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SYSTEM OF ADAPTIVE TASKS SELECTION IN THE TESTING PROCESS

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Abstract*—In this article, an automated knowledge testing system with adaptive parameters, which assumes the individualization of the training courses and test tasks content designed to control the knowledge of each learner is considered. Existing systems of automated testing of knowledge are considered. The analysis of existing approaches to the organization of adaptive testing is carried out. A system that has the ability to adapt to the level of knowledge of the learner and has the ability to select suitable topics for training is proposed. An algorithm for testing knowledge with the adaptation of the choice of topics depending on the level of knowledge of learner was developed and presented. The influence of the level of complexity of tasks on the criterion of knowledge of students is considered. The results of experimental use of the adaptive testing system and its impact on the level of knowledge control of learner are presented. An adaptive testing model using the apparatus of fuzzy mathematics is considered. The description of fuzzy characteristics of test tasks and functions of determining the level of learner training is proposed.*

Index Terms—Automated testing system; computer knowledge assessment; adaptive tests; knowledge testing algorithm, fuzzy logic.

I. INTRODUCTION

Due to the growth of technical progress, one of the main tasks is to improve the quality of teaching new technologies. One of the ways to solve this problem is the widespread use of computer technologies at all stages of training, in particular, in the process of testing knowledge.

Every day more and more new aviation systems are created, for which there are not enough qualified specialists. In order to avoid such a problem, it is necessary to provide quick and high-quality training that will allow achieving the most effective result in a short time, which, in consequence, will reduce the number of accidents through fault of insufficient qualification and increase the reliability of the use of modern systems.

Figure 1 shows a block diagram of an automated training system, one of the main elements of which is the knowledge control subsystem.

The knowledge control subsystem can work in two modes:

- test mode, when knowledge control is performed based on the results of test tasks;
- mode of knowledge control in the process of performing tasks on a functional or integrated simulator under teaching to work on specific equipment.

The first mode is used for pre-selection of learners.

The second mode is used for the final selection of learners for work on specific equipment.

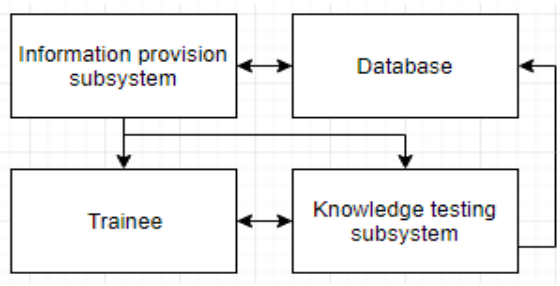

Fig. 1. Block diagram of training system

In this paper, knowledge control in the first mode is considered. The structural diagram of the knowledge testing subsystem is shown in Fig. 2.

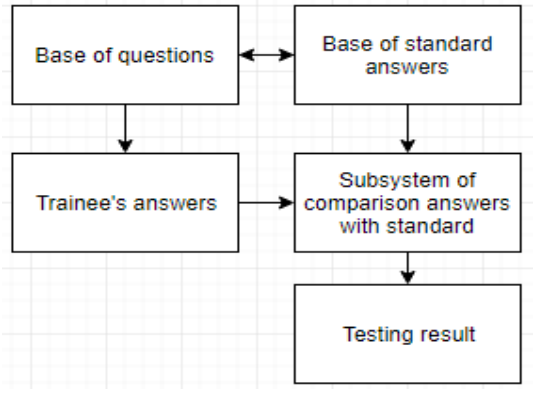

Fig. 2. Block diagram of knowledge testing subsystem

The computer testing [1] system should have the following characteristics: the availability of an interactive tool environment; multi-subject application; scalability; availability; friendly user interface; maintaining a database of test multi-level tasks; customized planning and management; achieving higher results and increasing motivation.

Considering the knowledge testing subsystem, it is possible to define two ways of its implementation – the traditional testing system and the adaptive one.

Adaptive testing is computer testing based on the principle of automatic selection of a subsequent task based on the responses to previous tasks, the level of difficulty of the next test task according to the current level of knowledge of the learner.

The essence of adaptive testing lies in the ability to respond to an individual learner, keeping it on targets with test tasks corresponding to the level of complexity. Improving the quality of the testing process is associated with its personalization, i.e. initial adaptation of tests to the current level of knowledge and personal characteristics of the learner.

Adaptive testing [2], in comparison with the traditional, allows you to determine the level of knowledge of the learner with fewer questions. When performing the same test, learners with a high level of training and learners with a low level of training will see completely different sets of questions: the first will see more complex questions, and the latter will see light ones.

Most modern testing systems are not adaptive, i.e. do not adjust to the level of knowledge of the learner but correspond to a rigidly structured template.

This article proposes a system of testing knowledge with elements of adaptivity that will change the educational trajectory of learners by selecting topics and questions with appropriate levels of complexity. Thanks to this approach, the information is easier and faster to absorb, which will increase the level of learning (the quality of mastering knowledge) and training (the amount of knowledge acquired).

To solve the problem of increasing the level of knowledge of learners for a minimum amount of time, an automated testing system with adaptive parameters is used.

II. Problem Statement

In the process of construction an automated system of adaptive testing, the following problems arise:

– minimization of tasks and training time;

– increase the level of knowledge of learners;

– reducing the cost of training.

Thus, the formulation of the problem of adaptive testing has the following form.

The tasks that are characterized by the following parameters are specified:

– i is a number of the training topic for a particular aviation system, $i = \overline{1, N}$;

– k the complexity level of the question, where $k = \overline{1, M}$;

– r_i is the number of the task from topic i, $i = \overline{1, N}$;

– r_{ik} is the task from topic i with complexity level k, $i = \overline{1, N}$, $k = \overline{1, M}$.

Complexity is a characteristic of a job that can be specified in two ways:

1) a clear quantification in the form of a certain number of points. Can be measured by integer or fractional number;

2) using fuzzy mathematics.

In the proposed system, a tool for estimating the complexity of tasks using fuzzy mathematics will be used.

The complexity of the task is estimated on a 100-point scale.

It is necessary to choose the optimal list of questions r_{ik}, corresponding to the current level of knowledge of the learner, in order to increase his level of knowledge and, in the end, to increase the criterion of knowledge:

$$I = \sum_{k=1}^{M} \sum_{i=1}^{N} a_{ik},$$

where a_{ik} is the number of correct answers for the ith topic with the kth level of complexity. Questions from the database are selected in accordance with the level of preparedness of learners, which is a characteristic feature of adaptive testing algorithms.

III. Existing Systems Review

At present, there is a sufficiently large number of automated testing systems, in which qualitative knowledge control is declared.

TestMaker [3] is a software complex for computer testing of knowledge, designed to create and edit tests included in training courses. TestMaker offers everything that is need to quickly create a set of test tasks for mastered material, for learning and controlling the knowledge of learners, it also allows to save and open previously created tests and make changes to them, save test results in text/encrypted format.

Advantages of the TestMaker system:

1) The TestMaker system is of a local nature, that is, to transfer all the data it is enough to make a copy

on an digital media and transfer it to another machine.

2) No user registration is required, which speeds up the work with this system.

3) It is a freely distributable software product that can be downloaded from the server.

The disadvantages of the system include:

1) Obsolete interface.

2) There is no possibility of splitting test tasks into groups (sections).

3) There is no possibility to set the weight characteristic of the test task.

4) There is no possibility to build reports on the results of testing.

5) There is no possibility of viewing the theoretical part before passing the test.

Indigo [4] is a professional tool for automating the process of testing and processing results, which is designed to solve a wide range of tasks: testing and control of knowledge. There is a demonstration version of the system, which can be downloaded on the official website, as well as purchase a licensed copy.

The main advantages of the Indigo system:

1) This system stores information about users of the system and can provide information about the passed tests by the user, and also issue a report on this information.

2. The program has an intuitive and modern interface.

3. It is possible to import questions from a file.

4. Breakdown of questions into groups and subgroups, which allows to set individual settings for each group.

Disadvantages of the Indigo system:

2) Program pay.

3) The large size of the program (reaches 125 MB without taking into account the tests).

4) There is no possibility to add additional types of test questions, except the main ones.

5) There is no possibility of modifying the program modules, integration of own blocks.

The problem of developing effective systems for adaptive testing of knowledge, despite the existence of existing systems, remains topical, due to the following factors: the relatively high cost of existing systems; the inability to create highly effective tests for the control of knowledge in special disciplines; unresolved issues of quality control of the proposed tests; lack of means of integration into a single integrated system of knowledge control.

IV. Problem Solution

To create an accessible and effective testing system, it is necessary to develop a structural diagram of the knowledge control system, in which it is necessary to adapt the adaptivity parameters programmatically.

The main purpose of the knowledge control system is to provide the learner with control tasks and determine his level of mastering the material. Knowledge control system consists of the following elements: a user interface, a processing block of listener action (PBLA), subsystem of control task formation (SCTF), block of comparison of answer with the standard (BCAS).

The control system of knowledge by means of testing, presented in Fig. 3, has the following algorithm of work:

– the control system sends a signal about the beginning of the assignment to the listener control tasks. In addition to the signal sends the information about the control topics on which the listener has to pass knowledge control, volume of control, its type;

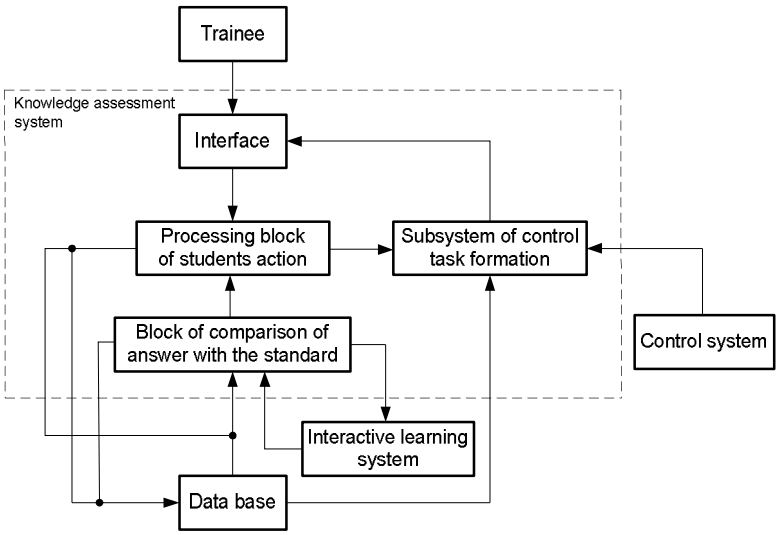

Fig. 3. Structural scheme of knowledge assessment system

– subsystem of formation control task makes a request to the database (DB), receives information for transmission to the listener (questions, answers, correct answer) and directs it to the interface;

– question is sent via the interface to the listener. The student answers the question by the use of the interface elements;

– information about the listener's answer via the interface enters the PBLA. If the question is a multi-level, from the PBLA the information about the listener action is sent to SCTF. Regardless of this the specific statistical information is saved in the DB. If the student pressed a button of the end of the answers, PBLA sends information to the BCAS;

– block of comparison of answer with the standard do request to the database about the standard solutions of specific control task. After receiving this information BCAS compares the standard and the existing results and enters the information about the comparison to the database.

Adaptive algorithms [5] allow the creation of tests with a variable number of tasks. Thus, the total time of passing the test is optimized.

A learner with a high level of knowledge should correctly answer a certain minimum number of complex questions in order that the testing system be able to make an appropriate assessment.

At the same time, for the learner who incorrectly answered the easy question, there is the possibility of randomly choosing the wrong option. Such an error should minimize the final result of testing, as it does not depend on the level of knowledge.

Thus, the level of learner's knowledge determines the complexity of the questions posed, and complexity in turn affects their number. Formally, this can be represented in the following form:

$$S_j = f_1(C_i), \qquad k_i = f_2(S_j),$$

where k_i is the total number of test questions for the ith tested; C_i is the level of knowledge of the ith learner; S_j is the complexity of the jth test question for the ith learner.

Every learner has his own training program, for this he has to solve an appropriate number of tasks for each topic.

The level of training depends on the following parameters:

- current level of preparation S;
- percentage of correct answers p;
- the complexity of the task T;
- response time for the task t.

All these parameters are fuzzy.

The application of fuzzy mathematics [6] makes it possible to describe more qualitatively the characteristics of both individual test tasks and tests in general, as well as to better interpret test results.

Thus, $S_1 = f(S, p, T)$ affecting as follows:

– the higher the percentage of correct answers, the higher the level of preparation;

– the higher the complexity of tasks, the higher the level of preparation.

If the number of given tasks is less than a certain critical number of tasks, which the learner must answer within the same level of complexity, then the following task is given to the learner. If the critical number of questions is exceeded, but the learner does not pass to a new level of complexity, then the training level of the learner is assumed to be equal to S_1, and he gets the estimate $R = R\ (S_1)$. This completes the testing procedure.

If the learner has transferred to the next level of complexity, then $S = S_1$ is set and a new set of tasks is issued. Thus, we have the procedure of adaptive testing (since the complexity of tasks varies depending on the correctness of the learner's answers), which uses the apparatus of fuzzy mathematics (because the concepts of the level of preparation, the correctness of the answer to the task, the complexity of tasks, and others are fuzzy). The complexity of the task and the level of preparation are independent and vary independently.

To create a test, it is necessary to use tasks of different types, such as: closed-type questions (alternative), questions for establishing consistency, for sequencing, open type (term definition, table completion, arithmetic expressions), situational issues (multi-step test). As a result, the test will consist of questions of different types and with different levels of complexity. Therefore, the evaluation of each task will differ depending on these parameters.

IV. RESULTS

Statistical data of a computerized testing system showed that with the systematic application of testing in knowledge assessment, the level of knowledge of learners is increased.

To check the effectiveness of the computer adaptive testing system, an experiment was conducted to compare the level of knowledge quality of learners with traditional and computer-based assessment.

Figure 4 shows the results of the assessment of knowledge in traditional testing, which was conducted in two groups – control and experimental.

To check the effectiveness of using the adaptive testing system, in the control group knowledge assessment was conducted by means of traditionally testing, and the experimental group used the computer system to assess the level of knowledge. The results are shown in Fig. 5.

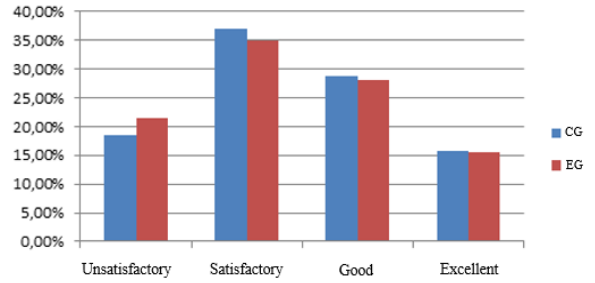

Fig. 4. The level of knowledge quality during traditional assessment

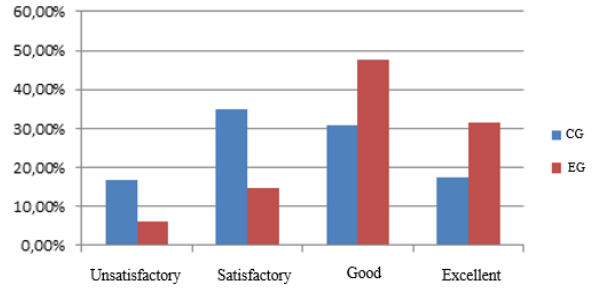

Fig. 5. The level of knowledge quality during computer assessment

Based on the presented experimental data, it can be concluded that the use of computer adaptive testing increases the training characteristics such as:

– efficiency: significantly fewer tasks are required to assess the level of preparedness of the subject;

– accuracy: the ability to assess the level of preparedness of each subject at his level with a minimum measurement error;

– reduced probability of guessing the correct answer;

– learners do not spend time and effort on tasks that do not correspond to their level of preparation (too easy for them or too difficult), therefore the influence on the results of additional factors (fatigue, anxiety, inaccuracy) decreases;

– the learners are more motivated and calm (because they are not offered tasks, which are too difficult for them).

V. CONCLUSION

Computer testing allows to use additional features when developing tasks and administering them in comparison with traditional blank testing. Thanks to adaptive testing, each learner gets his own set of tasks, so both the content and length of the test can differ for different learners, each learner is assessed individually (at his level) with a minimum measurement error.

Assignments that adaptive computer testing [7] offers the learner become more complicated gradually and ideally fit his or her knowledge and skills at each moment of testing, increasing the motivation to pass the test.

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В. М. Синєглазов, А. В. Кусик. Система адаптивного вибору завдань в процесі тестування

Розглянуто автоматизовану систему тестування знань з адаптивними параметрами, що передбачає індівідуалізацію вмісту навчальних курсів і тестових завдань, призначених для контролю знань кожного учня. Розглянуто існуючі системи автоматизованого тестування знань. Проведено аналіз існуючих підходів до організації адаптивного тестування. Запропоновано систему, що має можливысть адаптуватися під рівень знань того, хто навчається і має здатність підбирати відповідні теми для навчання. Був розроблений і представлений алгоритм тестування знань з адаптацією вибору тем в залежності від рівня знань тестованого. Розглянуто вплив рівня складності завдань на критерій знання учнів. Представлені результати експериментального використання системи адаптивного тестування і її вплив на рівень контролю знань учнів. Розглянуто адаптивна модель тестування, що використовує апарат нечіткої математики. Запропоновано опис нечітких характеристик тестових завдань і функцій визначення рівня підготовки учнів.
Ключові слова: автоматизована система тестування; комп'ютерне оцінювання знань; адаптивні тести; алгоритм тестування знань, нечітка математика.

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В. М. Синеглазов, А. В. Кусик. Система адаптивного выбора заданий в процессе тестирования

Рассмотрена автоматизированная система тестирования знаний с адаптивными параметрами, что предполагает индивидуализацию содержимого учебных курсов и тестовых заданий, предназначенных для контроля знаний каждого обучающегося. Рассмотрены существующие системы автоматизированного тестирования знаний. Проведен анализ существующих подходов к организации адаптивного тестирования. Предложена система, которая имеет возможность адаптироваться под уровень знаний обучающегося и обладает способностью подбирать подходящие темы для обучения. Был разработан и представлен алгоритм тестирования знаний с адаптацией выбора тем в зависимости от уровня знаний тестируемого. Рассмотрено влияние уровня сложности заданий на критерий знания обучающихся. Представлены результаты экспериментального использования системы адаптивного тестирования и её влияние на уровень контроля знаний обучающихся. Рассмотрена адаптивная модель тестирования, использующая аппарат нечеткой математики. Предложено описание нечетких характеристик тестовых заданий и функций определения уровня подготовки обучаемых.
Ключевые слова: автоматизированная система тестирования; компьютерное оценивание знаний; адаптивные тесты; алгоритм тестирования знаний.

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