Fuzzy Logic In Washing Machines (June 2022)

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I. INTRODUCTION

A. Background

Fuzzy Logic (FL) is a many-valued logic form in which the variables' truth values might be any real number that is between 0 and 1. Fuzzy Logic acts as the role of the human decision-making methodology. It is the term used to describe the concept of incomplete or partial truth. It always deals with imprecise and incomplete information. Fuzzy logic normally based on "degrees of truth" rather than the usual "true or false" or "1 or 0" from Boolean logic. In real life, there are many situations that unable to decide whether the statement is true or false. Therefore, fuzzy logic provided a very valuable flexibility for reasoning at the time.

Fuzzy Logic is commonly used in control systems. This is because the fuzzy control rules can be well utilized in designing a controller. Apart from that, able to utilize the human expertise and experience for designing a controller by applying fuzzy logic in the control system. Fuzzy logic is applied successfully in a variety of control applications such as washing machines, traffic lights controller, air conditioner, anti-braking system, and the others. Fuzzy logic based controllers have many practical advantages compared to the other controllers. For instance, the main advantages of the fuzzy logic controller are simplicity, effectiveness, and flexibility. Besides, it also gives a desired result with high accuracy and high precision however, it handles the problems with imprecise and incomplete data.

There are three steps of designing a fuzzy logic controller system : Fuzzification, Inference System and Defuzzification. First, Fuzzification is defined as the process of transforming a crisp set into a fuzzy set. In this method it converts the crisp set membership value into a fuzzy set membership value. Next, for the inference system, there are some methods that are used in the control system. One of the most commonly used methods is the Mamdani Fuzzy Inference System. Mamdani method is a method that creates a system by integrating a set of linguistic control rules obtained from human experience. In the Mamdani method, fuzzy set output can be obtained for each rule which derived from the output membership function. An aggregation method will be used to combine all of the output fuzzy sets into a single fuzzy set. Then, a process of transforming a fuzzy set into a crisp set called defuzzification will undergo. Defuzzification is used to compute the fuzzy set value into a final crisp set output value.

In this project, the fuzzy logic based control system application that has been chosen is a washing machine. Nowadays, washing machines are common household appliances which are more effective than traditional hand-wash approaches. However, the users have been facing the problem of selecting the length of wash time based on the type of clothes, type of dirt, dirtiness of clothes and amount of clothes. To overcome the problem, washing machines with fuzzy logic systems offer a lot of benefits such as saving cost, saving water, improving performance, and becoming more simple. The duration of washing, rinsing, and spinning is able to wisely calculate by using a Fuzzy Logic mechanism machine.

B. Objective

There are three objectives in this project :

- To develop the fuzzy logic based intelligent washing machine system.
- To implement the theoretical knowledge of fuzzy logic.
- To design an intelligent washing machine which can save water, time and detergent when washing the clothes.

II. LITERATURE REVIEW

Fuzzy logic control based washing machines are becoming increasingly popular. Most of the top brands implement fuzzy logic control in their washing machines such as LG, Samsung, and Electrolux. These machines provide the benefits of simplicity in performance and low cost.

Manish Agarwal, introducing the concept of utilizing a fuzzy logic controller to regulate the washing time. He uses two input variables which are degree of dirt and type of dity in the fuzzy logic controller to get a suitable washing time for different clothes. The fuzzy logic controller is designed using 9 rules. The results of his research are quite persuasive and appropriate. The result shows that when the type of dirty and dirtiness value is large then the wash time is very long.

Deepak Kumar and Yousuf Haider, 2013, the amount of clothes and dirtiness were chosen as inputs to the fuzzy controller in order to reduce wash time of the machine.

Mustafa Demetgul and Osman Ulkir, 2014, developed a fuzzy logic controller based washing machine with four inputs and five outputs to achieve economical wash. The input parameters are amount of dirt, type of dirt, sensitivity of cloth and amount of cloths. The output are washing time,washing speed, amount of detergent, amount of water and water hotness.

Tarik Ahmed and Aziz Ahmad, 2016, introduced a fuzzy logic controller which has five inputs and three outputs to improve the performance of washing machines. The five inputs include type of clothes, amount of clothes, types of dirt, amount of dirt and temperature, whereas the output consist of wash time, rinse period and spin period. The result shows that the fuzzy logic controller will respond to different wash time, rinse period and spin period.

In our project, the proposed fuzzy logic controller is using three input parameters and three output parameters. The input parameters include type of clothes, amount of clothes and amount of dirtiness while the output parameters are wash time, rinse time and spin time. The proposed fuzzy logic controller is designed and simulated by using the Fuzzy Logic Toolbox in MATLAB software.

III. METHODOLOGY

Four steps make up the design process of the fuzzy inference system, or FIS. The first stage is Fuzzification for the input variables. Crisp inputs are transformed into fuzzy inputs during the first stage. Membership functions were developed to represent each crisp input based on linguistic terms and their ranges. Second step is the rule assessment stage, which assesses the procedure. Aggregation of the rules is the third stage. Then, the fourth step is Defuzzification which is the conversion of the fuzzy inputs into crisp outputs. The Mamdani style and centroid defuzzification approach are used in this project. Three linguistic inputs (LIs) make up the suggested fuzzy logic controller for a washing machine.

<u>Input Parameters:</u>

I. Type of clothes (TC)
II. Amount of clothes (AC)
III. Amount of dirtiness (AD)

The fuzzy controller receives these three inputs and produces the following three outputs as shown below.

<u>Output Parameters:</u>

I. Washing time (Wash)
II. Rinsing time (Rinse)
III. Spinning time (Spin)

<u>Washing Machine Fuzzy Logic Modeling</u>

Control logic was employed in this study to flawlessly carry out the operation and run continual system checks. The Mamdani controller's actuation provides highly accurate running time calculations.

3.1 Fuzzy Input and Fuzzy Output Membership Function

The respective membership functions for each variable that is proposed and their corresponding fuzzy memberships is determined from the three input and three output variables listed above. Figure 1 displays the fuzzy inference system for a washing machine.

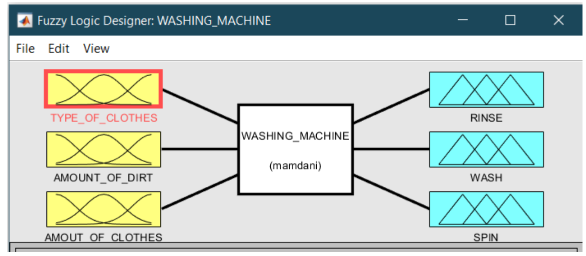

Figure1. FIS Editor ToolBox/ MATLAB

Linguistic phrases and the ranges of fuzzy inputs and fuzzy outputs associated with them are depicted in this fuzzy logic model of a washing machine as follows:

<u>Fuzzy Inputs</u>

In this study, the parameters are utilized to define membership function are:
TC = [-10 0 10], [5 10 15], [10 20 30] (Panties ,T-shirt or Pants,Jean or long sleeve shirt)
AD= [-20 0 20], [5 25 45], [30 50 70] (less, medium, large)
AC= [-35 0 35], [5 40 75], [45 80 115] (less, medium,large)

The fuzzy logic input membership functions are displayed in Figures 2, 3,and 4.

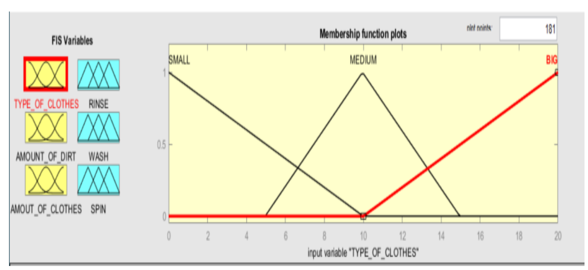

Figure2: Type of Clothes Membership Function

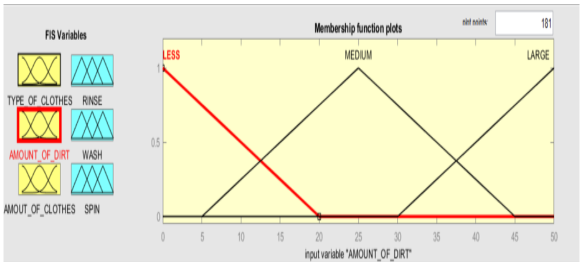

Figure 3: Amount of Clothes Membership Function

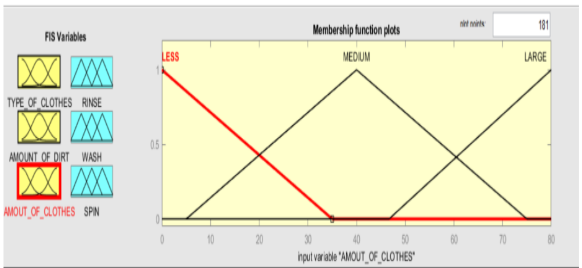

Figure 4: Amount of Dirtiness Membership Function

Fuzzy Outputs

RINSE = [-15 0 15] [0 15 30], [15 30 45] (short,medium,large)

WASH = [-30 0 30], [0 30 60], [30 60 90], [60 90 120], [90 120 150] (very short,short, medium,long,very long)

SPIN = [-15 0 15], [0 15 30], [15 30 45], [30 45 60], [45 60 75] (very short,short, medium,long,very long)

The fuzzy logic output membership functions are depicted in Figures 5, 6, and 7.

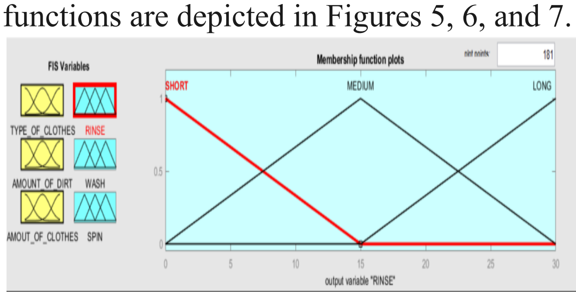

Figure 5: Rinse Time Membership Function

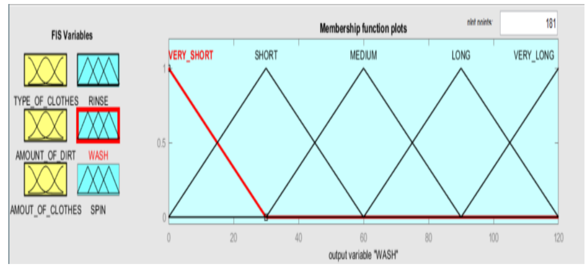

Figure 6: Wash Time Membership Function

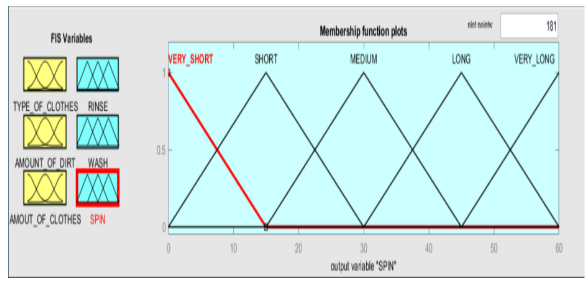

Figure 7: Spin Time Membership Function

3.2 Four steps in the Mamdani-style fuzzy inference procedure.

The "Mamdani" controller type is the one used in this model. Max is the aggregation. Min is the implication. The membership functions are symmetrical triangle shapes.

3.2.1 Fuzzification Method

The process of turning crisp values of an input variable into fuzzy values is known as fuzzification. Fuzziness helps us assess the rules.

3.2.2 Control Rules

Figures 8 depict the evaluation rules in fuzzy design for washing machines in order to determine the output. There is a total of 37 rules. These guidelines will govern how the system works. Decisions will be taken as a result, representing a controller's response.

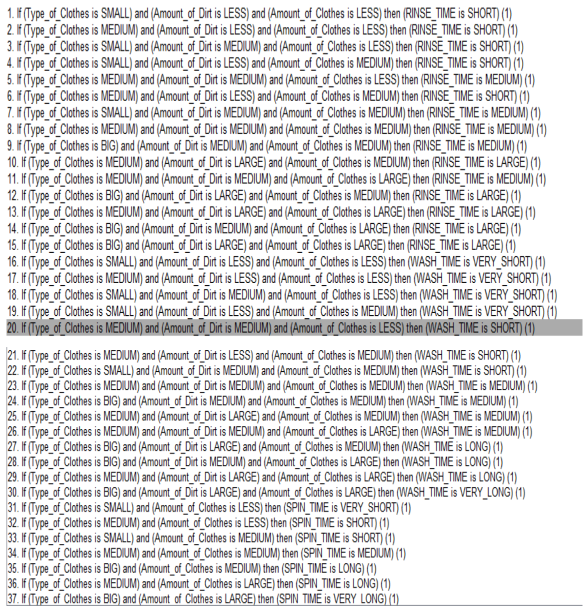
1. If (Type_of_Clothes is SMALL) and (Amount_of_Dirt is LESS) and (Amount_of_Clothes is LESS) then (RINSE_TIME is SHORT) (1)
2. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is LESS) and (Amount_of_Clothes is LESS) then (RINSE_TIME is SHORT) (1)
3. If (Type_of_Clothes is SMALL) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is LESS) then (RINSE_TIME is SHORT) (1)
4. If (Type_of_Clothes is SMALL) and (Amount_of_Dirt is LESS) and (Amount_of_Clothes is MEDIUM) then (RINSE_TIME is SHORT) (1)
5. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is LESS) then (RINSE_TIME is MEDIUM) (1)
6. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is LESS) and (Amount_of_Clothes is MEDIUM) then (RINSE_TIME is SHORT) (1)
7. If (Type_of_Clothes is SMALL) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is MEDIUM) then (RINSE_TIME is MEDIUM) (1)
8. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is MEDIUM) then (RINSE_TIME is MEDIUM) (1)
9. If (Type_of_Clothes is BIG) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is MEDIUM) then (RINSE_TIME is MEDIUM) (1)
10. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is LARGE) and (Amount_of_Clothes is MEDIUM) then (RINSE_TIME is LARGE) (1)
11. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is LARGE) then (RINSE_TIME is MEDIUM) (1)
12. If (Type_of_Clothes is BIG) and (Amount_of_Dirt is LARGE) and (Amount_of_Clothes is MEDIUM) then (RINSE_TIME is LARGE) (1)
13. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is LARGE) and (Amount_of_Clothes is LARGE) then (RINSE_TIME is LARGE) (1)
14. If (Type_of_Clothes is BIG) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is LARGE) then (RINSE_TIME is LARGE) (1)
15. If (Type_of_Clothes is BIG) and (Amount_of_Dirt is LARGE) and (Amount_of_Clothes is LARGE) then (RINSE_TIME is LARGE) (1)
16. If (Type_of_Clothes is SMALL) and (Amount_of_Dirt is LESS) and (Amount_of_Clothes is LESS) then (WASH_TIME is VERY_SHORT) (1)
17. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is LESS) and (Amount_of_Clothes is LESS) then (WASH_TIME is VERY_SHORT) (1)
18. If (Type_of_Clothes is SMALL) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is LESS) then (WASH_TIME is VERY_SHORT) (1)
19. If (Type_of_Clothes is SMALL) and (Amount_of_Dirt is LESS) and (Amount_of_Clothes is MEDIUM) then (WASH_TIME is VERY_SHORT) (1)
20. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is LESS) then (WASH_TIME is SHORT) (1)
21. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is LESS) and (Amount_of_Clothes is MEDIUM) then (WASH_TIME is SHORT) (1)
22. If (Type_of_Clothes is SMALL) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is MEDIUM) then (WASH_TIME is SHORT) (1)
23. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is MEDIUM) then (WASH_TIME is MEDIUM) (1)
24. If (Type_of_Clothes is BIG) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is MEDIUM) then (WASH_TIME is MEDIUM) (1)
25. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is LARGE) and (Amount_of_Clothes is MEDIUM) then (WASH_TIME is MEDIUM) (1)
26. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is LARGE) then (WASH_TIME is MEDIUM) (1)
27. If (Type_of_Clothes is BIG) and (Amount_of_Dirt is LARGE) and (Amount_of_Clothes is MEDIUM) then (WASH_TIME is LONG) (1)
28. If (Type_of_Clothes is BIG) and (Amount_of_Dirt is MEDIUM) and (Amount_of_Clothes is LARGE) then (WASH_TIME is LONG) (1)
29. If (Type_of_Clothes is MEDIUM) and (Amount_of_Dirt is LARGE) and (Amount_of_Clothes is LARGE) then (WASH_TIME is LONG) (1)
30. If (Type_of_Clothes is BIG) and (Amount_of_Dirt is LARGE) and (Amount_of_Clothes is LARGE) then (WASH_TIME is VERY_LONG) (1)
31. If (Type_of_Clothes is SMALL) and (Amount_of_Clothes is LESS) then (SPIN_TIME is VERY_SHORT) (1)
32. If (Type_of_Clothes is MEDIUM) and (Amount_of_Clothes is LESS) then (SPIN_TIME is SHORT) (1)
33. If (Type_of_Clothes is SMALL) and (Amount_of_Clothes is MEDIUM) then (SPIN_TIME is SHORT) (1)
34. If (Type_of_Clothes is MEDIUM) and (Amount_of_Clothes is MEDIUM) then (SPIN_TIME is MEDIUM) (1)
35. If (Type_of_Clothes is BIG) and (Amount_of_Clothes is MEDIUM) then (SPIN_TIME is LONG) (1)
36. If (Type_of_Clothes is MEDIUM) and (Amount_of_Clothes is LARGE) then (SPIN_TIME is LONG) (1)
37. If (Type_of_Clothes is BIG) and (Amount_of_Clothes is LARGE) then (SPIN_TIME is VERY_LONG) (1)

Figure 8: Rule Editor From FIS Editor

3.2.3 Aggregation of the output

Aggregation is the process of combining all of the outputs of rules that are taken from membership functions. All rules are aggregated to create a specific fuzzy set so that it can obtain one set of fuzzy set.Then, the defuzzification uses the aggregated output fuzzy set as input variables.

3.2.4 Defuzzification

Defuzzification is the process of going from a fuzzy set to a crisp set. Therefore, the result of the defuzzification process is a single number, which in turn represents the controller's response. Since there are other defuzzification techniques, we choose to utilize the Centroid method in this study because it is the most widely used.

The suggested system uses sensors to sense input values, fuzzyfies their responses using aggregation and if-else rules, and then extracts the output variable using a defuzzification mechanism.

IV. RESULTS AND DISCUSSION

As is well known, the Min-Max operator is used to define control rules. The following figures show these laws in the form of 3D graphs. The relationship between the input and output parameters is depicted in figure 9a, 9b and 9c.

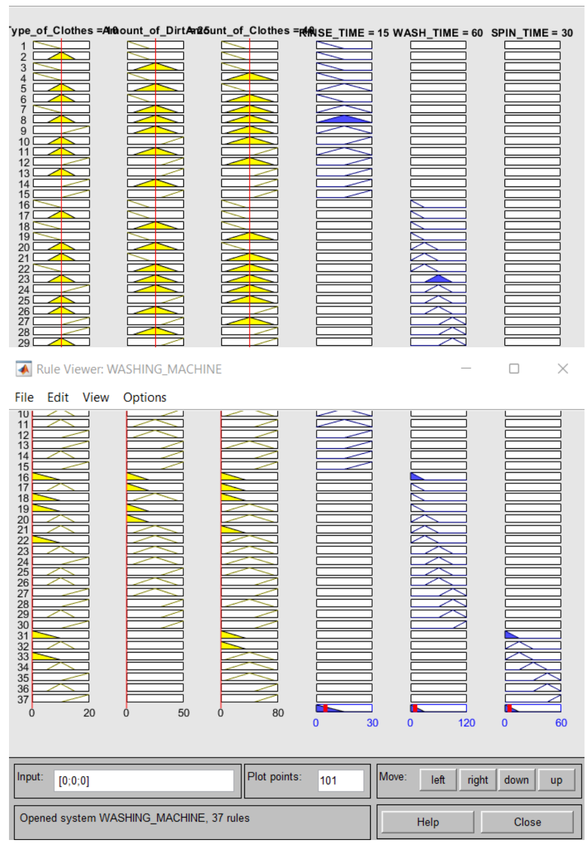

Figure 9a. Rule Viewer from Fuzzy Logic Toolbox

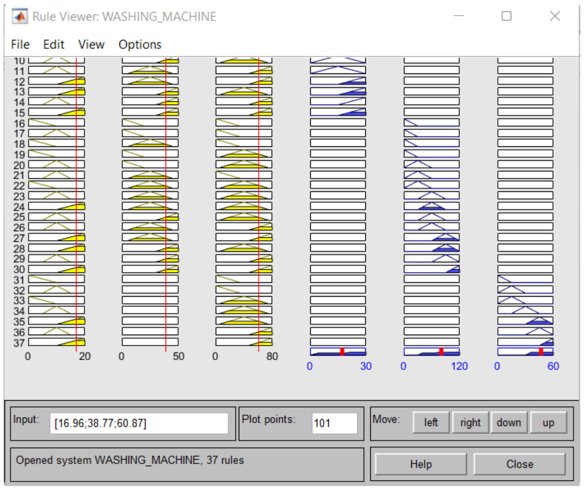

Figure 9b. Rule Viewer from Fuzzy Logic Toolbox

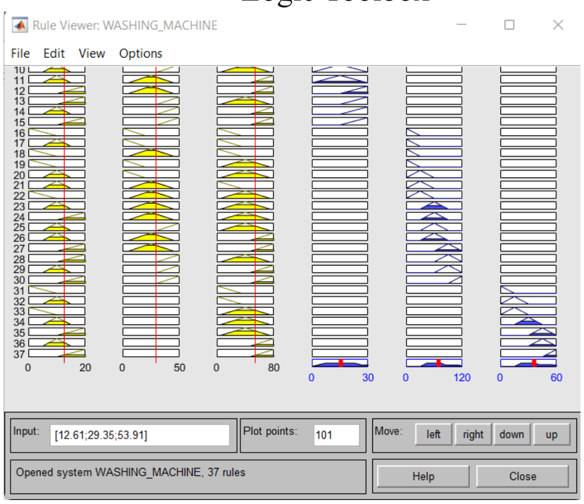

Figure 9c: Rule Viewer from FIS Editor

From Figure 9a, when input AC=low, AD=low, TC=low, the output obtained at the left side of the graph. As the output results are low, the washing, rinsing and spinning time needed becomes less. When all inputs increase to high (Figure 9b), the result of the graph is in between middle and high, the time needed for rinsing and washing is average, but the spinning moderately longer.. If all inputs are set to middle and high (Figure 9c), the result of the graph is at the middle, the time needed for spinning, washing and rinsing is also average.

The FIS has been generated by using the fuzzy logic toolbox in MATLAB. Therefore, the surface rule views of FL modeling rules can be shown in Figure (10.a, 10.b, 11.a, 11.b, and 12.a, 12.b) as 3D graphs. From the surface view, it can be seen the response surface of relation between input and output variables respectively.

<u>Outputs of SPIN_TIME</u>

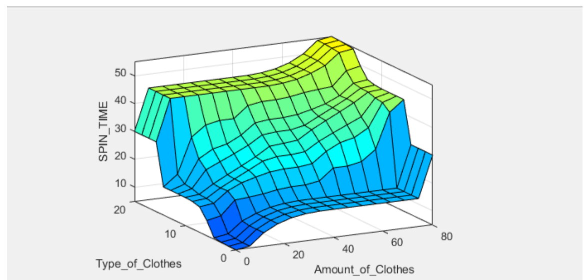

Figure 10.a: Surface Viewer from FIS Editor Toolbox

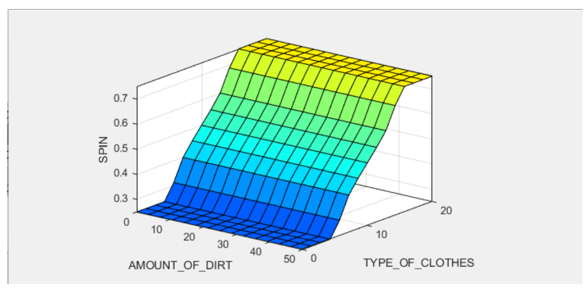

Figure 10.b: Surface Viewer from FIS Editor Toolbox

From figure 10.a, spin time is not affected much by the type of dirt and amount of clothes. While, from figure 10.b, that the amount of dirt has no effect on the spin time, and the spin time is proportional to the type of clothes. The more types of clothes in the washing machine, the longer the spinning will be.

<u>Outputs of RINSE_TIME</u>

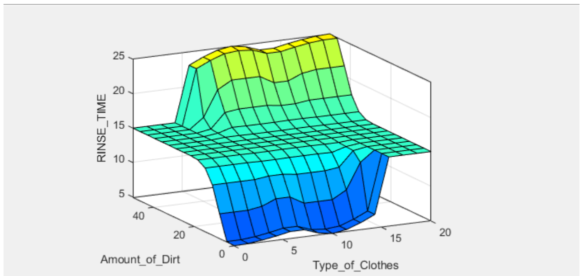

Figure 11.a, Surface Viewer from FIS Editor Toolbox

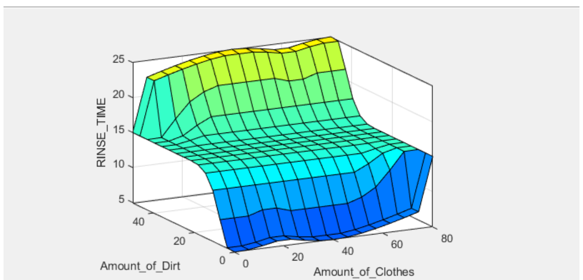

Figure 11b, Surface Viewer from FIS Editor Toolbox

From Figure 11a the rinse time is fixed after the amount of clothes more than 20. In Figure 11b, the amount of dirt influences rinse time more than the type of clothes. All clothes will take the same rinse time unless the clothes are extremely heavy and many, then the rinse time will be slightly longer in the washing machine.

<u>Outputs of WASH_TIME</u>

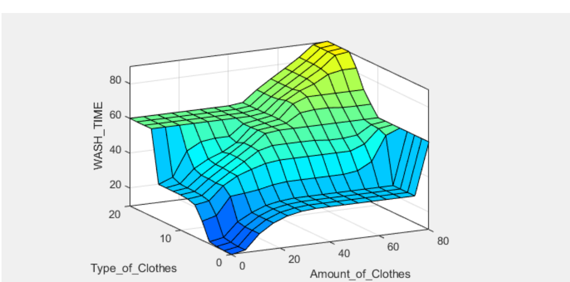

Figure 12.a, Surface Viewer from FIS Editor Toolbox

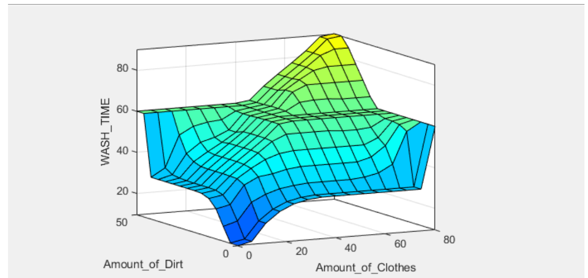

Figure 12.b, Surface Viewer from FIS Editor Toolbox

From Figure 12.a and 12.b the wash time has almost the same output toward the type of clothes and the amount of dirt. The thicker the types of clothes and the dirtier the clothes, the washing machine needs a longer time to wash. The amount of dirt and type of clothes has a much higher effect on washtime than the amount of clothes.

V. CONCLUSION

Fuzzy logic is used for the washing machine response in different conditions. The input parameters of the washing machine have affected the output of the washing machine. Example, more clothes might need more washing time. With the implementation of a fuzzy logic system, the machine is able to complete its work with better results and save power consumption in different situations. In this project, by using the proposed fuzzy logic controller, we successfully obtain the wash time, rinse time and spin time (output parameter) for different types of clothes, amount of clothes ,amount of dirtiness (input parameter). This analysis can bring the advantages of saving water, time and detergent when washing the clothes. Fuzzy logic controllers' application areas have a greater dynamic range. It is vital to note that one fuzzified solution may not be appropriate for all users, so there is a pressing need to standardize the fuzzified solution domain.

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