OBSTACLE DETECTION AND AVOIDANCE SYSTEM

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OBSTACLE DETECTION AND AVOIDANCE SYSTEM

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

IR	Infrared
VFH	Vector Field Histogram
APF	Artificial Potential Field
LED	Light Emitting Diode
DC	Direct Current
PI	Proportional Integral
WD	Wheel Drive
DOF	Degree of Freedom
PWM	Pulse Width Modulation
PCB	Printed Circuit Board

SISTEM PENGESANAN DAN PENGELAKAN HALANGAN

ABSTRAK

Teknologi kian menuju ke arah automasi dan manusia kini ingin menyiapkan kerja-kerja dengan cara automatik. Sistem pengesanan dan pengelakan halangan telah dikaji untuk aplikasi dalam mesin-mesin. Komponen elektronik seperti alat pengesan dan kereta robot telah diguna pakai untuk mengkaji pergerakan sistem. Sistem ini banyak diaplikasi dalam kenderaan di ruang yang tertutup. Respon alat pengesan terhadap bahan di sekeliling telah dikaji untuk memastikan sistem ini berkesan. Alat pengesan telah ditetapkan untuk mengesan halangan dalam jarak yang tertentu dengan beberapa ujian untuk menentukan jarak yang sesuai. Tindakan ini dilakukan supaya sistem ini dapat berjalan dengan lancar. Algoritma sistem telah dilaksanakan supaya kenderaan boleh mengelak halangan selepas mengesan halangan. Kereta robot telah direka untuk mengelak halangan yang terletak di hadapan kereta robot dan bergerak kembali laluan yang lurus. Kereta robot membuat keputusan dengan cara Logik Fuzi mengikut keadaan yang ditentukan. Kereta robot dapat bergerak dan mengelak halangan dalam masa kurang daripada tiga puluh saat. Ujian telah dibuat untuk mengesahkan pergerakan ini.

OBSTACLE DETECTION AND AVOIDANCE SYSTEM

ABSTRACT

Current technology trend is moving towards automation and people need things to be done automatically. The obstacle detection and avoidance system is being researched to study its application in automated machine. Few electronic components like sensors and robot car as experiment tool are needed to study this system and the motion or kinematics of the system is also studied throughout the research. The application of this system is mostly for moving vehicle in indoor. In order to make this system works, the effect of obstacle material in the environment to the response of the sensing unit is studied and few experiments are carried out to ensure better performance in the system. The determination of the threshold distance to be set in the sensors will get the system to work better in obstacle avoiding. The algorithm on how the robot car responses when obstacle is detected is also designed. The algorithm sets to interpret the data obtained from the sensor and makes the decision for the mobile robot to react. The robot car is designed to avoid obstacle detected in front of the robot car and continues to move back the path in straight line. The robot car makes its own decision using Fuzzy Logic method to avoid obstacle with the condition set. The robot car able to move and avoid obstacle in less than thirty seconds of response time with experiment conducted as prove.

CHAPTER ONE

INTRODUCTION

1.1 Research Background and Motivation

The automation system is now the trend for the current technology. People nowadays are looking forward to make things done with less man power. Robot is a machine designed to execute multiple tasks and it could be remotely or autonomously controlled (Rouse, 2016). Autonomous robots have now become popular because of their reliability and great performance for doing tasks. Every autonomous robots have primary operating requirement which is to have an obstacle detection system installed (Agarwal, 2015). For moving vehicle to perform autonomous task, it needs a system that helps to get to know the surrounding for ease in movement. Mobile robot vehicle usually equip with system to detect obstacle for ease in remote control while autonomous robot need extra obstacle avoidance system for its automatic operation (Eom & Jeon, 2014). Obstacle detection and avoidance system is designed to ensure that autonomous robots able to move automatically when task is given.

In obstacle detection system, an electronic component is needed to detect obstacle and send certain signal to microcontroller for further process. Sensing unit such as ultrasonic sensor, infrared sensor, stereo vision camera and bump sensor have played their role in obstacle detection and they are needed to acquire robot’s environment status for robot decision making in avoidance system (Agarwal, 2015). Transducer like ultrasonic sensor and infrared sensor are fast, accurate, reliable and inexpensive for obstacle detection application (Uman Khalid, 2015). Reliability of these transducers can be high due to the ease in control using sensor fusion method with the processing by microcontroller (Berisha et al., 2016).

Apart from obstacle detection, obstacle avoidance system performs the decision making process to give command to the robot car to react. The microcontroller used will process data and give commands to the robot to control the movements of the DC motors when condition is fulfilled. The most common method used by many previous works is Fuzzy logic method which this method provides sequential control in robot car movement when condition is met and the sequence of command will then continue for reloop (Berisha et al., 2016).

This obstacle detection and avoidance system is getting more common now. This system has commonly applied in most of our daily life like in some car with parking assistance, robot vacuum cleaner. The technology for this field is evolving and there are many methods or algorithms for the operation of system (Sharma et al., 2014). This system should have algorithm that have certain condition set to let the robot to response ahead once the condition is met. The algorithm of the system helps to control the DC motors to move the robot car out of obstacle. This project has the main objective to control the robot car to response to different type of obstacle after detection.

1.2 Problem Statement

Every autonomous robot is able to work on its own because there is environment sensing unit equipped (Bartók & Vásárhelyi, 2017). Different environment has different type of obstacle and most of the mobile robot is designed to move in indoor. Once the working environment for the mobile robot is interpreted, the control for the robot movement will be easier (Berisha et al., 2016). The different type of obstacle in terms of size and material of the obstacle will affect the response time for the robot car. The problem of response time of the robot car for some of obstacle has to be solved to achieve similar result (Kang, Kim, Noh, Han, & Ko, 2014). Position sensing of obstacle is the core of the project to help in obstacle avoiding (Bartók & Vásárhelyi, 2017).

The mechanical error in design of car wheels has given a problem of imbalance movement. Closed-loop control is able to correct the motor performance with the help of sensor (Suman & Giri, 2016). Optical encoder sensors are used in both wheels and implementation of closed-loop system is to provide balance movement of DC motors. After obstacle detection, mobile robot system needs a suitable algorithm for decision making using the input data obtained from the sensors (Berisha et al., 2016). The decision can be set according to the working environment.

1.3 Project Objectives

In order to implement an obstacle detection and avoidance system, objectives in the followings are set for this project:

I. To design a system for the robot car to detect indoor obstacle using ultrasonic sensor and infrared sensor for obstacle avoidance purpose.

II. To design the kinematics of robot car in avoiding each obstacle and continue back to its straight line path with response time of less than 30 seconds.

1.4 Research Scopes

The application and case study for this system is mainly on the household appliance like vacuum cleaner robot. The environment studied for this system is similar to living environment with flat surface for movement and obstacle that made of commonly used materials like wood, metal and fabric. The obstacle detection range for the system is limited for ahead for robot car and not underneath the robot car or along the moving path. The project is also assumed to be applicable in indoor environment only.

The assumption made for this project is the friction on the surface for movement is assumed to be similar as like most of the home environment. This system is assumed to be worked only for obstacle environment that suits the robot car size. The obstacle used for the project is fixed with size of width not more than 15cm.

1.5 Thesis Outline

This thesis consists of five chapters which explain and discuss the project in detail. Chapter one discuss the research background, problem statement of the project, project objective and research scopes. Chapter two presents the literature review from the previous work. The use of sensor type, algorithm and control system from previous work are discussed. The advantage and disadvantage of the techniques are also discussed. Chapter three presents the project methodology. This chapter presents detail in components used in the project. Project overflow and how the algorithm works are also explained in this chapter. Chapter four presents the result and discussion from the related experiment for the project. Results are obtained after experiments conducted. Discussion is also made from the results obtained. Chapter five presents research conclusion. It summarizes the research outcome and suggests future improvement.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

In this chapter, previous works done with various techniques related to the project problem statement are reviewed. There are two sections which are section 2.2 and section 2.3 that have discussed the components that need to be used and have done by previous works. In section 2.2, the sensor characteristics and working principle are discussed. In section 2.3, the algorithm used by previous work is discussed. Section 2.4 covers the summary for this chapter.

2.2 Sensor

From the previous works done by others, sensors as a sensing device are used by most of the works to get to know the robot's environment. The input signal was received from robot's environment and could be distance measured for further processing in control system (Panda et al., 2016). Application of sensor was common in previous works. In general, sensors could be categorized as passive sensor and active sensor. Passive sensor sensed the changes in the surrounding in term of light intensity, temperature and many more. Active sensor emitted energy in form of waves and received the waves reflected by the objects. Infrared sensor and ultrasonic sensor are the typical example for passive sensor and active sensor respectively (Raghavendra et al., 2016).

Apart from the category of passive and active sensor, sensors could be also contact type like limit switch and non-contact type like ultrasonic sensor and infrared sensor. Non-contact sensor or device like ultrasonic sensor and infrared sensor were better choice than contact device because non-contact device would get the environment input without any collision or contact for better avoidance mechanism (Koval et al., 2016). Ultrasound wave in ultrasonic sensor provided fast response with delay time of only microsecond, low cost and non-contact so it is widely used (Ke et al., 2017). Its detection range was minimum at 2cm and maximum at 200cm with good accuracy (Maddukuri et al., 2016). The working principle of ultrasonic sensor was transmitter part of the sensor will transmit a pulse signal with certain frequency and the receiver part of the sensor would take a role to receive the pulse signal after reflected from the obstacle. The distance between the sensor and obstacle could be known by calculating the time interval of the reflection of signal by the microcontroller that used with the sensor (Mustapha et al., 2013). The working principle of ultrasonic sensor was illustrated in Figure 2.1.

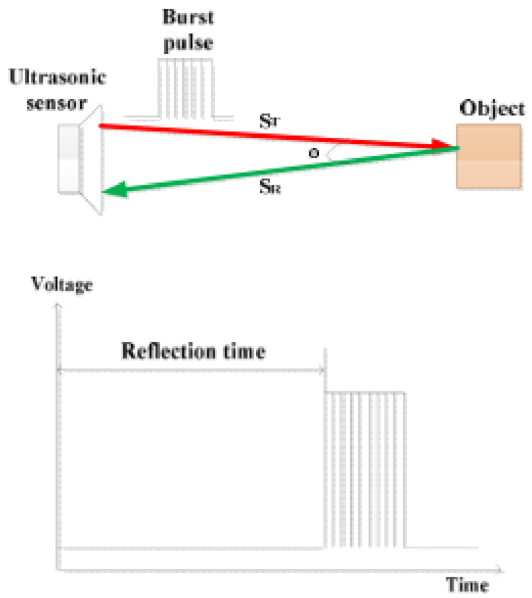

Figure 2.1: The working principle on the process of distance measurement by ultrasonic sensor (Mustapha et al., 2013).

Besides of ultrasonic sensor, infrared (IR) sensor was also one of the non-contact sensors in the market. IR sensor had slightly more advantage than ultrasonic sensor because of its higher resolution of 1cm and ultrasonic sensor had resolution of approximately 2cm. Infrared sensor had slightly better performance in distance measurement because its emitted signal was through beam while ultrasonic sensor emitted signal in divert waveform (Mustapha et al., 2013). However, there was disadvantage for IR sensor because its range of detection was very narrow and it will not give accurate result if the obstacle was too far (Kang et al., 2014). IR sensor could be mainly divided into two types which are thru-beam type and diffuse reflective type (Javed, Tariq, & Khalid, 2017). The general working principle for both types of IR sensor were illustrated in Figure 2.2 and Figure 2.3 respectively. The thru-beam type IR sensor was not applicable because the transmitter and receiver parts needed to place in separate location while the diffuse reflective type IR sensor had both transmitter and receiver part to place parallel to each other to operate (Javed et al., 2017). The working principle of diffuse reflective type IR sensor was similar with ultrasonic sensor which the transmitter part will emit the laser beam signal and the receiver part would receive the reflected signal. The distance measurement depends on receiver IR LED which would produce a certain voltage after receive the signal. The sensitivity of IR sensor and range of detection could be varied by tuning the potentiometer (Javed et al., 2017).

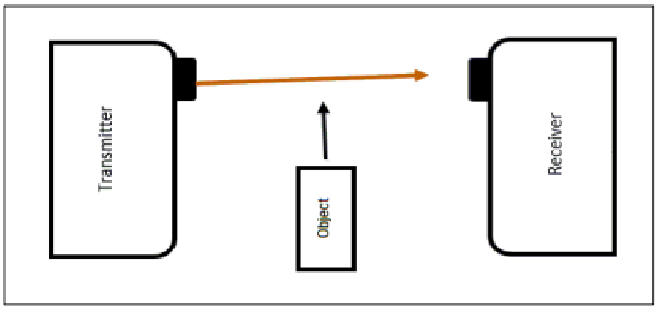

Figure 2.2: The working principle of thru-beam type of IR sensor (Javed et al., 2017).

Both ultrasonic sensor and IR sensor had their own pros and cons in distance measurement. There was a previous work by Mun-Cheon Kang team where they used both IR sensor and ultrasonic sensor for more precise distance measurement. IR sensor had narrow range of detection and it helped to detect the near obstacle while ultrasonic sensor with sound wave detects the further obstacle (Kang et al., 2014).

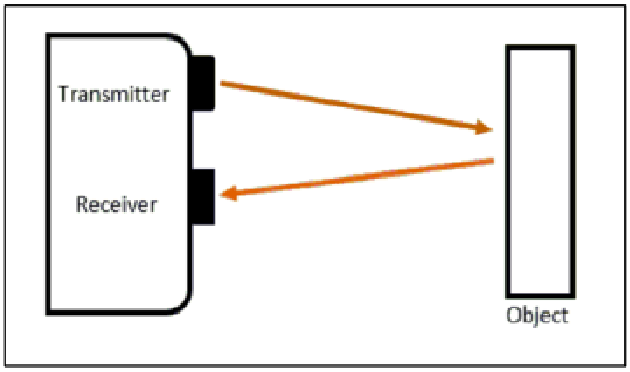

Figure 2.3: The working principle of diffuse reflective type of IR sensor (Javed et al., 2017).

2.3 Kinematics of Mobile Robot System

2.3.1 Mobile Robot Movement

The mobile robot kinematics motion could be divided into few types of motion. The motion of robot could be altered by controlling the wheels rotation. Wheel drives would also limit the degree of freedom (DOF) in movement of robot car like 2WD would only need to control 2 motors to vary its DOF and 4WD car needed 4 wheels movement control. The major motions for robot car were forward, backward, right and left movement (Berisha et al., 2016).

The control of moving forward and backward of robot car was similar which is to send Pulse Width Modulation (PWM) signal from microcontroller to motor driver to the same forward or backward pin to actuate this motion. The speed of DC motors might vary and the error correction can be done by using Proportional Integral (PI) controller where one of the motor was set as master unit (Suman & Giri, 2016). The motion for left and right movement could be control by varying each spinning direction of DC motors to alter the rotating axis of robot car along the centre axis B as shown in Figure 2.4. The turning axis or degree of rotation for both left and right could be adjusted by setting the speed of motor to response to the command from microcontroller. For switching direction in kinematics of mobile robot system, the elements that affect the switching direction were speed of response and switching degree (Berisha et al., 2016). Both elements affect each other if speed high than the switching degree would be greater. The speed of response could be controlled where two motors spin for fast response and only one motor spin for slower response. Common kinematics model showed direct 90 degree direction change for left or right movement change in mobile robot system. The motion of motor should be spinning opposite with each other for faster response. For slower response, one of the motor spins would change the direction or axis of robot car where if turn to left, right motor spins only and vice versa. 2WD mobile robot is easier to control than 4WD where only two motors need to be controlled. There was also another motion which was motor stop to control the stop of robot car. The stop of robot car was not in real time which will delay awhile due to the inertia of motor spinning and the friction of moving surface. The tolerance of car stop should be set and remarked (Zaki et al., 2014).

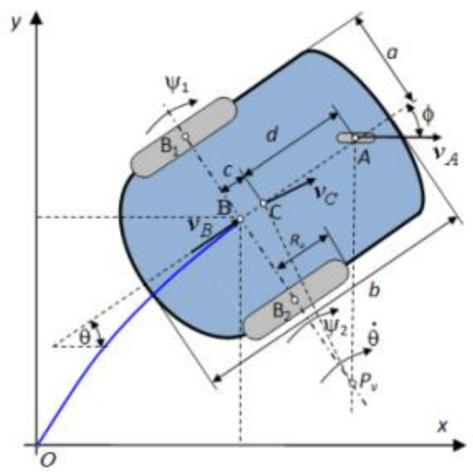

Figure 2.4: Top view of mobile robot system (Berisha et al., 2016).

2.3.2 Proportional Integral Derivative (PID) Controller

The robot car movement especially when moving forward and backward would face certain issue like the robot car would deviate and move away from the correct path. This was due to the DC motors were not moved synchronously. PID controller was the less expensive solution and it was feasibly utilized since 1940s as control application (Suman & Giri, 2016). Proportional Integral (PI) controller was commonly applied in DC motor speed control because Derivative element mostly was very small until it was negligible (Suman & Giri, 2016). The function of this controller was to control the velocity rate of DC motors using the formula in equation 2.1 (Suman & Giri, 2016). Equation 2.1 showed the transfer function or general formula for PID control which had three elements like Proportional, Integral and Derivative.

$$G(S) = K_P + K_I \frac{1}{S} + K_D S \tag{2.1}$$

K_P was the Proportional gain or constant which controlled the present error and took the role to compensate the error based on the value set (Suman & Giri, 2016). K_I was the Integral gain or constant which worked to compensate past error based on the value set (Suman & Giri, 2016). K_D was the Derivative gain or constant which worked to correct the future error calculated based on the value set (Suman & Giri, 2016). All of the constants were the sensitivity needed to correct where the sensitivity in compensating the error would be high if greater constant value was applied (Suman & Giri, 2016). However, there was trade-off where too high value set would cause oscillation so tuning was needed to get the appropriate value. The tuning sequences started from Proportional, Integral and then Derivative element.

2.3.3 Mobile Robot Moving Environment

Many previous works were reviewed and most of project had their approach using line following mechanism. Line following mobile robot system was widely applied and the mobile robot system movement would be more precise (Almasri et al., 2016). Line following provided ease in the calculation of path planning because the track for mobile robot system was fixed (Almasri et al., 2016). Line following approach had few advantages and ease in program or control is the significant advantage. However, line following approach had few limitation. Addition of sensor was needed for line following approach. One of the limitation is the movement of mobile robot system was not flexible in experimental setup and line following approach was not suitable to apply widely in daily application (Almasri et al., 2016).

Besides line following approach, mobile robot system was also designed to move in open environment with sensors to guide in obstacle avoidance operation by Kun Qian's team project. Open moving environment without line following was a challenge in control of robot car. This approach provided ease of application widely but there is challenge to program so that the robot car able to function in different moving environment (Qian, 2015). Disadvantage of this approach was path planning for this approach involved more complicated calculation and configuration in program code.

2.4 Algorithm

2.4.1 Fuzzy Logic Method

There were many methods that have been done by many previous works. The most common techniques were to have the environment condition upload to the controller for further process and it is some sort like maze solving (Kumar et al., 2017). The other technique was creating an algorithm that let the controller to make decision once certain obstacle was detected and this technique was be known as Fuzzy logic method (Bartók & Vásárhelyi, 2017). Fuzzy logic was a better way to make the robot car to operate automatically with its own decision. Fuzzy logic method involved conditioning method with IF *certain condition*, THEN *certain action*. This method able to let the controller to make its own decision and control the DC motor movement (Berisha et al., 2016). This method was commonly applied and it was easy to control with any condition set for decision making purpose.

2.4.2 Vector Field Histogram Method

There was few approach by previous work on obstacle avoidance. The vector field histogram (VFH) was a real-time obstacle avoidance method that used the two-dimensional Cartesian histogram grid from the analysis of sensor data to perform a two-stage data reduction process (Almasri et al., 2016). The two-dimensional histogram was converted to a one-dimensional polar histogram and the most suitable sector with low polar density was selected (Almasri et al., 2016). The steering angle in that direction would then calculate. A known problem of the VFH was that the robot could only detect static obstacles.

2.4.3 Artificial Potential Field Method

The Artificial Potential Field (APF) was also another method used to find the shortest path between the starting and target points (Almasri et al., 2016). The obstacle produced a repulsive force to repel the robot while the target produced an attractive force to attract the robot. The total force on the robot could be calculated based on the attractive and repulsive forces. This approach was very sensitive to the environment.

2.4.4 Bug Algorithm

Another obstacle avoidance method was the Bug algorithm where the robot followed the boundary of each obstacle in its way until the path was free (Almasri et al., 2016). The robot would move toward the target without taking into account any other parameters. This was the simplest method compared to the others and applied more in line following robot. It involved the addition of accessories like black tape for sensor to detect for the boundary of obstacle to aid the algorithm.

2.4.5 Algorithm Comparison

In general, the common algorithm worked with the sensor such as ultrasonic sensor attached in the front of robot car and the sensor would collect or sense the environment every few microseconds in real time. The microcontroller would process the input data and give command to the robot car for obstacle avoidance. The decision making could be improved by using two different type of sensor like ultrasonic sensor and IR sensor to gather more precise data (Mustapha et al., 2013). Fuzzy Logic method involved condition set for the algorithm and let the robot to make its own decision in real time. Vector Field Histogram method was also a real time algorithm to calculate the steering angle for the robot car according to the intensity of obstacle detected. Artificial Potential Field method involved the insert of environment data at first for obstacle avoidance use later on but it had the limitation which it could be applied for narrow environment only. Bug algorithm was a real time algorithm and its operation was similar with Artificial Potential Field method where accessories needed to setup to aid in obstacle avoidance.

2.5 Hardware Setup Performance Comparison

Three similar previous works were mainly referred and compared in terms of performance. Kun Qian's team used RGB sensor as sensing unit. Certain obstacle colour was set for the algorithm to detect obstacle. The sensor had different application compared to ultrasonic sensor and IR sensor because RGB sensor worked to detect object colour. Roland Bartok's team proposed an idea to design a robot car to solve maze. Its sensing unit which was IR sensor only was experimented and able to avoid obstacle but in short detection range about 10cm. Through the review of project, Roland Bartok's idea was suitable for wall following robot. However, IR sensors were also suitable to use for short distance obstacle detection. IR sensor performed well in narrow place. Maddukuri's team proposed an idea of using ultrasonic sensor and servo motor. Its sensing unit was flexible due to the use of servo motor with sensing unit. However, this setup needed stop of robot car for data acquisition. All of the setup was referred and improvement was made. In order to design a robot car with response time of less than 30 seconds, the stop of robot car should be avoided. The first setup tested was similar to Maddukuri's team and the problem was found out that the robot car needed some delay for data acquisition. In order to minimize the delay time, the sensors arrangement was changed to three ultrasonic sensors placed in front, left and right of robot car. By referring most of the projects, IR sensor was good in short distance obstacle detection so IR sensor was added to enhance the robot car obstacle avoidance mechanism. The build of the present project used the idea of placing the sensor in the front of mobile robot. The use of sensor was then decided with the reference from previous works especially by Maddukuri's team. Their design was then modified and some improvement was made. The final design was as shown in Figure 4.1.

The algorithm of Fuzzy logic method was used by Maddukuri, Kun Qian and Roland Bartok. The program flow by these previous work was gone through as reference. The application for each project was different but the concept of obstacle avoiding was referred. The algorithm was then developed with some guideline on program flow. The design on algorithm was then improved to achieve the project objective set and the overall concept was similar to these previous works.

Apart from hardware and software developed by the previous works referred, working environment for these previous work was also referred. Most of the previous works worked for indoor environment. Kun Qian's team designed their project to move in any environment in indoor using ultrasonic sensor. Roland Bartok designed the project to work in narrow indoor environment like corridor using IR sensor. Maddukuri's project application was also indoor. By referring these works, the indoor environment was chosen.

The reason was sensor like IR sensor worked well in indoor only. The present project was also tested to work well in indoor environment.

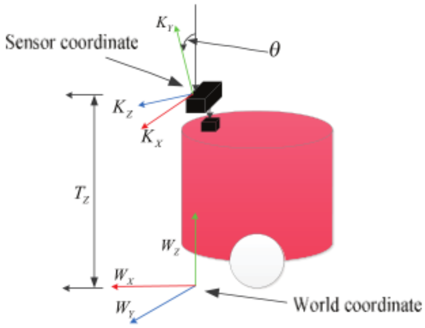

Figure 2.5: The project layout by Kun Qian's team which used RGB sensor as sensing unit (Qian, 2015).

Figure 2.6: The project layout by Roland Bartok's team which used three IR sensors (Bartók, 2017).

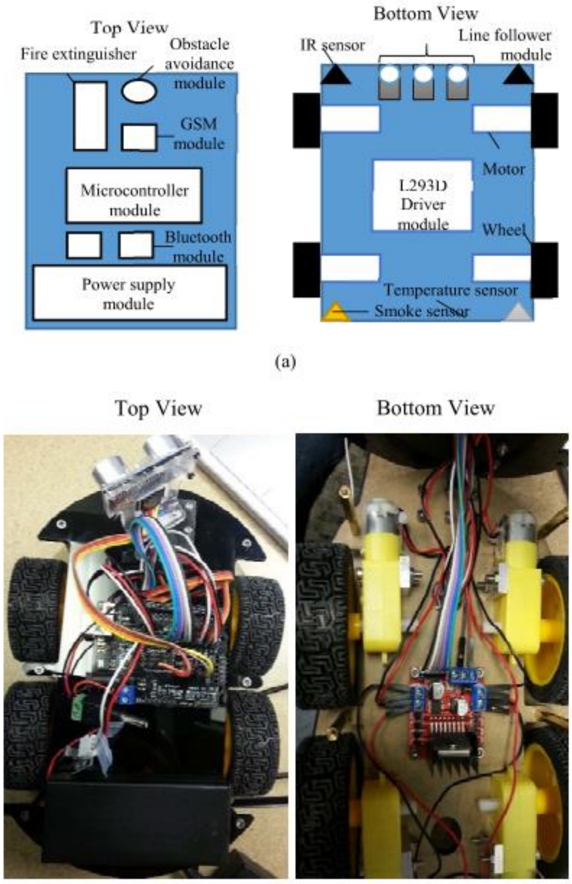

Figure 2.7: The project layout for Maddukuri's team which used ultrasonic sensor and servo motor. (Maddukuri, 2016)

2.6 Summary

In this chapter, the sensing unit used by previous work is discussed. The reason and benefit to use sensor like ultrasonic sensor or IR sensor was discussed. The working principle of the sensors cited from previous works was showed for comparison and decision to use which sensor. Ultrasonic sensor operated with ultrasound wave and has wider range of detection. IR sensor operates with IR laser beam and had narrow detection range. Besides of the working principle, the experimental environment done by previous work was also discussed. The kinematics of robot car movement and way to improve the performance of DC motor using PID controller were elaborated. The method and approach by previous work was also elaborated. The algorithm by previous work and the comparison was made among the algorithm. Hardware setup by previous works were also compared with the present work done.

CHAPTER THREE

METHODOLOGY

3.1 Overview

In this chapter, the project setup in mechanical and electronic parts is explained. There were 6 sections in this chapter. The general flow of the project from the beginning until the ending stage is explained in section 3.2. The components used in this project and their technical details are then explained in section 3.3. Section 3.4 discusses the hardware setup and schematic diagram for the project. Section 3.5 discusses the program flow of the project. Section 3.6 provides the experimental procedure for the project. Section 3.7 is the summary for this chapter.

3.2 Project Implementation Workflow

The project starts with research of previous works and planning is carried out. All of the electronic components are tested out. From the few review from research articles, I decide to use ultrasonic sensor and IR sensor as my sensing devices. In planning process, the other electronic components needed are studied. The sensors and the related electronic components like robot car chassis set are assembled together. Few experiments are carried out with obstacles that have different type of material to watch the response of the robot car when it meets obstacle. Upon experiment, the robot car is implemented with closed-loop system to have balance movement in DC motor. After few experiments, the average distance need to set for sensors is known after the data analysis and the implementation of obstacle avoidance system is further implemented. The project is then further upgraded in term of the kinematics of robot car to achieve the objective of obstacle avoiding and continue back in its straight path. The general workflow is also illustrated in Figure 3.1. The details of implementation process will be discussed in detail in other section.

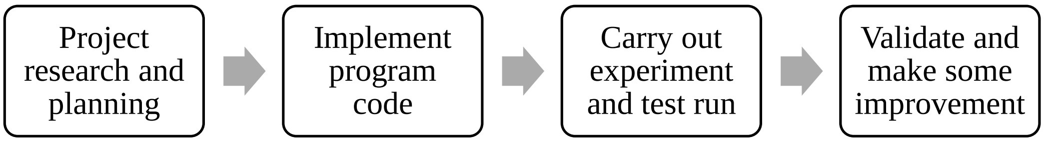

Figure 3.1: The general workflow for the design of obstacle detection and avoidance system.

3.3 Hardware Description

3.3.1 Microcontroller

Microcontroller is a “brain” of the system to process commands using program code. Open source microcontroller is often a best choice. Arduino microcontroller is a common open source microcontroller and it is widely used by researchers. There are many types of Arduino microcontroller in the market. Arduino Nano is picked as microcontroller due to small in size to be carried by smart robot car chassis set.

3.3.2 Smart Robot Car Chassis Set

From previous work reviewed, the obstacle detection and avoidance system project is mostly tested on a small and low cost vehicle for research study purpose. For this project, an inexpensive vehicle which is 2WD smart robot car chassis set is proposed to set the obstacle detection and avoidance system on. There are 2 DC motors to actuate the movement of robot car. These motors are driven by a L298N H bridge module. This motor driver has H-bridge circuit which able to control two motors’ speed and rotating direction at the same time.

The robot car is first assembled and tested with simple code to examine its movement. The mechanical error in robot car is observed and the necessary of closed-loop design is then decided. PI controller is implemented after some test to correct the difference in motor speed for balance in movement of robot car.

3.3.3 L298N H-bridge motor driver module

The DC motors can be powered up from 5V to 16V from the user manual of the robot car. However, 5V from microcontroller itself is unable to power up 2 or more DC motors. Any H-bridge motor driver module is able to power up 2 DC motors. L298N module is picked due to its compact size of well fabricated motor driver so the DC motors can plug with it directly without using breadboard for more stable connection.

This module is controlled by sending Pulse Width Modulation (PWM) signal through microcontroller. The speed of motor able to vary by sending different PWM signal to enable pin. PWM is type of modulation which encodes message in form of pulsing signal like square wave. Duty cycle is an element which control the PWM characteristics. Lower duty cycle, lower speed of motor spins and vice versa.

3.3.4 Optical Encoder

This component looks unnecessary but it plays a quite important role in this project. It has the same working principle like IR sensor. The receiver part is thru-beam type IR sensor and there is another part which is encoder wheel. The program code is coded to calculate the number of times the cutting of the beam of IR sensor part. The counted numbers can be applied to correct the error in speed of DC motor to achieve balance movement for straight car movement. It can also use to get the car moving speed using equation 3.1 (DroneBot Workshop, 2018). Apart from the speed, the application of this component in this project is then further upgraded to count for the steps of robot car moved to complete the sequence in avoiding an obstacle.

$$Speed\ in\ rpm = \frac{number\ of\ count\ when\ the\ encoder\ wheel\ cut\ the\ IR\ beam}{number\ of\ slot\ in\ encoder\ wheel} \times 60 \quad (3.1)$$

3.3.5 Sensing Unit

Sensing unit is very important for this project because it helps to determine the environment condition and the microcontroller will process commands based on the sensing unit's data. Ultrasonic sensor and IR sensor are chosen as sensing unit due to their ease in control and their reliability.

In Chapter 2, the working principle for both sensors is explained and they operate in non-contact condition so they are the suitable solution for the system to detect obstacle before collision. As mentioned before, ultrasonic sensor operates with diffuse ultrasound wave while IR sensor operates in diffuse reflective method. Ultrasonic sensor able to determine the obstacle distance using the formula in equation 3.2 (HC-SR04 Ultrasonic Sensor Datasheet, 2018). It uses the time interval in receiving the transmitted ultrasound signal to get the distance measured. Time in equation 3.2 and equation 3.3 indicates the width of echo pulse in microsecond.

$$Distance = \frac{Time \times Speed\ of\ sound}{2} \qquad (3.2)$$

The distance values measured can be converted into centimetre by equation 3.3 where microseconds is the time taken for the sonar receiver of ultrasonic sensor to receive bounce back sound wave from obstacle (HC-SR04 Ultrasonic Sensor Datasheet, 2018). With certain distance set, the sensor will give command to microcontroller that there is an obstacle ahead if there is any and the robot will avoid the obstacle based on the sequence set.

$$Distance\ in\ centimetre = \frac{Time}{58} \qquad (3.3)$$

The infrared sensor is also able to detect obstacle with distance measured by detecting the brightness of received signal. Its working principle similar to ultrasonic sensor which emits signal and receiver will receive signal with different brightness.

3.4 Experimental Setup

3.4.1 Electronic Circuit Design

All of the electronic components are assembled and constructed as illustrated in Figure 3.2. The 18650 type batteries are used as power supply for the project. Most of the electronic components are powered by 5V power supply from Arduino Nano and Arduino Nano gets its power source from the motor driver which regulates the 9V power from battery to 5V. In the schematic diagram, there are 3 ultrasonic sensors, 2 IR sensors, 2 IR encoder sensors at pin 2 and 3 of Arduino Nano and 2 DC motors. The IR encoder sensors are connected to interrupt pins to acquire the data in real time for processing by the microcontroller. The switch in schematic represents IR sensor or IR encoder module. The layout on how the hardware is set up is also shown in next subsection.

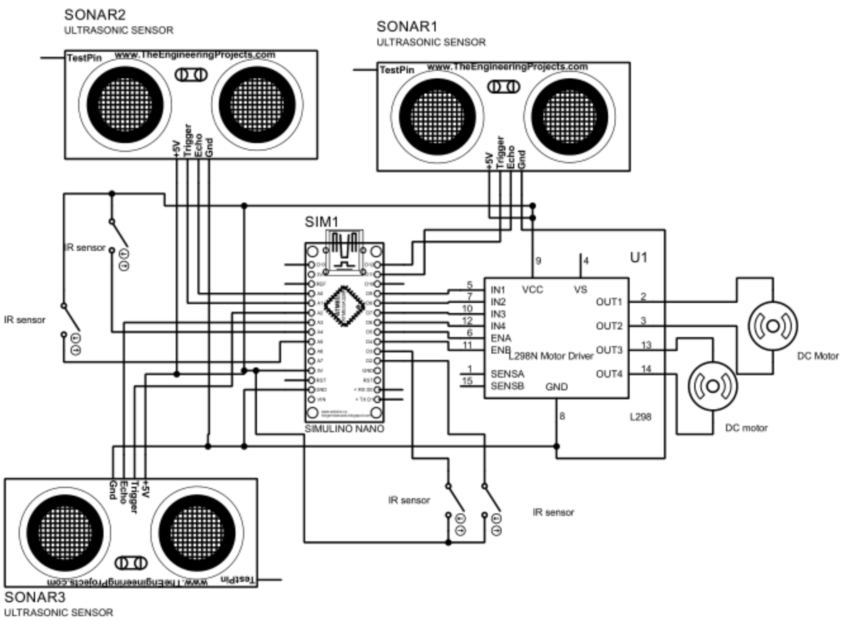

Figure 3.2: Schematic diagram for the project.

3.4.2 Hardware Assembly and Test

Before smart robot chassis set is chosen, few findings are done to find the best hardware to present the obstacle detection and avoidance system. The main consideration factor is whether there is common parts available in market so smart robot car chassis set is chosen because it is common to use by researcher to show the project outcome. The robot car is setup with microcontroller, motor driver, sensors and power supply unit.

In the initial stage of project, the movement of robot car is observed and the problem in imbalance movement of DC motors is found. In order to correct this imbalance movement of DC motors, few research is done and finally come out that a closed-loop controller which is Proportional Integral controller is implemented by using two IR encoder sensor to calculate errors between them. Gain of proportional and integral are tuned in trial and error method with tuning sequence from proportional gain to integral gain. Tuning method for gain value referred to the work by Santosh Kumar Suman's work. The method of tuning each gain was started with increasing them to high value at first to observe for oscillation and then decrease the value slowly until no oscillation was observed (Suman & Giri, 2016).

The project has different setup on the sensors numbers and positions from the beginning of the project. The project is first started with only one ultrasonic sensor in the front of robot car as illustrated in Figure 3.3. The performance of robot car in every obstacle detection and avoidance test is observed and is reviewed for improvement. The improvement is then done with adding another two ultrasonic sensors and the setup was also adjusted in alignment as illustrated in Figure 3.4. This improvement was made because the data acquisition of obstacle with only one ultrasonic sensor is just in front of robot car and the obstacle at the left or right of the car is unable to detect for the robot car to perform correctly. Two ultrasonic sensors are added for better decision making when there is any obstacle at the side of robot car and more data can be collected. Two infrared sensors are then added to enhance the performance of robot car. The two infrared sensors are used to enhance obstacle detection in front of robot car for better obstacle avoidance. This setup was illustrated in Figure 3.5.

The first experiment is then conducted to determine the average distance to be set for the ultrasonic sensor. The testing environment is set up with the moving distance from robot car to obstacle is varied with 10cm, 15cm, 20cm, 25cm, 30cm, 35cm, 40cm, 45cm and 50cm. The response of robot car for different moving distance and speed of robot car set are recorded. The results are then analysed to determine the average threshold distance to be set for the ultrasonic sensor.

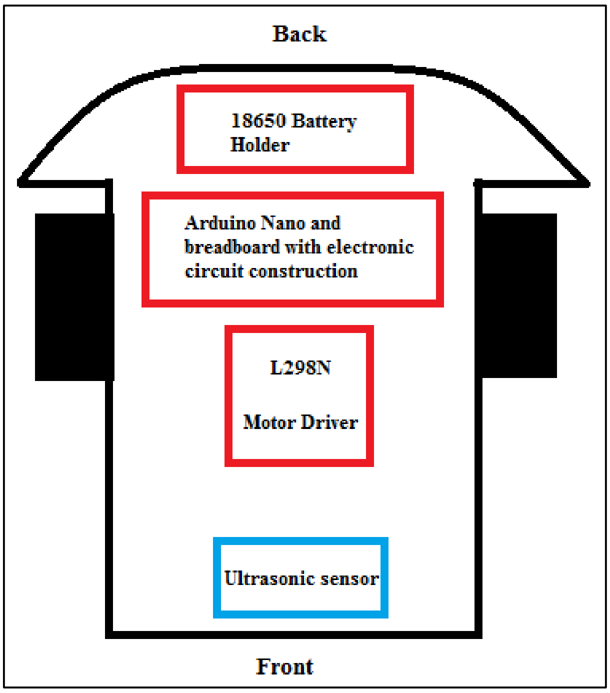

Figure 3.3: Layout of hardware setup with one ultrasonic sensor.