Implementation of the control algorithm for the 'buggy' mobile robot via application of infrared distance measuring sensors

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***Abstract*— Paper presents one simple control algorithm for specific mobile robot system. The hardware architecture of the buggy robot and the use of certain types of sensors have been reviewed. The implementation of the movement of a mobile robot on a flat surface is presented and certain defects of applied robotic platforms have been discussed. A software library for sensors applied in this particular case has been established. Improvements of control structures by using intelligent systems and the data obtained from the sensors have been recommended. At the end of the paper there is a presentation of the results and potential further development suggestions.**

***Key Words*—Controlling systems, Buggy, IR Distance Sensors**

I. Introduction

Mobile robots, with their versatility in areas of application, gradually move from the classical industrial plants to our everyday lives. In most cases, people act and reside within a robot's working space. Consequently, such a working space becomes extremely dynamic; therefore, the robots are faced with growing demands for an intelligent behavior.

Establishing a safe trajectory within a dynamic working area is one of the main issues of mobile robotics. The solution of this task seems to be a prerequisite for solving more complex problems that robots face. The great progress in the development of robotics allowed for the emergence of new technologies for implementation of control systems - microcomputers, which have significantly increased the ability of the robots to, among other things, process a variety of sensor-received information in real time, based on which decisions are made as to what action should be carried out next. In that way, they perform tasks characterized by the reduced level of determinism.

Mobile robots explore new, unknown space using their sensors, which collect information about their environment in order to solve the problem of safe path [1-5]. Buggy represents a motorized robotic development platform, expandable with all types of sensors and transceivers, and as such is used for a very wide range of tasks.

The method presented in this paper represents the expansion of robotic development platforms. Buggy, with its infrared distance measuring sensors, respectively bypasses dynamic obstacles within the operation area of the robot, demonstrating integration of these components.

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II. Overview of the System Components and the Tools Used

For implementation of the presented control system, due to its advantages, a mobile robot Buggy [6] (Figure 1) was used, with STM32 [7] development panel, as well as two proximity sensors placed on opposite sides of the mobile robot, one on the front, the other on the rear.

A. Buggy the mobile robot

Buggy, a four-wheeled robot, represents a work station which includes all the advantages and innovations that have occurred in the last few years. This mobile robot uses clicker2 plates for processing the information, which makes it compatible with a wide range of micro controllers' designs. The robot consists of a micro controller panel, four DC motors, a port for sensors and batteries. Mobile robot has a four-wheel drive system without incremental encoders, which represents a particular difficulty during implementation.

Fig. 1. Buggy (Microelectronics) - robot rover platform expandable with all sorts of sensors and transceivers.

By adding microbus [8] ports, the four-wheeler is enabled to use multiple different sensors and communication panels, which constitutes a major advantage of this platform. Microbus represents a specially designed convector standard with SPI, I2C, Analogue, UART, Interrupt, PWM, Reset and

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Power pins.

The Buggy contains three microbus sockets, two at the front and one at the rear side. For this purpose, two outlets/sockets were used, one on the front and one at the rear side.

B. Proximity sensors

Detection of obstacles and determining the distance from the obstacle can be achieved through different types of sensors. Available are Infrared IR sensors, ultrasonic US sensors, laser detectors, etc... Infrared sensors are most commonly used as detectors of obstacles and for measuring distance of obstacles because of their price and precision. The recommended platform applied the proposed IR distance click panel [9]. With the IR distance the click panel comprises of an infrared signal detector, an infrared diode, the emitter and the signal processing circuit(s). The panel has the possibility of measuring the distance from 10 to 150 cm.

Fig. 2. IR distance click - distance measuring sensor, which comprises of an integrated PSD (position sensitive detector), an infrared LED and a signal processing circuit.

When using these sensors there is a variation of the measured distance from obstacles. For example, due to variations caused by the reflection of the object, we cannot determine the exact distance from the obstacle when it comes to a classic mirror. In addition to reflection, the factors that affect the precision of measurement are: dust (steam, smoke ...) on the receiver and transmitter on the panel, and similar.

As a result, the sensor provides an analogue signal corresponding to the distance between the emitter and the object that reflects the signal emitted by the infrared diode.

C. Tools used for development

The complete development of programs on ST micro controller of the robot is performed by using a tool that is provided by the manufacturer of the robot. The code is written in the programming language micro C and is switched via USB HID bootloader to the micro controller to execute.

III. DEVELOPMENT OF THE CONTROL MODULE

The control system of the buggy mobile robot was implemented in several stages. First, a library was created to move the mobile robot inside a space, and then the module for to calibration of the sensor distance was developed. After completion and testing of the first two stages, the integration of components and the implementation of the algorithm for moving the robot were conducted on the basis of the values observed from the proximity sensor(s).

A. The development of the library for the robot movement

One of the main tasks was to create a library which implements the movement of the robot in a straight line. For that purpose, modules are created which allow the basic movements functions of the robot: moving robot forward, moving backward, turning to the left, turning to the right.

Moving forward and backward is done issuing commands that all engines run at the same speed and in the same direction allows this kind of movement. Unfortunately, due to the robot's configuration, there was no information on the engine speed. Therefore, when issuing a command, the output motor drivers must, according to the identical control information, emit equal driving power and voltage, and the robot motors are of identical mechanical characteristics.

Moving the robot to the left or right is more complex problem because of the inability of measuring the position or speed in each wheel. For that reason, an alternative approach is implemented, which is reflected in the implementation of turning left or right at a 90° angle, without changing its current position (changing only the position of the robot, not the coordinates in space).

By moving a corresponding side of the motor forward, i.e. of the opposite side backward, the desired effect is achieved. As there is no possibility to measure the exact angle of rotation of the wheel, we started measuring time for which the robot will rotate its position 90° in the desired side. The time for which the robot performs a 90° (quarter of a circle) turn was determined, with three surfaces with different friction coefficients (in order: tiles, parquet and carpet) (Table 1).

	Measured time ***tiles***	*Measured time* ***parquet***	*Measured time* ***carpet***
Time ***1(s)***	0.298	0.512	0.588
Time ***2(s)***	0.301	0.531	0.581
Time ***3(s)***	0.305	0.526	0.592
Time ***4(s)***	0.295	0.521	0.600
Time ***5(s)***	0.300	0.533	0.644
Time ***6(s)***	0.298	0.518	0.594

Table 1. Measurement values of time necessary for robot rotation for diferent coefficients of friction
tiles (μ 1) < parquet (μ 2) < carpet (μ 3)

The measurement results confirmed the hypothesis that the speed of the robot greatly depends on the surface on which it is placed. This fact has limited the precision of operation of the system depending on the surface on which it is placed. In order to further test the system and the development of control algorithms, the robot was moving on surface I. A middle value of the formula has been selected as the time interval of rotation of the robot:

$$t_{avg} = \frac{t_{\max} + t_{\min}}{2} \tag{1}$$

From the Table 1 we can observe that $t_{\max} = 0.305$ s and $t_{\min} = 0.395$ s, so the average respond time is:

$$t_{avg} = \frac{0.395 + 0.295}{2} = 0.3\,\text{s} \qquad (2)$$

With help of these assumptions, applications for moving the robot are designed, which allowed turn to the left and to the right and at a desired angle.

B. The development of the library for reading values from the proximity sensor(s)

Measuring and determining the distance from the obstacle by using the infrared sensor(s) mounted in front and in the back of the buggy robot is implemented with appropriate restrictions which the robot possesses. The infrared sensor that is used in this application possesses certain technical characteristics. Figure 3 shows the reading of the voltage output characteristic of the sensor [10], depending on the distance of the obstacle which the sensor has detected. Figure 4 shows that the voltage is proportional to the distance from the obstacle, and a nonlinear function. Also, this voltage depends on the operating voltage of the system. Since robot requires a voltage of 3V for power, an appropriate graphic of output functions was used.

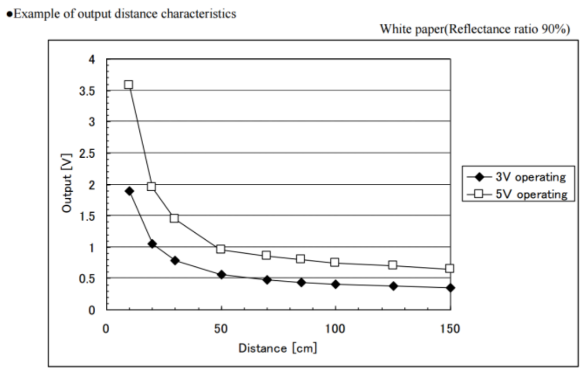

Fig. 3. IR Distance Sensor – Example of output distance characteristics

Since the operating voltage of the sensor in this case is 3.3V, we took the darker curve into consideration. Brief analysis of points obtained by measuring leaded us to the mathematical solution of the curve shown with the equation:

$$f_{(x)} = x^{-1.49} \cdot 49.956 + 0.37 \qquad (3)$$

Due to the mentioned robot 3.3v operating voltage, the output function is corrected, and the equation (3) is based on the modification due to the changed operating voltage. Therefore, the appropriate reflection function is calculated.

$$f_{(x)} = k \cdot x \qquad (4)$$

$$f_{(x_{\min})} = k \cdot x_{\min} \wedge f_{(x_{\max})} = k \cdot x_{\max} \qquad (5)$$

$$0 = k \cdot x \wedge 3.3 = k \cdot 4100 \qquad (6)$$

And finaly we can calculate and determine value of k $k = 0.000804878$.

Furthermore, in order to start with the calculations of distance, the read voltage value must first be multiplied with the coefficient k. From the value obtained in such way, by simply applying formula (3), we get the value of the distance from the object that reflects the emitted signals.

C. The implementation of the algorithm for avoiding collision with an obstacle on the buggy mobile robot

Obstacle collision avoidance algorithm is shown in the diagram in Figure 4.

The robot initially implemented straight line movement forward. When the sensor reads an obstacle in front of it, it makes a turn at the 90-degree angle to the right. If there are no obstacles located at the distance lower than 40cm in front of it, the robot continues moving forward in a straight line. The time loop in which the robot detects a potential obstacle takes place in the interval of one second, after which the decision process is repeated.

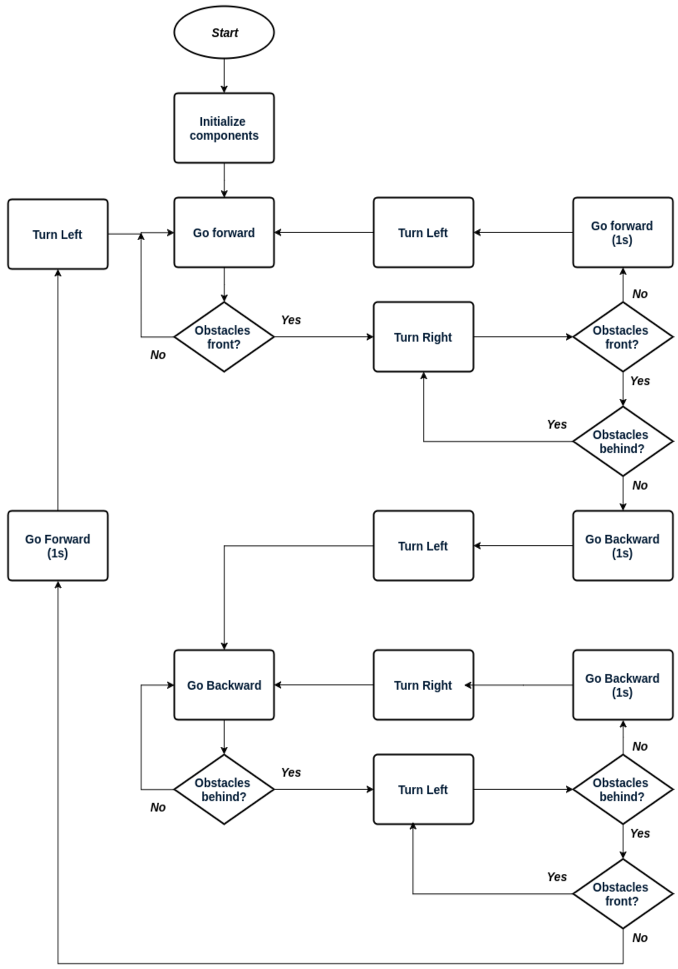

Fig. 4. Algorithm flowchart

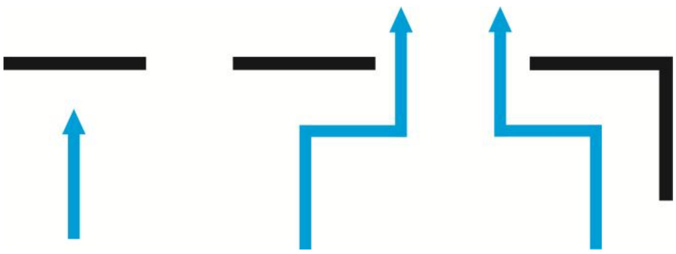

Fig. 5. Rounding obstacles when the robot is moving straight forward is dependent on the type of obstacles.

If there was an obstacle at the distance lower than 40cm, it will attempt to redirect its movement backwards in a straight line. In case it detects an obstacle in front of it and behind, it will perform another rotation to the right. After the linear movement over a period of one second, the robot tries to return its path to its original position, by turning to the left. Such process is repeated as long as the robot is moving.

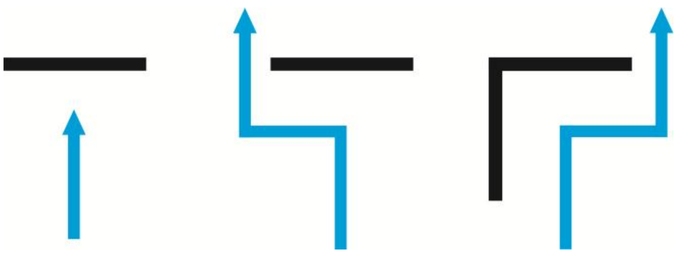

Fig. 6 Rounding obstacles when the robot is moving straight backward is dependent on the type of obstacles.

A similar process is happening when the robot is moving backwards. In contrast to moving the robot forward, when passing the obstacle, it turns to the left. Figures 5 and 6 shows the trajectories of potential movement of the robot depending on the detected obstacle. Detailed results of the proposed algorithm can be observed at the small video demonstration at [11].

IV. Conclusion

Controlling mobile robots is one of the most challenging research activities in robotics. Mobile robots are distinguished by their technical and sensory characteristics. This paper presents a control algorithm for the buggy mobile robot with the minimal number of sensors. It is proven that the systems which are deprived of hardware structures can successfully be oriented in space. The minimum number of sensors contributes to a lower price and faster signal processing. The suggested control system for the buggy mobile robot is one of the simplest intelligent systems. The application of two infrared sensors for the detection and calculation of the distance allows avoiding a collision with obstacles in the environment. The proposed solution comprises a creation of the library which will utilize several sensors simultaneously, which can be used in the development of more complex systems.

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