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MOBILE ROBOT CONTROL IN OBSTACLES AVOIDANCE TASKS BY MEANS OF A MOTOROLA-BASED HARDWARE PLATFORM

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Abstract **– This paper presents a mobile robot control strategy while performing tasks like obstacles avoidance in an unknown environment. The control strategy has been implemented within a 128 bit Motorola microcontroller kit mounted on a mobile platform. The system requires only a reduced number of proximity infrared sensors. The effectiveness of the implemented control strategy has been tested in our Robotics laboratory and proven during a student contest.**

Keywords*:* Mobile robot, Control, Proximity Infrared Sensors, Obstacle avoidance

1. INTRODUCTION

A mobile robot is an automatic machine that is capable of movement in a given environment and is not fixed to one physical location. Mobile robots are the focus of a great deal of current research and almost every major university has one or more labs that focus on mobile robot research. Mobile robots are also found in industry, military and security environments. They also appear as consumer products, for entertainment or to perform certain tasks like vacuum cleaning or lawn-mowing [1].

The challenge is to build and program a mobile robot system that is able to perform fast controlled motions and to provide it with sufficient intelligence to explore and to negotiate obstacles in the most effective way [2], [3]. The term *obstacle avoidance* describes a set of software techniques that allow mobile machines, such as autonomous robots to adjust their trajectory and speed according to their surroundings [4], [5]. Used in conjunction with distance measurement and motor control solutions, the implemented software gives the reflexes to handle obstacles intelligently, and to avoid any collisions.

Infrared sensors (IR) have many applications, including distance measurement in mobile appliances, inter-device communications and even multiplayer remote control for toys [1], [6]. A real-time obstacle avoidance approach for mobile robots has been developed and implemented. This approach allows the detection of unknown obstacles and provides the steering control required in order to avoid collisions [7].

A MC9S12E128 Motorola-based hardware platform has been used to implement the control strategy. Based on the information received from the proximity infrared sensors mounted on the robot, it allows the mobile robot system to move forward, to avoid obstacles that appear in its way and to follow a certain trajectory.

2. METHOD AND CONSTRUCTION

2.1. Mobile Robot Configuration

Figure 1 presents the mobile robot platform that has been tested in obstacles avoidance tasks.

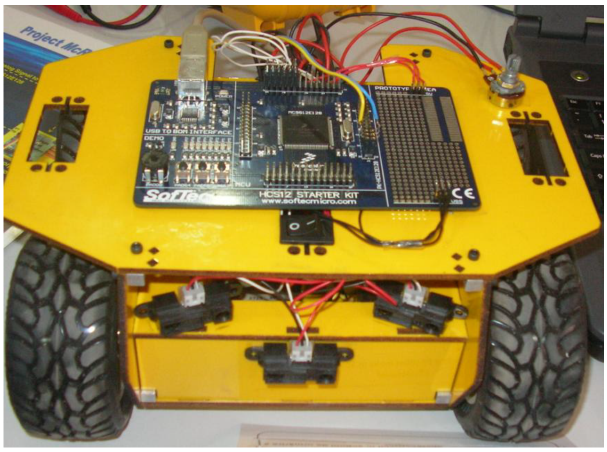

Figure 1. The mobile robot system

Our application uses a mobile robot platform that contains:

1) Three SHARP GP2D12 infrared proximity sensors, with a 10 to 80 cm detecting range. Figure 2 presents the diagram of analog output voltage versus detection distance that has been verified in laboratory tests.

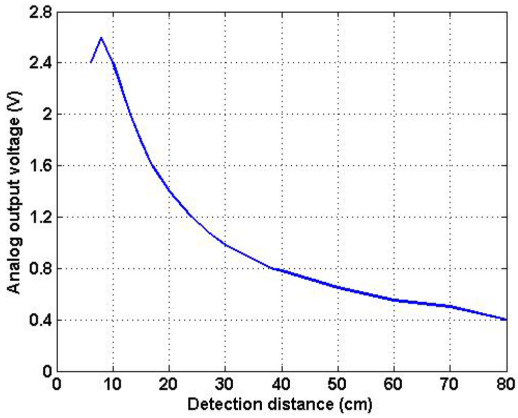

Figure 2. SHARP GP2D12 sensors detection distance diagram

2) Motorola HCS12E128 kit based on the MC9S12E128 microcontroller that has been used to implement the control strategy.
The HCS12E128 Kit is designed for the evaluation of the MC9S12E128 microcontroller and the debugging of small user applications. This kit uses the Metrowerks CodeWarrior Integrated Development Environment (which groups an Editor, Assembler, C Compiler and Debugger) and the Motorola BDM interface, that allows user applications to be downloaded and debugged into the microcontroller's FLASH memory.
Full-speed program execution allowed us to perform hardware and software testing in real time. A prototyping area allowed us to wire our own application.
3) A Scorpion speed controller – it is a drive unit engineered and tested to provide superior performance and control, with a 2.5A continuous (4.5A peak) current on each Left and Right drive channels which may be combined into a single 5A continuous forward/reverse channel.
4) A 4WD1 mobile platform equipped with four GHM-04 7.2 VDC motors, 175 RPM; the motors placed on the same side are wired in parallel making the mobile robot system to steer like a tank.

2.2. Control and detection method

In order to navigate effectively the autonomous mobile robots have to be able to determine their location according to their surroundings, and continuously adapt their trajectory. The main objective was to have a simple and effective system, with a reduced number of sensors that can be easily controlled and offers a fast response in an unknown environment. Figure 3 presents the main parts interconnection of the mobile robot system and the communication signals between them.

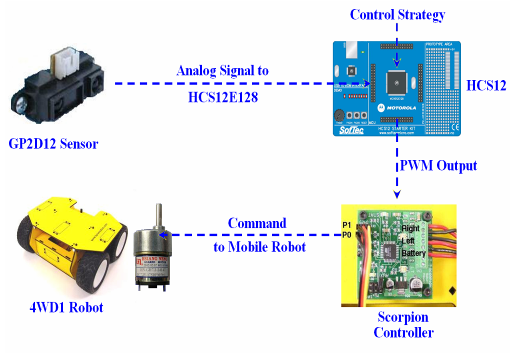

Figure 3. Main interconnections between the mobile robot subsystems

In order to detect different obstacles, the mobile robot has been equipped with 3 infrared SHARP GP2D12 proximity sensors, identified as *a, b* and *c* in figure 4. They are able to measure the distances to an obstacle in a range of 10 to 80 cm. We proposed a simple and effective detection scheme which requires only these three proximity sensors, as shown in figure 4. The signals emitted by the proximity sensors create a "detection cone" which allows the detection of all the obstacles in front of the robot. Far away or close obstacles can be detected properly.

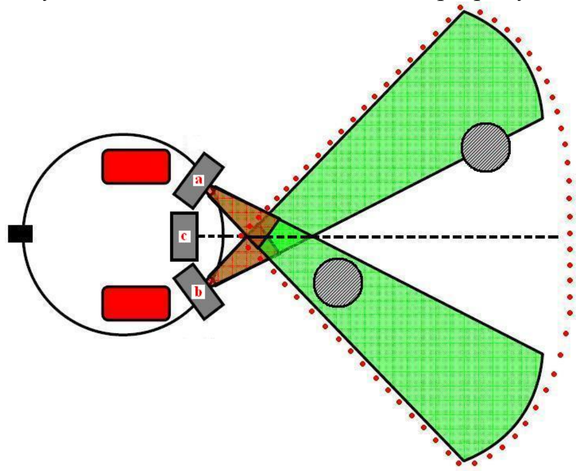

Figure 4. Obstacles detection cone

The *a, b* and *c* sensors send analog signals (voltages between 0.4 – 2.4 *V)* to the MC9S12E128 microcontroller. The voltages are proportional with the measured distances in a range of 80 to 10 cm between the mobile platform and the detected obstacles (see figure 2). In accordance with these values the implemented control strategy generates the outputs as PWM signals that are fed into the speed controller. The Scorpion speed controller provides the four DC motors with the amplified PWM commands. In accordance with the imposed pulse width, every pair of two motors on a side is driven at a different speed allowing the mobile platform to move to a chosen direction.

The PWM commutation period is 2.4 *ms*. At a 1.2 *ms* pulse width, the DC motors shafts are locked.

The implemented program is a simple one and contains different levels where the decision of avoiding an obstacle is taken. The control decision is taken in accordance with different situations that the mobile robot may encounter in the real world. In fact obstacles that are detected (within the detection cone) close to the mobile robot requires a fast turn while those being detected far away requires a slower turn. As an example some program sequences are listed below:

```
// case with an obstacle detected on the left side of
//  the detection cone
            if ((a>0.4) & (a<0.8) &(b<0.4) & (c<0.4))
            {
// right side wheels turn forward at a medium speed
            PWMDTY1=85;
// left side wheels are locked
            PWMDTY0=95;
            }
                        …
// case with obstacles detected by all the sensors at
 // medium and small distances
            if ((a>1.2) & (b>1.2) & (c>1.8))
            {
// right side wheels turn backward at high speed
            PWMDTY1=110;
// left side wheels turn forward at high speed
            PWMDTY0=80;
            }
                        …
```

PWMDTY1 and PWMDTY0 are the variables defining the pulse width values corresponding to the right and left PWM outputs. In order to convert the values of the PWM duty cycle into PWM output signals, we have to use the following formula:

$$PWMx = \frac{PWMDTYx}{PWMPERx} * 100 \qquad (1)$$

where: PWMx – duty cycle for channel 0 or 1;
PWMPERx – PWM commutation period.

In the program, PWMDTYx = 95 corresponds to a duty cycle of 50 % which determine the DC motors shafts to be locked. A PWMDTYx = 140, means a duty cycle of 75% in which case the DC motors are turned backwards at full speed, while a PWMDTYx = 50, means a duty cycle of 25% that corresponds to DC motors being turned forward at full speed.

If a very close obstacle is detected, the speed is differently decreased for each of the both sides and the mobile robot avoids the obstacle by steering like a tank. If the obstacle is detected at a medium distance, it is avoided by reducing the speed only for the wheels of one side of the robot while the other pair of wheels is driven at a maximum speed. If the obstacle is sensed to be far away, the robot avoids it in the same way, with only a small reduction in speed for a pair of driven wheels. If all three sensors detect obstacles the mobile robot makes a 180° turn.

3. RESULTS AND DISCUSSION

Different laboratory tests have been performed with obstacles being placed all around the mobile robot in order to create diverse scenarios and therefore to appreciate the effectiveness of the proposed control method. Mainly, if the mobile robot detects obstacles in its way, it has to take a decision to fast turn if the obstacle is too close or to reduce the speed of a certain pair of wheels and to turn to the left or to the right in accordance with the position of the detected obstacle.

Firstly, Matlab&Simulink simulations were made in order to evaluate the effectiveness of the method. Figure 5 shows a map of a simulation scenario and the results obtained while performing an avoiding obstacles task by means of the implemented control strategy.

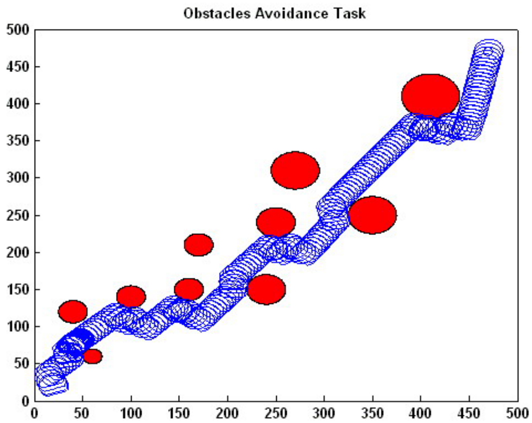

Figure 5. Simulation results for a ten obstacles case

Another idea taken into account was to surround the mobile robot with obstacles and to evaluate its behavior. Because the mobile platform is programmed to turn 180 degrees if all its sensors detect obstacles in a closer proximity of the robot, the robot keeps turning in circle until a gateway is found giving it a chance to exit from the surrounded area.

The mobile robot named McROBY and the control method have been presented by our McROBY team during a Siemens VDO Open Doors Day – Student Competition, organized in Iasi. Our team has been awarded for its original idea being on the 8th place from a total of 30 participant teams. Figure 6 presents the mobile robot performing real obstacles avoidance tasks.

Figure 6. Mobile robot control sequences while avoiding obstacles

4. CONCLUSIONS

A mobile robot structure that is able to perform tasks as obstacles avoidance while exploring an unknown terrain has been tested in simulation and in a real environment. The proposed control method has been implemented within a Motorola-based microcontroller kit. The overall system has been kept very simple requiring only a reduced number of proximity sensors. The mobile robot has been able to avoid any obstacles encountered while mapping an unknown environment, and furthermore finding gateways while trapped. Further developments will follow aiming to combine fuzzy logic control methods for obstacles avoidance along with trajectory tracking.

Acknowledgments

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