Autonomous Mobile Robotic System for Coastal Monitoring and Forecasting Marine Natural Disasters

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Abstract The paper presents the steps of creating an experimental prototype of an autonomous mobile robot for coastal monitoring and forecasting marine natural disasters. These systems of continuous coastal monitoring are the necessary link in predicting possibilities of developing the resources of the Russian shelf (areas of the Arctic and the Far East). One of the most difficult issues, associated with the creation of the described product, is to ensure the necessary level of mobility in

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inaccessible areas of coastal zones. This problem is solved by development of the chassis of modular design with the possibility to be reequipped with different types of movers (wheeled, tracked, rotary-screw), depending on operating conditions and the physical and mechanical characteristics of the ground surfaces. The presented robotic complex is also equipped with a set of measuring instruments (circular scanning radar, weather station, navigation system, lidars, video cameras), which allows to carry out comprehensive studies of any coastal zone and evaluate the risks and hazards for providing data for engineering simulation of hydraulic systems and structures. The results of experimental investigations of the coastal zone in the south-east of Sakhalin Island, using the developed experimental prototype of the autonomous mobile robot, are given.

Keywords Coastal monitoring · Mobile robotic system · Instrumental data
Field observations

Introduction

To carry out coastal zone monitoring, which can be connected with the measurement of the wave climate, ice conditions, the dynamics of spread of pollutants in inaccessible places, is necessary to have reliable means to rapidly take the measurements over a large area. Undoubtedly, the task of evaluating the possible hazards in providing oil and gas production in coastal and offshore fields is extremely important for the Russian Federation.

The use of vehicles and mobile robots with the production of such measurements is very promising [1, p. 2; 2, p. 50; 3,p. 566; 4, p. 89; 5, p. 215; 6, p. 1; 7, p. 7; 8, p. 2]. Radar systems (with some modifications) are applicable as means for carrying out hydrodynamic measurement and assessment of hazards in a coastal zone, determine the velocity and size of drift ice.

The necessity of using radar systems in remote areas requires from the vehicle's structure to be able to adapt to a wide range of operating conditions. A possible solution to this problem is the use of different types of interchangeable movers (wheeled, tracked and rotary-screw) for the expansion of the range of operating conditions.

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Development of the Autonomous Mobile Robotic System

The project aims to develop a set of scientific and technical solutions in the field of autonomous mobile robotic system (AMRS) for monitoring and forecasting the state of the environment in order to ensure the reliability and safety of hydraulic structures in coastal zones.

In accordance with the intended purpose the following research objectives were formulated:

1. Investigation of physical and mechanical properties of ground surfaces of coastal areas and interaction of different types of movers with terrain, conducting mathematical modeling of the AMRS movement in conditions of coastal zones, selection of the parameters for designing mobile chassis with interchangeable movers (wheeled, tracked, rotary-screw).
2. Development of a list the necessary measurement and research equipment to be installed on AMRS, allowing to monitor coastal zones with the maximum adaptability to the environment.
3. Development of software for the operation of the measuring equipment of the AMRS experimental prototype and its unmanned control system.
4. Development of design documentation, creation of the experimental prototype and conducting experimental tests of the AMRS on the Gulf of Mordvinov (Sea of Okhotsk, Sakhalin Island).

The first step in designing calculations of the AMRS experimental prototype was correct account of special characteristics of ground surfaces of the coastal zones. For this purpose with the support of Special Research Bureau for Automation of Marine Researches (SRB AMR, Sakhalin Region, Yuzhno-Sakhalinsk, Russian Federation) experimental studies of topography and physical and mechanical properties of the coastal areas were conducted by the group of authors. The obtained data were used to develop new statistical models of surfaces of coastal areas to predict the ways of ensuring the efficiency of the mobile robot [9, p. 16; 10, p. 528].

The next step was the implementation of the design calculations and simulation of vehicle-terrain interaction in conditions of the coastal areas. As a result there were selected parameters for designing AMRS's chassis. [11, p. 78; 12, p. 46; 13, p. 940; 14, p. 6].

AMRS uses the navigation equipment of Orient Systems Company. It consists of a high-precision mobile GPS/GLONASS receiver (OC-103), mounted on the chassis, and a base station installed on the ground. The base station (OC-203) transmits the amendments to AMRS's receiver to increase the accuracy of positioning. Navigation equipment is used to obtain the coordinates of the AMRS and bind measured characteristics to a point on the map.

For remote sensing of water surface AMRS uses Omni Directional Radar MRS-1000. The ability to determine the parameters of sea waves by means of the ship's radar is justified by authors in [15, p. 91; 9, p. 13; 16, p. 30].

To monitor the weather conditions of the coastal zones the weather station Vaisala WXT520, which allows to measure the temperature, wind speed and direction, humidity, pressure, precipitation, is used.

For videofixing of waves in addition to data obtained from the radar the AMRS is equipped with a video camera AXIS Q6045-E, which creates a synchronized video stream. This camera is to be also used for AMRS's remote control system.

In order to detect obstacles on the path the AMRS uses laser scanning system, which is a continuously rotating platform with two lidars Sick LMS291Pro.

The board computer Adlink MXE-5400 is set on the AMRS for controlling instrumentation, data collection, data storage and processing. The laptop Panasonic Toughbook CF-31WEUAHM9 is used to remotely connect to AMRS's onboard computer by Wi-Fi, view the data on state of the measuring equipment and send instrumentation commands.

Description of the structure and capabilities of developed software for functioning the measuring equipment of the AMRS experimental prototype and its unmanned control system is presented in [17, p. 6; 10, p. 526].

General views of created experimental prototype are shown in Fig. 1, and the technical characteristics of AMRS's chassis are summarized in Table 1. The modular AMRS's design allows adapting the layout of the chassis depending on the task and modifying its individual units in accordance with the requirements of the end consumer.

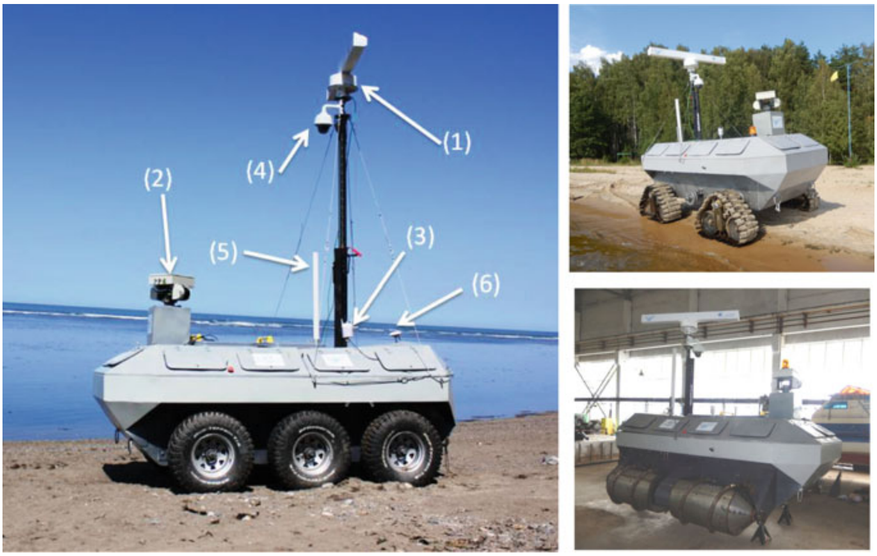

Fig. 1 General view of the AMRS for coastal monitoring: X-band radar (*1*), obstacles detection system (*2*), multi-weather sensor (*3*), high resolution video camera (*4*), long range Wi-Fi antenna (*5*), GNSS antenna (*6*)

Table 1 Technical characteristics of AMRS chassis options

Parameters	Characteristics		
Type of mover	Wheeled	Track	Rotary Screw
Cargo weight, kg	500		
Dimensional (overall) length, mm	3800		
Dimensional (overall) width, mm	2100	2360	30,000
Dimensional (overall) height (in the transport position), mm	3500	3690	3540
Dimensional (overall) height (in the operating position), mm	6400	6590	6440
Parameters of mover	Tire size: 33 × 12, 5–15	Width of the tracks, mm: 400	Diameter of the rotor, mm: 600
Ground clearance, mm	300	490	350
Angle of ascent at full load, deg	30		
Angle of roll (In transport mode), deg	45		
Maximum speed on highway, km/h	45	45	45

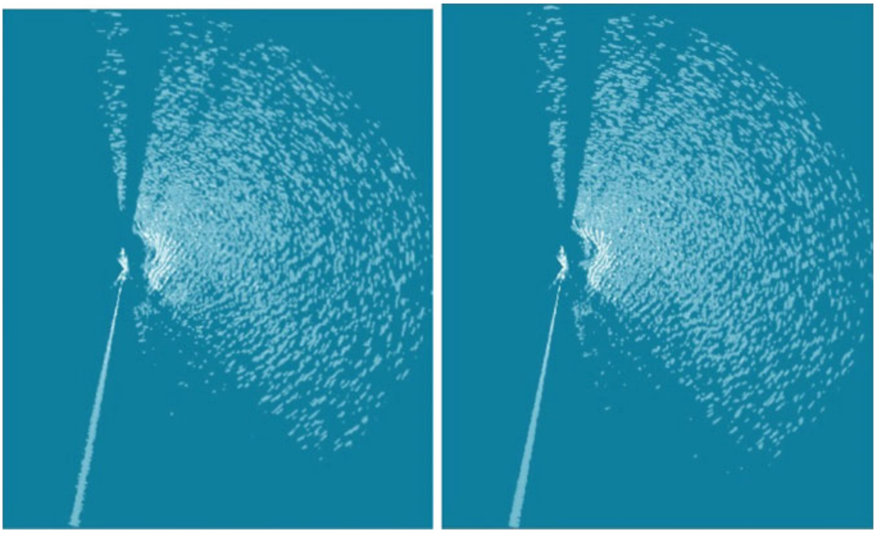

Fig. 2 Screenshots of radar work (Okhotsk Sea)

The AMRS prototype was tested in field conditions in the area of the south-eastern coast of Sakhalin Island (Cape Svobodny) in May–June 2016 with the support of SRB AMR FEB RAS.

Fig. 3 Video from camera during AMRS remote control

During experimental investigations there were conducted measurements of the sea surface and atmosphere: the intensity of the reflection of radio signal from waves of the sea (Fig. 2), air pressure, temperature, relative humidity, wind direction and speed. The results of processing the received dependences between the reflected intensity of the radio signal and distance to the point of the AMRS position are described in [9, p. 14].

When studying the efficiency of the AMRS experimental prototype, the quality of standard maneuvers in the remotely controlled (Fig. 3) and autonomous modes was assessed. The probability of failure and time of equipment operation were also investigated.

Trafficability tests showed that approach of using interchangeable movers allows raising essentially the possibility of the AMRS and significantly expanding the area of its territorial use.

Conclusions

The article describes the main stages of research and approaches to the practical implementation of its results in the creation of the AMRS experimental prototype, used for unmanned coastal monitoring.

Design features of the developed AMRS for specific operating conditions, description of measuring equipment and sensors of unmanned control system have been presented.

In the design, the approach of predicting mobility and determining optimal modes of functioning of the AMRS on preliminarily studied routes of coastal zones has been used.

The results of experimental studies confirm the efficiency of the AMRS for measuring of sea waves, obtaining environmental data, performing typical maneuvers and driving in conditions of coastal zones. The decisive contribution to ensuring the necessary level of AMRS mobility according to terrain characteristics makes the choice of the type of mover.

Thus, the project provides a complete solution to the problem associated with the development of a new kind of AMRSs for coastal monitoring, supplying data for the assessment of hazards and engineering simulation of hydraulic systems and structures.

The results make a significant contribution to the creation methods of unmanned vehicles for monitoring natural objects, emergencies and special operations.

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