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Development of the Ground Mobile Robot with Adaptive Agility Systems

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Abstract

The development of unmanned vehicle traffic control systems is a world trend. The development of a market of unmanned vehicles is stimulated by various contests and competitions. This paper presents the prerequisites and the first steps in the development of unmanned vehicle traffic control systems by the NNSTU n.a. R.E. Alekseev with the support of engineers from the United Engineering Center of the GAZ Group and specialists from PJSC GAZ. This system is developed for operation in difficult road-climatic conditions in the territory of the Russian Federation. As a chassis for installation of the system, an electrical platform was chosen. The component composition of the unmanned vehicle traffic control system is proposed, the location and coverage of the equipment are determined. The software modules of the unmanned traffic control system are implemented. Experimental studies of the system were carried out.

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Keywords: agility; ground mobile robots; adaptive control systems.

1. Introduction

Ground-based robotic platforms equipped with a wide range of active and passive sensors are currently used in order to monitor coastal areas, to perform rescue and special operations, to search and extract different minerals. The use of robots is caused by a reduction in the workload on a human, as well as by the restrictions associated with the risk to human life and health during carrying out the work described above.

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The monitoring of coastal zones is an important task in the development and study of marine areas. There are several complexes [1-5] for long-term deployment with the possibility of continuous data acquisition, covering several hundred meters from the shoreline, and allowing to study coastal areas on different time and spatial scales.

One of such complexes is the Autonomous Mobile Robotic System (AMRS), developed by the scientific team of the NNSTU n. a. R.E. Alekseev [6]. This complex is equipped with all necessary measuring equipment and is capable of continuous monitoring of the coastal zone in any climatic conditions and on any type of support base. On the basis of experimental researches it was concluded that for the effectiveness of the fulfillment of the tasks set, the use of large unmanned vehicles leads to significant financial and time costs associated with the deployment and maintenance of the complex's operation. The most effective is the use of a group of light unmanned ground mobile robots. The advantages of group application of these robots in the indicated tasks are as follows: a larger range of action, achieved by dispersing robots throughout the work area; extended set of functions; high probability of accomplishing the task, achieved due to the possibility of redistribution of goals between the objects of the group; the ability to perform measurements at several points simultaneously.

In this connection, a mobile robotic platform was developed, which is one of the participants in the group intended for coastal zone monitoring.

At the first stage of the development, an analysis was made of existing small-sized robotic platforms capable of moving over rough terrain.

One of the robotic platforms is the Locked Martin's company Squad Mission Support System [7], which is one of the leaders in the production of ground robots and the creation of control systems for unmanned vehicles (Fig. 1a).

a b c

Fig. 1. (a) Squad Mission Support System [7] (b) Innok TX[8] (c) Wheeled Platforms [9]

The robotic platform is based on a six-wheeled chassis with the geared steering mode. For unmanned control, it is equipped with the laser rangefinder, video, and thermal imaging cameras. The platform is designed for the accommodation of technological equipment and transportation of payloads weighing up to 300 kg. The robot is controlled remotely, it is capable to work in the mode of following another vehicle, or the person going ahead of the machine.

Innok TX has developed a more compact version of the robotic complex High-Speed Off-Road Robot Platform [8]. This complex is a remote-controlled platform with possible accommodation of various equipment, including navigation systems, computer equipment and various types of sensors (Fig. 1b).

A similar robotics platform «Wheeled Platforms» [9] is developed by AMBOT (Fig. 1c). The complex has a four-wheel drive, independent suspension with the ability to turn all four wheels. This platform is equipped with a remote control module. Different equipment can be installed on the platform.

According to the results of the analysis of the existing robot systems on the market, it can be concluded that light platforms weighing up to 300 kg do not have sufficient characteristics (in most cases) for efficient off-road work: low ground clearance, lack of suspension, impossibility of adjusting the torque on each wheel, equipment for motion on the given coordinates without the participation of an operator remotely controlling the robot.

Thus, the aim of this work is to develop an unmanned ground vehicle chassis, adaptive control systems that provide the higher level of mobility, and the development of positioning systems, detection of obstacles along the way for the realization of autonomous motion in coastal zone conditions.

2. The development of robotic complex for coastal zone monitoring

Based on the analysis of existing types of robotic platform designs, a ground mobile robot with a wheel formula 6x6 and an electric transmission with an individual drive of each of the wheels was developed. Fig. 2 shows the general view of the developed platform. Table 1 presents the technical characteristics of the developed complex.

Fig. 2. general view of the robotic platform.

Table 1. Technical characteristics of the robotic platform.

Parameter	Value
Dimensions, m	1.8x1.5x0.77
Weight, kg	300
Dimension of tires	23x7-12
Max. motor torque, Nm	21
Gear ratio of the planetary gearbox	10
Maximum speed, km / h	10
Max. climbing angle, degree.	30

The electric transmission consists of stepper motors ST110-150 and planetary gearboxes PX110-10ST, providing a torque of 210 Nm on each of the wheels of the platform. OMD-88 drivers are used to controlling the motors, providing a wide range of torque control.

To power the electric motors, measuring and other equipment located onboard, the lithium-ion batteries with a voltage of 48 V and a capacity of 12.5 Ah are used.

For the functioning of control and positioning modules, detection of obstructions along the way, maintenance of adaptive mobility, environmental monitoring, an onboard computer based on the NVIDIA Jetson TX2 computer is used

3. Obstacle detection module

This module is necessary for detecting objects on the route, calculating the distance to these objects and identifying objects that can be treated as obstacles.

As the main sensor of the obstacle detection module, it is proposed to use LIDAR Velodyne VLP-16 [10]. This sensor provides a real-time 3D model of the space within a radius of 100 m. The VLP-16 supports 16 channels, has a scan rate of 300,000 dots per second, a horizontal viewing angle of 360°, a vertical viewing angle of ± 15°. VLP16 has a level of protection IP67, which makes it suitable for use in difficult road and climatic conditions. Application of LIDAR in the field of technical vision makes it possible to construct systems for responding to positive and negative (pit, moat, ditch) obstacles. LIDAR data is used in the positioning module to select the optimal trajectory of the platform motion.

To detect obstacles according to LIDAR data, the software was developed, based on clustering algorithms for the cloud of points and methods of linear algebra. All implemented modules for interaction with each other have been integrated into the ROS infrastructure (Robot operating system) [11-13].

4. Control and positioning module

This module is designed to control the robotics platform by the operator both in the remote mode and in the following the route specified by the operator. To operate the positioning module, a GPS/GLONASS navigation station of high accuracy OS-103 [14] with the ability to work in the RTK mode (receiving corrections from the base station) is used.

Telemetry data and control signals (in piloting mode) from the onboard computer are transmitted over a secure Wi-Fi channel. As a transceiver, an industrial Wi-Fi Ubiquiti Rocket M5 point is installed with an antenna at a frequency of 5 GHz.

5. The module for maintaining adaptive mobility

During the design of the chassis, one of the important tasks was choosing the way to maintain adaptive mobility. To solve this problem, it was proposed to control the position of the hull depending on the terrain and the torque control on each of the wheels. Sustainability of robotic platforms is especially important when operating in coastal areas characterized by hilly and stony areas of the terrain with a variable angle of the steep slopes. The concept of adaptive suspension in this design is reduced to adjusting the clearance and the angles of the chassis body to reduce the likelihood of overturning by means of a pneumatic suspension. This design makes it possible to adjust the position of the platform body by changing the air pressure in the elastic pneumatic element. The structural scheme of the adaptive suspension is shown in Fig. 3. With the help of LIDAR, terrain unevenness, obstacle height will be recognized and directed to the control unit. In the control unit, the data will be compared with the given height parameters for the onboard computer to make a specific decision. If the unevenness lies in a range of non-critical heights, the ground clearance of the platform will be adjusted. Regarding the terrain, the system will pre-adjust the position (tilt) of the platform body for adaptation and reducing the probability of overturning.

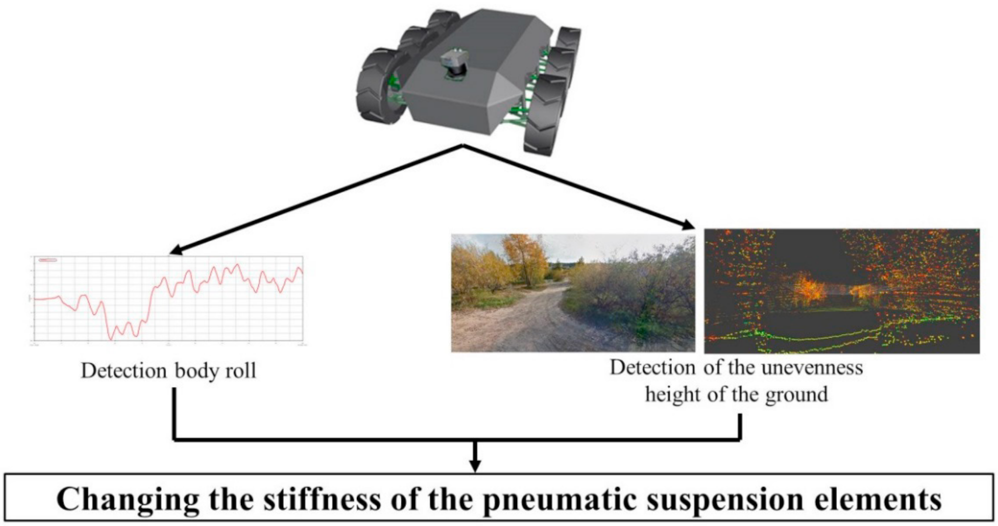

Fig. 3. structural diagram of adaptive suspension operation

The implementation of this system will significantly improve the safety and efficiency of the developed platform's work in the coastal zone, and will also expand the area of application of these complexes on steep slopes, stony and hilly terrain.

At the stage of development of the adaptive suspension system, computer simulation of the platform motion in the MSC Adams software complex in conjunction with Matlab/Simulink has been conducted. In the course of virtual tests, a number of races were conducted along the typical coastal zone [15-17]. An algorithm was developed for changing the tilt of the hull and ground clearance, depending on external control actions. The results of the simulation are shown in Fig. 4.

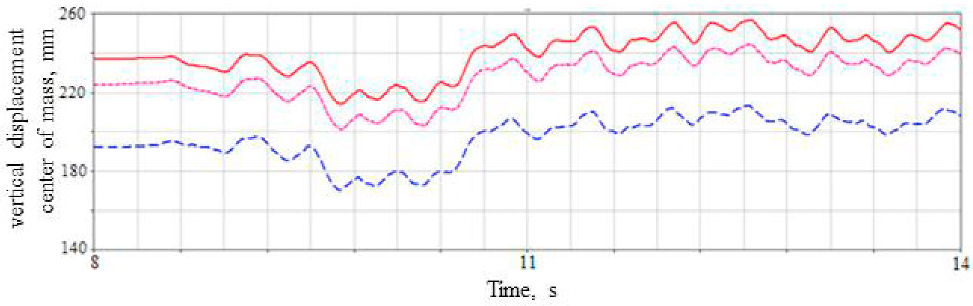

Fig. 4. changing the ground clearance of the platform depending on the control actions

The difference between the minimum and maximum body position is 80 mm.

Based on the results of computer modeling, we can conclude that the chosen suspension system is correct. This system has a lot of adjustments, which, when working in the system, will increase the mobility and safety of the complex's operation.

In the development of a torque control system, an analysis of the papers [18-20] was carried out and conclusions were drawn that, for the implementation of this system, the chosen type of transmission is the most acceptable. The control of slippage consists of adjusting the torque on each of the wheels by changing the applied current to the electric motors. Using this system allows realizing the maximum coupling capabilities of each wheel, thereby increasing the mobility of the platform.

To create a mathematical model, the software complex MATLAB/Simulink was used. The model takes into account the following requirements: mutual influence of the power motor, transmission, and thrusters, bearing capacity and parameters of soil displacement, application and changes in the laws governing the individual drive of thrusters. The transmission control was carried out according to the law of individual regulation of the outer slip of the bead wheels with the known linear velocity of the center of mass of the platform [21-26].

The values of the coefficients of skidding of the right board wheels relative to the conditionally non-slip wheel during the operation of the torque control system, as well as in its absence are shown in Fig. 5.

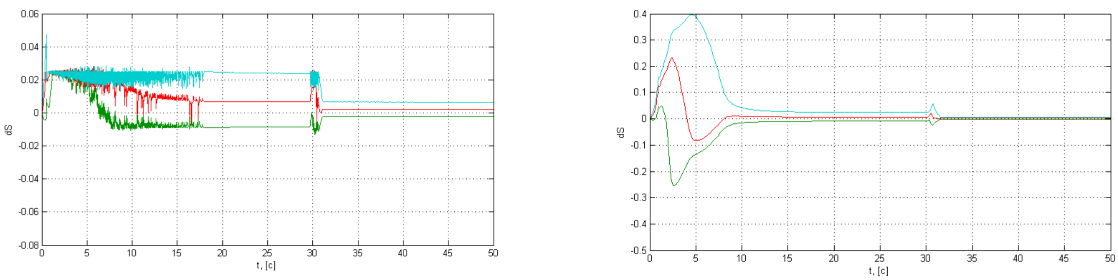

Fig. 5. values of the coefficients of skidding of the right board wheels relative to the conditionally non-slipping wheel: (a) when the torque control system is in operation, (b) without a torque monitoring system.

As can be seen from Fig. 5, when the torque control system is in operation, the skidding level is maintained in the required range, depending on the characteristics of the support base. In the absence of this system, as the slipping increases, the thrust force ceases to increase, and all engine energy is expended to overcome the increasing resistance to movement, which can lead to a complete loss of mobility [27,28]. Using this system allows you to ensure maximum traction and minimum rolling resistance of the wheel. Using the developed systems of suspension and torque control allows in an adaptive mode to maintain the mobility of the platform.

6. Conclusions

Based on the results of the review and analysis of existing unmanned vehicles, the overall layout of the mobile platform was developed. The component composition and chassis design features of the developed mobile robot were presented.

The hardware of the control and positioning modules, and also the module of obstacle detection on the route are presented. The algorithms of work and software of the given platform modules are considered, allowing to operate the platform both in the remote mode and in the mode of following the route specified by the operator.

The structural scheme of the module for maintaining adaptive mobility is shown. Based on the results of modeling the work of the adaptive suspension system and the torque control system, it can be concluded that the use of these systems makes it possible to increase the mobility of the platform and expand the zone of operation in the complex road and climatic conditions of coastal regions.

In the summer of 2018, experimental studies of the developed platform are planned with the aim of confirming the theoretical results of traction and speed characteristics, and investigating the developed modules.

In the future, it is planned to use this platform as one of the objects in a multi-agent system consisting of several robots for improving the effectiveness of monitoring the coastal zone.

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