Assessment of the Reliability of a Human Operator in Access Systems to Information Resources

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Abstract: **The article deals with the automated systems providing information services. To describe the operator's activities, functional networks of Professor Anatoly Gubinsky were used. Models and technology for estimating the human operator reliability were obtained. Computer experiments were conducted. The possibility of taking into account the influence of the structures of activity algorithms, working conditions and operator qualifications is shown. Results will be useful to reduce the number of human operator's errors and to search for ergonomic reserves to improve the efficiency of information support systems.**

Keywords: Information resources; reliability; contact-center; man-operator; ergonomics; information technology; human factor; human-machine; effectiveness; mathematical model; computer simulation

I. Introduction

In the conditions of the fourth industrial revolution [1] the problem of quality and efficiency of access to information resources increases [2]-[4]. A new scientific direction "Security Incident Management" begins to develop [4].

II. Problem Statement

Undisclosed sources of efficiency can be found if there is an opportunity to conduct a thorough study of the "human factor" [5]—[10]. In this regard, the purpose of this work is based on the analysis of real contact centers that provide access to information resources:

- to analyze and describe all options of operators activity including search for causes of accidents and elimination of services quality violations;
- to substantiate the concept and method of accounting for the human factor;
- to describe the possibilities of computer simulation and analysis of options for the activities of operators.

III. Results

A. *Justification of the Need to Support Decision-Making on the Organization of the Activities of Operators*

Ergonomic research of control systems and contact centers that provide access to information resources 11]-[14] revealed:

- presence of alternative algorithms of operators' activity;
- significant influence of operator's skills, structure of algorithms of operators' activity and working conditions on the quality of functioning.

Often, there is no decision support systems in the field of recommendation concerning the organization of the operator's activities based on the assessment of reliability and time of activity.

If we analyze all possible activity structures, their description and quality statistics, we will be able to estimate the time and the inerrancy of the implementation of incoming applications.

For this we need [14], [18]-[20]:

- mathematical models for describing and evaluating activities;
- computer technology for designing activities.

B. *Formalized Description and Assessment of Reliability for the Activities of Operators*

1) Methodology of the functional network as a model of human activity.

The most effective activity modeling apparatus is a functional network by prof. Anatoly Gubinsky [16]-[18]. The modeling of elementary actions of operators and automatics is carried out using typical functional units (TFU).The most common of these are the "work operation" with the designation "rectangle", "control operation" with the designation "circle", and "alternative operation" with the designation "rectangle with several outputs". A complete description of TFU models is given in [9]. The functional network (FN) that describes the algorithmic activity of the human operator is built of those TFU. Mathematical models for accuracy and run-time estimation for typical functional structures have been obtained. Examples of models (accuracy and run-time estimation) for (TFS) are given in Table 1. Here: B' is the probability of error-free handling operation; K'' is the probability of recognizing the correct operations performing; K''° is the probability of detecting any errors; *M(T)* is mathematical expectation of the operational run-time; *D(T)* is the variance of the operational run-time.

These models are used to evaluate the entire FN. The estimation is carried out by the method of folding (reduction) FN [16]-[18].

2) Examples of alternative embodiments of the f unctional element in the customers application processing

a) A content analysis: Let's consider operator's activity organization in the sphere of public Internet services. Operator implements the application for "services restoration".

This activity can be represented as an algorithm of operation groups [7]:

- service application reception;
- customer's problem analysis;
- solution;
- informing the client about the results of the implementation.

b) Examples of formal "problems elimination" models: The content analysis of instructional subsystem of real processes was carries out. It revealed basic algorithms used by operators in case o admission applications for the removal of problems in the IT services. Some of these algorithms are summarized in Table I.

Problem 1 is Limited Internet access due to the failure to notify about payment.

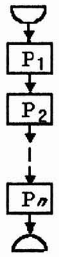
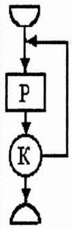
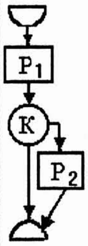
Problem 2 is Lack of Internet access (due to the client hardware problem).

Problem 3 is Lack of Internet access (due to the company's equipment problem).

Problem 4 is Restricted access to digital television due to the non-payment.

Table II provides a detailed description of the troubleshooting transactions.

TABLE I. EXAMPLES OF TYPICAL FUNCTIONAL STRUCTURES

Content of typical functional structure	TFS diagram	Index	Formula for computation
1.Consistent implementation of operations		Probability of error-free operation	$B = \prod_{i=1}^{n} B_i$
		Expectation value of the time of operation	$M(T) = \sum_{i=1}^{n} M(T_i)$
		Dispersion of the time of operation	$D(T) = \sum_{i=1}^{n} D(T_i)$
2.Cyclic functional structure "An operation with action control without restrictions on the number of cycles"		Probability of error-free operation	$B = B^1 * K^{11} * \frac{1}{1-(B^1 * K^{10} + B^0 * K^{00})}$
		Expectation value of the time of operation	$M(T) = (M(T_p) + M(T_\kappa)) * M(L)$ $M(L) = \frac{1}{1-(B^1 * K^{10} + B^0 * K^{00})}$
		Dispersion of the time of operation	$D(T) = D(T) * (M(T_p) + M(T_\kappa))^2 + (D(T_p) + D(T_\kappa)) * M(L)$ $D(L) = \frac{B^1 * K^{10} + B^0 * K^{00}}{(1-(B^1 * K^{10} + B^0 * K^{00}))^2}$
3. Functional structure "An operation with action control and without restrictions on the number of cycles"		Expectation value of the time of operation	$B = B_1^1 * K^{11} + (B_1^0 * K^{00} + B_1^1 * K^{10}) * B_2^1$
		Expectation value of the time of operation	$M(T) = M(T_{p1}) + M(T_\kappa) + (B_1^0 * K^{00} + B_1^1 * K^{10}) * M(T_{p2})$
		Dispersion of the time of operation	$D(T) = D(T_{p1}) + D(T_\kappa) + (B_1^0 * K^{00} + B_1^1 * K^{10}) * D(T_{p2}) + (B_1^0 * K^{00} + B_1^1 * K^{10}) * (B_1^1 * K^{11} + B_1^0 * K^{01}) * M^2(T_{p2})$

a. - Subscripts in formulas correspond to the type (operating course – p; course of control - k) and / or to the number of TFU.

c) Estimation of algorithm implementation reliability (problem 4): Here is an example of estimation procedure. Algorithm of activities is given (Table. I , column 4). Affecting factors are: qualification of operators and their working conditions.

d) Initial data formation: We have the system providing access to computer networks. Initial data is generated from the system's statistical database. These data are given in Table III.

Since working conditions (noise, vibration, lighting, tasks complexity, congestion degree, work in a queue, and etc.) substantially affect operational quality [15-17], we use correction factors method [16, 18]. It allows calculating predicted reliability and runtime values for work severity categories greater than 1 (There are 6 categories. The higher category -worse working conditions [16]). Table HI shows reliability values for 1, 3 and 6 categories only (corresponding integral scores of work severity are 18.3; 43.3; 60).

3) Software development: To solve this problem, we developed models [20] and information system [14], [19] based on the technology of functional structures typing and the folding of network functions (Table I).

4) Examples of computer modeling: Quality performance indicators for operations of the 4-th algorithm for operators of different qualification are given in Table IV. Videogame of functional network reduction results (obtained using our software) is shown in Fig. 1. A fragment of the calculation of the results is given in Table V. The dependence between probability of timely and error-free execution of the algorithm and the time of decision-making of the operator is given in Fig. 2–5.

TABLE II. EXAMPLES OF FORMALIZED DESCRIPTION OF ACTIVITY ALGORITHMS (IN TERMS OF [9])

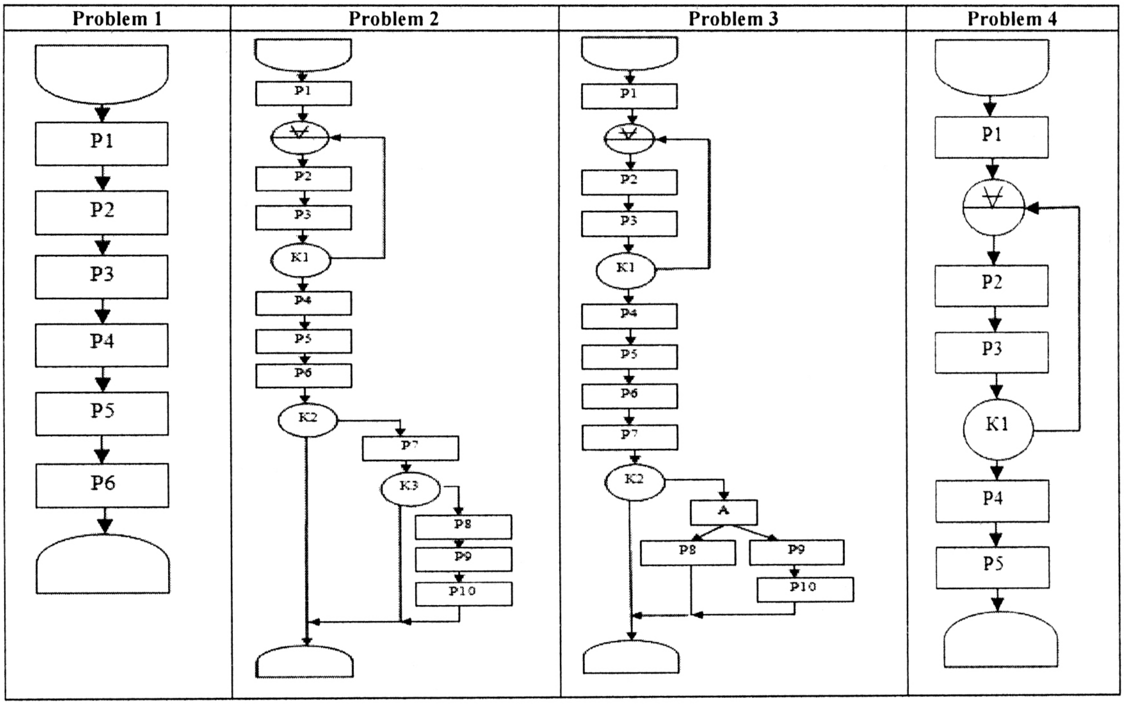


TABLE III. DESCRIPTIONS OF OPERATIONAL TROUBLESHOOTING ALGORITHMS

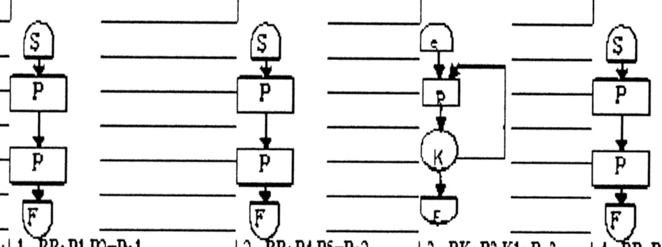
	Problem 1	Problem 2	Problem 3	Problem 4
P1	Receiving an application of Internet access restriction	Receiving an application on Internet access restriction	Receiving an application on Internet access restriction	Receiving an application on Internet access restriction
P2	Execution of the application	Execution of the application	Execution of the application	Execution of the application
P3	Problem analysis	Problem analysis	Problem analysis	Problem analysis
P4	Search for information about payment	Analysis of the client's connection to the Internet	Analysis of the client's connection to the Internet	Analysis of the client's connection to the Internet
P5	Restoring of Internet access	Informing client about problems with user equipment	Informing client about problems with company equipment	Informing the client about the need to pay for services
P6	Informing the customer about problem solution	PC restarting proposal	Clarification of the problem	
P7		Router restarting proposal	Problem solution	
P8		In case of no solution, informing the customer of the need to call the master	Additional troubleshooting operation	
P9		Making an application for a challenge to master	In case of no remote solution by the operator, a challenge to master	
P10		Informing the customer about application accepting	Informing the customer about application accepting	
K1		Checking the customer information in the database	Checking the customer information in the database	Checking the customer information in the database
K2		Checking the solution of the problem after router restarting	Monitoring of the telecommunication system	
K3		Checking the solution of the problem after PC restarting		

TABLE IV. QUALITY PERFORMANCE INDICATORS FOR OPERATIONS OF THE 4-TH ALGORITHM FOR OPERATORS OF DIFFERENT QUALIFICATION (DIFFERENT CATEGORIES OF SEVERITY ARE POSSIBLE)

Indicator	Designation of data	Operator 1 (low qualification). Category of severity			Operator 2 medium qualification). Category of severity			Operator 3 (high qualification). Category of severity		
		1	3	6	1	3	6	1	3	6
P1	B	0,94	0,89	0,65	0,95	0,89	0,65	0,96	0,9	0,66
	M, min	2,2	2,6	5,5	2,1	2,47	5,25	2	2,35	5
	D, min^2	0,49	0,52	0,64	0,47	0,52	0,61	0,45	0,5	0,58
P2	B	0,97	0,91	0,67	0,98	0,92	0,67	0,99	0,93	0,68
	M, min	3,3	3,89	8,25	3,15	3,71	7,87	3	3,5	7,5
	D, min^2	0,11	0,12	0,14	0,1	0,11	0,13	0,1	0,11	0,13
P3	B	0,95	0,89	0,66	0,96	0,9	0,66	0,97	0,91	0,67
	M, min	5,5	6,5	13,75	5,25	6,18	13,1	5	5,9	12,5
	D, min^2	0,55	0,62	0,72	0,52	0,59	0,68	0,5	0,56	0,65
P4	B	0,967	0,91	0,67	0,977	0,92	0,67	0,987	0,93	0,68
	M, min	2,75	3,2	6,87	2,63	3,1	6,6	2,5	2,95	6,25
	D, min^2	0,33	0,35	0,4	0,3	0,34	0,39	0,3	0,34	0,39
P5	B	0,96	0,9	0,67	0,97	0,91	0,67	0,98	0,92	0,67
	M, min	2,2	2,6	5,5	2,1	2,5	5,25	2	2,35	5
	D, min^2	0,44	0,48	0,57	0,42	0,49	0,55	0,4	0,43	0,52
K1	K^{11}	0,975	0,95	0,9	0,985	0,96	0,91	0,995	0,992	0,99
	K^{00}	0,978	0,961	0,95	0,988	0,975	0,96	0,998	0,99	0,975
	M, min	3,3	3,45	3,7	3,15	3,25	3,5	3	3,2	4
	D, min^2	0,22	0,4	0,68	0,21	0,3	0,67	0,2	0,4	0,7

Protocol of reduction

№ of reduction step	Collapsible TFE	Equivalent TFE	Probability of error-free performing the equivalent operation	Mathematical expectation of the equivalent operation run-time	Variance of the equivalent operation run-time	The type of collapsible TFE
1	P1,P2	Pэ1	0,95	3,50	0,55	RR
2	P4,P5	Pэ2	0,97	5,50	0,70	RR
3	P3,K1	Pэ3	1,00	6,21	2,05	RK
4	Pэ1,Pэ3,Pэ2	Pэ4	0,93	15,21	3,30	RR



Reduction step: 1 - RR: P1,P2=Pэ1 | 2 - RR: P4,P5=Pэ2 | 3 - RK: P3,K1=Pэ3 | 4 - RR: Pэ1,Pэ3,Pэ2=Pэ4

Fig. 1. An example of functional network reduction protocol for type 4 algorithm (highly skilled operator, severity category -1)

TABLE V. RESULTS OF THE EVALUATION OF TECHNICAL SUPPORT OPERATORS

Indicator	Decision-making time, min	Operator 1. Category of severity			Operator 2. Category of severity			Operator 3. Category of severity		
		1	3	6	1	3	6	1	3	6
Probability of error-free performing the algorithm B		0,872	0,72	0,25	0,9	0,74	0,26	0,93	0,79	0,35
Mathematical expectation of the algorithm performing time M(t), min		20,57	26,2	58,2	19,3	24,5	50,7	15,2	20,6	45,1
Variance of the algorithm run-time D(t), min		10,09	15,1	30,1	8,95	14	29,4	3,3	11,7	20,5
Probability of performing the algorithm in time Ptim(To)	15	0,29	0,13	0,08	0,32	0,25	0,11	0,48	0,32	0,07
	21	0,52	0,30	0,11	0,58	0,40	0,16	0,96	0,51	0,12
	25	0,67	0,45	0,14	0,74	0,51	0,19	1,00	0,65	0,16
	29	0,80	0,61	0,17	0,86	0,63	0,23	1,00	0,76	0,22
	32	0,87	0,72	0,19	0,92	0,70	0,26	1,00	0,84	0,26
	40	0,97	0,91	0,27	0,99	0,87	0,36	1,00	0,95	0,40
Probability of error-free and timely performing the algorithm B B*Ptim (To)	15	0,25	0,16	0,02	0,28	0,18	0,03	0,44	0,25	0,03
	21	0,45	0,26	0,03	0,52	0,30	0,04	0,89	0,41	0,05
	25	0,58	0,34	0,03	0,66	0,38	0,05	0,93	0,51	0,07
	29	0,70	0,41	0,04	0,77	0,46	0,06	0,95	0,60	0,09
	32	0,76	0,47	0,05	0,83	0,52	0,07	0,96	0,66	0,10
	40	0,85	0,59	0,07	0,89	0,64	0,09	0,99	0,75	0,15

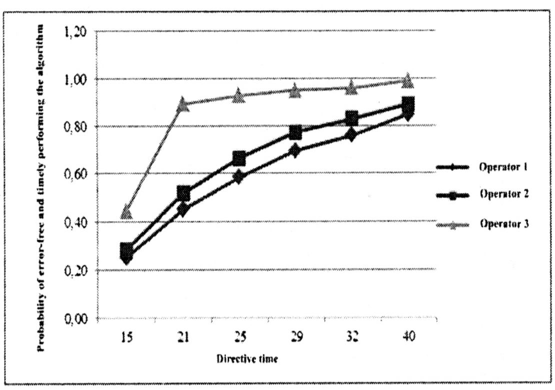


Fig. 2. The dependence between the probability of timely and error-free performing the algorithm (problem 4 solution) and the decision-making time (for normal working conditions)

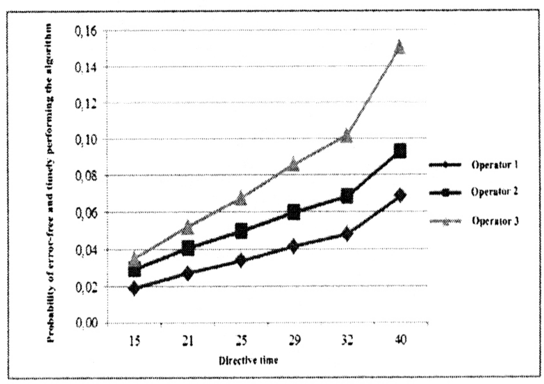


Fig. 4. The dependence between the probability of timely and error-free performing the algorithm (problem 4 solution) and the decision-making time (for the sixth category of work severity)

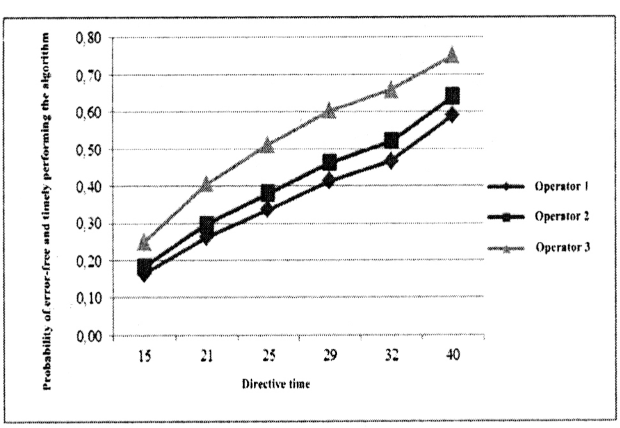


Fig. 3. The dependence between the probability of timely and error-free performing the algorithm (problem 4 solution) and the decision-making time (for the third category of work severity)

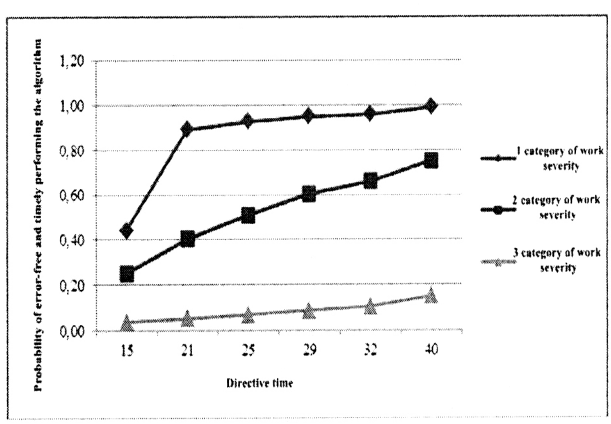


Fig. 5. The dependence between the probability of timely and error-free performing the algorithm (problem 4 solution) and the decision-making time for different work conditions (for the 3 operators of high qualification)

Examples of calculations are prepared on the basis of analysis of the work of specific provider centers located in Sumy (Ukraine) with the participation of the student of postgraduate education Krivodub Anna and the student Shapochka Julia (Sumy State University).

IV. Conclusion

The work is done within the man-system approach to modeling automated systems, solving one of the practical problems of ergonomic support, which was formulated in [7]. Thus, we have laid the foundations of decision support for the organization of the activities of operators in automated systems.

Scientific novelty. Unlike the existing intuitive methods, we developed:

- formal methods to describe and valuate the reliability and timing of the functions (in relation to systems of information resources);
- new method of automatic reduction of a functional network;
- new method of taking into account the individual characteristics of the human-operator and working conditions at the workplace.

A new information technology was proposed, which should be useful for the practice of the work of contact centers. Results can also be extended to other types of automated systems. This will allow in the future to reduce the number of errors and accidents caused by the human operator.

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