The Navigation System for the NAVIGATOR 1 Mobile Robot

Eyes on All Sides

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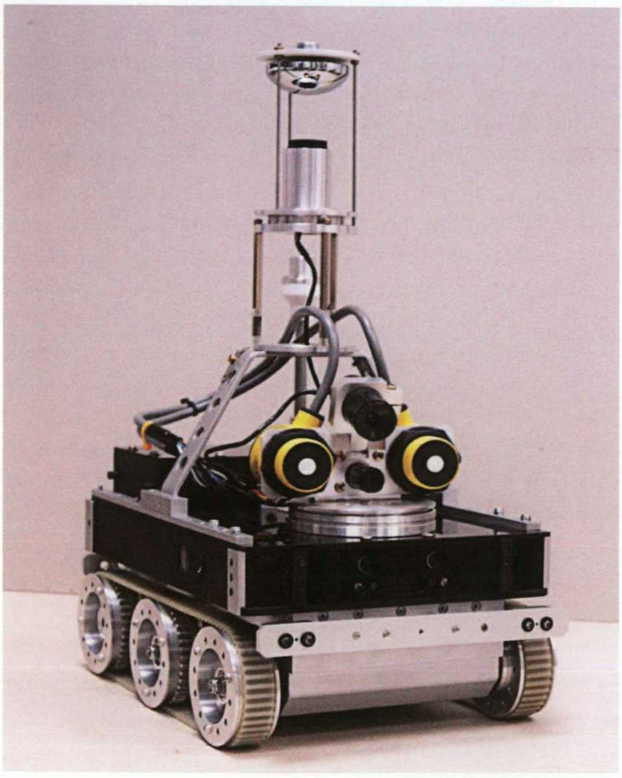
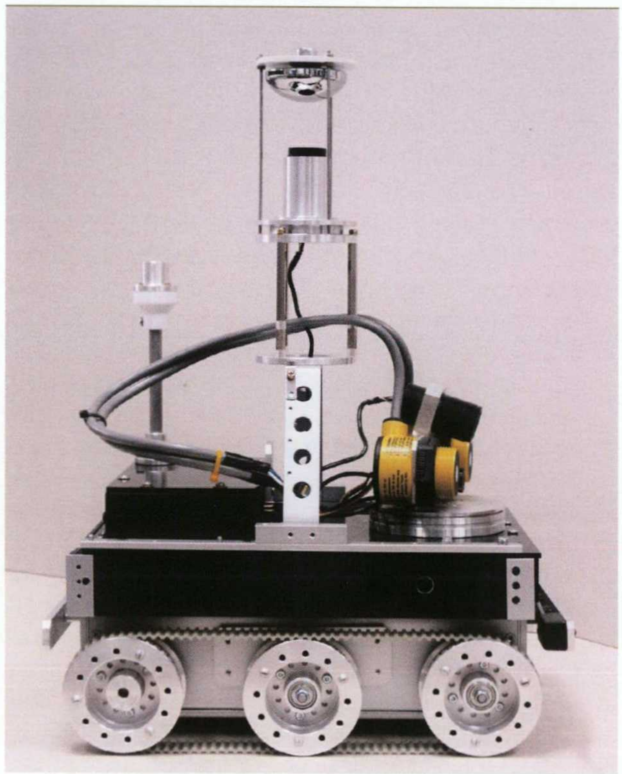
Recent years have brought increasing commercial interest in new robot applications, giving rise to greater demand for new robot navigation technologies

Robots are now beginning to operate in human environments and to perform tasks like cleaning, carrying objects, surveillance and assisting elderly or handicapped individuals. Such service robots should move freely and must adapt their behavior to the environment. Autonomous navigation by a mobile robot in an unknown environment still remains an open technological problem, so the aim of our research is to build a system which allows a mobile robot to move from one place to another without collision.

Our research uses the NAVIGATOR I Polish miniature mobile robot, designed and built at the Institute of Automatic Control and Robotics, Warsaw University of Technology. Occupying dimensions of 281 x 174 x 390 mm, it includes the following basic modules: a drive unit, a central unit, a scanner unit, and an omnidirectional vision sensor unit.

The drive unit was designed around a crawler chain undercarriage. The chassis is manufactured from a light

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The NAVIGATOR I Polish miniature mobile robot will, in the future, form part of the navigation system of an autonomous wheelchair

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The Omnidirectional sensor - the main source of information about the robot's environment

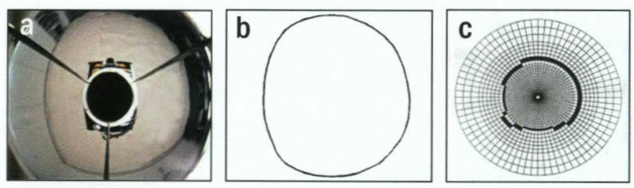
aluminum alloy and equipped with two electrical motors with gearboxes. Each caterpillar, made of hard polyurethane, is suspended by an assembly of three equal wheels. The DC electrical motors are supplied with 12V DC. The velocity of the motors is measured by Hall effect rotational pulse encoders. The micro controller is housed directly in the frame between the engines, where it is well protected from mechanical damage. A boom with tactile sensors was mounted on the front part of the unit. These sensors detect physical contact with an object. The central unit, consisting of mechanical and electronic parts, was placed directly on the undercarriage. The mechanical part is made of a light metal cabinet covered by plexiglass plate. The middle unit cabinet is easily attachable to the undercarriage. The robot tracks its own movements using an accelerometer and gyro sensor. A compass is used to determine vehicle orientation. To detect walls and obstacles, a scanner unit is mounted directly on the central assembly. This consists of an infrared (IR) optical sensor, two ultrasonic analog sensors and a color camera.

The main source of information about the robot's environment, however, is an omnidirectional vision sensor. Sensors of this kind have been very popular over the last decade because they provide 360-degree information about the environment, and thus enable a 3D model of the scene to be constructed. The omnidirectional vision sensor is mounted directly over central unit, at the robot's center of gravity. It consists of a CCD camera pointed directly upwards, towards the vertex of a spherical mirror. The optical axis of the camera and that of the mirror are aligned.

Following J. J. Leonard and Durrant-Whyte's analysis, the task of navigation involves answering three questions: *"Where am I?"*, *"Where am I going?"*, and *"How do I get there?"*. In order to answer them, a robot should first build a map.

In our system, the map of the robot's environment is built autonomously based on images taken from the omnidirectional camera. Angular information about the position of objects relative to the robot is immediately available from the image, without any additional computation. The distance to an obstacle is determined through a calibration process. By performing image analysis, we can transform the image into a polar map of the environment. This map allows the robot to move from place to place without colliding with obstacles, and to enter narrow passages, such as doors.

The next problem that needs to be solved is determining the robot's position within the environment. Our approach uses the natural landmark localization method. In such methods the main task is to detect and match characteristic features of the environment. The decision as to which kind of landmarks to use for localization depends on the robot's sensors. When sonars or laser range finders are used, then walls, edges and discontinuities are the best features. In our approach, vertical and horizontal lines and areas of unique color are recognized. The localization method consists of two stages: first landmarks are detected in the robot's environment, then the position of the robot relative to the landmarks is determined. When the robot travels a short distance, new sensor indications are obtained and new positions of the landmarks relative to the robot are computed. Determining the displacement of the robot relative to the landmarks allows us to update its position in the environment.



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Map-building stages:
a - the original image taken from the camera,
b - the transformed image,
c - a map of the environment has been produced.
Black areas represent parts of the environment occupied by obstacles, while white areas are free from obstacles

The system is being tested in a real office environment. In the future, it will form part of the navigation system of an autonomous wheelchair. ■

Further reading

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