Evaluation of the Mobile Simulator for Fire Protection Training

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Abstract

The concept of development, construction of mobile training simulator complexes, which need to be integrated into the transport technological system of the forest industry, as well as the evaluation of the effectiveness of joint training of specialists in the field of fire safety. The practical value of the study lies in the fact that the proposed procedures, concepts and approaches to the development of technical training tools have allowed the introduction of modern digital technologies in information and training simulation complexes, capable of conducting real-time sessions of joint training and training as a part of a team for different categories of workers associated with one task.
Situational modeling ensures the maximum reduction of the impact of errors of trained personnel on the overall level of fire safety with limited resources for real exercises. Decision-making in extreme conditions and with the existence of extreme assumptions leads to an increase of the number of errors of personnel for firefighting. The analysis of typical mistakes of personnel of fire protection is carried out. Establishing a link between errors of personnel and the consequences of fires, as well as determining the impact of certain types of errors on the consequences of fires is an important task, since its solution is a necessary condition for effective information and Advisory support of decision - making processes in fire fighting. Results of researches testify to advantages of use of training systems by means of which there is a joint preparation of staff of fire protection and personnel of dangerous objects.

Introduction

The main tools of the forecast are geographic information systems (GIS), combining information from a variety of sensors, simulation models of dangerous natural and man-made processes.

Information technologies have become inalienable part of life of modern society. In this connection before the modern system of preparation of personnel the intricate problem of the LED teaching is put in the conditions of existence and professional activity in global informative society.

Drawing on trainer complexes as teaching systems allows operators to get all necessary skills which need him during work on the real object. Such effect is reached because the program exercise machine it is most realistic recreates the course of technological process, logic of work of an automated control system for technological process, including indication, blocking, logic of work of the real equipment. Using of exercise machines when training in methods of elimination of the fires and accidents is especially effective [1].

As advantages of use of exercise machines it is possible to note the following:

- tutoring intensification without loss of quality of digestion of material;
- are capable of broad change of conditions of carrying out accident free trainings;
- are capable of rather easy and fast modification of elements of the studied equipment to the latest industrial samples;

- essential energy saving in comparison with use of real models, economy of the educational areas, decrease in capital, operational and other expenditure is provided [1].

The mathematical model of estimation of results of the command trainings offered first is most efficient in organizing both the collaborative occupations (joint) in team and individual work with each of the participant of trainings on activities, exposing their professional qualities and personality features of conduct during joint work in a command.

Experimental part. Method of organization of joint trainer preparation of personnel of subdivisions of fire prevention and personnel of dangerous objects

Basic directions of works on research-and-development trainers presently are in the whole world [1, 9]:

- making of new forms of representation of knowledge (educational material) maximally close to the real terms, and also variants of the use of this knowledge;
- developing of models of acquisition of knowledge, providing the maximal mastering at minimum temporal and financial expenses;
- forming of different styles of conduct taught at the situational teaching.

The carried-out analysis has shown that there is a number of the restrictions complicating use of the developed training systems within a solvable task.

To the number limitations it is possible to take followings:

- strict methodology of teaching and generalized, mass («line») preparation, not taking into account individual features taught and efficiency of their cooperation in composition a command;
- absence or low display of intercommunication in a chain «Taught» is the «Teaching system (Teacher)», that hampers organization of situational management teaching or does its impossible;
- ways of answers estimation are limited clear rules and (or) does not suppose the variant (multiple) choice of different ways of decision of situational tasks;
- activity of fire divisions in team together with personnel of the enterprise isn't considered [2,5,6,9].

Requirements to the joint trainer complexes, taking into account the specific features of subject domain of preparation of personnel of fire prevention and personnel of fire-hazardous enterprises, to which attributed, are certain:

- big volume and heterogeneity of the processed information;
- high dynamics of change of operative situation;
- vagueness of situations at the decision of tactical task;
- hard temporal limits on making and making decision;
- is not capable of complete formalization of teaching task.

The concept of the command trainings is entered as to one of effective methods of the joint teaching of personnel of fire subdivisions and operative personnel of enterprises of fire-hazardous enterprises.

The command trainings are a method of design of situation for making of variants of decision of tactical tasks in the conditions of multi-variant approach of making decision, dynamic quality of external environment, limited in time and ticker-coil. This method is used in an educational process, to imitate the real situation [3-7].

Making decision in extreme terms results in growth of amount of errors of personnel at fire extinguishing. Establishing a connection between the errors of personnel and for-consequences of fires, and also determination of measure of influence of error of certain type on the consequences of fires are an important task, as its decision becomes the necessary condition of effective management the processes of making decision at fire extinguishing.

The analysis of errors at fire extinguishing specifies on that more frequent than all errors accompany one other. The exposure of one of errors specifies on certain probability of appearance of concomitant error [4-6]. For establishment of fact of existence of connection between errors a cross-correlation matrix is built (table 1). A table is a 1- Matrix of coefficients of pair correlation

Table 1: The matrix of coefficients of pair correlation

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1	1	0.937	-0.153	0.629	0.049	0.336	0.834	0.177
Q2	0.937	1	-0.460	0.371	0.371	0.320	0.614	-0.088
Q3	-0.153	-0.460	1	0.651	-0.720	0.295	0.414	0.891
Q4	0.629	0.371	0.651	1	-0.390	0.628	0.950	0.871
Q5	0.049	0.371	-0.723	-0.390	1	0.364	-0.316	-0.443
Q6	0.336	0.320	0.295	0.628	0.364	1	0.522	0.667
Q7	0.83	0.614	0.414	0.950	-0.310	0.522	1	0.676
Q8	0.177	-0.080	0.891	0.871	-0.440	0.667	0.676	1

From the values of coefficients of pair correlation ensues [2, 4-6]:

- slow increase of forces the slow increase of forces and facilities (Q1) most depends on the off-grade lead through of secret service (Q2) (to to = 0,94);

- non-acceptance of measures on evacuation of people (Q7) is determined the slow increase of forces and facilities (Q1), un using of gas and smoke protective facilities (GSPF) (Q4), un effective use of fire technique (Q8);

- the un effective use of fire technique (Q8) is caused mainly the incorrect choice of decision direction of fire extinguishing (Q3) and errors of application of GSPF (Q4);

- the clumsy pumping over or transport of water (Q6) is straight related to un using of the nearest water sources (Q5);

- the un effective use of fire technique (Q8) is simultaneous it is unconnected with un using of the nearest water sources (Q5), but influences on the clumsy pumping over or transport of water (Q6);

- far of errors depends on the un effective use of fire technique (Q8).

On the basis of analysis of activity of controller's composition of fire prevention classification of errors was developed and the coefficients of their mass weight (M), which show the relative size of error depending on harm which they can lead to, are set (figure 1) [1, 4,11]:

à) stage of accepting challenge and their service:

- accepting challenge incorrectly recorded or the address of fire is wrong caught (M = 0.14467);

- accepting challenge the floor of origin of fire, building height or other parameters of object, is not certain (M = 0.13822);

- district of departure is wrong certain fire brigade (M = 0.13905);

b) stage of making decision and delivery of order about deportation of forces and facilities, in obedience to the curriculum of departures:

- forces and facilities were not sent (M = 0.12042);

- untimely dispatch of forces and facilities (M = 0.130952);

- dispatch of forces and means to the wrong address (M = 0.13271);

- wrong determination of enough body of forces and facilities on basic fire cars (M = 0.12813).

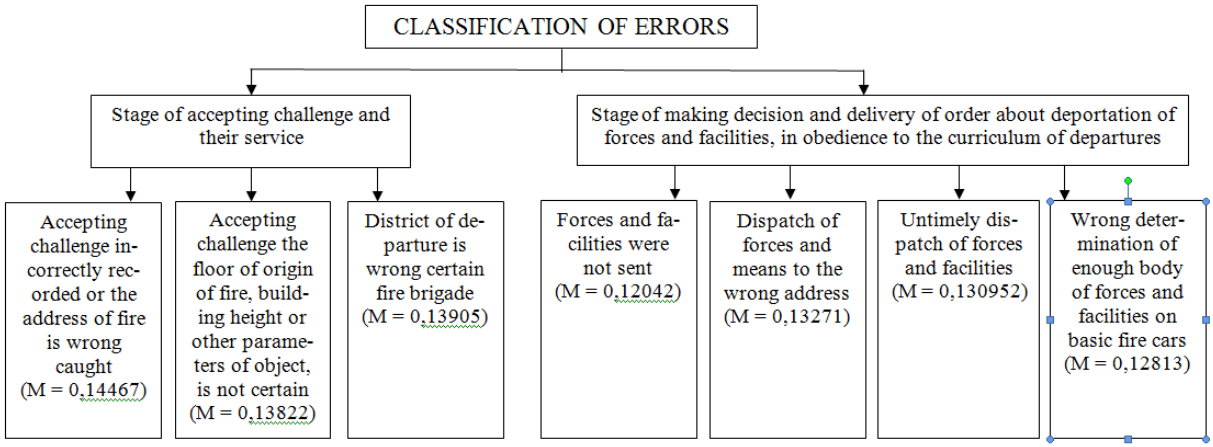


Figure 1: Classification of errors and coefficients of their mass weight (M)

Consequently, the lead through of practical employments is expedient, studies, where the actions of controller's composition of the Central point of fire connection (CPPS) will be examined in case of occurring two and more than fires on the raised rank [4,15].

However much such employments carry single and optional character, because they are not foreseen in the program of preparation of personnel MINISTRY of emergency measures of Russia, therefore by the optimum method of decision of this question, coming from calculations and prognoses, there is introduction in the process of preparation of personnel of fire prevention of computer trainer complexes.

Applying terminology of the theory of mass service, on the panel of the dispatcher the stream of calls from n of objects comes to continual time points.

In the process of research streams of calls, arrived to the dispatcher of fire prevention of the Ufa garrison for a year with the purpose of determination of their descriptions have been analysed and processed.

Table 2 are Descriptions of operative negotiations of controllers in normal terms and at a fire

Table 2: The operational characteristics of the negotiations managers of CPPS in normal conditions and in case of fire

Descriptions of negotiations	Mode	Interval, cut						
		0-10	10-20	20-30	30-40	40-50	50-60	60
Number of negotiations	Norms.	15.5	28.5	16	9.5	5	3.5	2

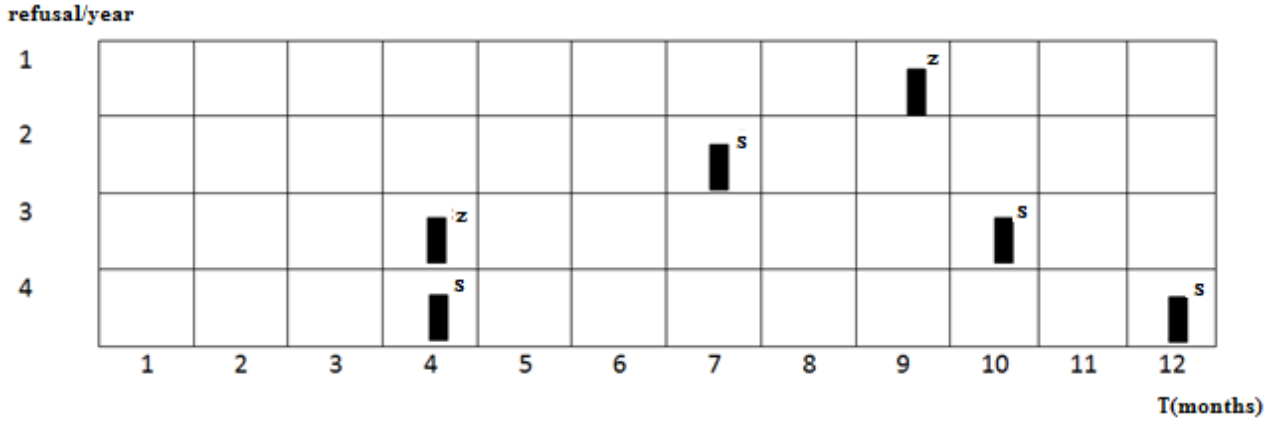
	Avar.	17	16	8	5	2	2	-
It is a midfrequency	Norms.	0.194	0.357	0.200	0.119	0.063	0.044	0.023
	Avar.	0.34	0.32	0.16	0.10	0.04	0.04	-
It is the Expected value duration of negotiations, m, cut	Norms.	18.39						
	Avar.	12.84						
Function of distributing of duration of negotiations, F(t)	Norms.	0.237	0.560	0.745	0.850	0.914	0.982	-
	Avar.	0.323	0.682	0.855	0.935	0.970	-	-
Are Criteria	Norms.	p=0.68>0.05						
	Avar.	p=0.42>0.05						

With the purpose of confirmation of these positions, and also determination of descriptions of negotiations in a table 2 information is resulted on maintenance of calls the controllers in normal terms and at a fire. An analysis shows that in the normal mode mean time of negotiations of controller is 18-20 cut, at a fire – 12-13 cut [3, 6, 9].

At the estimation of reliability of operative-controller's management of fire prevention apply two criteria:

- reliability at making of administrative decisions;
- possibility of operative deportation of forces and facilities into place of fire.

Statistical information (picture 2) show that a danger of refuses of controllers is a size permanent.



Z - appropriate refuse of S - casual refuse

Figure 2: Are the Exposed refuses of controller's changing Because

The refuse of changing comes then, when both controllers assume an error simultaneous, from point of reliability it is necessary to examine them as elements, included parallell [3-5].

On pictures 3 and 4 dependence of index of quality of preparation is rotined on intensity of refuses in time before and after introduction of joint preparation.

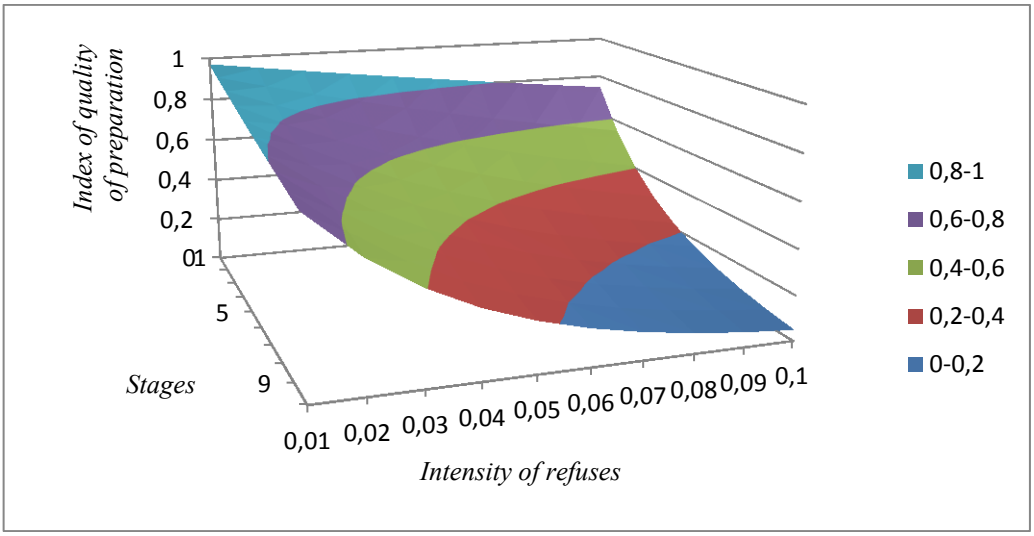


Figure 3: Graphic dependence of index of quality of preparation to introduction of joint preparation

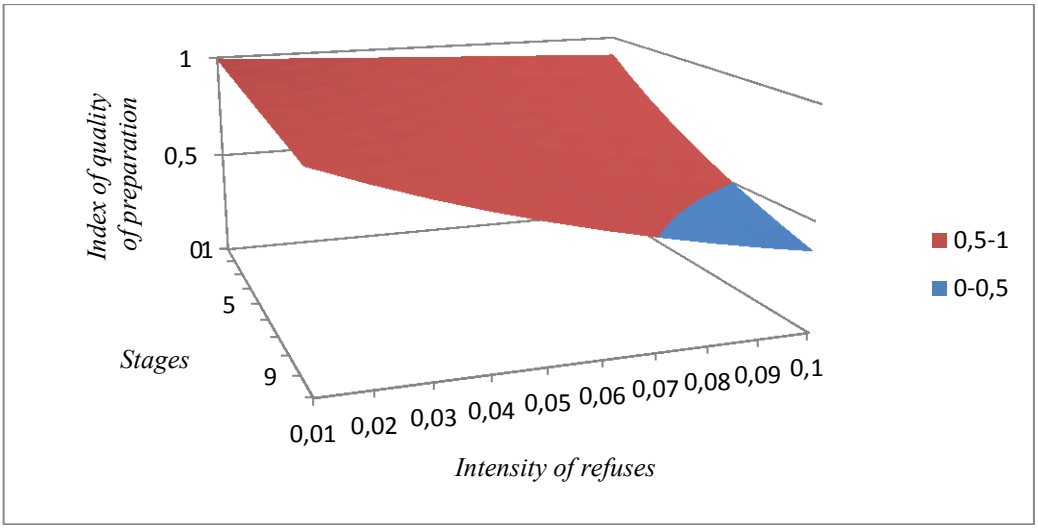


Figure 4: Graphic dependence of index of quality of preparation after introduction of joint preparation

For ten months intensity of refuses arrives at a value 0,1, and quality of preparation of personnel goes down to 0,2. This index is low.

If to accept sufficiently arbitrary probability of origin of one refuse on appropriate reasons of equal 0,5 (Rz = 0,5), it is necessary to conduct the term of verification of knowledge of controller's personnel two times in a year. Reliability, determined casual refuses, to the size 0,5 (Rs = 0,5) taking into account said before goes down for 2 – 3 months.

Having 10 – 12 duty controllers in composition controller's service, work with them it is necessary to conduct approximately one time per a week with each, I.e. practically continuously.

The results of the experiments and their analysis. Method of estimation of efficiency of application of joint trainer complexes

The model of trainer is offered for working off the united actions of leader of extinguishing of fire (LEF), controller of fire prevention (CFP), controller (operator) of service of life-support of object, setting (CSLSO).

For the analysis of efficiency of «command» trainer preparation of personnel of fire subdivisions and personnel of object from the results of trainings the detailed protocol of actions of participant undertakes and every his action which behaves to one of the followings classes is examined [4, 5, 11]:

1) Faithful actions, executed within the limits of the rationed time (K1).
2) Actions, not giving a necessary result (K 2).
3) Incorrect actions (K 3).

4) Executed with exceeding of the rationed time of action (K 4).
5) Too late executed actions (K 5).
6) Unavailing, superfluous actions (K 6).
7) Inefficient actions (K 7).

The index of efficiency (V) of trainer preparation can be estimated on the basis of analysis dependence of the job processing on a trainer from the followings factors:

actual time of implementation of the certain training (td), got during implementation of training;
rationed time (tn) for every type of trainings;
penalty (bonus) time Δt;
amounts of run-time jobs training of N (we set in natural numbers);
the ratio (weight) of Ki error (in fractions of the whole) specific error Ni.

Thus, it is possible to write the mathematical model of estimation of quality of trainer preparation of training participant [4, 6] *V=f{td,tn,Δt,N,K}*.

As can be seen the implementation of training directly depends on the allowed error, i.e. the error and the weighting factor of this error. So, V is directly proportional to N and K.

The more time spent training, the less likely that it will be executed, and Vice versa. Therefore, V~1/T . The integration will enable to calculate the effectiveness of the implementation of the training from normalized to actual.

$$V=1 - \sum_{i=1}^{n} \frac{N_i \cdot K_i}{N} - \ln\left(1 + \frac{\Delta t}{t_n}\right)$$

For the estimation of efficiency of joint trainer preparation the mathematical model of calculation of criterion of efficiency of the joint trainings, which is described «Pyramid of the joint teaching», is built» (picture 5).

Sides of foundation of pyramid $0 \le V_i \le 1$ correspond efficiency of implementation of trainings the separate participants of trainings: leader of extinguishing of fires (LEF), controller of garrison of fire prevention (Controller FP) and operator of service of life-support of object (Operator SLSO) [5, 8, 9].

The criterion of efficiency of joint actions of the team members ($K_{н_i}^{j}$ – the assessment index quality) corresponds to the area of the base (horizontal section) of a triangular pyramid [4, 5, 7]:

$$K_{н_i}^{j} = S = \frac{1}{4R^j} \prod_i \prod V_i^j$$

where, i=1, 2,3 are training participants (sides of foundation);
j=1,2,3…n are types of preparation (horizontal sections of pyramid);
1/Rj - is a coefficient of change of operative situation;
V_i - is an index of efficiency of implementation of training every participant.

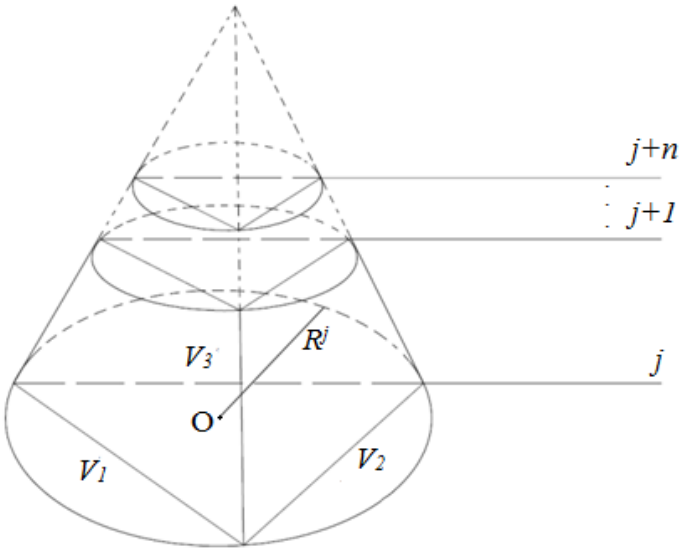


Figure 5: Model of pyramid of the joint teaching

Stability of the system, and accordingly, the criteria of implementation of the united actions at implementation of trainings are described through geometry of the masses.

The ideal variant of implementation of trainings all members of command comes in the case when V_I=1 (figure 6). The centre of gravity coincides with centers described and entered. Take this case for the criterion variant of implementation of trainings [3, 5, 8].

Top limit of criterion of efficiency of the united actions of command participants (figure 7):

$$К_{н_{max}}^{j} = S_{ABC} = 0{,}433$$

In Chapter 3 it was noted that in justifying the required frequency of training the upper limit of the achieved level of proficiency equal to 0.5.

Calculate relative V_i=0.5 of the stability parameters of the system. The lower limit of criterion of efficiency of joint actions of the team members (figure 8) [2, 9]:

$$К_{н_{min}}^{j} = S_{ABC} = 0{,}108$$

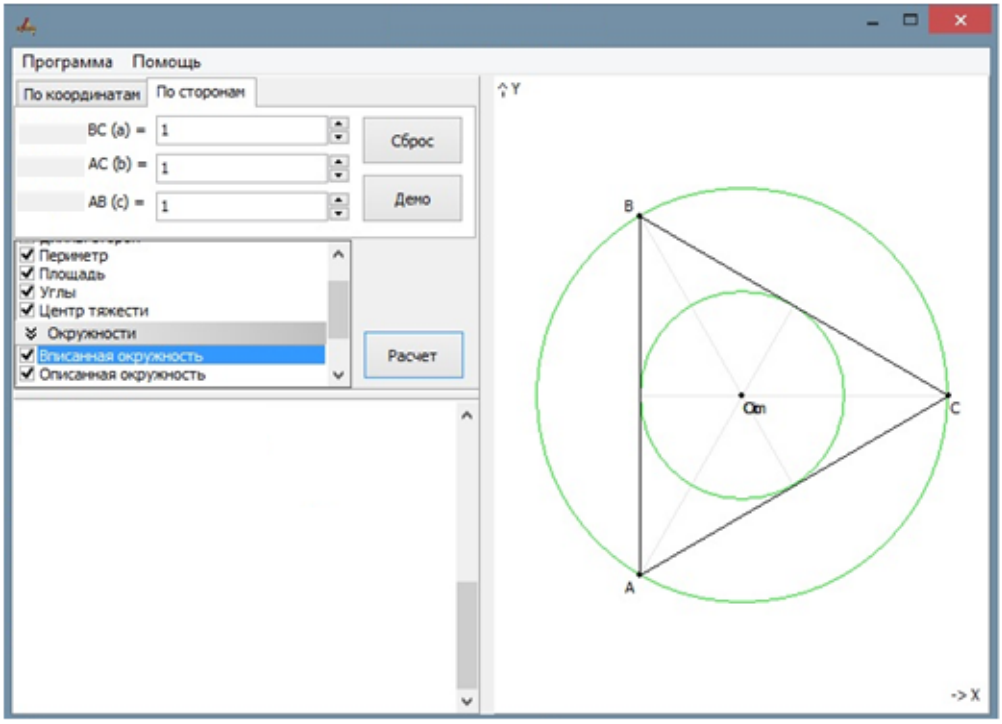


Figure 6: Calculation of criteria of implementation of the joint trainings in «ideal» case, at Vi=1

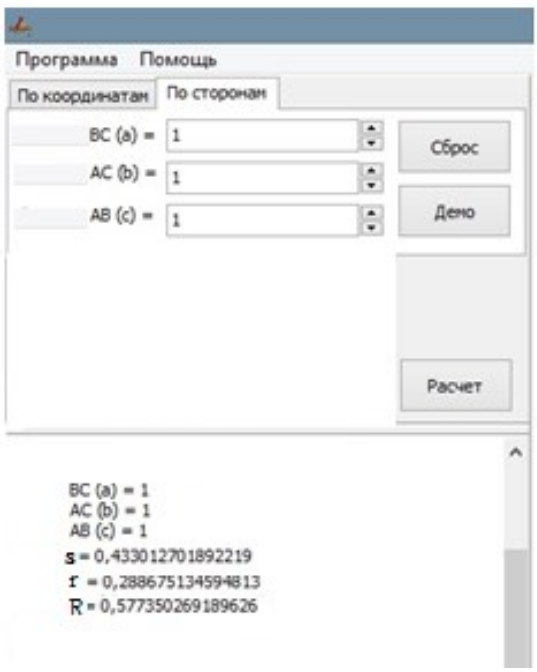


Figure 7: Panel of calculations at Vi=1

Figure 8: - Panel of calculations at Vi=0,5

In the case when the coordinates of the center of mass fall outside of the inscribed circle, irreversible event in the development of fire or emergency. The same continuation of training becomes inadvisable. Such is possible even at faultless implementation of trainings and acceptance of faithful administrative decisions two participants, but at the low result of the third participant of command (figure 9) [5, 12].

At unsatisfactory implementation of the training sessions two or more participants further operation stop (figure 10).

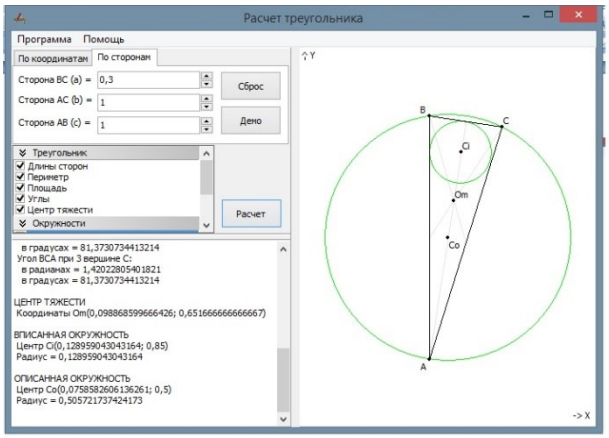


Figure 9: the Critical situation – the center of mass of a triangle is outside a circumscribed circle

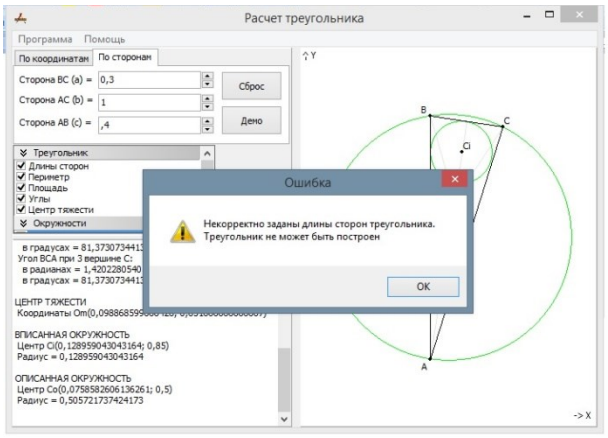


Figure 10: A critical situation – the low level of knowledge of two participants of team

Conclusion

Today the problem of forest fires is one of the most acute problems in the Russian Federation and in many countries of the world. The use of mobile training complexes of joint training for specialists engaged in the elimination of consequences of emergency caused by forest fires, based on the use of digital technologies and methods of mathematical and situational modeling, can be of fundamental importance in addressing this issue.

As a result of the analysis of a current state and tendencies of development of training complexes requirements to computer training complexes are developed. The use of computer simulators for the joint training of personnel of fire-hazardous facilities of the Russian forest sector and personnel of fire protection is currently promising, but the existing training systems do not provide the possibility of joint training, and there is no methodology for assessing the effectiveness of joint training. Efficiency and quality of training of staff of fire protection and personnel of objects of an oil and gas complex increases by 1,73 times due to application of the training complex on management of joint actions in a dynamic operational situation.

The created and scientifically based situational models of trainings have allowed to provide interrelation between participants. Interaction between the head of fire extinguishing (HFE), the dispatcher of garrison of fire protection (the Dispatcher of FP) and the operator of service of life support of object (Operator SLSO) during performance of trainings, mutual influence of mistakes of certain participants is defined by change and complication of an operational situation in situational trainings.

Necessary value of effective frequency of training preparation of personnel is established depending on intensity of emergence of natural and casual refusals. At intensity of natural refusals λz=0.042 (refusal)/(month) and intensity of casual refusals λs=0.084 (refusal)/(month) the required frequency of joint training preparation makes time in 14 days, in the presence of five duty shifts as a part of 10-12 people preparation happens continuously that difficult without use of training complexes.

The mathematical model of evaluation of efficiency of training of personnel of fire departments and personnel of the objects allowed us to determine the values of criterion of efficiency of joint actions of the participants ($К_{н_i}^{j}$– the assessment index of quality), appropriate to the area of the base (horizontal section) of a triangular pyramid collaborative co-education. Top limit of criterion of efficiency of joint actions of participants of team $К_{н_{max}}^{j} = S_{ABC}$=0,433. Lower limit of criterion of efficiency of joint actions of participants of team $К_{н_{min}}^{j} = S_{ABC} = 0{,}108$.

The experimental assessment has allowed to establish that the offered actions allow to lower time expenditure on studying by trainees of standard and unusual situations by 1,39 times, and also to increase quality of studying of training materials by 1,73 times.

In order to effectively combat natural fires, it is necessary to solve the problem of training of qualified personnel, which is impossible without practical training. One way of getting practical knowledge is the simulation of real situations and their solution the students in real time.

The use of mobile training complexes allows, without significant financial costs, to cover with practical training large areas, especially remote forests.

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