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Low Cost Obstacle Detection System for Wheeled Mobile Robot

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Abstract

This paper presents a new low cost obstacle detection system for wheeled mobile robot. The hardware implementation of the proposed detection system uses two Sharp GP2D02 infra-red range sensors which are placed cross over each other in front of the robot in order to detect any object and avoid collisions. The software implementation of the proposed detection system is implemented using timer with the overflow interrupt for generating the required waveform for driving the Sharp GP2D02 infra-red range sensor. As a result, the mobile robot is able to execute different tasks without a delay on the processing time, for example driving the robot wheels and drive the Sharp sensors for detecting an object. Experimental results show that the proposed detection system successfully detect an object placed in a path of the mobile robot.

Keywords- Obstacle, Detection system, Mobile robot, Sharp Infra-red Range Sensors.

1. Introduction

Robots are very powerful elements of today's life. They are widely used in many industries due to the high level of performance, reliability, capability of performing many different tasks and operations. Recently, mobile robots are more and more involved in our daily lives. They can be employed in several missions such as cleaning rooms, taking care of patients, playing with kids, etc. It is important for many mobile robots to have ability for understanding and be aware of their environment such as the ability to detect an object and avoid collisions. To achieve this, mobile robots have used several types of sensing sensors, such as ultrasonic, infra-red, laser rang finder, charge-coupled device (CCD), web camera, mini-radar and bump sensors [1, 2,3]. The visual sensors can provide the richer source of useful information about the surroundings. However, they are slow in computing data and more expensive [4]. The infrared sensors have widely used for object detection and avoidance collisions due to their low cost and ranging capability [5]. Authors in [5] presented a software implementation of an obstacle detection and avoidance system. In this system, three sharp GP2D12 infra-red range sensors were used to cover the large area in the front of the mobile robot. This type of the infrared sensor offers a analogue voltage corresponding to the distance measured. Therefore, an analogue to digital converter (ADC) is required using such this sensor, so extra cost is required for this system. Authors in [6] designed and developed a low cost mobile robot that designed in as a circle–shaped and five sharp GP2D12 Infra-red Range Sensors were used in order to cover the large area.

In this paper, a new low cost obstacle detection system for wheeled mobile robot is proposed. In comparison with existing approaches, the proposed system possesses the following advantage: (i) the proposed detection system requires only two infra-red range sensors to cover a large area. By contrast, method in [5] uses three infra-red range sensors and method in [6] uses five infra-red range sensors. (ii) The proposed detection system is implemented using the Sharp GP2D02 infra-red range sensor which is a digital sensor and does not required an analogue to digital converter (ADC). By contrast, methods in [5, 6] are implemented using the Sharp GP2D12 infra-red range sensors which is an analogue sensor and required an analogue to digital converter (ADC) and therefore, extra cost is required using such this sensor.

The rest of this paper is structured as follows. Section 2 describes the interfacing between the Sharp GP2D02 infra-red range sensors and the PIC microcontroller. Section 3 covers the details of the proposed obstacle detection system. Section 4 presents experimental results. Conclusions are drawn in Section 5.

2. Interfacing the Sharp GP2D02 Infra-red Range Sensor to the PIC microcontroller

The Sharp GP2D02 infra-red range sensor uses an open-drain input which means it can not be interfaced directly to the PIC microcontroller due to the maximum characteristics of the open drain input which is in range -0.3 to 3 voltages. Therefore, a diode is used to only enable the current to flow when I/O pin is low [7]. Figure 1 shows the Interface between PIC and the sharp GP2D02 infra-red range sensor. As shown, this sensor requires two lines from the PIC in order to be controlled. One line provides the signal to begin a measurement and also is used to provide clock pluses, this line is called V_{in} and the other line is called V_{out} which is used to transmit the measurement back to the PIC microcontroller. The output of this sensor is 8 bit serial measured.

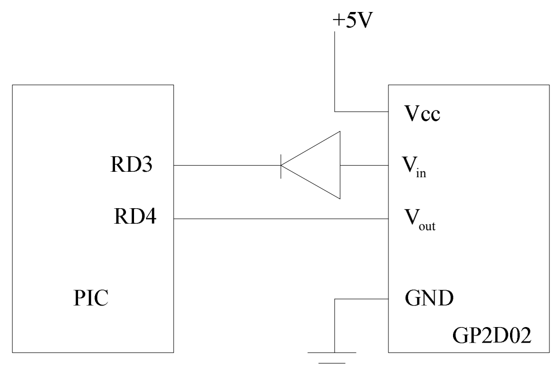

Fig. 1 Interfacing PIC with GP2D02

2.1 Driving the Sharp GP2D02 Infra-red Range Sensor

The sharp GP2D02 infra-red range sensor is driven according to the timing diagram which illustrates in figure 2. As shown, the measurement is initiated by forcing the V_{in} signal to logic low for at least 70 ms or until the V_{out} signal from GP2D02 sensor becomes logic high. Once that occurs, V_{in} signal is toggled at the rate of 0.2 ms or less to start clocking in the serial bits from the sensor. Once the entire byte is read, V_{in} is floated high for at least 1.5ms in order to reset the sensor for another reading.

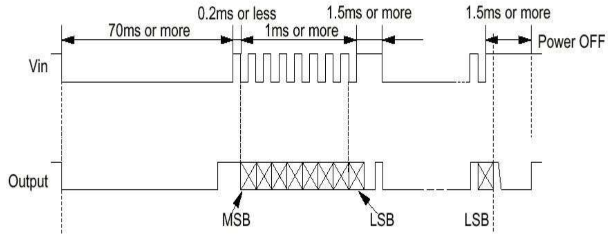

Fig. 2 the timing diagram for GP2D02 infra-red sensor

3. The proposed obstacle detection system

The proposed obstacle detection system uses two sharp GP2D02 infra-red range sensors that are mounted in front of the mobile robot cross over each other in order to provide coverage for a large area as shown in figure 3. The sharp GP2D02 sensors can measure a distance to an object by emitting infra-red pulses and then receives back the reflected signal. It can measure distances in the range 10cm – 80cm.

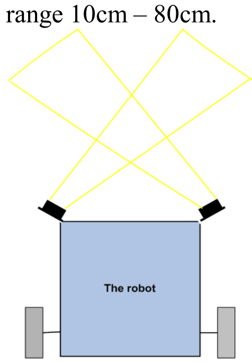

Fig. 3 Block the diagram of the mobile robot with two Sharp infra-red range sensors.

3.1 The implementation of the detection system

The implementation of the proposed detection system is divided into two stages: The first stage covers the hardware implementation and the second covers the software implementation. In the hardware implementation, two Sharp GP2D02 infra-red range sensors are used to implement the hardware part of the proposed detection system as shown in figure 4; RD3 pin of the PIC 18F452 is used as the output pin for controlling both of the Sharp sensors. Therefore, one timing waveform is used to initiate, read a byte from each sensor and reset both of the Sharp sensors. RD1 and RD2 are used as input pins in order to read a byte from each sensor.

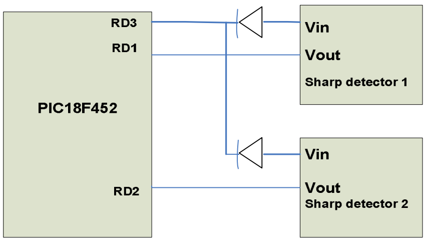

Fig. 4 the hardware implementation of the detection system

In the software implementation, the required waveform is generated for driving the Sharp GP2D02 Infra-red sensor as described in section 2. This required waveform can be implemented by using a delay function. However, this will take about 74ms, and will slow down the processing time on the PIC 18F452 microcontroller. If the required waveform is implemented using a delay function; the robot will be unable to execute different tasks without a delay on the processing time, for example driving the robot wheels and drive the Sharp Infra-red sensors to detect an object. To overcome this, the proposed detection system uses a timer with the overflow interrupt to generate the required waveform for driving the Sharp GP2D02 sensors. The software implementation is divided into three functions that are described as follows.

- **Initial function**

The aim of this function is to initiate the general and the overflow timer 0 interrupt. Also timer 0 is initiated as 16- bit timer/count. Two flags are used to distinguish between the first interrupt which should occur after the timer 0 reaches 70ms and other interrupts that should occur after the timer 0 reaches 0.2 ms and 1.5 ms as shown in figure 5.

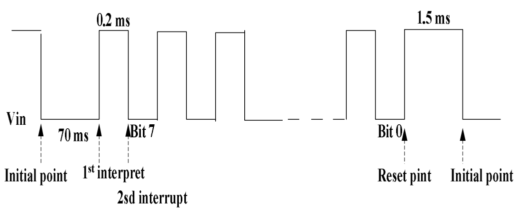

Fig. 5 Timing waveform and interrupt edges

The following Pseudo-codes describe the implementation of the initiate function.

```
void initGP2D02(void)
{
 Enable the interrupt (GIE& timer 0
  overflow INT)
  OpenTimer0( as 16BIT &  256 prescale value);
  WriteTimer0(TIMER_VAL_70MS);
  timer to overflow after 70 ms
  Set timer0_70ms_flag;
  Vin= 0;
  Clear timer0_15ms_flag;
  sensor value=0;
 }
```

- **Read byte from Sharp sensor**

The aim of this function is to read the distance information from the sensors. This information is serial bits and it is converted into a distance of centimeters. The sensors are calibrated using a linearization formula. The sensors output has an inverse relationship to the distance of an object. That is the further the object, the output values of the sensor will be small. The output values of the sensors are converted into distances using the equation (1) [8].

$$D = Kg/(X-Ko) \quad (1)$$

Where D denotes a distance and it is given in units of centimeters (cm), X is the sensor output, Kg is the gain and Ko is an offset. The values of Kg and Ko can be determined as follows:

Let D and X be the distance and output, respectively of the first measurement. Let D' and X' be the distance and output, respectively, of the second measurement.

$$Kg = (X'-X)\, D'D / (D-D') \quad (2)$$
$$Ko = (D'X' - DX) / (D' - D) \quad (3)$$

The Pseudo-codes of this function is described as follows.

```
int readGP2D02(void)
{
 int ret_val = sensor_value;
 Disable Timer 0 interrupt
 ret_val =1560/(ret_val-82);
 Enable Timer 0 interrupt
 return ret_val;
}
```

The ‘sensor_value’ stores the output byte from the Sharp sensor. This value is updated via the interrupt function. The timer 0 overflow interrupt is disabled at the begging of this function and it is enabled at end by clear or set the timer 0 enable bit in the interrupt control register (INTCON) respectively.

- **Interrupt function**

The aim of this function is to deal with the timer 0 interrupt by generating the required waveform on the V_{in} input pin of the Sharp sensor in order to initiate and read a byte from the output of the Sharp sensors also after the eight bits output from the Sharp sensors are read, it will generate the reset pulse to initiate the sensors to be ready for next measurement. This waveform is generated according to the waveform shown in figure 2. The design of the interrupt function is illustrated in figure 6.

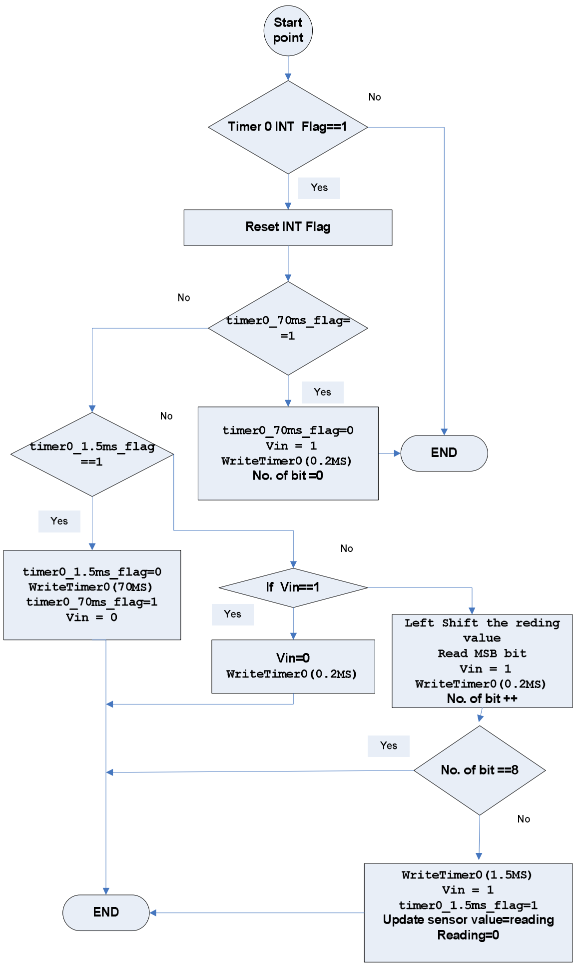

Fig. 6 flowchart of the interrupt function

4. Experimental Results

The experiments were organized in two phases. The first phase evaluated the relation between the output of the Sharp GP2D02 Infra-red sensor and the distance to the reflective object. The second phase evaluated the performance of the proposed detection system. To complete the first experimental phase, the Sharp Infra-red sensor was mounted as shown in figure 7 and a reflective object was placed in the front of the sensor in different distances in order to find out the relation between the output of the sensor and the distance to the reflective object.

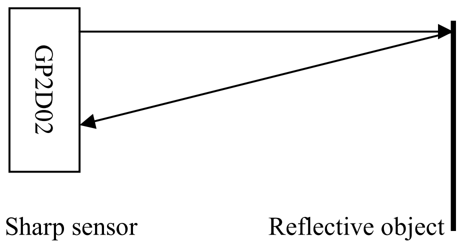

Fig. 7 the first experimental phase

The results of the first experimental phase are shown in figure 8. As shown, the output of the Sharp detector within the range 10 cm - 80 cm. The sensor gives a wrong value for distances less than 10 cm or more than 80cm [7] therefore, an object closer than 10 cm will appear to be further away. The measurement unit of the distance is centimeter and the outputs of the sensors are decimal values.

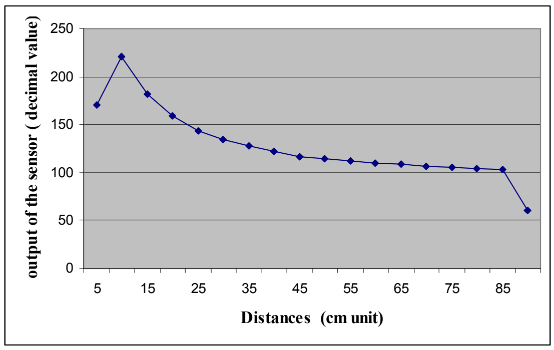

Fig. 8 the results of the first experimental phase

The second experimental phase is divided into two stages; the aim of the first stage is to test each Sharp sensor individually in order to find out if the beam of one sensor affects other sensor. The first stage was achieved by recording the output of each sensor according to the distance to the object without driving the robot; in case one by activating one sensor and record its output; and in the case two by activating both sensors and record the output of one sensor. This was achieved by using the PORTB as output port and using an oscilloscope to read the output of the sensor from PORTB. The results of these tests are shown in table 1 and table 2. As shown in table 1 and table 2, the output of the Sharp sensor 1 is affected by the beam of the Sharp sensor 2. As a result of this, the output of the Sharp sensor returns a wrong distance measurement to an object. To overcome this problem, extensive experiments were carried out to find the best position for mounting the Sharp sensor. It has been found that the best angle for mounting the position of the Sharp sensors should be 5 degree. If this angle is increased, the sensors will affect each other and they will return wrong distance measurements to an object.

The aim of the second stage is to find out if the proposed detection system is able to detect different types of objects place in deferent positions in the front of the robot; this test was achieved by driving the robot and using a different type of object in different position in front of the robot. The result of this test is carried out that the robot is able to detect any object even if a small object For example, a pen or a wire.

Table 1 Result of testing sensor 1

sensor 1 is activated Output of sensor 1 (Decimal)	Both sensors are activated Output of sensor 1 (Decimal)	Distance in cm
226	226	10
157	218	20
135	27	30
133	14	40
134	124	50
95	94	No object

Table 2 Result of testing sensor 2

sensor 2 is activated Output of sensor 2 (Decimal)	Both sensor are activated Output of sensor 2 (Decimal)	Distance in cm
212	212	10
145	145	20
126	125	30
111	110	40
97	98	50
32	39	No object

4. Conclusion

A new mobile robot detection system based on two Sharp GP2D02 infrared range sensors is presented. To detect an object in front of the mobile robot, the proposed detection system is implemented using two sharp sensors cross each other in order to cover all the area in front of the mobile robot. The experimental results show that the best angle for mounting the position of the Sharp sensors should be 5 degree. Moreover, experimental results show that the proposed detection system is able to detect any object placed in front of the mobile robot.

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