The development of ground unmanned vehicles, driver assistance systems and components according to patent publications

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Abstract. The paper contains the analysis of the main trends in the patenting of ground unmanned vehicles, driver assistance systems (ADAS) and unmanned vehicle components abroad during the period from 2010 to 2016. The conclusion was made that the intensity of their patenting abroad increased.

1. Introduction

The development of industry and the economy in developed countries significantly depends on the further development of vehicles and systems that must ensure greater mobility of the population, the efficiency of cargo and passenger transport, the improvement of road safety, the reduction of the burden on the environment and improve the comfort of drivers and transport users. Effective way to solve these problems is the creation of ground unmanned vehicles and driver assistance systems.

This report presents the results of a patent search in ground unmanned vehicles, driver assistance systems (ADAS) and components for them, performed on Russian and foreign patents, scientific and technical materials for the period 2010 - 2016.

Last decade, the development of unmanned vehicles has been experiencing a technological boom in the automotive industry of all leading countries [1]. The most active work on the creation of unmanned vehicles is carried out in the United States, Germany, Japan, China, Great Britain, Sweden, France, and Korea [2, 3]. A significant number of projects on the creation of the unmanned vehicle are defense-related and for this reason, the results of the research are seldom published in the open press. Complex high technology solutions, mathematical apparatus, motion control algorithms, software, control systems sensors of unmanned vehicles in many countries are classified as dual-purpose products.

The main advantages of unmanned vehicles are:

- improvement of transport and environmental safety, minimization of road accidents and the number of human victims in them;
- reduction of time and costs for transportation of goods and passengers;
- reduction of fuel consumption, emission of harmful substances into the atmosphere;
more efficient use of road capacity;
expansion of car use opportunities for disabled people;
possibility to transport goods in hazardous areas, during natural and technological disasters or military operations;
improvement of passengers' comfort.

The most complex and knowledge-intensive in the ground unmanned vehicle is an automatic traffic control system (ATCS). Figure 1 shows a typical functional diagram of the main subsystems in the ATCS.

![Figure 1. A typical functional diagram of the main subsystems in unmanned vehicle’s automatic control system.](image)

The navigation and orientation systems ensure the location of unmanned vehicle on the ground. The system of technical vision forms a picture of the environment, provides recognition of other vehicles, obstacles on the route, road markings, road signs, traffic lights [4]. The information management system is the core of the unmanned vehicle traffic control system. It is responsible for building the traffic route, emergency decision-making depending on the surrounding traffic situation and the formation of control signals for actuators. Actuators in accordance with the control signals provide a control effect on the units and vehicle systems, simulating the actions of the driver. Depending on the chassis design of the unmanned vehicle, the system of executive drives provides the operation of thrust control drives (fuel supply when using internal combustion engine), clutch, gear shift, steering gear, brake, starter, lighting devices and etc.

The variety of vehicle and aggregate design predetermines a large number of technical proposals for automating traffic control. Technical proposals are reflected in patent documents belonging to organizations and individuals from leading industrialized countries. Patent research in the field of "Electronic systems for traffic control of land unmanned vehicles" included analysis of patent documentation on methods and devices for automatic control of cars, agricultural and special equipment, mobile robots, etc.

Patent research was conducted in the following key areas:
1. Ground unmanned vehicles;
2. ADAS systems;
3. Components of the unmanned vehicle.
The purpose of patent studies was to assess the number and dynamics of patented developments in these areas by country and key developers. The patent search was conducted on the basis of the following electronic databases located on the Internet:

- database of the European Patent Organization (EPO) (http://worldwide.espacenet.com);
- database of the World Intellectual Property Organization (WIPO);
- database - register of inventions and published filed applications of the Industrial Property Federal Institute of the Russian Federation (http://www.fips.ru);
- database of Thomson Reuters Derwent World.

Based on the subject of the search and on the patent classifier analysis, the relevant classification clauses of the International Patent Classification (IPC) were selected.

The analysis shows that the development of the unmanned vehicle is carried out in two main directions:

- on the way of introducing and expanding the functionality of various driver assistance systems (cars of all classes are being currently equipped with these systems);
- on the way of creating methods and control systems for fully unmanned vehicles (which are currently in the stages of prototypes, including operational ones).

A modern car contains many electronic assistance systems for the driver with varying degrees of the driving process automation. They include cruise control systems, traffic stability, collision avoidance, parking distance control, preventive preparation for an accident, etc. These systems take on a part of the vehicle management functions, for example, the functions of automatic speed control, acceleration, braking, turning, engine and transmission modes. Thereby in some conditions (for example, when driving on a highway) the car is able to move in an autonomous mode, and the driver can not interfere with the control process. Further improvement and expansion of the driver assistance systems functionality ensures an increase in the autonomy of the car, bringing it closer to a completely unmanned vehicle.

Figure 2 shows the dynamics of patenting in respect of unmanned vehicles, ADAS systems, and unmanned vehicle components abroad.

![Figure 2](image-url)

**Figure 2.** Dynamics of patenting in respect of ground unmanned vehicles abroad, ADAS systems and unmanned vehicle components in general and separately for the period from 2010 to 2016.
Patenting of autonomous ground unmanned vehicles abroad is most active. At the same time, the number of patents for working methods and assistance systems for the driver, as well as for the components of the unmanned vehicles, is also constantly growing. Patenting by leading foreign developers is conducted, as a rule, by patents packages in the directions under consideration.

The number of issued patents and published patent applications for the period from 2010 to 2016 indicates the priority of the subjects among foreign automakers in comparison with other developments in the automotive industry.

There are many manufacturing companies among the developers. Toyota Corporation (Japan) is the universally recognized world leader in the patenting of ground unmanned vehicles. Then follow other corporations: Bosch (Germany), Denso (Japan), Hyundai (South Korea), FORD GLOBAL TECH LLC, GM (USA) - see figure 3.

In order to realize autonomous control over the movement of an unmanned vehicle, the development and patenting of traffic control systems are most actively carried out, which include: intelligent chassis control units, vision systems, information processing and transmission, navigation and orientation systems (figure 1). In general, the patented traffic control systems of the unmanned vehicle provide the following operations:

- receiving and processing the data from sensors;
- consolidation and harmonization of the received data;
- image processing;
- identification of obstacles, road conditions and vehicles, distance to them;
- positioning of the unmanned vehicle and determining the current state of the system;
- implementation of automatic control: speed, trajectory (course) of traffic, automatic response to objects surrounding;
- making decisions on management actions;
- control of executive devices;
- formation of a database for further analysis.
Figure 3. Quantitative data on the patenting in the field of unmanned vehicles by leading foreign automakers for the period from 2010 to 2016.

In the patented complex traffic control systems of the unmanned vehicles, the software usually includes two levels - the lower and upper level. Lower level software is responsible for interaction with sensors and actuators, and the upper one directly corresponds to the implementation of the unmanned vehicle motion control algorithm. For testing in the vehicle traffic control system, a group of patents provides for the use of algorithm modeling processes.

In the patenting of unmanned vehicles, Japan occupies the leading positions in the world - see figure 4. Leaders in this direction are the corporations Toyota (Japan), Denso (Japan), Bosch (Germany), Nissan (Japan) and Honda (Japan). The American company Google takes 19th place in this area, and FORD is on the 20th place. Representatives of Asian countries took eleven positions in the list of the leading 20 corporations.

The development and patenting of driver assistance systems (ADAS) were conducted ahead of ground unmanned vehicles developments. Main systems of driver assistance are:

- adaptive cruise control;
- warning of leaving the lane;
- helping in movement in the lane;
• assistance with changing lanes;
• frontal collision warning;
• warning of frontal collision with pedestrians and obstacles;
• emergency braking system;
• intellectual speed limit;
• parking assistance (parallel, perpendicular);
• helping in traffic jams;
• highway autopilot;
• control of the driver's condition;
• recognition of traffic signs;
• recognition of traffic light signals;
• adaptive control of headlight;
• night vision;
• side video surveillance;
• circular view;
• detection of vehicles during the return movement;
• tire pressure monitoring;
• automatic control of the conditioning system operation;
• automatic windshield wiper.

The largest number of patents for ground-based unmanned vehicles and driver assistance systems belongs to Bosch Corporation - see figure 4. Toyota, Hyundai, Daimler, Continental, GM are also major developers in this area. Out of five first places, three belong to German companies: Bosch is the leader in patenting; Daimler and Continental occupy the fourth and fifth places respectively. Toyota (Japan) is on the second and Hyundai (South Korea) is on the third place.

In the field of unmanned vehicle components following developments are patented: methods of work, devices and telecommunications systems, unmanned transportation management technologies, additional systems and means for improving road safety, information transfer and exchange systems, especially between vehicles, vehicles and the infrastructure of intelligent transport systems. The scale of patenting in this area is much smaller than the patenting of ground unmanned vehicles and active safety systems. However, these issues are important and promising for solving the problem of improving the road safety [5, 6].

General Motors Corporation (USA) takes the first place in patenting of unmanned vehicle components (figure 4), followed by Hyundai (South Korea), Marvell (USA), LG (South Korea) and Denso (Japan). In this area, special attention is paid to systems and methods for the transfer and exchange the information between vehicles, vehicles and the infrastructure of intelligent transport systems.
Summarizing the foregoing, it can be stated that for the period from 2010 to 2016, the number of foreign patents and published patent applications for ground unmanned vehicles, driver assistance systems and components for them exceeds 35,000. This branch of the automotive industry is rapidly developing and it is priority one. In the Russian Federation for the same period, the number of published patents and patent applications for the ground unmanned vehicles, driver assistance systems and components submitted by domestic developers does not exceed 80 patents. The owners of patents in the Russian Federation are both enterprises and organizations, as well as individuals, with no leader among them. In the Russian Federation FORD GLOBAL TECH LLC is actively patented their developments.

2. Conclusions
The total number of patents and patent applications abroad for ground unmanned vehicles, driver assistance systems and components for the period from 2010 to 2016 exceeds 35,000, which indicates the priority and prospects of this direction in the development of the automotive industry and transport
systems. Patents in the territory of the Russian Federation are received and supported by the majority of foreign firms.

The number of patents and patent applications for ground unmanned vehicles, driver assistance systems and components in the Russian Federation of domestic developers for the same period does not exceed 80 patents. Owners of patents are enterprises, organizations, and individuals. The leader among them was not identified. It could be conclude, that the patenting in the Russian Federation of ground unmanned vehicles, ADAS systems and their components by domestic developers in comparison with foreign ones is extremely slow and does not have a systemic character. At the same time, every year the competition with patents of foreign firms is becoming more and more complicated.

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