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Informational Graphic Technologies for Fire Safety Level Determination in Special Purpose Buildings

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***Abstract* — The article deals with the problem of public awareness about existing special purpose buildings such as protective buildings and shelters that can be used to protect against emergencies. The status update on the problem is considered. During research were analyzed recent scientific papers in the field of modern information technologies integration into civil protection system. The necessity of using modern informational graphic technologies for fire safety level determination in such type of shelters was substantiated. The features of actual data visualization with the involvement of mathematical transformations and methods of visual information graphing are investigated. Based on the offered methods of visualization graphics information has been developed software emulator "Fireware Emulator". It can be used for fire safety level determination in buildings of such type.**

Keywords— informational graphic technologies, software emulator, shelter, civil protection, room plan.

I. INTRODUCTION

The current integration state of modern information technologies to human life environment initiate appearance of new natural threats which can be serious risks to its normal and safety life. Military conflicts and the risks to use mass destruction weapon forced us to make protective purpose buildings - safety places such as housing units and shelters where peoples could stay and live during emergency situation.

Based on the daily facts of human life process both society and its individual members, we observe a progressive tendency towards increasing potential threats to humanity. The amount of the increasing anthropogenic and natural character risks is proportional to the number of tasks to be undertaken to ensure the safety of human life. Among these problems we could highlight the problems of peoples safe staying in protective purpose buildings: housing units and shelters.

The process of necessary building choosing is based on own human's preferences, its geographic location, type of emergency situation and other additional factors. But the most important among them is security (Fig.1). First, in such protective building, user should to determine the state of fire safety, the possibility of safe evacuation from the rooms and the comfortableness level of staying. After it, on the basis of visualized data about protective building, human should to analyze the possible deterioration causes of the situation in the shelter and to identify ways to better its planning. All upgrades must be produced by taking into account the position of ensuring proper level of fire safety.

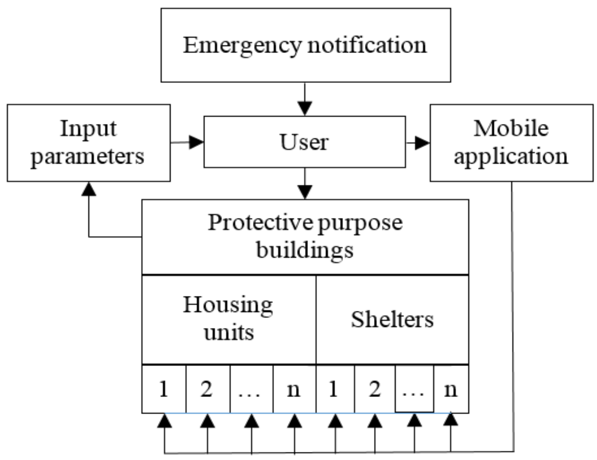

Fig. 1. Flowchart of necessary protective purpose buildings choosing process

If emergency situation will appear and it will be necessary to use protective building or air raid shelter, user should know in advance all important data, including comfortableness level and safety stay in it.

The main requirements that applies to protective buildings and shelters are regulated by the relevant state documents and the Civil Protection Code of Ukraine. These documents specify the external and internal parameters of the protective buildings. External includes geographical location and distance from neighboring homes, and internal includes buildings configuration and planning of elements for safe staying users indoors. However, it is also important for users to have actual information about such buildings.

II. PROBLEM STATEMEN

Review of recent international research shows numbers of existing developments in the fire safety field, particularly about uses of information technologies to improve human's life safety. The whole process of modeling protective environment in buildings for different purpose, including shelters has been describing in detail by scientists. In [1] were explored some aspects and approaches for creation of user-oriented mobile information technologies. This software is developing for individual use to help people in choosing suitable fire protective building where they could hide during emergency situation. According to [2], authors had analyzed fire safety requirements to information technology for implementation in selected commercial building. The main practical requirements to information technologies for fire safety providing in different types of buildings are highlighted and analyzed in [3, 4, 5].

Researches [6 - 10] refer to evaluation system of building fire emergency response capability maturity (FE-CMM) that based on the capability maturity model (CMM). Mostly they are considering to acceptable ways for emergency situations response. Authors declared that the proposed module could preliminarily realize the intelligent evaluation of building fire emergency response capability. Also, it able to improve the practice and intelligence of the fire emergency response capability evaluation, especially in smart cities. Studies [10-12] analyze the main features of developing, improvement and uses of modern information technologies in the field of civil protection, particularly during implementation of safety-oriented emergency response projects.

However, there are still little number of studies that related to software development for protective buildings safety evaluation, as well as for situation comparing capability in different buildings during best option choosing process. Today, there are also not enough information about qualitative evaluation of information technology impact to decision making process of choosing particular building type.

Current state regulatory documents determine all requirements to protective structures, buildings and shelters arrangement, particularly, from the point of safe stay in them. But, due to requirements universality and generality, shelters are objectively limited in ability of getting attention to each ones. The reason of it – lack of a real possibility to create completely safe building for a long stay. As a result, people must make choice of protective building and carry out its arrangement by themselves. This will be possible only if the following conditions will meet:

- the choice of each protective building or shelter is based both on its level of comfortableness and fire protection;
- all possible ways of getting to the protective building or shelter are analyzed depending on humans' location during an emergency;
- information technologies are used as a helping tool to make choice of protective building;
- preliminary prediction is made to determine unforeseen occasions appearance possibility during humans' stay in shelter;
- it is possible to make own additions to the contingency plan.

Therefore, according to previously outlined problems, developing of graphic information technology for fire safety evaluation of protective purpose buildings is one of the most important and urgent task in nowadays moving world.

III. SUBSTANTIATION OF DATA VISUALIZATION METHODS USE IN PROTECTIVE BUILDINGS FIRE SAFETY EVALUATION PROCESS

In general, users informational content I about protective buildings or shelters include two components: visual (presence component) and virtual (technological component) object review. Some users can get necessary information directly by observing selected object without using any information technology (IT), while others can use special software. Bases on this and according to [10], informational content I could be determine by the following equation:

$$I=u+iv=(x+iy)^3 \tag{1}$$

where u, v – components of information content, respectively, without and with the use of information technology; x – presence component parameter that indicate the level of knowledge about object without using IT; y – technological component parameter that indicate the level of knowledge about object with using IT.

Parameter y also takes into account both the level x' of knowledge about the object(building) and the use of developed application f:

$$y=x'+f \tag{2}$$

In most cases, x' does not always equate to x, but for simplifying research, we accept that $x = x'$. According to this, (1) takes the following form:

$$I=u+iv=x((4x^2+6xf+3f^2)+i(x^2-3f^2)) \tag{3}$$

The working range of variables x and f in information content I level determining process is in diapason between 0 and 1. Equation (3) determine information contents value I as a direct numerical dependence to the parameter x: for each level of information support f, the value of information content is equal to zero if $x = 0$. As a result, information content components u and v defines function of x and f. Thus, if we take these conditions into account, components values will determine like (4) and (5):

$$u=4x^2+6xf+3xf^2 \tag{4}$$

$$v=x^3-3xf^2 \tag{5}$$

If user does not use software for help in choosing suitable shelter and condition (2) is fulfilled, the value of components u and v will determine (6) and (7):

$$u=4x^3 \tag{6}$$

$$v=x^3 \quad (7)$$

Component v has value change restriction (8) of x and f. In our research we use only positive values that fits condition $x>3f = a$ and belongs to zone A (Fig. 2).

$$v=x(x^2-3f^2)= x(x-\sqrt{3} f)(x+\sqrt{3} f) \quad (8)$$

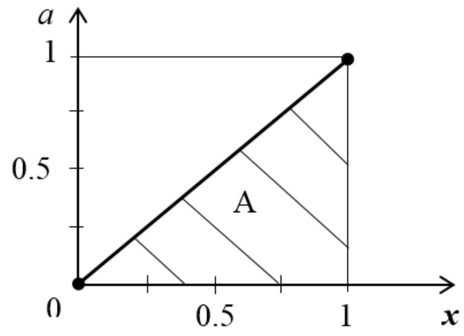

Fig. 2. Restriction zones of parameters

Now, let we determine the influence of parameters x and f to component u (4) values change. Even if x gets small values, such as $x = 0.1$, the values of component u increases extremely fast (Fig. 3 a). This proves the efficiency of using information technologies f.

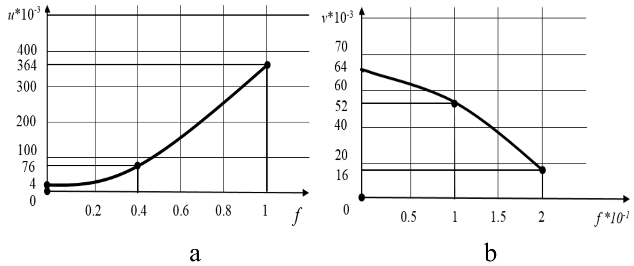

Fig. 3. Dynamics of components u (a) and v (b) values change

The information contents' component v is determined by the amount of knowledge set ($x'= x$) about buildings fire safety state according to which IT is used for help. The main condition that applies to v it is $x'= x >\sqrt{3}f$ (Fig. 3 b).

IV. Development process of information graphic technology for protective purpose buildings safety level determining.

Information technologies and its use in the field of Civil Defense can solve problem of visualizing data about protective purpose buildings. Basically, proposed emulator will work with graphical parameters of the buildings, which are used during its floors plan creation. Also, there will be possibility add another data, such as temperature of the shelter environment, the presence of fire extinguishers, etc. (Fig. 4).

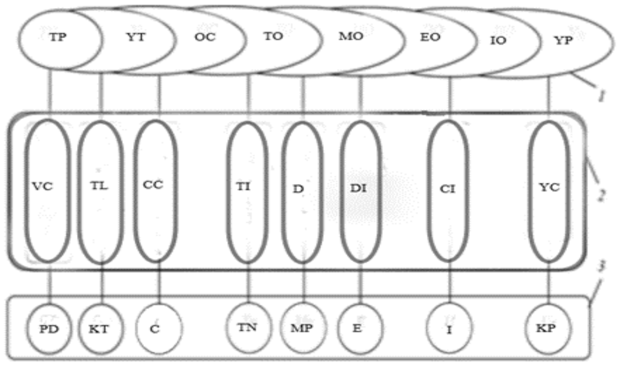

Fig. 4. Information model of data visualization process about protective purpose buildings with use of emulator

where 1 – emulator software operation block: TP - the technological process of emulator creation; YT - control units; OC - provision by programmers; TO - the level of equipment provision; MO - material resources; EO - energy resources; IO - the financial value of technology; YP - software resources; 2 - functional parameters of providing data visualization processes: VC - emulator implementation environment; TL - involved information technologies to the emulator creation process ; CC - the level of performers provision; TI - the level of information provision; D - the level of GPS monitoring technologies involvement of ; DI - the level of easy getting to the building; CI - transport infrastructure near buildings location; YC - basic standards for program creation; 3 - visualization resources: PD - the output product of emulator ; KT - programmers team; C - the product of created program; TN - technical means; MP - material resources; E - energy resources; I - information resources; KP - IT project team.

Information graphic technology is designed as an emulator program “Fireware Emulator”. For its development were chosen Java. “Fireware Emulator” allows users to evaluate protective buildings or shelters safety level.

Java is an object oriented language which gives a clear structure to programs. There are some major advantages of this language. Java is straightforward to use, write, compile, debug, and learn than alternative programming languages. Object oriented programming is associated with concepts like class, object, inheritance, etc. which allows you to create modular programs and reusable code. Java code runs on any machine that doesn’t need any special software to be installed. Those advantages are essential in developing secure, powerful device or computer system that gives you possibility for quick use of the right class and method. Software emulator “Fireware Emulator” was developed using Intellij IDEA 2019.1 Community Edition.

A flowchart of proposed software development stages was designed to facilitate the process of its programming (Fig. 5). The emulator has friendly user interface, is quite reliable and provides high speed of safety evaluate algorithm calculation.

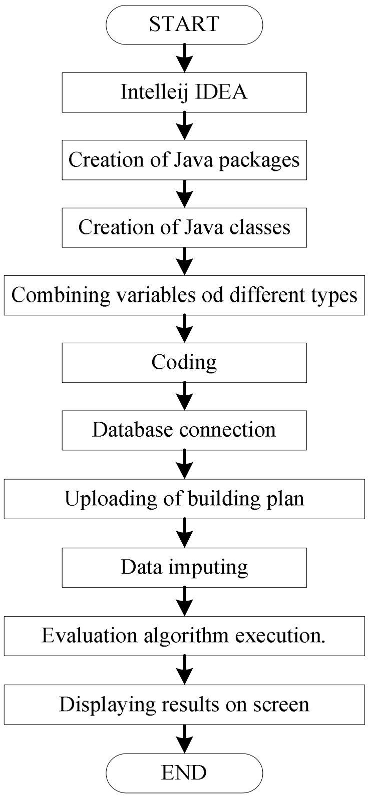

Fig. 5. The flowchart of the "Fireware Emulator" development process

Designed information graphic technology as an emulator program allows users evaluate the security level of shelters independently. The software supports different types of protective buildings and their plans. An algorithm for the process of choosing a safe building is presented in Fig. 6.

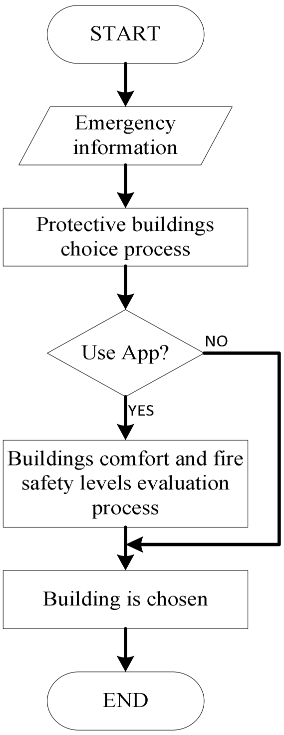

Fig. 6. The flowchart of protective building choosing process

User obtain actual information about buildings fire safety level and can check its reliability and evaluate his own protection in emergencies. This is possible by integrating buildings plan into emulator's database.

When buildings or shelters plans are importing into software database, the following parameters must be specified: inner temperature, height and width of the room, a wall material, the number of persons who may present at the same time. Lighting and air filtration settings are also available. Based on all this data, the program makes analyze and outputs the result of security level evaluation.

Software adaptation to the real conditions of the shelters and protective buildings is provided by changes of their plans. They are made based on additional perimeter measurements. Emulator "Fireware Emulator" stores visualized data of plan in its database, that makes them acceptable for changes up to different conditions.

The emulator interface for the school building is shown in Figure 7.

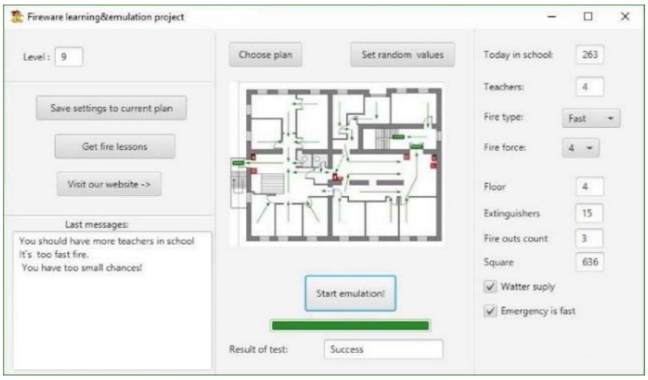

Fig. 7. Initial parameters values setting in software"Fireware Emulator"

Input parameters: two hundred sixty-three students and four teachers will be staying in building at the same time and each of them had passed a fire safety courses; there are four floors, three emergency exits and fifteen fire extinguishers; all-day water supply.

Developed software is open for updates. There is an opportunity to quickly add plans of buildings, functionality, providing reliability, accessibility and multiplatform. A high level of protection against unauthorized changes to the code was used.

V. USES OF DEVELOPED SOFTWARE IN FIRE SAFETY EVALUATION PROCESS

Next stage of research is analyzing correctness of the software algorithms. There were 4 practical experiments conducted using different input parameters, protective building plans and squares.

Experiment 1. Input parameters used in experiment: storage temperature - 21 °C, height - 2.45 m, width - 4.35 m, wall material - metal construction, number of persons - 5. The result of emulation (Fig. 8) demonstrates that such protective building complies to all standards and regulations and is completely safe to stay in an emergency.

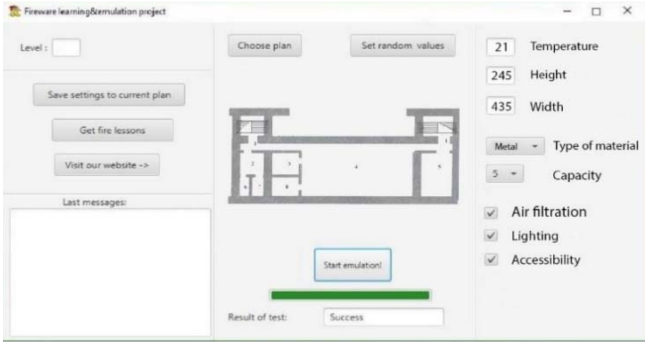

Fig. 8. Experiment 1: result of "Fireware Emulator" running with imput paramemters

The program provides a large number of parameter combinations. The algorithm selects the most optimal by analysing of given data [10]. In case of inconsistency, the program produces a negative result.

Experiment 2. Were used parameters which did not complies to standards or regulatory documents. Due to input parameters this shelter is uncomfortable for staying and the result of fire safety evaluation is negative (Fig. 9).

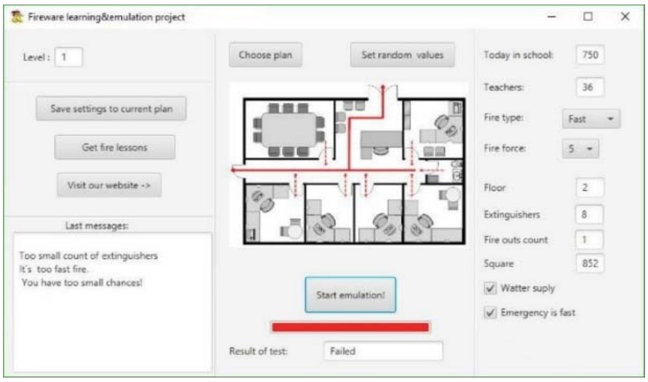

Fig. 9. Experiment 2: the result of buildings fire safety evaluation with many people inside

This is because there is no ability to avoid the danger: the building has a large square and only one spare exit, the number of people is too big, the fire ignites quickly and there are only eight fire extinguishers.

Experiment 3. A shelter with small square were analysed. Also there were a low wall height and inside temperature (8 ° C), the number of staying persons - 6. According to the normative documents, such protective building is not suitable for a comfortable staying despite positive level of fire safety evaluation. The result of the program demonstrates a similar conclusion (Fig. 10).

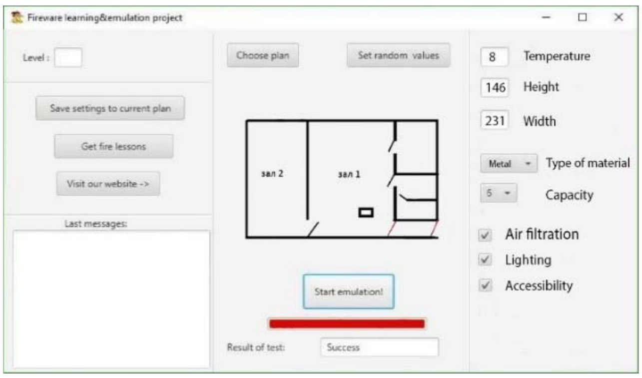

Fig. 10. Experiment 3: negative result of shelter staying comfortability

Experiment 4. In developed software "Fireware Emulator" is predicted a graphic information window for displaying problems which must be solved to increase both fire safety and comfortability levels. In Fig. 11. is presented the result of evaluation process, according to the input parameters. In information window is displayed text message with recommendations.

Analyses of input conditions and received recommendations (Fig. 11) shows that the algorithm of message output is correct. The inside temperature of 4 degrees above zero storage does not correspond to the norm, the height - 1.68 m and the width - 4.61 m. In this experiment, there is lighting, but no air filtration. All this conditions are dangerous and not comfortable for staying of 52 people in shelter.

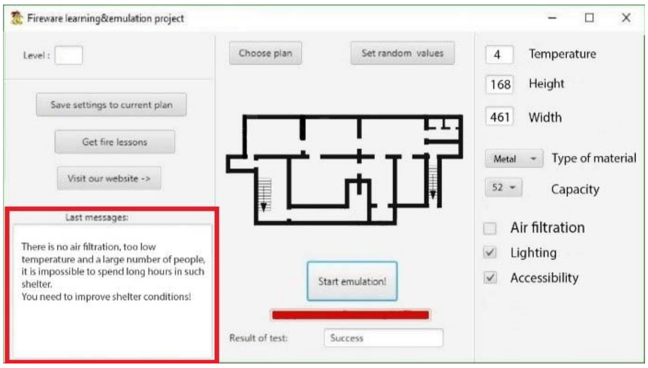

Fig. 11. The result of evaluation process with generated recommendations

The errors and deviations of the program are minimal, and their analysis indicates correctively of algorithms calculations.

VI. Conclusion

Current rates of science and technology development, integration of information technologies into everyday life of society, state of ecology and influence of anthropogenic factor on the environment lead to appearance of new emergencies. The ability to make the right decisions in such circumstances is a guarantee of safety human's life. That is why it is so important for human today to have as much as possible information about around environment.

Informational graphic technology was developed as an emulator program to help people in process of protective buildings fire safety level evaluation. The emulator program "Fireware Emulator" is a product of universal purpose. It helps to determine the level of person's security staying in protective purpose buildings. Developed software is designed for personal use. Performance of the program can be enhanced by the combination of prior knowledge about object and the information component comparing. Also were made mathematical substantiation of evaluation algorithms execution correctness.

Integration of the latest information technologies in the field of civil protection will provide to society an effective tool for analyzing and using data to explore possible ways of avoiding or protecting against emergencies.

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