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CONTROL AND SENSORIC SUBSYSTEM OF MECHATRONICS SYSTEM OMR III

Summary: The robot is able to make plane movements in the surroundings using a locomotive mechanism including planned interaction with the variable surrounding environment. The OMR III control system has been divided into three levels. The external subsystem represents the top level of control. The operator can control the robot through it in case of the artificial intelligence algorithms are not able to solve the given situation. The planning subsystem creates a higher level of control and it solves localisation of the mobile robot during global navigation. The lowest level of control consists of the control subsystem of locomotion. The individual levels are inter-connected into a distributed network. The sensorial subsystem consists of two functionally different groups of sensors. The internal sensors provide information about changes of inner conditions of the robot. The external sensors provide information about changes of the external environment of the robot.

Key words: mobile robot, sensor system, control system, motion control, matching, navigation, serial communication

1. INTRODUCTION

The submission describes the structure and activity of the control and sensor system of the autonomous locomotion robot (ALR) OMR III. The attribute autonomous means that the robot will be able to make individual motions (without human action) in its own work environment while using algorithms of artificial intelligence. The work environment of the robot may be known (e.g. navigation with beacon system), partially known (e.g. navigation using passive landmarks) or unknown (the robot must obtain information about its work environment by using scene sensor systems and it must plan and control the motion on the basis of the information). For reading the distance passed so called odometrical sensor systems are used for robots. But the systems are burdened with errors, caused by inaccuracy of the undercarriage kinematics, slippage of wheels during acceleration or deceleration etc. Due to these reasons it is necessary for the locomotion robot to be equipped with a scene sensor system. By using scene sensor system the robot is able to distinguish obstacles on the track and - based on obtaining data by using various methods - to specify its position, obtained from the odometric sensor system. The scene sensors include especially laser range finders or ultrasonic range finders and CCD cameras. For application in mobile robots it is optimal to use laser range finders that are very fast and accurate. Their disadvantage is represented by expensiveness. This submission describes the use of the plane laser range finder PLS 200 produced by the German firm SICK. Another possibility includes possible use of CCD cameras. These problems are a subject of the actually conducted scientific research of the authors.

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2. DESCRIPTION OF ALR OMR III

2.1. Structure of the ALR OMR III

The robot ALR OMR III is based on the conception of so-called omnidirectional undercarriage [2]. Omnidirectional movements are enable by three wheels equipped with rolling members along the perimeter. An undercarriage designed in this way can move along any plane curve. The main activity of the autonomous locomotion robot includes individual movement from initial point A to end point B. The robot must have an idea about the environment and obstacles in track, and must be able to side-track. The robot is designed for use in so-called IN-DOOR application. The range of the laser range finder is restricted. Navigation is practically Impossible in case of no objects being in sufficient distance so as the robot can orient. The whole structure of the ALR OMR III is conformed to the pre-assumptions.

Structure is conceptually divided into two layers:

Lower layer:

- undercarriage
- batteries
- motors + gear-boxes + coders
- high power tube (regulation of revolution motors)
- laser range finder PLS 200

Upper layer:

- main board of PC
- microprocessor module TOS-CPU-3.0
- radio module (communication between operator and robot)

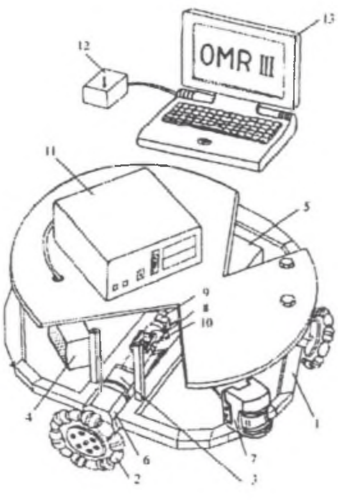


Fig. 1: The OMR robot disposition:
1-frame, 2-omnidirectional wheel, 3-bearing house, 4-gear box, 5-PWM module, 6-DC-engine, 7-optical encoder, 8-stabilised source, 9-battery, 10-control computer, 11-transfer module, 12-operator notebook, 13-laser rangefinder

Placement of individual components in the robot is shown in Fig. 1.

3.SENSORS USED IN ROBOT ALR OMR III:

3.1. Laser range finder PLS 200

This range finder is the only one scenic sensor used in ALR OMR III. Distance measuring is performed by the method of transit time measuring. A short impulse the optical power of which is 10 W is sent. There is used a special technology of production of integrated circuits of the counter. So as to get the required resolution of 20mm, it works with the sampling rate of 3 GHz. The laser infrared ray deflection is performed by a rotating mirror in one plane. One scanning under the angle of 180° takes 40ms with angle resolution 0,5° (Fig. 2). Maximal measuring distance is 80m with a guaranteed error ± 50mm. Based on measuring distances there is created a map of the environment ALR OMR III (Fig. 3).

3.2. Sensors of passed distance (IRC sensors)

Three of these sensors create a system of odometrical sensors. Each of them consists of a rotation coder PIR which is equipped with 34 holes and an optical sensor SFH 910 by SIEMENS. The optical sensor has two-channels, consisting of two identical parts – a transmitting and a receiving diode. Both of the diodes work in the infrared part of spectrum. For accurate distinction of the logic 0 and 1 the coder is equipped with a Schmitt flip-flop.

Except for their basic function, the sensors also serve as a feedback for control of motors.

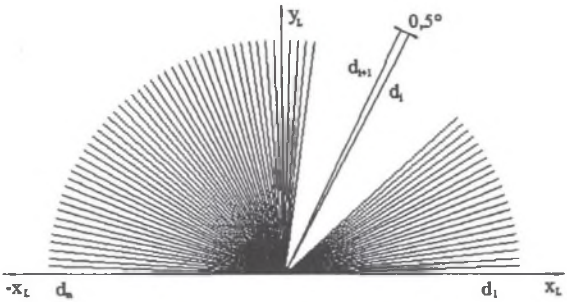


Fig. 2. Process of scanning by laser range finder PLS 200: $d_1, \ldots, d_i, \ldots, d_n$ – measured distances, n – a number of measured distances, x_L, y_L – axis of the system of coordinates $i \in \langle 1, n \rangle$

4. DESCRIPTION OF THE ROBOT CONTROL SYSTEM

The control system OMR III was divided into three levels. Each level has its own task and they are inter-connected into a distribution net. The levels and their tasks: are as follows

- the lower level ensures locomotion of the undercarriage,
- the upper level ensures data collection from coders and determination of the track of movement,
- external level – the operator makes it possible for the tasks to be given or possible the staff manual entry. The structure of system can be seen is Fig. 4.

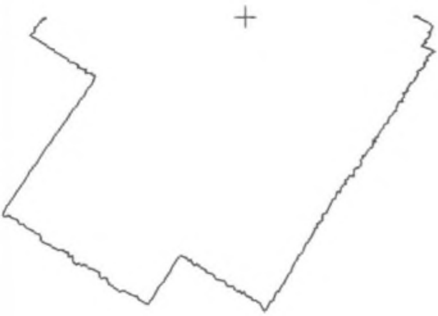


Fig. 3. Example of a local map obtained by the laser range finder PLS 200

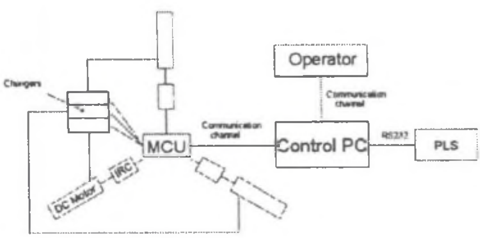


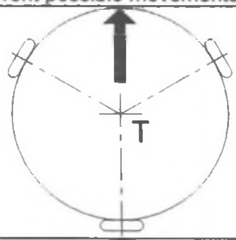
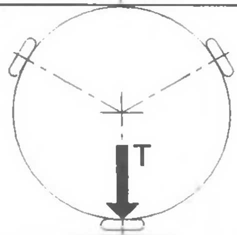
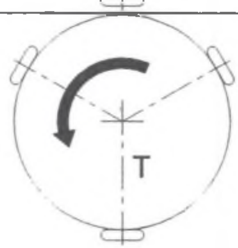
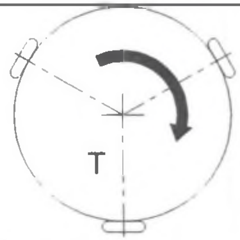
Fig. 4. Diagram of structure connection of OMR III levels

4.1. Communication between individual levels of the control system OMR III

Basic request for communication between levels control system is transfer of about ten or a hundred bytes per second. Communication must be easy, safe, low usage of computer power and low price. Therefore serial communication of connection levels was used. Connection of lower and upper level control was designed for series terminating RS232C, connection upper and external level is realized by radio transmission with half duplex mode. Communication protocol is realized for maximal efficiency on communication.

Table 1

Current possible movements OMR III

FORWARD		The robot will move forward. The pre-set speed is the speed the robot centre of gravity movement.
BACKWARD		The robot will move backward. The pre-set speed is the speed the robot centre of gravity movement..
LEFT		The robot will turn to the left around the centre of gravity. The pre-set speed is the speed the robot centre of gravity movement.
RIGHT		The robot will turn to the right around the centre of gravity. The pre-set speed is the speed the robot centre of gravity movement.

Řídicí systém vyšší úrovně používá osobní počítač kompatibilní s IBM PC (dále jen PC). Vyšší

4.2. Lower level

The control system of the lower level uses the microprocessor module TOS-CPU-3.0 by UNIS, Ltd., Brno. The module consists of a 16-bit processor Toshiba TMP96C141AF, which has a 512KB FLASH memory, 32 KB SDRAM memory and two series channels (UART). TOS-CPU-3.0 controls the movement of the robot based on instructions from upper levels, it communicates with upper levels through a serial line and it makes diagnostics of function and status of equipment.

4.2.1. Control of the ALR locomotion

The ALR locomotion is arranged by three DC motors with permanent magnets equipped with one-channel coders. Speed of rotation of individual motors is controlled by a quarter-square pulse changer L6203 by SGS-THOMSON. Connection to the changer is shown in Fig. 5. Control of changer was performed by PWM. The module TOS-CPU-3.0 is also used for generation of PWM and simultaneously for counting impulses from coders and generation of the rotation feedback.

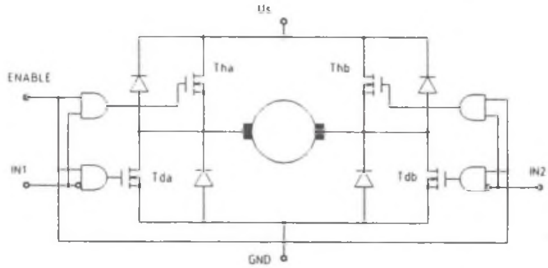


Fig.5. Wiring diagram of changer L6203 Description of outlets: ENABLE – signal for gneral switch off of the changer, IN1, IN2 – signal for control loop A, B of the changer, Us – power supply, here was +24V, GND – signal ground

4.2.2. Realization of motors control

The L6203 changer is controlled by three logical signals ENABLE, IN1, IN2 shown on the scheme. The changer has an internal thermal protector, which disconnects high-power tube in case of the changer to be overheated. The condition of disconnection by the heat protection is not signalled.

For control of the motor rotation it is possible to use two basic ways of PWM modulation – bipolar and unipolar.

4.2.3. Control of changers

After test of the individual types of modulations the unipolar control was decided to be used. The basic requirements for the control included maximal simplicity so as the time needed for the machine TOS-CPU-3.0 is minimal and so as it is able to perform other functions e.g. rotations monitoring, regulation of the speed of movement and series communication. More, the unipolar control reduces problems with running current, but it has higher requirements on generation.

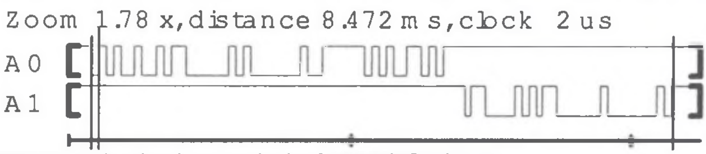


Fig. 6a: Time between start and end communication for speed 9600 bauds

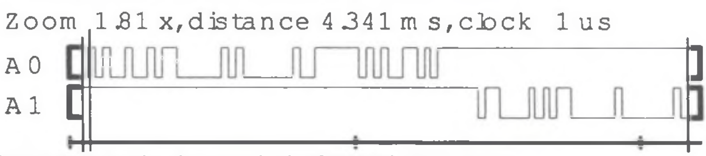


Fig. 6b: Time between start and end communication for speed 19200 bauds

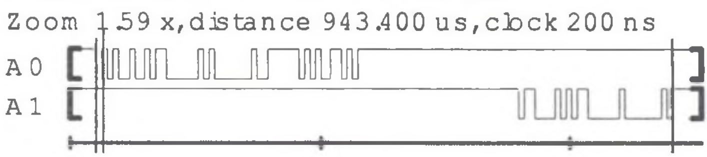


Fig. 6c: Time between start and end communication for speed 115200 bauds A0 – data received from upper level, A1 – data sending from lower level, distance – time from begin to end communication

This modulation was generated analogically by calibration of constant levels of voltage with the saw signal with load-bearing frequency. The resulting modulated signal is more complicated and it means partition of period T into 4 section, symmetric according to the half-length of period. This complicated course of signal means for the period to be divided into five parts and a port must be set for each of the parts. Taking into consideration the fact that each motor has different rotations it means nearly 100% loading of the TOS-CPU-3.0. That is why the control signals were simplified in such a way that the period was divided into two parts only and the load of the TOS-CPU-3.0 was comparable with the bipolar control.

In case of the changer to be controlled in this way, the thermal load was a function of rotation of motors and loading of motors. As the current running through the motor is smaller, even the acoustic noise level is lower with quite low modular frequency of 2 kHz.

4.2.4. Communication with upper levels

For communication there was used the above mentioned series interface RS232C. The speed of communication is freely adjustable, the basic speed is 9600 baud. The equipment provides information for detection of possible communication speeds and report for switchover to any possible communication speed.

The period of communication for different communication speeds is in Fig. 6a, 6b and 6c.

4.2.5. Diagnostics of equipment

For arrangement of maximal reliability of ALR and prediction of error conditions and failures the control system includes diagnostics for individual controlled parts, the status of communication, control and run of the control system.

4.3. Upper level

The control system of the upper level uses an IBM compatible personal computer (hereinafter referred to as PC). The upper level plans the track and control of movement. The structure of the upper level control system is shown in Fig. 5. The system is object-created and individual sub-classes can be easily replaced and modified. For truck planning, system obtains data from odometrical and scene sensors. For previous experiments there was used a laser range finder and at the present time there is prepared a system of using two cameras for stereovision. The movement control is performed by transfer of information about direction and speed of movement of ALR in lower level. Simultaneously, the system of the upper level controls the activity and status of the lower level and in case of occurrence of any failure it reacts to it. The upper level is designed as fully autonomous with a possibility of possible intervention into the ALR behavior though an operator.

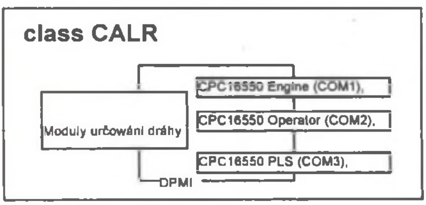


Fig. 7. Structure of the upper level control system

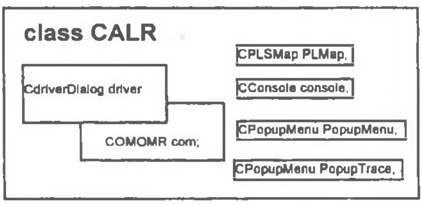


Fig. 8. Structure of individual levels of operators

4.4. Operator – External level

The operator consists of a personal computer with the operation system Microsoft Windows NT/9x and one free serial port.

The operator puts the ALR in operation, shuts it down and also makes the manual control of ALR possible. The operator can be used for obtaining data from ALR. The data stored can be provided to other robots in case of group cooperation. This can be especially advantageous in surveys of unknown environment, making maps of researched areas and their consequent specification. The structure of the control system is shown in Fig. 7 and Fig. 8. System is object-created and the individual subclasses are easily replaceable and modifiable.

5. DETERMINATION OF AN ABSOLUTE POSITION OF ALR OMR III

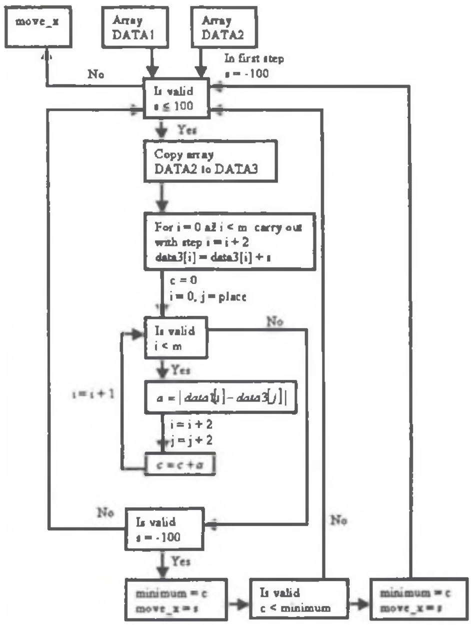


Fig. 9. Alghorithm of matching for x axis

For determination of the position of ALR OMR III there was selected the method of matching a global and a local map. An approximate position of ALR OMR III is determined by the odometrical sensor system. This approximate position must be set more precisely for more precise orientation. As the application area for ALR OMR III is aimed at INDOOR application [3], it is advantageous to use natural landmarks for specification. In this case these are the edges flags. The first task of the ALR OMR III is to obtain global model of the environment. It can be artificially put in to memory or it can be obtained from scenic sensor system of ALR OMR III through different strategy activities [4].

5.1. Method of matching global and local maps of the environment

When matching there is compared the local model environment obtained in real time from scene sensor system (Fig. 3) with the global model environment in the memory of the ALR OMR III. If there exist two similar maps, which can be matched then it is easy to compute the actual deviation from the distance and rotation from position using the odometrical sensor system.

A local map of an environment is created as a plane scan of the surroundings in the height of placement of the laser range PLS in angle range 180°. A map is created as a connection of individual end points of measured distances and their approximations.

So as it is possible to make any precision, it is necessary to find such a part of a global map which is identical with the local map. For correct function of the algorithm it is necessary for the deviation between the orientation and position not to be too large.

After finding identical parts of maps we can start their angle matching. The local map is rotated step by step and compared with the same part of the global map. The searched angle of rotation is in the position, where the value of the difference between the local map and global map is minimal.

Next step is to perform matching of feeding. The first matching is in x-axis. It moves the map up the x coordinate and the searched feeding is in the position, where the absolute direction x coordinate of the local map is minimal. For the y coordinate, the procedure is analogic. As a result, there is obtained the accurate position of the ALR OMR III. An example of the algorithm for the x-axis matching is shown in Fig. 9.

6. CONCLUSIONS

For testing the functionality there was created a model room for the purpose of obtaining the real data. In this room there was performed scanning in six different points with rotation of the laser range finder PLS in 60°. When simulating the algorithm on PC there were detected static deviations in position matching for x-axis and y- axis coordinates. The deviations of feed did not exceed ±180mm and the angle deviations did not exceed ±6,8°. These deviations are comparable with those from other methods (used at MOBIL II, Kaiserslautern) and they can be used for ALR OMR III.

Architecture of control system levels of the mobile robot OMR III was designed in consideration of the maximal using of power and equipment and the maximal reliability of the whole robot. Simultaneously, the architecture is solved as maximally opened. Individual levels are independent of each other. Between the levels there is only exchanged required information in pre-defined ways. The openness of the system OMR III presents e.g. possibility of control of other levels by the operator.

The control system of the upper level and the operator was written via the object technology. It enables easy refilling of new properties of the system through inheritability mechanisms. There are always used the mechanisms of encapsulations for separation of the object data and exchange of the data running between objects across defined interfaces. That ensures independence of individual classes and it increases the robustness and reliability of the whole system.

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