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Remote Visual Information System for Identification of Dangerous Substances Using Unmanned Aircrafts

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Abstract. Development of a functional model of the process of creating a knowledge base on the recognition of objects and actions of the enemy on the basis of neural networks and fuzzy logic. The aim of the work is to develop a set of software and hardware designed for remote identification of hazardous substances by machine visual recognition of information signs of dangerous goods with the output of relevant information to the means of visual display (interface). Recommendations concerning providing UAVs with the necessary technical means to monitor the zone of emergencies are analyzed. The recommendations of the organization of radio communication between the UAV and the operator depending on the range of the UAV departure, terrain conditions etc are analyzed and given. The structural scheme of the complex of remote recognition of HC in the form of blocks, units and software and hardware is developed. As a result of the analysis of programming systems, it was found that Python programming language is the best choice to ensure the full operation of the software due to the built-in capabilities and the involvement of third-party frameworks. A database containing information on more than 3.000 HCs with detailed recommendations for emergency response is developed. The hardware and software complex for remote identification of dangerous substances by machine visual recognition of information signs of dangerous goods by UAV, consisting of unmanned aerial platform with photo-video recording means, data transmission system to ground control station, PC for processing results and related software are substantiated and developed. A test of the UAV's capabilities in recognizing danger signs with UN numbers in different lighting conditions was tested. In all cases, the HC was accurately identified. The ideas and methods proposed in this article will allow to create cheap and simple tools for rescue units of Ukraine, which deal with the consequences of emergencies related to the leakage of HCs.

Introduction

The issue of civil security has always been one of the main issues for Ukraine, and in the conditions of aggression on the part of the Russian Federation it has played a key role. The destruction of the bombings affected a large number of places for storage of hazardous chemicals (hereinafter – HC), highways along which they move, temporary tanks and more. The work of the units of the SES of Ukraine on liquidation of emergencies, which are related to the circulation of the HC begins with a detailed reconnaissance of the scene. Reconnaissance is primarily about identifying HC, and this is a difficult task in the context of hostilities, as there is not always information on what substance leak needs to be eliminated, despite the fact that the situation at the scene may pose a threat to rescuers. Therefore, the identification of HC should be carried out at a safe distance, analyzing the special signs that inform about the dangerous substance that is in the tank.

For remote identification of the HC, it is advisable to use unmanned aerial vehicles (hereinafter – UAVs), which are in the service of SES of Ukraine.

UAVs have a number of advantages that make them indispensable for such tasks, namely, have a relatively low cost, availability and the ability to quickly master the skills of piloting UAVs by operators. Ways to use UAVs in emergency response areas require careful planning, starting from traffic routes, locations of operators, obstacles on traffic trajectories, formation of control decisions, etc.

This can be achieved by creating an intelligent decision support system (hereinafter – DSS) [1, 2]. Implementation of information technology for UAV flight route planning within the framework of DSS will allow to form the architecture of a promising intelligent decision support system for UAV action planning.

Analysis of Literature Data and Problem Statement

There are many ways to mark [3] HC in the world, but the most common in Europe and Ukraine is to mark HC with UN numbers.

The UN number is a numerical designation of the HC, which is determined by UN recommendations. It means that each HC has its own UN number.

To simplify the procedure for identifying the HC, unified rules for marking and transportation of HC by different modes of transport have been developed by UN (Fig. 1).

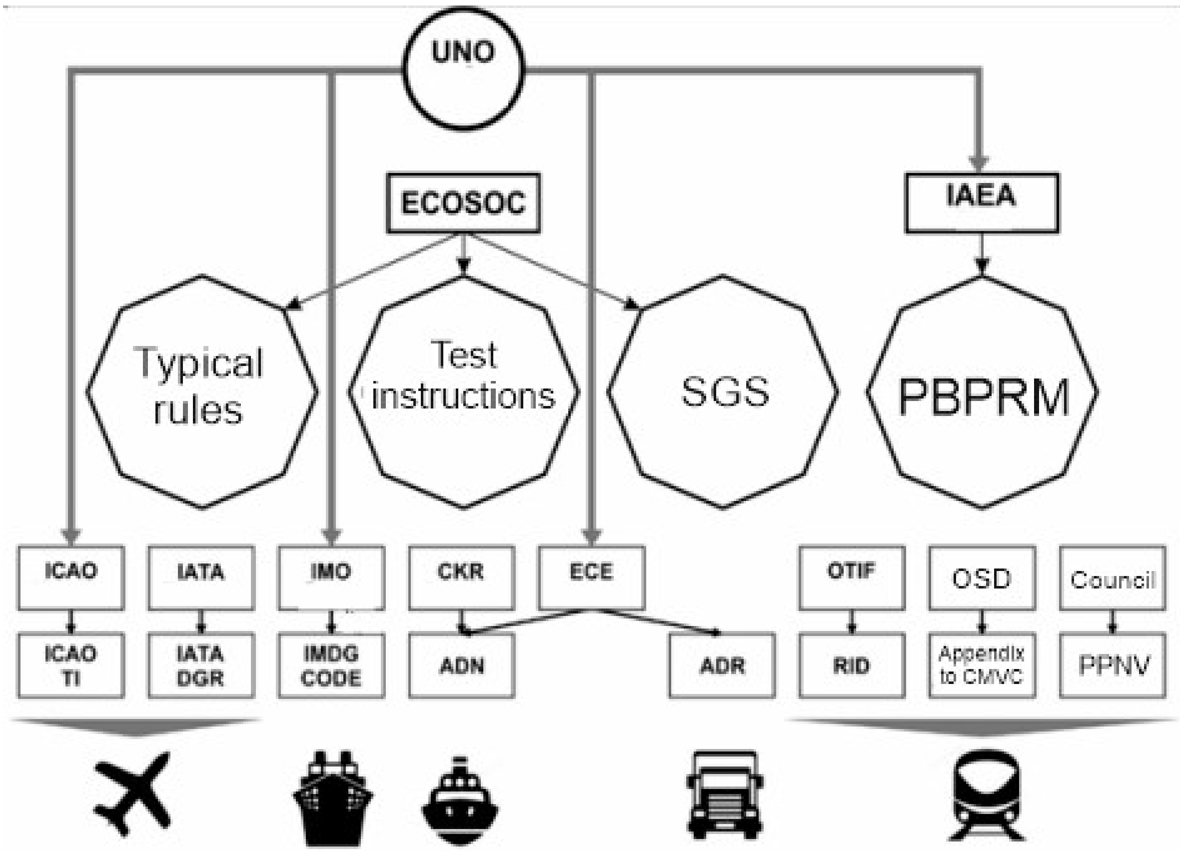


Fig. 1. Basic conventions and agreements governing the transportation of dangerous goods by various modes of transport

According to the recommendations developed by the UN, each dangerous goods transported by road or rail is equipped with an orange danger sign [4] (Fig. 2). The symbols on the warning plate are divided into two parts, which contain information about the danger of the cargo: the number of danger (upper field) and the UN number (lower field).

Fig. 2. Warning table for dangerous goods

The study of UAVs was started in the last century for military purposes, today UAVs are widely used in various areas of human life, including rescue units [5].

To date, the main efforts to use UAVs are aimed at studying the processes of automation of UAV route planning to find dynamic and stationary objects based on the use of systems analysis methodology, probability theory, mathematical modeling, elements of artificial intelligence, modern information technology. This leads to the need to develop information technology for automated planning of UAV actions during their mission using object-oriented design method within DSS. Many works have been devoted to the improvement of information technologies for these purposes [6–8].

It is clear that the issue of full automation of the process of identification of HC in the emergency is not possible today, but to begin its implementation today is an urgent task to improve the efficiency of SES units in dealing with emergencies with leakage of HC.

Purpose and Objectives of the Study

Development of a set of software and hardware designed for remote identification of hazardous substances by machine visual recognition of information signs of dangerous goods with the output of relevant information on the means of visual display (interface).

Software and hardware implementation of the above complex is possible if the following tasks are solved:

1. To identify the requirements for the hardware of the complex;
2. To develop a block diagram and algorithms of the software of the complex;
3. To determine the programming language;
4. To identify the necessary additional tools of the software complex;
5. To develop software for visual recognition of HC markings;
6. To verify the obtained research results.

Materials and Methods of Research

The following technical devices can be attributed to the hardware of the complex for remote identification of dangerous substances by machine visual recognition of information signs of dangerous goods:

- Unmanned aerial platform;
- Photo-video camera of the unmanned aerial vehicle;
- Data transmission system from the UAV to the ground control station;
- PC for the software part of the complex.

It should be noted that the unmanned aerial platform, in case of its use in places with possible leakage of HC, must be subject to special technical requirements aimed at the possibility of decontamination, both the platform as a whole and its individual technical components.

The main technical characteristics of photo-video cameras installed on UAVs for image recognition are resolution. Complicating conditions for the operation of visual aids can be considered weather conditions, the presence of aerosol or vapors of HC at the observation site, the angle of shooting, the presence of UAV vibrations that can lead to distortion of visual information etc. Therefore, it is clear that the resolution of the above means should be as high as possible, in accordance with modern technical capabilities. The photo-video camera of the unmanned aerial vehicle must be equipped with a stabilization system, have an appropriate level of protection against adverse environmental factors. The light-sensitive matrix of the photo-video camera of the unmanned aerial vehicle must provide the ability to work in low light conditions.

The most convenient way to obtain photo and video data is real-time observation, which involves the transmission of video signals in various formats over the air. The limitation of this method is the significant amount of information transmitted. This causes high demands on the systems of reception and transmission of such information and forces UAV manufacturers to make technical and economic compromises. Real-time video broadcast from the UAV is conducted to the ground control station, usually in the ultra-shortwave or ultra-high frequency range, which is characterized by the location of the aircraft in the "line of sight" of radio waves in space. The maximum range of video transmission depends on the specific characteristics of the UAV systems used, for example, at frequencies of 2.4 GHz, it is about 10–15 km. The presence of interference due to terrain, vegetation, building density, weather conditions and sources of electromagnetic radiation will significantly reduce the distance of video communication in real time. In view of the above, the main requirements for UAV data transmission systems to the ground control station are the maximum bandwidth of the communication channel, high power of the photo-video data transmission system, high-quality matching of antenna devices and sufficient power of the transceiver processors..

The use of image recognition technologies by machine learning requires significant computing power, which is determined by the clock rate and number of processor cores, the amount of RAM and the power of the video information processing system. Thus, it will be optimal to use a PC with maximum characteristics [9–11].

The block diagram of the complex in general can be represented as a set of blocks, nodes and software and hardware (Fig. 3).

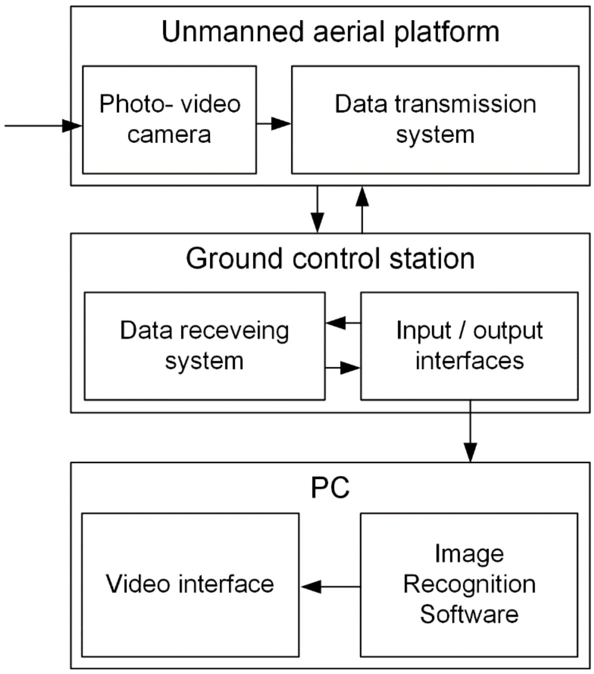


Fig. 3. Block diagram of the complex

The algorithm of the recognition system in general can be represented as follows:

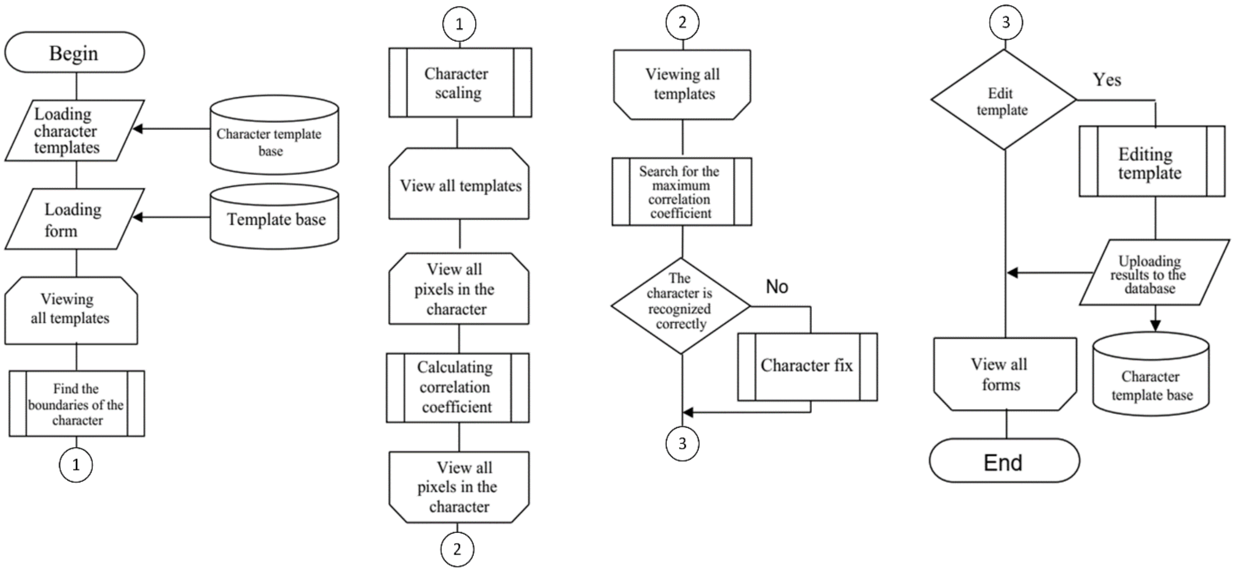


Fig. 4. The algorithm of the recognition system

As a result of the analysis of programming systems [6], it was found that programming language Python is the best choice to ensure the full operation of the software due to the built-in capabilities and the involvement of third-party frameworks. The key differences of this language are fully automatic memory management, the connection of types with objects rather than variables and a high level of abstraction when performing operations. The availability and relative ease of implementing projects with Python make it one of the leaders in high-level programming languages.

Pattern recognition technology is a fairly advanced technology at this stage, so to solve our problems it is advisable to use ready-made common software solutions.

One of them is Tesseract, an open source software that allows you to recognize characters with support for Unicode encoding and the ability to recognize more than 130 languages. This tool is open and free, as well as suitable for creating cross-platform software that can be used on computers with different operating systems.

OpenCV (Open Source Computer Vision Library) is an open source library for working with computer vision algorithms, machine learning and image processing. OpenCV element recognition uses object outlines, color segmentation, and built-in recognition methods that can be customized depending on the object and the sensitivity of the algorithm. OpenCV includes more than 2.500 tools and algorithms for computer vision and machine learning. Thanks to its high speed and cross-platform nature, OpenCV is suitable for working with real-time images.

In general, the following procedure is provided - when the operator receives an image from a UAV, which is in a dangerous environment, the software recognizes the text and automatically searches the database (Fig. 5). The database, which contains information on more than 3.000 HCs with detailed recommendations on emergency response, was developed by our team as part of previous research commissioned by SES of Ukraine [3].

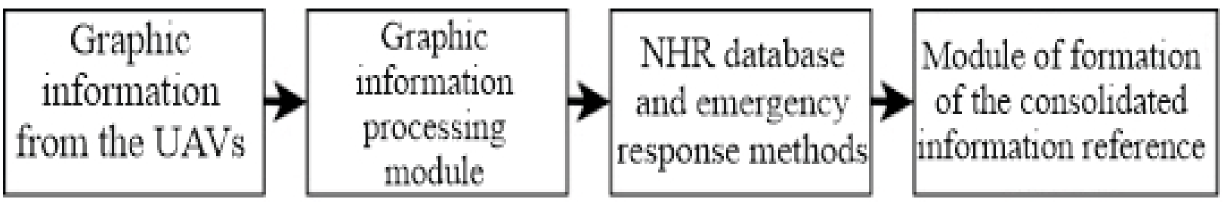


Fig. 5. Schematic diagram of the information system of action planning of unmanned aerial vehicle operators

Figure 6 shows the results of testing the software for recognizing the symbols depicted in the table of hazard. During the verification of the hardware and software complex, the influence of adverse weather conditions, lighting, etc; the effect of the presence of aerosols or vapors of HC at the observation site; the dependence of the number of successful recognitions on the shooting angle are checked.

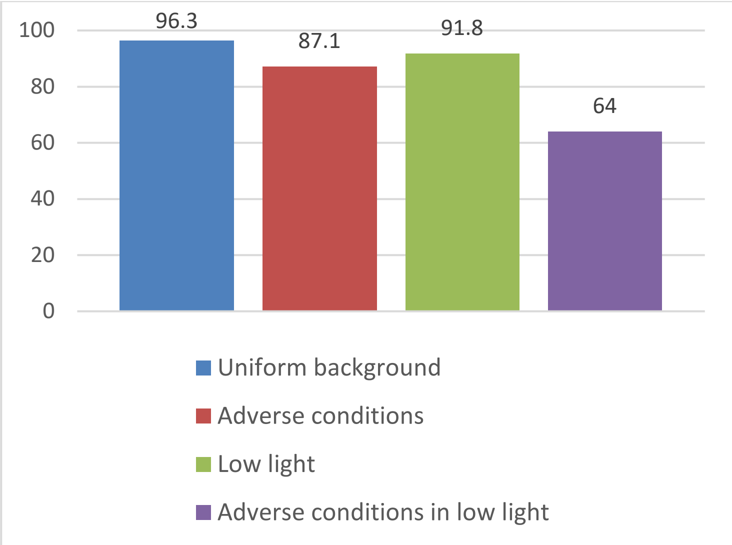
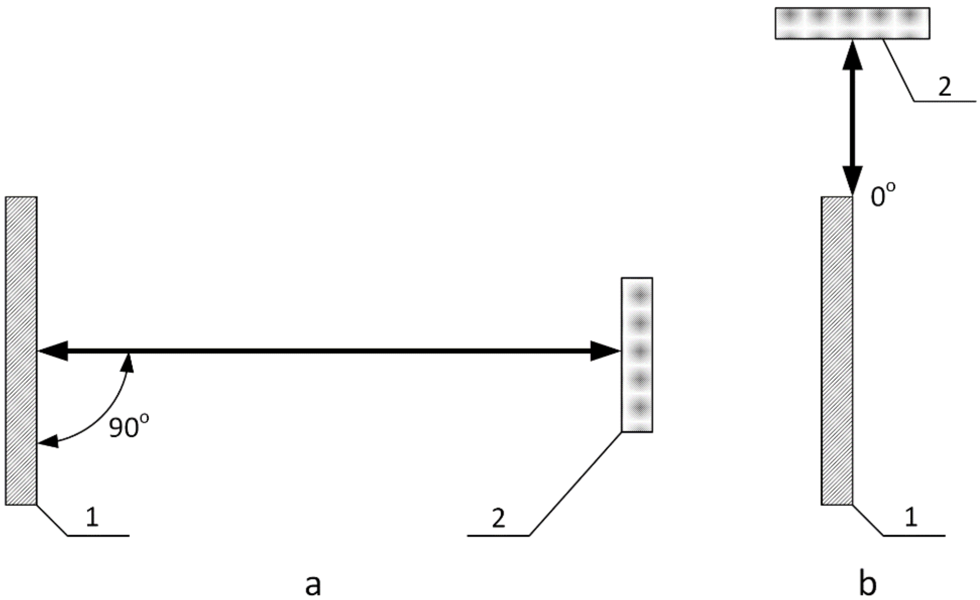


Fig. 6. Test results of character recognition software

The most ideal shooting option can be considered a situation where the movement of light rays from the shooting surface to the light-sensitive matrix of the camera will be carried out at an angle of 90 degrees (Fig. 7 a). The worst option that makes recognition impossible is the option when the movement of light rays from the shooting surface to the light-sensitive matrix of the camera will be at an angle of 0 degrees, which is not possible due to the location of the light-sensitive matrix to the shooting surface at an angle of 90 degrees. (Fig. 7 b)



1 – shooting surface; 2 – light-sensitive matrix

Fig. 7. Reciprocal location of the survey surface and the light-sensitive matrix

According to the results of research with a gradual decrease in the angle of observation from 90 degrees to 0 degrees with a step of 10 degrees, the dependence is obtained, as shown in the graph (Fig. 8).

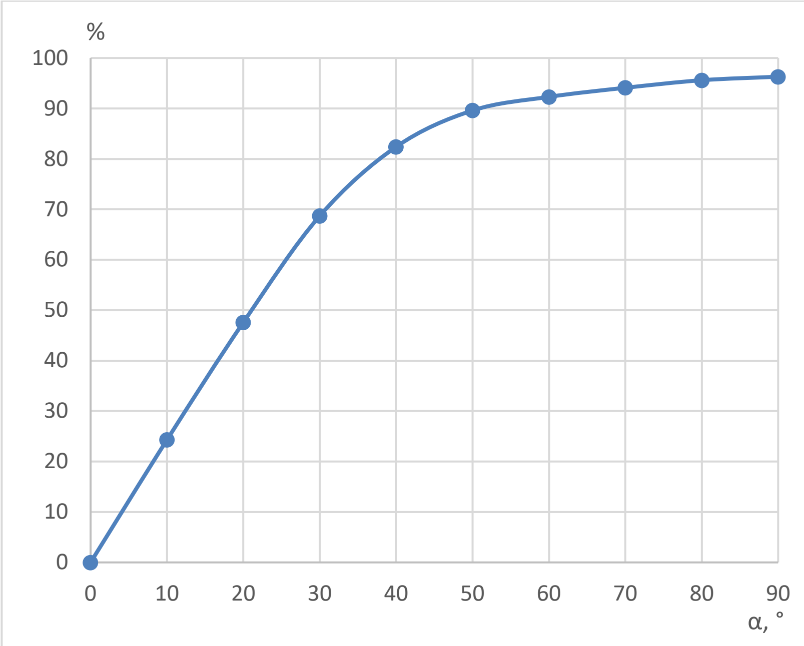


Fig. 8. Dependence of the probability of correct recognition of symbols on the angle of observation

The process of work of the developed software for remote visual information system for the identification of hazardous substances using unmanned aerial vehicles is shown in Fig. 9. As can be seen from the figure, the purpose of the work is achieved.

Fig. 9. General view of the research site with the use of the UAV

Discussion of Results

The technology of recognition of information signs of dangerous goods with the help of UAVs allows you to quickly determine the type of HC, which will optimize management decisions to eliminate the consequences of emergencies. The software and hardware complex implements the ability to automatically recognize the signs of dangerous goods with the help of UAVs during reconnaissance of emergencies with leakage (emission) of HC. Problematic issues of using UAVs for pattern recognition are adverse weather conditions, the presence of aerosol or vapors of HC at the observation site, the angle of shooting, the presence of UAV vibrations. The influence of the shooting angle, external conditions mentioned above, on the quality of image recognition is studied.

The next step in software development will be to adapt it to situations where the image is not clear. To work with such images, two methods of information processing will be used:

- automatic – when fuzzy image analysis methods are used, such as those described in [12];
- manual – when the operator will be able to query the database by entering the HC code from the image.

At this stage, the database of hazardous chemicals must be adapted for use with the image analysis module.

Prospects for further research are to add the ability to recognize graphic danger signs, text symbols on containers with HCs and reduce the impact of UAV vibrations on the quality of the resulting image.

Conclusions

The hardware-software complex for remote identification of dangerous substances by machine visual recognition of information signs of dangerous goods with the help of UAVs, consisting of unmanned aerial platform with photo-video recording means, data transmission system to ground control station, PC for processing results and corresponding software were substantiated and developed.

The ideas and methods proposed in this article will allow to create cheap and simple tools for rescue units of Ukraine, which deal with the consequences of emergencies related to the leakage of HCs.

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