Information systems modeling

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APPLICATION OF THE STRUCTURAL-ALGORITHMIC ANALYSIS METHOD FOR MODELING WORK DUTY SHIFT AREA CONTROL CENTERS

Development and implementation new service ways in the air traffic services system are connected with the solution of complex tasks researching the features of familiar business models of duty shift and determination the direction of their development. **The purpose of the article** is to analyze the existing business model of area control centers of air traffic controllers and search areas for their improvements. It is shown that insufficiently addressed issues relating to the problems of interaction between the air traffic controllers among themselves and with automation tools. In this regard, the harmonization of the business models is needed in order to research, process information and training tasks, that takes into consideration the requirements of visibility and accessibility, while maintaining the possibility of analytical and experimental studies. To improve the business model of the area control center duty shift has been proposed to add other elements into the situation detection scheme and classify the initiating situations. **Conclusion.** The article shows that it is rational to complement existing methods of modeling activities of air traffic controllers by structurally-algorithmic analysis method and method of generalized network models activity in order to address the research, information and training tasks.

Keywords: air traffic controller; area control center; duty shift; business model; network models.

Introduction

Statement of a problem. The problem of the development and implementation new service ways in the air traffic services system is connected with the solution of the complex tasks researching the features of known business models of duty shift, determination the direction of their development, verification models in the application and experience sharing.

Analysis of the known publications. Analysis of the literature [1 – 4], dedicated to modeling activities of area control centers of air traffic controllers and duty shift in general showed, that issues relating to the problems of interaction between the air traffic controllers and with automation tools has been insufficiently studied [5]. In this regard, it is needed the harmonization of the business models in order to conduct a research, information and training tasks, that takes into consideration the requirements of visibility and accessibility, while maintaining the possibility of analytical and experimental studies [6].

Aim of the article. The aim of the article is to analyze the existing business models of air traffic controllers of area control centers and the search areas for improvements.

Base material

To determine the degree of compliance with the above requirements of the various combinations of methods for constructing models, the need to identify possible options for grouping methods, comparative analysis and identification of the best. These stages are characteristic for morphological analysis of systems. In known pattern of morphological analysis the issue of selection of the most successful combinations has not been not sufficiently developed, so this scheme should be supplemented with a multi-attribute utility evaluation strategy, detailed disclosure in the utility theory (linear, conjunctive, alternative and configuration). Since the desired combination of methods should best meet the requirements, which in the case of standardized models can be considered equivalent.

To select the best option the conjunctive strategy is applicable. According to this strategy, the result gains positive usefulness, if all the measured values exceed the limits.

As characteristics (morphological features) of alternative activity modeling methods combinations based on the tasks of the study were selected:

– the ability to model situation in the workstation (X_1);

– possibility of constructing and evaluating model characteristics with variable structure (X_2);

– the ability to automate storage processes, search and reproduction of information in the activities of area control centers of air traffic controllers (X_3);

– applicability during the educative process of area control centers duty shift (X_4).

In this case, in the analysis type of value characteristics matrix can be used [7]:

$$R = \begin{vmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{ij} & \cdots & r_{2n} \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{vmatrix}, \qquad (1)$$

where i – the index of the method;

j – index of morphological characters;

n – number of accounted characteristics;

m – number of considered methods;

$r_{ij} = \begin{cases} \text{is } 1 \text{ if } i\text{-th feature obtained by } j\text{-th method,} \\ \text{otherwise is } 0. \end{cases}$

Possible options of the methods combinations are defined by grouping the rows of the matrix R by one, by two, by three, and so on up to m and characteristics of the options - by selecting the maximum feature value in the considered group of methods. The total number of alternatives V is contained in proportion:

$$V = \sum_{k=1}^{m} \frac{m!}{k!(m-k)!}, \ k = \overline{(1,m)}. \quad (2)$$

This morphological analysis scheme has been used to study the following well-known methods of modeling activities of Air Traffic Controllers:

– semigraphical (M_1);

– structural-algorithmic (M_2);

– method of network business models (M_3);

– method of reference operator (M_4).

Characteristic values obtained for this combination of the methods shown in Table 1.

Analysis of the table shows that, except for the trivial variants $M_1M_2M_3M_4$, the dominant variants are $M_1M_2M_3$ and $M_1M_3M_4$.

But option $M_1M_3M_4$ suggests the presence of obviously trained air traffic controllers or the fullness of reference materials on the duty shift area control center in various situations, which is quite difficult to provide in the context of a twenty-four-hour air traffic control.

For analytical methods, the rational is to supplement the existing techniques by structural-algorithmic analysis and method of network business models – option $M_1M_2M_3$.

Table 1. **Characteristics of possible area control center methods of duty shift modeling and work combination options**

No. of version	Combination of methods	Rankings of the options			
		X_1	X_2	X_3	X_4
1	M_1	1	0	0	1
2	M_2	0	0	1	1
3	M_3	0	1	0	0
4	M_4	0	0	0	0
5	M_1M_2	1	0	1	1
6	M_1M_3	1	1	0	1
7	M_1M_4	1	0	1	1
8	M_2M_3	0	1	1	1
9	M_2M_4	0	0	1	1
10	M_3M_4	0	1	1	1
11	$M_1M_2M_3$	1	1	1	1
12	$M_2M_3M_4$	0	1	1	1
13	$M_1M_3M_4$	1	1	1	1
14	$M_1M_2M_4$	1	0	1	1
15	$M_1M_2M_3M_4$	1	1	1	1

Application of the structurally-algorithmic analysis method for modeling work duty shift area control centers. In order to enhance the capabilities of existing working model building methods for air traffic controllers it is desirable to supplement it with structural-algorithmic work analysis method.

The method is based on the use of algorithms activity, representing a set of interrelated operational and decisive elements. Each operation member corresponds to the group of operations performed successively in the implementation of the algorithm (entering information into the automated management system, command issuing, receiving reports, etc.). Each decisive element corresponds to a choice of one of the two or more further actions (analysis of visual and verbal information, registration conditions, decision-making, etc.). For systems with parallel processes are additionally used expectations elements. The method of structurally-algorithmic analysis allows describing not only the physical action of the controller, but also his mental activity, which makes it possible to deal with the distribution of functions in the system and the design of the activity structure. The advantages of the method include the fact that if the characteristics of elementary operations are known, similar characteristics of algorithm in general can be found, and if it is necessary to change the structure of the algorithm by changing the composition and interrelations operations. As for disadvantages of the model, it should be noted the lack of consideration interactions between air traffic controllers and in this regard, its applicability it mainly describes the performance of individual air traffic controllers. Suppose that in terms of structurally-algorithmic analysis defined generalized m (typical) situations that may occur during operation k-th controller with a certain probability, and the corresponding activity algorithms. The presence of the decisive elements in the algorithm involves multivariate

operations air traffic controller act in its implementation, the total number of variants of the algorithm n can be determined from the proportion:

$$n = \sum_{q=1}^{R} V_q U_q - \Delta(G), \qquad (3)$$

where R – number of types of the decisive elements;

U_q – number of q-type decisive elements;

V_q – number of q-type decisive element alternateves;

$\Delta(G)$ – reducing the number of outcomes due to the structure of the activity algorithm.

Selection of the j-th option of the algorithm of activity ($j = 1, 2, \ldots, n$) in the i-th situation ($i = 1, 2, \ldots, m$) is performed by air traffic controller depending on the current operating conditions (the current situation), which also can arise with a certain probability. Thus, the problem is solved by the air traffic controller according to the probabilistic algorithm; every j-th embodiment is implemented with a probability of P_{ij} and represents the deterministic finite sequence of some elementary operations. Then, encoding operations of the k-th air traffic controllers in the i-th situation in some alphabet of symbols, you can build a general directed graph, whose vertices correspond to the operations and arrows between nodes – interrelation between operations. With such digraph is isomorphic adjacency matrix A_{ik}, number of rows and columns of which is equal to the number of operations and elements of the matrix a_{pq} characterized repetition rate operation immediately after the operation ($a_{pq} = 0, 1, 2, \ldots$). Due to the fact that a change in current conditions also changes the number of required operations and connections there between, each j-th option of the activity algorithm will match private digraph and private matrix A_{ijk}, whose number of rows and columns depend on the specified current situations.

For the construction of the structurally-algorithmic models of activity duty shift area control center (ACC), as a whole is invited to take a set of matrices A_{ijk} and isomorphic to them graphs $G_{ijk}(A, \Gamma)$, which should be compiled into a matrix D_{ij} or a graph $G_{ij}(A, \Gamma)$ describing the activities of all the controllers on duty shift. In this case we use the association operation of graphs:

$$G_{ij}(A, \Gamma) = G_{ij1}(A_1, \Gamma_1) \cup \\ \cup G_{ij2}(A_2, \Gamma_2) \cup \ldots G_{ijl}(A_l, \Gamma_l). \qquad (4)$$

Now the vertices of the $G_{ij}(A, \Gamma)$ graph shows the combinations of air traffic controllers operations, involved in the j-th variant of activity algorithm:

$$A = A_1 \cup A_2 \cup \ldots \cup A_l. \qquad (5)$$

Mapping for each vertex of the graph $G_{ij}(A, \Gamma)$ is obtained by the same vertex mappings combination for the initial graphs

$$G_{ij1}(A_1, \Gamma_1), G_{ij2}(A_2, \Gamma_2), \ldots, G_{ijl}(A_l, \Gamma_l).$$

When analyzing the business models of the area control center duty shift, issues require special attention – to identify the role of interactions in solving problems in the automated control system (ACS) of air traffic controllers group. In the known sources these issues not been insufficiently studied. In particular, considered only a part of the communication network (interaction between air traffic controllers), and features of communication systems. At the same time, the presence of interaction is mainly associated with loss of time as a result of expectation commands or messages and the interaction of the organization largely depends on the total time of solving problems in the ACS. Given that the interaction of controllers in these systems differ from other operations and are mainly in the implementation of the agreed between the controllers and the work of KSA pair of operations (such as "team - the reception team," "Message - receiving messages", etc.), it is proposed to allocate interaction operations in general adjacency matrix. For this role in a matrix A_{ij} must be grouped operations of each K-th air traffic controller in the order of their execution. The matrix elements analysis shows that the interaction must satisfy the following conditions:

$$a_{pq} \neq 0,\ p_k < p < p_{k+1},\ q_k < q < q_{k+1}, \\ p \neq 1,\ q \neq 1,\ p \neq p_l,\ q \neq q_l,\ k = \overline{(1, l)}, \qquad (6)$$

where p_k, q_k – the number of operations to be performed k-th air traffic controller.

The task of improving the algorithm of activity can be associated with the identification of interactions, minimizing their number and, respectively, with the reduction of the number of wait elements. It is also not fully considered in the method of structurally-algorithmic analysis the issues of input events classification and their recognition, although the type of situation depends largely on the nature of the operators' activities and the time required for solution of the problem.

Considering the situation in the air traffic controllers workplaces as a set of conditions, the processes of development and consequences of their classification, can be used certain features that characterize the environment - dynamism, complexity and uncertainty.

In systems engineering familiar with the procedure of recognition of the situation, which includes the following steps (Fig. 1):

– extracting information about the situation (atmosphere of the process and its development) from the information stream (block 1);

– analysis of this data, dividing it into parts, relating to different conditions and characteristics of the process (block 2);
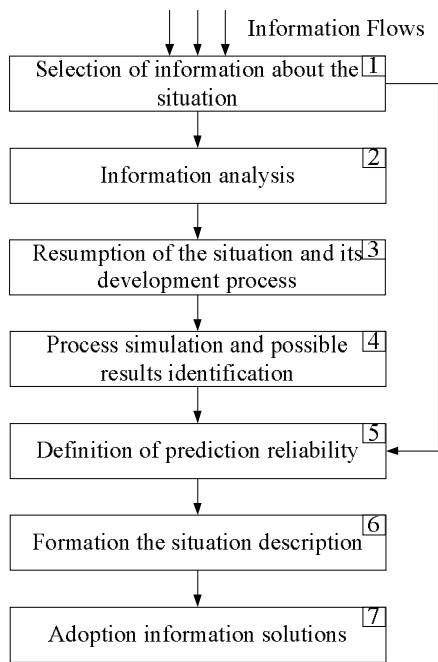
Fig. 1. known situations recognition scheme

– determining signs, i.e. recovery situation and its development process based on the received information (block 3);

– process prediction, the determination of possible outcomes (block 4);

– determining the degree of the forecast reliability (block 5);

– drawing describing the situation (block 6);

– adoption of information solutions (block 7).

In the procedure does not take into account this feature of the air traffic controllers activities, as the possibility of creativity in identifying the situation and development of the required algorithm performance. To overcome this drawback is proposed to include in the situation detection scheme a number of additional elements associated with comparing the signs of the situation with signs of known situations and identifying new situations (Fig. 2).

This addition allows us to pose the problem of finding previously unknown situations and activity algorithms and their inclusion in the future in a special software ACS, i.e. the task of forming a tunable external memory.
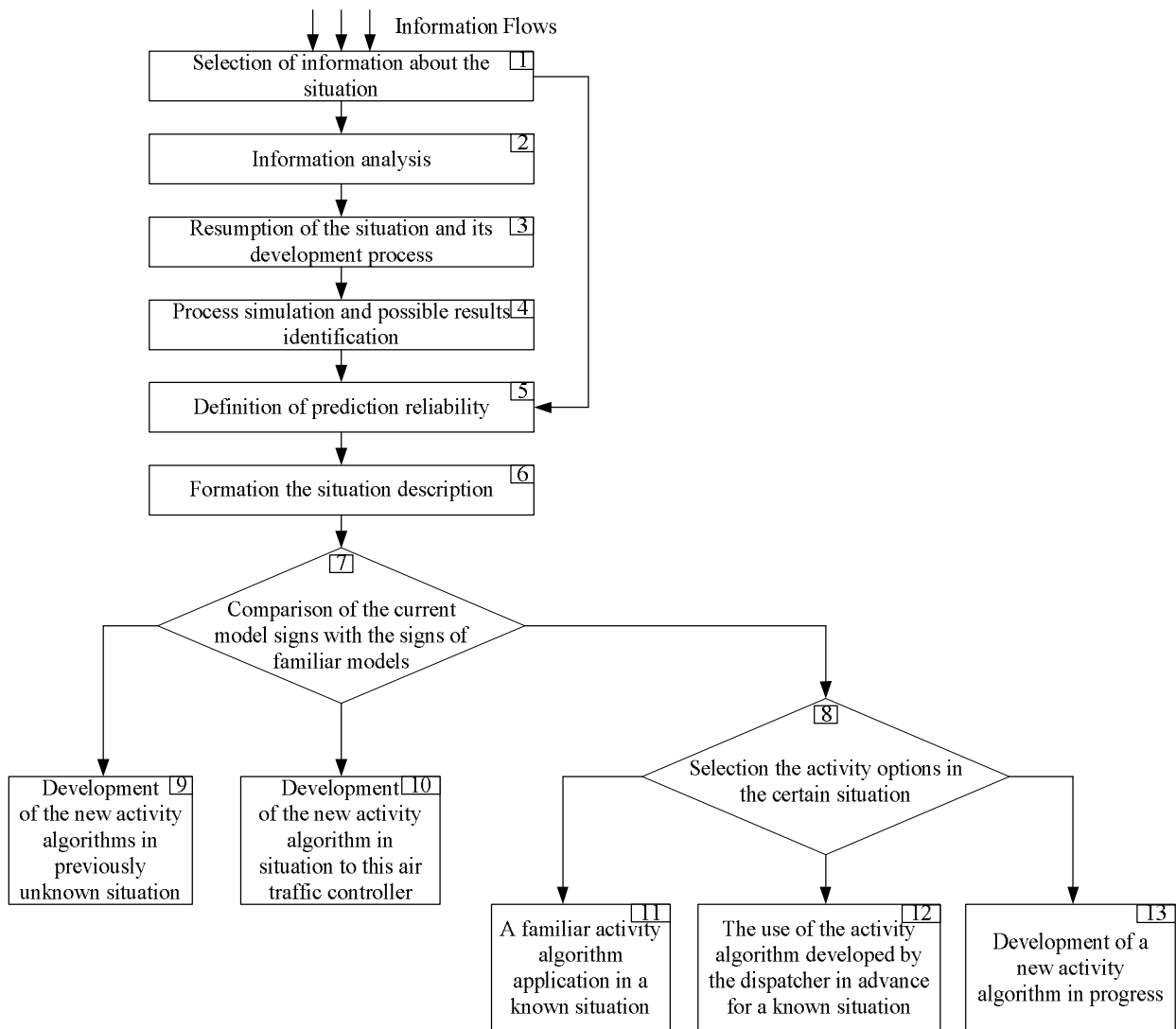

Fig. 2. Additional elements proposed for inclusion in a situation recognition circuit

In the classification of initiating situations for working models, standardized solutions for research, information and tasks of training, in addition to the degree of novelty it is advisable to consider the sources of the situation, management techniques, possible in this situation and the degree of development of the situation recognition process by the area control center duty shift (Fig. 3).
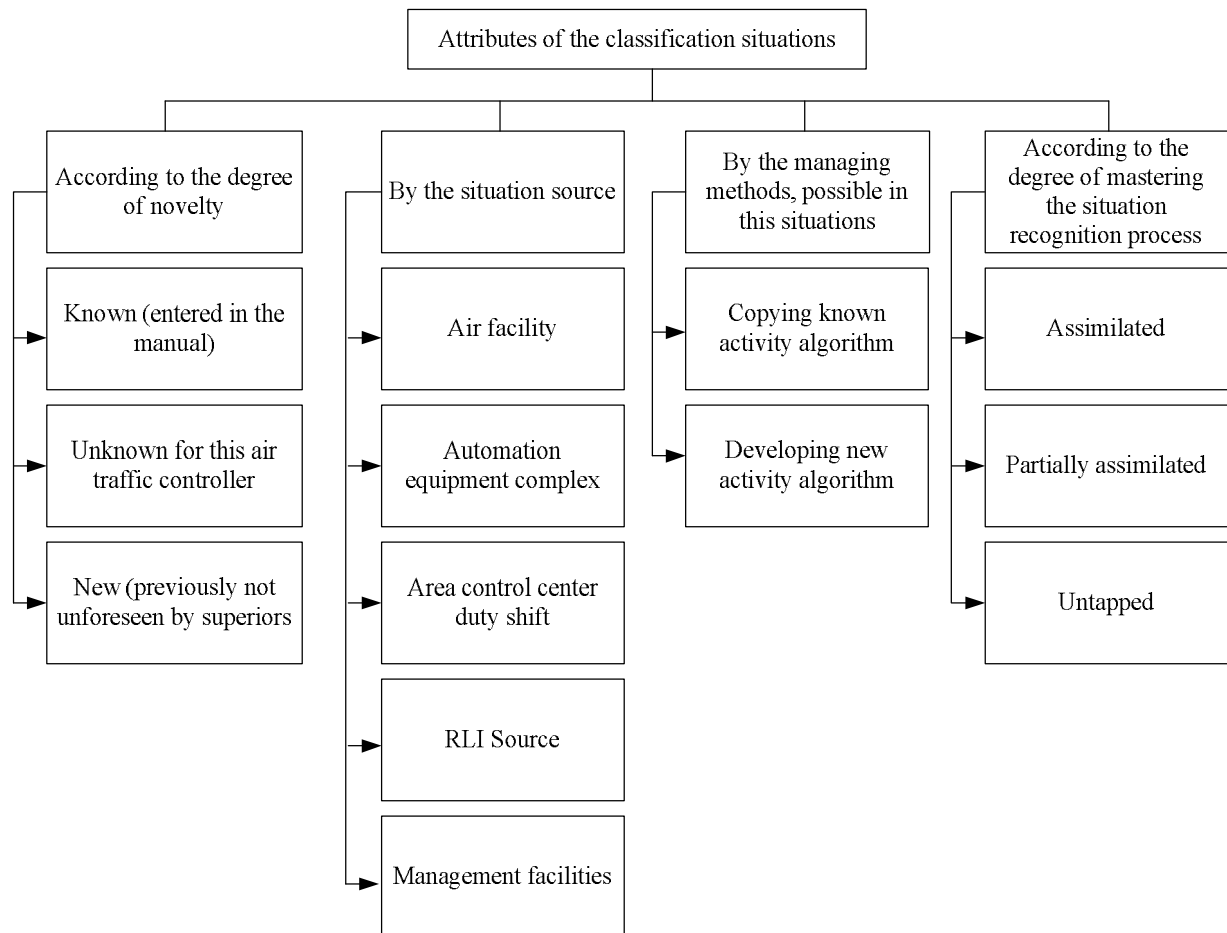

Fig. 3. Options for the classification of the situation
in the air traffic controllers workplace at duty shift area control center

Conclusions

On the basis of morphological analysis of different area control center duty shift operation modeling methods combination variants, shows that in order to address the research, information and tasks of training, it is rational to complement existing methods of modeling activities of air traffic controllers and the duty shift ACC by structurally-algorithmic analysis and method of generalized network models activity.

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**Застосування методу структурно-алгоритмічних аналізу
для побудови моделей роботи чергової зміни районного диспетчерського центру**

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Розробка і впровадження в систему обслуговування повітряного руху нових способів обслуговування пов'язані з вирішенням комплексу завдань з дослідження особливостей відомих моделей діяльності чергової зміни, визначення напрямів їх вдосконалення. **Метою статті** є проведення аналізу існуючих моделей діяльності авіаційних диспетчерів районних диспетчерських центрів і пошук напрямків щодо їх вдосконалення. Показано, що недостатньо повно вирішені питання, що стосуються проблем взаємодії диспетчерів між собою та з засобами автоматизації. У зв'язку з цим необхідна уніфікація моделей діяльності з метою вирішення дослідницьких, інформаційних та тренажних завдань, що передбачає врахування вимог наочності та доступності при збереженні можливості проведення аналітичних і експериментальних досліджень. Для вдосконалення моделей діяльності чергової зміни районного диспетчерського центру пропонується внести додаткові елементи в схему розпізнавання ситуації і класифікувати ініціюючі ситуації. **Висновок.** У статті показано, що для комплексного вирішення дослідницьких, інформаційних та тренажних завдань раціональним є доповнення існуючої методики моделювання діяльності авіаційних диспетчерів методом структурно-алгоритмічного аналізу та методом узагальнених мережевих моделей діяльності.

Ключові слова: авіаційний диспетчер; районний диспетчерський центр; чергова зміна; модель діяльності; мережеві моделі.

**Применение метода структурно-алгоритмического анализа
для построения моделей работы дежурной смены
районного диспетчерского центра**

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Разработка и внедрение в систему обслуживания воздушного движения новых способов обслуживания связаны с решением комплекса задач по исследованию особенностей известных моделей деятельности дежурной смены, определению направлений их совершенствования. **Целью статьи** является проведение анализа существующих моделей деятельности авиационных диспетчеров районных диспетчерских центров и поиск направлений по их совершенствованию. Показано, что недостаточно полно решены вопросы, касающиеся проблем взаимодействия диспетчеров между собой и с средствами автоматизации. В связи с этим необходима унификация моделей деятельности в целях решения исследовательских, информационных и тренажных задач, что предполагает учет требований наглядности и доступности при сохранении возможности проведения аналитических и экспериментальных исследований. Для совершенствования моделей деятельности дежурной смены районного диспетчерского центра предлагается внести дополнительные элементы в схему распознавания ситуации и классифицировать инициирующие ситуации. **Вывод.** В статье показано, что для комплексного решения исследовательских, информационных и тренажных задач рациональным является дополнение существующей методики моделирования деятельности авиационных диспетчеров методом структурно-алгоритмического анализа и методом обобщённых сетевых моделей деятельности.

Ключевые слова: авиационный диспетчер; районный диспетчерский центр; дежурная смена; модель деятельности; сетевые модели.