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DIGITAL IDENTIFICATION AND PATTERN RECOGNITION CAPABILITIES USING MACHINE LEARNING METHODS, NAVIGATION SYSTEMS, AND VIDEO SURVEILLANCE

The objects of the study are unmanned vehicles and branches of the bridge of the city of Kyiv (Ukraine), which connects the Great Ring Road, Zhytomyr Highway and Peremogy Avenue. The built routes were analyzed using the technology of recognition of road signs, people and vehicles. The important problem of this research is to analyze the possibilities of detecting obstacles by an unmanned vehicle using pattern recognition, which combines the methods of machine communication, navigation and real-time video surveillance.

Based on the study, the results of detecting and avoiding obstacles on the road, where a study was conducted to investigate the main reasons that can cause time delays (traffic jams, weather conditions, accidents). The results of planning and navigation are obtained to determine the appropriate road route, which allows detecting and eliminating obstacles on the road, as well as building a map plan of the route in advance using online map services (Google Maps). It is shown that recognition of road signs (based on the classification using a road sign map consisting of 7 categories), people and vehicles minimizes the occurrence of road accidents, traffic jams and time delays. To recognize the images of road signs, people and vehicles, we studied the road sections connecting to the branched bridge.

Thus, the authors have reviewed and analyzed the digital capabilities of pattern identification and recognition using machine learning methods, navigation and video surveillance systems, where the safety of vehicles with detection of road signs and obstacles on the way is of great importance. The results obtained can complement the possibilities of using unmanned vehicles to avoid obstacles and road accidents based on a trained pattern recognition system. This system, using convolutional neural networks and video surveillance navigation systems, will be able to provide the driver and the people around it with safe driving conditions.

Keywords: *unmanned vehicle, convolutional neural networks, pattern recognition, machine learning, navigation, planning, video surveillance.*

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1. Introduction

The development of information and digital technologies has contributed to the emergence of modern opportunities, which in turn can serve as smart technologies that combine the use of machine learning methods (MLM) in the processes of automation, navigation and video surveillance. Such a combined technology allows to study the processes of autonomous work with pattern recognition in real time in the absence of the human factor, where the main carriers of such technology can be automated devices, apparatuses and vehicles. Unmanned aerial vehicles (UAVs) and unmanned vehicles or autonomous vehicles (AUVs) must reliably process information in order to provide reliable data when scanning the actual location, as the development of future events on the road may depend on it [1, 2]. Fig. 1 shows the first prototypes of AUV companies Google and Tesla.

Problems in the processing of AUV pattern recognition are related to obstacles that may occur on the road, for example, traffic jams, traffic accidents (traffic accidents), weather conditions, etc. [3]. In parallel with this, AUV with the help of MLM is able to recognize people, road signs, traffic light indications and route instructions, which is explained by machine learning of the network, where neural networks of deep learning can be used among such examples [1, 4]. However, in order to solve the problems of processing with pattern recognition on the road, it is necessary to take into account unforeseen factors that can be avoided with the help of navigation systems with the construction and optimization of an appropriate route, which allows to reduce the time spent on the road [5].

a *b*

Fig. 1. Unmanned vehicles: *a* – Google; *b* – Tesla companies [2]

The main functions of the autonomous system include decision-making for AUV, which includes obstacle avoidance, path planning, navigation, and others [6]. Therefore, during path planning, the autonomous decision-making system first plans the global path according to the actual and target location, and then reasonably plans the local path for the self-guided AUV using the combination of the global path and the provided information about the local environment [2].

Over the last ten years, video surveillance systems have seen significant progress, driven by the use of simple video collection and display systems to intelligent, autonomous systems capable of performing complex procedures. Modern video surveillance systems are able to integrate some of the most complex image and video analysis algorithms from research areas such as classification, pattern recognition, decision making, image enhancement, and others. Therefore, modern video surveillance systems consist of image and video collection devices, data processing, analysis and storage modules, which plays an important role in the system's workflow [7].

However, video surveillance may contain problems even at the stage of designing automated systems, which is related to the detection and recognition of objects that demonstrate abnormal phenomena, for example, a malfunction or blurred frames, which requires the intervention of machine learning to automatically detect a malfunction [8]. Deep learning neural networks are an effective solution that can be applied for this purpose; however, the large computational requirements of such networks can require significant hardware resources, which can result in computational overhead [2].

Deep learning is one of the areas that has been significantly developed in the last ten years, and the possibilities in the application of this technology allow a wide range of applications in robotics with automated processes. Therefore, deep learning pushed the boundaries of what was possible in the field of digital image processing [5].

In work [9], a road sign recognition system was considered, which consisted of two parts – localization and recognition, where the authors investigated the effectiveness of machine learning methods, namely the support vector method and convolutional neural networks (CNN). At the time of the obtained results, the accuracy of these methods was obtained by the authors, where for the method of support vectors the accuracy was almost 98.3 %, and for CNN the result was accurate by 96.4 %.

In [10], based on the analysis of existing algorithms, methods and approaches to element recognition, an intelligent system for recognizing traffic elements using the support vector method was proposed, the recognition accuracy of which is 96 %. The research describes the problems of existing methods of element recognition and compares their accuracy characteristics.

In some cases, there is a need to switch from manual control to autonomous operation of the vehicle without human intervention, which is determined by the general condition of the driver. For example, due to the inattention of the driver, a traffic accident may occur, which requires the development of special intelligent driver assistance systems with a built-in function of monitoring the driver's vigilance. The work [11] describes a system that, on the CNN basis with automatic learning and forecasting, allows monitoring the condition of the eyes, mouth and ears of the driver. Such a system is trained on the basis of features to recognize the components of a person's face and looks for characteristic differences that can affect the general state of the driver behind the wheel.

The actual problem of this research is to analyze the possibilities of detecting obstacles by an unmanned vehicle using pattern recognition, which combines the methods of machine communication, navigation and real-time video surveillance. Among the identified obstacles, the greatest attention was paid to the recognition of characteristic features of people, traffic signs and traffic accidents. Therefore, for the application of unmanned vehicles, it is necessary to analyze the issues of safety and control in the autonomous mode of operation, where human life may be endangered.

The aim of research is to investigate digital capabilities for pattern recognition by unmanned vehicles and construction of an expedient route using machine learning, navigation and video surveillance methods. As machine learning methods, convolutional neural networks were considered, which are widely used for learning and recognizing road signs according to the classification of seven categories.

2. Materials and Methods

2.1. The object of research. *The objects of research* are unmanned vehicles and branches of the bridge of the city of Kyiv (Ukraine), which connects the Great Ring Road, Zhytomyr Highway and Peremogy Avenue. Fig. 2 presents the bridge using a satellite image courtesy of the online service Goggle Maps, showing:

a) connection between Zhytomyr Highway, Great Ring Road, and Peremogy avenue;

b) image of the research object in real time with a view of the Great Ring Road.

This bridge is a key hub when traffic jams occur, due to the occurrence of road accidents that may be caused by adverse weather conditions or vehicle breakdowns.

a *b*

Fig. 2. The bridge: *a* – connects Zhytomyr highway, Great Ring Road and Peremogy avenue on the map; *b* – depicted in real time with a view of the Great Ring Road

For example, if a driver needs to make a way from the Akademmistechko metro station to the National Aviation University, or to the Sikorsky Kyiv Polytechnic Institute, and an accident occurred on the Great Ring Road, then in this case it is more appropriate to cross the bridge to Peremogy Avenue and avoid spending a lot of time on overcoming traffic jams on the road. Therefore, the purpose of using machine learning for AUV is to build an optimal route, taking into account the time delay to overcome the road path. The used material was borrowed from the Google Maps online service.

Travel time prediction consists of navigation and route construction, which is very important for transportation networks, as web mapping services and services regularly serve a large number of travel time requests from users and businesses. At the same time, there is a need to account for complex spatio-temporal interactions, which is explained by the topological properties of the road network, where traffic jams can be expected during peak hours and as a result of road accidents [5, 12].

2.2. Navigation and video surveillance systems. The development of intelligent autonomous vehicles is a rather complex system that combines the reliability and safety of navigation in unstructured environments, where computer vision and artificial intelligence are used in mobile robotics to solve navigation problems [1, 13]. Such tasks include location and mapping, which allows to identify and remove obstacles on the road, as well as plan the route in advance [1, 14].

On the example of a UAV, the navigation of a structured environment with a wireless interface and a centralized control station is considered, in which methods are involved that allow the operation to maintain an internal map of the world using localization, planning and mapping methods for navigation. Regardless of how the technology of autonomous AUV is distributed for deployment in an unstructured environment (open terrain without a map), CNNs provide full autonomous (unmanned) control with the help of built-in platforms and technical vision systems to improve perception and recognition of information.

The autonomous mode is characterized by full perception and recognition of objects around itself, where the main devices for autonomous AUVs are video cameras that provide data for a wide range of tasks and can include 3D mapping, visual localization and 3D detection of obstacles during maintenance [4]. Let's consider the schematic definition for location and mapping in Fig. 3.

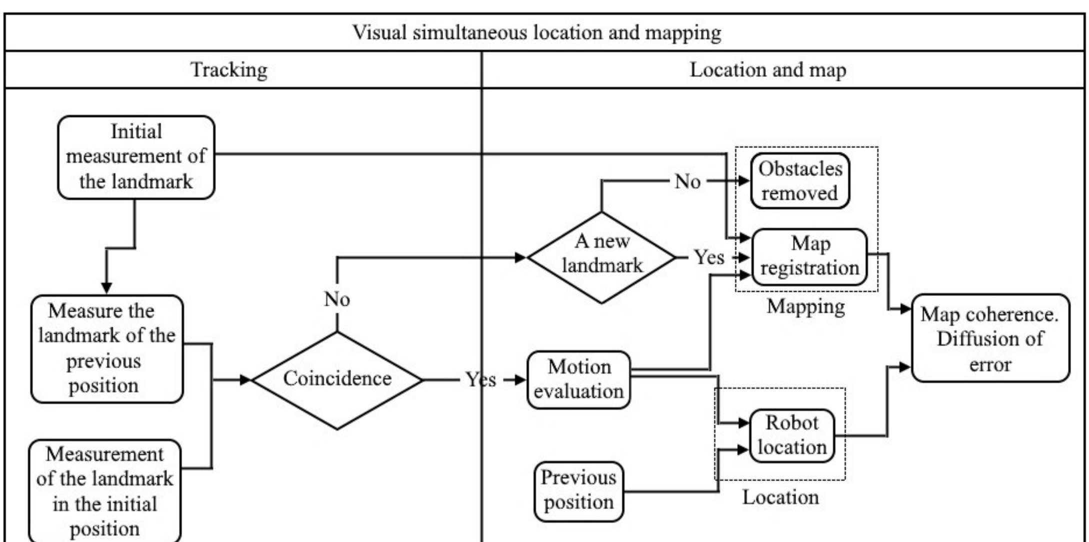


Fig. 3. Algorithms for visual simultaneous location determination and mapping (formed by the authors based on [14])

Visual detection has some advantages over photogrammetry, such as a large amount of visual data, low cost, convenience and ease of use, and minimal power consumption, which avoids the large computational burden due to post-processing. Therefore, the tasks of visual determination are the following tasks, which consist of the following stages:

– environment sensing;
– comparison and comparison of data;
– movement assessment;
– determination of location with updating and registration of updated data – landmarks.

However, the use of remote sensing imaging systems provides information on both the visual appearance of the object and the distance to it, which increases the reliability of mapping in real time.

Path planning enables autonomous navigation of complex environments, which is essential for real-world deployments. Therefore, the use of deep learning methodology provides an advantage for continuous improvement, depending on how the machine or robot learns [14].

Modern capabilities allow online monitoring using video cameras along the road traffic lane, where video cameras can be installed and equipped for video surveillance. Navigation and video surveillance also involve the use of such services, if in the case of route construction there are traffic jams caused by traffic accidents.

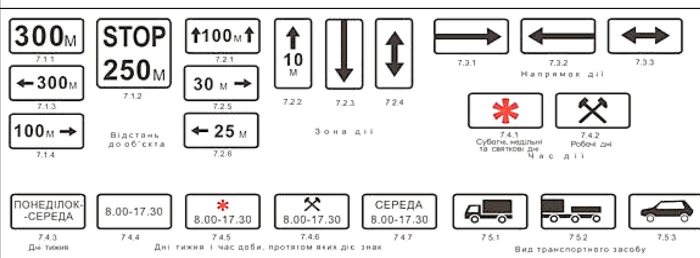
2.3. Learning deep neural networks for pattern recognition. Road signs will serve as objects for pattern recognition. In the Table 1 as an example, some road signs, which are taken for the CNN learning, are briefly given. The map with traffic signs for classification consists of 7 categories (warning, priority, prohibition, mandatory informational and indicative, service and tabular signs with instructions). The considered categories serve as classifiers for neural networks of deep learning, where each road sign from the category is entered into the network for their recognition on the road.

Based on the data in the Table 1 there is a classification with the CNN help. For classification in the learning process, the data of features of people and motor vehicles with a frame coverage radius of 15–20 meters for recognition were also given.

Fig. 4 shows the architecture of such a network, which consists of an input layer, feature maps (convolutional and subdiscrete layers) and an output.

Table 1

Map of road signs for motor vehicles

Name of the category of road signs	Traffic sign visualization for neural network learning
Warning signs	
Priority signs	
Prohibition signs	
Command signs	
Informational and indicative signs	
Service signs	
Signs with directions to road signs	

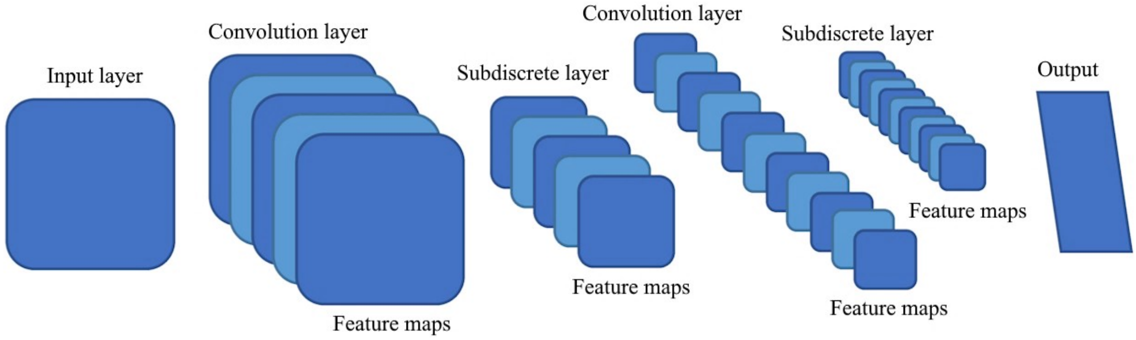


Fig. 4. Construction of the CNN architecture [15]

A practical application of CNN is that it represents a class of multilayer perceptron, which is characterized by having a two-dimensional structure that can be widely applied to image processing and recognition with a high degree of invariance to adjustments, such as scaling, shifts, rotations, and other possible distortions that may contain input data [15].

On the basis of the considered CNN architecture and the map of road signs, it is possible to teach the intelligent system to recognize objects that can be located along traffic lanes. Such an architecture will also be characterized by learning to recognize the characteristic features of people and vehicles.

3. Results and Discussion

3.1. Detection and avoidance of road obstacles. A smooth and stable obstacle detection system (pedestrians in the way) is a critically demanding condition from the point of view of safety. The development and capabilities of CNN in the localization and detection of obstacles makes it possible to apply such a methodology to detect pedestrians. However, in the field of autonomous driving, accurate three-dimensional localization and estimation of the location of objects outside the two-dimensional framework is required, which has contributed to the development of modern methods of localization of 3D objects using 3D survey systems.

Of the existing algorithms and 3D object proposals, the best performance is achieved by methods that see stereo (stereophony) as input data, since the CNN receives and processes information from input data that may differ from camera data and must be fully optimized. When developing object detection systems for specific domains, it is most practical and efficient to use general-purpose CNNs, for example, regional CNNs, fast regional CNNs (Faster R-CNN) to improve accuracy, MobileNets to improve the speed of logical inference and fine-tuning of the dataset using software software.

Let's consider and analyze as a 3D object a car that was involved in an accident. If the detection of obstacles involving pedestrians is a less simple task for a neural network, the detection of obstacles involving cars on a highway is a more difficult task. For example, Fig. 5 shows:

a) recording of the road accident frame from the street video surveillance camera;

b) a recorded frame on the Great Ring Road, where a traffic offense was recorded.

After fixing the road accident, which is shown in Fig. 5, and there is a noticeable accumulation of vehicles, which as a result creates traffic jams on the highway and leads to time delays.

Based on the recording of traffic accidents involving vehicles, information is published in online maps, where the problem causing traffic jams is indicated. Fig. 6 shows the data provided by the Google Maps online service in real time.

Object tracking, which involves the linking of detected offenses corresponding to the same object between successive frames within a certain time, provides an opportunity to estimate the direction and speed of the object's movement relative to the vision system. Tracking is an important requirement for autonomous vehicles, due to the prediction of the path with moving obstacles in order to make more appropriate decisions about the establishment of the movement trajectory.

a *b*

Fig. 5. Frame fixation: *a* – road accident; *b* – from a video camera on the Great Ring Road

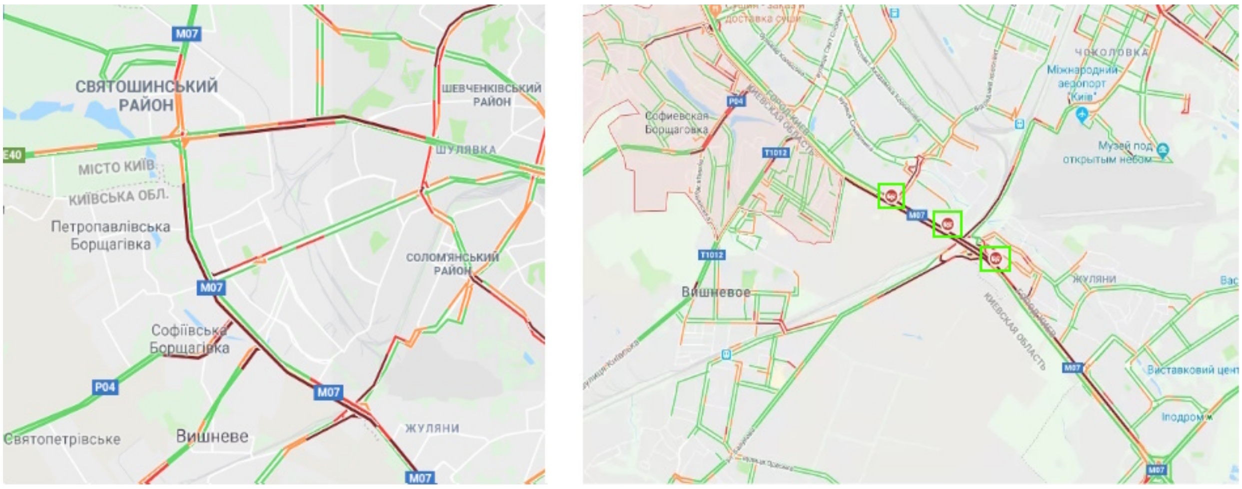


Fig. 6. Recorded frames of road accidents on the cartographic plan of the Google Maps online service

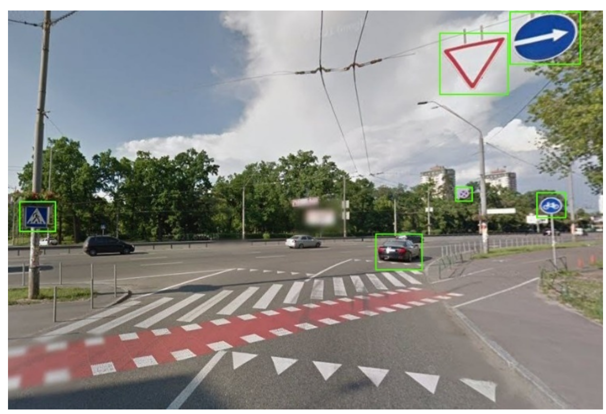
3.2. Recognition of images with the help of SNM and a video surveillance camera. For the recognition of road signs, people and vehicles, several road sections that can be connected to a branched bridge were considered. Recognized objects are fixed and shown with a light green outline. Since the nearby coverage radius is 15–20 meters, then not all objects will be recognized in the pictures. Recognition with such a radius is characterized by the fact that the trained network finds those objects that are nearby and can affect the roadway and traffic of AUV. For example, in Fig. 7, *b*, *c* shows the recognized objects, which include road signs and a vehicle when other vehicles are driving along the highway, which were not recognized due to the long distance from the AUV. A turn is shown in Fig. 7, *a*, which shows a road sign of a pedestrian crossing and bypassing an obstacle to the right or left.

Fig. 8 shows the road route with the recognition of road signs and vehicles on the way to the Zhytomyr highway, where in Fig. 8, and the entrance from the Great Ring Road is shown, and in Fig. 8, *b*, a road accident was recorded, which may complicate the movement of motor vehicles. When recognizing motor vehicles, it is necessary to pay attention to the fact that one of the recognized cars was stopped due to a violation of traffic rules and is standing in a prohibited place, which may prevent other vehicles with a large number from bypassing the obstacle. Fig. 8, *c* shows the identification of road signs and the recognition of people crossing the road where the road crossing sign is identified.

Fig. 9 shows the recognition of road signs and motor vehicles on the way to the Great Ring Road. However, it is worth noting that during recognition, the coverage radius is 15–20 meters, when the road signs in Fig. 9, *b* are behind the recognized car in front, which indicates a technical failure. At the same time, Fig. 9, *a* shows a person at the crosswalk, which is also outside the recognition radius.

Automatic road sign detection and recognition is a key feature in road sign inventory management, providing an accurate and timely way to manage road signs with minimal human effort. The vast majority of existing approaches work well with road signs, which is necessary for the improvement of driver assistance systems and autonomous systems. In work [16], the authors considered the problem of identifying and recognizing a large number of categories of road signs that can be involved in the processes of automating the management of the inventory of road signs. Therefore, the authors investigated the use of a conceptual approach using a convolutional neural network.

a



b

c

Fig. 7. Recognizing road signs on the way to Peremohy Avenue: *a*, *b* – the route from the Great Ring Road to Peremohy Avenue; *c* – the route from Zhytomyr highway to Peremogy Avenue

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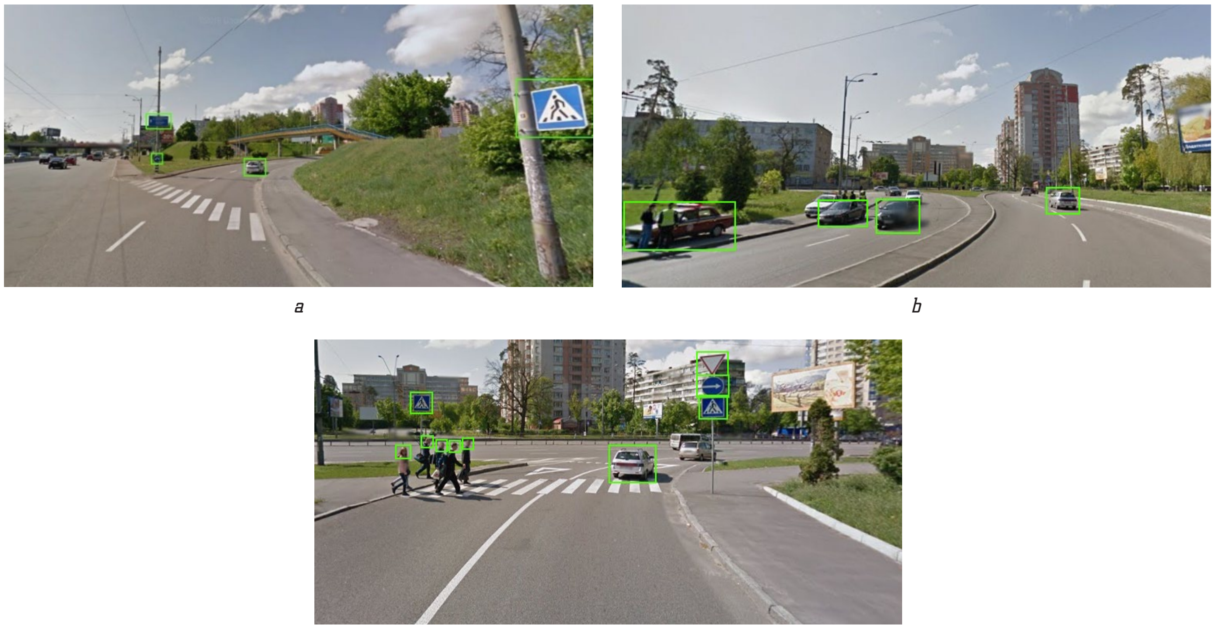
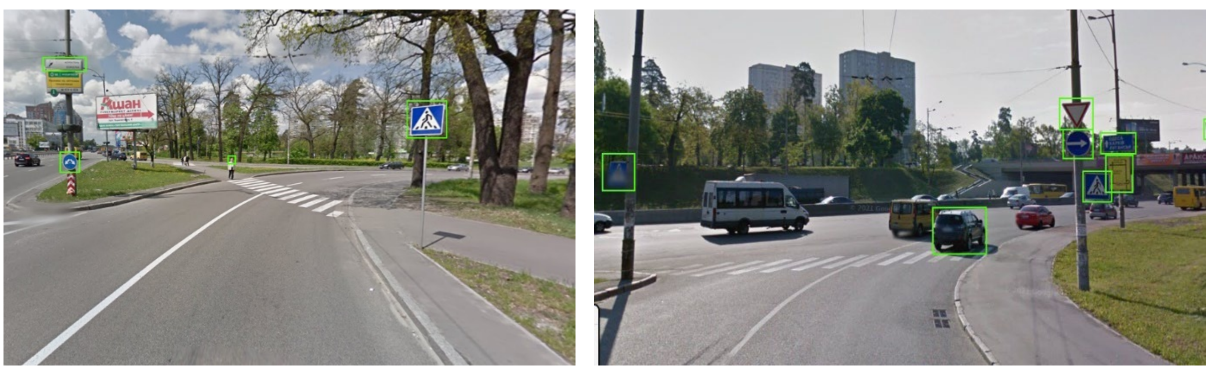


a *b* *c*

Fig. 8. Recognition and identification: *a* – vehicles and road signs before driving in the direction from the Great Ring Road to the Zhytomyr highway; *b* – recording of road accidents involving motor vehicles; *c* – road signs, vehicles and people



a *b*

Fig. 9. Recognition of road signs: *a* – before driving in the direction from Peremogy Avenue to the Great District Road; *b* – connection of Peremogy Avenue and the Great Ring Road with recognition of road signs and vehicles

The limitations of the study include difficulties with learning to recognize traffic accidents on a road route, as in some cases unforeseen circumstances may arise, for example, weather conditions that can create ice on a road section in the winter period, if the wheels are equipped with rubber tires of the summer period of the year. In addition, it is also necessary to take into account the serviceability of the automated AUV system, which requires periodic diagnostics and maintenance.

To date, there is a significant problem in the AUV research with pattern recognition, as military aggression continues in Ukraine, which is accompanied by unforeseen consequences, which in general has a negative effect on conducting research in the field of intelligent transport. The vector of further research will be focused on the studied military AUV, which can be widely used at the forward positions of the Armed Forces in order to recognize the signs of dangerous areas for demining.

4. Conclusions

The digital possibilities of identification and pattern recognition with the help of machine learning methods, navigation systems and video surveillance have been considered and analyzed, where the safety of motor vehicles with the detection of road signs and obstacles on the way plays a significant role. The obtained results indicate that the recognition technology can contain a number of advantages and disadvantages that are related to learning and identification of traffic accidents. But with the CNN help, the recognition technology was supplemented by the following:

1. Identification and avoidance of obstacles on the highway, where a study was conducted to study the main reasons that can cause time delays (traffic jams, weather conditions, road accidents).
2. Planning and navigation to determine the appropriate road route, which allows to identify and eliminate obstacles on the road, as well as to build a map plan of the route in advance using online services with Google Maps.
3. Recognition of road signs, people and vehicles, which minimizes the occurrence of traffic accidents, traffic jams and time delays.

From a theoretical point of view, the obtained results can be useful for supplementing the possibilities of pattern recognition with the help of machine learning methods, namely with the use of convolutional neural networks for further research in this field. From a practical point of view, this can expand the knowledge and experience in Ukraine, which will allow to delve deeper into the gaps and improve the recognition technology.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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