.

This stage is very important in the learning process, as for quality training it is necessary to optimally form a curriculum that satisfies not only the preferences of the learner, but also the current requirements of the labor market, thereby increasing the learner's further competitiveness.

Entry level test base contains tests to determine the initial level of knowledge of the learner. Determining the initial level of knowledge is an optional step, since, often, the learner begins to study a completely unknown field in which he does not have any knowledge. Nevertheless, in some cases, this is a necessary stage, allowing to exclude already known material from the curriculum and, thereby, optimize the learning process.

Learning goal formation block is necessary to determine the final result that must be achieved. These conclusions are made on the basis of the knowledge that the user already possesses for each of the sections of the training course. At this stage, the learner's knowledge in each of the sections can be assigned to some fuzzy groups as "excellent", "good", etc. Depending on which group the knowledge in each section is assigned to, priorities will be set and the costs of studying each of them will be determined. For example, if in a certain section the learner's knowledge level is defined as "excellent", then this section will require a minimum of time for study and repetition, and the section for which there is no knowledge at all will be considered as detailed as possible.

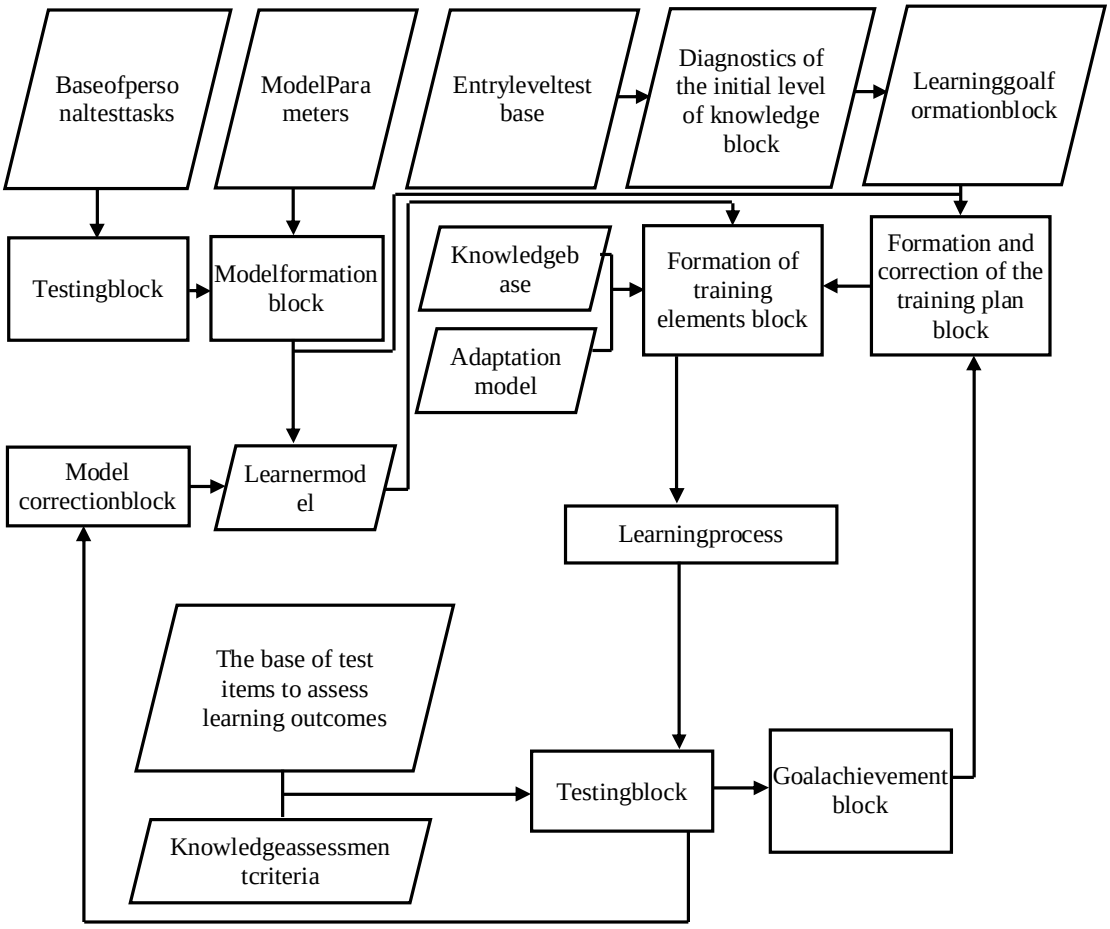

Figure 1: The structure of the adaptive system on distance learning

*Formation and correction of the training plan block*is necessary to draw up the sequence of the system in the learning process of a particular learner. On the basis of the learning objectives formed earlier, a strict sequence of training sections offered to the user with established priorities is formed. At the next stage, educational elements are formed, that is, units of educational material offered to the learner for study. As a rule, the educational element is understood to mean a certain part of the educational content, which fully reveals a certain part of

the academic discipline and, at the same time, according to the didactic (semantic) volume, can be learned in one lesson. As a training element, a topic of 15-12 thousand characters of text can be considered. If the material contains formulas, diagrams or tables, then this symbolic volume of one educational element is reduced.

Two resources are used to form educational elements: a knowledge base of educational material and an adaptation model. Let's consider them in more detail.

Knowledge base - a database designed to operate on knowledge (metadata). Full-fledged knowledge bases contain not only actual information, but also rules for searching, outputting and processing information. In relation to the adaptive educational system, actual information directly refers to the material of the training course, and metadata refers to the parameters of this material used to adapt to an individual learner and to form educational elements.

The adaptation model is a mathematical model that describes the interaction of the adaptive system with the knowledge base in the learning process using the parameters of the learner's model. The adaptation model describes the rules for selecting educational material taking into account the adaptation parameters, and also describes the process of making changes to the learner's model in the learning process [3-4]. The adaptation model uses algorithms based on the way the knowledge base is implemented. So, for example, if semantic networks are used to represent the knowledge base of an adaptive system, the adaptation model can be based on graph theory algorithms.

The training block is located outside the selected subsystems. In this block, the learner is offered learning elements formed for study.

The subsystem for assessing learning

The subsystem for assessing learning outcomes is necessary not only to control the quality of knowledge, but also to determine whether the learning outcomes are consistent with goals set earlier.

After completing the training, it is necessary to check the level of the learner's knowledge, draw conclusions about the achievement of the learning objectives, adjust the learner's model, if necessary, and determine further actions. To implement all of the above actions, a subsystem for evaluating learning outcomes is used.

One of the main resources of the subsystem is the base of test tasks for assessing learning outcomes. Test items have attributes that allow you to adapt the learner's testing process. For example, if the model contains information about the learner's preferred form for presenting tasks, then test tasks will be selected according to this parameter.

In the testing block, the learner is invited to perform test tasks. After testing, in the block of correction of test tasks, the complexity parameter of each task will be changed. The completion of testing is also the basis for the implementation of the learner model correction block.

Goal achievement block is checked whether the goals set at the stage of formation of the learning goals have been achieved. If the level of knowledge of the learner in the section has reached the level of "excellent" or "good", then we can conclude that the section is studied. Otherwise, it is considered that the goal under this section has not been achieved.

The field for assessing the achievement of goals makes a decision on the further behavior of the system. If all the set goals are achieved, then the training can be considered completed. Otherwise, a transition to the goal formation block takes place, where the sections necessary for the second study are again determined.

In addition to the structure of the developed adaptive system on distance learning, it is also necessary to present its functional model, which allows us to present a sequence of processes taking place in the adaptive system on distance learning. Within the framework of the IDEF0 standard of functional modeling and graphic notation, designed to formalize and describe the functioning of the developed systems, each process is associated with:

- input data;
- output data;
- standards and regulations;
- the resources necessary for the flow of these processes.
- The following standards and norms in the process of functioning of the adaptive system on distance learning are:
- educational standards;
- labor market requirements;
- standards for the functioning of distance learning systems.

3. LEARNER MODEL DEVELOPMENT

An important parameter of adaptive system on distance learning is the quality of its interaction with the user. It is necessary to take into account both predefined adaptation parameters and dynamically changing in the learning process (level of training, current goals and competencies). All necessary information is stored in the learner's model. The basis for the development of a high-quality adaptive system is the development of a learner model.

A learner model is a set of characteristics of a learner, measured during the system's work with the learner, and which determines the degree of mastering of knowledge on the subject being studied, as well as the methods (rules) of processing this aggregate. First of all, these rules should make changes to the learner's model itself based on the results of his work with the system.

The learner model should include information:

- about the purpose of training;
- on the learner knowledge within the framework of the course being studied;

about the features of the submission of training materials and the choice of control tasks and questions.

In the learning process, adaptive system on distance learning actively uses the learner's model, constantly adjusting its parameters, and also adapts the learning process based on them, making it as effective as possible for each learner.

The developed system involves an iterative approach to the learning process, that is, in the learning process, the user goes through many stages [5].

At the beginning of each stage, the learning objectives are determined, the curriculum is formed. At the end of each stage, an analysis of the achievement of goals, the adjustment of the learner's model parameters, which will be taken into account are performed. The learner model contains the parameters which are shown in Table 1.

Table 1: Learner model parameters

Data type	Profile	Characteristics
Immutable data	Base profile	Personal information (PI)
		Previous education (PE)
		Qualification (C)
		Initial knowledge (IK)
		Disadvantages (D)
	Psychological profile	Learning style (LS)
		Cognitive abilities (CA)
		Professional orientation (PO)
Mutable data		Learning objectives (LO)
		Curriculum (C)
		Data from previous steps (DPS)
		Knowledge gained (KG)
		Test results (TR)
		Acquired skills (AS)

In Figure 2 has been shown the structure of the components of the learner model. The model contains both constant (unchanged) data and data that are constantly adjusted in the learning process.

The learner model can be represented in the form of a structure with many elements, both dynamically changing and unchanged throughout the entire training.

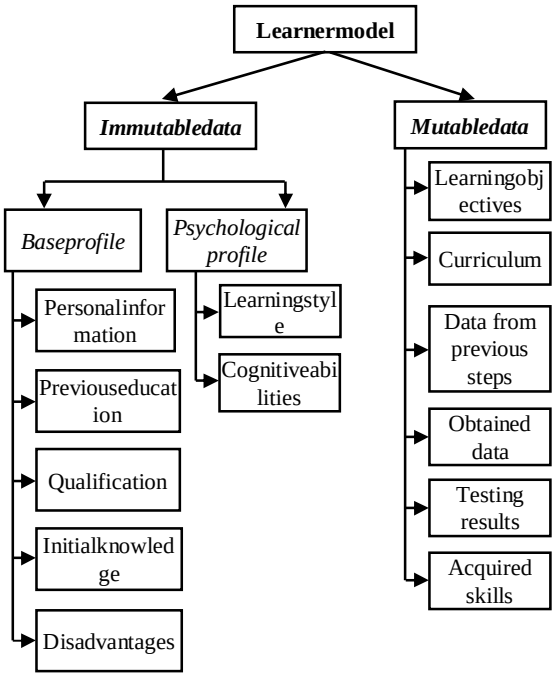

Figure 2: The structure of the components of the learner model

The advantage of this model is the ability to store in it all the information necessary for adaptation and subsequent analysis.

4. DEVELOPMENT OF A MATHEMATICAL MODEL FOR THE INTERACTION OF INFORMATION PROCESSES ADAPTIVE SYSTEM ON DISTANCE LEARNING

Information process - a set of sequential actions performed on information to obtain any result.

Adaptive system on distance learning in the field of information technology is a complex object, which includes many separate subsystems. Each of the subsystems is a separate information process. At each stage of training, a large amount of information is collected, processed and accumulated. It is necessary to develop a mathematical model of the interaction of information processes. This model allows you to structure the information used in the process of the system, as well as to predict the state of the system at any stage of training, changing the input data.

The first stage of modeling will be to determine the nature of the interaction of the system with the external environment [6-7]. For this, it is necessary to determine the input and output parameters of the system. As shown in Figure 3, the system in the process of its operation has a number of influences from the external environment and from the learner.

These effects are divided into three groups:

- the requirements of educational standards;
- the labor market requirements;
- the learner parameters.

As part of the interaction of each learner with the system, these effects are divided into static and dynamic. Static requirements include standards and the labor market, since these requirements do not change during the training process. The learner's parameters are dynamic, as they change during the learning process.

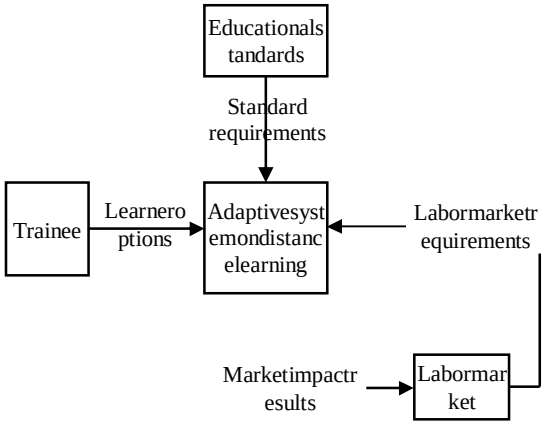

Figure 3: The structure of interaction of adaptive system on distance learning with the external environment

The set of values of the input actions realized over the entire period of the system's functioning will be called the input process and denoted by $\boldsymbol{X_t}$, then

$$\boldsymbol{X_t = \{x(t): t \in T\}}$$

A plurality of input actions values$X_t$as stated above, it is necessary to divide into two subsets:

X_D −the set of values of dynamic actions having different values at each moment of time$t$;

X_S −the set of values of static effects that are unchanged throughout the training period.

Thus,

$$X_t = \{X_D, X_S\}$$

The set of values of the output actions realized over the entire period of the system's functioning will be called the output process and denoted byY_t, then

$$Y_t = \{y(t): t \in T\}$$

There is a connection between the input and output parameters of the system, we write it in the form of an equation

$$A(T, X_t, Y_t) = 0 \quad (1)$$

For example, it can be seen from the above input and output parameters that the learner's identification information, entering the system's input, allows the learner to receive the contents of the learner's personal profile [8-9]. This dependence of input and output parameters within the framework of the distance learning system is clearly visible in the technology of implementing client-server programs "request-response". This technology provides for the behavior of the system located on the server, determined by the input parameters from the learner.

However, there are not always direct dependencies between the input and output parameters of the system. Often, the incoming input parameter changes the internal property of the system, which will be used for its further work.

The set of internal properties of the system, determined at a timeξ, denote by$z(\xi)$and take into account (1), which will have the following form

$$B(T, z(\xi), X_t, Y_t) = 0 \quad (2)$$

Appearance in the equation $z(\xi)$pursues one goal - to provide an unambiguous connection between$X_t$andY_t. In its meaning$z(\xi)$represents a set of existing system properties, knowledge of which at the present moment of time allows determining its future behavior.

We rewrite equation (2) as follows:

$$Y_t = G(T, z(\xi), X_t) \quad (3)$$

where

G −output operator;

Such a representation of the system is more convenient, since it allows you to determine the output parameters of the system.

Based on equation (2), it follows that at any moment in time the system is in some state, therefore, equation (3) can be written for any$\xi = t \in T$and a fragment of the output process$X_{t\eta}$.

Thus,

$$Y_{t\eta} = G(t\eta, z(\xi), X_{t\eta}) \quad (4)$$

where

$t\eta - [t, \eta]$ time interval.

Consider not the entire output process$Y_t$or a fragment thereof$Y_{t\eta}$, and output exposure$y(\eta)$. Then from (3) and (4), given that$y(\eta) \in Y_{t\eta} \in Y_t$, it gets

$$y(\eta) = G(T, z(\xi), X_t); \; y(\eta) = G(t\eta, z(t), X_{t\eta}) \quad (5)$$

On the interval$t\eta$it can equate the right sides of equation (5)

$$G(t\eta, z(t), X_{t\eta}) = G(T, z(\xi), X_t) \quad (6)$$

To fulfill (6) for arbitrary$z(\xi)$and$X_t$it is necessary that under the operator's sign$G$the same variables were in both parts of this equality. This condition will be satisfied if

$$z(t) = H(\xi t, z(\xi), X\xi t) \quad (7)$$

where

H −operator establishes an unambiguous relationship$z(t)$from a couple $(z(\xi), X\xi t)$, which is set on the interval$\xi t$and called transition operator.

Equation (7) is called the equation of state. It determines the final state of the system$z(t)$by given initial state$z(\xi)$and a fragment of the input process$X_{\xi t}$.

So far, we have assumed that at the inputs and outputs of the system at any given time$t$there is one input$x(t)$and one output$y(t)$impacts. In a real situation, there can be several such effects. In this case, it is necessary to consider the input and output parameters as vector quantities$x(t) = (x_1(t), \dots, x_N(t))$ и $y(t) = (y_1(t), \dots, y_M(t))$whose components$x_N(t)andy_M(t)$represent values$n$ −th inputand$m$ −th output impacts. Let be$x_N(t) \in X_N, y_M(t) \in Y_M$for all$t \in T$, $X_N$and$Y_M$will be called sets of permissible values of the effects$x_N(t)$and$y_M(t)$respectively. Descartes product

$$X^N = X_1 \times \dots \times X_N \quad (8)$$

forms a space of input actions such that any set of input actions realized at a moment in time$t \in T$, set by a point (vector)$x_N(t) \in X$. Similarly, for the vector of output actions$y(t)$the space of output actions is introduced$Y^M = Y_1 \times \dots \times Y_M$.

The state space can also be represented as a Descartes product$Z^K = Z_1 \times \dots \times Z_K$.

The model of interaction of information processes adaptive system on distance learning allows us to predict the process of its functioning on a given vector of the initial state of the system$z(\xi)$andrecorded in the process input vectorX_T. According to the above, to solve this problem, it suffices to set$T, X, Y, Z$of spaceX^N, Y^M, Z^K,output statements $G$and transition$H$. The model of interaction of information processes of the system is a tuple

$$M = \langle T, X \subseteq X^N, Y \subseteq Y^M, Z \subseteq Z^K, G, H \rangle \quad (9)$$

5. CONCLUSION

Based on an analysis of the requirements for distance learning systems a learner model structure is proposed that is the separation of parameters into static and dynamic data. A functional model of adaptive system on distance learning, which reflects the process of interaction of system components, converted input data into output data are developed.

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