An Adaptive Mobile Robot with

Gaussian type on Fuzzy Logic Type 2

SITI NUR ALIZA BINTI AZMI

BACHELOR OF ELECTRICAL ENGINEERING
(ELECTRONICS) WITH HONORS

UNIVERSITI MALAYSIA PAHANG

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ASSOCIATE PROFESSOR
FACULTY OF ELECTRICAL & ELECTRONICS ENGINEERING
UNIVERSITI MALAYSIA PAHANG
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Position : Senior Lecturer

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ID Number : EA18020

Date : 22/06/2022

An Adaptive Mobile Robot with Gaussian type on Fuzzy Logic Type 2

SITI NUR ALIZA BINTI AZMI

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College of Engineering
UNIVERSITI MALAYSIA PAHANG

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ABSTRAK

Projek ini merupakan implementasi robot mudah alih dengan menggunakan logic fuzzy jenis 2. Tujuan projek ini adalah untuk mengkaji kebolehan robot mudah aih dalam persekitaran simulasi. Projek ini juga bertujuan untuk memberikan penekanan kepada robot mudah alih dalam mengenal dan membaca peta atau persekitaran sekelilingnya dalam dunia simulasi. Latar belakang simulasi pada robot mudah alih ini adalah berdasarkan pengesanan dan pengelakan sebarang bentuk halangan. Secara ringkasnya, apabila robot mudah alih mengesan sesuatu halangan yang berdekatan dengannya atau berada dijalan untuk menuju ke titk terakhir, robot in akan berusaha untuk mengelakkan halangan tersebut.

Dalam navigasi, keaadan sekeliling dan posisi sesuatu halangan, titik permulaan dan pengakhiran adalah amat penting untuk robot mudah alih mengenal dan mengetahuinya terlebih dahulu. Robot mudah alih memerlukan kordinat tersebut untuk memudahkan perjalanannya. Navigasi robot di dalam dunia simulasi boleh digunakan untuk dianggarkan dengan kedudukan kordinasi titik permulaan, titik pengakhiran dan juga sesuatu halangan. Oleh itu, dalam kajian ini, teknik ‘cost function’ dipilih dalam simulasi Matlab agar dapat membaca dan mengesan titik – tiktik penting di persekitaran robot semasa simulasi.

Disamping itu juga, objektif projek ini adalah untuk mencipta robot mudah alih dalam navigasi dengan menggunakan system logik fuzzy. Serta untuk mencapai tahap perbezaan ralat antara nilai sebenar dan nilai kiraan sistem seminima mungkin. Dengan menggunakan teknik ‘Cost Function’ di dalam simulasi, hasil keluaran berjaya menunjukkan bahawa simulasi robot mudah alih untuk mrncapai ke titik pengakhiran dengan berkesan tanpa melanggar apa – apa halangan. Hasil akhir juga menunjukakan bahawa perbezaan ralat antara nilai sebenar dan nilai kiraan system adalah minima.

ABSTRACT

This is an adaptive Mobile Robot Navigation project based on Fuzzy Logic Type 2. The goal of this study is to investigate the performance of a mobile robot in an environment (navigation). As a result, this project will be emphasized on the outcomes of simulation for the mobile robot in navigation. The background for the simulation will be based on the obstacle avoidance. In brief, when the fuzzy controller detects any potential obstacle nearer or on the way for the robot going to the goal point, the robot will be able to avoid it.

In navigation, the surrounding environment for the robot and the position of the obstacle should be understood ahead of time. The robot is required to navigate to its destination by avoiding the obstacle. In such, the robot navigation in simulations can be estimated using prior information of the coordinates from the beginning point, the goal point, and the obstacle position. Thus, in this research, the cost function method was implemented to evaluate and estimate the robot's surroundings in a simulated environment.

Consequently, the objective of the project is to design a mobile robot in navigation using the fuzzy logic system and to develop the lower state estimation error for both estimated and measured simulation value. By using the cost function and fuzzy logic, the mobile robot navigation was proved as the result shows that the robot was able to avoid the obstacle on its way toward the goal point. Furthermore, the graph shows only a slight difference occurred between the measured and estimated values, indicating that the project was implemented as required.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The intelligence of a mobile robots are known as it can be assist using AI, software, sensors, and many more to explore and recognize their environments to move freely. The capacity to move and explore, transfer payloads or goods, complete tasks through the onboard system, such as robotic arms, and more are the essentials of a mobile robot.

Their advantages stem from their computer vision capabilities. Whereas mobile robots employ a comprehensive array of sensors to watch and detect their surroundings, allowing them to properly observe their environment in real time. This is one of the most important aspects in the industrial sector because it is always changing and evolving.

There are many applications of a mobile robots and one of them is the capability in environment navigation. For a mobile robot device, avoiding a harmful situation such as obstacle and unsafe surrounding is a must. Besides, it was designed with a system that can detect and observe their surroundings. Robot navigation denotes the ability of a robot to determine its own position in the frame as a reference for planning the path to the desired place.

This project involved the application of a cost function with Gaussian membership on Fuzzy Type 2 to examine the performance of a mobile robot navigation in simulation environment. While preparing for lower state estimation to improve the robot performance.

1.2 Problem Statement

In Navigation, the mobile robot mapping is the most crucial aspect, as the mobile robot must know how to go towards the desired destination. Most likely, the mobile robot is unable to navigate properly in the simulation environment due to unable to identify and estimate its location coordinate correctly, which lead to the robot poor performance.

1.3 Project Objective

The aim of this project is to develop a Matlab Simulation and to propose the best Fuzzy Type 2 configurations for the lower state estimation error. To achieve the goals, there are a few objectives that follows:

1. To simulate the Mobile Robot Performance in Navigation.

2. To design the lower state of estimation for better performance.

1.4 Project Scope

There are several parts that needed to be done for this project. First of all, it is to study and get more understanding on the components that will be used in the project, thus the scope covering this project are divided into two parts which is as below:

1. Analyzing the mobile robot Performance and Navigation in different conditions such as with and without a blocking obstacle on the robot path to the target.

2. Determining the best estimation results for Mobile Robot in Simulation Environment.

1.5 Thesis Outline

This section is a summarization of the chapters that were included in this thesis. As stated, the chapters were divided into five sections.

Chapters	Contents	Summarize
Chapter 1	Project Background, Problem Statement, Project Objective, Project Scope.	This chapter introduce or organize the view of the project.
Chapter 2	Literature Review	This chapter is to support the objective of the project and to give a better view for the whole project.
Chapter 3	Methodology	This chapter told the whole process and methods theoretically and mathematically.
Chapter 4	Results and Discussion	This chapter conclude and discussed the outcomes of the project
Chapter 5	Conclusion	This chapter will be summarizing the whole thesis

Table 1 : Thesis Outline

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The main purpose of this chapter is to explore the case study that was created by researching and studying based on the fundamentals of the project's topic, 'An Adaptive Mobile Robot Navigation with Gaussian Type on Fuzzy Logic Type 2'. This study will concentrate on specific components, methods or algorithm that will be finalize to be employ for the project later on.

2.2 Cost Function (Machine Learning)

Subsequently, cost function is known as an algorithm for a machine learning. Supported by (Badillo, 2020), a cost function is created in order to solve the understanding between the input and output parameters for model estimation. Cost function was created having a high potential of accuracy for a machine learning process. In his paper, (Mallouh, 2018) proposed a cost function is a precious algorithm that can define on the performance of a machine learning to correctly estimate the model parameters.

In simulation, the model will be evaluated for its performance. While accuracy functions indicate how well the model is functioning, it does not provide guidance on how to improve it. As a result, a correctional function was used in figuring out when the model is the most accurate, to find that sweet spot between an undertrained and an overtrained model.

As suggested by (Badillo, 2018) Cost Function is used to calculate how incorrect the model is in determining a relationship between input and output. It indicates how bad the model estimation is.

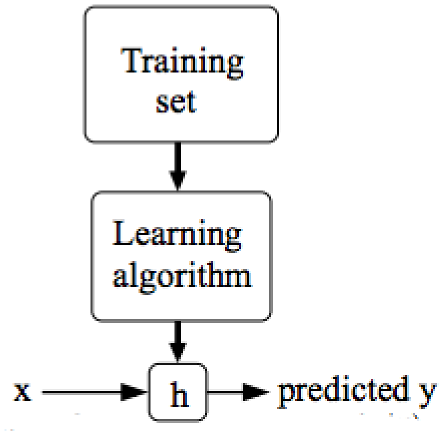

Figure 1 : CF Basic Block Diagram

In explanation, the cost function will explore the simulation environment and this state was called as training set, which it will train the model to knows the whole way in the setup environment. While, exploring this algorithm will locate and secure the important information such as the coordinates and position for anything instruct in path of x and y.

$$Output = a*Input + b$$

Equation 1 : CF Regression Equation

According to the equation, the two entities are changeable variables, a is an intercept point focused on x-axis while b is for the slope. First, the variables must be optimized properly so that it can fit the model properly. This will decide on how the data points later on whether the result muddled by noise or not. Thus, this algorithm are good for a robot to learn the simulation environment so that it can navigate through without colliding with any blocking obstacles.

2.3 Kalman Filter

Kalman Filter is known as an algorithm that provides the estimation of some unknown variables based on given measurements that is observed over time. It has been known for its functionalities that is useful in a various application. Kalman Filters is also known for having a simple form and its special ability to perform work on computing resources.

However, understanding and implementing the Kalman filters remains difficult for persons who are unfamiliar with the estimate theory. According to study (Kim, 2019), it provides a basic introduction to Kalman Filtering by starting with the most basic of all estimation problems, namely estimating a time independent scalar quantity from a set of noisy observations. Then investigate generalize the results to the estimation of a time dependent vector. Finally, showing how the resulting Kalman Filter equations may be used to a simple but actual navigation problem.

current estimation

measured value

$$\hat{X}_k = K_k \, . \, Z_k + (1 - K_k) \, . \, \hat{X}_{k-1}$$

Kalman Gain

previous estimation

$$x_k = Ax_{k-1} + Bu_k + w_{k-1}$$

$$z_k = Hx_k + v_k$$

Equation 2: Kalman Filters Basic Equations

The Kalman filter has been widely used for mobile robot navigation and system integration. Kalman filter is the iterative mathematical process that uses a set of equations and consecutive data inputs to quickly estimate the true value, position, velocity of any object or mobile robot that is being measured when the measured value contains unpredictable or variation or random error that is also known as uncertainty. The equation as shown as above are often used in order to solve the Kalman Filtering problem on the system (Esme, 2009).

2.4 Fuzzy Logic Controller

Fuzzy logic control system can be described as a mathematical system that analyses analogue input data in terms of logical variables with continuous values ranging from 0 to 1, as opposed to classical or digital logic, which operates on discrete values. Fuzzy logic is applied in artificial intelligence (AI) systems to mimic human reasoning and cognition. Instead of strictly binary examples of truth, fuzzy logic allows 0 and 1 as extreme cases of truth but with varying degrees of truth in between.

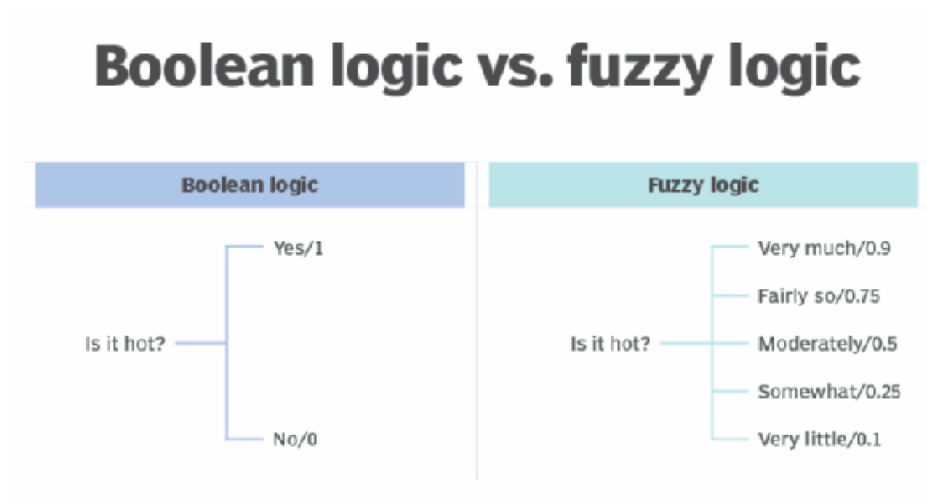

Figure 2: Simple Explanation for Fuzzy Logic

Fuzzy Logic Control is suitable for controlling a mobile robot as it was capable of making inferences even under uncertainties. Fuzzy logic control assists rules generation which settled by the fuzzy logic controller and decision making. Fuzzy logic operation performs by assigning the output based on the linguistic rule information. Where, it performs the approximate reasoning based on the human way of interpretation to achieve the control logic output.

A Fuzzy logic system were designed with two basic behavior such as, obstacle avoidance and a target seeking behavior. Therefore, a fuzzy logic controller is suitable to be used in a mobile robot navigation. For mobile robot navigation, several research have been done to investigate the fuzzy logic system. There's research (Hao Li; S.X. Yang, 2003) that proposed an obstacle avoidance approach using fuzzy logic, but the sensors are inferred. Another study shows some fuzzy logic methods for robot navigation (Iridia, 1997). Next paper proposed for fuzzy logic based model for mobile robot's navigation in an environment (S.M. Raguraman, 2009).

This project will be easy to understand with the material found for fuzzy logic system because many ways have already been studied and proven.

2.4.1 Fuzzy Logic Type 2

Based on the topic given, the focus of the study will be on fuzzy logic type 2. From the understanding, a fuzzy logic type 2 is more an advanced system or more robust that allow us to incorporate the membership function of uncertainty into fuzzy set theory.

A general membership function for fuzzy type-2 set, is where the value of the membership function is in the third dimension at each points of 2D domain that is known as Footprint of Uncertainty (FOU).

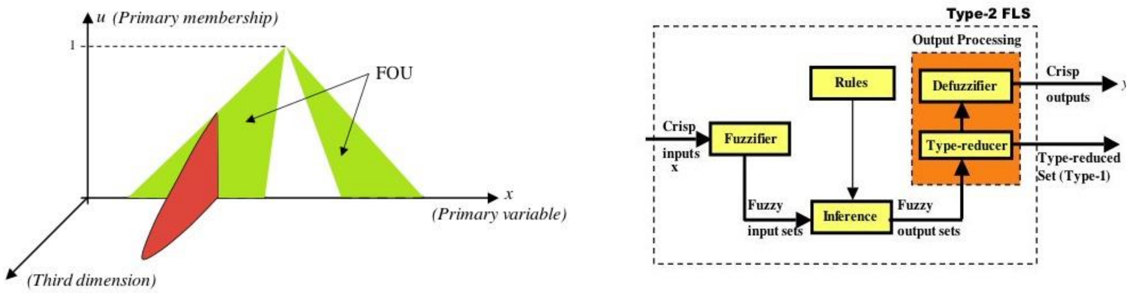

Figure 3: Figure shows for Footprint of Uncertainty (FOU) with A block diagram of Fuzzy Logic Type-2

According to the research (Castillo, 2019), that used fuzzy logic type-2 for path tracking and obstacle avoidance. The research was validated and tested using an autonomous mobile robot (AMR) in which they studied starting from the kinematic model and adapting the technique of linear and angular speed control, with the goal of minimizing the orientation and position error within the line that serves as a path to the vehicle.

2.4.2 Gaussian Membership

According to the findings, the Gaussian Membership Function was the major membership for an interval type-2 Fuzzy Set (W. Burgard, 2008). Gaussian MFs are popular methods for specifying fuzzy sets because of their smoothness and concise notation. These curves have the advantage of being smooth and nonzero at all points.

Based on algorithms, they present a new learning approach for learning optimal interval type-2 Gaussian fuzzy sets for sparse fuzzy rule-based systems (S. M. Chen, 2011). Gaussian fuzzy sets were built using a new sparse fuzzy rule base and interval type-2 Gaussian fuzzy sets, where each interval type-2 Gaussian fuzzy set corresponds to a type-1 Gaussian fuzzy set in the original sparse fuzzy rule base.

2.5 Literature Summary

From the research, I learn that the control navigation system is a method to determine the movement taken by the mobile robot in the existing environment. In modelling the robot position, it is crucial to know the main components that are combined as the vector states variable, which contains the coordinates and its orientation. A smart navigation was implemented in mobile robots, therefore by using fuzzy logic its can determine a right decision for the mobile robot movements. Fuzzy logic Controller esteem to be very suitable applications in mobile robot for navigation, as it seems to be said because the capacity of fuzzy logic controller to process the quantities of inaccurate input signals are big so that it can easily process the signals for automatic navigation in mobile robot. Thus, it is another important way or method for a mobile robot system to be using the fuzzy logic to reach its desired position of target goals. Besides, for a simulation the cost function algorithm believed to be a good method for the robot to learn the environment in simulation. Which made the whole navigating system is easier and more accurate in estimate the information.

CHAPTER 3

METHODOLOGY

3.1 Introduction

The main purpose of this chapter is to explore the case study that was created by researching and studying based on the fundamentals of the project's topic, 'An Adaptive Mobile Robot Navigation with Gaussian Type on Fuzzy Logic Type 2'. This study will concentrate on specific components, methods, or algorithm such as the Cost Function with Fuzzy Logic Type 2 Controller, and Gaussian Membership. All the components were employed in the project to obtain the final outcomes of analysis for an adaptive mobile robot performance and navigation in different conditions such as having to simulate with and without the blocking obstacle.

3.2 Flowchart Diagram

The diagram below was stated in order to illustrates the progressed for the proposed solution for the project.

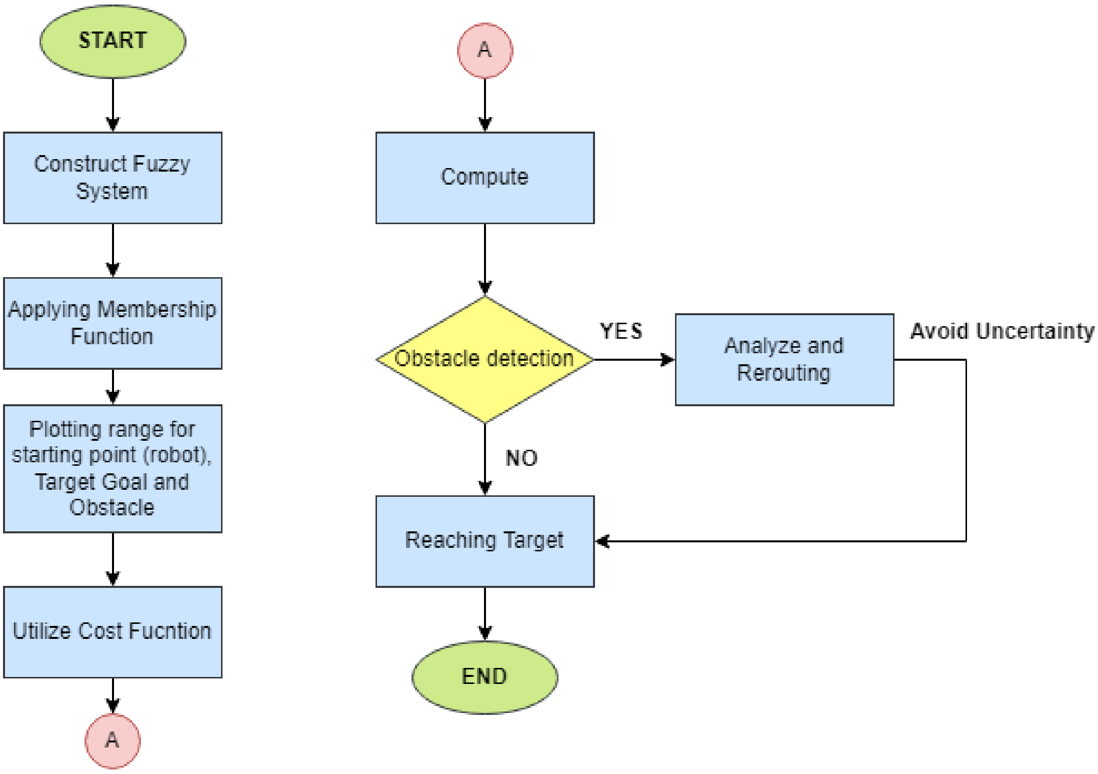

Figure 4 : Flowchart for Proposed Solution (Methodology)

This project was created based on Matlab Simulation software. By using the codes this project was successfully implemented in simulating an adaptive mobile robot in navigation. From the flowchart, you can see the progress flow for the project.

For a simple explanation of the project, a block diagram will be provided so that it can be seen easily on how the system's work. In this project, a cost function formula was used to help with the robot navigation. By using this algorithm, the robot can learn the simulation environment and it can help the robot to identify the locations that were decided on where the robot will be starting to move, and the location for the obstacle whether it block the robot path going to the target destination and of course lastly the location coordinate for the destination as for where the robot should stop.

3.3 Project Block Diagram

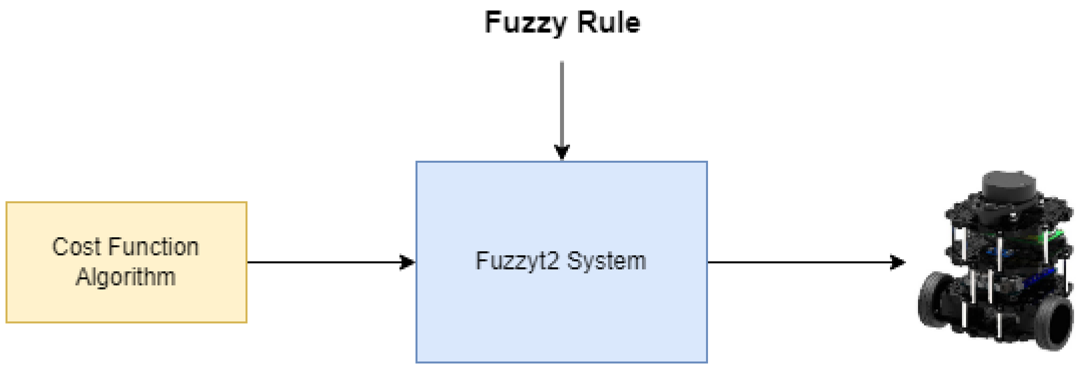

Figure 5 : Project System Block Diagram

For this block diagram, the robot used was only for an illustration as this project was based on simulation only. As illustrated, the system will be starting with the cost function. Here, this algorithm will explore the simulation environment and calculating the unit force vector for the direction from the robot to the target (F_t) and the obstacle (F_o). Later this information will be sent as an input to fuzzy type 2 system.

The information from the cost function will be transfer as an input to fuzzy logic system. Next the second stage which is rule evaluation stage, the fuzzy reasoning will be applied to the data so that the fuzzy logic can give an output instruction for the robot to process the output information. The fuzzy reasoning stage will be explained under the fuzzy logic part based on table 6.

3.4 Fuzzy Logic Type 2 Implementation

By Lotfi Zadeh, fuzzy logic was implemented in 1965 at the University of California. It was used as a way to express the process of a computer on true values over the binary values. Literally, it was used as method in processing the data, however later on it was used as a strategy controller.

Fuzzy logic Controller esteem to be very suitable applications in mobile robot for navigation. It is to be said because the capacity of fuzzy logic controller to process the quantities of unfinished and inaccurate input signals are big that it can process the signals for automatic navigation in mobile robot.

There are three steps to the process in fuzzy logic type 2. It is depicted in the diagram below.

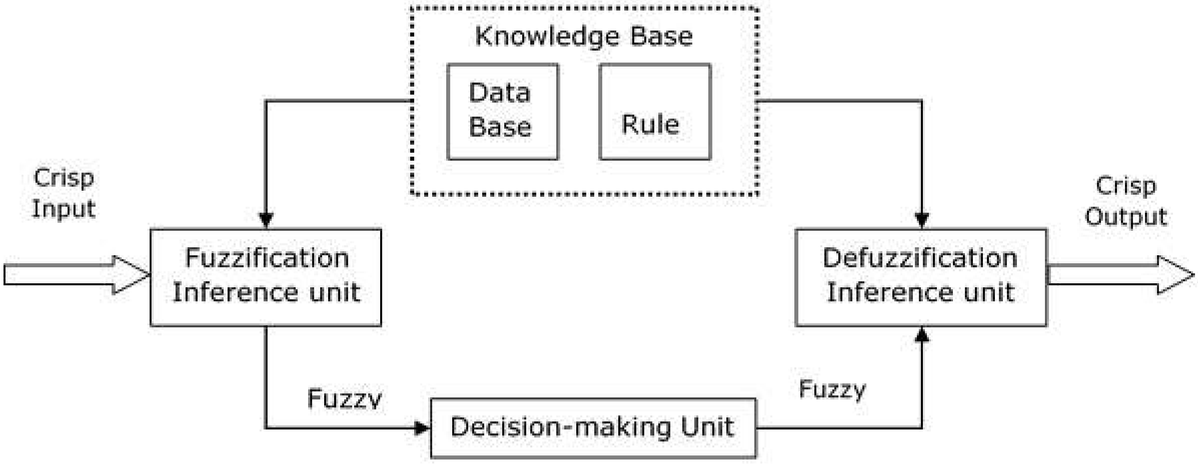

Figure 6 : Fuzzy Logic Block Diagram

Fuzzy logic system are commonly used in making decision. It works like a simple code that use the rule of 'IF, THEN" along wit "OR" and "AND". Based on the block diagram fuzzy logic controller works following three main steps which is :

i. Fuzzification

ii. Knowledge Base (Rule Evaluation)

iii. Deffuzification

Fuzzification is a unit that support numerous fuzzification's application method. This actively demonstrate that the fuzzy input was converted from the crisp input. The next step is the knowledge base stage or also known as the rule evaluation stage, where all rule and the database is collected which later will be formed as the conversion of fuzzy input from the crisp input. The last stage is defuzzication. Here, all the fuzzy input will finally be converted into the crisp output.

Fuzzy logic type-2 was created as an extension concept for an ordinary fuzzy set that were also known as fuzzy type-1. Type-2 fuzzy logic provides dispersion measure as it acts as the basis of the design systems that contain linguistic or numerical uncertainties that were described into the rule of uncertainties and a variance as the mean (Ren, 2011).

In this project, fuzzy controller will be receiving the information from the cost function as its input. The system will be creating the rules for the fuzzy system to navigate the mobile robot. The cost function was chosen as it consumed lower state of mathematical process. Besides, in this project only small rule bases were used. Fuzzy reasoning is only for 5 rules which will be explain in the table below:

Rules	**Robot to Obstacle (α)**	**Difference between Robot to Target (θ)**	**Robot Heading [-π/4, π/4]**
1.	Low	High	Low
2.	High	Low	High
3.	-	High	Low
4.	High	High	Low
5.	Low	-	Low

Table 2 Fuzzy Reasoning (Rules)

To simplify, in the table the first rules means that if the obstacle is far from the robot path the robot, then will speed to the target. And in the second rule, if the obstacle is near to the robot and it's blocking the robot path to the target then the heading angle will be in high state as the robot is avoiding the obstacle. The other three rules are created for any possibilities that might happens for the robot and the obstacle. In the end, these rules were created so that the robot are able to avoid any obstacle that were blocking it path on going towards the target.

3.4.1 Membership Function (Gaussian)

Fuzzy logic was commonly used for controlling system, identification system, recognition pattern problems and many more. To sum up, the membership function plays an important role in representing the overall of fuzzy performance. Know that the membership functions were blocks that are built from the fuzzy set theory, which the fuzziness in a system(fuzzy) is determined by their own membership functions. Based on the different types of membership functions that were used, the outcomes will also be in different shapes such as triangular, trapezoidal, Gaussian and so on. Hence, the membership function only condition in fuzzy logic control is that it must decide the values between 0 and 1.

3.5 Cost Function

In mobile robot navigation, the surrounding environment, such as the target point, goal, and obstacle positions, must be understood ahead of time so that the robot can simply compute the result. In an unfamiliar or new environment, the mobile robot must self-teach its location, goals, and detect any potential obstacles. Thus, the cost function method was implemented in this research to assist the mobile robot in learning its new surroundings. The cost function enables the mobile robot to learn navigation in a simulation environment. This allows the robot to effortlessly proceed from the target to the objective goal by assessing the surroundings to determine whether or not an obstacle is present.

However, there are three types of cost function in a machine learning process. Each were used depending on the cases whether it is a problem with regression or classification. Whereas, for this project the cost function method used is for classification problem as the technique needed to recognize the important coordinate locations for the robot, the obstacle, and the target.

Considering that the problem is classified to three cases like robot, obstacle and target. Then the learning model will provide with three probability distribution for these three classes so that it can comes up with an output data which later will be send as an input to the fuzzy logic controller.

Class (Robot, Target, Obstacle) --- (1)

Robot = [1 0 0], Target = [0 1 0], Obstacle = [0 0 1] -------------------------------- (2)

In this part, there will be two situation that were considered by the algorithm. First is the ratio consideration for the distance between the robot and the obstacle (α), and next is the difference for the direction of the obstacle and the target respected to the robot ($\theta_{t,o}$).

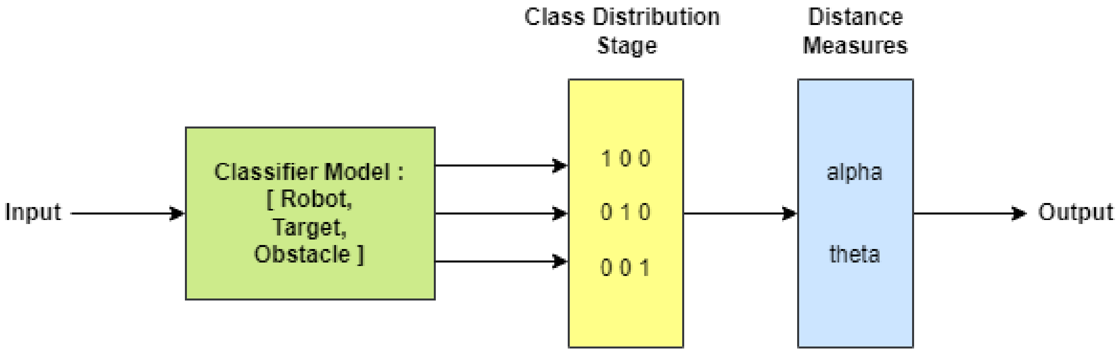

Figure 7 : Cost Function Block Diagram

To identify the problems, the classification methods were used. On which is the input and the output for the robot model to choose so that it can mark the positions of the target and the obstacle. Assuming that all the input class distribution as ‘n’ and its data for ‘D’.

In order to provide a collision free path for the robot, the vector will be calculate using the formula shows below. This is to assume that the robot has a kinematic simulation so that it can turn or rotate while avoiding the blocking obstacle. Thus, the degree set for the is limited to (-45, 45) degrees.

$F = wF_o + (1 - w)F_t$, where $0 \leq w \leq 1$ -- (3)

$\theta = \angle F$ -- (4)

$\theta_r(k + 1) = \theta_r(k) + \min(\max(\theta - \theta_r(k), \frac{\pi}{4}), -\frac{\pi}{4})$ -- (5)

Equation 3 are used to calculate the force vector of a distance ratio between robot to target and the obstacle to target respected to the robot. While equation 5 is to decide the turning angle for the robot so that it can avoid the blocking obstacle.

3.5.1 Cost Function Equation and Implementation

As introduced before, this project will be using a linear regression cost function. A straight line is used to fit a linear regression model. This is accomplished by utilizing the straight line equation, as shown:

$$\text{Cost Function (J)} = \frac{1}{n}\sum_{i=0}^{n}\left(h_{\Theta}\left(x^{i}\right) - y^{i}\right)^{2}$$

Equation 3 : Cost Function linear regression

As illustrate in the figure, the cost function linear regression formula is used to estimate its lowest error value. Here the minimal root mean squared is used to calculate the model minimal error by subtracting the expect or predicted values with the measured values.

$$\text{Gradient Descent } \theta_j = \theta_j - \alpha \frac{\partial J}{\partial \theta}$$

Equation 4 : Linear Regression Gradient Descent Function

This equation is used to define the error that will constantly appeared while the model is exploring the unknown area. The small difference of errors can be determined by differentiate and subtract the values of errors from the previous step. Equation 4 will determine the value of ‘J’. In addition, the alpha is the rate of learning that can decide on how fast the model can explore. Here the value of the alpha must be optimized perfectly because if the value is too big, the learning state for the model will miss the noise that led to inaccurate data and if the value is too small it will cause the model to drag the computational power.

To sum up everything that has been stated so far, all the information (values) from the cost function will later be transfer to fuzzy logic as an input. So that fuzzy can compute the data to the robot and navigate its accordingly.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

This chapter is to actively demonstrate all the outcome of the project. The results will be discussed to see whether the objective for the project is achieved.

4.2 Fuzzy Logic in Navigation

Considering the requirement for the project is to develop an adaptive mobile robot navigation in a simulation environment, the cost function algorithm was applied along with fuzzy logic. These techniques are proposed to can help the robot to explore in the unknown simulation area. Considering that, this project followed by the case study of two condition where, the Fuzzy Logic was implemented in navigation with and without the blocking obstacle on the robot path.

Since the fuzzy inference system starts with no rules or reasoning, the FIS tuning procedure is required (Liang, 2000). Tuning is the modification of a fuzzy set that alters the shapes of the fuzzy sets defining values in order to define the membership functions. This method depends on having a set of training data against which to calibrate the controller. Mentioned in (Herrera, 1995) in a fuzzy tuning process the training data are compulsory, as the data is a pairing of the desired input and output data of a fuzzy sets. In short, a fuzzy tuning process can be illustrated as a skilled controller behavior, which applied the rules in fuzzy logic to control and instruct the robot.

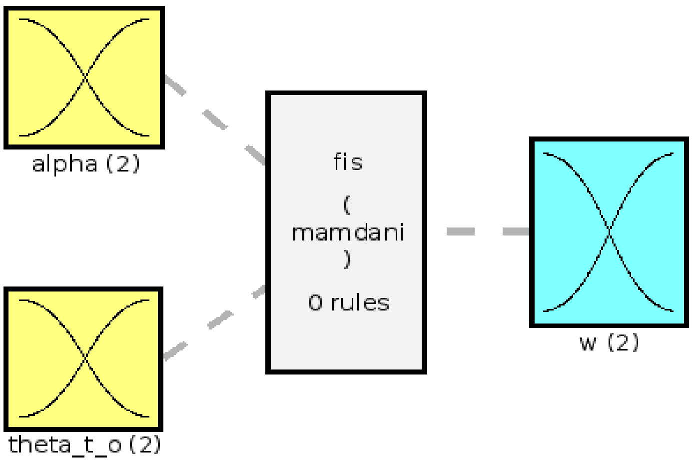

Figure 8 : Fuzzy Logic Before Tuning Process

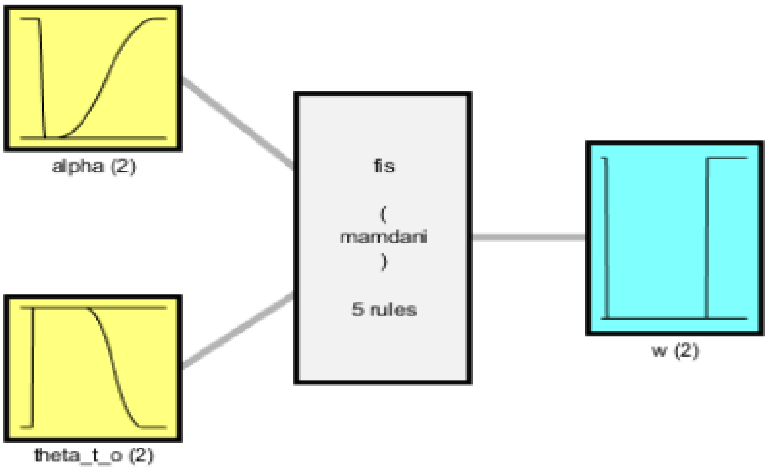

Figure 9 : Fuzzy During Tuning Process

A figure of fuzzy tuning process is illustrated as in figure 9. As mentioned before the fuzzy inference system starts with zero reasoning, and by tuning the fuzzy system the rules are created so that it can be applied to the robot.

After the tuning process, the first condition is obtained to represent the first case study, which is no obstacle blocking the robot path. For this reason, when the obstacle is not on the robot path, the robot will just move straightly towards the target without any difficulties as stated in Fuzzy Reasoning table on methodology.

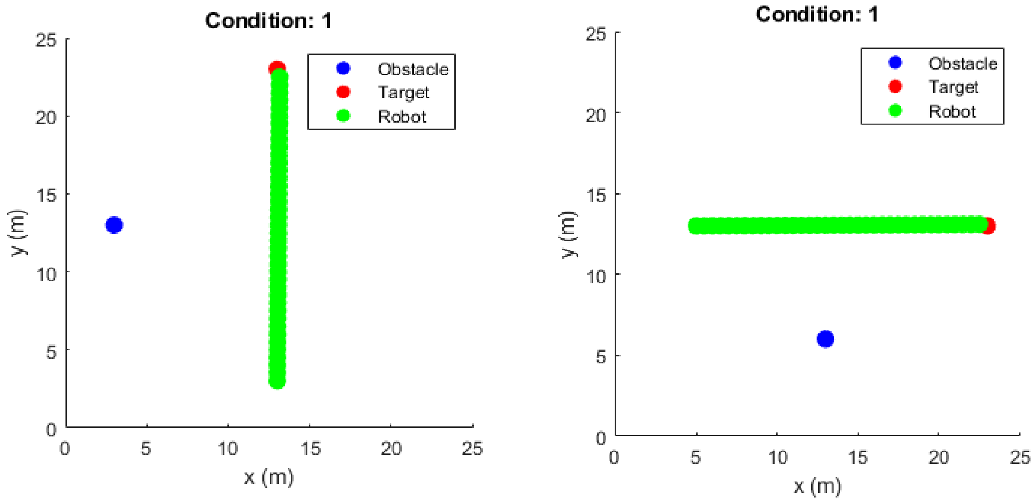

Figure 10 : Result for Condition 1

For the second condition the tuning process is done to represent the second case study where the obstacle is blocking the robot path. The cost function will calculate and estimate a new path while that the fuzzy tuning system is creating the rules so that the robot can be navigated to avoid the blocking obstacle and move forward towards the target. Along with it, a research proposed by (Miguel, 2009) supported that the Cost Function is capable of recognizing changes in the environment; if an impediment is placed in the path of the robot, it begins the rerouting process in order to bypass the obstructing object and reach the destination node.

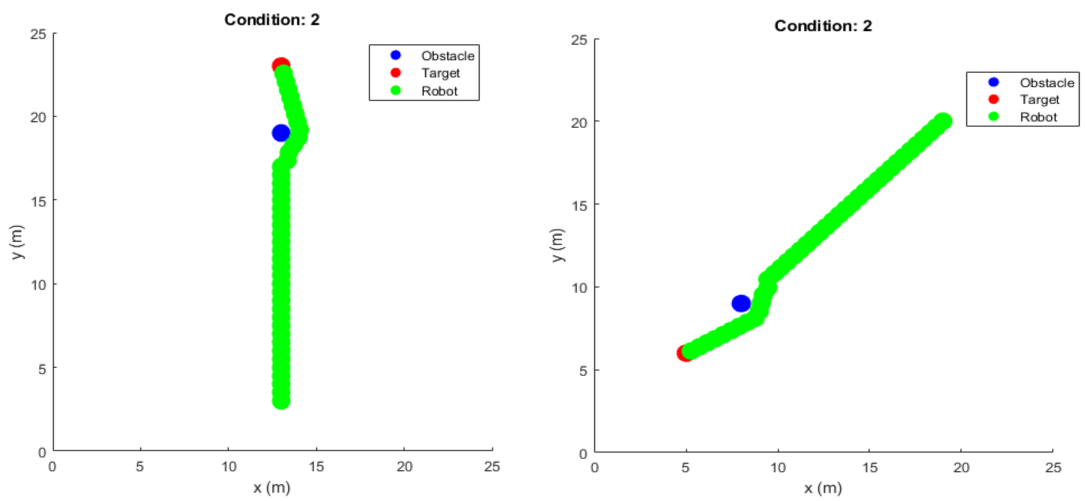

Figure 11 : Result for Condition 2

4.3 Gaussian Membership

In this section, the figures that illustrate below are to depicts the gaussian membership for fuzzy type 2. Gaussian Membership Function is to obtain the best estimation results. By taking account on the mobile robot behavior during the obstacle avoidance the gaussian membership functions are easier to represent for a small rulebases system. As it has a better convergence and has the most stable accuracy for a mobile robot navigation system.

Subsequently, in his paper (Wu, 2019) stated that Gaussian are simpler in design since they are easier to express and optimize. He noted that each Membership Function type has advantages that vary depending on the application. Taking account on this project the gaussian were used as it is always in a continuous state whereas trapezoidal depends on a certain act. Thus, the gaussian memberships are smoother and more controllable which stabilize the mobile robot performance.

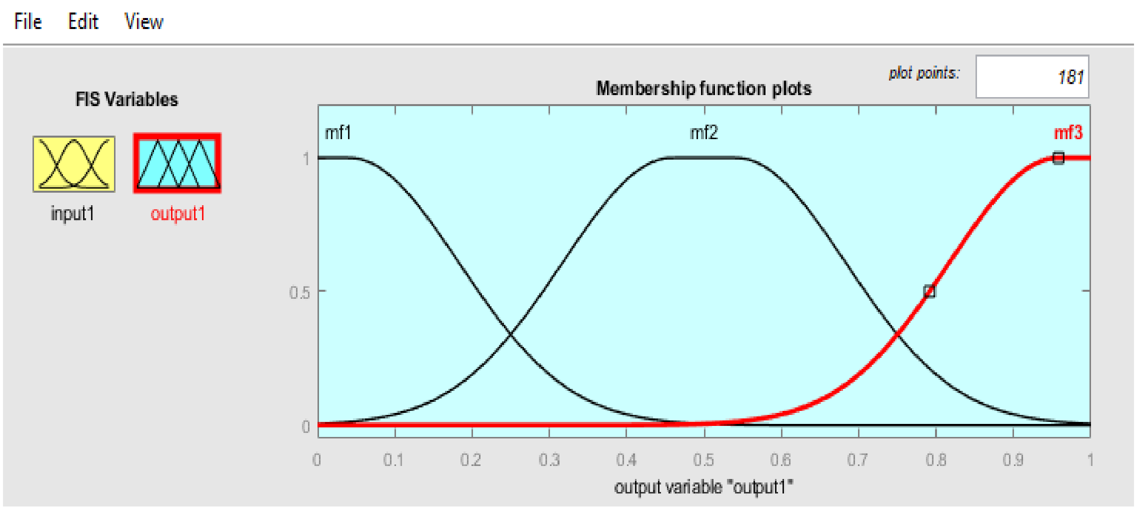

Figure 12 : Membership Function for Type 1

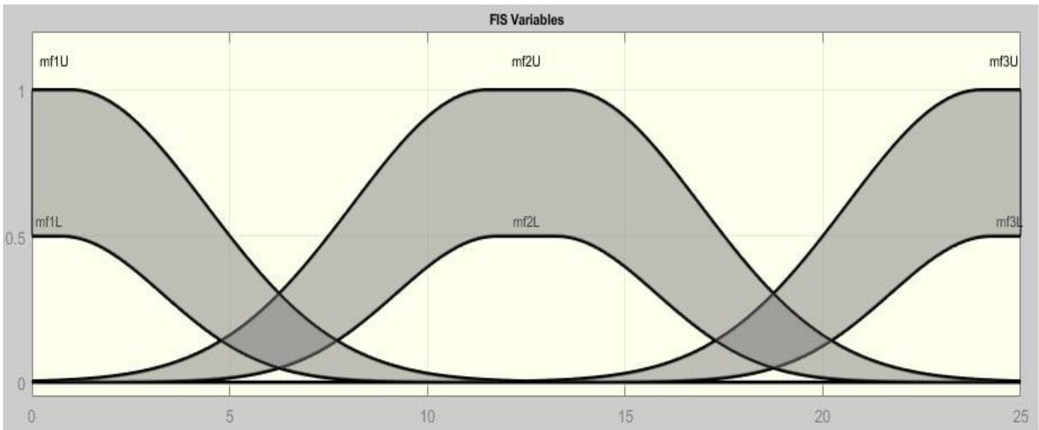

Figure 13 : Gaussian Membership Function for Type 2

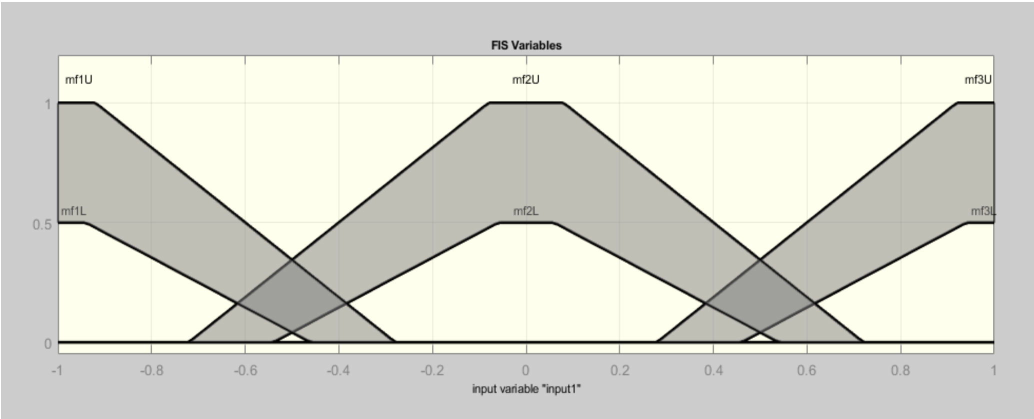

Figure 14 : Trapezoidal Membership Function for Type 2

4.4 Graph Behavior During Obstacle Avoidance

In this section, the graph results portray the behavior of the mobile robot during the whole journey. Illustrated by the graph below in figure 15, the robot successfully navigate towards the target as there are no obstacle blocking the path. In figure 16, it shows the journey of the robot when the obstacle is blocking it path to the target. Figure 17 illustrated when the robot successfully avoids the static obstacle that block the path on its way to the target.

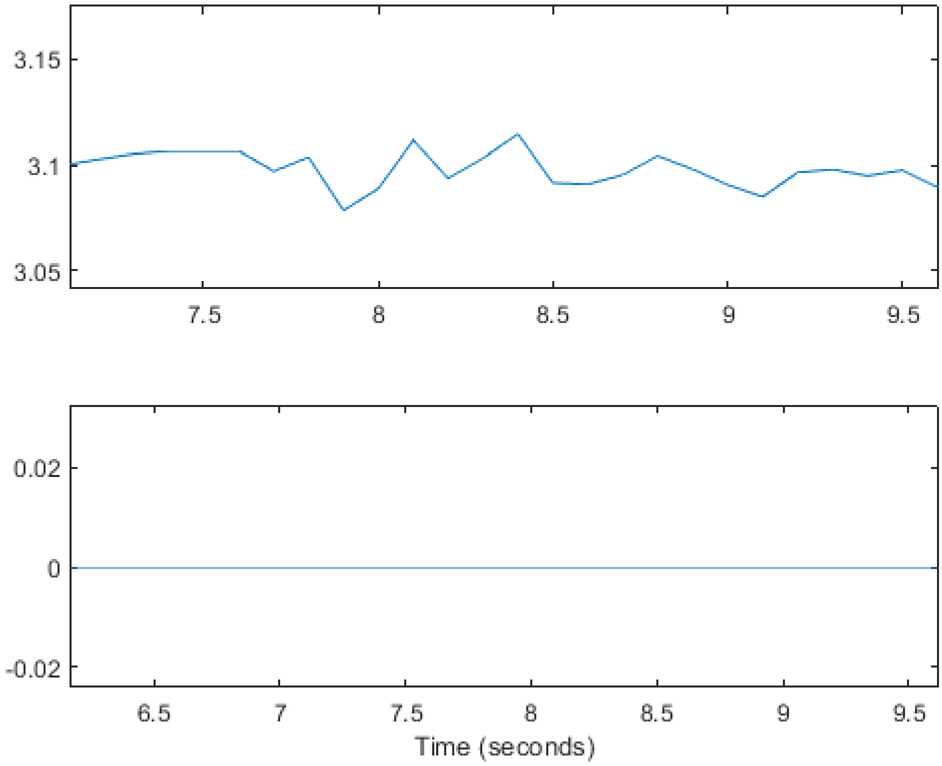

Figure 15 : During Condition 1 (No Blocking Obstacle)

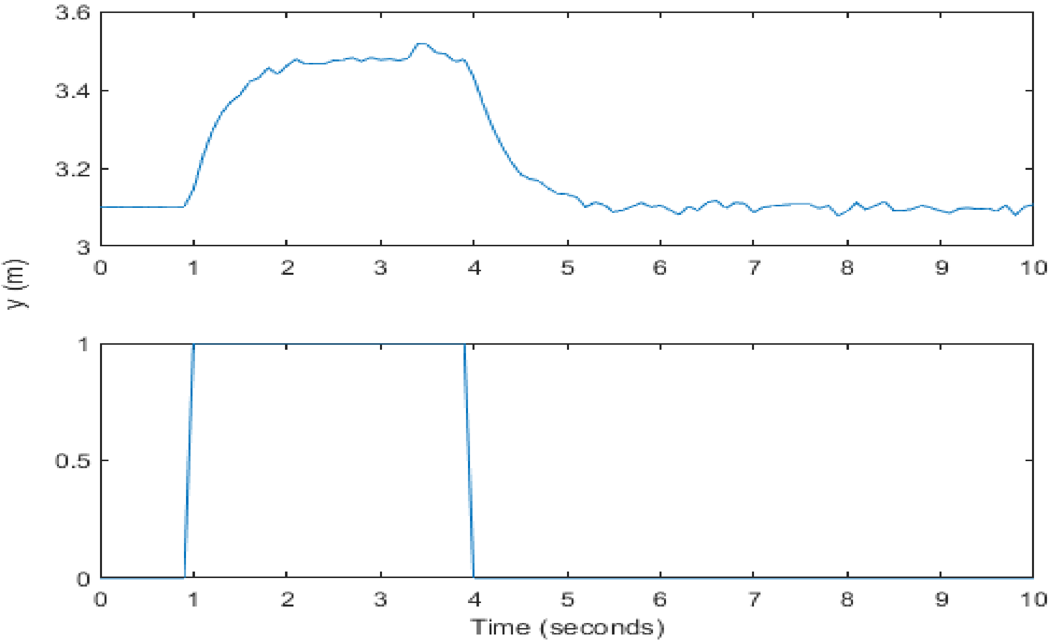

Figure 16 : During Obstacle Behaviour

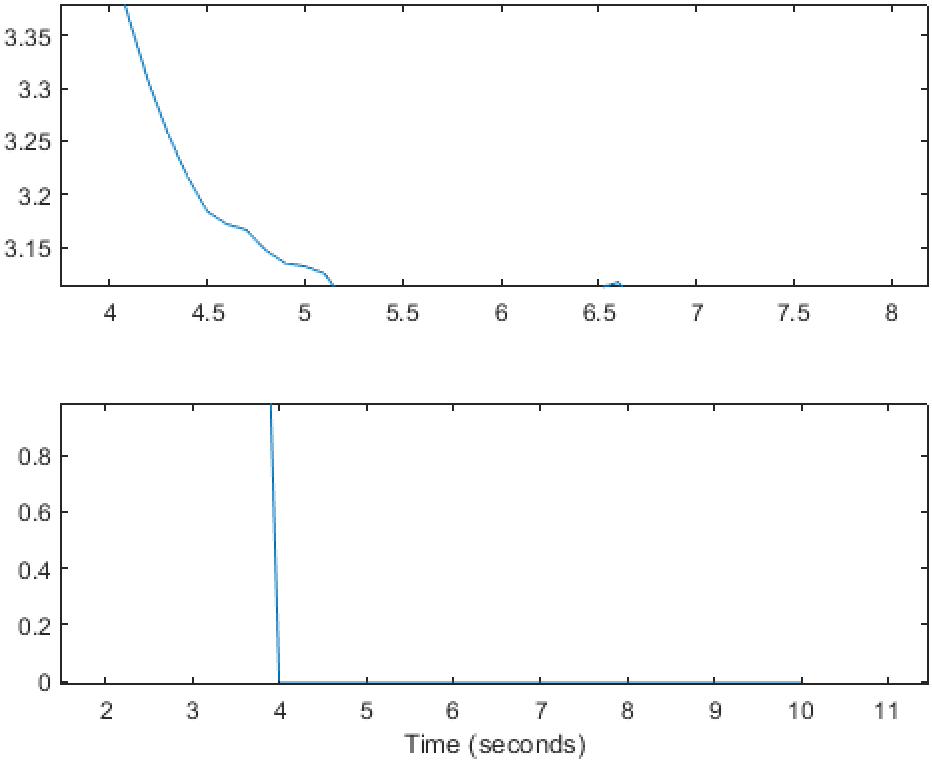

Figure 17 : Blocking the Obstacle

These graph shows the basic convergence of mobile robot towards the final destination. Means, when an obstacle is discovered on the path, the graph is in a high state, and it eventually returns to normal when there is no longer obstacle on the path, so the robot just moves straightly towards the target.

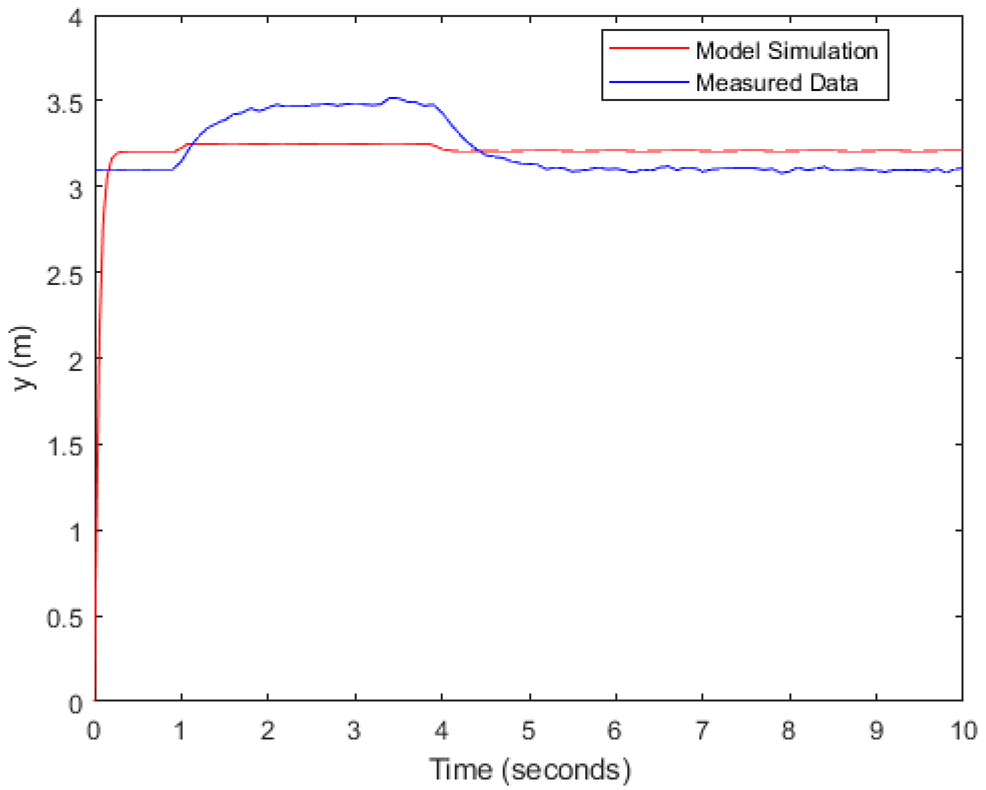

Figure 18 : Difference between simulation and measured data

Figure 18 is a graph represents for the difference between model simulation and measured data. The graph shows that the model simulation has less noise than the measured data, which minimize the computational cost that is required for the system to be executed especially when it is involving the hardware. Figure 19 and 20 shows the difference with and without and obstacle respectively. As shown in the graph the robot manage to reach the target without colliding with the obstacle whether it is blocking or not blocking the robot path reaching towards the target goal.

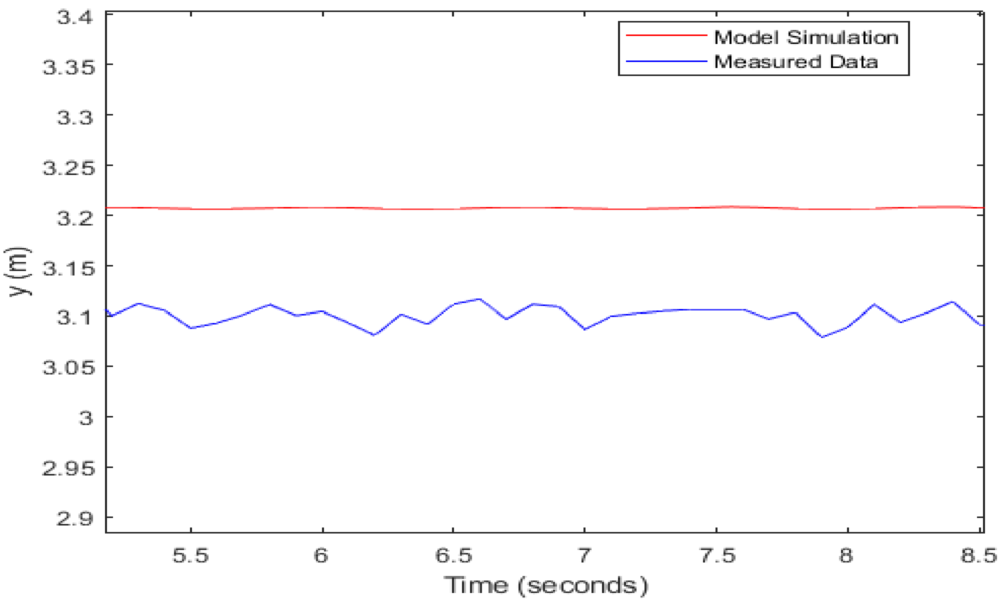

Figure 19 : Without Obstacle

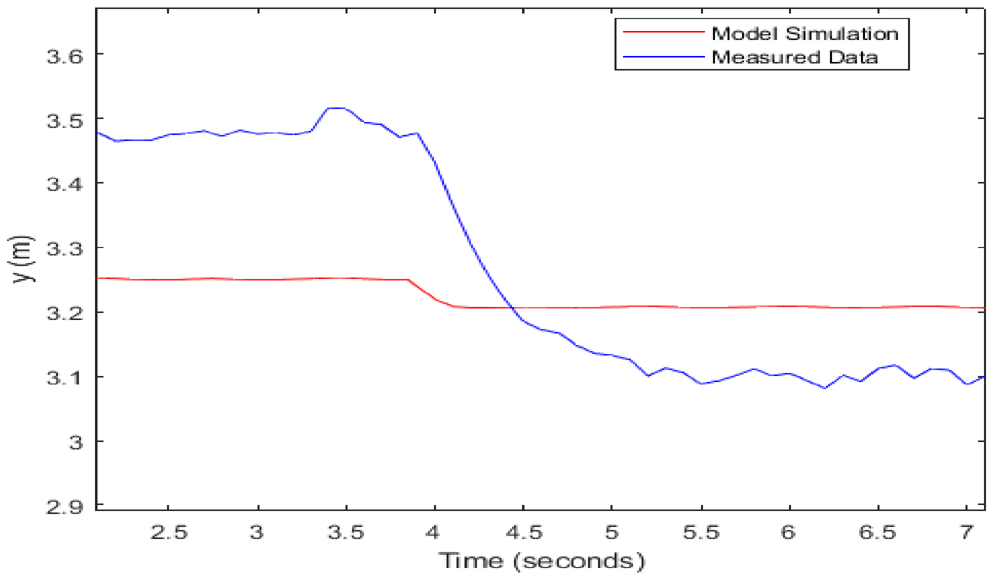

Figure 20 : With Obstacle

As shown in the graph the model simulation has a better line as the values are optimize by cost function algorithm so that it got the exact fit. A perfectly optimize model means the data information of the coordinates were learn and secure by the algorithm so that it can running through the path without colliding with anything as it estimate the values thus it can reduce the noise. Hence, with this algorithm the robot can learn its surrounding before starting its journey.

4.5 Result Summary

To sum up everything that have been stated before, these results were obtained from the MATLAB simulation which utilize the use of cost function algorithm with a fuzzy logic controller. In short, the cost function algorithm helps the robot to locate the coordinate of the obstacle and the target goals. Following by sharing the information data to fuzzy logic so that it can tune and create the rules to navigate the robot to move towards the target without colliding with any blocking obstacle in it way.

CHAPTER 5

CONCLUSION

Taking everything into account, this project proposed on Fuzzy Logic Navigation in a Simulation. The cost function algorithm is applied in the system to help the mobile robot in exploring the simulation environment. This algorithm helps the fuzzy logic in navigating the mobile robot reaching towards the target destination without colliding with anything that block its path. Where, the cost function algorithm helps the robot to locate the coordinate of the obstacle and the target goals. Following by sharing the information data to fuzzy logic so that it can tune and create the rules to navigate the robot to move towards the target without colliding with any blocking obstacle in it way. The Gaussian membership also portrays a good result for the robot performance during the obstacle avoidance. Besides, based on the comparing result the Gaussian memberships has a simple representation and suitable for small rulebases and it also can help the robot to provide best estimation which led to a better performance.

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APPENDIX A (GANTTCHART)

No	Task	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Explaination of Workflow for PSM 2 from Coordinator														
2	Discussion with Supervisor														
3	Deciding Project's Condition														
4	Research														
5	Matlab Simulation														
6	Result Analysis														
7	Result Progress Updated														
8	Logbook Submission														
9	Continue Matlab Simulation														
10	Preparation for Presentation														
11	Continue on Thesis for submission														
12	Submission for Thesis, Logbook and Simulation Video														