Methods of information systems synthesis

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METHOD DEVELOPMENT OF THE INFORMATION MODELS' DESIGN AND SYNTHESIS FOR INFOCOMMUNICATION SYSTEMS OF AIR TRAFFIC CONTROL

Abstract. The present article describes research of information models' design and synthesis as a necessary component of the information provision system for decision-makers in infocommunication air traffic control systems. It gives analysis of possible information models' construction and suggests linear or hierarchical structure for relatively simple situations. We use combined information model that permits to take into account possible changes in any situation, which lead to a significant increase of displayed information. The present study shows interrelations that give an opportunity to evaluate the characteristics of information models at the stage of their ergonomic design and to determine the number of information elements in a single displayed program, considering the minimization of search time of the specified element. It suggests possible variants of common use for different ways of information display of an individual as well as group and collective usage.

Keywords: information model; air situation, information element; display, activity of operators; air traffic control.

Introduction

Problem statement. Infocommunication Systems of Air Traffic Control (ICS ATC) usually use complex information display means (IDM) which include display devices of collective, group and individual usage. Use of a wide range of IDM of collective and individual usage provides a unified basis for assessing the main properties of the air situation (AS), contributes to determination of the degree of emerging situations' criticality and timely resolution of partial tasks by all operators involved in the preparation process of decision. This ensures the implementation of a single goal principle by all links of the system, as well as effective performance of management tasks [1, 4, 9–12].

Qualitative and efficient tasks' solution by operators of ICS ATC directly depends on the state of information security system (ISS). One of the basic directions of ISS improvement is the necessity of adapting the system of information models (IM) to the activity conditions and the tasks' specifics.

Research publications. There is a number of works [2, 3, 5–8, 13–22] describing improvement of information support for problems' solving in infocommunication complexes and systems' operation. The authors substantiated design methods of individual elements of the IM system for a considered class and made recommendations for their ergonomic qualities' improvement. However, a number of fundamental points specific to the operators' tasks as well as specificity of functional tasks in the formation of AS information models are not sufficiently considered.

In addition, the cited works are focused only on the IM design characterized by a change in the state of controlled objects; IM formation doesn't consider possibility of AS changes; composition, number of IM information elements and their placement can vary in a wide range. In our study, we are dealing with the IM, which is characterized not only by the change in a wide range of possible states of controlled objects, but also in the total number of displays.

The research aims and objectives. In practice IM AS, which is formed in the area of responsibility of the relevant management body, can be considered as distributed among different IDM. So it sets a problem of the distribution of AS information characteristics between means of information display to ensure the maximum effectiveness of situation assessment by the decision-maker (DM).

The structure of the distributed information model of the situation should ensure a prompt, reliable and adequate perception of the situation; operators of Infocommunication Systems of Air Traffic Control should have a coherent perception of the situation.

The purpose of the study is to develop a method of the information models' design and synthesis for informational decision support in ICS ATC, which, unlike existing ones, should take into account the stages of activity and the specifics of the tasks solved by the operators in order to improve the ISS quality of DM activities.

Research bases

It is appropriate to use a linear or hierarchical structure of the IM to solve relatively simple tasks of air traffic control. Its advantages are realized by explicit linear connections between elements of controlled objects and the process of assessing their condition. Also, the linear structure is often used to construct the IM of constituent elements' technical condition and complex technical systems in general.

Number of generalization levels (K) of such structure depends on the total number of information elements (the amount of data output that characterizes the operator's tasks) and the number of characters represented in a single IM display program (A), that is

$$K = f(N, A, M). \qquad (1)$$

N – total number of information elements; M – number of display programs.

The number of information elements (IE) in one display program is calculated by:

$$A = \sqrt[K]{N}. \qquad (2)$$

The number of display programs in this case can be defined as follows:

$$M = \sum_{i=1}^{k} A_i^{i-1}. \qquad (3)$$

These correlations provide an opportunity to evaluate the characteristics of the IM structure at the stage of its ergonomic design and determine the number of information elements in a single display program, taking into account the minimization of the specified elements' search time.

The structure of such IM corresponds to the a priori known display programs. But situation instability limits the usage scope of such structures.

In a difficult situation, when there may be several relatively independent AS evaluation tasks for DM, we may need additional information displayed in different IM fragments. In this case, it is advisable to use the functional structure of the IM.

Usually in practice the linear and functional structures of the IM are used jointly for the satisfactory conditions of the AS [9 – 12]. We can use elements of a linear structure to detail the IM fragments.

It is appropriate to use the IM combined structure to take into account possible changes in situations that result in the need for a significant increase in the amount of information to be displayed. The suggested variant of the IM combined structure is shown in Fig. 1.

The IM system structuring ensures the implementation of the necessary diversity principle in organizing rational access to detailed information.

Advantages of the IM combined structure can be realized only with application of the appropriate IDM and their structure. Each information display mean can have its own IM structure in accordance with suggested variant of the IM structure.

Large screens and board of aircrafts' characteristics, weather maps, etc. are commonly used as a collective display device. Individual IDM is a part of the automated workplaces of Infocommunication Systems of Air Traffic Control. The main variants of their application are given in Table 1.

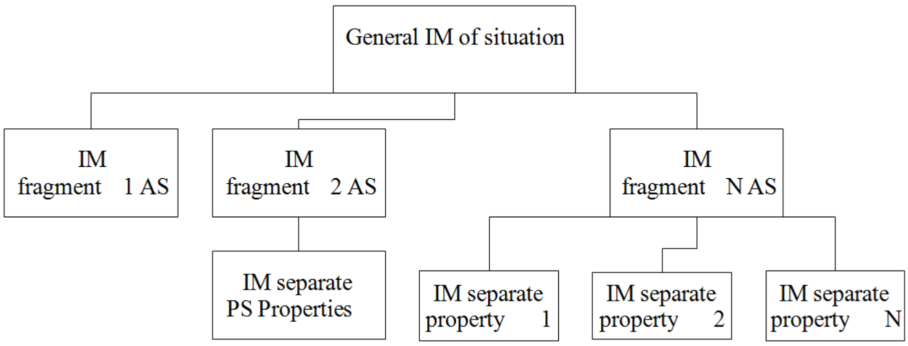

Fig. 1. IM combined structure option

Table 1 – **Options for using individual-usage IDM**

Working place option	Usage options for the info field of the display tool
1. One IDM	1. General AS display 2. AS fragments display
2. One IDM – polyscreen	1. The main part of the screen – general AS display 2. Free parts of the screen – IM fragments display
3. Two IDMs: the main – IDM_m additional – IDM_a	IDM_m – general IM display (partially the 1st working place option) IDM_a – IM fragments and details display

It should be noted that more than 50 years of ergonomic development of using workplaces with two or more IDM for the AS analysis and evaluation confirms the suitability of implementing such a variant of distributed IM. Inclusion of the tasks preparation complex and decision-making support to the special software and mathematical provision of ICS ATC leads to the necessity of revision for IE formation approaches, which make up the IM AS. So it is necessary to consider issues related to the formation of conceptual models in minds of operators. Those models should be closely related to the type of thinking of operators and information interaction between Infocommunication Systems of Air Traffic Control and DM.

Speed and efficiency of operator's decisions depend on the way he perceives information from Infocommunication Systems of Air Traffic Control.

Therefore, when substantiating the forms for submitting AS evaluation results, we should consider the following: information elements should correspond to the AS assessment stages and the ergonomic principles of the IM development; convergence of structure and content of information with conceptual models will reduce the number of transcoding operations for the transition to the conceptual model; information submission forms should correspond to the operator's experience, knowledge and intuition; information submission forms should consider the DM thinking characteristics.

Operational thinking is proper to decision-maker when situation is changing and data is unknown [10 – 12]. This thinking is mainly figurative – often DM mental activity is closely linked with images of objects of the situation (operational images).

They are formed as a result of comparison between current information about objects and ones stored in DM memory. Thus, an operational image is a certain set of information about objects of situations, reflected in DM mind and actively interacting with the information displayed in the IM, taking into account the dynamics of its change.

IM consists of many coherent information elements for better operator perception. Each IE reflects an abstract concept or a set of abstract concepts. Conceptual images that later form conceptual model are made in operator operational image with help of IE. But in order to create one conceptual image operator has to process, analyse and generalize several IE.

The complexity of the IE leads to an increase in its processing time. A set of IE in the MI overloads the operator's memory and causes errors in operational thinking. Inaccuracies in conceptual model's formation lead to ineffective decision making and increase time of solving problems. That's why task of IE development is one of the most difficult in IM design.

It is necessary to take into account a significant number of factors that collectively make up decision-making conceptual model in the process of operators' guiding. So there is a contradiction – IE must represent as many abstract concepts as possible and at the same time be simple.

IE should also support the process of operator's conceptual model formation with a minimum number of transcoding operations. It makes us setting a number of requirements for the IE. It should be: informative; simple; suitable for rapid perception and analysis by the operator; open for rapid formation of a conceptual model; correspond to ergonomic standards.

These requirements allow formalizing the process of IE development and meeting requirements of simplicity and informativity.

To reduce the IE processing time it is necessary to present them in the form of images reflecting connection between parameters and characteristics of objects and processes occurring in the analysed subject area.

Ideally, an IE image must display a large amount of information with relatively simple coding (form, size, flicker). This allows creating informative IM, effectively transformed into a conceptual model by operator for a relatively small number of IE. Ability to regulate parameters of IE images permits to compile and manage their display, which will create MI maximally adapted to the requirements of operators and the importance of their tasks.

Let's illustrate the process of developing IE form requirements. For example we will present "workload of ICS ATC operators in relation to the total volume of AS" in the IE form. The process of development should be the following: making requirements for an information element; analysis of the existing IM for compliance with the established requirements; development of IE options; study of suggested IE use effectiveness; analysis of results; introduction of information element in the information model.

Order and structure of the process of optimal content definition and development of IE structure are shown in Fig. 2.

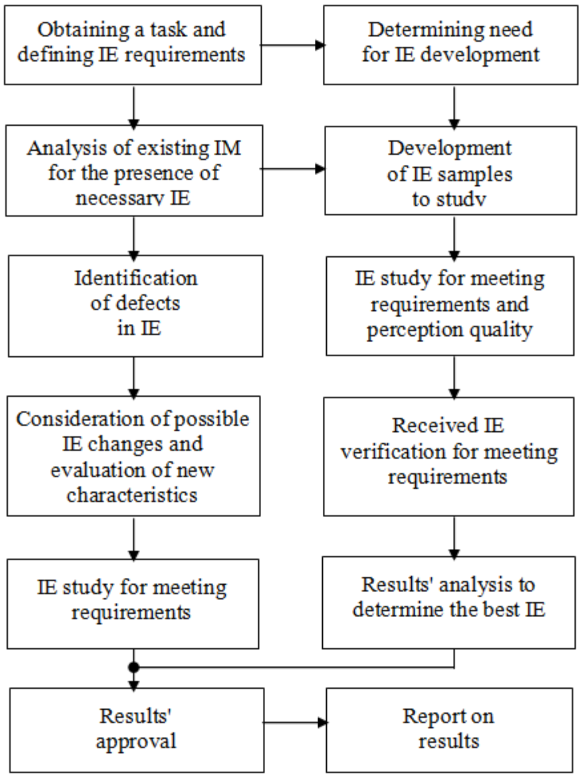

Fig. 2. Content and operations' order in IE process development

In our study we created different variants of representation for "workload of ICS ATC operators in relation to the total volume of AS" in the form of IE. Images of this IE are represented in Fig. 3.

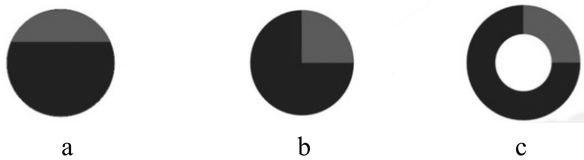

Fig. 3. Images of an information element (a – "float" type, b – "sector circle" type, c – "sector ring" type)

The proposed simple images allow: reflecting the total amount of AS in the area of ICS ATC; showing workload of each operator; presenting the summarized characteristics of the situation; providing dynamic IE correction. The choice of circle is explained by the simplicity of this figure that effectively reflects concept of correlation.

The present IE can also be placed in the IM providing additional information. Other IE parameters such as size, colour, brightness, sign parts' position are developed in accordance to existing ergonomic requirements [10].

The available IE options were investigated in the IM of Infocommunication Systems of Air Traffic Control usage in accordance with the IE development procedure. We developed an experimental installation with general interface shown in Fig. 4.

We conducted an experiment that helped to choose the IE in order to assess the compliance of suggested IE with the tasks.

The experiment involved 44 operators investigating 318 tasks.

As a result, we received assessments of the mathematical expectation for processing time and the probability of correct IE interpretation as a part of IM. The results are shown in the Table 2.

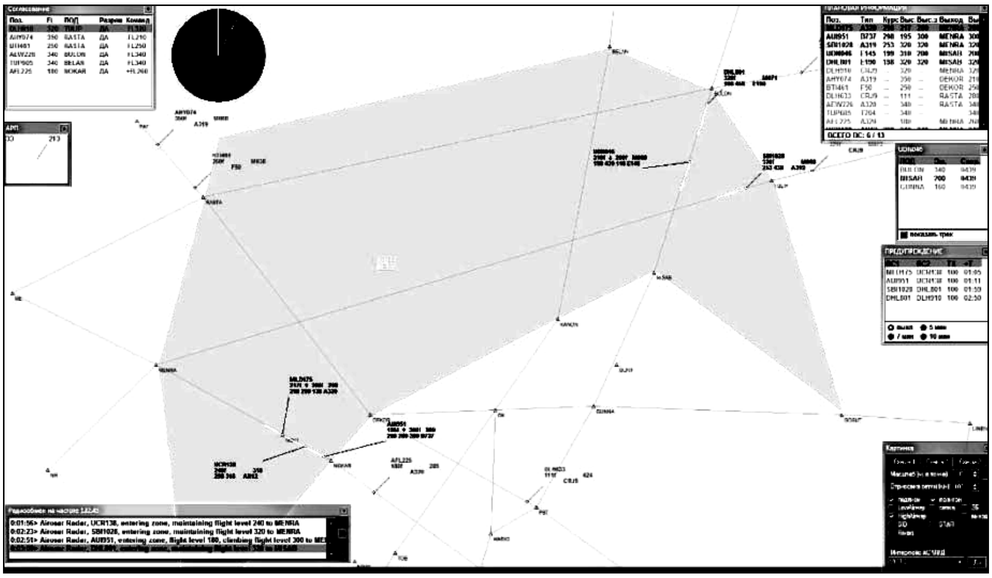

Fig. 4. Example of laboratory installation to study IE quality

Table 2 – **Experiment results**

Estimated parameters	Type of information element		
	"float"	"sector circle"	"sector ring"
Mathematical expectation of processing time, ms	5,439	4,960	5,928
Correct answer probability	0,50	0,78	0,52
Error probability	0,5	0,22	0,48

According to the results of IE evaluation we suggest that the best IE is a "sectoral circle" and it should be used to reflect the concept of "workload of Infocommunication Systems of Air Traffic Control operators in relation to the total volume of AS ".

The obtained results allow us to represent the structure of the method of information models' design and synthesis to support decision-making in the Infocommunication Systems of Air Traffic Control with dynamically changing conditions (Fig. 5).

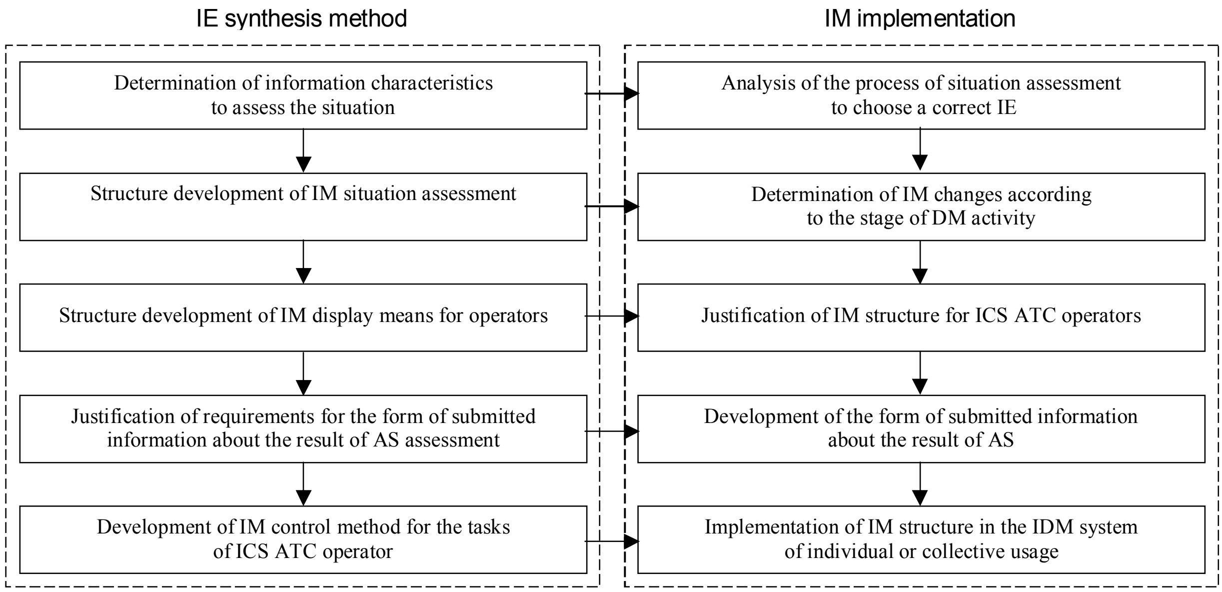

Fig. 5. Method of information models' design and synthesis structure for information decision support of situation assessment

The method of information models' design and synthesis for informational decision support in the ICS ATC, unlike existing ones, takes into account stages and specifics of the tasks solved by the operators. It permits to improve the quality of the information support system of the DM.

Conclusions

The suggested structure of the Infocommunication Systems of Air Traffic Control images display corresponds to the intellectual activity of DM in assessment of air situation.

The developed structure of information features' display is adequate to the stages of operators decision-making and provides high adaptive properties of the synthesized MI to the dynamics of air situation changes.

Further research should consider the effect of information models overload on the operators' efficiency of Infocommunication Systems of Air Traffic Control.

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Разработка метода проектирования и синтеза информационных моделей для инфокоммуникационных систем управления воздушным движением

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Аннотация. В статье изложены результаты исследований, посвященных вопросам проектирования и синтеза информационных моделей, являющихся необходимой составляющей системы информационного обеспечения лиц, принимающих решения в инфокоммуникационных системах управления воздушным движением. Приведен анализ возможных структур построения информационных моделей и предложено для сравнительно простых условий обстановки использовать линейную или иерархическую структуру. Для учета возможных изменений ситуаций обстановки, которые приводят к существенному росту объема информации для отображения, целесообразно использовать комбинированную структуру информационной модели. Приводятся структура, содержание и последовательность этапов метода проектирования и синтеза информационных моделей для информационной поддержки принятия решений по оценке обстановки. В отличие от существующих, предложенный метод учитывает этапы деятельности и специфику задач, решаемых операторами в инфокоммуникационных системах управления воздушным движением.

Ключевые слова: информационная модель; ситуация обстановки; информационный элемент; отображение; деятельность операторов; управление воздушным движением.

Розробка методу проектування і синтезу інформаційних моделей для інфокомунікаційних систем управління повітряним рухом

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Анотація. Якісне та ефективне вирішення завдань операторами інфокомунікаційних систем управління повітряним рухом напряму залежить від стану системи інформаційного забезпечення. Одним з базових напрямків удосконалення інформаційного забезпечення систем управління повітряним рухом є необхідність адаптації інформаційних моделей до умов діяльності та специфіки завдань, що стоять перед особами, які приймають рішення. В статті викладено результати досліджень, присвячених питанням проектування та синтезу інформаційних моделей, що є необхідною складовою системи інформаційного забезпечення осіб, які приймають рішення в інфокомунікаційних системах управління повітряним рухом. Наведено аналіз можливих структур побудови інформаційних моделей та запропоновано для порівняно простих умов обстановки використовувати лінійну або ієрархічну структури. Для врахування можливих змін ситуацій обстановки, що призводять до необхідності суттєвого зростання обсягу інформації для відображення, доцільно використовувати комбіновану структуру інформаційної моделі. Наведено співвідношення, які надають можливість оцінити характеристики структури інформаційних моделей на етапі їх ергономічного проектування і визначити кількість інформаційних елементів в одній програмі відображення з урахуванням мінімізації часу пошуку заданих елементів. Наведено можливі варіанти спільного використання засобів відображення інформації, як індивідуального, так і групового та колективного користування. Запропоновано структуру процесу та послідовність і зміст операцій при розробці вимог до форми інформаційних елементів. Наводяться дослідження ефективності використання різних форм подання інформаційних елементів. В підсумку наводяться структура, зміст та послідовність етапів методу проектування і синтезу інформаційних моделей для інформаційної підтримки прийняття рішень з оцінки обстановки, який на відміну від існуючих враховує етапи діяльності та специфіку задач, що вирішуються операторами в інфокомунікаційних системах управління повітряним рухом.

Ключові слова: інформаційна модель; ситуація обстановки; інформаційний елемент; відображення; діяльність операторів; управління повітряним рухом.