

Розроблено концептуальний підхід до створення експертної системи ідентифікації окремих процесів інтелектуальної діяльності. Обґрунтовано вибір критерію для оцінки процесів досліджуваних інтелектуальних систем. На прикладі процесів поповнення бази знань і формування поведінкових відгуків запропоновано ряд показників для характеристики досліджуваних процесів у вигляді оцінки динаміки, максимально досягнутого рівня ефективності та показника, що характеризує фактори розсіювання уваги

Ключові слова: ідентифікація процесів інтелекту, оціночний показник, діагностика інтелектуальної діяльності

Разработан концептуальный подход к созданию экспертной системы идентификации отдельных процессов интеллектуальной деятельности. Обоснован выбор критерия для оценки процессов исследуемых интеллектуальных систем. На примере процессов пополнения базы знаний и формирования поведенческих откликов предложен ряд показателей для характеристики исследуемых процессов в виде оценки динамики, максимально достигнутого уровня эффективности и показателя, характеризующего факторы рассеяния внимания

Ключевые слова: идентификация процессов интеллекта, оценочный показатель, диагностика интеллектуальной деятельности

FORMATION OF A CONCEPTUAL APPROACH TO THE CREATION OF AN EXPERT SYSTEM FOR THE IDENTIFICATION OF THE PROCESSES OF INTELLECTUAL ACTIVITY

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1. Introduction

Intelligence is traditionally seen by scientists as a complex controlled system. Accordingly, the studies focused on the efficiency of its functioning are based on the principle of investigating the processes of intellectual activity as a single entity.

It is also evident that certain aspects of intellectual activity are quite amenable to individual development. This, in turn, means that activity of intelligence is based on the functioning of many specialized systems, each performing a specific function. Therefore, adequate evaluation of a certain complex system can be obtained only if this aspect of the intellectual activity is investigated independently.

It follows that in the evaluation of intellectual activity, analysis of processes and development of expert systems, it is necessary to rely on the identification of a highly specialized process. As source data for evaluation, it is preferable to have the measured input and output parameters, and the evaluation criterion used should be based on all the major significant factors: task complexity, possible error in the solution and solution time.

It should also be noted that evaluation index is crucial. Ideally, to eliminate subjectivity, it should be based on the measured quantitative parameters of the input task and output response.

Moreover, since the intellectual activity is aimed at solving practical tasks as efficiently as possible, evaluation

of the intellectual activity should be coordinated with the evaluation principles of those tasks, on the solution of which it is focused.

In this regard, the response time should be added to the considered factors, required for an adequate evaluation of the intellectual process.

It can also be noted that real practical and scientific tasks are usually solved under substantial uncertainty. That is, for example, production tasks not only have many various solutions, but the solutions are, as a rule, not perfect, and advancement to some standard is made by the method of successive approximation.

This fact imposes special requirements to the statement of a special class of tasks for the evaluation of intellectual activity in relation to the conditions of uncertainty and methods of its diagnostics. Proceeding from requirements of practical activity, evaluation of the studied process should be based not only on a comparison with some quality standard but on the approach that takes into account the task complexity, the permissible deviation from the quality standard and solution time. Because fast, but not an exact solution of practical tasks is often much more effective than the perfect solution in the far future.

This, in turn, implies the need to develop a different approach to the issues of problem statement in expert systems of evaluating the intellectual activity, methods of recording the necessary data, techniques of investigating and interpreting the obtained data. At that, the choice of

system-grounded evaluation criterion – indicator, coherent with the principles of evaluation of activity results in open systems is of fundamental importance.

2. Literature review and problem statement

Any educational process, in varying degrees, involves the mandatory presence of the equipment for diagnostics of the trainee and making judgments concerning conclusions and recommendations on adjusting the knowledge presentation methods [1]. In this case, the ergatic expert system is always formed.

Regardless of whether the tutor is an automated object or a qualified educational psychologist, the issues of evaluation and examination adequacy are based on several factors that cast doubt on the adequacy of this process. What is the object of research? Is the evaluation criterion system-grounded? Are all the factors influencing the evaluation process taken into account? Based on what indicators the expert evaluation is based...?

Objective evaluation of the input data (preferably quantitative), purposeful research of particular aspects of intellectual activity, objective evaluation of the results, taking into account the task complexity, deviations from the standard and the solution time, the development of diagnostic estimates of the result – all these issues need to be resolved when forming a conceptual approach to the creation of more advanced expert systems.

In this regard, the development of an approach that is based on the principles, providing maximum opportunity is necessary.

The IQ coefficient is one of the most popular evaluation indices of the intelligence level [2]. The purpose of this criterion was obtaining the opportunity to identify the intellectual level of the examinee [3].

However, this technology of measuring the level of intelligence does not adequately reflect the real contribution of many scientists to our understanding of the hierarchy of scientific thought. For example, “test results of A. Poincare showed his abnormality while he has already been recognized as a world’s famous genius mathematician. A. Einstein, T. Edison and many other famous people “Have failed the test”. The reason is that too high IQ or too high erudition virtually in any sphere only alienate the person from the true creative success” [4].

Many scholars who have studied the intellectual activity of the person, such as Ya. A. Ponomarev, D. B. Bogoyavlenskaya, A. M. Matyushkin, I. S. Leites, E. Torrance, J. Gettsels, P. Jackson, J. Guilford noted the independence of the obtained results of the IQ test from productivity in creative activity [5].

Herewith, the idea of IQ criterion is tried to be used for evaluating not only the level of intelligence but also the intellectual capital [6].

It is noted that in addition to the adequacy of evaluating the intellectual activity as a separate operation, there is the problem of evaluating the intellectual process as a sequence of operations [7, 8].

There are studies in the field of intellectual activity of the person aimed at developing the technologies for evaluating individual processes of intellectual activity. In particular, [9] proposes to explore some logically related operations of intellectual activity in order to form judgments about the pro-

fessional skills of the testee. At that, the time of processing and solving the test task is used as the evaluation criterion.

An attempt in the work [9] to divide the processes of intelligence, performing various types of mental activity is noteworthy. However, these attempts are focused on the evaluation of not the individual operation, but a sequence of operations of intellectual activity. Using the time of processing and solving the test task also reduces the area of possible application of the obtained results, since time is a reliable evaluation criterion only in those rare cases when other influencing factors are fixed. For example, the complexity of tasks is similar, and the task has a definite answer.

Thus, the problem of creating an expert system for the accurate identification of the processes of intellectual activity remains open to date and requires the development of a qualitatively new conceptual approach to its solution [10].

3. Purpose and objectives of research

The purpose of the work is to develop a conceptual approach to the creation of an expert system for the identification of the processes of intellectual activity.

To achieve the above purpose, it is necessary to gain a number of objectives:

- to present an example of individual processes of intellectual activity according to the types of their basic functions;
- to define the basic criterion for the identification of the processes of intellectual activity;
- to assess the dynamics of individual processes, the maximum level of the result and the impact of adverse factors on the example of the study of individual processes of intellectual activity, using the selected evaluation index.

4. Selection of research object

Attempts of scholars, aimed at investigating and evaluating the processes of intellectual activity, the need to improve the effectiveness of the educational process lead to the necessity of creating various models, which, according to the authors, show the internal structure of the human intelligence systems.

At the present stage of development of our knowledge and elaborated biotechnology, there are no possibilities for direct testing of this or that hypothesis, and, accordingly, for its validation or disproving using the methods of decomposition.

But, there are always indirect methods.

To effectively achieve the purpose, the human intelligence creates artificial controlled systems. And if we assume that the independent functioning of these targeted systems is based on certain general cybernetic principles, then, by exploring the general principles of well-functioning artificial systems, we can come to an understanding of the general principles of constructing the systems of intellectual activity.

In the field of synthesis of efficient controlled systems, scientists have found that the maximum efficiency of the system under investigation can be achieved only if the system has necessary degrees of freedom [11]. According to [12], optimization of the intellectual process can be provided by fulfilling two basic conditions:

- the system aimed at solving the intellectual task should perform a basic function;
- the source and the consumer of the results of the intellectual activity are systems of buffering data signals.

Specialists in the field of investigating the processes of intellectual activity have not considered this issue in such a statement, but the focus of their research shows that they perceive such an approach as a priori established fact [13].

In this case, the object of research (a process of intellectual activity in the form of a special system) and its system environment can be presented in the form of the controlled system.

Obviously, the “individual approach” and system grounded evaluation provide a theoretical opportunity to form an “intelligence passport”, and to come close to the issue of diagnostics, as well as making recommendations on the adjustment of the processes of intellectual activity.

Having analyzed a number of tasks, on the solution of which the intellectual activity of the person is focused, it is possible to identify a number of systems, the research of which can be done relatively independently:

- 1) deductive conversion system;
- 2) inductive conversion system;
- 3) decomposition problem solution system;
- 4) synthesis problem solution system;
- 5) abstract image formation system;
- 6) knowledge base enrichment system;
- 7) structural optimization system;
- 8) behavioral response formation system.

Certainly, the list is far from complete and is not intended as a full classification.

As the object of research, the paper examines the enrichment process and the behavioral response formation system.

It is now established [11] that any controlled system consists of three types of systems: source systems of technology products, conversion or buffering system and receiver systems of conversion products. In particular, a block diagram of the conversion system has the form (Fig. 1).



Fig. 1. Conceptual model of the block diagram of the conversion system

In turn, the source systems are divided into two classes: conversion product feed systems and energy product feed system (Fig. 2).

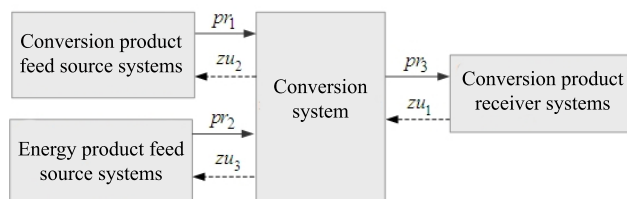


Fig. 2. Block diagram of the information product conversion system with the taxonomic structure of the technology product feed systems

Studies of conversion processes have shown [14–17] that, regardless of their specifics, the time during which

the conversion product achieves a predetermined quality, is the greater, the smaller the portion of the energy product. If the portion of the energy product is not changed, it is necessary to increase the number of fed portions of energy until the conversion product achieves a predetermined quality.

Such a situation is observed in the systems, providing the knowledge base enrichment. If the amount of assimilated information does not correspond to the specified quality, the process of assimilation is repeated until a predetermined quality is achieved. Each repetition operation is provided by feeding a certain portion of energy.

To speed up this process, it is recommended to raise the emotional level, which accompanies the assimilation process. Raising the emotional level of perception is, of course, also accompanied by an increase in energy related to the process of assimilation of the necessary information.

Thus, the knowledge base enrichment system (Fig. 3) corresponds to the general structure of the controlled conversion system (Fig. 2).

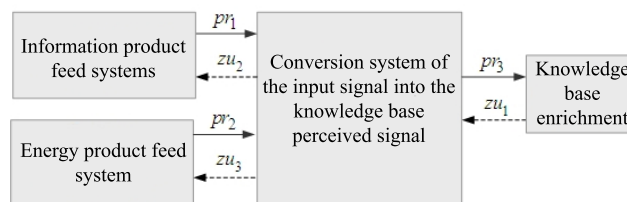


Fig. 3. Conceptual model of the controlled knowledge base enrichment system in the form of the block diagram

The process of formation of behavioral responses or skills can be explained in a similar way. The greater the frequency and periodicity of our attempt to form a behavioral response, trying to reach a predetermined reference value as its reproduction, the faster we will achieve the improved efficiency of the process under investigation.

To assess the dynamics of processes, their efficiency and factors affecting the stability of the intellectual activity, the processes of two interrelated systems: the knowledge base enrichment system and the behavioral response formation system were selected in the paper as research objects.

This choice was determined by the relative simplicity of the possibility of an accurate recording of the examinee’s response to the task and consideration of deviations from the reference value.

5. Selection of evaluation index

For evaluating the studied operations and processes, the previously developed relative indicator was selected as a criterion of identification [18].

$$Q = \frac{(k - \text{fol} - 1)^2}{kT^2}, \tag{1}$$

where Q is the evaluation criterion; k is the task complexity level; fol is the deviation of the result from the standard; T is the task time.

Using the evaluation index of own development is caused by a lack of analog.

In particular, the criterion logically adequately responds to change of each factor with the others being fixed (Fig. 4).

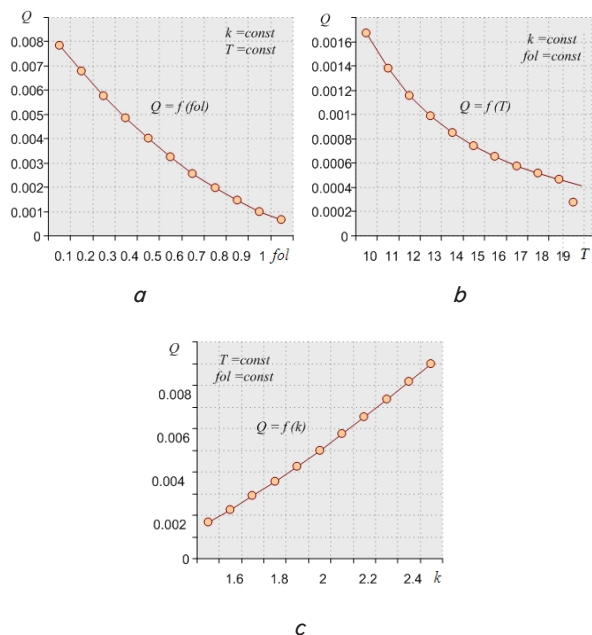


Fig. 4. Diagram of dependence of the value of evaluation index Q on basic components k, fol, T: a – the value of the indicator at the change of fol, T=const, k=const; b – at the change of the actual task time T, fol=const, k=const; c – at the change of the value of the task complexity coefficient k, with fol=const, T=const

In some cases, it is of interest to use an absolute indicator of the resource intensity of the task k [19].

6. Plan of experiment

To achieve the purpose of the research, the examinee was asked to learn a number of dialogues in a foreign language. To ensure the possibility of quantitative measurement of response, keyboard input that provides the process automation prospects in the future was used.

The process of conducting this experiment is determined by the following procedures:

- 1) familiarization with the text of the dialogue in a foreign language, learning new words (the first day);
- 2) typing of fragments was fixed in memory by repeated reproduction after passing the lower evaluation threshold of quality (under the experimental conditions seven repetitions were selected);
- 3) synthesis of the dialogue parts and cyclic typing of the full text until its faultless reproduction (the second day);
- 4) over the next days the text reproduction is brought to the specified quality level, determined by the upper limit of the evaluation index.

7. Results of studies of the processes of intellectual activity

The procedure of typing the fragment and the process of bringing the quality of typing the first test fragment to a pre-determined value of the evaluation index Q is shown in Fig. 5.

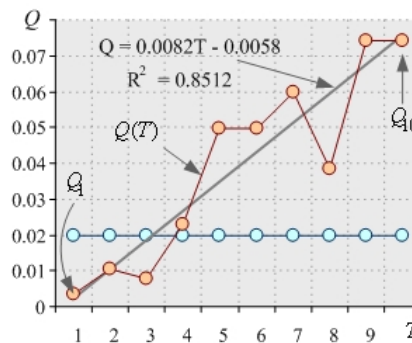


Fig. 5. Dynamic series of the efficiency development of the process of reproducing the portions of the accumulated information in the operating signal buffering system (the first day)

With every attempt to reproduce the text, there was a gradual reduction of mistakes, decrease in the time of text reproduction and, accordingly, an increase in the efficiency of the current process and the value of the evaluation index respectively.

Accounting the share of mistakes was performed by calculating the penalty function. The scaling factor of the penalty function was determined using the least-squares method.

To evaluate the characteristics of the process, it is proposed to use three main indicators.

Initially, the growth of the evaluation index can be approximated by a linear trend, so the process under investigation can be characterized as a growth factor, that is a derivative of the evaluation index $dQ/dT = (Q_{10} - Q_1) / (T_{10} - T_1) = 0,0078$.

Another important factor is the maximum value of the evaluation index, which determines the achieved level of efficiency within the process under investigation ($Q=0,74$).

One more characteristic indicator which does not directly determine the quality of the studied process, but shows some personal qualities, is a standard deviation $R^2 = 0,8512$. The essence of this indicator has yet to be identified, but one thing is clear that an increase in this indicator is likely to be associated with absent-mindedness, reduced concentration, distractions, or their combination.

All three of these indicators can serve as a basis for comparison of similar indicators of other respondents, and are the basis for the diagnostics of the studied process and making recommendations concerning its correction.

Similar operations were carried out for all other text fragments.

The next day the examinee's task was a complete reproduction of the text. Evaluation of reproduction operations in the form of a dynamic series is shown in Fig. 6.

To characterize the process dynamics, the same system of evaluation indices was used:

$$dQ/dT = (Q_{10} - Q_1) / (T_{10} - T_1) = 0,00106,$$

$$Q = 0,009817, R^2 = 0,858.$$

Fig. 7 shows the dynamics of the combined processes of the knowledge assimilation system on the second day of studies (System 1) and the behavioral response formation system (System 2) until achieving a specified level of quality.

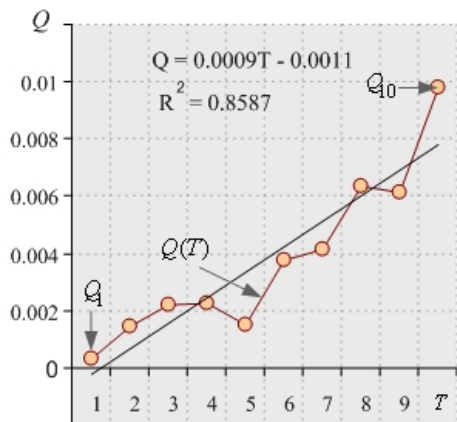


Fig. 6. Dynamic series of increase in efficiency of multiple typing of the full text performed on the second day

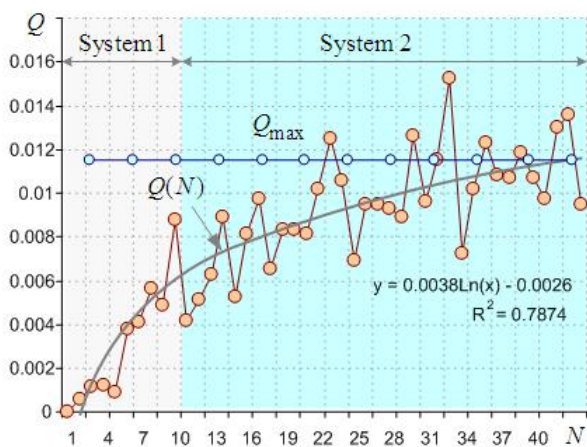


Fig. 7. Dynamics of the processes of the knowledge base process control system and the behavioral response formation system

As before, the process of formation of behavioral responses can be characterized by the derivative, the maximum level of the evaluation index and standard deviation.

8. Analysis of research results

The paper was not intended to develop an expert system for evaluating the processes of intellectual activity or accounting the completeness of relevant data. The main objective was to elaborate a conceptual approach to its construction. To implement the possibility of evaluation, diagnostics, and grounded comparison of quality and efficiency of the processes of intellectual activity, an attempt was made to highlight the controlled systems of intelligence and targeted effect on the studied process. Selection of research objects was based on the possibility of a full recording of response throughout the experiments.

According to the results, it is still difficult to clearly differentiate the areas of the process of knowledge enrichment and formation of skills for their use. This skill always accompanies the knowledge assimilation process. But using a single evaluation criterion, these processes can be investigated as relatively independent. Also, con-

sidering their interrelation at the stage of knowledge base enrichment, the data can be presented in the form of a single dynamic series.

In the author's opinion, the use of a single evaluation criterion for the identification of different, in terms of cybernetics, processes is important.

Thus, adequate evaluation of the knowledge base enrichment process is fundamentally impossible without the use of the evaluation criterion based on accounting the effect of mistakes and task complexity.

It would seem that time can be used as a criterion for evaluating the behavioral response formation process, but there are strong arguments against the use of different criteria in principle.

So, firstly, if the criteria are incomparable, it is impossible to get a picture of the overall dynamics of transient processes as shown in Fig. 7.

Secondly, using the "time" indicator, it is impossible to compare such seemingly similar processes as the assimilation of texts with the same information richness, but one of which is given in a foreign language, and another - in the native language.

Using the proposed criterion, the issue is solved by changing the coefficient k , responsible for evaluating the task complexity.

Moreover, in order to make a judgment about the impact of selected parameters for experiments of the first and second days, it is necessary to evaluate the whole process. This can be done only by using a single evaluation index, but modified for evaluating a set of sequential operations in a single process.

The work does not consider the issue of choosing the level of evaluation to determine the completion time of the task. The resolution of this issue will be discussed further using the developed criterion and methods of parametric optimization.

9. Conclusions

The paper presents a conceptual approach to solving the problem of the formation of the principles of creating an expert system for the identification, analysis and diagnostics of individual processes of intellectual activity on the example of evaluation of related processes of the knowledge base enrichment system and processes of behavioral response formation. The essence of this approach lies in implementing the evaluation of intellectual activity not as a single system entity, but an individual process of a set of specialized and interrelated systems by the system-grounded evaluation criterion.

The choice of criterion for the identification of the processes of intellectual activity based on accounting the task complexity, the deviation of the result from the reference value and the time of the evaluation operation was substantiated.

Diagnostic indicators for evaluating the dynamic series, reflecting the evaluation of the process of knowledge base enrichment and behavioral response formation in the form of a derivative of growth rates of the evaluation index, evaluation index maximum and standard deviation of the data in relation to the selected trend were proposed.

Directions for further research were outlined.

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