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MECHANICAL CARRIER OF AN AUTONOMOUS MOBILE ROBOT FOR INSPECTING TECHNICAL OBJECTS

Key words

Autonomous mobile robot, inspection, mechanical carrier, nonholonomic robot.

Summary

This paper describes the development of an autonomous mobile robot for inspecting various technical objects. The inspection robot allows the substitution of traditional human patrol groups during the inspection of technical objects. With the prototype robot it, is possible to register video images and values of characteristic quantities in the open area of the technical object. Next, this information could be transmitted by a wireless network to a base station. The robot presented in this article is equipped with an adequate detection system, which allows it to work in an autonomous mode in a variable environment. In this paper, the author also briefly describes other systems of a mobile robot for inspecting technical objects: a universal mounting system that allows attaching various sensors and video cameras as required, a communication system between the robot and user, and a system for self-localisation during a mission.

Introduction

Nowadays, autonomous inspection robots are used at a large scale in many branches of industry and in everyday life. The development of robotics makes a lot of applications of mobile robots possible, especially in such places and situations where human operation is dangerous (e.g. in a radioactive or explosive hazards environment), arduous (e.g. in environment with a large dustiness), or even impossible (e.g. in a small canal ducts) [2].

To this end, manual inspection of many extensive technical objects (e.g. aerodromes, large magazines, and military bases) is carried out by human personnel. To allow exhaustive control of the technical object, it becomes ever more and more popular to apply remote controlled or even autonomous mobile robots. Robots are able to travel to any place of the inspected area and acquire relevant data, which could be sent to the control unit to allow its careful examination by the experienced human operator [5].

This paper deals with a project and development of a mechanical carrier of a mobile robot for inspecting technical objects. The project was carried out by researchers from the Department of Fundamentals of Machinery Design, Silesian University of Technology at Gliwice. The project was part of the scientific work called “The team of specialised autonomous mobile robots to group inspection of technical objects.” The main goal of the project was to develop a team of robots that consists of the autonomous transport robot and four inspection robots [6]. The paper deals with the description of the development of the mechanical carrier of the autonomous inspection robot only.

1. Research problem

The main goal of the research was to develop a non-commercial prototype of the autonomous mobile robot, which is capable of inspecting large areas of technical objects. The robot should confirm to some requirements. One of the main problem addressed within this project was to assure full mobility in different weather and terrain conditions. The inspection robot should be able to keep mobility during movement on snow, mud, gravel, sand, tarmac, grass, etc. Moreover, the robot should be able to operate on a rainy day and in a wide range of ambient temperatures (-20^{O}C ÷ +50^{O}C). The next main problem addressed from this project was to assure autonomous operation at the appointed time. The minimum time of autonomous running equals 0.3 hours of continuous running and 4 hours of interrupted running. Additional requirements for the inspection robot are as follows:

- Minimum velocity (during rectilinear movement): 0.1 m/s,
- The ability to movement on a slope: min. 20%,
- The minimum useful lifting capacity of platform: 10 N,
- Maximum mass: 5 kg.

According to brief pre-design, the small inspection robot is transported to his workplace with the use of an autonomous transport robot [5]. Next, the small robot makes an inspection. For this purpose, the robot should be equipped with special accessories. Thanks to a special universal mounting system for sensors and cameras, the operator is able to equip the robot before the mission with a vision camera, a night-vision camera, a motion sensor, microphone, a smoke sensor, a gas sensor, etc. Output data from sensors and cameras could be sent by the wireless network to the transport robot and to the base station. A special universal mounting system for sensors and cameras was the next problem addressed in the framework of this project.

For the final design of the inspection robot, the following basic systems should be also developed: a control system, a system for detection and recognition of the environment, a communication system, and a system for self-localisation. These systems are also briefly described in this paper.

2. Prototype of the inspection robot

Prior to the designing process, the research group made an attempt to analyse the following problems: the type of drive, the type of power supply, the method of positioning in an unknown environment, and the selection of necessary electronic components. Based on the brief pre-design and analysis of these problems, many conceptions were formulated. The final constructional shape of the robot was obtained as a result of the design process with the help of a CAD/CAM/CAE system – CATIA v5. Based on the design process, the prototype inspection robot (Fig. 1) was designed. The robot consists of the following units:

- Drive system and chassis,
- Control system,
- Supply system,
- Universal mounting system which allows to fix various sensors and video cameras, as required,
- Detection system which allows to work in an autonomous mode in variable environment,
- Communication system between the robot and user, and
- A system for self-localisation during the mission.

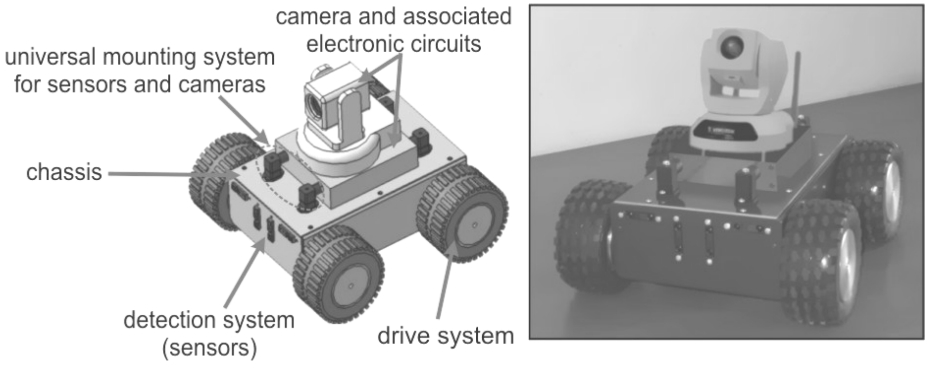

Fig. 1. The mobile autonomous inspection robot

2.1. Drive system, chassis, and power supply system

There are many possible solutions of drives for mobile robots. In the presented prototype of the inspection robot, a four-wheeled drive was used. Each wheel is driven independently. Wheels are non-torsional, and they are mounted directly on output shafts of DC motors. The drive system used in the robot is often introduced into mobile robots and tracklaying vehicles. It is a nonholonomic system that allows the robot to drive forward and backward in straight line, drive forward and backward on a certain curve, and turn round on the spot [4].

The drive system consists of four independently controlled 12 V DC motors with planetary gears. Motors are controlled by H-Bridges (based on electronic circuits L298). Standard 2.2” wheel hubs are attached to the shafts of the motors and special tyres are put on wheel hubs. Tyres are exchangeable, so it is possible to change a tyre as required (tyres for snow, for sand etc.).

Elements of the frame have been made from aluminium by laser cutting and bending. Aluminium elements allow obtaining a low mass of the frame and relatively high durability features.

The power supply system consists of two 12 V gel accumulators (each with 1.3 Ah capacity). Accumulators are mounted inside the frame on both sides. Special connection clips were used to mount accumulators inside the frame of the robot.

2.2. Universal mounting system for sensors and cameras

The main goal of “the universal mounting system” problem in the project was to develop a system that allows the attachment of various sensors and video cameras on the robot as required. This system should allow the attachment of cameras and sensors used during inspection in an easy, quick and efficient way. The following sensors can be mounted to the robot: vision camera, night-vision camera, motion sensor, microphone, smoke sensor, gas sensor, etc.

The universal mounting system (Fig. 2) was designed with respect to some requirements. The obtained system is based on four special industrial connectors that protect against moisture and other medium that can get inside a connection. Each connector allows to send a signal by four pins.

The system for mounting sensors and cameras consists of two modules. The lower module (with sockets G30A5M) is permanently mounted on the robot. The upper module is exchangeable and consists of four plugs (G30W3F), a sensor or camera, and an encasement of electronic circuits for sensors or cameras.

The functioning of the presented system is quite easy. Before the mission, the operator of the robot before should mount the module with the selected sensor or camera on the robot. Next, the robot can make an inspection. A special electronic system, as an element of the universal mounting system, with the help of a microcontroller, receives the signal from the camera or sensor. This signal is converted into an adequate format and sent by the connectors (by I^2C bus) to the communication system of the robot. Finally, the information is transmitted wirelessly to the operator.

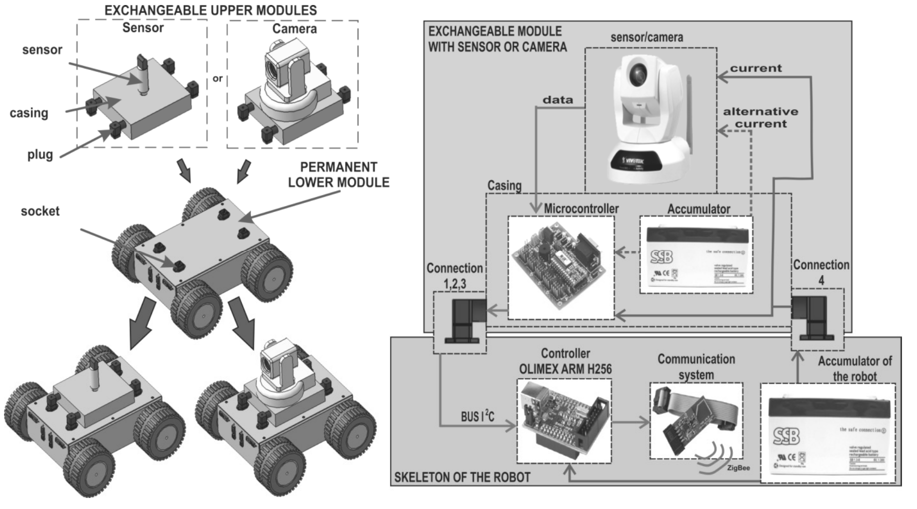

Fig. 2. Universal mounting system for sensors and cameras

2.3. System for environment detecting

The detection system (Fig. 3) carries out different tasks. Sensors allow active operation of the robot in an unknown environment. The detection system estimates both the internal and external state of the robot and delivers data to the control system.

Various sensors may be applied in mobile robots [1]. For measuring the distance to obstacles, infrared (IR) and ultrasonic sensors were selected for the described detection system. The inspection robot is equipped with 6 IR sensors (4 sensors with measurement distance: 40–300 mm and 2 sensors with measurement distance: 10–800 mm) and one ultrasonic sensor (measurement distance: 1–3500 mm). Because the IR and ultrasonic sensors have some disadvantages, it is necessary to use both of these sensors in the detection system. Infrared sensors are insensitive to the shape of the obstacle, but the colour of the obstacle has an influence on the functioning of the sensor. To reduce the error rate of infrared sensors, it is important to also apply ultrasonic sensors. Ultrasonic sensors are insensitive to the colour of the obstacle. Whereas, the shape of obstacle may have an influence on functioning of the ultrasonic sensor. These two types of sensors are supplementary to each other [2].

In the system for environment detecting, the author also used an acceleration sensor (MXR9500M) and a gyroscope (ADXRS300). These sensors allow identifying the position and orientation in an absolute co-ordinate system. It is possible to determine deflection of the robot from a horizontal position or the ground.

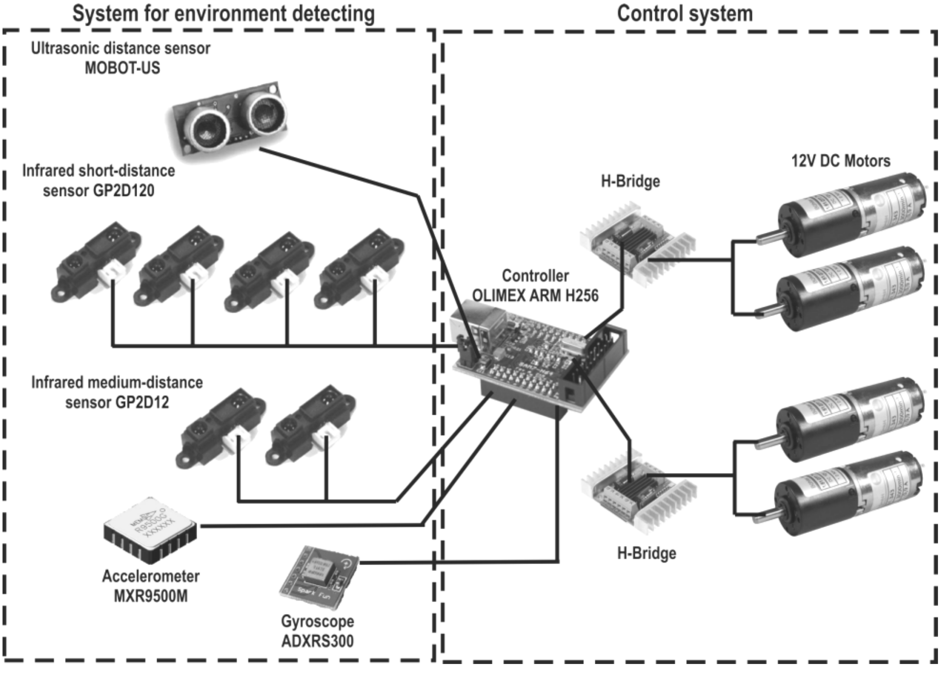

Fig. 3. Scheme of a system for environment detecting and the control system (physical layer)

2.4. Control, communication and self-localisation systems

To allow autonomous operating, the mobile inspection robot was also equipped with the following systems: an intelligent control system, a communication system, and a self-localisation system.

The control system consists of two major parts (physical layer): a main control computer (OLIMEX ARM H256) and two H-bridges for controlling the rotational speed and direction of the rotation of the motors. The main control computer allows the connection of all sensors, the H-Bridges and WiFi/LAN card, the communication module, and the GPS receiver. The major function of the main control computer is to supervise sub-systems during the navigation and perform behaviour-based control and position estimation [3]. Windows Embedded Developer Center with Hard Real-Time addition and Microsoft Robotics Studio programming environment are applied as part of the software layer of the control system.

An applied communication system allows the transmission of data between the inspection robot and the transportation one. It is possible to transmit data from intelligent sensors on the robot (video images from the camera, other instrument reading etc.). The communication system is based on Wi-Fi 802.11b/g and ZigBee standards. Signals from the robots may be transmitted at a distance up to 100 m.

The last system of the inspection robot is a self-localisation system during mission. This system allows the inspection robot to determine its position and orientation relatively to the transport robot and a map of the terrain. For that purpose, a GPS system was applied. The research group decided to use the NovAtel SUPERSTAR II dGPS module that allows operation in a differential system. With the help of the dGPS system, it is possible to achieve a precision of localisation up to 1m.

Conclusions

The capacity of independent movement without intervention of a human is one of the characteristics of autonomous robots. The main problem for designers is to provide a reliability of the detection of obstacles in an unknown environment that can occur in front of a robot [2]. Another important problem is to design a proper drive system that allows movement on a given terrain.

In the paper, a non-commercial autonomous mobile robot capable of inspecting technical objects is shortly described. The robot allows the substitution of traditional human patrol groups during the inspection of technical objects, especially in such places and situations where the operation of humans is dangerous, arduous, or even impossible. The presented robot is capable of operating on various terrains and in various weather conditions. The construction of the robot allows efficient and quick changing of a sensors as required. The robot is equipped with a variety of sensors that can detect obstacles, identify location and direction, and many more.

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References

1. Branwyn G.: Absolute beginner's guide to building robots. Indianapolis, Que, 2004.
2. Garbacz M.: Planowanie ścieżki robota mobilnego na podstawie informacji z czujników odległościowych. Automatyka 2006,10, 3, 135–141 (in Polish).

3. Panfil W. et al.: Behavior-based control system of a mobile robot for the visual inspection of ventilation ducts. Recent Advances in Mechatronics, 2007, 62–66.
4. Sandin P.E.: Robot mechanisms and mechanical devices. NY, McGraw-Hill, 2003.
5. Wyleżoł M.: Specialized autonomous transport robot – development of design. Proc. of Symposium on Methods of Artificial Intelligence. Gliwice – Poland, 2007, 77–78 (in Polish).
6. Laboratorium Robotyki Mobilnej, https://kpkm2.polsl.pl/lrm/

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Konstrukcja mechaniczna autonomicznego robota mobilnego do inspekcji obiektów technicznych

Słowa kluczowe

Autonomiczny robot mobilny, inspekcja, konstrukcja mechaniczna, robot nieholonomiczny.

Streszczenie

W niniejszym artykule przedstawiono wyniki prac dotyczących autonomicznego robota mobilnego do inspekcji różnorodnych obiektów technicznych. Opracowany prototypowy robot inspekcyjny pozwala zastąpić tradycyjne systemy monitorująco-kontrolujące oraz ludzkie grupy patrolowe kontrolujące obiekty techniczne (magazyny, lotniska itp.). Robot umożliwia rejestrację obrazów oraz dokonywanie pomiarów wybranych wielkości fizycznych na terenie danego obiektu technicznego, a następnie przesyłanie tych informacji poprzez sieć bezprzewodową do użytkownika. Robot wyposażony jest w odpowiedni układ detekcji dla zapewnienia pełnej autonomiczności w zmiennym środowisku. Posiada także specjalnie zaprojektowany uniwersalny system mocowania czujników i kamer, którego zadaniem jest umożliwienie szybkiego i sprawnego mocowania różnorodnych sensorów na robocie inspekcyjnym, w zależności od rodzaju wykonywanego zadania. Dodatkowymi układami robota, krótko opisanymi w artykule są: układ komunikacji robota z użytkownikiem oraz samolokalizacji podczas wykonywania misji.