UDC 681.51:351.814.33 **doi: 10.20998/2522-9052.2018.3.05**

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IMITATION MODEL OF SUPPORT FOR DECISION-MAKING BASED ON ASSESSMENT OF THE SITUATION BY OPERATORS OF THE AUTOMATED AIR TRAFFIC CONTROL SYSTEM

Significance. A human-operator cannot conduct a situation assessment in a timely manner and to react in a proper manner when situation changes. The problem is worsening with the uncertain procedure of selection of dispatchers for duty shifts in control centers and their adequate preparation to carry out the tasks for intended purpose. This doesn't allow to reach the adequate level of competency during the process of their professional activities. **Aim of the article**. Developing an imitation model of the operator's complex activities to make a decision based on the situation assessment. **The results of the work.** The analysis of automated air traffic control system (AATCS) operator activities while assessing the situation with use of existing automation complexes allowed to identify following limitations of informational support of AATCS, which are influencing the effectiveness of its work. Most of the time of situation assessment (up to 41%) is spent by operator to receive additional information from another decision makers and informational elements, showed as part of informational model (IM). These time expenditures are due to low level of information content of information elements presented as part of IM and which are not corresponding to the character of the operator's activity in situation assessment. Methods for reducing the errors of the ACS operator can be divided into the following groups: automation of the most complex operations; introduction of information redundancy at the stage of designing systems for ensuring operators activities; increasing the workload of operators; advanced training for the operator; increased responsibility for errors with increasing interest in error-free operation etc. **Conclusions.** The generalized analysis of the operator's activity is conducted, the features of the operator's work with the information model are marked; the directions of the conceptual model formation in the decision-making process during the situation assessment are determined; simulation modeling has been carried out and a model of the operator's activity has been developed for the study of the activities of decision-makers during the situation assessment; giving the estimation of time expenses for performance of the various actions connected with the analysis of information models in various conditions.

Keywords: simulation modelling; operator activity; situation assessment; decision-making.

Introduction

Significance. The problem of ensuring the required indicators of the effectiveness of decision-making by operators of the automated air traffic control system is being thrown into sharp relief recently. Both physically and morally outdated automated systems at the given level of command results into a slow reaction in critical situations and information lags. As a result – a human-operator cannot conduct a situation assessment in a timely manner and to react in a proper manner when situation changes. The problem is worsening with the uncertain procedure of selection of dispatchers for duty shifts in control centers and their adequate preparation to carry out the tasks for intended purpose. This doesn't allow to reach the adequate level of competency during the process of their professional activities.

Aim of the article. Developing an imitation model of the operator's complex activities to make a decision based on the situation assessment.

Literature analysis. The development and description of models of operator activity in man-machine systems has been devoted to a sufficiently large number of works, for example [1–4]. Series of works [1, 2] are devoted to the principles and theoretical foundations of the formation of human activity models, others are looking on models of simple actions or processes that are elements of a complex human activity. Models of complex systems [5, 6] are usually formed on the basis of the application of the theory of queuing systems. Such models allow us to obtain generalized characteristics of the system and its "human" link (average service time of applications, probability of service, etc.). At the same time, the reliability of studies of air traffic control systems largely depends on the degree of detailed consideration of human activities in the system. The development and implementation of simulation models of complex activities of the operator [2, 7] became possible with use of the achievements of modern information technologies.

Main part

In order to estimate the influence of informational models (IM) quality on the situation assessment conducted by the operators of the automated air traffic control system (AATCS) we will analyze main processes related to them. In the system being under consideration, decision maker's (DM) activities are related to the perception and analysis of the IM environment and its fragments. Materials in the field of ergonomics and human factors engineering are devoted to analysis of these activities [3]. Many DMs can take part in situation assessment during the process of obtaining information about current air situation, air objects, airfield objects etc.

In consequence of this, during the analysis of DMs activities it is important to take into account group hierarchical character of their activities and special aspects of controlmen and analysts activities.

Mark out a set of features, which are present while working with environment informational model: during the assessment DM is correlating received data to really possible results; data is being decrypted during its analysis. Herewith, in some instances, human can reconstruct several parameters which have not been present at the IM;

basing on the operational image of situation status and experience, DM can predict changes in the situation and, therefore, the emergence of new information; assessing the complex situation, the DM is acting on the assumption of more extensive information than the one, he is getting from IM; on the basis of previously gained knowledge and experience, DM is armed with additional intelligence about possible situation condition and objects under control in comparison with those displayed at the informational model.

Data received from IM together with additional intelligence is utilized as a basis to form a conceptual model (CM) of the analyzed object (current situation) [9] which is specifying DMs' activities. This way, IM is specifying only a part of CMs' content and serves as a basis for its forming.

Conceptual model is helping the DM to understand the whole amount of information on current situation and represents a basis to decision-making when determining the variant of control actions based on the situation analysis. In its turn in order to assess the situation DM has to create a particular CM based on gathered and processed data about current situation.

The process of forming the CM used to assess the situation by DM is influenced by [10] current air situation, active tasks, sophistication of the situation, flights, different in terms and conditions: normal conditions and low flight intensity; normal conditions and average intensity of flights; complex conditions and maximum intensity of flights. Variation of difficulty of the situation will influence on the order of situation assessment and will define the necessity to attract other AATCS operators to decision-making process, which is caused by: absence of specified beforehand methods how to solve current task; lack of beforehand specified pieces of information required to assess the situation; high tempo of situational changes, which leads either to necessity of constant adjustments of CM or to its significant simplification; peculiar properties of the intellectual character of DMs activities during the creation of CM aimed to choose an optimal decision on situation assessment depending on the difficulty of the situation.

We will carry out an analysis of the process of situation assessment by the AATCS operator in difficult conditions with the maximum intensity of flights. Received results of the study of the process of situation assessment will be used to establish the expenditures time required to carry out actions related to assessment of DMs.

Situation assessment is a complicated process, which main aim is to establish its true state for the AATCS operator's benefit. The complexity of this process is due to involvement of a number of interrelated elements of the information support system (ISS) for the situation assessment and each of them affects, to a greater or lesser degree, the achievement of the goal.

In its turn, the effectiveness of situation assessment is also conditioned by the uncertainty of determination of its difficulty, dynamics of change, for reliable estimation of which it is necessary to use various IM and to involve other operators of the air traffic control center (ATCC). Content and degree of detail or generalization of information about current situation are affected by the conditions, assessed by the DM.

Research on the process of situation assessment by the DM can be conducted in several ways [11, 12].

The most objective results of the DM's activities assessment can be received during the researches of his activities at the ATCC, which is economically impossible.

It is impossible to build the analytical model of DM's activities during situation assessment due to absence of adequate ways of formal description of DM's intellectual activity, absence of strict algorithm of his activity, impossibility to calculate all factors which are affecting his activity [2, 4, 11].

Thus, the only one way to carry out researches of DM's activity is to conduct simulation modeling.

Imitation model allows to take into account group character of activity during situation assessment, DM's capabilities on processing and deciphering of the information, represent his particular qualities on work with different information display devices (IDD), take into consideration necessary time expenditures needed to conduct conversion from IM to CM.

DMs' activity model during solving the task of air traffic control in complex situation with maximum intensity of flights can be represented as a graph (Fig. 1). The considered model of DMs' activity in situation assessment can formally be defined as follows:

$$P = \left| p_{ij} \right|, \quad (1) \qquad T = \left| t_{ij} \right|, \quad (2)$$

where P – a matrix of possibilities of transition between events ij; T – matrix of time spent on work, while transiting from event i to event j; p_{ij} – possibility of transition from event i to event j; t_{ij} – time spent on transition from event i to event j; i = j = N – corresponds to an amount of states in which DM can be.

On Fig. 1 values of p_{ij} and t_{ij} are represented as w_{ij}, where w_{ij} (p_{ij}, t_{ij}).

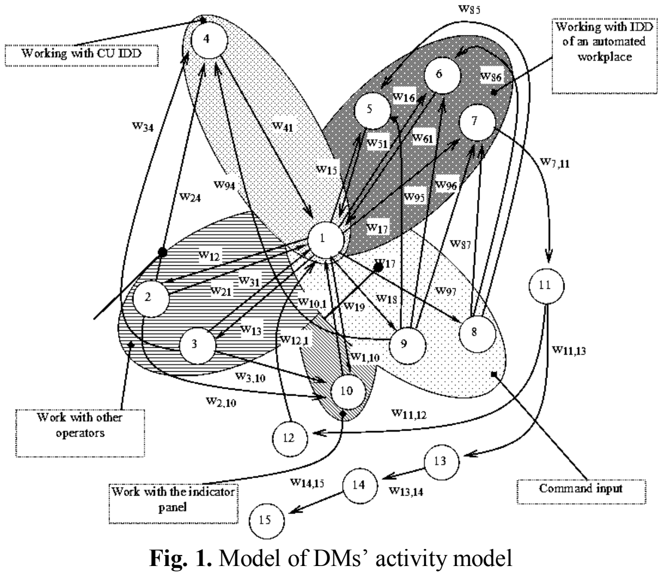

Fig. 1. Model of DMs' activity model during situation assessment

It is impossible to establish the order and sequence of the actions, performed by the DM in the proposed model. Therefore, in general case, transitions between p_{ij} states are equally possible. Suppose that a variant of the complexity degree – are normal conditions with a low intensity of flights. In this way, the situation will be relatively simple, DM is well-informed about it and can analyze and decide on the information, displayed on the CU IDD. Suppose that in this case transition $w_{9,11}$ has next characteristics: $w_{9,11}$ (0,75; $t_{9,11}$). Herewith, the sum of the probabilities of the transition from state 9 to other states is equal to 1. Vertices of the graph correspond to events, such as “information, presented with collective use information display devices (CU IDD), apprehended”, “Input of commands into the computer is completed”, while edges of the graph correspond to possibilities of transition from one event to another and also time expenditures on each transition. Determine the content of the vertices of a given graph, as well as the meaning and sequence of transitions between vertices (Tables 1, 2).

Table 1 – **Events in the process of situation assessment**

Events	Event content
1	The beginning of the automated control system operator’s work for solving problems of situation assessment
2, 10	Perception of information displayed on CU IDD
3, 11	Searching for additional (up-to-date) information about situation, also changing the content (form) of the information showed on CU IDD upon operator’s request.
4, 12	Searching for additional (up-to-date) information about situation of other operators, also changing the content (form) of the information showed on CU IDD upon operator’s request.
5, 13	Assessing the situation basing on information, presented on AW IDD.
6, 14	Input of control commands, to change the composition of information displayed on the IDD
7, 15	Other operators’ work on receiving required information about the situation
8, 16	Other operators’ work on clarification of quality of sources of information about the situation, actions, conducted to improve the quality of information about the situation
9	Operator’s transition to solution of the control actions problem
17, 18	Work of an operator with other operators on proposals development to improve the quality of provided information.
19, 20	Report of conclusions made from situation assessment to the chief of duty shift with proposals on the degree of impact on air objects and their agreement
21	End of work for solving problems of situation assessment

Table 2 – **Contents of transition from state to state**

Transitions	Actions, taken by DM when transiting from one state to another
W_{12}, $W_{9,10}$	Operator’s assessment of the situation with CU IDD
W_{21}, $W_{10,9}$	Finding more information about the situation by the operator
W_{13}, $W_{9,11}$	Referring to other DMs for searching or clarifying information about the situation, or to change the content of the information, shown on CU IDD
W_{14}, $W_{9,12}$	Referring to other DMs to receive information about situation or to change the content of the information, shown on CU IDD
W_{15}, $W_{9,13}$	Assessing the information shown on AW IDD
W_{65}, W_{56}, $W_{13,14}$, $W_{14,13}$	Input of commands to change information display parameters on AW IDD and control (processing) of the command input results.
W_{73}, W_{37}, $W_{15,11}$, $W_{11,15}$, W_{48}, W_{84}, $W_{12,16}$, $W_{16,12}$	Searching and receiving additional information about situation from other DMs.
$W_{9,17}$	Information about situation has been assessed by the operator.
$W_{18,17}$, $W_{17,18}$	Stating the tasks on specification of control actions.
$W_{17,19}$	Report of conclusions made from situation assessment to the chief of the duty shift.
$W_{19,20}$, $W_{20,19}$	Refinement of the results of situation assessment with the chief of the duty shift
$W_{19,20}$	Input of the control commands into the computer, end of the situation assessment phase.

In case of complex conditions and maximum intensity of flights, it is possible to suggest a decrease of information volume, displayed on the IDD. This determines the need of the operator to contact other DMs for information. Researching the model when possibilities of transitions p_{13}, $p_{9,11}$, p_{14}, $p_{9,12}$ sequentially take values (0,25; 0,5; 0,75), while in each experiment the sums of the probabilities of the transition from one state to another are equal to 1. Consider the obtained results of the study of the proposed model of the ATC operator's activity.

Based on the results of the imitation modeling, the mathematical expectation of the time spent working with CU IDD ($\overline{t}_{CU\ IDD}$) is $\overline{t}_{CU\ IDD}$ =75,7 – 863,15 sec.

Allocation of time, spent by DM on processing the information presented on the IDD received with use of both researched model of an ATC operator activities and from expressions (1, 2) for different situation options is presented on the Fig. 2.

On diagrams, presented on the figures we can see allocation of time expenditures of operator working with other DMs in standard conditions; in normal conditions with low intensity of flights; in conditions of situation assessment under normal conditions and the average intensity of flights and during situation assessment in difficult conditions and the maximum intensity of flights respectively.

Thus, situation assessment in normal conditions with low intensity of flights; under normal conditions and the average intensity of flights, time expenditures remain practically unchanged and are equal to $\overline{t}_{DM} \approx 158{,}33$ sec.

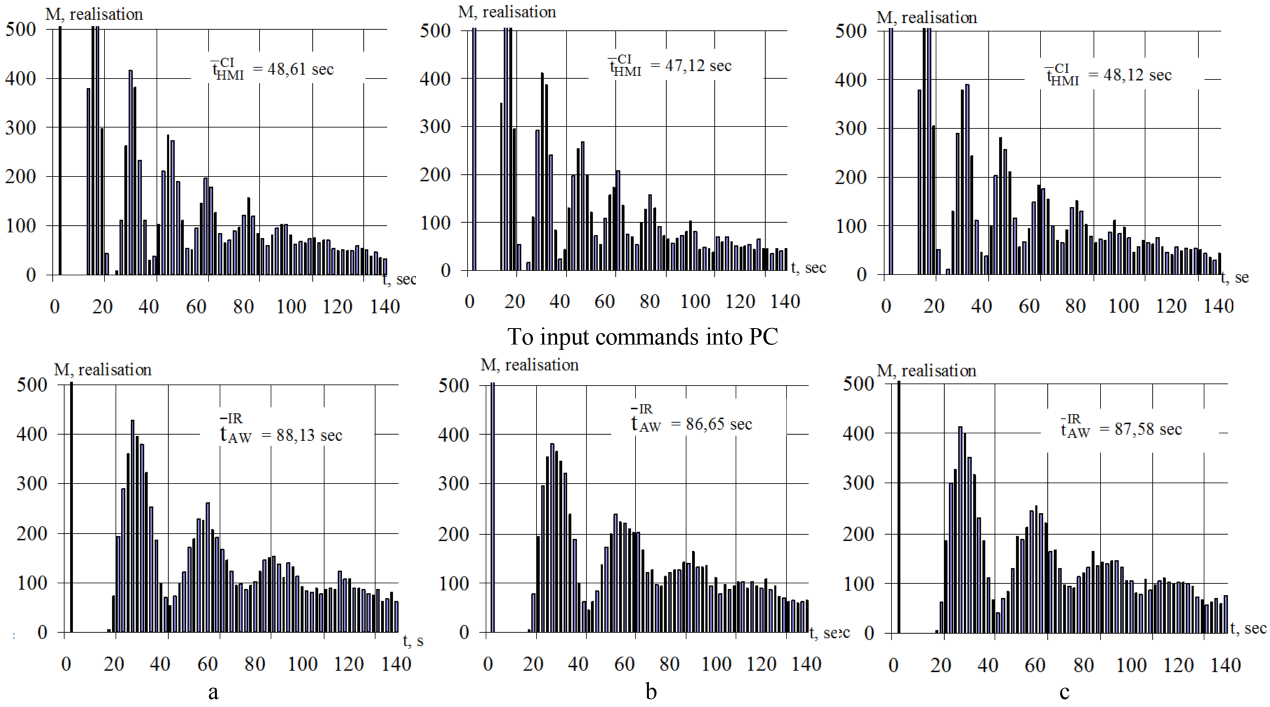

Fig. 2. Time expenditures to assess information: a – on IDD; b – on IDD in normal conditions; c – on IDD in difficult conditions

This is due to the inability of the DM to conduct an independent comprehensive assessment of the situation and the need for a great deal of time to process information and to create CM. DM produces a large number of decoding operations, reveals the structural elements of the situation, tries to process the information presented both on CU IDD and received from other DMs. From Fig. 3 we see that time expenditures on work with CU IDD are decreasing as the situation becomes more complicated.

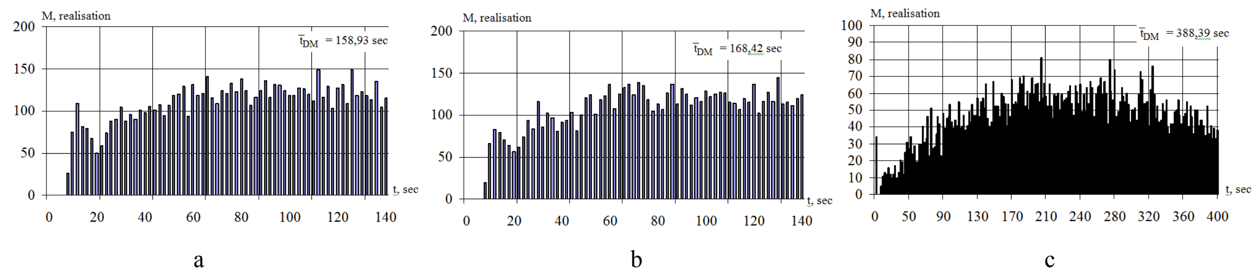

Fig. 3. Allocation of time expenditures of operator working with: a – other DMs;
b – other DMs while assessing situation in normal conditions; c – other DMs while assessing situation in difficult conditions

Therefore, it is necessary to distribute the task of assessing the situation between the operators of the duty shift, in order to ensure a time reserve for the establishment of the DMs' CM. In the study of the developed model of the DM activity, an estimation of the time spent on the evaluation of the information presented on the operator's automated workplace IDD of the automated control system and on the input of commands to the computer. The allocation of time for the situation assessment using the automated workplace and the input of commands are presented on the fig. 4.

Mathematical expectation of time spent by DM for processing information about the situation is $\bar{t}_{HMI}^{IR} \approx 87$ sec, and mathematical expectation (ME) of time spent for input of commands and control of their accuracy is ($\bar{t}_{HMI}^{CI}$) - $\bar{t}_{HMI}^{CI} \approx 48$ sec. Obtained results demonstrate that time expenditures on work with IDD of automated workplace and input of commands into computer practically do net depend on the degree of situation's complexity. This, in its turn, leads to the fact that main sources of information are CU IDD and other duty operators. Automated workplace is used to solve additional tasks of situation assessment.

The analysis of DM activities made it possible to establish the following: an operator of automated ATC workplace is performing actions and operations to assess the information, shown on CU IDD and of individual use; performs independent actions to change the display settings on IDD of the automated workplace, assesses their results; collects information and corrects its displaying on CU IDD with help of other operators, and receives from them information about the situation, absent on the IDD. Time expenditures to solve mentioned tasks: processing information, displayed on CU IDD will take $\bar{t}_{DM}$ = 75,7 – 863,15 sec, which is 50% from the time, spent to solve current tasks; analysis of the information, displayed at the computer-automated workplace takes 13% from the overall time.

$\overline{t}_{HMI}^{IR} \approx 87$ sec are spent on data analysis, which is 9,4% from the overall time, input of commands into the computer and analysis of their accuracy takes $\overline{t}_{HMI}^{CI} \approx 48$ sec or 4,6 % from overall time; time spent on work with other operators is equal $\overline{t}_{DM} = 158{,}33 - 388{,}39$ sec or 37% from overall time.

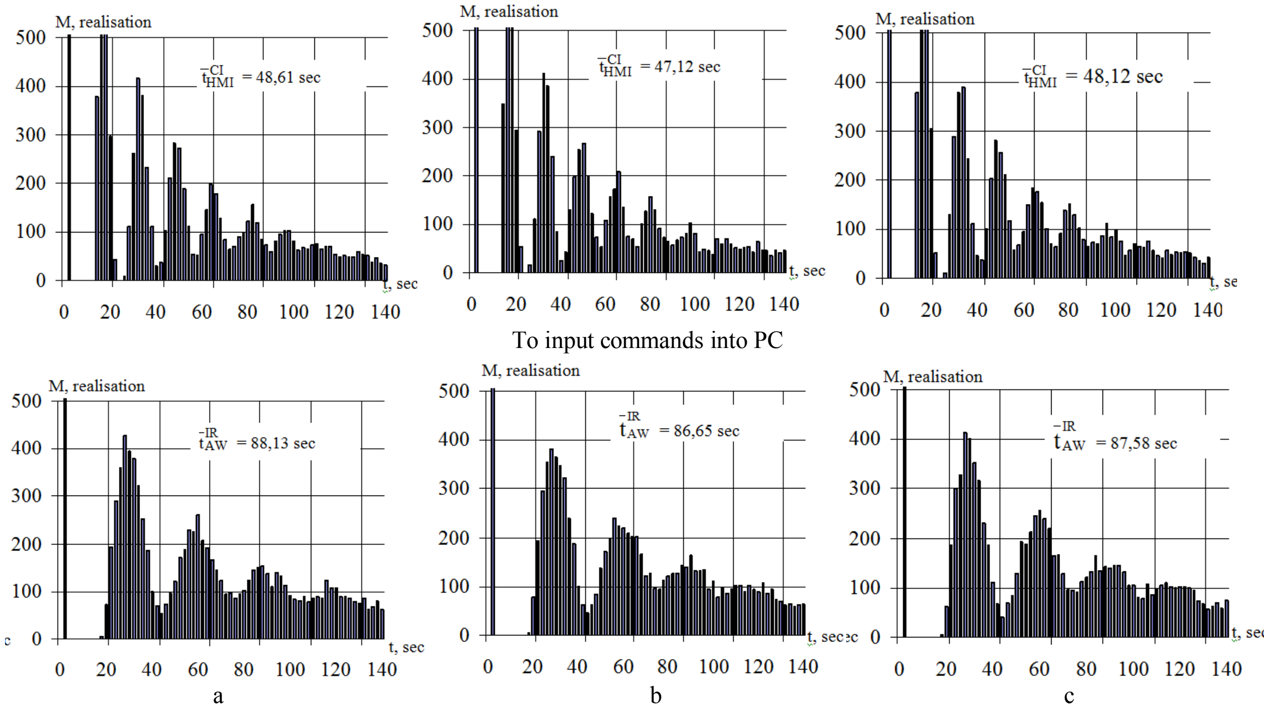

Fig. 4. Time expenditures to assess information: a – on IDD; b on IDD in normal conditions; c – on IDD in difficult conditions

Conclusions

The analysis of AATCS operator activities while assessing the situation with use of existing automation complexes allowed to identify following limitations of informational support of AATCS, which are influencing the effectiveness of its work.

Most of the time of situation assessment (up to 41%) is spent by operator to receive additional information from another DMs and informational elements, showed as part of IM. These time expenditures are due to low level of information content of information elements presented as part of IM and which are not corresponding to the character of the operator's activity in situation assessment.

Significant time expenditures to input commands to change parameters of displaying IM on the computer-automated workplace.

Necessity to conduct big amount of operations to decrypt information when creating CM, caused by discrepancy of the way information is displayed in the IM to the peculiarities of information processing by the AATCS operator.

Limited use of automation tools of ATCC to select data and form IM, controlling parameters of displayed information on CU IDD.

Low automation of solving these tasks leads to sufficient time expenditures to solve them.

Wherein human made mistakes are subdivided into logical (wrong decisions), sensorial (false information perception) and operational, or motoric (wrong realisation of the decision). Intensity of human made mistakes can vary widely from 1-2% to 15-40% of overall amount of operations, conducted when solving the task.

Methods for reducing the errors of the ACS operator can be divided into the following groups:

- automation of the most complex operations;
- introduction of information redundancy at the stage of designing systems for ensuring operators activities;
- increasing the workload of operators;
- advanced training for the operator;
- increased responsibility for errors with increasing interest in error-free operation etc.

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Надійшла (received) 21.06.2018
Прийнята до друку (accepted for publication) 22.08.2018

Імітаційна модель підтримки прийняття рішень з оцінки обстановки операторами автоматизованої системи управління повітряним рухом

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Актуальність. Людина-оператор не може своєчасно проводити оцінку ситуації і реагувати належним чином при зміні ситуації. Проблема посилюється невизначеною процедурою відбору диспетчерів для чергових змін в центрах управління і їх адекватної підготовкою до виконання завдань за призначенням. Це не дозволяє досягти достатнього рівня компетентності в процесі їх професійної діяльності. **Мета статті.** Розробка імітаційної моделі комплексної діяльності оператора для прийняття рішення на основі оцінки ситуації. **Результати роботи.** Аналіз діяльності оператора при оцінці ситуації з використанням існуючих автоматизованих комплексів дозволив виявити наступні обмеження інформаційної підтримки системи, які впливають на ефективність його роботи. Велику частину часу оцінки ситуації проводить оператор для отримання додаткової інформації від інших ОПР та інформаційних елементів, показаних як частина ІМ. Ці часові витрати обумовлені низьким рівнем інформаційного наповнення інформаційних елементів, представлених як частина ІМ, і не відповідають характеру діяльності оператора при оцінці ситуації. Методи скорочення помилок оператора АСУ можна розділити на наступні групи: автоматизація найскладніших операцій; впровадження інформаційної надмірності на етапі проектування систем для забезпечення діяльності операторів; збільшення робочого навантаження операторів; підвищення кваліфікації для оператора. **Висновки.** Проведено узагальнений аналіз діяльності оператора, виділені особливості роботи оператора з інформаційною моделлю; визначено напрями формування концептуальної моделі прийняття рішень щодо оцінки обстановки; для дослідження діяльності осіб, що приймають рішення при оцінці обстановки, проведено імітаційне моделювання та розроблена модель діяльності оператора; наведено оцінку витрат часу на виконання різних дій, пов'язаних з аналізом інформаційних моделей в різних умовах.

Ключові слова: імітаційне моделювання; діяльність оператора; оцінка обстановки; прийняття рішення.

Имитационная модель поддержки принятия решений по оценке обстановки операторами автоматизированной системы управления воздушным движением

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Актуальность. Человек-оператор не может своевременно проводить оценку ситуации и реагировать надлежащим образом при изменении ситуации. Проблема усугубляется неопределенной процедурой отбора диспетчеров для дежурных смен в центрах управления и их адекватной подготовкой к выполнению задач по назначению. Это не позволяет достичь достаточного уровня компетентности в процессе их профессиональной деятельности. **Цель статьи**. Разработка имитационной модели комплексной деятельности оператора для принятия решения на основе оценки ситуации. **Результаты работы.** Анализ деятельности оператора при оценке ситуации с использованием существующих автоматизированных комплексов позволил выявить следующие ограничения информационной поддержки системы, которые влияют на эффективность его работы. Большую часть времени оценки ситуации проводит оператор для получения дополнительной информации от других ЛПР и информационных элементов, показанных как часть ИМ. Эти временные затраты обусловлены низким уровнем информационного наполнения информационных элементов, представленных как часть ИМ, и не соответствуют характеру деятельности оператора при оценке ситуации. Методы сокращения ошибок оператора АСУ можно разделить на следующие группы: автоматизация самых сложных операций; внедрение информационной избыточности на этапе проектирования систем для обеспечения деятельности операторов; увеличение рабочей нагрузки операторов; повышение квалификации для оператора. **Выводы.** Проведен обобщенный анализ деятельности оператора, выделены особенности работы оператора с информационной моделью; определены направления формирования концептуальной модели принятия решений по оценке обстановки; для исследования деятельности лиц, принимающих решения при оценке обстановки проведено имитационное моделирование деятельности оператора; приведена оценка затрат времени на выполнение различных действий, связанных с анализом информационных моделей в различных условиях.

Ключевые слова: имитационное моделирование; деятельность оператора; оценка обстановки; принятие решения.