LINE AND WALL FOLLOWER HEXAPOD ROBOT

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A thesis submitted in
fulfilment of the requirement for the award of the
Master of Electrical Engineering

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Dedicated to my wife Balkhis binti Mohamad Sopi and my son Muhammad Solihin. For without your love, patient, support and sacrifice this thesis of mine will never come true. My heartiest gratitude for everything. May Allah bless both of you.

Ameen.

ACKNOWLEDGEMENT

First of all, I would like to send my deepest appreciation to my project supervisor, Dr. Dirman Hanafi bin Burhannuddin for giving me sufficient support and guidance throughout whole year which bringing me out of difficulties of the project.

Also, I would like to thanks my course mates since they were giving me much technical support in term of software and hardware and also contributed some idea during project construction.

Lastly, I would like to thanks my family members in giving me mentally support and motivation. Their advices motivate me to handle the problems faced during the progress of the project. Thanks once again to everyone for technically and mentally support to finish the project. Thank you.

ABSTRACT

Robot widely use to help human to do something, especially for difficult or danger task. To fulfil the robot requirements, some techniques, sensors and controller have been applied. Due to kind of robot is a hexapod robot, which it develops in this research. Hexapod robot is a mechanical vehicle that's walk on 6 legs. A hexapod robot movement are guided with guidance, they are line and wall. Fuzzy logic control as intelligent control is applied to govern the robot follow line and wall. Fuzzy logic controller is used to create a smooth response of robot behaviour rather than logic programming**.** Infrared sensors are used to sense line and distance to the wall as the input variable for the controller. Based on these signals, the controller control the turning angle of forward movement thus making robot to move forward and turning in same time.

ABSTRAK

Robot banyak digunakan untuk membantu manusia untuk melakukan sesuatu, terutama untuk tugas yang sukar atau bahaya. Untuk memenuhi keperluan pada robot, beberapa teknik, sensor dan kawalan telah dilaksanakan. Dalam kajian ini robot Hexapod telah digunakan. Robot Hexapod adalah struktur mekanikal yang berjalan menggunakan 6 kaki. Gerakan robot hexapod dikawal dengan panduan garisan dan dinding. Kawalan Fuzzy Logik diterapkan untuk menetapkan robot mengikuti garis dan dinding. Fuzzy logic digunakan untuk mendapatkan respon robot yang lebih lancar berbanding pengaturcaraan logik. Sensor inframerah yang digunakan untuk membaca garis dan jarak dari dinding adalah sebagai pembolehubah masukkan untuk controller. Berdasarkan bacaan sensor, robot akan mengawal pergerakan ke depan dan juga pusingan pada masa yang sama.

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LIST OF SYMBOLS AND ABBREVIATIONS

cm -	Centimetre
LCD -	Liquid Crystal Display
RC-	Radio Control
ms -	Millisecond
IR -	Infrared
KHz -	Kilohertz
Hz -	Hertz
HIGH -	Logic for true or binary value of 1
LOW -	Logic for false or binary value of 0
“ -	Inches
V*cm -	Voltage multiply with centimetre
LED -	Light Emitting Diode
PIC -	Harvard architecture microcontrollers made by Microchip Technology

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CHAPTER I

INTRODUCTION

1.1 Project Background

Line and wall following method are always popular as robot guidance in moving. Here in this project, this technique is combined together into one robot of 6 legs which called a hexapod robot. Although there are many configurations in 6 legs robot, in this project only use a simple 3 servo hexapod robot. This project only considers a line and wall following using a forward movement of robot. So a simple robot is sufficient to use in this project.

For the control method, fuzzy logic control with Sugeno style infrerence method is used. Wall following method and line following method is done in separate rules but they share a same output. Only one method is trigger in one time. When the line is present on wall, line following method is takes place. But when the line is not present, the wall following method will takes place. There is also simple obstacle avoidance at front of robot to ensure no collision happen at the front of robot. Simulation using Matlab is done to get a good expected output.

For line detection, Auto-Calibrating Line Sensor LSS05 sensors is use. For wall detection, two Sharp GP2Y0A21 distance sensors are use to measure front right and rear right distance from wall at right. PIC16F877A microcontroller is use as main controller for robot. Then the program will be written into this microcontroller for robot operation.

1.2 Problem Statements

Single guidance of autonomous robot tends to have its limits when there are conditions which can limit robot movement. Using line navigation, not all surface of floor suitable can be planted a line as guidance. If using colour line on a high traffic area makes the line more to become dirty or damaged. Using wall navigation, not all paths for movement is along walls. If some space is located at walls, when robot crossing at the front of the space, sensor will detect a far distance. This condition makes false reading of wall. According to these two problems, in this project these two kinds of guidance are applied. Line navigation will takes place if wall navigation cannot be used in certain condition. Fuzzy logic controller is used to create a smooth response of robot behaviour rather than logic programming.

1.3 Project Objectives

Objectives for this project are:

1. To design a hexapod robot with wall and line following behaviour.
2. To design fuzzy logic controller for hexapod robot.
3. To simulate the robot system for design analysis.
4. To test the robot performance at real time.

1.4 Project Scopes

This project is primarily concerned the use of fuzzy in wall and line following into a simple hexapod robot. The scopes of this project are:

a) A wall distance is set on 40 cm and cannot be adjusted to other distance value because of the suitability of the sensor range.
b) Turning movement with fuzzy rules is done in a forward movement of the robot only. Others movement is done in an open loop programming.
c) The wall is considered for the right side of robot only because to lower the cost of sensor needed.
d) Walking surface is on even surface because of the limitation on leg degree of freedom. Also no leg slipping is assumed when the robot is moving.

CHAPTER II

LITERATURE REVIEW

2.1 Technology Developments

There are many researchers who implement fuzzy rules on robot. An adaptive fuzzy line path tracking and obstacle avoidance control method is presented by Baoguo Li and Chunxi Zhang. The mobile robot moves toward the target point by tracking the virtual line path between the start point and the target point. An adaptive fuzzy controller is designed to minimize the tracking error caused by the uncertainty of the mobile robot velocity due to wheels radius error, assembly and gearing errors.

Sakr and Petriu presents a fuzzy logic controller for a hexapod robot that is able to move freely on an uneven surface environment without tipping over. The robot has the feel of the surface it's on through touch sensors located at the bottom of each of the six legs.

Azlan *et al.* describe the development of two miniature LEGO robots, which are the line following and the light searching mobile robots to provide a better understanding of fuzzy logic control theory and real life application for an undergraduate training system.

Yousef Moh. Abueejela Mosbah presented the modeling and development of an autonomous wall following robot which use fuzzy logic as controller. In his method, the sensor reading of distance different at front and rear makes the angular velocity of left and right wheel will be different thus making a turning movement.

2.2 Fuzzy Logic control

Fuzzy control provides a formal methodology for representing, manipulating, and implementing a human's heuristic knowledge about how to control a system. The fuzzy controller block diagram is given in Figure 2.1, where a fuzzy controller embedded in a closed-loop control system. The plant outputs is denoted by $y(t)$, and inputs is denoted by $u(t)$,while the reference input to the fuzzy controller is denoted by $r(t)$ [3].

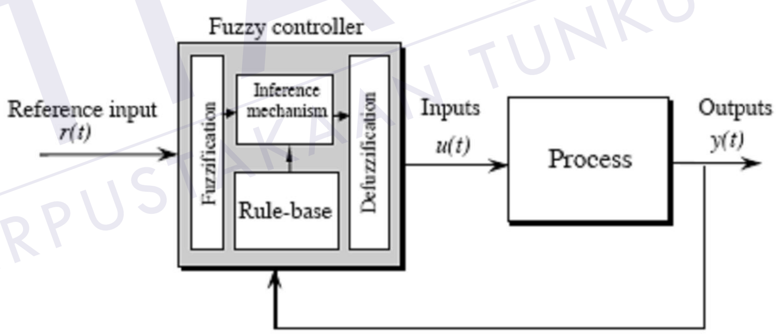

Figure 2.1: Fuzzy Controller Architecture

The fuzzy controller has four main components as below:

1. The "rule-base" holds the knowledge, in the form of a set of rules, of how best to control the system.
2. The inference mechanism evaluates which control rules are relevant at the current time and then decides what the input to the plant should be.
3. The fuzzification interface simply modifies the inputs so that they can be interpreted and compared to the rules in the rule-base.

4. The defuzzification interface converts the conclusions reached by the inference mechanism into the inputs to the plant.

2.3 Wall detection

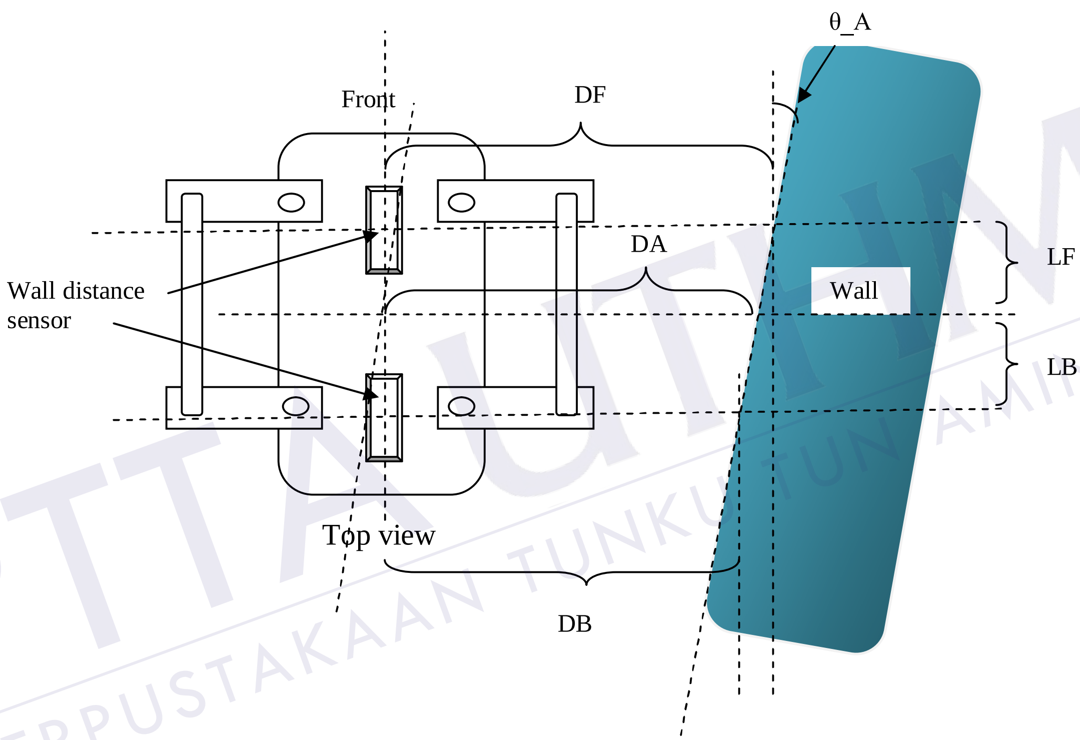

Figure 2.2: Connection between robot position and wall

Based on figure 2.2, DF is distance between front distance sensor and wall. DB is distance between rear distance sensor and wall. DA is distance between wall and the centre of robot. LF is distance between centre of front sensor and centre of robot. LB is distance between centre of rear sensor and centre of robot. θ_A is a angle between robot and wall. The connection of variable above can be described in figure 2.3 as follows:

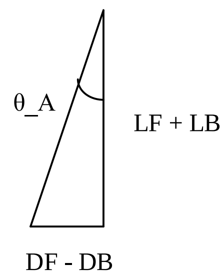

Figure 2.3: variable connection between wall angle and distance

From figure 2.3, equation below is formulated:

$$DFB = DF - DB \quad (1)$$

Where DFB is sensor different value

$$\theta\_A = \text{atan}\,((DFB)/\,(LF+LB)) \quad (2)$$

Where θ_A is angle between robot and wall

Assuming LB is same value with LF then:

$$, DA = (DF+DB)/\,2 \quad (3)$$

Where;

DA is distance between robot and wall

LF and LB is a fixed by distance between centre of two sensor

DF is front sensor reading

DB is rear sensor reading

In this project, LF and LB is set to 4 cm. To make sure robot is still align to the wall, value θ_A must be less than 35 degree. So from equation 2, maximum value of DFB can be derived as follows:

Maximum value of DFB= (LB+LF) tan θ_A

= (4+4) tan 35 = 5.6 cm

Considering this value, maximum value of DFB is set 5 cm. The value of DFB and DA values are used as input to the fuzzy process to generate the value for turning angle, θ_T needed. In fuzzification, input DFB is assumed in linguistic variable as negative, zero and positive with a range from -5 cm to 5 cm. And Input DA is assumed in linguistic values as decrease, steady and increase with a range from 10 cm to 70 cm with 40 cm is a centre distance.

2.4 Line detection

In line following mode, there are a few factors that can influent the performance of robot. The sensor arrangement can affect performance because wrong arrangement the line cannot be detected accurately. In this project, sensor is placed at the centre of robot because at robot centre, the turning effect is very small. Line width also can affect the performance. If the line width is small than specific width, sensors cannot detect the line properly. Here the line width is set to minimum 1 cm related to the line sensor gap is also 1 cm. If the line width is less than 1 cm, the line sometimes cannot be detected. Figure 2.4 shows how the arrangement of the line sensors installation.

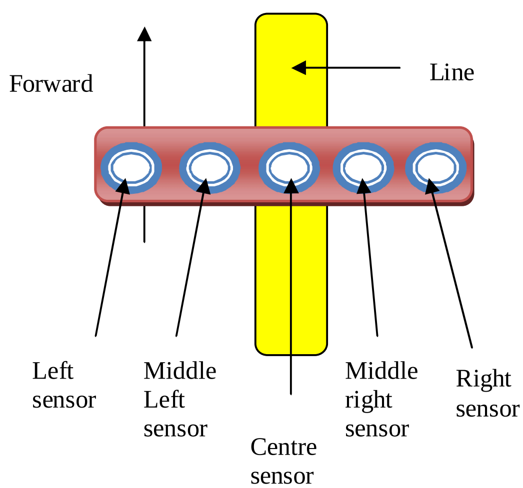

Figure 2.4: The line sensor installation arrangement

Each sensor will give a digital output either line is present or not. Using the arrangement like in figure 2.4, the condition of sensors output with can reflect how the line is place under the sensor. Table 2.1 shows how an analog range is created from sensors output.

Table 2.1: Sensor output to analog value

	Sensor arrangement				
	Left	Mid left	Centre	Mid right	Right
Analog value, L (cm)	-2	-1	0	1	2

Referring to the table above, if left sensor is triggered, L value is set to -2 cm. If two or more sensor is triggered, the average L value is calculated. For example, if mid right and right is triggered, L= (1+2)/2 = 1.5 cm. Then the position of line is located between mid right and right. The value of L will be used as input to the fuzzy process to generate the value for turning angle, θ_T needed. In fuzzy process, input L is defining as left, centre and right with a range from -2 cm to 2 cm.

2.5 Forward movement and turning

In robot fabrication, planning is needed to make sure robot can move. Here how the step of forward movement is planned. Firstly, right leg is in forward position, left leg in backward position and centre leg is lifting the body at left side. Then right leg is moving to backward position which makes a robot body move to forward at right side. At the same time, left leg move to forward position but there is no effect to the body because the left body is still in lifting condition. The details of robot mechanism are represented in figure 2.5 at no 1 and no 2.

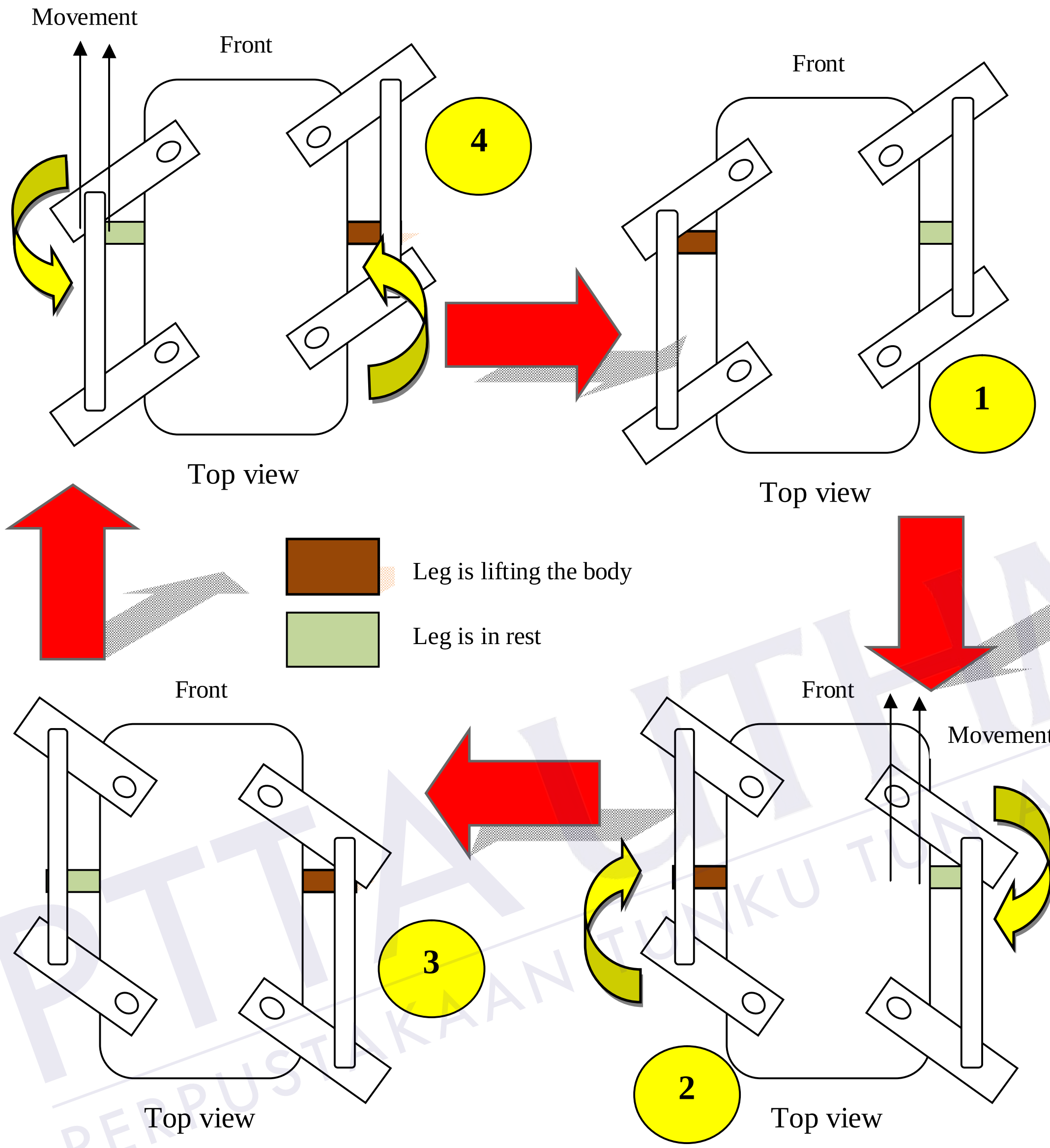

Figure 2.5: Forward movement sequence

After that, the centre leg will change position which cause the robot body is lifting at right position. Then left leg is moving to backward position which makes a robot body move to forward at left side. At the same time, right leg move to forward position but there is no effect to the body because the right body is still in lifting condition. Combinational of forward movement of left and right side makes the forward movement of the robot. . The details of robot mechanism are represented in figure 2.5 at no 3 and no 4.

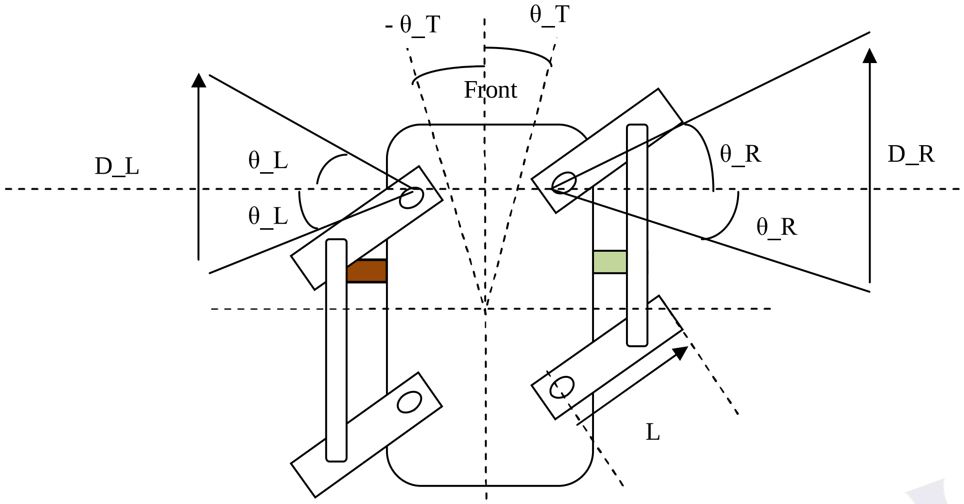

Figure 2.6: Parameter definition

Referring to figure 2.6, there a few parameter defined. L is a leg length. D_L is left forward distance movement. D_R is right forward distance movement. θ_L is left servo angle. θ_R is right servo angle. θ_T is a turning angle of robot body after a complete forward movement. If is positive them it is assume right turn happen but if θ_T is negative, it is assume left turn happen. These parameters can be linked as follows:

$$D\_L = 2 \times (L \times \sin (\theta\_L)) \quad (4)$$

$$D\_R = 2 \times (L \times \sin (\theta\_R)) \quad (5)$$

Where L is assumed same for all leg

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