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Comparative Study Between PID Controller and Fuzzy Logic Controller for Robotic Hand

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Abstract: A controller is such a complement to a system in order to let it working at a suitable specification. In this paper, Proportional-Integral-Derivative PID controller and Fuzzy logic controller are being compared to see which one has a better performance between them on a three fingers robotic hand application. MATLAB-Simulink used in this study to proceed with the simulation to obtain the results from the output graph. The simulation results demonstrate that PID controller realize a good behavior on the Robotic Hand, with less rise and settling time, minimum overshoot, and give better performance compared to Fuzzy Logic controller.

Keywords: PID, Fuzzy Logic, Position Control, Performance Comparison

1. Introduction

Based on a survey of over eleven thousand controllers in the refining, chemicals and pulp and paper industries, 97.00 % of regulatory controllers utilize PID feedback [3]. Understanding PID controller is all about a control loop mechanism employing feedback that is widely used in industrial control system and a variety of other application. The first theoretical analysis and practical application was in the field of automatic steering systems for ships, developed from the early 1920s onwards. It was then used for automatic process control in the manufacturing industry, where it was widely implemented in Pneumatic, and then electronic, controllers. Today the PID concept is used universally in applications requiring accurate and optimized automatic control.

Not forgettable, Fuzzy logic systems are well suited to nonlinear systems and systems that have multiple inputs and multiple outputs. There are many applications that use fuzzy logic, but fail to tell us of its use. Probably the biggest reason is that the term "fuzzy logic" may have a negative connotation. Fuzzy logic can be applied to non-engineering applications as illustrated in the stock trading application. It has also been used in medical diagnosis systems and in handwriting recognition applications. In fact a fuzzy logic system can be applied to almost any type of system that has inputs and outputs.

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1.1 Problem Statement

For those controllers, they are observed to have a quite the same in functionality. Previous research shows that PID control is often used because of its adaptability to a wide range of applications and operating conditions. However, there are several common problems occur during the PID tuning process [7]. In many cases, complex variables need to be finely tuned to reach the optimal performance for a controlled system. This process can be time-consuming and frustrating, often requiring the engineer to request support from distributors or manufacturers.

Moving to the application of fuzzy logic controller, linear programming techniques and advanced control have been implemented to obtain optimal disposition of water injection flow in oil production facilities. Better control increased field production and allows more effective responses to deviations that can damage people, goods or reduce production [8].

1.2 Research Objective

For a clear cut, the objectives of this study will be based on the following scopes:

- To study about the difference between PID controller and Fuzzy Logic controller in robotic hand application.
- To compare the performance between PID controller and Fuzzy Logic controller using MATLAB Simulink.
- To measure the efficiency of performance between PID controller and the Fuzzy logic controller using suitable parameters.

2. Methodology

In this study, MATLAB – Simulink will be as a platform to see the performance in the implementation of those controllers in a real situation. Due to the basis of hands on and practicality, the methods used to handle this study is basically by firstly understanding the Robotiq User Interface along with the basic working principle of the PID controller and Fuzzy logic controller that have been tested on any other application previously.

2.1 Fingers Robots Interface

It is observed to be the easiest way to learn and experience the different motion of the robot in the scope of gripping position with the gripper on the desk. From the Robot User Interface prompt, users may decide to choose any robots used among those type of Adaptive Robot Gripper as below.

- 2-Finger
- Vacuum
- 3-Finger
- IO Coupling

Relatable to this scope of study, 3-Fingers Adaptive Robot Gripper is chosen to be analysed due to its transfer function used. Manual IP Address may be just ignored because it will be automatically recognise when the real Robot Gripper linked to the computer.

2.2 Flowchart

Most of the technique used in this study would be focusing on how to analyze data from the output graphs simulated by the MATLAB-Simulink. This situation is due to lots of trial on tuning and manipulating the input of the controllers involved. However, the list of trials is not being tabulated due the scope of the study. Thus, the best tuning may be taken based on previous research to be set up in the system.

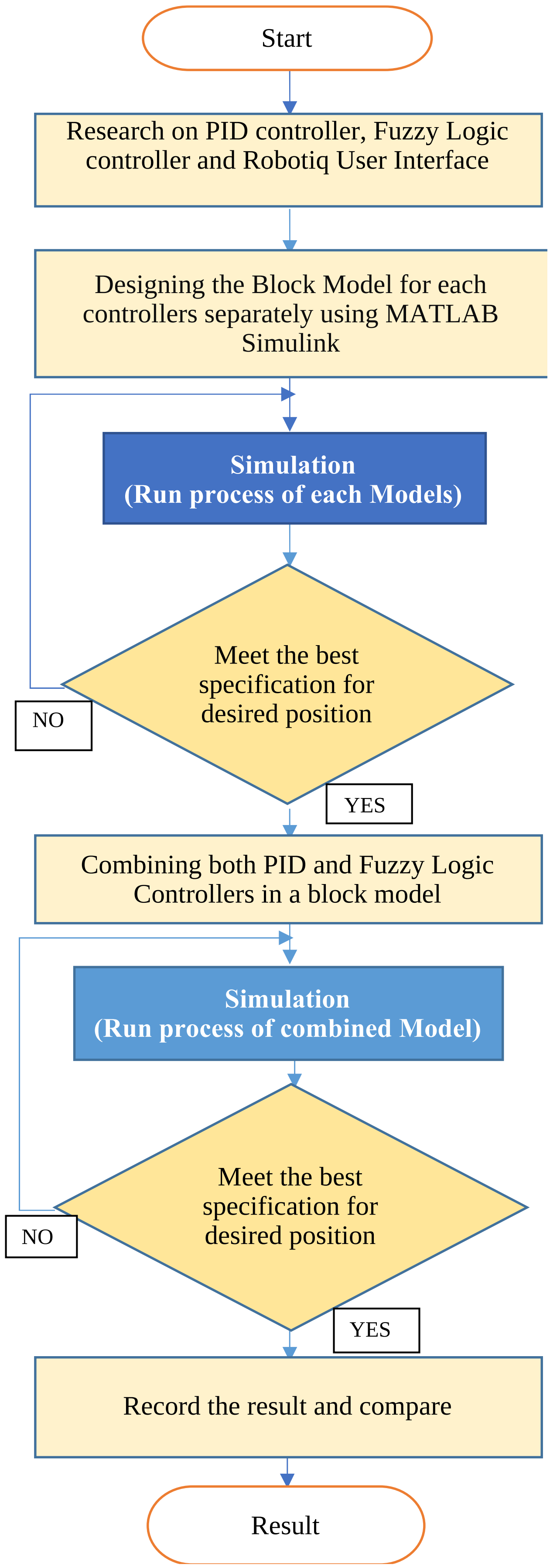
Start
Research on PID controller, Fuzzy Logic controller and Robotiq User Interface
Designing the Block Model for each controllers separately using MATLAB Simulink
Simulation (Run process of each Models)
Meet the best specification for desired position
NO
YES
Combining both PID and Fuzzy Logic Controllers in a block model
Simulation (Run process of combined Model)
Meet the best specification for desired position
NO
YES
Record the result and compare
Result

Figure 1: Flowchart of Project Progress

3. Results and Discussion

Simulation process broadly brings lots of new things and exploration that need to be discussed. This field is pointed especially on the tools and icon used in a block model construction. In developing the design, initialization each of the parameters involved could determine the accuracy and quality of the result obtained. Then, the mathematical model are defined so that the simulation could be carried out either using the previous value or the latest changed.

3.1 Transfer Function Suitability

The transfer function that is involved to be the closed-loop system will be the transfer function that is used to control an adaptive robots finger in a research paper found on title of Active Compliance Control Strategies for Multi-fingered Robot Hand [17].

Table 1: Model Identification for Finger A [17]

Data	Plant Transfer Function	Best Fit (%)
Test 1	$\frac{11.27\,s + 13.91}{s^2 + 12.9\,s + 13.93}$	99.33%
Test 2	$\frac{23.88\,s + 22.92}{s^2 + 24.82\,s + 22.95}$	99.33%
Test 3	$\frac{8.98\,s + 3.557}{s^2 + 9.389\,s + 3.562}$	97.65%
Test 4	$\frac{0.1303\,s + 0.2759}{s^2 + 0.9497\,s + 0.2737}$	72.2%

Among all of the tests, transfer function in Test 4 is chosen to be proceeded in this study due to its most accurate response in the model validation process. Even though Test 4 seemed to give the least in best fit, it gives the smallest difference in Standard Deviation calculated among the other tests. Which means, the highest similarity on the input and output data is produced by Test 4. Hence, it has been the most suitable transfer function representing robot finger in the simulation [17].

3.2 Simulation Set-up

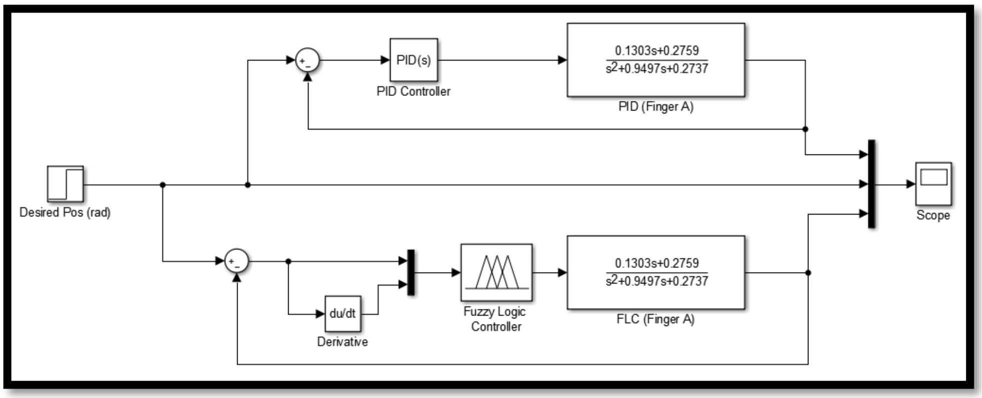

Figure 2: MATLAB Simulink Model for combination of PID Controller and Fuzzy Logic Controller

Figure about shows the construction of a Simulink model consist for both PID and Fuzzy Logic Controllers. The models are combined together with the desired position and the output result to have two output at the same output graph that will be shown by the ‘Scope’ block.

3.2.1 PID Controller Set-up

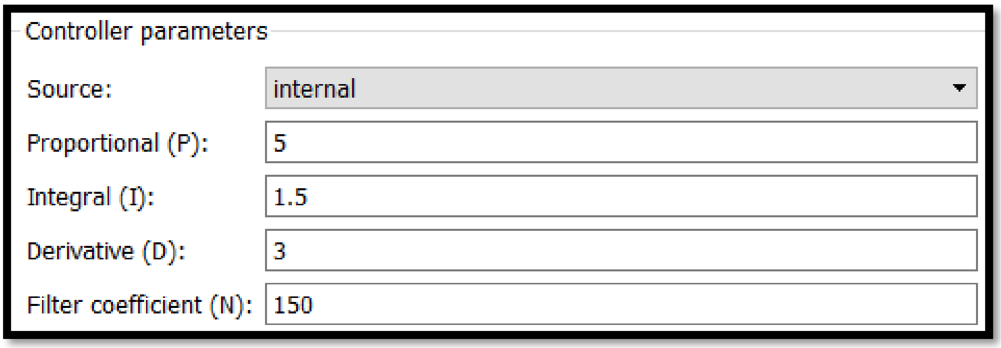

Figure 3: Controller parameters set-up for PID Controller

The Controller parameters for PID Controller is set-up as the above figure. Based on observation from the previous study with several try and error, the value set up above is proceeded for the output. For the Filter coefficient (N), it is observed that a higher filter coefficient would give smoothen output line.

3.2.2 Fuzzy Logic Controller Set-up

The fuzzy sets may be defined by typing “fuzzy” on the MATLAB prompt, to let the Fuzzy Logic Designer popped up. The following actions is to add the variables that must be involved adhering the Fuzzy Membership in the Fuzzy Sets.

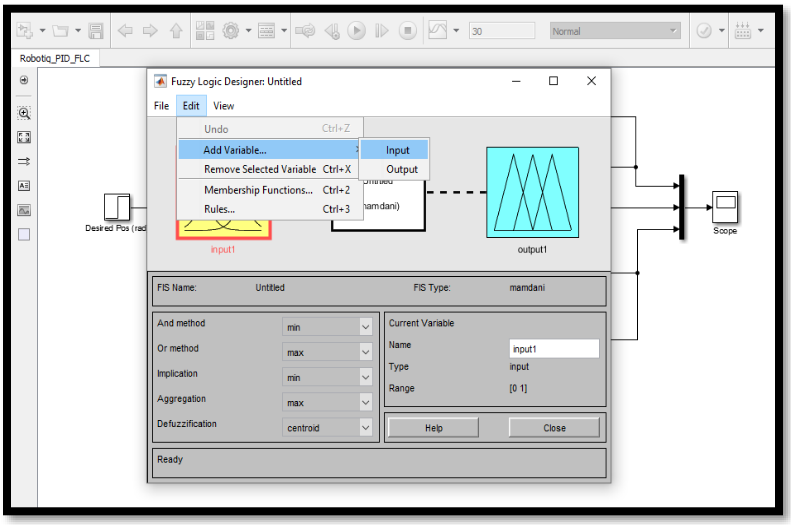

Figure 4: Adding Variables Fuzzy Logic Designer

Table 4: Linguistic variables representing Membership Functions in Fuzzy Sets

Symbol	Linguistic Variable
NB	Negative big
NS	Negative small
Z	Zero
PS	Positive small

PB	Positive big

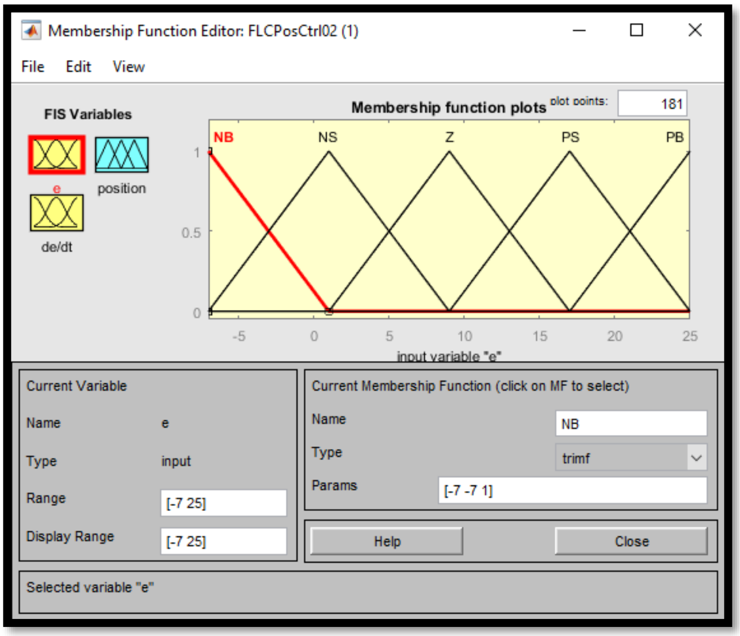

Figure 4(a): Membership Function plots of Error, e

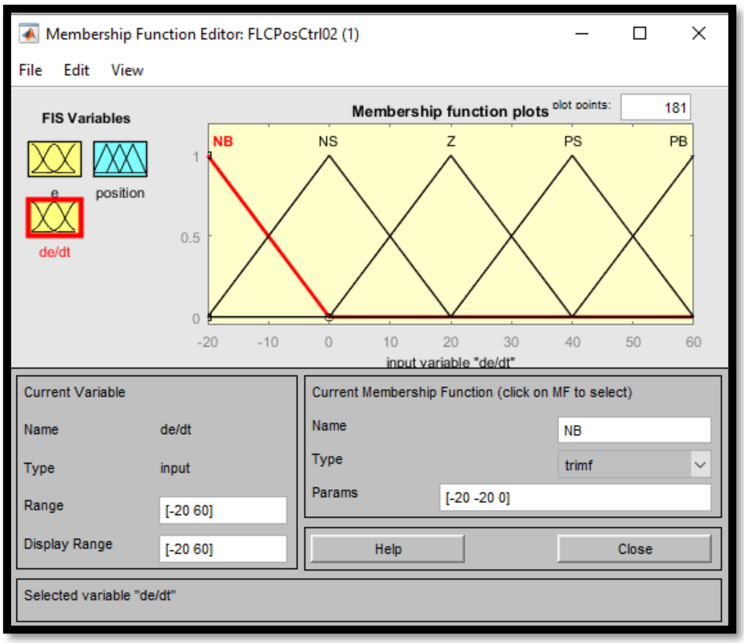

Figure 4(b): Membership Function plots for Difference of Error, de/dt

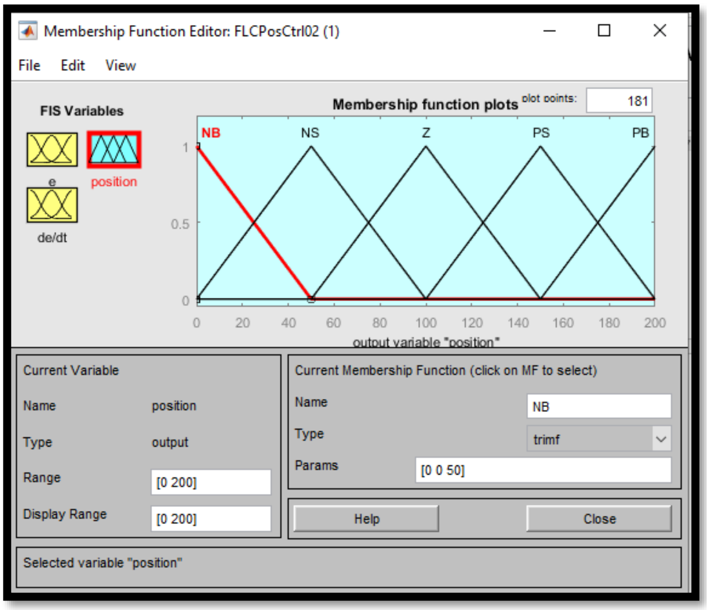

Figure 4(c): Membership Function plots for the Output Variables (position)

3.2 Output Result

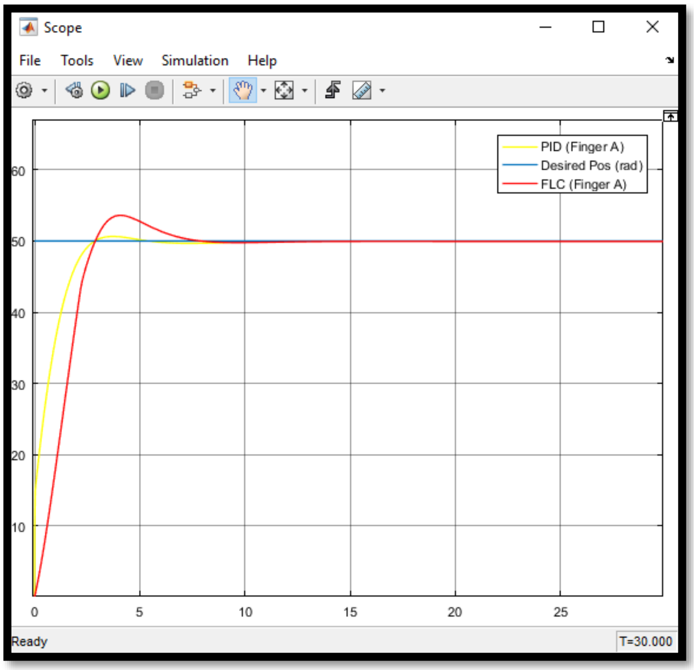

Figure 5: Response of the Model Simulated

For the output result, desired position output is represented by the blue line, meanwhile PID Controller and Fuzzy Logic Controller are represented by the yellow and red line respectively. Simulation time is set for a real time of 30 seconds and the desired position is set as 50 at the final value.

All the value of parameters needed for comparison in this study and reference of the desired position may be recorded from the command below that would be typed at the command window of MATLAB.

<u>Desired Position:</u>
REF= stepinfo(Demand.signals.values(:,2),Demand.time)

PID Controller:
PID= stepinfo(Demand.signals.values(:,1),Demand.time)
Fuzzy Logic Controller Command:
FUZZY= stepinfo(Demand.signals.values(:,3),Demand.time)
The output from the command given is tabulated in the following tables for each of the controllers.

Table 2: Performance specifications for PID Controller

Parameter	Value
Overshot Percentage	2.5494
Rise Time(sec.)	1.7434
Peak Time(sec.)	3.6949
Settling Time(sec.)	2.4727

Table 3: Performance specifications for Fuzzy Logic Controller

Parameter	Value
Overshot Percentage	14.8794
Rise Time(sec.)	1.9796
Peak Time(sec.)	4.0532
Settling Time(sec.)	6.3876

4. Conclusion

Based on the comparison of simulation results, it is found that the PID Controller is better than Fuzzy Logic Controller in the performance on the robotic hand. This is due to presents the following satisfactory performance indices:

1. Overshoot percentage: Overshoot may be reduced by using PID Controller.

2. Rise Time: A lower rise time compared to Fuzzy Logic Controller.

3. Peak Time: A lower peak time means giving a faster response.

4. Settling Time: Less in settling time means taking lower time to get stabled.

The performance of the fuzzy logic controller, however, can be further improved with the study of different membership function manipulation for its input and output variables. The membership rules were also playing a part in the output performance of the fuzzy logic controller while the used of fuzzy methods of Mamdani versus Sugeno may give different result to the fuzzy performance.

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