An Option of Building the Distance Learning System with Artificial Intelligence Elements

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Abstract

The article considers the scientific problem solution of ensuring the required quality training of the specialists who acquire practical knowledge with the help of computer training equipment or intelligent computer training systems using distance learning technologies. The offered decision is directed on the construction distance training system of experts on intensive training technologies. The offered option of training intensification by the principle of "inner conviction". This variant of distance learning system construction may provide preparation of future experts to the maximum possible education level in the shortest time. In addition, the adaptively controlled algorithm variant to management future experts' training process with the best results and the minimum preparation time was proposed.

Keywords 1

Distance Learning System, Artificial Intelligence Elements, Intelligent System, Adaptively Controlled System, Intensive Training, Educational Task, Computer Training Systems.

1. Introduction

The tempestuous computer technology development and its application in various activities have led to an inability of teaching future professionals in higher education institutions without computer training systems. Today developing the computer distance learning system (DLS) and methods of its use is an important task. Also the DLS may become a foundation for an intelligent training system for training personnel, which would best meet their purpose. Due to the increasing complexity and information saturation of different professionals training methods, we meet a need for effective management of the learning process. As the training system becomes more complex, multifunctional and is designed for different categories of users, there is a need for adapting it to each user's characteristics. The ability of adapting DLS to the user is one of the indicators of its effectiveness and, as a consequence intelligence. To ensure this user adaptation models of the trainee are developed, which store information about each user and also the learning management process [1].

2. Related Works

Nowadays a huge number of programs that to some extent increase the effectiveness of learning through the organization of adaptive dialogue with the user (as a pupil, student, listener, and even teacher). However, at the present stage, the volume of information growing tempestuously, thus, we need such e-learning tools that would allow the user not only to view information of interest by navigating hyperstructures but also to ask various complex questions. It leads to expanding of the user

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questions typology, which saves the user's time in searching information. Thus, in resources [2-3] we can see general information about LMS systems and a description of all LMS systems' aspects, such as their general structure, types, and so on. In particular, the very popular Moodle LMS system was described in details. There are aspects of the learning styles theory together with the analysis of students' behaviour in distance learning described [4]. Another resource [5] propose an adaptive e-learning system, which able to create learning trajectories adapted to the student's profile.

Unfortunately, a user has a long time to look through the electronic directory in search of an answer to one question in many modern systems. The complexity of the nomenclature and the user's question require the improvement of describing the educational material options, i.e. except the structure and content, it is also necessary to take into account the semantic connections between the described concepts. Using this approach allows to develop of intelligent reference systems or systems with elements of artificial intelligence, which are needed not only in the DLS but also in any computer system [6, 7]. Artificial intelligence systems are a type of computer system for effective training and educating of specialists. The specific feature of such systems is a knowledge base, which stores the solution to many problems, including the laboratory and practical tasks that the curriculum integrates. The knowledge base is constantly replenished and modify in accordance with the experience and requirements of consumers.

3. Methods

The analysis of the existing scientific and methodological apparatus of DLS construction shows its focus on an extensive path of learning (due to an increase of classes and training number), which has almost exhausted itself. On the other hand, modern information technologies and teaching methods with the DLS using open up huge opportunities in the field of intensive educating. As evidenced by foreign and domestic experience, there is only one rational way: the construction of DLS intensive training (by improving the quality characteristics of training while minimizing material, resource and time costs). In this regard, there is a necessity for further development of methodological foundations for the computer DLS construction with elements of artificial intelligence. This task means the solution of the following scientific problems:

1. Development of methods for analyzing the process of computer adaptive-controlled DLS functioning.
2. The development of methodology for structural and parametric computer DLS's synthesis with artificial intelligence elements and organization of their optimal functioning in the learning process.
3. The development of requirements to DLS's foundation methodical bases on the offered methodology of their synthesis.
4. The development of DLS's constructing and functioning methodical principles and their basic elements that provides realization of requirements for it.
5. The development of an algorithm for specialists' training process adaptive control.

In general, the task of scientific research formulates as follows. We need to determine a rational option for the DLS construction, which provide training of future professionals to the highest possible educating level in the shortest time. The solution to this problem is possible by the use of modern intensive training technologies. In this case, intensive technology is defined "as a system of factors that intensify the learning process: ideal, aimed at increasing the activity of trainee, and material (technical), which providing a given level of training in the shortest time" [1, 8, 9]

4. Results and Discussion

In process of the first scientific problem solving, we define the purpose and model of DLS functioning and the problems solved by it; conditions of DLS functioning in the future specialists' intensive training process.

The basic concepts of DLS construction's methodical bases founded on categories of the general systems theory [10-13]. At the same time, the commonality of the systems theory concepts is manifested in a specific subject area, among them intelligent computer simulation systems. The main elements of DLS consider to be intelligent computer-based learning systems (CBLS), combined with hierarchical, informational, control links, where each element is aimed at achieving a common goal of providing the necessary level of future professionals' knowledge. In the DLS creating process determining its structure and range of algorithms that best meet the purpose of the system is necessary. To solve such applied problems knowledge about the effectiveness of DLS structural organization methods and methods of managing its operation processes are needed. The properties and patterns of dynamic adaptive functioning, placed in computer networks with different organizations in the future professionals training, are the subject of the DLS theory. Its main tasks are the analysis and synthesis of intellectual CBLS.

The tasks of the first group, the analysis of DLS, are characterized by the following two stages of research. The first stage connects with building a conceptual model of DLS operation, and the second stage connects with building the dynamic adaptive-controlled process' mathematical model, which is created on the basis of the accepted conceptual model. The dynamic adaptive-controlled process consists of: the object of management – future specialists; controlled parameters – trainee's activities quality indicators; control influences – educational tasks (ET), formed by intellectual CBLS; the algorithm for controlling the learning process – the algorithm for changing the intensity of the ET in accordance with the level of future professionals training. In addition, the system of indicators and methods for assessing the effectiveness of intelligent CBLS are also being developed. The analysis provided within the framework of the DLS construction theory show processes models, its functioning and regularities which are inherent in these processes or system in general.

The basis of the proposed methodological intensification approach is that the "inner conviction" of future professionals in the limited time left to study and perform the educational task, causes them a state of tension. If the tension does not exceed the limit value V_{ij}, the maximum allowable tension, the impact becomes organizing [14, 15]. In the DLS functioning model, the tension (h_{ij}) is defined as the internal state of the *j* specialist immediately before the execution of the *i* elementary task.

The concept of tension is realized in DLS by reducing the cycle of educational information display (educational task content) on PC monitors until the tension reaches a given level *V*, at which the lack of time acts as an organizing factor. The organizing influence of emotional tension (*S*-tension) is determined by the fact that in the learning process specialists work more focused, more precisely, and the probability of correct and timely execution of ET increases.

The tension function (*h*) is the ratio of the time required to complete the training task to the actual available time that have specialists in each cycle of DLS

$$h = \frac{\sum_{i=1}^{I} \bar{t}_{iTp}}{T} \qquad (1)$$

where $\bar{t}_{iTp}$ is the average time required for specialists to perform the *i*-th ET; *I* is the number of tasks remaining to be performed; *T* is the full time available to future professionals to perform the *I* learning tasks remaining in each cycle of DLS functioning [12].

The average values of elementary educational tasks' performance time are calculated on the statistical data received during trainings. The calculations of the intensity h_{ij} value in the training process are limited in the DLS by the range from 1.0 to 4.0.

In the general case, the problem of intensive training is as follows: to find from the set of possible options (*X*) such a variant of construction DLS (*x*), which provides intensive future professionals training (*h* -> *V*) to the required (maximum possible) level (*P*) with minimal financial (*C*) and time (*T*) costs.

The formal statement of the scientific problem is presented in the form of a solution to the following problem:

$$P \to \max_{x \in X},\ C \to \min_{x \in X},\ T \to \min_{x \in X},\ h \to \max_{x \in X} \qquad (2)$$

As we see from (2), all the criteria are contradictory and it is extremely difficult to find the best option for constructing a DLS that satisfies all the above conditions. Without the development of methodical such systems construction's bases, structure optimization methods and parameters of DLS, the decision of the specified problem is impossible.

The conceptual basis for the intensive training DLS construction is a combined solution of the following two main tasks [16, 17]:

- Accelerated specialists training to the required level of the educational tasks' implementation with minimal time costs (the first phase of intensive training);
- Training of specialists to perform tasks up to the maximum possible level of professional training with given time (cost) constraints during the planned training sessions (the second phase of intensive training).

The solution to the first problem depend on test results when the specialists have not reached the required level of training. If it is, the PC of those who are taught are connected to the teacher PC in order to organize the first phase of intensive training. Thus, the various educational tasks on the personal computer forms in accelerated mode in such quantity at which the time (financial) expenses for preparation of the required level expert is reduced.

On the other hand, an adaptive structure of DLS is created for those who have successfully passed the test. This DLS structure forms the necessary number of educational tasks on the PC display of trainee and provides further maximum training level increasing.

In the second problems group of the intellectual DLS construction theory, one of the main is the task of their optimal synthesis, which is aimed at choosing the building a system method that is best suited to perform the given functions. The initial data in the synthesis problem are next: functions and tasks of the system; list of restrictions on system characteristics (time, resource); efficiency criterion that establishes the method of assessing the system quality as a whole. Based on this information, we can determine the system structure, the parameters of the elements and the processes management strategy, which must meet the given constraints and be optimal in terms of the content of performance criteria. The procedure for the synthesis of DLS is divided into procedures of structural and parametric synthesis. The purpose of structural synthesis is determining the structure of the system: the subsystems type, the composition of the elements and the relationships between them. The purpose of parametric synthesis is determining the optimal way of subsystems technical characteristics and basic elements with a fixed structural scheme of the system. The problem of synthesis of the optimal structure is considered as the problem of determining the optimal, mapping the set of performed DLS functions to the set of its interdependent elements.

Thus, implementation of intensive learning technology closely connected with an adaptive change of the educational tasks speed issuing from the teacher's PC to the trainee PC. In this case, the structure of the DLS is conventionally divided into computer (training) classes, which include the teacher's PC plus the trainee PC and the distance learning subsystem, which includes the teacher's PC and the PC of future professionals. The physical connection of the PC to the DLS may be provided through the internal computer network intranet or the global computer network Internet, which provides a flexible intellectual DLS structure for the most efficient conduct of all computer training types.

The method of solving the parametric synthesis problem includes the following main stages. First, the efficiency indicators of each options constructing DLS on a set of system functioning conditions to select the best of them are determined. At the second stage, the problem of situations classification on the satisfaction basis with the accepted restriction is solved. Under the situation in the multidimensional factor, space means a solution, as well as the conditions of its implementation. For each situation's point, performance indicators are calculated and the obtained values are compared with the allowable ones. The third stage implies narrowing the set of solution options that is achieved by using the Pareto optimization principle, which distinguishes the allowable Pareto-effective set of solutions [16, 17]. Further narrowing of the solutions set is associated with the conceptual choice of such a DLS construction variant from the whole set, which provides a sufficiently high (necessary) level of target and economic efficiency. Thus, the optimum decision help to define a range of intelligent training system parameters admissible values that provides preparation of future experts to the necessary level on performance of the set tasks.

Methodical bases of requirements substantiation to DLS are based on the methodology of their synthesis and include the decision of the third problems group: training level dynamics modelling in the course of future experts' preparation and according to the received indicators of target and economic efficiency, so requirements to DLS construction are formulated. Also, the requirements for DLS architecture, knowledge base, expert subsystems of objective control, planning and management of training and information environment, hardware and software of all DLS subsystems are substantiated.

The fourth group of tasks involves the development of DLS construction technical principles, i.e. technical solutions that will ensure the implementation of reasonable requirements for them. A conceptual point of view shows DLS is an integrated intellectual-adaptive system that first studies educational tasks, and then with the help of artificial intelligence elements at the stage of initial training educates specialists to perform these tasks. As the necessary skills and work abilities are learnt, the information support of artificial intelligence changes adaptively.

The main purpose of DLS is to train professionals to the required (maximum possible) level ($P_и$) with minimal time (T) and resources (C).

In this case, the generalized indicator C should take into account the costs of development (C_1), serial production (C_2) and implementation (C_3) of each r-th (r = 1, ..., R) DLS variant, time (C_4), as well as operational costs (C_5) required for the optimum level specialists training ($P_н$). In addition, the generalized indicator C should take into account the costs of creating and maintaining databases (knowledge bases) of learning tasks (C_6), the organization of objective control and learning process management (C_7). Also, the generalized indicator C may include the costs (C_8) required to increase the stability of the computer software functioning and network equipment of each r-th DLS variant. In this case, the value of the k-th (k =1, s) cost indicator should not exceed the maximum allowable value of $C_{Кдоп}$.

The cost indicators are set in different units and have different physical meaning, so for choosing a rational option for building and organizing the DLS functioning in the first phase of training let us use the concept of compromise's nonlinear scheme [16, 18].

In process of selecting the r-th (rational) version of the DLS, which provides accelerated training, it is advisable to use the following generalized indicator (C_r):

$$C_r = \sum_{k=1}^{s} \left(\frac{F_k C_{kдоп}}{C_{kдоп} - C_{kr}} \right) \rightarrow min \qquad (3)$$

with $P_r > P_и$, $C_{Kr} < C_{Kдоп}$, $\sum_{k=1}^{s} F_k = 1$;

where P_r is the average level of specialists training, which is achieved by using the r-th DLS version in the first phase of training; $P_и$ is the required level of specialists training; F_k is the coefficient of the k-th indicator importance.

In addition, the r-th (rational) DLS version construction, in the second phase of training, must meet the following performance criteria:

$$P_r \rightarrow \max, \qquad (4)$$

at $C_{Kr} < C_{Kдоп}$, $\sum_{k=1}^{s} F_k = 1$, (r =1, … , R; k = 1, … s),

The initial stage of any complex system designing is building its architecture and knowledge base, which depends on the means and methods of this system's implementation.

The option for organizing the adaptive management of the specialists training process follows below.

The goals of the learning process' adaptive management may be substantiated by the main stages of organization and conducting specialists training using adaptive training tools (Figure 1).

At the first stage, the goals and tasks of training are formulated. The ultimate goal of such training is to educate staff to the required level, which ensures the implementation of educational tasks in the most difficult conditions.

If the staff have reached an "excellent" training level as a result of previous education, then the main purpose of further training is to maintain the previously achieved level.

If the staff have not reached a "satisfactory" level in previous training, then the purpose of each subsequent training is to achieve a "satisfactory", "good", and then "excellent" level of training. The level of trainees training is characterized by its ability to timely and accurately perform standard operations at a given intensity of training tasks.

The average number of simulated situations per time unit that require personnel's intervention characterizes the intensity of the learning tasks flow.

Consider the main stages of organization and specialists' training with using adaptive training tools to substantiate the goals of the learning process adaptive management (Fig. 1).

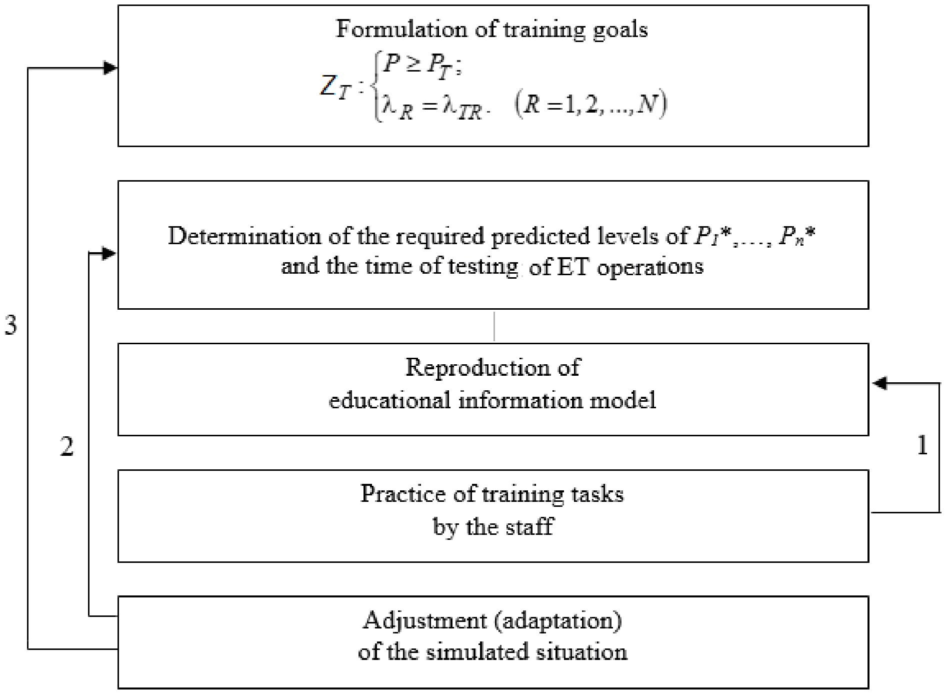

Figure 1: The main stages of organization and specialists training using adaptive DLS

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It is assumed that during simulation of certain typical situations by personnel, in accordance with the algorithm of its work, certain types of ET operations are performed.

In order to achieve by trainers a training level that allows timely and error-free do ET operations in the most difficult conditions it is necessary, based on the actual level of the studied, to determine for each training dose-progressive intensity of simulated situations (X_R) exponentially.

Thus, the ultimate goal of training (Z_t) is to achieve by staff the required level of training (P_T) to perform basic ET operations types at a given intensity of simulation situations (λ_{TN}):

$$Z_T : \begin{cases} P \geq P_T \\ \lambda_R = \lambda_{TR} (R = 1,2,\ldots,N) \end{cases}.$$

In the second stage (as shown in Fig.1) the required predicted levels of staff training to perform the main ET operations types are determined: $P^*, \ldots, P_n^*$. Since any ET contains a large number of similar operations, it is convenient to use the probability of timely and error-free (correct) execution of operations P_i*, i = 1, … n as an indicator of the required predicted staff's knowledge level in the implementation of the i-th type of operations.

The required level of staff training to perform ET in general (P_T) may be described as a function:

$$P_T = P_T\,(P_1^*,\ldots, P_i^*,\ldots, P_n^*).$$

It follows that the required level of staff knowledge to perform ET (P_T) depends on the levels of staff training in the realization of each operation type (P_i*, i = 1, …, n).

The solving of determining the indicators P_i*,…, P_n* on the basis of the established requirements to the level of staff training for the implementation of the entire ET (P_T) task is ambiguous. The number of all possible solutions (n - 1) is a parametric set.

For example, consider ET, which consists of six operations. If ET must be performed with a reliability of not less than 0,8, then

$$P_T\,(P_1^*,\ldots, P_i^*,\ldots, P_8^*) = 0{,}8.$$

This equality is a mathematical record of the requirements and constraints imposed on the level of staff training to perform eight types of operations. Moreover, the probabilities of seven types of operations can be chosen arbitrarily, calculating the reliability of only the operation of the i-th type:

$$P_i^* = P_T^{-1}\,(P_1^*,\ldots, P_{i-1}^*, P_{i+1}^*,\ldots, P_8^*). \quad (5)$$

Since P_i* is the root of equation (5), the number of unknown variables is a seven-parameter set [19, 20].

It follows that the task of determining the requirements for the levels of staff training to perform operations of each type has plenty of solutions.

Each of these solutions has its advantages and disadvantages. Firstly, the level of staff knowledge to perform ET depends on the levels of staff training in the realization of each operation type and, secondly, there is a relationship between the required projected level of staff training (P_i*) and time of performing each operation type (T*, i = 1, … n).

In the process of staff training with using DLS, the above dependencies are usually not taken into account. The basic types of operations are practised to some extent until the staff reaches the required level of training to perform ET as a whole (P_T). In the best case, the experience of the training head helps to practice one or another type of operation to the level set by the head. At the same time, the training manager uses an approximate intuitive, far from optimal, solution, which, in turn, increases the time of staff training to the required P_T level.

The disadvantages of such staff training process management are:

- Subjectivity of the training head both at the organization and at management of training process;
- The complexity of defining, memorizing and analyzing quantitative staff training levels indicators to perform basic types of ET operations;
- The difficulty of recording and analyzing the individual staff abilities to perform certain ET operations types;
- The difficulty of determining the required predicted staff training levels to perform each operation type without special mathematical apparatus using.

This does not take into account the fact that staff may perform some types of operations in a timely and error-free manner from the beginning to the end of training. These types of operations are actually practised throughout the training, although the time of their training, and, consequently, the total training time could be reduced.

Thus, in the second stage of the training organization and conduct, taking into account the requirement to perform all ET (P_T), from the whole set of possible solutions for each type of operation is determined such that the training time to the required predicted levels P_1*,…, P_n* will be minimal.

To prepare staff to the above-mentioned knowledge levels, and, consequently, to the required training level for the implementation of the entire ET (P_T), the estimated training time is calculated by the formula:

$$T = \sum_{i=1}^{n} T_i$$

where T_i (i = 1, … n) is the average time of staff training to the required predicted level P_i*.

With

$$T_i = S_i \cdot \tau_i$$

where S_i is the minimum required number of the *i*-th type situations, the simulation of which provide the *i*-th type ET operation’s testing and the staff achieve the required predicted level P_i*; τ is the average time of the *i*-th type situation simulation.

The calculation of P_i*,…, P_n* and T_i*,…, T_n* should be carried out taking into account the patterns of increasing the staff training level (P) from the time of ET operations each type’s practice.

At the third stage of the organization and providing staff training a situation in accordance to design, in advance the optimum plan of intensive preparation is simulated.

In order to make the simulated situation as close as possible to the real one, it is necessary to use a set of such situations that took place in the staff work or may arise in conflict situations.

Direct testing of ET operations main types is carried out in the fourth stage, the essence of which is as follows.

In the process of simulating a circumstance, the staff performs a finite number of operations types n. At the same time, depending on the level of staff training to perform standard operations, a certain type of situations that require intervention in the staff management process is created. In other words, a simulated circumstance is a source of information for staff, using which they assess the situation, make decisions and perform appropriate operations types of the training task.

In the process of standard operations realization by staff, an adaptive change of circumstances is taken place, i.e. adjusting the number (intensity) of simulated situations depending on the staff training level to perform standard operations (arrow 1 in Fig.1).

At the same time, there is an objective control over the staff work. The assessment of the staff training level is based on the analysis of probabilistic characteristics, which take into account the accuracy and timing of the operations main types and ET in general.

For the above-mentioned reason, at certain intervals, the registration of the actual staff training level to perform each *i*-th type of operation P_i, (i = 1, … n) and the entire ET ($P_{бр}$) are provided:

$$P = P\,(P_1, P_2, \ldots, P_1, \ldots, P_i, \ldots, P_n).$$

Simultaneously, a comparison of the actual and required training levels (P and P_T) is conducted. If the condition

$$P \geq P_T \qquad (6)$$

performed, the training may be completed as the staff has reached the required knowledge level to perform ET. In other cases, the following condition is checked:

$$|P_i^* - P_i| \leq \Delta P_i\,,\ (i = 1, \ldots n) \qquad (7)$$

where ΔP_i is the value of the maximum allowable error in the implementation of operation ET *i*-th type by staff.

If condition (7) is met, it is assumed that the actual indicators of staff training levels P_i, …, P_n with the established accuracy degree (P_i, i = 1, … n) correspond to the required predicted levels P_i*, … , P_n*. Therefore, the practice of typical ET operations continues according to pre-set time intervals T_i,…, T_n.

If condition (7) is not met, then there is a need for a gradual adjustment of the organizing and conducting staff training process, i.e. in the adaptive management of the training process.

The realization of such management is needed due to the actual level of staff training or incorrectly formulated training purposes (Z_T), or insufficient accuracy of the time indicators T_1, …, T_n are determined during which staff are trained to the required predicted levels P_1*, … , P_n*. The explaining of this is primarily the uncertainty (at the initial stages of training organization and conducting) in the initial data on the staff training individual level in performing the main types of operations and ET in general. Therefore, at the fifth stage of the training organization and carrying out, it is necessary to correct (adapt) parameters: of the simulated circumstance S_1, ..., S_n; T_1, …, T_n of the required predicted levels P_i*, … , P_n*, as well as P_T due to changes in the actual level of staff training (P).

In other words, as soon as conditions (6) and (7) are not met in the training process, it is necessary to adjust the indicators P_1*, …, P_n* and, respectively, the minimum required number of situations S_1, ..., S_n. This simple adaptive control cycle of situation simulating process (arrow 2 in Fig.1) is the lower adaptation level of the organizing and conducting training process. At this level, an adaptive change of the simulated circumstance is provided depending on the level of staff training to perform each ET operations type.

The main purpose of the circumstance's simulating's process's adaptive management is to minimize the time of staff training for the required predictable levels to perform the main ET operations types. Thus, adaptive control of circumstance simulation process consists in change of the simulated situations parameters S_1, ..., S_n and, accordingly, working off operation each type for the minimum time intervals T_i, …, T_n.

If the lower limit of process adaptation (training conduct and organization) is not effective enough, i.e. conditions (6) and (7) are not constantly met, it is advisable, based on the actual level of staff training, to adjust training objectives (Z_T) and then the corresponding indicators P_1*, …, P_n*, T_1, …, T_n (S_1, ..., S_n). This cycle of the circumstance's simulating's adaptive process control belongs to the upper level of training (its organization and conduct) processes adaptation (arrow 3 in Fig.1). The adjustment of the required staff training level (P_T), the intensity of situations reproduction (λtr) based on the actual level of staff training to perform ET are upper adaptation level characteristic features.

The main purpose of situation simulation process adaptive control (Z_v) is to reduce staff training time to the required level for the implementation of ET in general:

$$Z_T : \begin{cases} P(P_1,...,P_n) \geq P_T(P_1^*,...,P_n^*); \\ \lambda_R = \lambda_{TR}\left(R = 1,2,...,N\right); \\ T = \sum_{i=1}^{n} T_i \to min. \end{cases} \tag{8}$$

According to mentioned conditions (8), an important task of circumstance's simulating's process's adaptive control's implementing the is determining the required predicted levels P_1*, …, P_n*.

This problem solving requires the investigation of the dependence between the staff training level and the time of the ET operations main types and on this basis to develop a method of optimal requirements distribution for personnel training levels to perform typical ET operations.

5. Conclusions

Thus, in the article are proposed ways to solve the scientific problem of building and organizing the DLS functioning with artificial intelligence elements for training specialists with using simulators or intelligent computer training systems for practical and laboratory classes. The requirements to the intellectual DLS are substantiated by the structural and parametric synthesis problem's solving and organization of their optimum functioning in the training course with using the offered criteria. The algorithm for the adaptive management organization of specialists' training process using the predicted training levels in order to reduce training time was offered for training staff with using of adaptive training tools.

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