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Prospects for the Use of Artificial Intelligence and Computer Vision in Transport Systems and Connected Cars

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ABSTRACT

As statistics show, the use of artificial intelligence and machine vision for cars can significantly improve road safety. Even before self-driving vehicles dominate the road, connected vehicles with computer vision-based ADAS will dramatically reduce road accidents. New automotive technologies such as machine vision not only improve road safety, but also open new business opportunities for companies from related industries and sectors such as insurance, car sharing and driver training. Soon, the automotive market, car service services and industries close to transport will change dramatically. This means that those who invest in such developments right now will be able to seize leadership in the era of the spread of innovative technologies.

In modern cars, video cameras are used not only as an alternative to the rear-view mirror but are also an important part of active safety systems. Their task, first, is to support collision protection systems through object detection. Cameras are also used to keep track of the lane, to automatically recognise road signs and traffic lights, and monitor the condition of drivers. Together with radars and lidars, they are used to control unmanned vehicles. However, these are far from all the possible areas of useful application of video cameras on board a vehicle. With development of artificial intelligence systems, a decrease in size and an increase in the power of on-board computing facilities, as well as with an increase in the throughput of mobile communications and development of cloud technologies, it becomes possible to implement new services based on video cameras and computer vision.

For this reason, the objective of this article is to analyse the trends in development of artificial intelligence, computer vision systems and, considering these trends, to form a list of useful services based on them. The article provides information about what cars can «see» today, how they do it, and what useful services can be implemented for drivers, for transport organisations and for areas related to transport.

Keywords: *transport, artificial intelligence, neural networks, machine learning, computer vision, connected cars.*

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For the original Russian text of the article please see p. 74.

BACKGROUND

Computer vision and artificial intelligence are among the most demanded areas in the modern world of information technology. At the same time, there are many «myths» around computer vision and artificial intelligence. Some believe that computers can already easily «see» and «think», surpassing humans. Others, on the contrary, think that this is just a fantasy or a publicity stunt of tech companies.

The first attempts to force a computer to «see» date back to the early 1960s. However, only in recent years, with the increase in computing power and memory capacity, technologies of artificial intelligence, machine learning and computer vision began to find more and more applications in various industries, including transport [1].

The automotive industry is considered the «pioneer» in the field of machine vision systems and their largest consumer. The automotive industry forms up to 23 % of the computer vision market. It is not surprising that machine vision began to be actively used in cars themselves, and not only at the stages of their production [2]. At present, computer vision is used in autopilot driving, when recognising various objects: cars, lanes, license plates, road signs, traffic lights, pedestrians, etc. With its help, it is possible to estimate the distance to neighbouring cars and their speed, get recommendations for choosing a safe distance and speed. It allows evaluating various actions and conditions of the driver, such as: falling asleep, being distracted from the road, talking on the phone, smoking, etc. The use of computer vision in cars has a positive effect on reducing accidents.

Rear-view cameras, replacing mirrors, first appeared in concept cars. The first such car was the Buick Centurion, appeared in 1956 [3]. There were no rear-view mirrors in the concept version of the car; they were replaced by a camera housed in the tailgate. The image from the camera was displayed on a display mounted on the dashboard. Of course, in 1956 the monitor screen looked like a small picture tube. The idea of using the camera as a mirror was taken up by Volvo in 1972. For the first time, the manufacturer installed it on a Volvo Experimental Safety Car directly above the rear bumper. The situation changed in 1991. The third generation Toyota Soarer, better known as the Lexus SC (model Z30), entered the Japanese market. On request, a camera could be installed in the car under the rear spoiler. The image, according to tradition, was broadcast on an already coloured screen inside the cabin. Rear-view cameras have entered cars forever only since 2000 [3].

In modern cars, video cameras are an important part of active safety systems, and not only as an alternative to the rear-view mirror. They are used to keep track of the lane at night, to detect and recognize road signs and traffic lights, monitor the condition of drivers, signalling about falling asleep, and to participate in driving unmanned vehicles. However, these are far from all the possible areas of useful application of video cameras on board a vehicle. In the last decade, artificial intelligence and machine learning systems have advanced far, and the power of on-board minicomputers has increased. More high-speed channels appeared in mobile communications, which gave impetus to development of cloud technologies and distributed services.

Proceeding from this, a need arose to analyse the trends in development of artificial intelligence, computer vision systems and, considering these trends, to form a list of new useful services based on them, which was the *objective* of writing this article. Already today, cars can «see» and «analyse» much more information than before. And not only to see, but also to report what it saw to other road users and various ground services.

RESULTS

Technology description

In modern cars, cameras are an important part of active safety systems. Their task, first, is to support collision protection systems through object detection. Cameras are also used for lane tracking, automatic recognition of road signs and traffic lights. Together with radars and lidars, they are used to control unmanned vehicles.

According to their functional purpose, computer vision systems for manned vehicles can be divided into the following groups:

• Assessment of the driver's condition.
• Assessment of the driver's actions.
• Assessment of the environment.

As for assessment of the driver's condition, modern systems can solve the following tasks:

• Detection of the driver falling asleep and issuing signals for waking up.

• Detection of driver's distraction from the road (smoking, talking on the phone, eating, looking not at the road, uncharacteristic posture, etc.).

• Recognition of the identity of the driver who is behind the wheel.

The latter function is relevant, for example, for checking the identity of the driver, who must have a permit for driving (taxis, special vehicles), for carsharing cars, where it is necessary to check that the person who rented the car got behind the wheel.

Using artificial intelligence and computer vision systems, the following driver actions can be assessed:

• To fix the exit outside the road markings or the intersection of solid lines.

• To estimate the distance to the vehicle in front and warn of a dangerous approach.

• To determine speed of own car and to warn about a dangerous speed excess.

• To fix the aggressive driving manner (frequent lane change, e.g., «checkers game»).

As for assessment of the environment, then using a video camera directed in the direction of movement, it is possible to:

• Recognise traffic lights and their current signals.

• Recognise road signs with getting a hint about the permissible mode of movement.

• Detect vehicles suddenly appearing on the left or right from adjacent roads.

• Recognise pedestrians, cyclists, motorcyclists and other objects in front of the car and on the side of the road, receive a warning about a dangerous approach.

• Assess quality of roadway markings.

• Fix speed of the overtaking vehicle.

• Recognise and fix license plates of vehicles driving in the same direction.

• Register an accident or the presence on the road of foreign objects affecting traffic safety (tires, large puddles, holes, stones, cracks, debris, etc.).

Since their invention, cars have changed dramatically. Self-driving and flying cars are already being tested. They are predicted a great future, and connected cars are driving on the roads today. A connected car is a vehicle that exchanges data with other vehicles and devices, networks and services spanning a wide range of infrastructure, including home and office.

The first connected cars can be considered cars with telephones, the primitive models of which hit the streets of the United States back in 1946. Weighing more than 35 kilograms with limited functionality, car telephones were originally used mainly by drivers-forwarders, journalists, and important persons [4, p. 1]. In 1968 another breakthrough took place for the Connected Car market. Volkswagen introduced the first on-board computer system [4, p. 1].

A necessary element of Connected Car is a stable communication channel. Viewed from this perspective, the first «connected» car was created by General Motors (GM) in collaboration with Motorola Automotive. The solution was called OnStar, it entered the American market in 1996 [4, p. 2]. This enabled the vehicle to be connected to cellular networks and created a new niche for safety and security innovation.

The following innovations were not long in coming, and already in 2001, the first mobile phones were connected to the car via Bluetooth [4, p. 3]. This stage opened the concept of hands-free communication via a mobile phone, and laid the foundation for voice recognition technologies. In 2003, GM implemented the ability to receive remote reports on the condition of the vehicle, transmit GPS navigation parameters, and receive data from the Internet [4, p. 3]. With development of cellular communication technologies, since 2007, carmakers have begun to one by one embed telematics systems into their cars using the data transmission channels of cellular operators. In 2008, Wi-Fi first appeared on board cars [4, p. 3].

In general, «connected» functions can be divided into five broad categories: safety (ADAS driver assistance systems), navigation, information and entertainment, trouble-shooting, and payments. To ensure the exchange of information between cars and the corresponding services, a telematics platform is needed, and such a platform is already being created in Russia. In 2019, a project was officially launched to create such a platform [5], and in December 2020, the Russian standard for collection of automotive data was approved [6].

With such a platform, as well as considering the latest advances in artificial intelligence and computer vision, opportunities open to create new services for connected cars. Besides cars, which are both sources and consumers of data, there are several new consumers that can benefit from information from connected cars. Such consumers, in addition to citizens with personal transport, may include:

- Passenger transportation enterprises (operating bus, trolleybus, tram, taxi).
- Aggregators of taxi transportation.
- Driving schools.
- Insurance companies.
- Car sharing companies.
- Subdivisions of the traffic police (patrol services, subdivisions of driving examinations).
- Subdivisions of the Ministry of Internal Affairs and the Ministry of Emergency Situations.
- Ambulance stations.
- Road services.

Let us consider in more detail what new solutions can be implemented for the above consumers and citizens using artificial intelligence and computer vision systems in connected cars.

Passenger transportation enterprises

For employees of motor transport enterprises, all solutions that relate to monitoring the condition of drivers during their work on the line and fixing traffic violations are of interest. It is necessary to assess driving behaviour since the health and life of many passengers depends on it. The traffic safety services of road transport enterprises can use such systems to train drivers, evaluate the results of the training, make an objective, and not subjective, decision on the admission of drivers to work on the routes. Driving behaviour monitoring data while working on the line will allow rewarding accurate drivers and punish offenders. In addition, the computer vision system can record cars that violate the borders of the designated traffic lane for public transport, recognise their license plates and send information about offenders to the traffic police through a telematics platform.

Taxi transport aggregators

Taxi transport aggregators will be able to control the driving style of drivers during their work on the line, reward accurate drivers, and punish offenders. It becomes possible to record the identity of the driver who is behind the wheel, to control his mode of operation (e.g., exceeding the duration of the shift), to reveal the facts of work of drivers who do not have a license for taxi transportation. In addition, this system can record cars that enter the designated traffic lane for public transport, recognise their license plates and send information about offenders to the traffic police through a telematics platform. A video camera aimed at the interior of the vehicle, in addition, will be able to record cases of inappropriate behaviour of passengers, including attacks on the driver, as well as monitor revenue.

Driving schools (intelligent instructor)

The computer vision system will be able to control the number of hours of driving instruction for each cadet, all facts of distraction of the cadet from the road, all traffic violations, uncertain movement within the road markings, non-observance of the distance or speed limit. This will help the cadet view the video materials, independently or with a driving school instructor, to carry out an analytical analysis of the mistakes made during the training rides. In the process of training, it is possible to objectively assess the degree of preparedness of a particular cadet, make an informed decision about quality of training and the possibility of admitting a cadet to exams at the traffic police.

Traffic police departments (taking driving exams)

During the driving test, the computer vision system will be able to objectively record all the mistakes and violations made by the cadet during the test. Traffic police inspectors will be able to objectively assess the degree of preparedness of this or that driving school cadet. The system will allow indicating all the mistakes made by the cadet and summarise the results of the exam in the form of a score based on the totality of all mistakes. This will increase the objectivity of the decision whether a cadet has passed or not passed the driving test. The system will help to exclude the omission of erroneous actions of the driver due to the examiner's inattention, or, conversely, will not provide an opportunity to attribute errors in case of biased actions of the examiner. The video materials of the test can be used in cases of filing an appeal from the side of the cadet, to assess quality of the work of the inspectors taking exams. The accumulated data will make it possible to objectively assess the efficiency and quality of driving schools.

Traffic police departments (patrol services)

If a car is declared wanted, it is entered into the database of wanted cars of the telematics platform. All connected vehicles (buses, trolleybuses, trams, taxis, trucks, car-sharing vehicles, personal cars, special vehicles) will automatically receive information about the wanted car through the telematics platform. During movement, video cameras of these cars will be able to recognise the license plates of all surrounding cars in the background. If the wanted car is found, its location will be transferred through the telematics platform to the traffic police patrol services, which will be able to quickly arrest it. Thus, tens, or even hundreds of thousands of cars in a given region will be instantly connected to the detection of the wanted vehicle, which will ensure the efficiency of its search and interception. In addition, all connected vehicles can be involved in identifying violations of the speed limit by the vehicles driving in the same direction. After processing the video stream, it is possible to determine speed of the overtaking vehicle, if the permissible speed is exceeded, fix its number and transfer data about the speeding offender to the telematics platform. In essence, these are millions of mobile cameras that record speed violations. This approach will significantly reduce the number of accidents associated with speeding.

Insurance companies

For insurance companies, all the functions of computer vision systems are of interest since they refer to assessment of the driver's condition and compliance with traffic rules. Reliable results of monitoring driving behaviour can serve as the basis for a personal decrease or increase in the amount of insurance premiums. In addition, by mutual agreement of the insurance company and the owner of the car, the insured vehicle can be involved in the system for detecting traffic violations and in the system of «interception» of stolen vehicles. For this, insurance companies will be able to receive additional income from government agencies (as the developer of a network of mobile cameras), and the owners of the vehicles insured will be provided with discounts on insurance (due to the use of its car in the aforementioned systems).

Car sharing companies

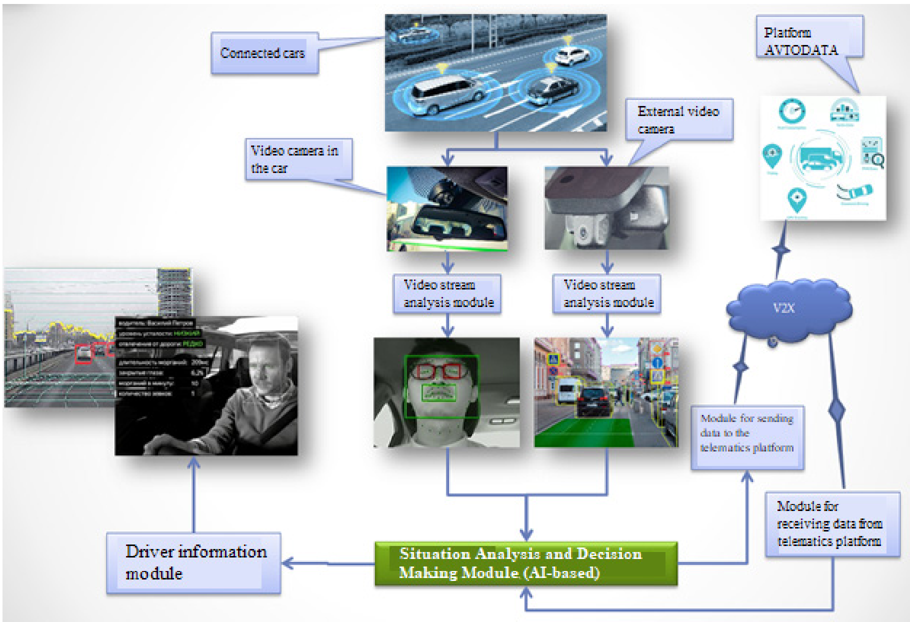
Owners of car sharing companies will be able to monitor the driving style of their customers. It becomes possible to record the identity of the driver, to control his mode of operation (exceeding the duration of continuous driving, driving in an inadequate state), to identify the facts of the use of cars by drivers who do not have access to the rented vehicle, to block the movement of the car from a standstill in case that a driver who is not registered in the system tries to use the car. Reliable results of the monitoring of driving behaviour can serve as a basis for a personal reduction or increase in car rental fees. The vehicles of a car sharing company can be used in the system of detection of traffic violations and in the system of «intercepting» stolen vehicles. For this, car sharing companies will be able to receive additional income from government agencies (as the developer of a network of mobile cameras), and, due to these funds, partially reduce the rent, which may attract a larger number of customers.

Road services

All connected cars can be used in the monitoring system of road conditions (quality of markings, holes, cracks) and the presence of foreign objects on the road or roadside that affect traffic safety (tires, large stones, debris, etc.). This information will automatically go to the telematics platform, and from it to the relevant road services. This will make it possible to promptly inform the road services about the presence of problems on remote segments of the roads and take appropriate measures to eliminate them. In addition, other connected vehicles will receive operational information about the presence of a hazard on a particular section of the road.

Telematics platform

This platform acts as a single centre for collecting and processing data from connected vehicles about various types of traffic violations, monitoring the condition of drivers and driving behaviour, searching for stolen vehicles, road conditions, etc. Through this platform, data is exchanged between the connected transport and consumers of information coming from it. Here, reporting statistical data are formed, based on which decisions will be made on taking certain measures to improve traffic



Pic. 1. Schematic diagram of operation of computer vision software for connected cars (compiled by the author).

safety. It is also possible to establish control over implementation of certain measures (for example, whether a hole on the road has been repaired, whether garbage has been removed from the roadside, whether worn out road markings have been fixed, etc.).

A schematic diagram of operation of computer vision software for connected cars is shown in Pic. 1.

To implement a computer vision system on a connected car, in addition to a satellite navigation receiver, it is necessary to have at least two portable video cameras (for viewing the passenger compartment and the road in front of the car), and a minicomputer with appropriate software that solves the following tasks:

- Video stream analysis.
- Analysis of the current situation and decision-making.
- Communication with the telematics platform (sending and receiving data).
- Informing the driver.

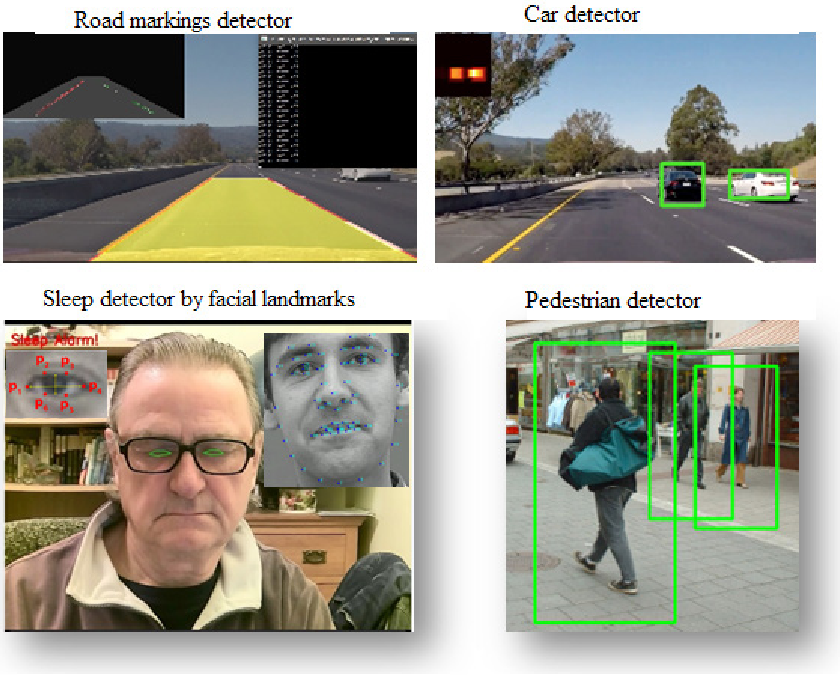
This software works in the following sequence. The video stream analysis module processes incoming images in the background, segments and recognizes various objects. The module for analysing the current situation and making decisions provides formation of a log of various events that relate to the state of the driver, his actions, environmental parameters, and road conditions. The module for communication with the telematics platform ensures sending information from the event log to the server site and receiving useful information from the telematics platform. The information module provides the driver with all useful operational information in the form of audio or visual messages.

Smart Information Systems has now launched services software for connected vehicles. The solution to this class of problems is based on the use of neural networks, machine learning and various methods of image processing. In this case, the following tools are used:

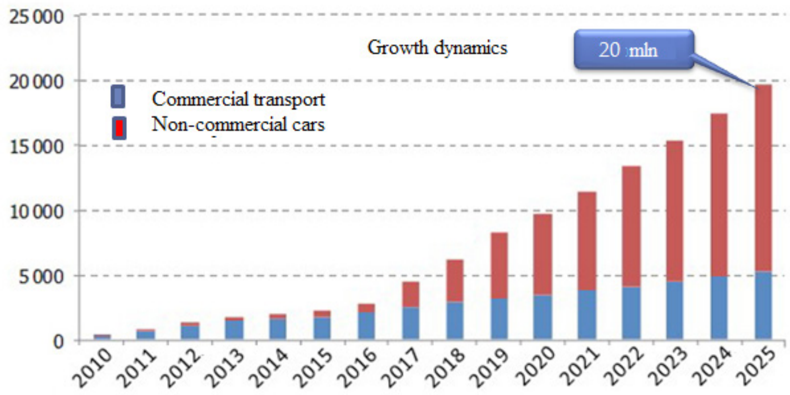
- Programming language Python.
- Specialized libraries for building neural networks and machine learning (Keras [7], PyBrain [8], Scikit-learn [9], TensorFlow [10], PyTorch with torchvision [11], etc.).
- Libraries for image processing and work with matrices (OpenCV [12], ImageAI [13], NumPy).

To simplify development of similar applications and reduce the program code, we have developed our own Postoperative Library for Image Transformation – PostoLIT.

To date, using this toolkit, some basic modules of the computer vision system for connected cars have been implemented, in particular:



Pic. 2. Examples of the operation of some software modules of computer vision for connected cars (compiled by the author).



Pic. 3. Dynamics of growth in the number of connected cars in Russia [16].

• Neural networks R-CNN for recognition of road infrastructure objects (road markings, cars, pedestrians, traffic lights, road signs, etc.).

• Image segmentation and clustering modules based on Haar cascades.

• Modules for recognition and segmentation of object instances based on Mask R-CNN networks.

• Modules for recognising the driver's state based on detectors of facial landmarks and face elements (falling asleep, being distracted from the road, talking on the phone, etc.).

Examples of the operation of some software modules are shown in Pic. 2.

The number of connected cars is constantly growing. If in 2015 there were 26,5 million connected cars in the world, then by 2022 their number will increase to 82,5 million [14]. In Russia, where 53 million vehicles are currently registered [15], a similar trend is observed. If at the end of 2019 the number of connected cars was about 8,4 million, then by 2025 it is expected to increase to 20 million (Pic. 3) [16].

The constant growth in the number of connected cars indicates the prospects for the demand for computer vision systems for them. However, there is a rather serious factor that hinders development of systems based on neural network image processing technologies in road transport, and this is the lack of qualified personnel. According to statistics, the total number of IT specialists in Russia among the working-age population is only 1,5 %. For comparison, Finland – 7 %, Great Britain – 5 %, Norway – 5,5 %. The annual need for IT specialists for Russia in 2020 was 220 thousand people, by 2024 it will increase to 300 thousand [17]. To create systems based on artificial intelligence, not just programmers are needed, but specialists with a deep knowledge of higher mathematics and an understanding of the processes in the applied field for which intelligent systems are being developed. Currently, more than 50 universities in Russia are training specialists in artificial intelligence. However, there is still an acute shortage of such specialists. To cover these needs, measures are needed to train personnel with appropriate qualifications. From this point of view, implementation of the Federal project «Human Resources for the Digital Economy» was launched in Russia in a timely manner. These steps will accelerate the pace of development of neural network technologies and computer vision systems, including in road transport.

CONCLUSIONS

1. Computer vision and artificial intelligence form perhaps the most demanded trend in development of information technology.

2. The number of connected cars is constantly growing, cars with semi-autonomous and autonomous driving appear, respectively, the demand for innovative services based on computer vision for this group of cars will only increase.

3. For successful creation and development of new types of services for connected and unmanned vehicles, a revision and improvement of the training system is required, the implementation of new types of educational programs with an emphasis on the study of special sections of mathematics, neural networks, machine learning and computer vision.

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