VOL. 11, NO. 1, JANUARY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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DEVELOPMENT OF AUTOMATED FIRE FIGHTING SYSTEM FOR USING IN THE ROAD TUNNELS

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ABSTRACT

The article suggests a conceptual design solution of hardware-technical equipment for virtual interaction with automated control system to counter fire in a road tunnel. The algorithm of the system of detection and localization of fire, including the direct control of the operator performing devices, with the possibility of revision in the direction of non-person as a member of the system to improve the efficiency of the complex as a whole. The concept of automated control system for robotic machines to ensure effective response to emergency situations in confined spaces, as well as the layout made it a software implementation using the language C # and XAML.

Keywords: fire fighting, system, software, program code, optimization, data processing, decomposition.

1. INTRODUCTION

The development of modern transport infrastructure of cities leads to the necessity of construction of road tunnels. Operational experience of transport tunnels, especially those located within the cities indicates a high probability of emergencies and road accidents involving fires, which are very difficult to eliminate in a limited space. The necessity to design a single system that combines with their own means of fire detection and elimination methods to replace outdated countermeasures explains the relevance of the topic of this work.

The purpose of the installation of automatic systems (plants) fire-fighting (AFES - Automatic Fire-Extinguishing System, AFEU - Automatic Fire-Extinguishing Unit) - localization and extinguishing fires and saving lives, as well as movable and immovable property.

All automatic fire-extinguishing systems include tools:

- Fire detection (mechanical devices - thermocouples, electrical devices - thermal, gas, optoelectronic and other detectors);
- Turning on the system;
- Delivering the fire extinguishing substances (water, foams, powders, aerosols, gases).

The most effective means of fighting the fires are just automatic fire-extinguishing systems, which, in contrast to the alarm systems and manual fire-fighting equipment, create all conditions for the rapid and efficient localization of fires with minimum risk to life and health.

2. LOGICALLY DESIGN

Generally, developed man-machine complex, like any other real-time system [1-5], is a collection of sub-systems and components designed to run appeared the task within the given time limit and on the basis of the target set in the development of the project, while It is a resource, which is necessary to minimize consumption.

The main idea of the development of the designed system is the intention to abandon the outdated method of emergency response in urban traffic in particular - in the tunnels. In favor of the use of remotely controlled robotic machines [2, 3, 6, 7, 8, 9] automatic fire extinguishing (AFEU), which can operate 24/7/365 and are located directly in the tunnel, which shortens the response time and consequently reduces the cost of consumables and damage.

To display the conceptual model [10, 11] of the designed system was developed use-case model describing the structure of the concepts used in the project. Use-Case diagram is shown in Figure-1.

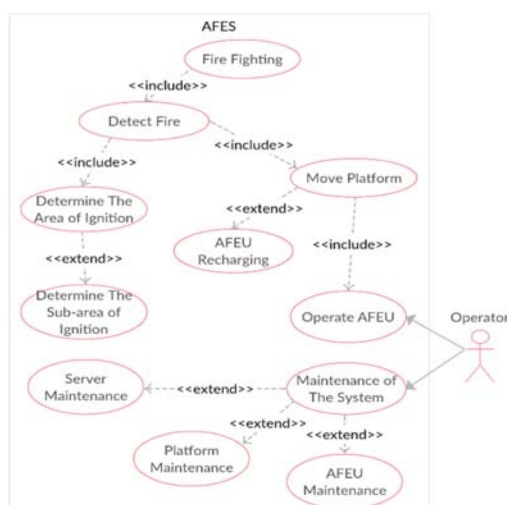

Figure-1. Use-Case diagram.

In Figure-2 shows the Structural Scheme of the designed system. Based on the structural scheme, you can highlight the main components of the system, switching between these components, as well as to determine the structure of the transmitted messages.

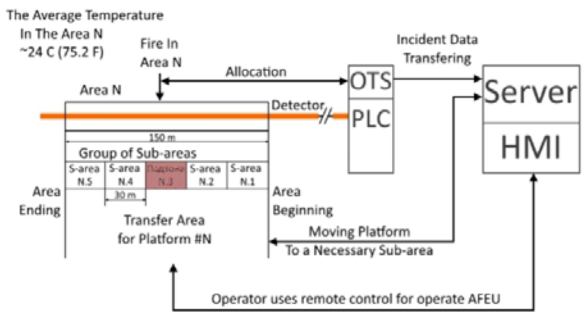

Figure-2. Structural scheme of the developed system

Server [4, 5] in the project called the computer, located directly in the technical area of the tunnel in which the system is used. The system is in this case takes place via a remote connection to the server from another machine with client software.

Determining the structure of the transmitted messages, and analyzing the possible scenarios that may arise during the operation of the system were made collaboration and sequence diagrams, visualize the distribution of roles in the system in processing. Collaboration diagram is displayed in Figure-3; a sequence diagram is shown in Figure-4.

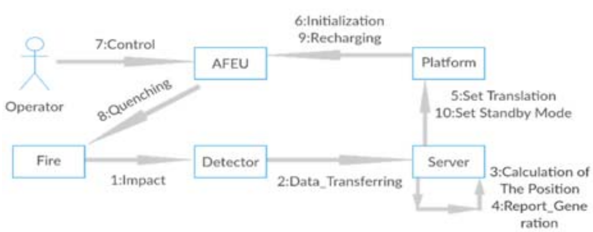

Figure-3. Collaboration diagram.

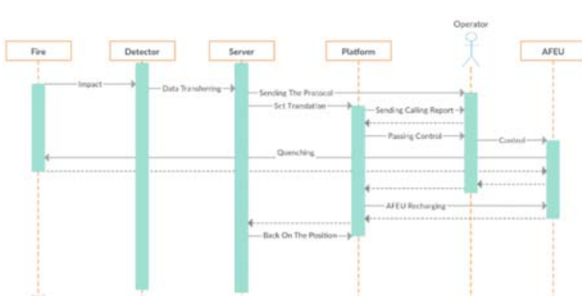

Figure-4. Sequence diagram

This diagram clearly reflects the basic entities, their lifeline, and transmitted messages during of activity.

Entities are objects of the material world, which interact with each other throughout the entire period of his life with the transmitted messages, incentives, during the project reports are call to specific functions, as well as the results of these functions. The essence of "Operator" in this case, a separate expert system [1 ... 3], which includes a report generator, not only a human operator which takes control of AFEU. Mobile fire-fighting platform is indicated in Figures 3 and 4, as the "Platform".

Lifelines represent the period of time during which there is each object designed system, in this case the object "Fire" is the only object that is destroyed during the operation of the system.

Management focus in the diagram shows how objects interact between themselves over time, in response to incoming messages. Due to this system can be regarded as the real time operating system.

One embodiment of the system involves the use of artificial intelligence [1 ... 3], which in turn will lead to the fact that the entity "Operator" will not mean a human person as an expert system operator.

After analyzing the sequence diagram was compiled class diagram that shows the interaction of classes at the logical level in view of specific transmitted messages, as well as the functions performed within reach of each individual class, and the whole system. An important feature is the displaying multiplier relations between classes in the designed system, as it shows the number of connections between the objects represented by each of the classes. The class diagram is shown in Figure-5.

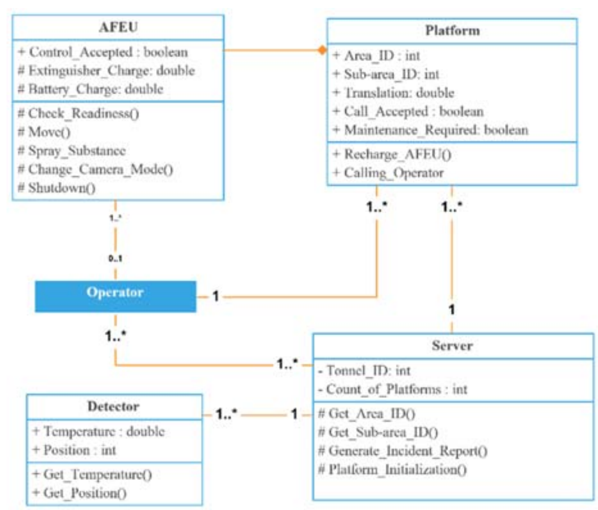

Figure-5. Class diagram.

VOL. 11, NO. 1, JANUARY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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3. OPERATION ALGORITHMS

Work designed system based on the algorithm, an enlarged version of which is presented in the form of activity diagram in Figure-6. The algorithm was developed on the basic fire-fighting algorithms that are used in automatic systems to counteraction and do not include in their work direct control and followed by refinement in favor of more efficiency.

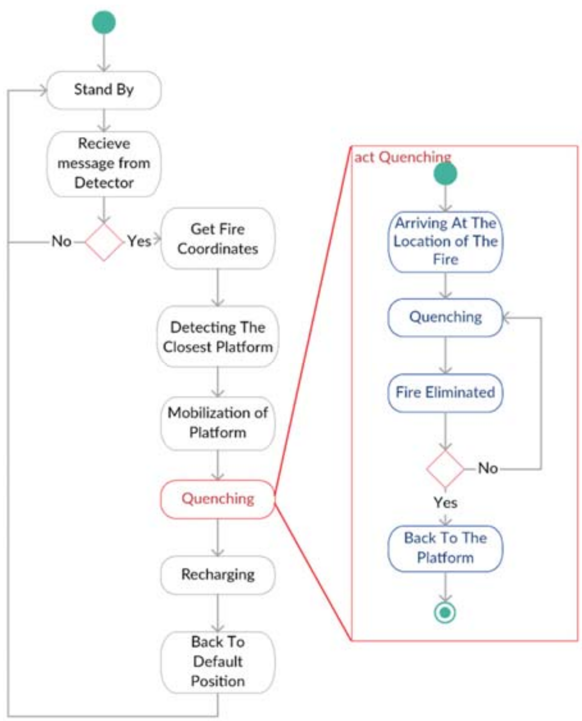

Figure-6. Activity diagram.

The algorithm is not attached to a particular hardware platform, thereby achieving some flexibility in the possible technical realization of the project.

Conventionally, the entire operation of the system is reduced to three modes - standby, response, recharging. Mostly the system is in standby mode and is fully autonomous - It does not require human intervention to detect the place of origin of the fire. When a fire is detected, the system automatically activates the response mode, during which the interaction between the operator and the machine takes place.

As soon as the sensors are located throughout the complex scope, fix fire, the system automatically determines the location of fire. Due to the linear structure of the tunnel, the location can be readily determined by a single coordinate, through the use of technology developed by the cable detection system. Determine the coordinate, may be calculated the location of the nearest Platform, on the basis of the established default positions. Then, the selected platform is "mobilized" - using the built-in motor Platform moving along the guide rails until it reaches the coordinates of the fire location, next the Platform "releases" AFEU (Automatic Fire Extinguishing Unit). Simultaneously to this, reports of the emergency are send to the control room located in the geographically nearest fire department; report contains the obligatory logging of place, time, responsible operator and identifier of the initialized Platform.

After the report of the emergency was automatically generated, the operator takes control of AFEU and in real time proceeds to the immediate liquidation of fires. With this approach, operator can immediately visually assess the extent of the damage, identify the number of victims and on the basis of these data form a squad of specialists for the particular situation. After quenching, the operator returns AFEU to the Platform and sets the AFEU to standby mode, and this is the final stage, where requires the participation of a person - after changing the AFEU and Platform mode, system is completely autonomous. It should be noted that if the operator does not set the standby mode after the work, the system will be considered operation as uncompleted and as a consequence will not go into recharging mode, and the protocol of the emergency will not be completed. This was done for reasons of preserving the functionality of the AFEU, as in case of a powerful fire can be a problem of lack of extinguishing agent in the AFEU's tank, replenishment which is precisely at the MP, thus achieving an increase in the efficiency of the whole system.

In case of the system has received a message of the completion of the operation, the recovery process begins. During recharging mode system diagnoses AFEU, compensates spend extinguishing agents in module's tanks and charges module's battery. After the recharging process, the Platform returns to the default point of it position.

It should be noted that the system is multi-threaded, which means that it is able to respond to emergencies, even at the time of liquidation, so that the maximum number of simultaneous calls is limited minimum of parameters - number of Platforms or the number of operators.

4. DESIGN GUI CONCEPT

From the beginning of development, the entire complex was conceived as the "human-machine system", so the design of intuitive user interface is an important task.

Future development of the system involves the use of AI for further automation, which further lead to the partial abolition of the human operator, and eventually to a fully automated (automatic) system. The presence of such interface in the system is a second, since human intervention is minimized, but at the time of virtual prototyping, the use of artificial intelligence is not considered.

VOL. 11, NO. 1, JANUARY 2016 ISSN 1819-6608
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After the researching of the thermal maps of human attention, the initial concept was drawn up of the user interface that takes into account the efficiency of perception as a live image and AFEU readings, system status, etc.

Shown in Figure-7, the concept of interface is used to display data when working operator with the system at the machine control automated fire extinguishing.

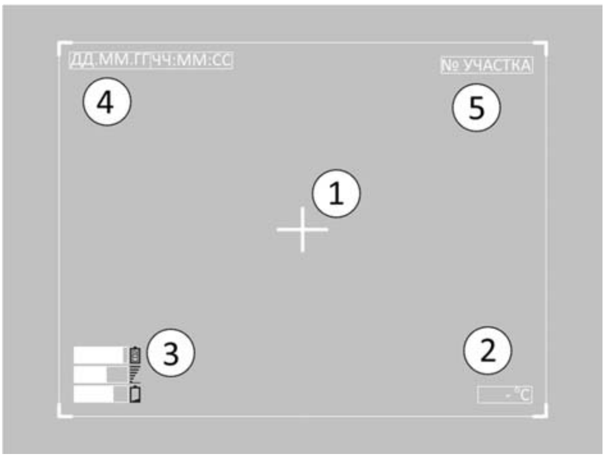

Figure-7. Early Version of AFEU User Interface
1 - Aim point; 2 - Temperature in aim point; 3 - Charge-Level lights for battery, signal strength and extinguisher capacity; 4 - Current Date/Time; 5 - Current sub-area identifier.

Aim Point the direction of the nozzle is a static element, which allows the operator to direct most accurately the extinguishing agent onto the heat source. The temperature data obtained from the integrated laser thermometer, and level data extinguishing agent calculated based on the output stream pressure value of extinguishing agent. For information on the level of signal reception and battery power supply respond the relevant controllers.

Objects interface does not depend on the mode of transmission of the signal - Thermal or Normal.

During the design, it was decided to introduce additional interface elements, which are designed to facilitate the usability of the AFEU by a human operator, and also lays the foundation for the subsequent fully automate the process.

Adding information about the current date / time and number of area / sub-area of work is designed to improve the usability of the system, and to improve the usability of the software interface. The point of highest temperature is determined by the operator on the basis of data obtained from the thermal imaging camera.

It should be noted that the imposition of interface elements set for programming the camera directly on the MAP.

5. SOFTWARE IMPLEMENTATION

Video from the camera is transmitted by means of a separate stream technology RTSP (Real Time Streaming Protocol) and MJPEG (Motion-JPG) and incorporated into the MediaElement item [4, 12, 13]. The using of this technology reduces the size of data transferred, as a matter of fact decomposed into video frames in JPEG, which are combined in a package and passed in the stream. Using such a method allows you to reach speeds of 28-30 frames per second video, which is the best in the ratio quality / size of data. If you change the shooting mode the controller MAP changes the source of the incoming video stream to another camera, the technology and the method of transmission is not changed, it's a turn allows to minimize transition time from one shooting mode to another without the need for the second link.

Demonstration software client to work with AFEU shown in Figure-8.

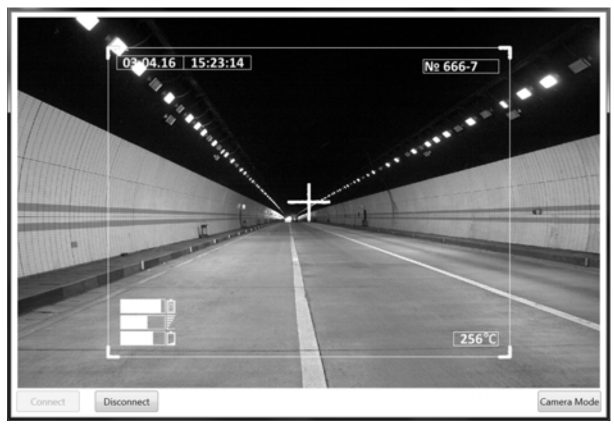

Figure-8. In Progress UI demonstration.

AFEU's Sensor data have no direct connection with the client, passed only a calculated data of the temperature, the level of reserve extinguishing mixture and so on.

The opening/closing of the exhaust valve is controlled by the electric motor, which in turn has two modes of operation - on opening and closing of the feed mixture. This method of operation limits the flexibility of application of AFEU, but is simpler and more fault-tolerant than an adjustable flap.

As a result it should be noted that the client application [5, 14 ... 20] is a kind of transmitting shell, whose main objective is the installation of the communication channel by the Internet (using the protocols TCP / IP, RTSP, and others) and transfer of operator commands in the command perceived AFEU's controller. This generalization is caused by physical implementation features: as the controller can serve a variety of hardware and technical means, such as Arduino platform, Raspberry Pi, and others; In addition to these controllers, the basis of the AFEU can act full personal computer (PC) [4, 5]. However, in this case the use of such client is not justified, since the connection via SSH is more effectively and directly control it would be logical to carry out through the software installed on the inner PC of automated fire extinguishing unit.

6. CONCLUSIONS

Researching the experience of operating transport tunnels located within the city, revealed a high probability of emergency and road accidents involving fire, which are very difficult to eliminate in a limited space, which in turn leads to increased damage by fire.

Developed the concept of automated control robotic machinery ensures the effectiveness of emergency response (fire) in confined spaces (road tunnels).

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