INFRASTRUCTURE FACILITIES FOR UNMANNED VEHICLES

Kremlev, Ivan A., *National Research Tomsk Polytechnic University, Tomsk, Russia.*
Tyryshkin, Alexander V., *National Research Tomsk Polytechnic University, Tomsk, Russia.*

ABSTRACT

The article considers the technological aspects of creating infrastructure facilities for organization of movement of unmanned vehicles on the roads. The features of operation of cars with an autonomous control system in Russia and other regions of the world are analyzed. Basing on the study, the authors offer a fundamentally new approach for solving a problem of recognizing objects along the route of unmanned vehicles. The study suggests installation of stationary points that are interconnected in a single network and exchange data with the cloud storage. The effectiveness of existing and alternative systems is evaluated.

Keywords: *unmanned vehicles, infrastructure, object recognition system, method of recognizing road signs, control technology, mobile networks, road transport.*

Background. *One of the core trends in modern car production is translated through development of cars with an autonomous control system. Initially, autonomous control transport systems appeared in the United States in the 2000s for military purposes [1]. Autonomous vehicles were then developed to overpass fields of fire and to deliver cargo to the designated points. Since then engineering innovation has taken root in the civilian environment as well. Now consumers are familiar with Tesla Motors and General Motors self-driving cars. European and Japanese manufacturers – Nissan, Toyota, BMW and others – have not stood aside and have already got serious achievements in the field of autonomous control.*

Currently, autonomous transport control systems take into account not only infrastructure data (roads, road surface marking, traffic lights, etc.), but being powerful computers that have many cameras, sensors, scanners, can instantly process information and make decisions about maneuvering based on the real situation on the road. Of course, the better is the quality of the roads and the markings and the more predictable are the actions of other drivers (meaning driving respecting traffic rules), the safer is movement of an unmanned vehicle. Cars with autonomous control system should reduce the level of incidents on the roads (the probability of human error will be reduced to zero), as well as save the drivers from the need for a long stay behind the wheel [1].

According to experts, the use of unmanned vehicles will reduce the number of accidents by 80–90 %. In addition, these cars will provide significant savings in fuel and operating costs (up to 30 %) by optimizing the speed mode. Another effect of using unmanned vehicles will be an increase in the maximum capacity of the roads, streamlining traffic and minimizing the distance between vehicles.

For all that, one of the most difficult tasks facing researchers is recognition of various objects that are encountered on the vehicle's route in real time.

Objective. *The objective of the authors is to study existing and developed infrastructure facilities to be used for safe operation of unmanned vehicles and to suggest new approaches to their design.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, evaluation approach, communication and informatics methods.*

Results.

***

During past twenty years, many scientists from different countries have tried to solve the problem of recognizing road signs. The very first research on this topic appeared in the 80s of 20th century. However, the computing power at that time did not allow satisfactory implementation of video sequence processing. In addition, there were no cameras that would have allowed obtaining images of the desired format and size. Today, the technical level of mobile processors has reached the point where it is possible to install road sign recognition systems on mass produced cars with certain confidence. For example, CUDA technology from NVIDIA, which significantly increases computational performance due to the parallel computing architecture, allows reducing time for image processing to a few milliseconds, which meets the requirements for video sequence processing online [2]. But the systems that are used in mass produced cars have low recognition accuracy, and do not always correctly detect domestic signs.

In 2011, on the basis of 50 thousand images of German road signs, specialists from the University of Lugano created a program for their recognition based on neural networks. At the competition, it showed a result of 99,46 %, ahead of not only other programs, but even the best «human» of 32 people participating in the competition (99,22 %), and the average among people was 98,84 % [3, p. 81].

The vast majority of traffic sign oriented systems are based on technical vision. From the standpoint of detection and recognition, such signs are fairly simple objects. In addition, their type and shape are determined by standards (e.g. in Russia by state standard GOST R52290-2004 [4, p. 2–14]).

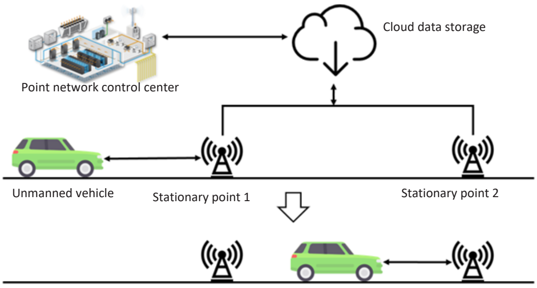
According to classification of approaches, there are methods for recognizing road signs on the basis of color, on the basis of form, or combined methods. However, they are united by the use of threshold processing or color segmentation to highlight the area of the image where the road sign is located, and its subsequent recognition by pixel-by-pixel comparison with the standard. This model of color representation has its drawbacks.

First, it is the influence of shadows and light on the recognition efficiency. Secondly, for implementation of such a system, serious computing power is needed, which significantly increases the cost of an unmanned vehicle.

Another method by which the unmanned vehicle is able to recognize road signs is based on the use of QR codes. Among the 2D barcodes, Quick Response (QR) deserves the special attention of engineers. QR codes have many advantages compared to their own kind, including high reliability, confidentiality of information, readability from any direction, the possibility of error correction (hence, of noise and partial damage to the image).

QR codes have recently started to be used in intelligent transport systems and vehicles, for example, in parking systems, tyres' condition monitoring systems, navigation systems [5].

The main purpose of using the system with QR codes is to combine the advantages of the classic



Pic. 1. The structure of the system of control of unmanned vehicles.

Table 1

Comparative characteristics of DSRC and LTE-A

Characteristics	DSRC	LTE-A
Channel width	10 MHz	Up to 100 MHz
Frequency ranges	5,86–5,92 GHz	450 MHz–4,99 GHz
Operation range	Up to 1 km	Up to 30 km
Coverage	Local	Full

Table 2

Unmanned vehicle tasks

Tasks	Unmanned vehicle	Controller
Choice of a motion path of an unmanned vehicle		+
Maintaining a safe distance to vehicles ahead	+	
Maintaining a selected traffic lane	+	
Dynamic obstacles tracking	+	
Assistance when passing intersections		+
Assistance when turning left		+
Interaction with other vehicles		+
Calculation of a vehicle route		+
Prioritization of vehicle traffic		+
Traffic accident reporting		+
Bad weather warning		+

systems of road signs with the advantages of QR codes. In particular, such systems will be resistant to changes in the external environment, they will easily support processing in real time, but most importantly, they are capable of correcting errors due to a slight damage to a traffic sign.

The disadvantages of such systems are that QR codes are put on a classic road sign, which means that it needs constant maintenance and, if necessary, replacement.

***

The authors of the article propose a new approach, that involves installation of stationary points that are interconnected into a single network and exchange data with the cloud storage. In turn, the cloud storage is connected with the control center of the network of points where the dispatcher is located, who monitors all indicators in real time and intervenes in the work of the system only when necessary. A transmitter is installed at a stationary point, which emits a signal in the direction of the transport stream, and in an unmanned vehicle, a receiver receives a signal and generates a control action on the actuators of a vehicle (Pic. 1) [6]. As a result, an unmanned vehicle can move according to the traffic rules.

The demonstrated approach can significantly reduce the required computational power of the central processor unit for processing traffic information in the transport flow, as well as reduce the cost of development of an unmanned vehicle.

To implement such a system, two main methods are known: of DSRC technology (Dedicated short-range communications) or 4G mobile networks (LTE), followed in the future by 5G networks.

DSRC devices, created in accordance with international standards IEEE802.11p and IEEE1609, help solve the problem of rapid transmission of information between vehicles and transport infrastructure while minimizing the cost of data centers, without creating expensive infrastructure and using global communication channels.

Supplementing DSRC with dynamic routing technologies for building peer-to-peer networks, DTN (Delay & Disruption-Tolerant Networking), with global GLONASS/GPS geolocation solves most of the problems inherent to traditional control and communication systems. At the same time, the technical characteristics of the system are significantly increased by placing primary data processing facilities directly on receiving-transmitting devices without sending large amounts of information to computer centers.

Thanks to such technologies, it became possible not only to automate and intellectualize traffic control, to build an effective collision avoidance system, but also to create an open platform for constructing targeted solutions of a scale similar to that of smart cities.

At the same time, DSRC technology also has disadvantages. One of the most serious of them is the need for personification (assignment of a unique code) to the transceiver equipment of each vehicle, which poses both the insurmountable technical problem of generating a large number of orthogonal codes and the need to solve accompanying legal problems.

In addition, the data transfer speed in DSRC technology is quite low compared to LTE-A. Comparative characteristics of two technologies are shown in Table 1.

Based on the table, it can be concluded that LTE-A networks can be used in conjunction with DSRC to solve the problems of vehicle interaction between each other and wiht the infrastructure facilities.

***

The communication system between cars is widely used in traffic control. The main purpose is to prevent traffic jams, as well as to adapt traffic to weather conditions. The main directions of wireless traffic control are as follow:

- *flow speed control;*
- *transport intersection control;*

	Technical vision
Road sign with installation	20 000• 10 000 rub. = ~ 200 mln rub.
Onboard computer for image processing	150 000• 1 000 000 rub. = ~ 150 bln rub.
Camera	150 000• 30 000 rub. = ~ 4,5 bln rub.
Total	~ 159,7 bln rub.

	Barcodes
Road sign with installation	10 000• 10 000 rub. = ~ 100 mln rub.
Barcode reader	150 000• 10 000 rub. = ~ 1,5 bln rub.
Onboard computer	150 000• 10 000 rub. = ~ 1,5 bln rub.
Total	~ 3,1 bln rub.

	Wireless signals
Installation of stationary points	5 000• 20 000 rub. = ~ 100 mln rub.
Portable module for a car	1 000• 1 000 000 rub. = ~ 1 bln rub.
Equipment of control center and cloud storage	~ 100 mln rub.
Total	~ 1,2 bln rub.

Pic. 2. Calculation of the economic efficiency of the system in Tomsk.

• ensuring movement of emergency services vehicles;

• ensuring movement in the «green wave» mode;

• warning about «traffic jam»;

• selection of an optimal route according to different criteria (time, fuel, charge).

Along with traffic control, the communication system between cars also allows to control this movement, which will definitely be required by the supervisory authorities (e.g. road police).

Let's consider in table 2 the tasks that are intended to be solved by an unmanned vehicle and which are removed in case of installation of the proposed system on public roads.

A number of these tasks have already been solved in modern cars with the help of a video camera and a radar – for example, in emergency braking systems, assistance in changing lanes, recognition of road signs. But the technical capabilities of the proposed system are much wider; e.g., none of the existing systems can look around the corner.

To date, the most popular on-board computer for unmanned vehicles is Nvidia Drive PX2 model (the cost is about 15 thousand dollars). The power of such a computer is comparable to the power of 150 Macbook Pro laptops [7, p. 1]. In case of installation of stationary traffic controllers for organizing traffic of unmanned vehicles, a serious computational load is removed from the central processor unit of the car, since there is no need to choose a trajectory, to pass intersections and to interact with other vehicles – all this is done by the traffic control system.

Let us calculate the economic efficiency of introduction of such a system in a city like Tomsk (with a population of 570 thousand people) [8], where there are about 20 thousand road signs (evaluation of the number of signs was carried out independently) and about 150 thousand cars registered [9] (Pic. 2).

Conclusion. *The introduction of stationary points for organization of traffic on public roads will save considerable funds when designing a new city or a microdistrict. Summing up the results, there is a reason to say that technologies in the field of unmanned vehicles are constantly evolving and we are awaiting for new engineering solutions that will allow to organize traffic with maximum speed from one point to another, while maintaining the required level of safety for people and equipment.*

REFERENCES

1. Towards the future using self-driving vehicle. Do we need cars without a driver? [*V budushchee na avtopilote. Nuzhny li mashiny bez voditelya?*]. [Electronic resource]: http://www.insur-info.ru/press/120787/. Last accessed 19.02.2019.

2. Parallel computing with CUDA [*Parallelnie vychisleniya s CUDA*]. [Electronic resource]: http://www.nvidia.ru/object/cuda-parallel-computing-ru.html. Last accessed 19.02.2019.

3. Progress in development of neural networks for machine learning [*Progress v razrabotke neirosetei dlya mashinnogo obucheniya*]. [Electronic resource]: https://habr.com/post/160115/. Last accessed 19.02.2019.

4. GOST R52290-2004. Technical means of traffic organization. Road signs. General technical requirements *[GOST R52290-2004. Tekhnicheskie sredstva organizatsii dorozhnogo dvizheniya. Znaki dorozhnie. Obshchie tekhnicheskie trebovaniya*].

5. Eken, S., Sayar, A. A Smart Bus Tracking System Based on Location-Aware Services and QR Codes. International Symposium on Innovations in Intelligent Systems and Applications. June, 2014. DOI: 10.1109/INISTA.2014.6873634.

6. The advantages of modern standard Wi-Fi 802.11ac [*Preimushchestva sovremennogo standarta Wi-Fi 802.11ac*]. [Electronic resource]: http://ipboom.ru/info/articles/2017/preimushchestva_sovremennogo_standarta_wi_fi_802_11ac/. Last accessed 19.02.2019.

7. First picture of Tesla's new NVIDIA onboard supercomputer for Autopilot installed in a car. [Electronic resource]: https://electrek.co/2017/01/20/first-picture-of-teslas-new-nvidia-onboard-supercomputer-for-autopilot-installed-in-a-car/. Last accessed 19.02.2019.

8. Wikipedia – the free encyclopedia. [Electronic resource]: https://ru.wikipedia.org/wiki/Томск. Last accessed 19.02.2019.

9. Tomsk took the 32nd place among the cities of the Russian Federation in terms of the vehicle fleet. RIA News [*Tomsk zanyal 32 mesto sredi gorodov RF po ob'yemu avtomobilnogo parka. RIA novosti*]. [Electronic resource]: https://www.riatomsk.ru/article/20150313/tomsk-objem-avtomobiljnogo-parka/. Last accessed 19.02.2019. ●

Information about the authors:

Kremlev, Ivan A. – Master's student at the department of Automation and Robotics of National Research Tomsk Polytechnic University, Tomsk, Russia, ivankremlyov@mail.ru.

Tyryshkin, Alexander V. – Ph.D. (Eng), associate professor at the department of Automation and Robotics of National Research Tomsk Polytechnic University, Tomsk, Russia, tyryshkin@tpu.ru.

Article received 19.02.2019, accepted 07.03.2019.