Discrete-Continuous Stochastic Model of Behavior Algorithm of Surveillance and Target Acquisition System

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Abstract. This paper presents discrete-continuous stochastic model for solving tasks of multivariate analysis of efficiency index and synthesis of functionality indexes of ground surveillance and target acquisition system. Surveillance and target acquisition system consists of passive and active radio electronic subsystems – reconnaissance units. As an efficiency index it is considered the probability of successful execution of task (detection and recognition of an object that is situated on controlled territory) within specified time interval. In the proposed model it is considered such features of the surveillance and target acquisition system as structure of the investigated system, the functionality indexes of its units and functional behavior. For construction of this model the advanced technology for modeling algorithms of information systems behavior was used. This technology represents a researched object by a structural automatic model. Available software tool automates the processes of constructing the graph of states and transitions and formation of an analytic model in the form of system of linear Chapman-Kolmogorov differential equations. The acceptable level of particularization of behavior of the surveillance and target acquisition system is determined only by known information about it. This discrete-continuous stochastic model enables increasing certainty for development of information-driven system for automation of the process of detection and recognition of objects for reconnaissance.

Keywords: Behavior Algorithm, Discrete-Continuous Stochastic Model, Structural Automatic Model, Information-Driven System.

1 Introduction and task statement

One of the directions for improving the quality of artillery reconnaissance is the creation of new ground surveillance and target acquisition system. Surveillance and target acquisition system (STA) must effectively conduct reconnaissance of the enemy's objects (targets) in conditions of fleeting military actions, dynamic changes of the situations, active electronic counteraction from the enemy's side, and control of artillery fire while performing combat missions.

Nowadays, there are many studies about the performance of separate radio electronic systems, which solve the tasks of ground artillery reconnaissance, e.g. Mobile

Artillery Monitoring Battlefield Radar (MAMBA), Counter Battery Radar (COBRA), Hostile Artillery Location (HALO) and others [1].

Extensive practical experience of National Army Academy officers led to the conclusion that use of separate artillery STA is not sufficiently effective, moreover sometimes, in certain conditions, application is impossible. Relying on this practical experience, three feasible variants for the integration of existing artillery reconnaissance units were proposed, as well as algorithms of the interaction of these units during the task execution.

So, in our case, a complex artillery STA is an object of study. This STA consists of passive and active radio electronic subsystems – reconnaissance units, which differ in their functionality. Passive units are: acoustic (ACU), optical (OPT), optoelectronic (OEC) and infrared (IFR) systems. Active units are radar (RDR) and unmanned aerial vehicle (UAV). The objects (targets) are recognized by the object recognition system (ORS). Thus, the STAs are designed to expose the movable and immovable objects (targets) of the enemy by using contained surveillance systems. The interaction of these systems is provided by an information-driven system (IDS).

Since IDS ensures the successful performance of the STA, the determination of the STA's performance indicators at the stage of the system design before the practical implementation of the STA prototype is very important task. Such task can be solved basing on the model of the STA behavior algorithm. The behavior algorithm (BA) is formal representation of the logic of the information from STA components usage for the performance of the task and consists of a sequence of certain procedures [2]. This algorithm describes the functional interrelations between the elements of the system and the functional behavior of the system in general. Also, behavior algorithm can be used for reliability behavior representing. Behavior algorithm is implemented in the IDS, so it is crucial for the successful functioning of the STA.

As efficiency index of STA, it is considered the probability of successful execution of a task within specified time interval. Under the successful execution of the task, we understand the detection and recognition of an object that is situated on controlled territory. To select a reasonable version of STA it is necessary to obtain a set of tools (models, methods and software) that will provide reliable results during the reasonable time at the stage of system engineering design.

Therefore, the purpose of the article is to present the mathematical model of the complex artillery STA, which will enable to determine the values of the functionality indexes of its units. In this case, the STA would provide the necessary value of the probability of successful execution within acceptable time.

2 Overview of the methods of simulation of the behavior algorithms of radio electronic systems

For the analysis and optimization of structural-algorithmic systems, to which BAs of short-term used STA can be applied, academician V.M. Glushkov proposed the language of algorithmic algebras [3]. Using canonical regular forms of algorithms (linear, disjunctive, iterative and parallel), one can simulate both the external (functionality) and the internal (reliability) behavior of any structural-algorithmic system. Solving the design tasks and evaluating the reliability of algorithms has been continued in paper [2].

Formalization of logical-probabilistic modeling methods, theoretical and methodological foundations of which were laid down by I.A. Ryabinin [4], are oriented to analysis of reliability and safety, and demands construction of the functional integrity schemes. In paper [5] there is presented the method of automatization of the fault trees construction, that are proceeded from the behavior of a system.

To evaluate the probability of BA successful execution and the average value of its duration, the trajectory modeling method can be used [6]. For this purpose, the graph model of the STA behavior algorithm is used. The BA efficiency indexes can be determined in such model by using the transactional probabilities of alternative transitions and the sequencing of all possible routes passing through the graph from the input node to the output one.

For the analysis of certain systems, Petri nets are used [7], [8]. However, during the simulation with cycles, the decision-making action can put the network into conflict. Therefore, the modeling of behavior using Petri net requires the formation of some sequence of events that will make a conflict between two permitted transitions impossible. The usage of colored Petri nets also did not provide an acceptable result for practical use because of the complication of the cycles description [9].

Attempts to solve the problem of counting cycles for the analysis of the systems behavior were made by using the GO-FLOW-method. While applying this method, there is a significant extension of the GO-FLOW circuit when the number of L signals increases that form 2^L state combinations with increasing number of cycles [10].

The computer simulation methods allow solving the analysis of large systems, including the tasks of evaluation: variants of the system structure, the efficiency of various algorithms of system management or their behavior, the influence of changes in various parameters of the system [11]. However, the development of each simulation model (simulating algorithms) is a separate task that is time-consuming and not flexible, when BA to be modified. Also, this approach does not allow to investigate the behavior of a complex system in each state in particular.

Note, that the article shows that the behavior of the STA is discrete-continuous (it is detailed shown in paragraph 4.1). This circumstance determines the choice of an alternative method for analyzing behavior algorithm method of simulation, namely the state space method, which enables constructing discrete-continuous stochastic models. This model gives information about a research object in the form of probabilities distribution of staying in states for a given value of the duration of certain operation. For the use of the space-state method it is expedient to use the technology of modeling BAs of information systems [12] - [15]. This technology makes it possible to automate the construction of BA that considers the features of short-term radio-electronic systems and enables the synthesis of BAs by multivariate analysis.

The essence of this technology is to present a researched object by using of structural automatic model (SAM), which contains three sets of data: state vector (representing the essence of each state); set of formal parameters (visualizes the structure of the object, the possibilities of procedures, and characterizes event streams), and tree of the rules for modifying the component of the state vector (displays the object in the selected structure). The structural automatic model formally reproduces the behavior of a complex system and by using special algorithm it allows us to obtain a graph of states and transitions, which is incidental to behavior of researched system.

The available ASNA software tool, which was created on the basis of this technology, allows solving the problem of multivariate analysis of BAs of complex systems. It automates the processes of constructing the graph of states and transitions, and formation of an analytic model in the form of system of linear Chapman-Kolmogorov differential equations, the order of which is determined by the number of states. While using this technology, the engineer is able to choose the necessary extent to consider the processes, occurred in the system. This technology was used in studies [16] and [17]. The acceptable level of particularization of behavior description of the artillery STA is determined only by known information about it.

3 Behavior algorithm of surveillance and target acquisition system

The development of the STA behavior algorithm is preceded by the analysis of probable variants of the conditions for its application - terrestrial environment monitoring. Table 1 lists the selected STA application conditions and provides recommendations for the integration of methods and tools of reconnaissance. An object (target) is considered to be identified if it is detected and recognized at least by the results of two units of reconnaissance. According to the three variants of STA application conditions, three algorithms for its behavior have been developed. The main requirement for all BA variants is the minimum duration of use of active reconnaissance units.

Table 1. Options for the situation in STA will be used and recommendations for the integration of methods and units of reconnaissance.

№	Conditions	Recommendations for units of reconnaissance
1	Conditions are favorable (atmosphere is transparent, visibility is within the limits of permissible norms).	Reconnaissance is carried out by passive units: OPT, OEC, ACU. For short period of time the usage of active units of reconnaissance – radar and UAV are allowed. Priority is given to any of the reconnaissance units.
2	The conditions are medium (the atmosphere is translucent; smoke and fog are possible).	Reconnaissance is carried out by passive units: ACU, IFR. For short period of time the usage of radar is allowed. Priority is given to radar.
3	Conditions are unfavorable (the atmosphere is opaque, poor visibility, rain and snow).	Reconnaissance is carried out mostly by active units (UAV, radar). At the same time, the passive units (ACU, IFR) are available. Priority is given to UAV and radar.

In this article the one of developed algorithms – STA behavior algorithm for favorable conditions is shown (Fig. 1). The STA behavior algorithm consists of 14 operational blocks (one of them is start and two are ends) and three conditional blocks. This BA involves two cycles – to select reconnaissance unit and to select confirmation unit. The STA behavioral algorithm involves the usage of such procedures as: selection of reconnaissance unit, the UAV usage, the radar usage, the OEC usage, the OPT usage, the ACU usage, the IFR usage, detection, data transmission, recognition, results transmission to the control panel, selection of confirmation unit. All three STA behavioral algorithms will be used as the basis for software development for the IDS. The purpose of IDS is to automate the process of the STA task execution.

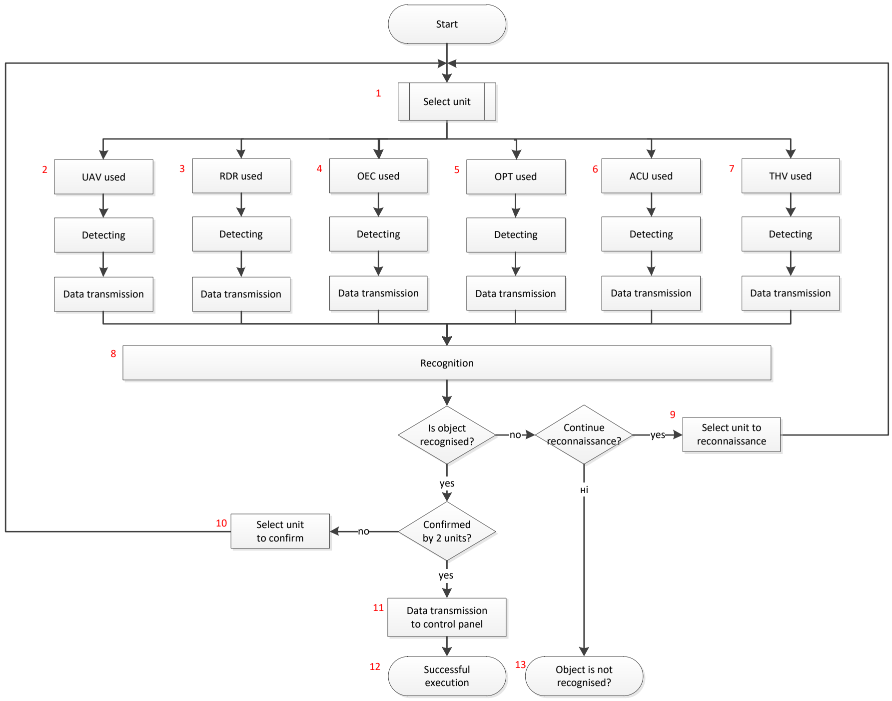

Fig. 1. Flowchart of STA behavior algorithm for favorable conditions.

For the STA behavior algorithm, the input data should be specified. The input data contain the indexes of the functionality for each reconnaissance units and describe the character of their interactions. In accordance with the flowchart of the STA behavior algorithm, we denote the parameters of the operational and conditional blocks as functionality indexes of its components (Table 2).

Used functionality indexes of STA units, namely the probability of object detection, probability of object recognition, average value of the detection time and average value of the recognition time are indexes of their complex efficiency. A posteriori values of these parameters are obtained after their testing and application. The theory of system analysis makes it possible to determine the a priori values of these indexes.

This is very important at the decision-making stage while choosing the principles of STA design.

After the development of algorithms, there is one more task: it is necessary to check whether the value of STA efficiency index will meet the requirements and if the values of the functionality indexes of the units are correctly chosen for it? So, if the received value of the STA efficiency index does not meet the requirements, it is necessary to solve the inverse problem – to determine the values of the functionality indexes of the components, for which the value of the STA efficiency index meet the requirements. It is a statement of the task of analyzing the STA efficiency and the task of synthesizing the functionality indexes of the reconnaissance units, which are part of the STA.

To solve such tasks, it is necessary to have mathematical model of the STA behavior algorithm. The behavior algorithm of STA is corresponded by discrete-continuous stochastic model. For this model construction the advanced technology for modeling algorithms of information systems behavior was used.

Table 2. Functionality indexes of the STA components.

Index denotation	Index name
p_ACU	Probability of object detection by acoustic unit
p_UAV	Probability of object detection by UAV
p_OEC	Probability of object detection by optoelectronic unit
p_OPT	Probability of object detection by optical unit
p_RDR	Probability of object detection by radar
p_IFR	Probability of object detection by infrared unit
p_RID	Probability of object recognition by the object recognition system
T_ACU	The average value of the detection time of the object by acoustic unit
T_UAV	The average value of the detection time of the object by UAV
T_OEC	The average value of the detection time of the object by optoelectronic unit
T_OPT	The average value of the detection time of the object by optical unit
T_RDR	The average value of the detection time of the object by radar
T_IFR	The average value of the detection time of the object by infrared unit
T_RID	The average value of the recognition time of the object by object recognition system

The object recognition system compares signatures of objects (targets) received from other reconnaissance units, and proposes decision about the type of object.

4 Development of discrete-continuous stochastic model of behavior algorithm of the surveillance and target acquisition system

To develop a discrete-continuous stochastic model of STA behavior algorithm the technology of modeling behavior algorithms of complex systems was used. This technology enables the development of appropriate model with a required degree of adequacy. The high degree of formalization of the technology for developing the graph of state and transmissions, allows to automate partially this process by ASNA software.

4.1 Assumptions introduced into the developed model

The first assumption: the change of the STA state depends only on its current state, but does not depend on the previous state. The current state is known, and does not depend on its values at the past moments of time. Thus, the Markov process can be used to simulate a system stochastic behavior that changes its state according to the rules of transitions depending on the current state.

Second assumption: for Markov processes, which are used as a partial case in the space-state method, the exponential law of time distribution between two events is inherent feature. It has predetermined their widespread use at the initial stage of designing systems for the comparative assessment of the reliability of complex technical systems.

Third assumption: it is considered that the ORS does not allow false recognition, that is, an object can either be detected, but not recognized or detected and correctly recognized.

4.2 Definition of basic events

To determine the basic events, it is necessary to consider all the processes and procedures that are reflected in the developed STA behavior algorithm (see Fig. 1).

For each procedure, there are proper events that represent their beginning and end. Each procedure is characterized by its average duration. Events that represent the end of the procedure are considered as base events (BE). For the algorithm of STA behavior, basic events are presented in Table. 3.

Table 3. Basic events of the behavior of surveillance and target acquisition system.

№	Beginning event	End event	Average duration
BE1	The beginning of the procedure of object detecting by acoustic reconnaissance unit.	The end of the procedure of object detecting by acoustic reconnaissance unit.	T_ACU
BE2	The beginning of the procedure of object detecting by optoelectronic reconnaissance unit.	The end of the procedure of object detecting by optoelectronic reconnaissance unit.	T_OEP
BE3	The beginning of the procedure of object detecting by optical reconnaissance unit.	The end of the procedure of object detecting by optical reconnaissance unit.	T_OPT

№	Beginning event	End event	Average duration
BE4	The beginning of the procedure object recognition by the object recognition system.	The end of the procedure object recognition by the object recognition system.	T_RID
BE5	The beginning of the procedure of object detecting by radar and object recognition.	The end of the procedure of object detecting by radar and object recognition.	T_RDR+T_RID

4.3 Assignment of the component of the state vector

Assigned components for the STA state vector, that reflect the current state of the reconnaissance, are shown in Table. 4. For the convenience of reading the symbols of state vector, a semantic representation of the indexes is proposed, which reflects not the conditional number of the component of state vector, but its functional purpose. The appropriate presentation provides the convenience and speed of forming formulas for calculating the intensity of transition from state to state.

Table 4. Components of state vector of surveillance and target acquisition system.

Components of state vector	Initial values	Component name
V_ACU	0	Acoustic unit state
V_UAV	0	UAV state
V_OEC	0	Optoelectronic unit state
V_OPT	0	Optical unit state
V_RDR	0	Radar state
V_IFR	0	Infrared unit state
V_USD	0	The current value of the number of used reconnaissance units
V_TLD	0	The current threshold value of the reconnaissance units that detected the object
V_RID	00	Result from object recognition system

The component V_ACU represents the state of the acoustic reconnaissance unit. This component can take the following values: V_ACU = 1 – acoustic reconnaissance unit was used, V_ACU = 0 – the acoustic reconnaissance unit was not used. The initial value of the component is V_ACU = 0.

Similarly, the components V_OEP, V_OPT, V_RDR represent optoelectronic, optical and radar reconnaissance units respectively.

The component V_USD represents the current value of the number of used reconnaissance unit. This component can take the following values: V_USD = [0 .. 4]. The initial value of the component is V_USD = 0.

The V_TLD component represents the current value of the number of detected objects used by the reconnaissance units. This component can take the following values: V_TLD = [0 .. 3]. The initial value of the component is V_TLD = 0.

The V_RID component represents the result of object recognizing. This component can take the following values: V_RID = 0, 11, 12, 13, 21, 22, 23. The initial value of the component V_RID = 0. V_RID = 11 – the object is detected by more than one passive reconnaissance unit and recognized by ORS; V_RID = 12 – the object is detected by the passive reconnaissance units but not recognized by ORS and needs to be confirmed by the active reconnaissance units; V_RID = 13 – the object was not detected by passive reconnaissance units; V_RID = 21 – the object is detected both by passive and active reconnaissance units and recognized by ORS; V_RID = 22 – the object was detected both by passive and active reconnaissance units, but not recognized by ORS; V_RID = 23 – the object was not detected by both by passive and active reconnaissance units.

The condition for the successful execution of the STA target function is actual for situation, when the object is detected only by passive or both by passive and active reconnaissance units and recognized by ORS. Formalized representation of the conditions for successful execution of the target function is (V_RID = 11 or V_RID = 21).

The condition for the tolerant execution of the STA target function is actual for situation, when the object is detected only by passive or both by passive and active reconnaissance units and but not recognized by ORS. Formalized representation of the condition for the tolerant execution of the target function is (V_RID = 12 or V_RID = 22).

The condition for non-successful of the STA target function is actual for situation, when the object is not detected both by passive and active reconnaissance units. Formalized representation of the condition for non-successful of the target function has the following form: V_RID = 23.

4.4 Development of the base graph of states

The development of the base graph of states was carried out by using the method of constructing graph of states on the basis of basic events. The inputs are: basic events of the STA behavior algorithm, components of the state vector, functionality indexes of the reconnaissance units and recognition system.

The development of the base graph of states is carried out in the following sequence:

Step 1. Form the initial state of the graph, which gives the start of the actual version of the STA behavior algorithm according to the situation for the task execution: [V_ACU = 0, V_OEP = 0, V_OPT = 0, V_RDR = 0, V_USD = 0, V_TLD = 0, V_RID = 0]. To this state give №1.

Step 2. Consider state №1. Determine if the BE1 is relevant for this state: it is relevant, because the usage of the ACU is provided by the developed behavior algorithm. Note that BE1 generates 2 alternative transitions with the probabilities p_ACU and (1-p_ACU) (see Table 2). The first alternative transition represents the continuation of the process, when the object is detected by ACU. This is represented by changing the values of such components of the state vector: V_ACU = 1, V_USD = 1, V_TLD = 1. The state vector [V_ACU = 1, V_OEP = 0, V_OPT = 0, V_RDR = 0, V_USD = 1, V_TLD = 1, V_RID = 0] is received for the first time. As a result, it will be assigned №2 and the transition from state 1 to state 2 is appointed. Since the intensity of the BE1 is determined by the formula 1/T_ACU, the intensity of the transition from state 1 to state 2 in the graph is determined by the formula p_ACU·(1/T_ACU). The second alternative transition represents the continuation of the process when the object is not detected by the ACU. This is displayed by changing the values of such components of the state vector: V_ACU = 1, V_USD = 1, V_TLD = 0. The generated state vector [V_ACU = 1, V_OEP = 0, V_OPT = 0, V_RDR = 0, V_USD = 1, V_TLD = 0, V_RID = 0] is also received for the first time. This state is assigned to№3. and the transition from state 1 to state 3 is appointed. The intensity of the transition from state 1 to state 3 is determined by the formula 1/T_ACU·(1-p_ACU).

Steps 3 and 4. Continue to consider state №1. Determine whether the basic events of BE2 and BE3 are relevant for this situation. Yes, they are relevant, because their implementation is provided by the STA behavior algorithm. This means that OEC and OPT can be used. The model parameters for alternative transitions after the basic events of BE2 and BE3 are determined in the same way as after the BE1.

Steps 5 and 6. Continue to consider state №1. Determine if the BE4 and BE5 are relevant for this situation. These events are not relevant for state №1, because the recognition procedures in this state cannot be performed.

Then sequentially examine all the formed states and repeating steps 2, 3, 4, 5, and 6, define new states and graph transitions, and also form formulas for determining the intensities of transitions from state to state.

While developing the graph of states on the basis of basic events, the SAM is verified for the fulfillment of the condition that the sum of the probabilities of alternative transmissions should be equal to 1. In the developed model there is an alternative transmission from basic events for which the given condition is fulfilled.

4.5 Development of structural automatic model of behavior algorithm

During the development of the structural automatic model of the STA behavior algorithm, the following tasks were solved: formal description of situations in which basic events occur; formulas for calculating the intensity of transitions (FCIT) from state to state; the rules for modifying components of the state vector are established (see Table 5).

Table 4. Structural automatic model of the STA behavior algorithm.

Basic events	Formalized description of the situation	FCIT	Rules for modifying components of the state vector
BE1	(V_ACU=0) and (V_RID=00)	p_ACU/T_ACU	V_ACU:=1; V_USD:=V_USD+1; V_TLD:=V_TLD+1
	(V_ACU=0) and (V_RID=00)	(1-p_ACU)/T_ACU	V_ACU:=1; V_USD:=V_USD+1
BE2	(V_OEC=0) and (V_RID=00)	p_OEC/T_OEC	V_OEC:=1; V_USD:=V_USD+1; V_TLD:=V_TLD+1
	(V_OEC =0) and (V_RID=00)	1-p_OEC/T_OEC	V_OEC:=1; V_USD:=V_USD+1
BE3	(V_OPT =0) and (V_RID=00)	p_OPT/T_OPT	V_OPT:=1; V_USD:=V_USD+1; V_TLD:=V_TLD+1
	(V_OPT =0) and (V_RID=00)	1-p_OPT/T_OPT	V_OPT:=1; V_USD:=V_USD+1
BE4	(V_USD›0) and (V_TLD›1) and (V_RID=00)	p_RID/T_RID	V_RID=11
	(V_USD›0) and (V_TLD›1) and (V_RID=00)	(1-p_RID)/T_RID	V_RID=12

Basic events	Formalized description of the situation	FCIT	Rules for modifying components of the state vector
	(V_USD›0) and (V_TLD=1) and (V_RID=00)	(1-p_RID)/T_RID	V_RID=12
	(V_USD›0) and (V_TLD=0) and (V_RID=00)	1/T_RID	V_RID=13
BE5	(V_RDR=0) and (V_RID=12)	p_RDR*p_RID/ T_RDR	V_RID=21; V_RDR:=1; V_USD:=USD+1; V_TLD:=V_TLD+1
	(V_RDR=0) and (V_RID=12)	p_RDR*(1-p_RID)/ T_RDR	V_RID=22; V_RDR:=1; V_USD:=USD+1; V_TLD:=V_TLD+1
	(V_RDR=0) and (V_RID=12)	(1-p_RDR)/(T_RDR+ T_RID)	V_RID=22; V_RDR:=1; V_USD:=USD+1; V_TLD:=V_TLD+1
	(V_RDR=0) and (V_RID=13)	p_RDR/(T_RDR+ T_RID)	V_RID=22; V_RDR:=1; V_USD:=USD+1; V_TLD:=V_TLD+1
	(V_RDR=0) and (V_RID=13)	(1-p_RDR)/(T_RDR+ T_RID)	V_RID=23; V_RDR:=1; V_USD:=USD+1

The construction of the states and transitions on the basis of SAM is carried out using ASNA software. The fragment of the received graph of states and transitions for the first behavior algorithm of the STA (in favorable conditions, see Table 1) is shown in Fig. 2.

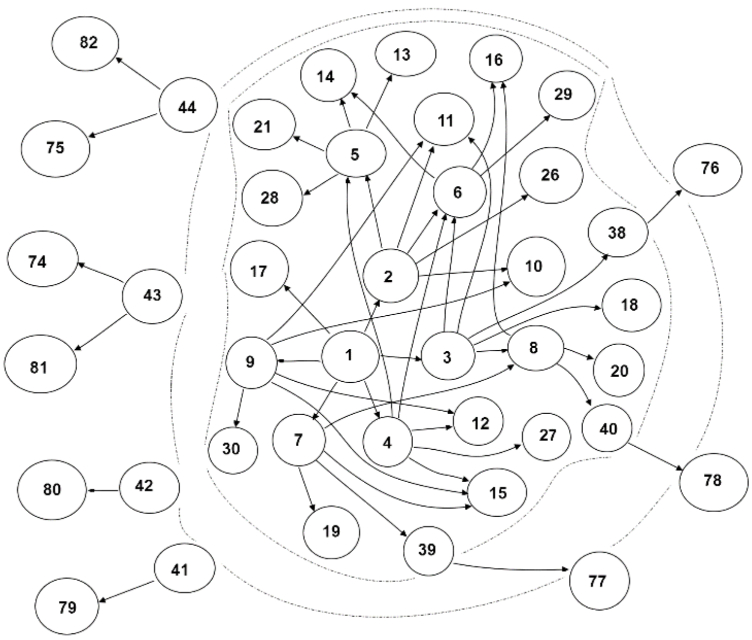

Fig. 2. Fragment of the graph of states and transitions for the behavior algorithm of the surveillance and target acquisition system in favorable conditions.

From the obtained graph of states and transitions, which contains 82 states and 123 transitions, form a mathematical model in the form of system of Chapman-Kolmogorov linear differential equations (1):

$$\frac{dP_1(t)}{dt} = -(\lambda_{1\_2} + \lambda_{1\_3} + \lambda_{1\_4} + \lambda_{1\_7} + \lambda_{1\_9} + \lambda_{1\_17})P_1(t)$$
$$\frac{dP_2(t)}{dt} = \lambda_{1\_2}P_1(t) - (\lambda_{2\_5} + \lambda_{2\_6} + \lambda_{2\_10} + \lambda_{2\_11} + \lambda_{2\_26})P_2(t)$$
$$\frac{dP_3(t)}{dt} = \lambda_{1\_3}P_1(t) - (\lambda_{3\_6} + \lambda_{3\_8} + \lambda_{3\_11} + \lambda_{3\_18} + \lambda_{3\_38})P_3(t)$$

- (1)

$$\frac{dP_{80}(t)}{dt} = \lambda_{42\_80}P_{42}(t)$$
$$\frac{dP_{81}(t)}{dt} = \lambda_{43\_81}P_{43}(t)$$
$$\frac{dP_{82}(t)}{dt} = \lambda_{44\_82}P_{44}(t)$$

where: λ_{n_m} – intensity of transition from the state *n* into the state *m;*
$P_i(t)$ – probability of being in the *i* state at the *t* count of time.

Initial conditions for Chapman-Kolmogorov equation system are (2):

$$P_1(0) = 1$$
$$P_2(0) = 0$$
- - - - - - - - (2)
$$P_{82}(0) = 0$$

The development of SAM is completed after its verification. The verification method of SAM is needed to detect inconsistencies by comparing base graph with graph of states and transitions, constructed using the ASNA software. Detected inconsistencies are pointers of errors in the SAM that need to be corrected.

5 Validation of the discrete-continuous stochastic model of the behavior algorithm of the surveillance and target acquisition system

The task of model validation is to check the relevance of qualitative representation of the IDS characteristics by quantitative changing the efficiency index values. This approach is equitable when there are no experimentally determined efficiency index values of the research object. Quantitative changes in the efficiency index were studied with the developed model of the STA behavior algorithm. An efficiency index STA is the probability of its successful execution during the critical duration.

The task of the study was formed to obtain the results, according to which engineer can give a forecast of the efficiency index changing.

Four models of STA construction were used to validate the developed model. They differ in their values of functionality indexes of the STA reconnaissance units (see Table 7).

Table 7. Values of functionality indexes of the STA reconnaissance units.

№ of test	Reconnaissance units and their values of functionality indexes – probability of successful detection or recognition of the object				
	ACU	OPT	OEC	RDR	ORS
1	0,6	0,6	0,6	0,6	0,6
2	0,7	0,7	0,7	0,7	0,7
3	0,8	0,8	0,8	0,8	0,8
4	0,9	0,9	0,9	0,9	0,9

For validation of the developed model, two studies were conducted.

Study 1. Objectives of the study: to check how the difference between the probabilities of recognition and non-recognition of objects is changing with the growth of the quality of STA reconnaissance units.

The expected result – with increasing of functionality indexes values of STA reconnaissance units, the proportion of recognized objects should increase, that is, the difference between the probabilities of recognition and non-recognition of objects should increase.

Conducted research according to the tasks 1 correspond to the curves in Fig. 3. The study was performed as follows: the curves show the relation between the probabilities of recognition and non-recognition of objects.

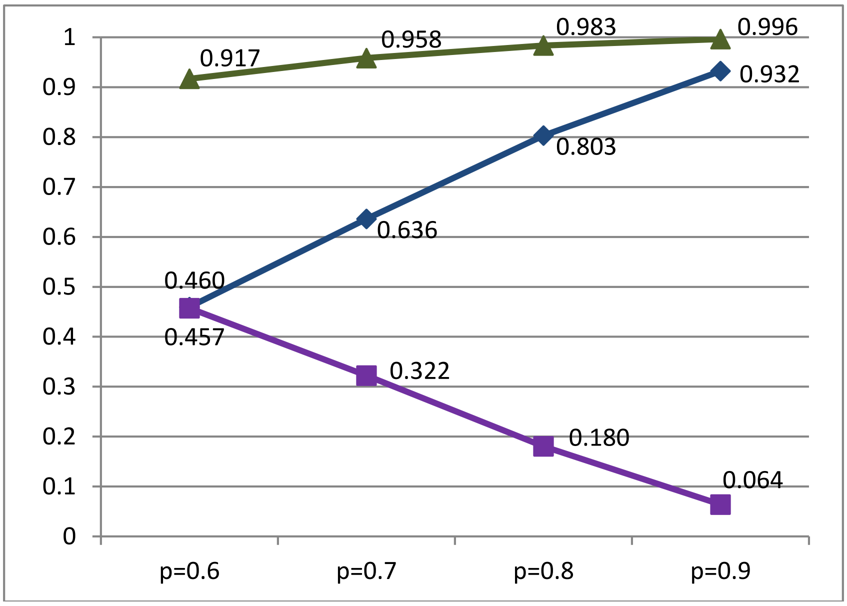

Fig. 3. The dependence of the probability of the task execution by STA on the functionality indexes values of reconnaissance units: ▲ – probability of objects detection by passive and active reconnaissance; ♦ – probability of objects recognition by ORS; ■ – probability of objects non-recognition by ORS.

To control the reliability of the results, the dependence of the probability of detecting objects of exploration was investigated. The sum of the probabilities of recognition and non-recognition of objects is equal to the probability of detecting objects, which confirms the certainty of the results. In general, the result of the study coincides with the expected.

Study 2. Objectives of the study: check how the relative frequency of the usage of active reconnaissance units with is changing the increasing quality of passive reconnaissance units.

Expected result – with the growth of the quality of passive reconnaissance units, the probability of their successful execution also should increase. At the same time, the relative frequency of implication of active reconnaissance units should decrease. This is explained by the fact that after the task is performed by passive reconnaissance units, the necessary to use active reconnaissance units is decreasing.

The results obtained by study 2 are shown in Fig. 4. Overall, the result of the study confirms the expected.

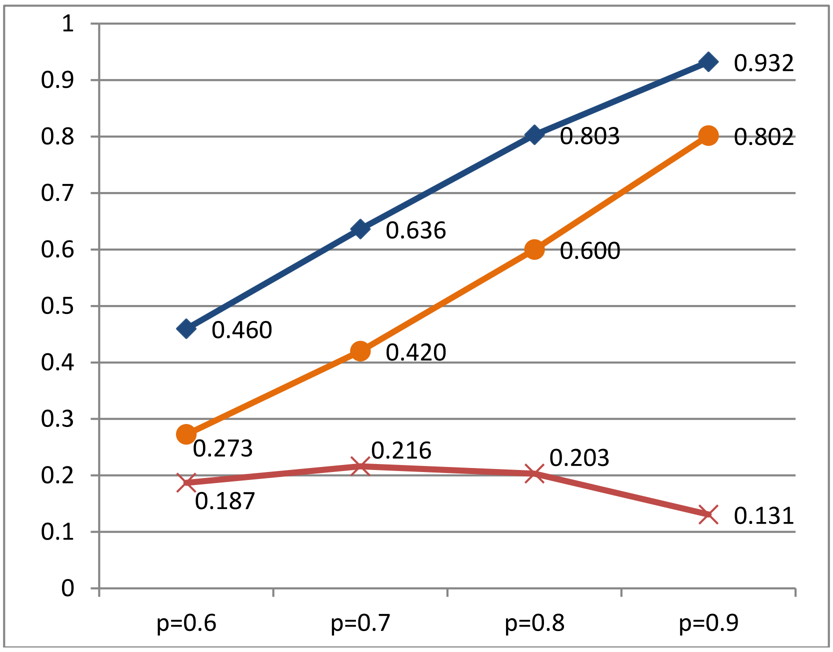

Fig. 4. The dependence of the probability of the task execution by STA on the functionality indexes values of reconnaissance units: ♦ – probability of objects recognition by ORS; ● – probability of objects recognition by ORS after using passive reconnaissance units; ×- probability of objects recognition by ORS after using active reconnaissance units.

6 Conclusions

The proposed behavior algorithm (in favorable conditions) of the surveillance and target acquisition system, is designed to develop software for information-driven system for automation of the process of detection and recognition of objects.

Having used the improved modeling technique, the discrete-continuous stochastic mathematical model of behavior algorithm of surveillance and target acquisition system was constructed. It considers the structure of the investigated system, its functionality indexes, and the features of functional behavior. This model was used at the structural design stage of the surveillance and target acquisition system. The proposed model of the behavior of the surveillance and target acquisition system provides a solution of task of synthesis of the functionality indexes of this complex through multivariate analysis. The developed model can be used by engineers who design a new artillery surveillance and target acquisition system.

The task of further research will be the development of behavior algorithms of surveillance and target acquisition system for medium and unfavorable conditions and the study of their efficiency as well as considering the incorrect recognition of objects (targets).

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