SIMULATION FOR POSITION CONTROL OF DC MOTOR USING FUZZY LOGIC CONTROLLER

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ABSTRACT

The purpose of this project is to control the position of DC Motor by using Fuzzy Logic Controller (FLC) with MATLAB application. The scopes includes the simulation and modelling of DC motor, fuzzy controller and conventional PID controller as benchmark to the performance of fuzzy system. The position control is an adaptation of Closed Circuit Television (CCTV) system. Fuzzy Logic control can play important role because knowledge based design rules can be easily implemented in the system with unknown structure and it is going to be popular since the control design strategy is simple and practical. This make FLC an alternative method to the conventional PID control method used in nonlinear industrial system. The results obtained from FLC are compared with PID control for the dynamic response of the closed loop system. Parameters such as peak position in degree, settling time in second and maximum overshoot in percent will be part of the simulation result. Overall performance show that FLC perform better than PID controller.

ABSTRACT

Tujuan projek ini dilaksanakan adalah untuk pengawalan posisi *DC motor* dengan menggunakan *Fuzzy Logic Controller* (FLC) dengan menggunakan aplikasi MATLAB. Skop kajian merangkumi simulasi dan model *DC motor*, kawalan *Fuzzy* dan kaedah lama iaitu dengan menggunakan kawalan *PID* sebagai garis pengukur bagi menentukan prestasi dalam sistem *fuzzy*. Kawalan posisi ini adalah adaptasi kepada sistem litar tertutup (CCTV). *Fuzzy Logic control* memainkan peranan penting kerana pengetahuan asas dalam peraturan rekaannya boleh dikatakan mudah untuk digunapakai dalam sesuatu sistem, di mana strukturnya tidak dikenal dan ianya akan menjadi popular kerana kawalan rekaannya adalah mudah dan praktikal. Ini akan membuatkan *FLC* sebagai satu cara alternatif kepada cara lama iaitu kawalan *PID* yang digunakan di dalam sistem industri yang tidak linear. Keputusan yang diperolehi dari *FLC* dibandingkan dengan kawalan *PID* untuk respon yang lebih dinamik dalam litar tertutup. Parameter seperti posisi paling puncak dalam darjah, masa stabil dalam unit saat dan juga kenaikan melebihi posisi yang ditetapkan dalam peratusan. Ini semua akan menjadi sebahagian dari keputusan simulasi. Secara keseluruhannya prestasi menunjukkan bahawa kawalan *FLC* adalah lebih baik dari kawalan PID.

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LIST OF ABBREVIATIONS AND SYMBOLS

DC	-	Direct Current
PWM	-	Pulse Width Modulation
PID	-	Proportional Integral Derivative
FLC	-	Fuzzy Logic Controller
FC	-	Fuzzy Controller
CCTV	-	Closed Circuit Television
PAN	-	Horizontal adjustment
TILT	-	Vertical adjustment
M_P	-	Peak overshoot
e_{SS}	-	Steady state error
t_s	-	Settling time
t_r	-	Rise time
t_p	-	Peak time
$I_a(t)$	-	Motor current
V_a	-	Armature Voltage
R_a	-	Armature resistance
L_a	-	Armature inductance
T_m	-	Motor torque
J_m	-	Motor inertia
B_m	-	Damping ratio / Viscous friction coefficient
K_m	-	Torque constant
K_B	-	Back EMF constant
θ	-	Angular speed
ω	-	Speed

K_p	-	Proportional gain
K_i	-	Integral gain
K_d	-	Derivative gain
K_u	-	Ultimate gain
T_u	-	Ultimate time
T_I	-	Integral time
T_p	-	Peak time
T_D	-	Derivative time
u(t)	-	Control signal
OS%	-	Percentage of Overshoot

CHAPTER 1

INTRODUCTION

1.1 Project overview

An electric motor is an electric machine that converts electrical energy into mechanical energy. Electric motor can be powered by Direct Current (DC) sources such as batteries, motor vehicles or rectifiers ,or by and Alternating Current (AC) sources, such as from power grid, inverters, or generators.

In this thesis, DC motor have been selected because it is widely used in industrial applications, robot manipulators and home appliances where speed and position control are required. The dc motors can comes in many shapes and sizes, makes the development of dc motor application quite easy and flexible.It is also has high reliabilities and low cost.[1]

The scope of this project is to mimic the position control of Closed-circuit Television (CCTV). The starting point for any CCTV system must be the camera. The camera creates the picture that will be transmitted to the control position. A movable camera may be placed on a platform that may be controllable in both horizontal and vertical planes and it is generally known as PAN where it is the ability to sweep left to right (horizontally) and TILT where it is the ability to move up and down (vertical) movement. The vertical movement start from 0 to 90 degree while for horizontal movement the range is from 0 to 360 degree. Each movement can be done one by one at a time.

Many types of conventional control schemes, such as Proportional-Integral (PI), Proportional-Integral-Derivative (PID), optimal, adaptive and robust controllers have been developed to reduce load effects. Although each approach has its advantages and disadvantages in practical realization, most controllers still have to be designed on the basis of the parameters and the detailed structure of the plant. Failing this, better control performance will not be obtained as load effects occur. Therefore, this work develops a control structure to eliminate heavy and / or unbalanced load effects.[2]

In control systems, fuzzy logic is considered as an alternative for conventional control theory in the control of complex nonlinear plants where precise mathematical modelling is difficult or impossible [3].

The main advantage of fuzzy logic as compared to conventional control approach resides in the fact that no mathematical modelling is required for the design of the controller. The control rules are based essentially on the knowledge of the system behaviour and the experience of the control engineer. Since the fuzzy logic controller requires less complex mathematical operations than classical controllers, its implementation does not require very high speed processors.

Both controllers mentioned above will be using Pulse Width Modulation (PWM) as it is the most frequently consider method among the various switching control method (J. Alvarez-Ramirez, Jan. 2001) .This controller often applied to the converters because of their simplicity.

In this project, MATLAB/Simulink is used as a platform in designing the fuzzy logic controller. Simulation of PID controller also included in this thesis as a comparison in terms of its performance.

1.2 Problem statement

An attempt to carry out the control of a system applying the classical control theory, mathematical model is needed for the process and information about the evolution of the system variables to close the control loops. Normally both conditions are difficult to resolve: sometimes because of the complexity of the process or lack of knowledge we have about it, and other times because of the insufficient technological level reached at the moment in the sensor field. New process control techniques now combine advances in computer hardware and sensors with new programming techniques. In this way they attempt to solve difficult control problems [4].

PID controller can perform very well but somehow not adaptive enough to support different possibility occurred. This is appealing when the load is changed, where the original controller generally cannot maintain the design performance and thus should be re-designed for the new system conditions. Therefore, fuzzy logic controller can be implemented due to its good robustness. However the implementation require experience and skill and the response is a bit slower than conventional controller.

The pioneering work dealing with expert knowledge that can be well applied to the control of systems with uncertained, nonlinear dynamics is credited to Zadeh (Zadeh, 1968) who proposed fuzzy control theory to overcome the weakness of conventional controllers. Fuzzy systems are capable of handling complex, non-linear and sometimes mathematically intangible dynamic systems using simple solutions. Fuzzy logic uses human-like but systematic properties of converting linguistic control rules based on expert knowledge into automatic control strategies [5].

1.3 Project Objectives

This project are performed to study the characteristic of DC motor by conducting simulations of a DC motor using Fuzzy Logic controller systems for position control. The objectives are as follows:

i. To built a modeling simulation for DC motor using MATLAB/Simulink.
ii. To simulate position control of DC motor using Fuzzy Logic Controller (FLC).
iii. To simulate position control of DC motor using conventional controller (PID) as a comparison to FLC in the same range.

1.4 Project Scope

The scopes of this project are described as follows:

i. Simulation of DC motor controller using MATLAB/Simulink.
ii. Simulation for position control using fuzzy logic controller and conventional controllers will range up from 0 to 360 degree.
iii. Implementation of fuzzy logic controller in controlling the position of the DC motor adaptation of Closed Circuit Television (CCTV) application.
iv. The analysis of both controllers involved with peak overshoot and settling time.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Electric motors are standardized versions for general-purpose applications. Other electric motors are intended for specific tasks. In any case, electric motors should be selected to satisfy the dynamic requirements of the machines on which they are applied without exceeding rated electric motor temperature. Thus, the first and most important step in electric motor selection is determining load characteristics. Electric Motor selection is also based on mission goals, power available, and cost.

2.2 Existing Model

There are many papers about DC motor fuzzy control system design. Lin et. al. compared PID and FLC for position control and observed that FLC performed better than PID (Lin 1994). Azevedo et. al. have shown that FLC is less sensitive than PID to load variations (Azevedo,1993) Bal et.al. designed an FLC for an ultrasonic motor which has different operation principle than electromagnetic motors (Bal.2004). Mishra et. al. made a comparison between PID and FLC for servomotor control and described that PID parameters had to be tuned again under variations of plant parameters or noise wherever FLC parameters had not (Mishra,1998). Kwon et. al. designed a PI controller for a brushless DC motor and built an adaptive fuzzy tuning system to modify the controller parameters under load variations during operation (Kwon,2003). M.H. Zadeh et.al. explained that one of the best methods for control of DC motor with time-varying parameters was fuzzy sliding mode control (Zadeh, 2006)[1]

The authors in [6] made a comparison between proportional control and fuzzy control on a laser beam alignment system. It was shown that the fuzzy controller significantly reduced the overshoot and virtually eliminated limit cycling.

Li and Lau [7] investigated the possibility of applying fuzzy algorithm in a microprocessor-based servomotor controller, which requires faster and more accurate response compared with other industrial processes. A set of simulation results on the performance of PI control, model reference adaptive control and fuzzy controllers are compared in terms of steady-state error, settling time and response time. According to the simulation results, the settling time of the fuzzy controller is only two-fifths that of PI controller.

Smith and comer [8] compared a fuzzy position controller with a PD controller using only the simulation result. The PD controller was tuned to minimize rise time with less than 5% overshoot. it was claimed that fuzzy controller is better than the PD controller.

Paul and John Chou [9] examine the application of real-time reasoning fuzzy controller and digital PID control algorithm to a PC based dc motor position controller. The specification for PC-based position controller including system hardware and software. the experimental study reveals that using FLC control to the position control application, shorter settling time can be achieved by tuning the control rules, membership functions and universe of discourse of the output variable. Comparison of experimental results of the PID and FLC position controllers show that the FLC controller is able to perform better than PID controller.

2.3 Introduction to DC Motor

A common actuator in control systems is the DC motor. It directly provides rotary motion and coupled with wheels or drums and cables, can provide translational motion.

2.3.1 Physical system

Consider a DC motor, whose electric circuit of the armature and free-body diagram of the rotor are shown in figure 2.1.

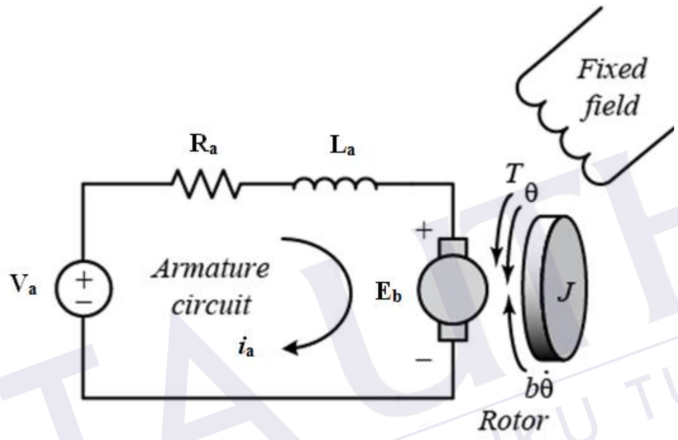

Figure 2.1 : Schematic representation of the considered DC motor

The input is the armature voltage V in Volts (driven by a voltage source). Measured variables are the angular velocity of the shaft ω in radian per second, and the shaft angle θ in radian.

Where:

V_a = armature voltage (V)

R_a = armature resistance (Ω)

L_a = armature inductance (H)

i_a = armature current (A)

E_b= back emf (V)

T = Torque (Nm)

θ = angular position of rotor shaft (rad)

2.3.2 System Equations

In armature control of separately excited DC motor, the voltage applied to the armature of the motor is adjusted without changing the voltage applied to the field where the output voltage and motor torque is relate to the equation below:

$$V_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + Eb(t) \qquad (2.1)$$

The motor torque, *T*, is related to the armature current *i*, by a constant factor *K*:

$$T = Ki \qquad (2.2)$$

The back electromotive force (emf),e_b is related to the angular velocity by:

$$E_b = K\omega = K\frac{d\theta}{dt} \qquad (2.3)$$

From figure 2.1, the following equations based on the Newton's law combined with the Kirchhoff's law can be write as:

$$J\frac{d^2\theta}{dt^2} + b\frac{d\theta}{dt} = Ki \qquad (2.4)$$

$$L\frac{di}{dt} + Ri = V - K\frac{d\theta}{dt} \qquad (2.5)$$

2.3.3 Transfer Function

Using the Laplace transform, equations (2.4) and (2.5) can be written as:

$$Js^2\theta(s) + bs\theta(s) = KI(s) \qquad (2.6)$$

$$LsI(s) + RI(s) = V(s) - Ks\theta(s) \qquad (2.7)$$

where s denotes the Laplace operator. From (2.7) we can express I(s):

$$I(s) = \frac{V(s) - Ks\theta(s)}{R + Ls} \qquad (2.8)$$

and substitute it in (2.6) to obtain:

$$Js^2\theta(s) + bs\theta(s) = K\frac{V(s) - Ks\theta(s)}{R + Ls} \qquad (2.9)$$

The equation for the DC motor is shown in the block diagram in Figure 2.2.

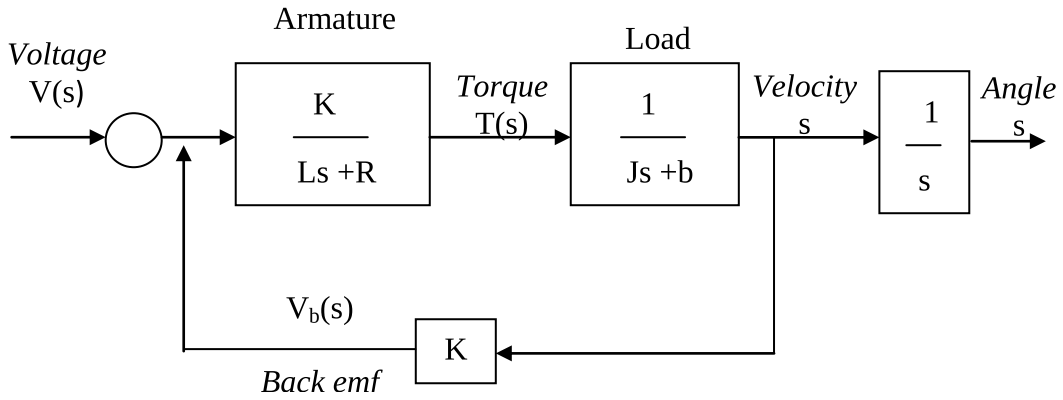

Figure 2.2 : A block diagram of the DC motor

From equation (2.9), the transfer function from the input voltage, V(s), to the output angle, θ, directly follows:

$$G_a(s) = \frac{\theta(s)}{V(s)} = \frac{K}{s\left[(R+Ls)(Js+b)+K^2\right]} \qquad (3.0)$$

From the block diagram in Figure 2, it is easy to see that the transfer function from the input voltage, V(s), to the angular velocity, ω is:

$$G_v(s) = \frac{\omega(s)}{V(s)} = \frac{K}{\left[(R+Ls)(Js+b)+K^2\right]} \qquad (3.1)$$

2.4 Conventional Controller

The classical controllers like PI or PID controllers are widely used in process industries because of their simple structure, assure acceptable performance for industrial processes and their tuning is well known among all industrial operators. However, these controllers provide better performance only at particular operating range and they need to be retuned if the operating range is changed. Further, the conventional controller performance is not up to the expected level for nonlinear and dead time processes. In the present industrial scenario, all the processes require automatic control with good performance over a wide operating range with simple design and implementation. Typically two types of conventional controller will be discused in this report namely Proportional-Integral (PI)and Proportional-Integral-Derivative (PID).Both have a signifant functions toward the development of DC servo motor controller.[10]

2.4.1 PI Controller

PI controller is unquestionably the most commonly used control algorithm the process control industry. The main reason is its relatively simple structure, which can be easily understood and implemented in practice, and that many sophisticated control strategies, such as model predictive control, are based on it [11].

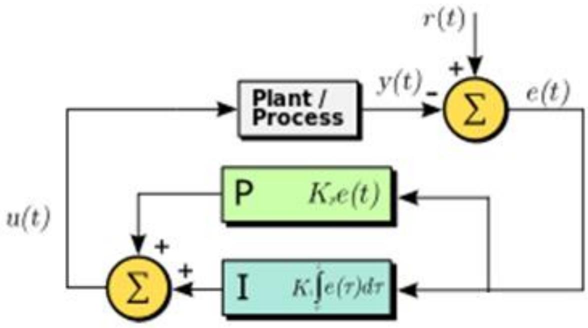

Figure 2.3 : PI controller block diagram

2.4.2 PID Controller

Conventional PID controllers are characterised with simple structure and simple design procedures. They enable good control performance and are therefore widely applied in industry. However, in a number of cases, such as those when parameter variations take place and/or when disturbances are present, control system based on a fuzzy logic controller (FLC) may be a better choice.

The PID controller is a universal controller which is used particularly in the field of material processing. Practical controllers are usually assembled with one or more operational amplifiers, whereby the PID behaviour is realised by suitable feedbacks.

Several approaches were developed for tuning PID controller such as the Ziegler-Nichols (Z-N) method, the Cohen-Coon (C-C) method, integral of squared time weighted error rule (ISTE), integral of absolute error criteria (IAE), internal-model-control (IMC) based method and gain-phase margin method (Taifour et al, 2012).

It is a generic control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an "error" value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the process control inputs.

The PID controller calculation (algorithm) involves three separate constant parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted *P*, *I*, and *D*.

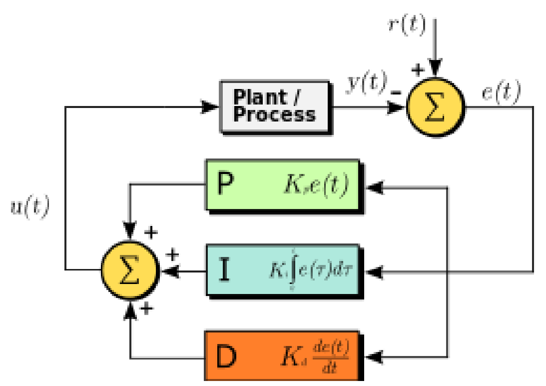

Figure 2.4 : PID controller block diagram

The influence of the three components can usually be set externally. Each of the three components covers one of the controller's tasks.

i. the P part by the proportional sensitivity Kp
ii. the I part by the integral action time Tn
iii. the D part by the derivative action time Tv

The D part therefore ensures that the controller reacts quickly even in the case of slow changes at its input. The P part takes care of medium amplification and the I part causes the controller to operate accurately without leaving a control difference. deriving the individual controller parameters from the jump reply or rise reply is difficult since the three components overlap.

PID controllers are usually tuned using hand tuning or Ziegler-Nichols methods to obtain the desired performance according to preset criteria. The basic continuous feedback control is PID controller. The PID controller exhibits good performance but is not adaptive enough (Oyas & Nordin, 2008).

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1.5 Project report Layout

In chapter one (Chapter 1) , the project overview, problem statement, project objective and project scope that relates with position control of DC motor using fuzzy logic controller have been discussed.

In second chapter (Chapter 2), all the literature review from the previous study related to the objectives of the study had been gathered. This includes conventional controller as the comparison to fuzzy logic controller.

In third chapter (Chapter 3), the overall design and methods to apply in this study had been stated. The main methodology that been stressed out related position control of DC motor using fuzzy logic controller and PID controllers.

In forth chapter (Chapter 4), consist of expected outcomes that been stated based on the objectives of the study. It shows that by using fuzzy logic controller the position controller of DC motor can be simulated.

In last chapter (Chapter 5), is the conclusion and recommendation for future study. References cited and supporting appendices are given at the end of this project report.

2.5 FUZZY LOGIC CONTROL

The basic FLC structure is shown in figure 2.3, where FLC is used a supplementary role to enhance the existing control system when the control conditions change. It consists of four principle units [12].

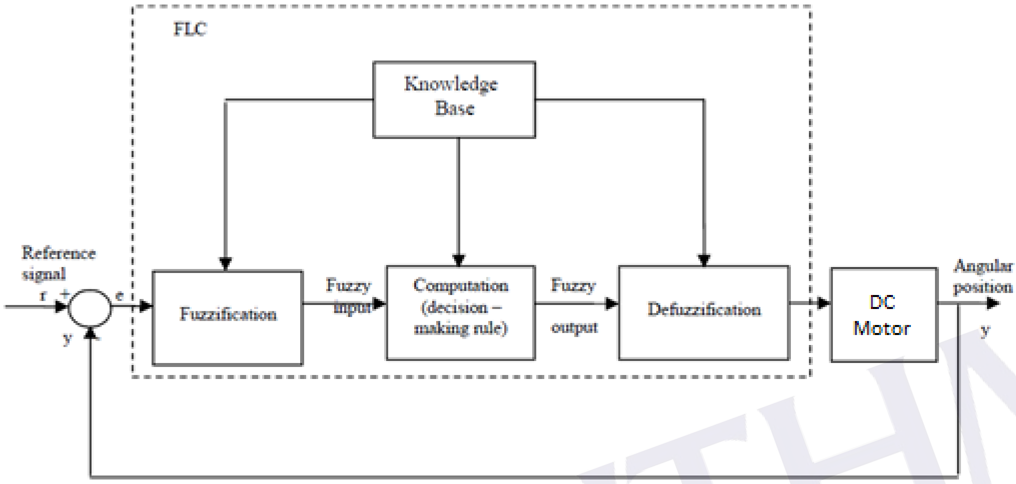

Figure 2.5: Basic structure of fuzzy logic controller

These are the fuzzification, knowledge base, decision making (computation) and defuzzification units. Since data manipulation in an FLC is based on fuzzy set theory, a fuzzification process is required to convert the measured "crisp" inputs to "fuzzy" values. The fuzzification unit first maps the measured values of input variables into corresponding universes of discourse U. The U is quantified and normalized to [-1, +1]. It then converts the mapped input data into fuzzy sets based upon fuzzy values. The control rules table of FLC are shown as example in Table 2.1 below.

Table 2.1:The control rules of Fuzzy Logic Controller

DE \ E	NL	NM	NS	ZR	PS	PM	PL
NL	NL	NL	NL	NM	NS	NS	ZR
NM	NL	NL	NM	NS	NS	ZR	PS
NS	NL	NM	NS	NS	ZR	PS	PM
ZR	NM	NM	NS	ZR	PS	PM	PM
PS	NM	NS	ZR	PS	PS	PM	PL
PM	NS	ZR	PS	PS	PM	PL	PL
PL	ZR	PS	PS	PM	PL	PL	PL

The knowledge base contains a set of rules which construct the decision-making logic rule table tabulated in table (1) where 49 rules are used. The rule in column 1 (E=NL) and row 1 (DE=NL) marked NL presents: If (E) is negative large (NL) and (DE) is negative large (NL) then control input (CI) is negative large (NL) . The label and number of rules can be changed according to project preference. An addition of input and output sets can provide much more accurate results but longer time is needed to run the simulinks.

2.5.1 Fuzzy Logic Principles

Fuzzy logic (FL) has the following general observation [13]:

- FL conceptually easy to understand.
- The mathematical concepts behind fuzzy reasoning are simple and flexible.
- With any given system, it's easy to message it or layer more functionality on top of it without starting again from scratch.
- FL is tolerant of imprecise data. Everything is imprecise if you look closely enough, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end.
- FL can be built on top of the experience of experts. In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, FL lets you rely on the experience of people who already understand your system.
- FL is based on natural language. The basis for fuzzy logic is the basis for human communication.

2.5.2 Advantage Of Using Fuzzy Logic Controller

The main advantage of fuzzy logic as compared to conventional control approach resides in the fact that no mathematical modelling is required for the design of the controller. The control rules are based essentially on the knowledge of the system behaviour and the experience of the control engineer. Since the fuzzy logic controller requires less complex mathematical operations than classical controllers, its implementation does not require very high speed processors [14].

CHAPTER 3

METHODOLOGY

3.1 Project Design

The idea of this project is to develop a Fuzzy Logic Controller (FLC) and conventional PID controller by using MATLAB simulink. The target of the project is control the position of the DC motor. The result for both simulations are elaborate and discuss in Chapter 4 in Result section.

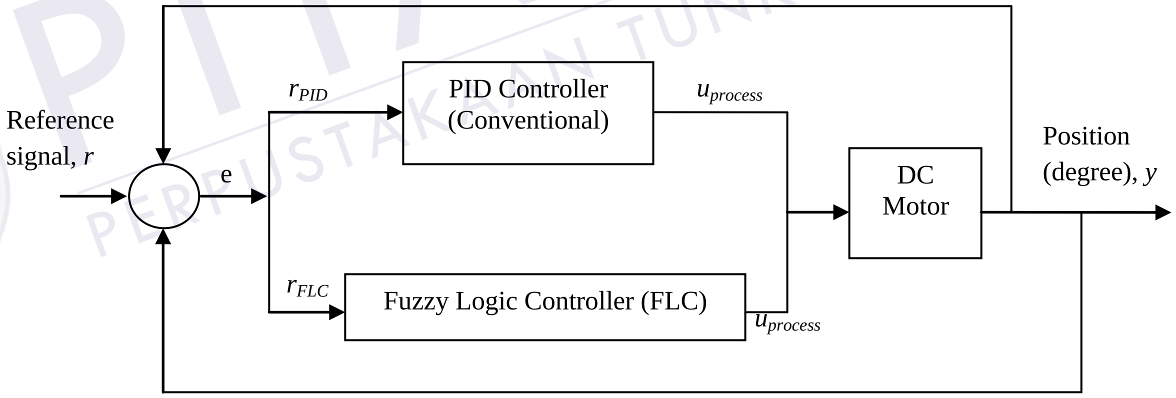

Figure 3.1 :Block diagram of position control of DC motor

Main controller of this project is to perform Fuzzy Logic Controller while PID controller is use to compare the performance of the controller. The FLC will provide a modified control action to the existing PID control system[15].

3.2 Flow chart

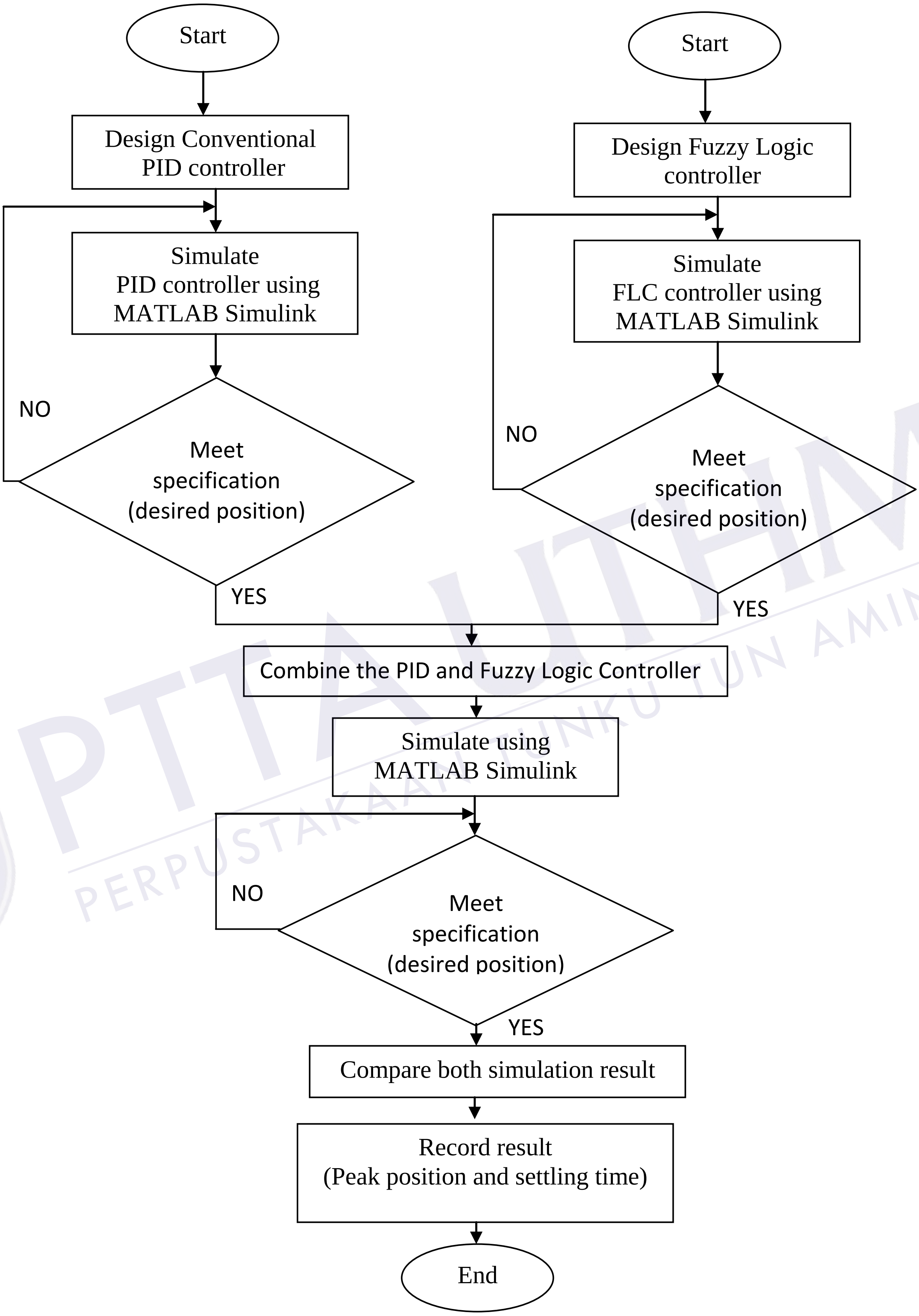

Figure 3.2: Flow chart of overall methodology

3.3 Design steps for Conventional controller (PID)

PID controllers are widely used in industrial control applications due to their simple structure, comprehensible control algorithm and low cost. Figure below shows the schematic model of a control system with PID controller.

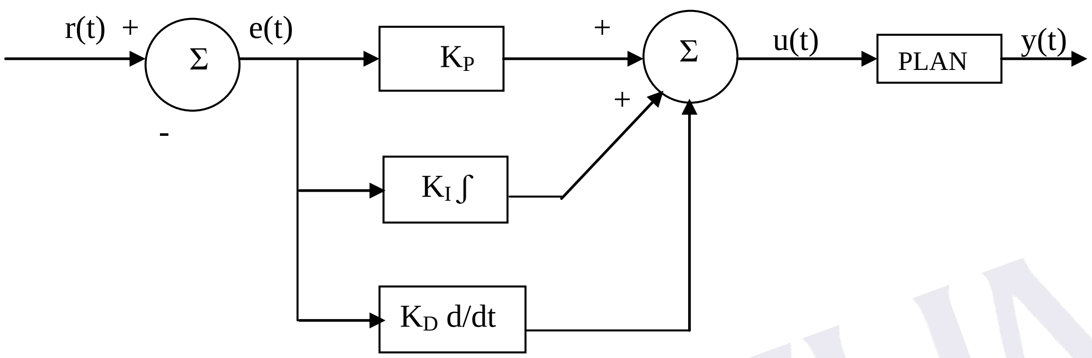

Figure 3.3:PID control system

Control signal *u*(t) is a linear combination of error e(t), its integral and derivative.
In this project the parameters for P,I and D is choose to 0.5,0.0001 and 0.01 respectively[1].

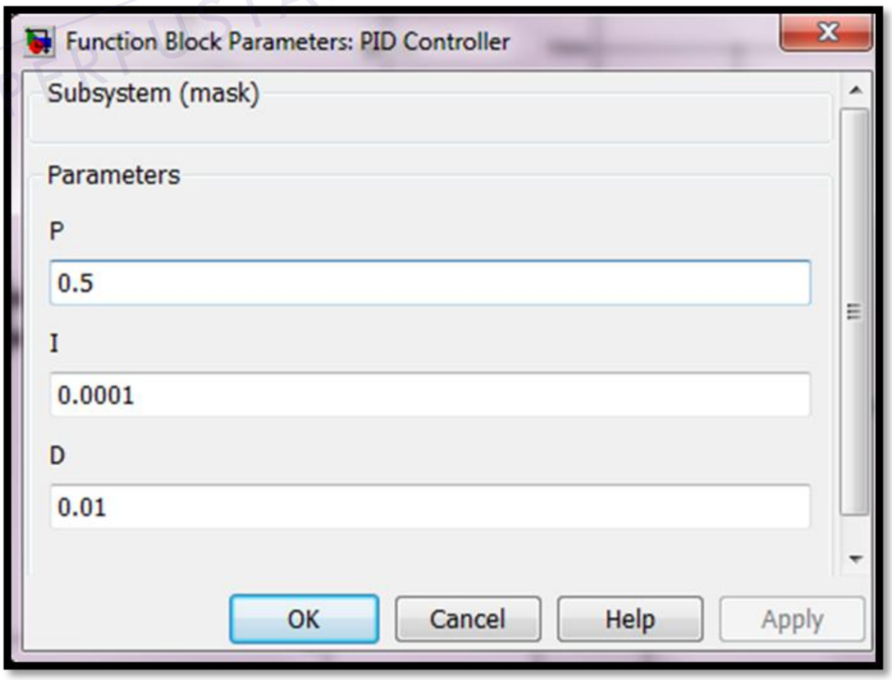

Figure 3.4:PID parameters.

3.4 Design steps for Fuzzy Logic Controller

The most important aspect in Fuzzy logic control system designs start with a process of converting the measured inputs called crisp values, into the fuzzy linguistic values used by the fuzzy reasoning mechanism. The process of reasoning mechanism will perform fuzzy logic operations and result the action according to the fuzzy inputs. a collection of the expert control rules known as knowledge needed to achieve the control goal.

3.4.1 Structure of Fuzzy Logic Controller (FLC)

A typical FLC consists of three basic components, namely input signal fuzzification, a fuzzy engine and output signal defuzzification. The fuzzification block tranforms the continous input signal into linquistic fuzzy variable. The fuzzy engine handles rule inference where human experience can easily be injected through linguistic rules. The defuzzification block transforms the fuzzy control actions to continuous (crisp) signals which can be applied to the physical plant. The knowledge base includes fuzzy sets, which are defined on the interval of the inputs and outputs of the FLC, and rule base, which is constructed from fuzzy implication [16].

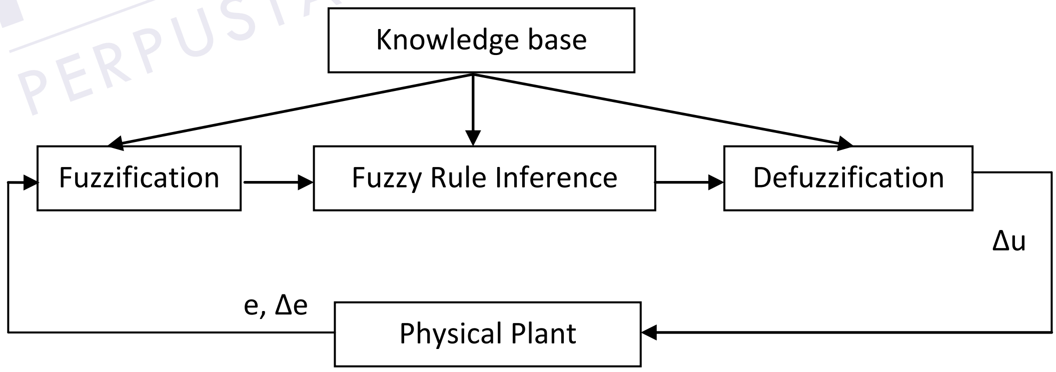

Figure 3.5:Typical configuration of a fuzzy logic controller

The error and error change for both position and time are scaled using appropriate scaling factors. These scaled input data then converted into linguistic variables which may be viewed as labels of fuzzy sets.

In this paper, the following linguistic variables are used for the input variables for example Negative Big (NB),Negative Medium (NM), Negative Small(NS), Zero(Z), Positive Big (PB),Positive Medium (PM) and Positive Small (PS).

3.4.1.1 Preprocessing

The inputs are most often hard or crisp measurement from some measuring equipment rather than linguistic[17].

3.4.1.2 Fuzzification

The first block inside the controller is fuzzification which convert each piece of input data to degrees of membership by a lookup in one or several membership function. The fuzzification block matches the input data with the conditions of the rules to determine [17].

3.4.1.3 Rule Base

The collection of rules is called a rule base. The rules are in "If Then" format and formally the If side is called conditions and Then side is called the conclusion. The computer is able to execute the rules and compute a control signal depending on the measured input error(e) and change of error (Δe). a rule base controller is easy to understand and easy to maintain for non-specialist end user and an equivalent controller could be implemented using conventional techniques[17].

3.4.1.4 Defuzzification

Defuzzification is when all the actions that have been activated are combined and converted into a single non-fuzzy output signal which is the control signal of the system. The output levels are depending on the rules that the systems have and the positions depending on the non-linearities existing to the system. To achieve the result, develop the control curve of the system representing the I/O relation of the system and based on the information, define the output degree of the membership function with the aim to minimize the effect of non-linearity[17].

3.5.1.5 Postprocessing

The postprocessing block often contains an output gain that can be tuned and also become as an integrator [17].

3.4.2 Fuzzy Logic Toolbox

There are five primary graphical user interface (GUI) tools for building, editing and observing fuzzy inference systems in the toolbox:

i. Fuzzy Inference System (FIS) editor
ii. Membership Function editor
iii. Rule Editor
iv. Rule Viewer
v. Surface Viewer

These GUI are dynamically linked and if the changes make to the FIS to one of the toolbox, the effect can be seen in other GUIs.

3.4.2.1 Fuzzy Inference System (FIS) editor

The FIS editor handles the high level issues of the system. Fuzzy Logic toolbox does not limit the FIS editor displays general information about fuzzy inference system. There is a simple diagram at the top shows the name of each input variable on the left and the output on the right[17]. FIS editor can be open as steps shown below:

Step 1: Type fuzzy at MATLAB prompt and enter.

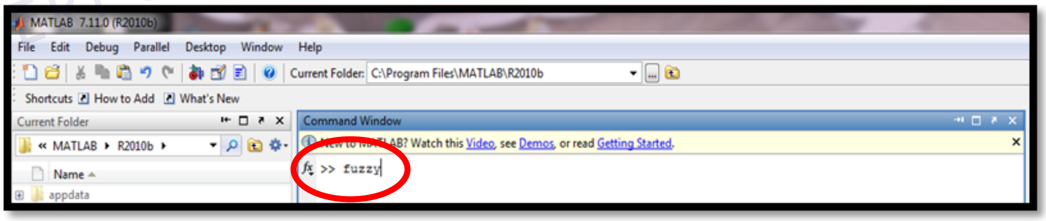

Figure 3.6: MATLAB prompt

Step 2: Select Edit to Add Variable. Input can be added to more than one.

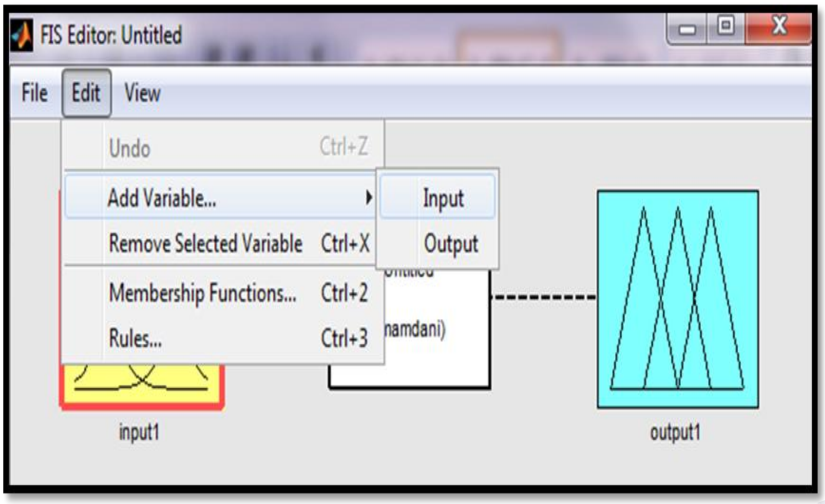

Figure 3.7: Edit section in FIS Editor

Step 3: Click input1 (yellow box and highlighted with red outline)

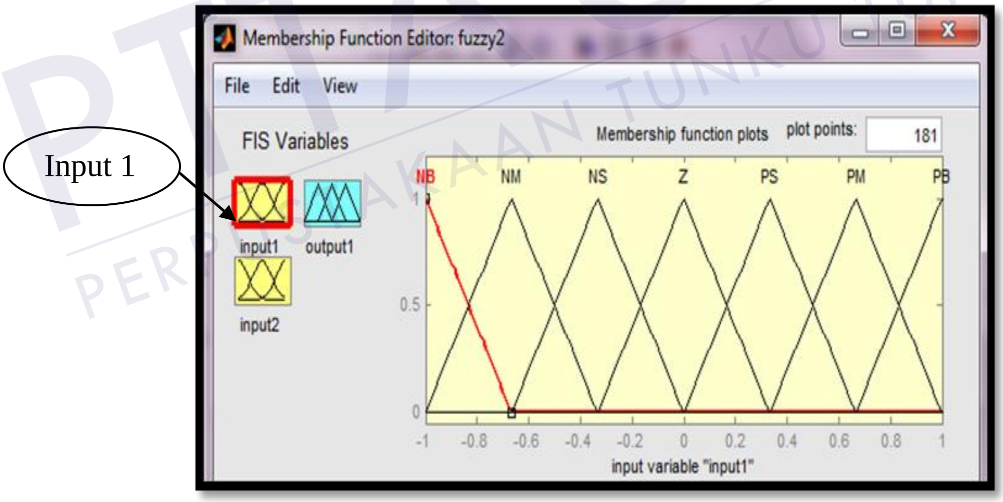

Figure 3.8: Input 1 in FIS Editor

Step 4: Click input 2 (yellow box and highlighted with red outline)

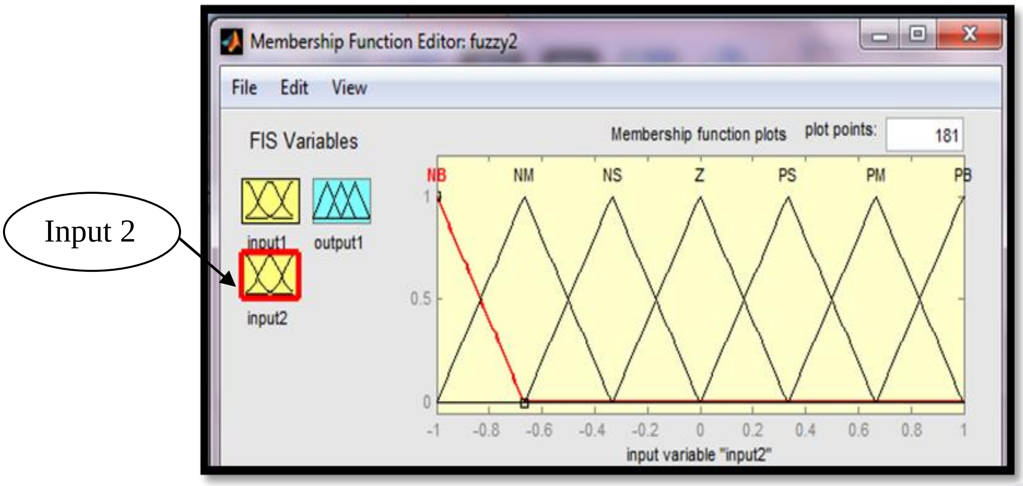

Figure 3.9: Input 2 in FIS Editor

Step 5: Click output (green box and highlighted with red outline)

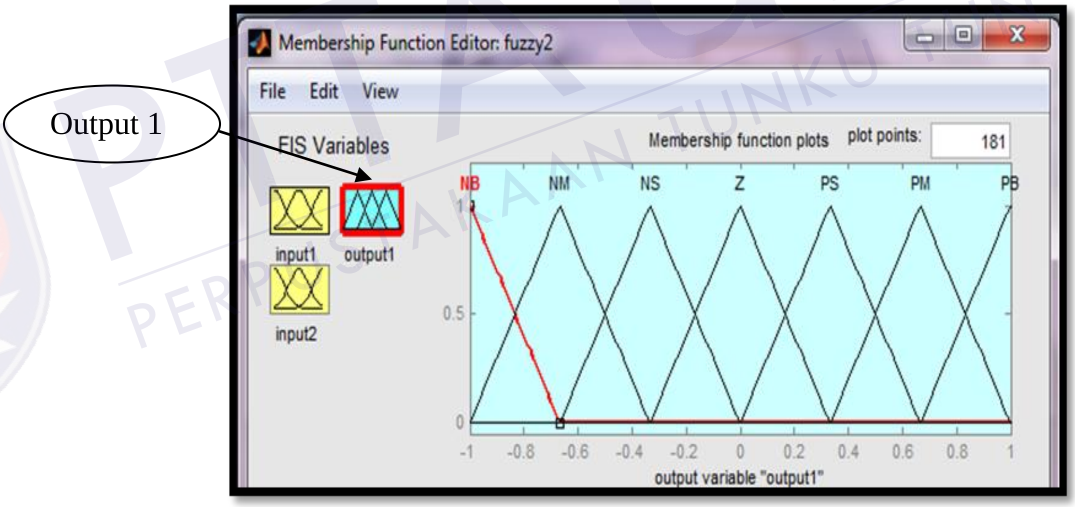

Figure 3.10: Output 1 in FIS Editor

Step 6: Click File, Export and To Workspace

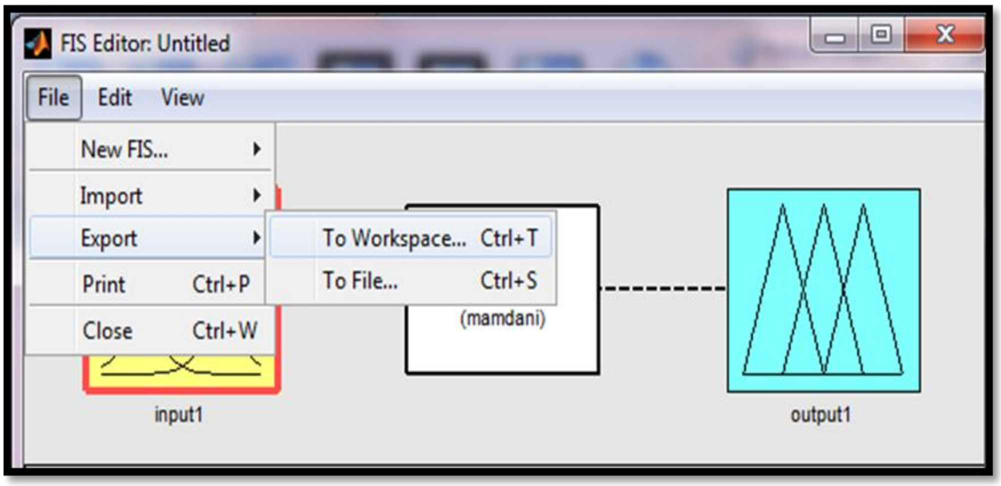

Figure 3.11: File section for Export To Workspace in FIS Editor

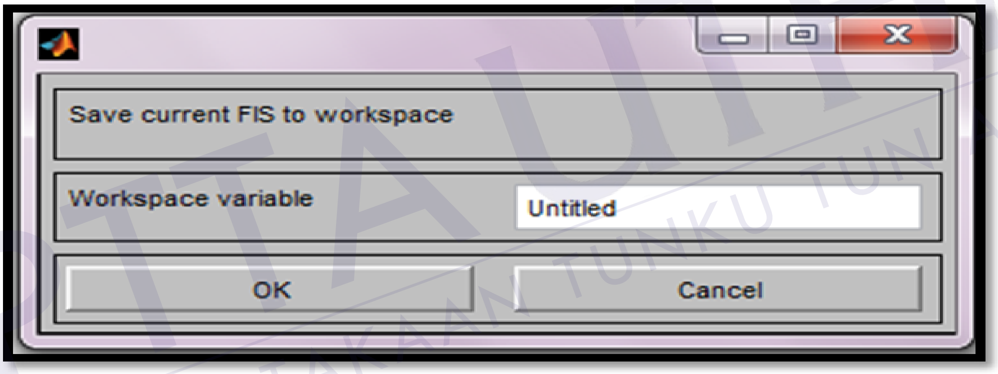

Figure 3.12: Save current FIS to workspace

REFERENCE

[1] Manafeddin Namzov & Onur Basturk.DC motor position control using fuzzy proportional-derivative controllers with different defuzzification method. *An official journal of Turkish Fuzzy System association (Vol.1 No.1,pp. 36-54,2010)*

[2] Nasser T. and others "Design and Applications of Fuzzy Logic for The Speed Control of a Direct-Drive DC Motor", 4th International Conference, Cattaee, Amman-Jordan 2002.

[3] Williams T. "Fuzzy Logic Simplifies Complex Control Problems", Computer design, March 1991.

[4] Warwick K. "Control System",Prentice-Hall, 1989.

[5] Haytham M. Fayek an d I. Elamvazuthi " Type-2 Fuzzy Logic PI (T2FLPI) Based DC Servomotor Control"Electrical and Electronic Engineering Department, Universiti Tecknologi PETRONAS, Malaysia

[6] R.D Marchbanks andM.Jamshidi, " A Fuzzy Control Approach to a Two-Axis Mirror Laser Beam Alighment system," *Engng Applic. Arcif, Intell*, Vol. 6, No 2,1993, pp.117-122

[7] Y.F.Li and C.C. Lau, "Developement of fuzzy algorithm for servo systems," *IEEE Control System*, April 1989, pp.65-72.

[8] S.M. Smith and D.J. Comer, "Automated Calibration of a fuzzy Logic Controller Using a Cell State Space Algorithm," *IEEE Control System*. August 1991,pp.18-28

[9] Paul I-Hai Lin, Santai Hwang and John Chou "Comparison on Fuzzy Logic and PID controls for a DC Motor Position Controller" National Taipei Institute of Technology, Taipei, Taiwan,Republik of china, 1994 IEEE.

[10] Fuzzy Coordinated PI Controller: Application to the Real-Time Pressure Control Process Retrieved January 25 http://www.hindawi.com/journals/afs/2008/691808/

[11] Fuzzy Coordinated PI Controller: Application to the Real-Time Pressure Control Process Retrieved January 25 .http://www.hindawi.com/journals/afs/2008/691808/

[12] Lee C. "Fuzzy Logic in Control Systems",Fuzzy logic controller, part II . IEEE Trans. On Systems, Man. And cybernetics 1990.

[13] Jamshidi M. and others "Application of Fuzzy Logic Towards high Machine Intelligence guotient System" ,prentice Hall PTR ,1997.

[14] Lim C. Hzyama T. "Experimental Implentation of a Fuzzy Logic Control Scheme for a Servomotor" , Mechatronics 1993.

[15] Ming-Yuan Shieh and Tzuu-Hseng S. Li, "Design and implementation of integrated fuzzy logic controller for a servomotor system", Department of Electrical Engineering, National Cheng-Kung University, Tainan,Mechatronics 8 (1998) 217-240.

[16] Hasan A.Yousef and Hanan M.Khalil, " A Fuzzy Logic-Based Control of series DC Motor Drives," Department of Electrical Engineering auniversity of Qatar Doha and Universiti of Alexandria,Egypt pp.517-522

[17]Fuzzy Logic Toolbox 2, User’s Guide (January 10, 2008)