Software Implementation of Obstacle Detection and Avoidance System for Wheeled Mobile Robot

Aye Aye Nwe, Wai Phyo Aung and Yin Mon Myint

Abstract**—** Nowadays, Wheeled Mobile Robots (WMRs) are built and the control system that used to control them are made by Electronic Engineers. Depend on their desire design of WMR, Technicians made used of Microcontrollers as controlling machines and DC Motors for motion control. Autonomous robotic vehicle guidance for indoor navigation has been developed for Mobile Industrial Robot model. The resulting design will navigate the environs in a building without the need of human intervention. The guidance system consists of infrared sensors for obstacle detection, range determination and avoidance. It can detect the obstacles within the range 10 to 80 cm. This paper represents mainly on software implementation of obstacle detection and avoidance system for Wheeled Mobile Robot. This system consists of infrared sensors and microcontroller. In this system three infrared sensors are used for left, front and right. In this robot system, the input signal is received from sensor circuit and PIC is operated according to the received sensor's signal.

The infrared sensor reading is taken and processed to avoid the obstacles. The 5V power supply is used to operate PIC board and sensor circuit board. The obstacle avoidance algorithm is simply evaluated on PIC 16F877 microcontroller based mobile robot. The type of infrared sensor is GP2D12 distance measuring sensor. The desired goal of this system is to avoid obstacles along its path and to determine the distance.

Keywords**—**Infrared Sensors, Obstacle Avoidance, Microcontroller Based Control System, Robot Navigation, Fuzzy Logic, Mobile Robot.

I. INTRODUCTION

ROBOTS are now widely used in many industries due to the high level of performance and reliability. All mobile robots feature some kind of obstacle avoidance.

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Designing autonomous robot requires the integration of many sensors and actuators according to their task. Obstacle detection is primary requirement for any autonomous robot. The robot acquires information from its surrounding through sensors mounted on the robot. Various types of sensors can be used for obstacle avoiding. Methods of obstacle avoiding are distinct according to the use of sensor. Some robots use single sensing device to detect the object. But some other robots use multiple sensing devices. The common used sensing devices for obstacle avoiding are bump sensor, infrared sensor, ultrasonic sensor, laser range finder; charge-coupled device (CCD) camera web cam and so on can be used as the detection device. Among them infrared sensor is most suitable for this obstacle avoiding robot because of its low cost and ranging capability.

The IR object detection system consists of the Sharp GP2D12 distance measuring sensor. The GP2D12 is a compact, self-contained IR ranging system incorporating an IR transmitter, receiver, optics, filter, detection, and amplification circuitry. The unit is highly resistant to ambient light and nearly impervious to variations in the surface reflectivity of the detected object. The paper is mentioned on the basic research of "Development of an Intelligent Wheeled Mobile Robot (WMR)". This is a type of IR Sensors based Wheeled Mobile Robot and it mainly function as an Obstacle Avoidance Vehicle. All these processes are design in this research and it is mainly focus to software implementation of this WMR. For each three main portions, comparisons with other possible ways or devices are included and the choosing methods to optimize the desire Control System are also considered. Background theories and techniques of Electronic Control Technology are analyzed in this paper using both Hardware and Software Consideration.

II. SYSTEM OVERVIEW

This mobile robot is designed to explore in the environment by detecting obstacles and avoiding collision base on the distance measurement information obtained from the infrared sensors. This robot system is obstacle avoiding robot using infrared sensors. Infrared sensor senses the obstacle along its path. In this system three infrared sensors are used for left, right and front. The infrared sensors, used for obstacle avoidance, are connected to the processor via analog ports. The input signal is received from sensor circuit and PIC is operated according to the received sensor's signal.

The reason to choose IR sensors as Obstacle detected device is that to determine the range of object and by this data, to control the Obstacles avoiding process. In this research, by using its effective rating, GP2D12 analog IR sensor is used. Analog to Digital Converting (ADC) process is done in PIC by software and these data used to control the require outputs that will effect to the second Module, Navigated Control System. The basic circuit that makes these processes is shown in Figure 2.

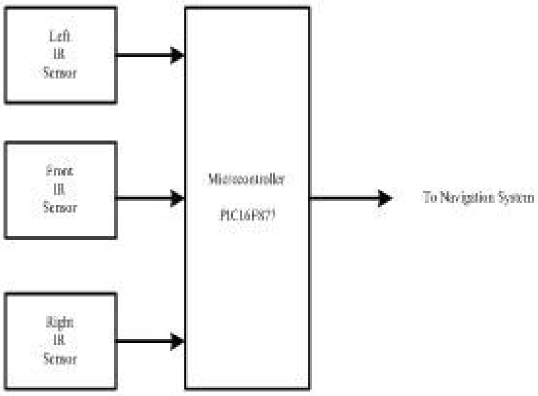

Fig. 1 Block Diagram of Obstacle Detection and Avoidance System for Wheeled Mobile Robot

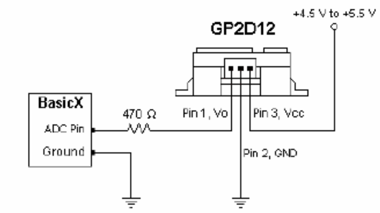

Fig. 2 GP2D12 IR Sensor that apply to PIC

Using the input signals from sensor circuit, the navigation system determines a direction to avoid the obstacle. After turning a suitable angle, the navigation system negotiates the robot to the desired direction and check whether there is an obstacle along its way.

According to the sensing information, microcontroller controls the driver unit. And then, the driver unit drives the robot's wheels individually.

III. GP2D12 Infrared Distance Measuring Sensor

In this paper, three GP2D12 infrared sensors are utilized for distance measurements. The infrared sensor consists of a LED emitting the infrared light and a position sensing devise (PSD) that outputs voltage based on results of the triangulation procedure. Measurement of the distance using triangulation is illustrated in Figure 3. The angles in a triangle connecting the IR emitter, a distant object and PSD are dependent on a position of the object with respect to LED/PSD plane and therefore, are used to calculate the distance between IR sensor and the object. This sensor enables to detect objects without any influence on the color of reflective objects, reflectivity, the lights of surroundings. is able to continuously measure the distance to an object.

Maximum range that can be detected using the GP2D12 is from 10 to 80 cm. It is also sensitive to alignment of the surface being measured. It generates an analog voltage that is a function of range. The output voltage can be measured by an analog-to-digital ADC input line. It has three wires, positive (+5V), negative (ground), and data output. Typical Output/Distance Characteristics of GP2D12 are presented in Figure 3.

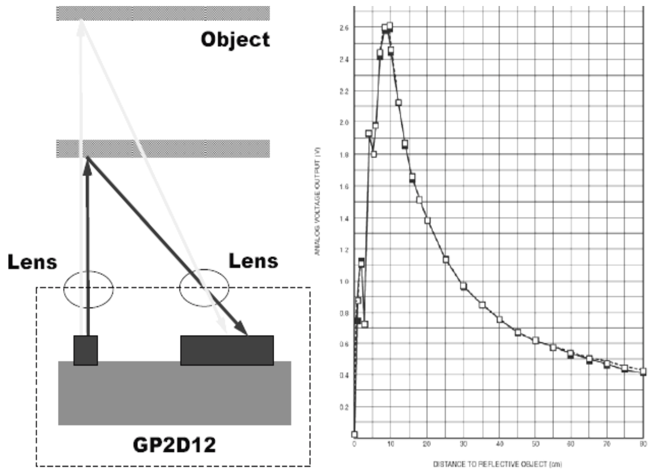

Fig. 3 Triangulation Measurements Using the GP2D12 IR Sensor and Its Output/Distance Characteristics

IV. Analog-to-Digital Converter and Sensor Accuracy

Distance sensors are typically not read at a rate of more than a few samples per second, so the performance characteristics of most ADCs will be sufficient. Assuming that the noise on the V_{out} input signal has been kept to a minimum, the main concern is to ensure that the number of bits used for the ADC output is sufficient for the desired resolution. The change in voltage from 70 cm to 80 cm is only about 0.06 V, which corresponds to 0.006 V/cm. If the 8-bit ADC with a reference voltage of 5V is used, each bit of the ADC output represents 0.0195 V which means a one bit swing in the ADC output will result in a distance swing of about 3 cm. The maximum voltage output from a GP2D12 sensor is about 3V. If the reference voltage for the 8-bit ADC is changed to 3V, each bit of the ADC output represents 0.0117 V, which means a one bit swing in the ADC output will still result in a distance swing of about 2 cm. The resolution is better at shorter distances because there is a larger voltage change.

V. Circuit Operation of Obstacle Detection and Avoiding System

This IR range sensor works by returning a voltage proportional to the distance of the object detected. Therefore an object that is farther away returns a lower voltage than an object that is closer. This sensor measures distance using the triangulation method, as shown in Figure 3.

The emitter emits a pulse of IR light. This light travels out in the field of view and either hits an object or just keeps on going. In the case of no object, the light is never reflected and the reading shows no object.

If the light reflects off an object, it turns to the detector and creates a triangle between the point of reflection, the emitter, and the detector. The angles in this triangle vary based on the distance to the object. The receiver portion of the sensor included a lens that transmits the reflected light onto various portion of a CCD array based on the angle of the triangle described above. The CCD array can then determine what angle the reflected light came back at and therefore, it can calculate the distance to t he object.

The GP2D12 is an analog infrared proximity sensor. It can be used to detect obstacles. This sensor has a LED that emits infrared light. Infrared light has the interesting property that it bounces on obstacles. On the front of the sensor, beside the LED that emits the infrareds, there is a photodiode that is sensible to infrared light. It will vary the output voltage based on the amount of infrared light that bounces back to the sensor. The more infrared light it sees, the closer is the object and the higher the output voltage generated by the photodiode.

This sensor will provide an analog output voltage that is promotional to the distance of the object it senses. It's analog output will then be fed into the analog-to-digital converter of the PIC16F877 microprocessor, via pin number 2. If the voltage output is connected to a microcontroller with analog to digital conversion capability (such as a PIC16F877 microcontroller), it is possible to translate this voltage to a numerical value. This value can be used to determine whether or not there are obstacles close to the sensor and how far these obstacles are. Figure 4 shows how to interface a PIC16F877 microcontroller to a Sharp GP2D12 sensor.

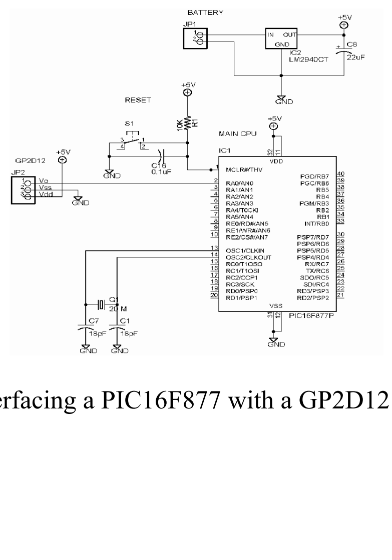

Fig.4. Interfacing a PIC16F877 with a GP2D12

VI. Sensing Statements

The sensing in mobile industrial robot relies mostly on infra-red light (IR) detectors, either for obstacle and goal area detection, although a few robots used ultrasound distance detectors. Obstacles are detected with proximity sensors. To detect obstacles teams usually use IR sensors, although a few robots used ultrasound sensors operating as sonar's, based on pulse reflection and time of flight. Used IR sensors are mainly of two different types: The first type is based on a hacked Sharp GP1U58.

Obstacle detection is active in the sense that the robot emits IR light, and looks at the reflection received by the detectors. This allows a gross measure of the distance of a given obstacle, as the output voltage increases with the intensity of the modulated IR light (at 40KHz) received by the detector, which is inversely proportional to the distance between the robot and the obstacle. The voltage/distance relationship is approximately quadratic. Obstacle detection typically uses 3 of infrared sensors, given their relatively wide aperture (+/-30º). To improve detection efficiency, the use of more than one IR LED/sensor is in order to better illuminate the detection area. In some robots the obstacle detection was also improved using more than 3 sensors.

The second type of IR-based obstacle sensor uses a distance measuring device, the Sharp GP2D12. It uses the triangulation principle to compute the distance between the sensor and the obstacle being useful in the range 10-80 cm. The sensor output is a voltage that varies with the position of the spot as captured by the position sensing device (PSD), being inversely proportional to the distance between the robot and the obstacle.

Reliable obstacle avoidance is an essential feature. The simplest way to avoid obstacles is to use at least two non-contact (IR or ultra-sound) proximity sensors looking left and right. Detecting an object on the left side of the robot makes it turn right and vice-versa. This can be done by simple proportional control, using directly the output of the sensor, or by quantizing the sensor value in a few discrete levels (close, medium-range and far).

However, most of the robots used at least 3 obstacle sensors with one facing the robot front. This improves obstacle detection area while maintaining the capability to detect obstacles in front. In this case, use of randomization can also be useful. By not turning always to the same side when facing a frontal obstacle, chances of developing vicious cyclic behaviors are reduced.

VII. Software Consideration of Obstacle Detection and Avoiding System

The consideration data of GP2D12 IR Sensor that mentioned the graph comparing between its voltages depend on the distance of the detected object is shown in Figure 5. For assembly software program consideration for PIC, the following step by step consideration should be made.

- Five inputs from five sensors are to be converted as digital data of PIC input.
- These data must be represented as input bits of control system that can determine which sensors are detected and which position of Robot is require rotating.
- Output of PIC must be made as data signal that mentioned each meaning of how in real states of Sensor, i.e. five bit outputs of this Module makes the Navigation Module as inputs of 32 state to be determine.

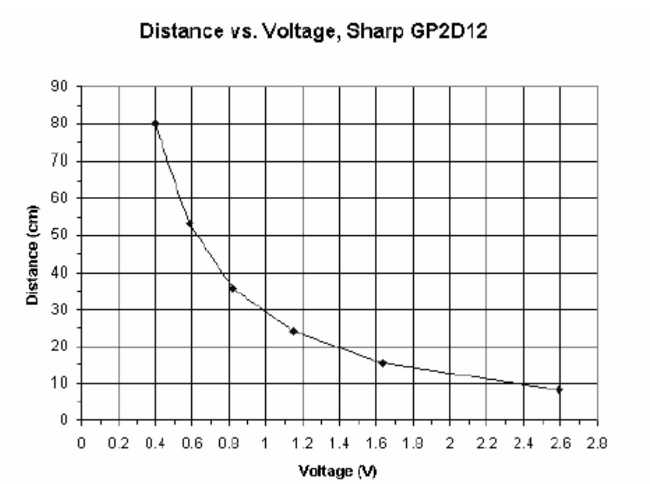

Fig.5. Data Consideration Graph of GP2D12 IR Sensor

A. Software Consideration of Navigated Control System

The input and output consideration of this Module can be seen clearly as shown in Table I. The navigation system employed on this robot is based upon a fuzzy logic control system. Both the path following and obstacle avoidance behaviors are implemented using a fuzzy logic based architecture. Each behavior consists of a set of fuzzy control rules and a fuzzy inference module. The output from each behavior is not be a crisp control value, but is instead a fuzzy set. These sets are then combined through a command fusion module and defuzified to produce a crisp output value.

The output of the path following behavior produces a fuzzy set representing the desired turning direction while the output from the obstacle avoidance behavior produces a fuzzy set representing the disallowed turning directions.

B. Consideration of Rules for Obstacle Avoiding and Navigating

1) Path predetermining state

The system must be pre-limited for going straight distance, turning left or right and returning back straight to the starting point for no obstacles condition.

2) Obstacle avoiding state (obstacle is detected at the front)

Table I Outputs from Navigation System depend on its Inputs

State No.	Input data	Detected Sensors	Decision to WMR	Output data	No. of Pulse
1	00000	None	Forward	100	12
2	00001	1	Left 150°	101	4
3	00010	2	Left 120°	101	8
4	00011	1,2	Left 120°	101	8
5	00100	3	Left 120°	101	8
6	00101	3,1	Right 60°	110	8
7	00110	3,2	Right 30°	110	4
8	00111	3,2,1	Left 150°	101	4
9	01000	4	Right 60°	110	4
10	01001	4,1	Stop	111	12
11	01010	4,2	Stop	111	12
12	01011	4,2,1	Stop	111	12
13	01100	4,3	Right 30°	110	4
14	01101	4,3,1	Stop	111	12
15	01110	4,3,2	Stop	111	12
16	01111	4,3,2,1	Stop	111	12
17	10000	5	Right 30°	110	4
18	10001	5,1	Stop	111	12
19	10010	5,2	Stop	111	12
20	10011	5,2,1	Stop	111	12
21	10100	5,3	Right 30°	110	4
22	10101	5,3,1	Stop	111	12
23	10110	5,3,2	Stop	111	12
24	10111	5,3,2,1	Stop	111	12
25	11000	5,4	Right 30°	110	4
26	11001	5,4,1	Stop	111	12
27	11010	5,4,2	Stop	111	12
28	11011	5,4,2,1	Stop	111	12
29	11100	5,4,3	Right 30°	110	4
30	11101	5,4,3,1	Stop	111	12
31	11110	5,4,3,2	Stop	111	12
32	11111	All	Stop	111	12

The system must be stop for a while. It must turn to the left and check if there is any obstacle or not in this turning state. And then it will return to right and go straight at normal line.

C. Obstacle is detected at the left

Stop for a while whether one or both left sensors are detected. The system must turn to right and check if there is any obstacle or not in this turning state. It must return to left and go straight at normal line.

D. Obstacle is detected at the right

The system must be stop for a while whether one or both right sensors are detected. It must turn to left and check if there is any obstacle or not in this turning state. And then it will return to right and go straight at normal line.

E. Software Consideration of Motor Drive System

The Block diagram of Motor Drive System that used in this research is shown in Figure 6.For Software consideration, the inputs and outputs considerations of Motor Drive System should be made as shown in Table II. For the assembly software programming of the control circuit, the process is very simply and the procedure can be mentioned as the following steps.

1. Initialization
2. Ports Declaration: all Port B's pins are declared as inputs, four MSB Port C pins are declared as outputs for Stepper and four LSB Port D pins are declared as outputs for H-bridge circuit.
3. Start program:

Check RB 2 high or low
Check RB 1 high or low
Check RB 0 high or low

4. Determined outputs:

- If all inputs data are low outputs Port D pins, "1010" for freely going forward for DC motor and make sure stepper in 90 degree.
- If one or more input pins are high, detail checking state are to be considered.

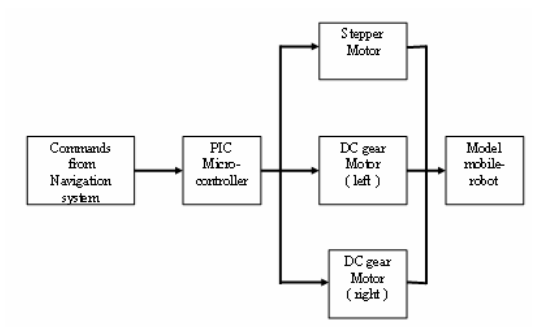

Fig. 6 Block diagram of Motor Drive System

In Table II, the inputs bits from navigation system are mentioned as (bit2 bit1 bit0). The output bits of Stepper Motor are also mentioned as (bit3 bit2 bit1 bit0) and for two DC motors' outputs, bit number are mentioned as (bit1 bit0) of Motor1 and that followed by (bit1 bit0) of Motor2.Although outputs of stepper are the same pulses data, depend on given pulses number of input data, it rotate in different angle ,e.g. if the input is given as four pulses of "101", it make output of 150° while eight pulses of that make output of 120°. For two DC Motors' output, it can be clearly mentioned by applying H-bridge circuit.

Table II Motor drive System Inputs – Outputs Considerations

I/P state	**No. of Pulses**	**Direction**	**Stepper O/P**	**DC Motor O/P**
100	12	Forward	0101,90°	1010
101	4	Left	0101,150°	0010
101	8	Left	0101,120°	0010
110	4	Right	0101,30°	1000
110	8	Right	0101,60°	1000
111	12	Stop	0101,90°	1111

VIII. EXPERIMENTAL RESULTS

For Obstacle detection part, the result of data confirming of GP2D12 is shown in Figure 5.The main consideration result of this Control System, Navigational Consideration is made as shown in Table I. The experimental results of the Modeling and SIMULNK procedures of Motor Drive System are shown in Figure 7 and Figure 8. This Figure shows the result of analyzing the DC Motor internal circuit that it is suitable to use or not using MATLAB. And the Experimental results of Control System testing circuit for this process are shown in Figure 9.

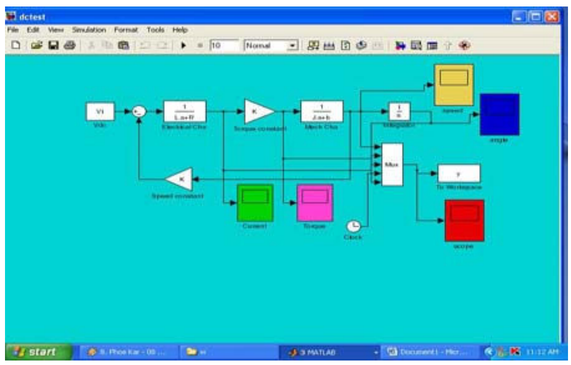

Fig.7. DC Motor Model created in MATLAB SIMULINK

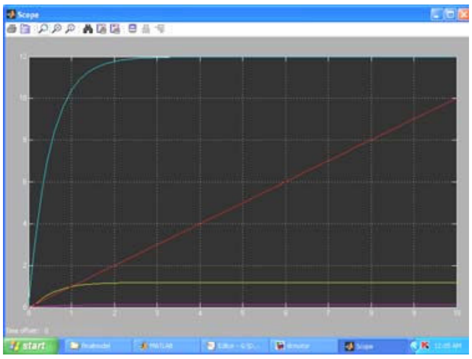

Fig.8. Scope Output of all Ratings

Fig.9. DC Motor Driving Circuit Testing Photos

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