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System of personnel training in decision making in fighting wildfires

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Abstract. Wildfires fighting is a complex and often dangerous process connected with cooperation of many organizations and crews that requires good organization. An important role in this process plays the qualitative training of personnel involved in the fire fighting. Training of personnel in the techniques and tactics of combating wildfires is conducted in educational systems of various levels, but, regardless of the level, members of firefighting crews should have basic knowledge of fire safety techniques, methods, and tactics. It is known that one of the most effective forms of personnel training is the use of interactive computer systems that allow individual approach to the trainees. Given the dynamic nature of the wildfire spread and the need to make rapid decisions, training system should include an imitation subsystem, which can help a trainee to observe the development of the fire situation on the map, make decisions and evaluate their effectiveness. In the work presented, an interactive simulation system FIREMAN is discussed. The system is designed to train personnel in basic knowledge and decision making in combating wildfires. The structure of the system is described, and an example of how it works is given.

1. Introduction

Wildfires fighting is a complex and often dangerous process, connected with cooperation of many organizations and crews. Thus, suppression of a wildfire is a complicated process that requires a good organization [1-4].

Wildfires cause huge economic and environmental damage to the countries and regions in which they occur, leading to death of people. To support effective control of wildfires, many information systems have been developed to simulate and predict fire behavior (BehavePlus [5], FARSITE [6], WFDS [7], etc.).

However, in addition to modeling directly the edge of natural fire, there is a need to simulate various external effects on fire for its localization and elimination. Such models can be actively used in the management of fire situation to solve the problem of effective management of firefighting forces and facilities [8, 9], etc.

An important role in this process plays the qualitative training of personnel engaged in fighting the fire. Today in Russia, personnel of various organizations are involved in the process of extinguishing wildfires: employees of Russian Aviation Forest Protection agency Avialesoohrana, crews of the Russian Ministry of Emergency Situations, members of voluntary fire crews created by municipalities, and staff of other organizations involved.

In Russia, a new standard has been introduced in 2018, according to which a new working specialty - forest firefighter - has appeared. The specialists have rather high requirements. They should not only be able to extinguish fires, but also know basics of firefighting tactics, have skills of rescuers, psychologists, organizers and communication specialists. Extinguishing fires involved, for example, fire jumpers, paratroopers, workers of fire and chemical stations. Forest firefighters can work in land groups and in aviation units. These structures are under the jurisdiction of Avialesoohrana and are subordinated to Rosleskhoz.

According to the professional standard, forest fire extinguishers are divided into three classes. Firemen of the third class should be able to extinguish fires with the help of hand-held technical means (for example, a shovel or a fire extinguisher), the second - with the use of special equipment (including tractors for extinguishing forest fires). Firefighters of the first class, in addition, must have skills of organizers and must be able to conduct search and rescue operations. Forest firefighters in special cases should be able to perform the functions of managers. It is impossible to find so many firefighters to provide each group with a leader.

According to the professional standard, forest firefighters should be able to correctly apply various means and methods of extinguishing, considering the characteristics of the terrain and fires, to choose safe places for creating strong points, to navigate in the forest. They should be able to act in extreme situations, adverse weather conditions, under the influence of stress factors.

Personnel training in techniques and tactics of combating wildfires is carried out in educational systems at various levels - from special education in universities [10], where forest pyrology course is taught, to short-term courses for recruited employees of outside organizations. However, regardless of level of the educational institution in which the training is conducted, members of firefighting crews should have basic knowledge of fire safety techniques, methods and tactics of wildfires combating.

It is known that one of the most effective forms of personnel training and professional development is the use of interactive computer systems that allow individual approach to the trainees both in material mastering and testing. A separate class of training systems are computer simulators that widely used in various fields. Given the dynamic nature of the wildfire spread and the need to make operational decisions, training system should include an imitation subsystem, which can help a trainee to observe the development of the fire situation on the map, make decisions and evaluate their effectiveness.

In the work presented, an interactive simulation system FIREMAN is discussed. The system is designed to staff training in basic knowledge, skills and decision-making in the elimination of wildfires.

2. Structure and functions of the FIREMAN system

The system is a web-oriented software package based on learning management system (LMS) MOODLE [11] and the TAIGA simulation program. Structure and components of the FIREMAN system are shown in figure. 1.

2.1 Functions of LMS MOODLE:

- preliminary training and testing of trainees,
- assignment to a trainee the game scenario variant for TAIGA simulator,
- receiving game events protocol from TAIGA,
- appraisal of trainee's decisions by tutor,
- formation an overall assessment of the trainee's work,
- formation the report with final grades.

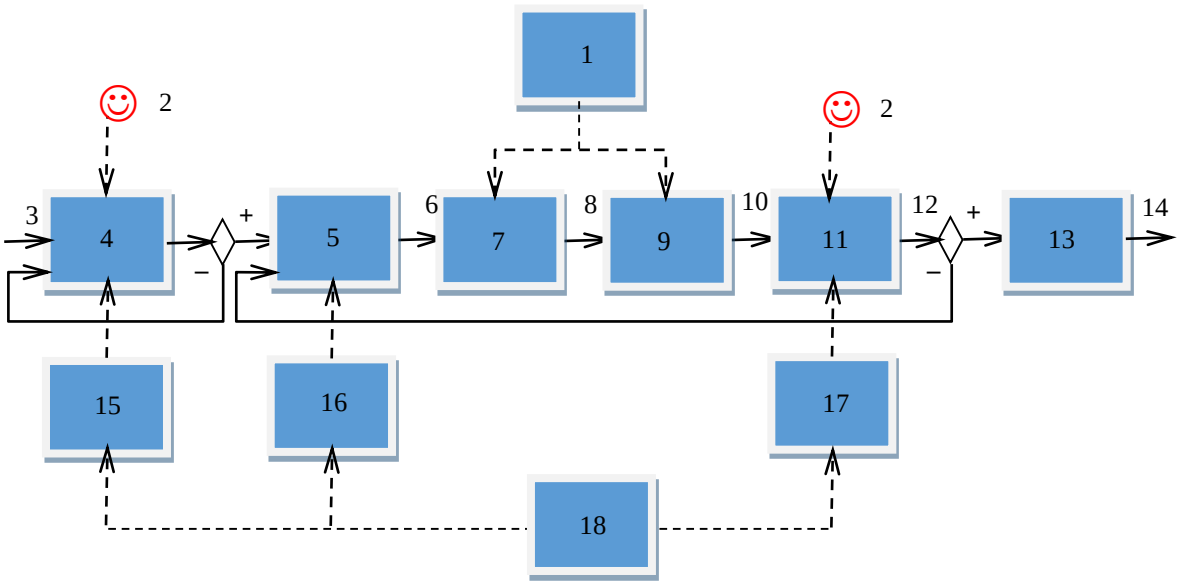

Figure 1. The structure of the imitation training system FIREMAN.

Designations in the figure: 1 - program TAIGA; 2 - tutor; 3 - login to the system; 4 – preliminary training and testing; 5 - selection of the game scenario; 6 - scenario data; 7 - simulation of the firefighting process; 8 - events in the system; 9 - formation of events protocol; 10 - protocol of events; 11 - appraisal of the trainee's actions; 12 - assessment of the success of the trainee's actions; 13 - formation of the training passage report; 14 - end of training; 15 – e-learning course on the basics of firefighting and safety techniques; 16 - base of scenarios; 17 - rules for appraisal of the trainee's work; 18 – LMS Moodle.

2.2. Functions of the TAIGA program:

- demonstration of various scenarios for the development of wildfire and its elimination;
- formation of the game situation based on the initial data of the scenario: a map of the terrain with the indication of possible protection objects, characteristics of vegetable fuel materials, fire danger class, wind speed and direction, initial configuration of the fire, list of available firefighting forces and facilities;
- modeling the fire dynamics on basis of the agent approach and displaying fire situation on the terrain map: fire spreading, action of fire-fighting forces and facilities [12, 13];
- messages generation on the fire dynamics: area passed by fire, length of the burning edge, distance to the object of protection - after a predetermined time interval;
- messages generation about the decisions made by the trainee: calling personnel and technical means, instructions for their movement, placing firemen along the edge of the fire, building fire protection bands, etc., time-bound;
- revealing of catastrophic situations: objects of protection fire capture, fire damage to a firemen or vehicle, uncontrolled growth of fire area and length of a burning edge, etc.;
- events data transfer to MOODLE.

2.3 Functions of a tutor (moderator):

- consultations and assistance to a trainee at the stage of preliminary training and supervision;
- appraisal of a trainee's actions when working with the imitation program is over, preparation of a training report.

Let us consider in more detail the components of the system.

3. Learning subsystem on the base of MOODLE

Learning Management System (LMS) Moodle is today one of the most popular in the world and is used both in the traditional educational process, and in the training of personnel, the conduct of various trainings. The acronym Moodle is formed from the initial letters of the name: Modular Object-Oriented Dynamic Learning Environment. In the Moodle system, you can create and store electronic learning materials and specify the sequence of their study. Electronic format allows to use not only text, but also interactive resources of any format from an article in Wikipedia to a video on YouTube. To do that, the system provides a lot of tools: wiki, glossary, blogs, workshops, hyperlinks, files and much more. Thus, Moodle is designed to create quality distance courses and to organize an effective educational process.

Moodle can also be useful for staff training automation on basis of combating wildfires tactics. For this purpose, a distance course integrated with the computer simulator Taiga has been created. The course consists of three main sections. The first section is called "Testing" and contains a block with input tests (Figure 2). Choice of the input test for a trainee is determined by tutor. An example of the input test is shown on the Figure 3. If the trainee correctly answered more than 90% of questions, a link to the computer simulator Taiga, which is in the second section of the course, becomes available to him. The second section is called "Interactive imitation system Fireman (figure 4).

4. Educational and training systems TAIGA

Educational and training system TAIGA developed by the authors can be used for training of various categories of trainees in educational and playful way on the basics of tactics to combat wildfires. TAIGA is a network geographic information system (GIS) with the reference to real terrain. The system has client-server architecture. To reduce the load on the network and better scalability, most calculations are performed on the client side that allows a user to distribute the load evenly between all devices. The server part is developed on PHP. The server contains a database that stores information about the simulation environment (real terrain). The client part is developed on JavaScript using a library of open source OpenLayers. This library is used to create maps-based programming interface (API) and allows a user to create web-based interface to display maps. This library can work with data from different map services, such as OpenStreetMap, Google, Yandex, and others.

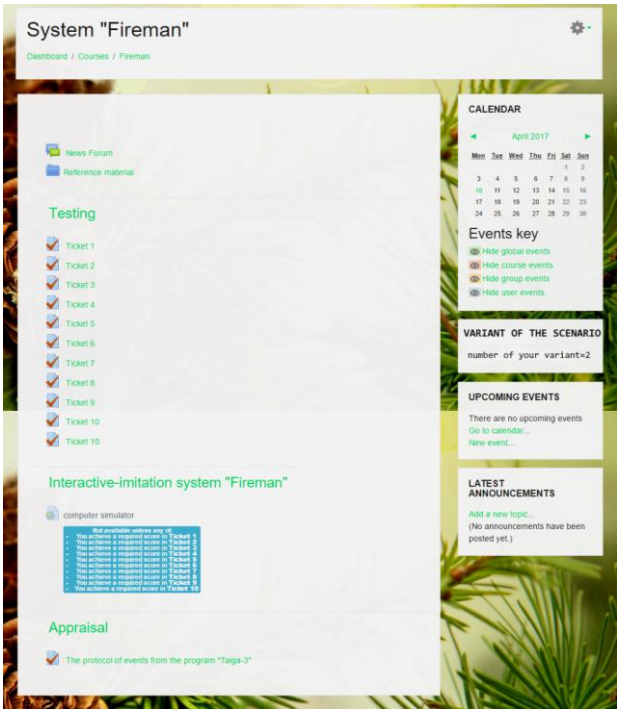

Figure 2. Appearance of the FIREMAN Course Page.

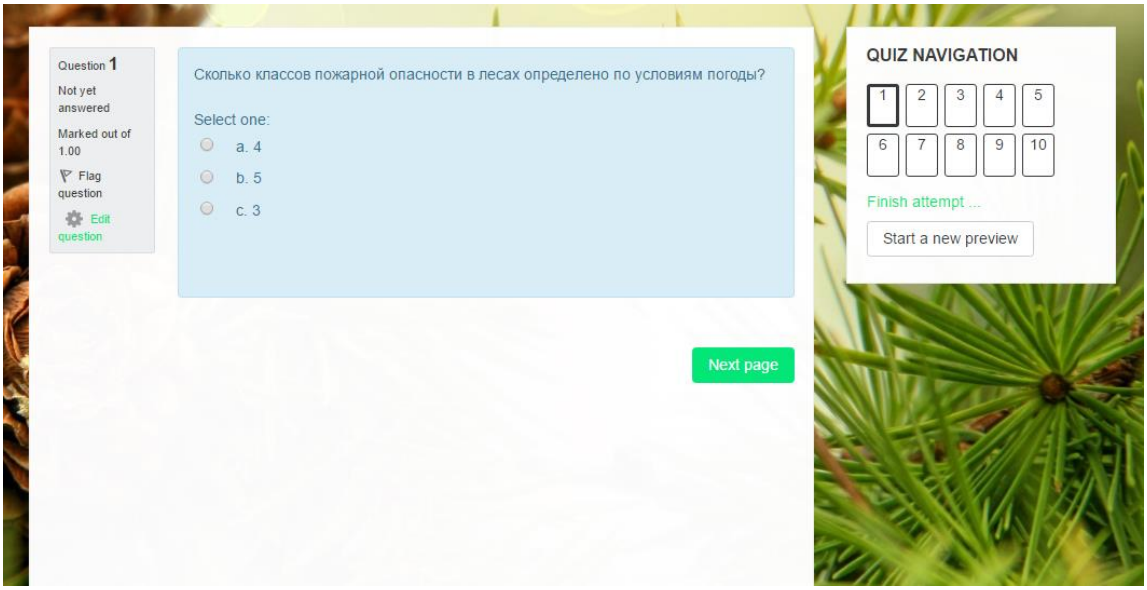

Figure 3. Preliminary Test Example.

The authors have developed an agent-based system containing two types of agents, designated A and B. Type A agents simulate the movement of the wave front. They can be in the active and passive states. A-agent, which is in the active state, determines the motion of the process front. Agents of type B (B agents) simulate the impact on agents of type A. They pursue a single goal - to transfer all A-agents into passive state. To do this, B-agent moves through the simulation environment to the nearest A-agent and, approaching it, carries out a control action aimed at destroying it. Figure 4 shows the localization menu, which is located on the right side of the system interface. This menu consists of buttons, switches and text fields. On the left side of the system interface there is a map of real terrain.

Figure 4. User's menu of TAIGA system.

A simple example of combating wildfire imitation is given below.

5. An example of decision making

The environment settings of the fire simulation are as follows.

- Dashed polygon allocated a settlement (protected object).
- Area of the wildfire at the start is 0.22 ha.
- Wind speed under the canopy is 2 m/s.
- Wind direction is north.
- Fire danger class is 4.
- Aim of the game – to protect settlement from wildfire.

The place where the fire starts is appointed by the tutor. Initial fire contour is constructed automatically. In this example the trainee decided to construct fire barriers to exclude the possibility of reaching the protected area by wildfire. Figures 5(a) – 5(c) shows the dynamics of fire propagation. A reader can see that the thickness of the fire barrier is not enough. The wildfire continued to spread and reached the settlement. Thus, simulation is over with negative result.

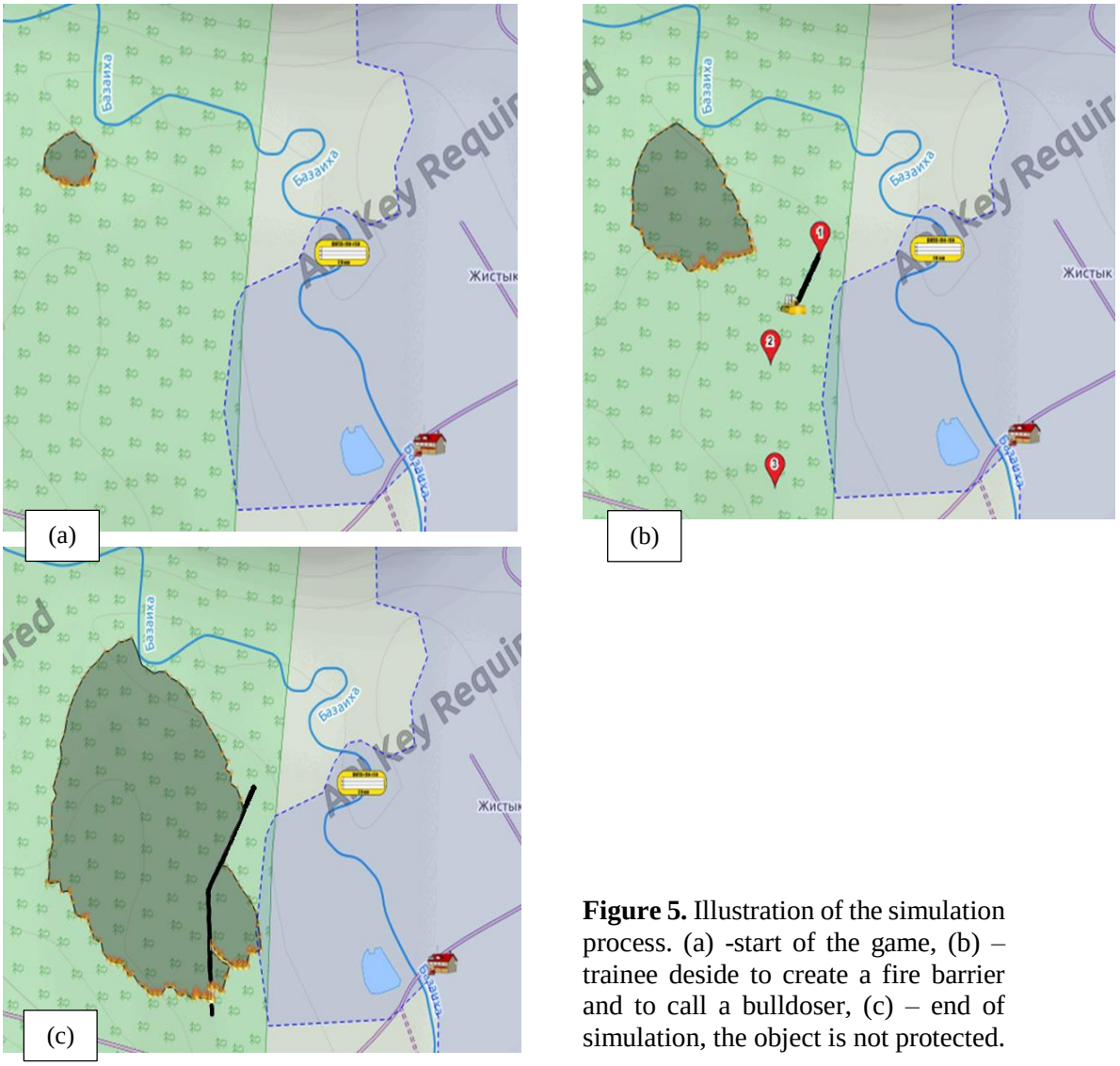

Figure 5. Illustration of the simulation process. (a) -start of the game, (b) – trainee deside to create a fire barrier and to call a bulldoser, (c) – end of simulation, the object is not protected.

During the simulation process, an event log of the trainee's actions was generated. The fire situation protocol is presented below.

Time: 0 h, 0 m

Detected wildfire with area 0,22 ha;
Distance to the protection object 393 m;
Fire spread is 2,8 m/min;
Time: 0 h, 45 m
Trainee calls bulldozer D-533 for piercing the fire barrier;
Time: 1 h, 0 m
Area of wildfire 0,95 ha;
Distance to the protection object 281 m;
Fire spread is 3,19 m/min;
Time: 1 h, 25 m
Bulldozer D-533 began piercing the fire barrier width 0,5 m;
Time: 2 h, 0 m
Area of wildfire 1,995 ha;
Distance to the protection object 183 m;
Fire spread is 2,08 m/min;
Time: 2 h, 10 m
Bulldozer D-533 ended construction the fire barrier;
Time: 3 h, 0 m
Area of wildfire 3,413 ha;
Distance to the protection object 110 m;
Fire spread is 3,34 m/min;
Time: 4 h, 0 m
Area of wildfire 5,435 ha;
Distance to the protection object 50 m;
Fire spread is 2,42 m/min;
Time: 4 h, 40 m
Area of wildfire 6,995 ha;
Distance to the protection object 0 m;
Fire spread is 3,36 m/min;
Wildfire reached the protected object (see figure 5 (c)).

6. Conclusion

The presented work describes a computer system FIREMAN. The system is designed to train personnel in the basics of wildfire fighting tactics. The system is a combine of popular e-learning system MOODLE and wildfire imitation system TAIGA developed by the authors. This combination provides effective training for firefighters of different skill levels.

The FIREMAN system is currently undergoing testing in Reshetnev Siberian University of Science and Technology and in Siberian Fire and Rescue Academy.

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