Department of Electronics Engineering

Experiment No.: 07
FIS Design: Washing Machine Controller

Aim: To study Mamdani style fuzzy interference for design of a fuzzy inference system for a washing machine controller.

Apparatus: SCILAB

Theory: The most commonly used fuzzy inference technique is the so-called **Mamdani** method. In 1975, Professor Ebrahim Mamdani of London University built one of the first fuzzy systems to control a steam engine and boiler combination.

The Mamdani-style fuzzy inference process is performed in four steps:

1. Fuzzification of the input variables
2. Rule evaluation (inference)
3. Aggregation of the rule outputs (composition)
4. Defuzzification.

1. Fuzzification:

The first step is to take the crisp inputs and determine the degree to which these inputs belong to each of the appropriate fuzzy sets.

2. Rule Evaluation:

The second step is to take the fuzzified inputs and apply them to the antecedents of the fuzzy rules. If a given fuzzy rule has multiple antecedents, the fuzzy operator (AND or OR) is used to obtain a single number that represents the result of the antecedent evaluation. This number (the truth value) is then applied to the consequent membership function.

For OR rule: $\mu_{A\cup B}(x) = \max\,[\mu_A(x), \mu_B(x)]$

For AND rule: $\mu_{A\cap B}(x) = \min\,[\mu_A(x), \mu_B(x)]$

Now the result of the antecedent evaluation can be applied to the membership function of the consequent. This can be done by clipping.

The most common method of correlating the rule consequent with the truth value of the rule antecedent is to cut the consequent membership function at the level of the antecedent truth. This method is called **clipping** (alpha-cut).

Since the top of the membership function is sliced, the clipped fuzzy set loses some information. However, clipping is still often preferred because it involves less complex and faster mathematics, and generates an aggregated output surface that is easier to defuzzify.

3. Aggregation of Output:

Aggregation is the process of unification of the outputs of all rules. We take the membership functions of all rule consequents previously clipped or scaled and combine them into a single fuzzy set. The input of the aggregation process is the list of clipped or scaled consequent membership functions, and the output is one fuzzy set for each output variable.

4. Defuzzification:

The last step in the fuzzy inference process is defuzzification. Fuzziness helps us to evaluate the rules, but the final output of a fuzzy system has to be a crisp number. The input for the defuzzification process is the aggregate output fuzzy set and the output is a single number.

Design: Design a fuzzy logic controller to determine the wash time of a domestic washing machine. Assume that the input is dirt and grease on the clothes with 3 descriptors each. Output should be prediction of wash time using 5 descriptors.

Step 1: Identify inputs and outputs and their descriptors.

Input 1: Dirt – 0 to 100 % (SD, MD, LD)

Input 2: Grease – 0 to 100 % (SG, MG, LG)

Output : Wash time – 0 to 60 mins (VS, S, M, L, VL)

Step 2 : Build a rule-base for the given system.

GREASE → DIRT ↓	SG	MG	LG
SD	VS	S	M
MD	S	M	L
LD	M	L	VL

Step 3 : Assign membership functions to the input and output variables.

To-do: *(Draw the membership functions for each input and output and accordingly write down the mathematical equations for all the membership functions.)*

Step 4: Rule evaluations for some specific input.

Step 5: Defuzzification of the given system.

Step 6: Derivation of the output.

To-do: *(students are supposed to perform steps 4, 5 and 6 and write the description accordingly with proper equations and calculations.)*

Procedure:

1) Open SCILAB and type sciFLTEditor in the editor.
2) As fuzzy tool opens, select Mamdani type fuzzy problem.
3) Select number of inputs.
4) Assign the inputs their name, number of member variables, parameters of the member variables and the type of fuzzy sets the respective member variables belong to.
5) Assign output its name, number of member variables, parameters of the member variables and types of fuzzy sets the respective member variables belong to.

6) Define all the fuzzy rules in the rule-box.
7) Simulate the fuzzy problem.
8) Open Rule Viewer and test the output by giving various combination on the input, observe whether desired output is achieved.

Results:

1. **Solve the design problem step by step and derive the output for a specified value of inputs. Attach the images for the solved problem in the space below (write SAP ID and name on each page).**

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NNFL Lab 7
FIS DESIGN

1 of 4

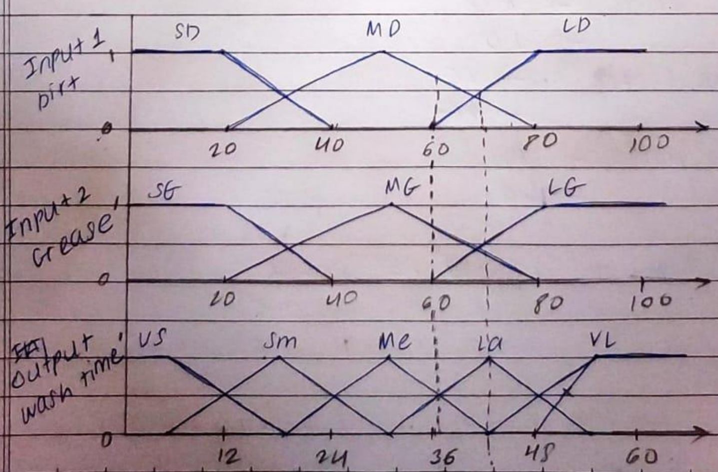
* washing machine controller

2 inputs [dirt and grease] => 3 descriptors
1 output [wash time] => 5 descriptors

solution:

* Step I Identify input and output
Input 1 : Dirt : 0 to 100%
(SD - MD - LD)
Input 2 : Grease : 0 to 100%
(SG - MG - LG)
output : wash time 0 to 60 mins.
(VS - Sm - Me - La - VL)

* step II : Assigning membership functions to the variables.



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* Step III: Design a rule base

		Grease		
		SG	MG	LG
Dirt	SD	VS	Sm	Me
	MD	Sm	Me	La
	LD	Me	La	VL

Step IV: Rule evaluation

Assume Dirt = 60%
Grease = 70%

~~Step V~~

Dirt 60% → MD
→ LD

Grease 70% → LG
→ MG

Wash time → Me
→ La

Dirt → MD → $\mu_{MD}(x) = \frac{80 - x}{80 - 50}$

$\mu_{MD}(60) = 0.66$; $\mu_{LD}(60) = 0$

$\mu_{MG}(70) = 0.33$; $\mu_{LG}(70) = 0.5$

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Step V Decision table

	SE	* ME	* LE
SD	x	x	x
* MD	x	$\mu_{ME}(T)$	$\mu_{LE}(T)$
* LD	x	$\mu_{LE}(T)$	x

output membership functions:

$$\mu_{ME}(T) = \frac{42-T}{42-30}$$

$$\mu_{LE}(T) = \frac{T-30}{42-30}$$

Step VI Defuzzification

$$\left.\begin{array}{l} \mu_{MD}(60) \wedge \mu_{MG}(70) = 0.66 \wedge 0.33 = 0.33 \\ \mu_{MD}(60) \wedge \mu_{LG}(70) = 0.66 \wedge 0.5 = 0.5 \\ \mu_{LD}(60) \wedge \mu_{MG}(70) = 0 \wedge 0.33 = 0 \\ \mu_{LD}(60) \wedge \mu_{LG}(70) = 0 \wedge 0.5 = 0 \end{array}\right\} \max = 0.5$$

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Step VII predicting the output

substituting defuzzified value in the output membership functions.

$T_1 =$ 36 minutes

$T_2 =$ 36 minutes

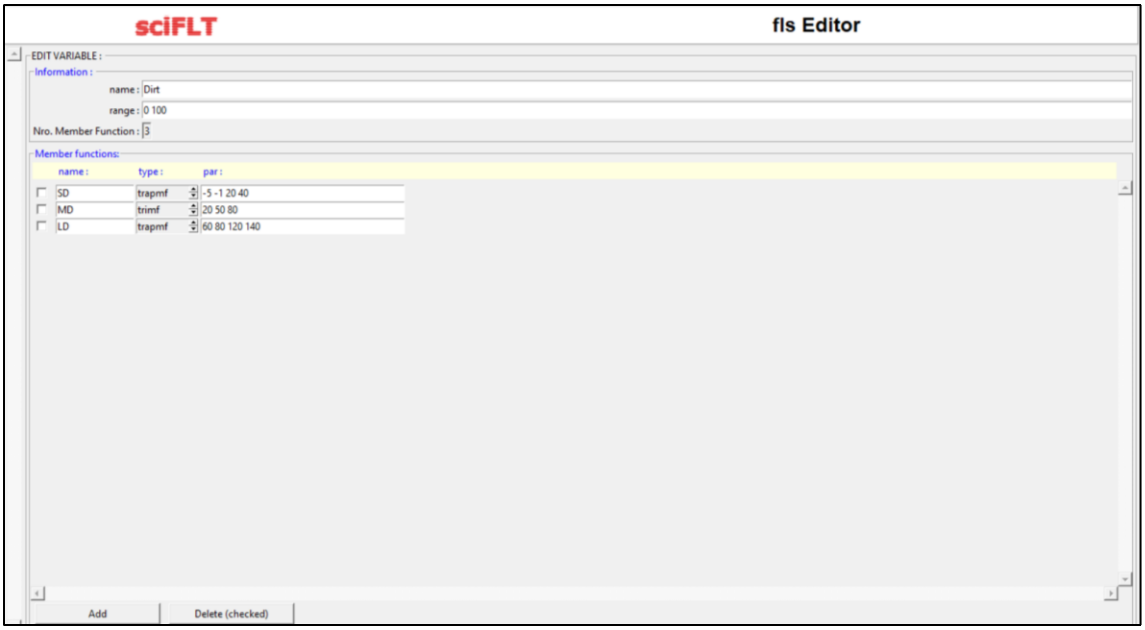
$T = \frac{T_1 + T_2}{2} = 36$ minutes.

2. **Attach screenshots for description, inputs (dirt and grease), output, rules and run the system for 3 conditions of the input values.**
   (Mention the SAP Id with each descriptor and then run the interface to get the output)

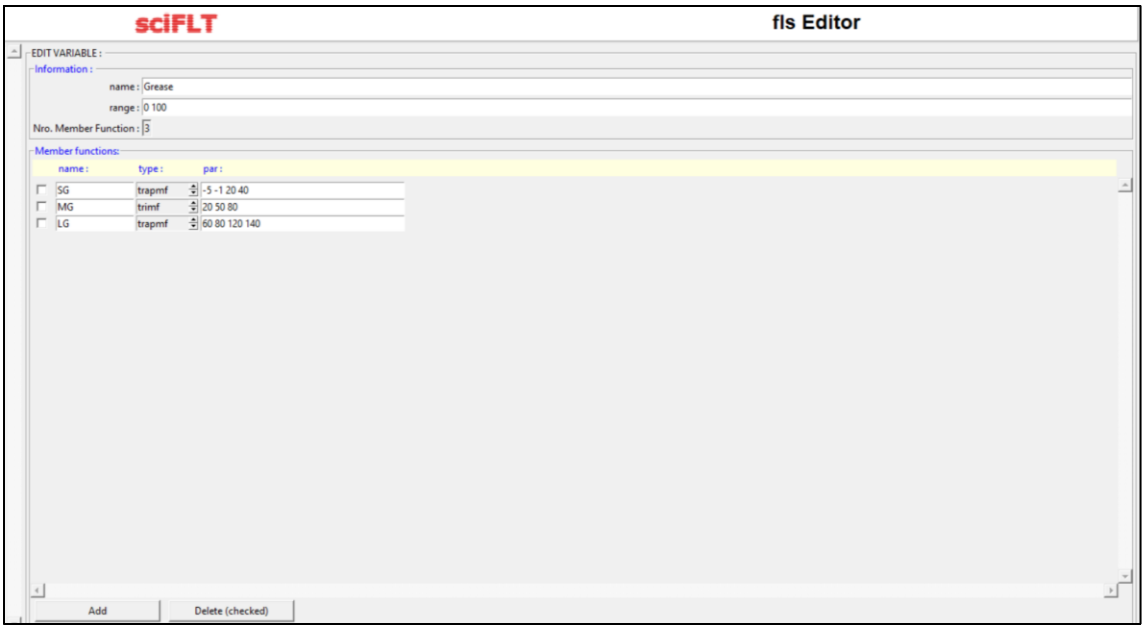
1. Description:

2. Inputs:

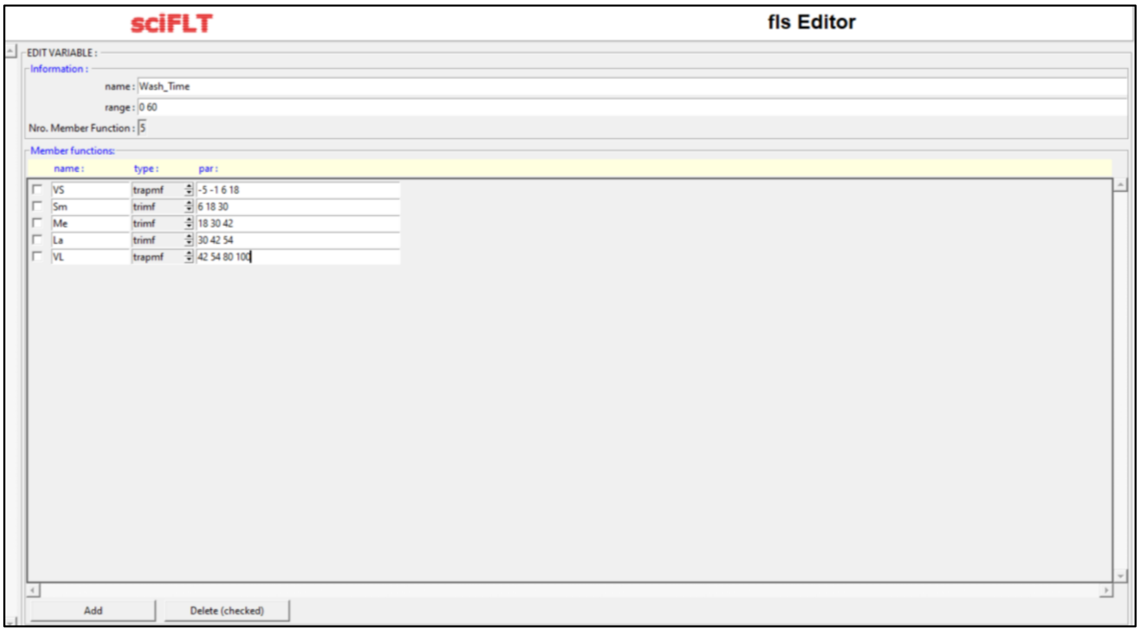
a. Dirt



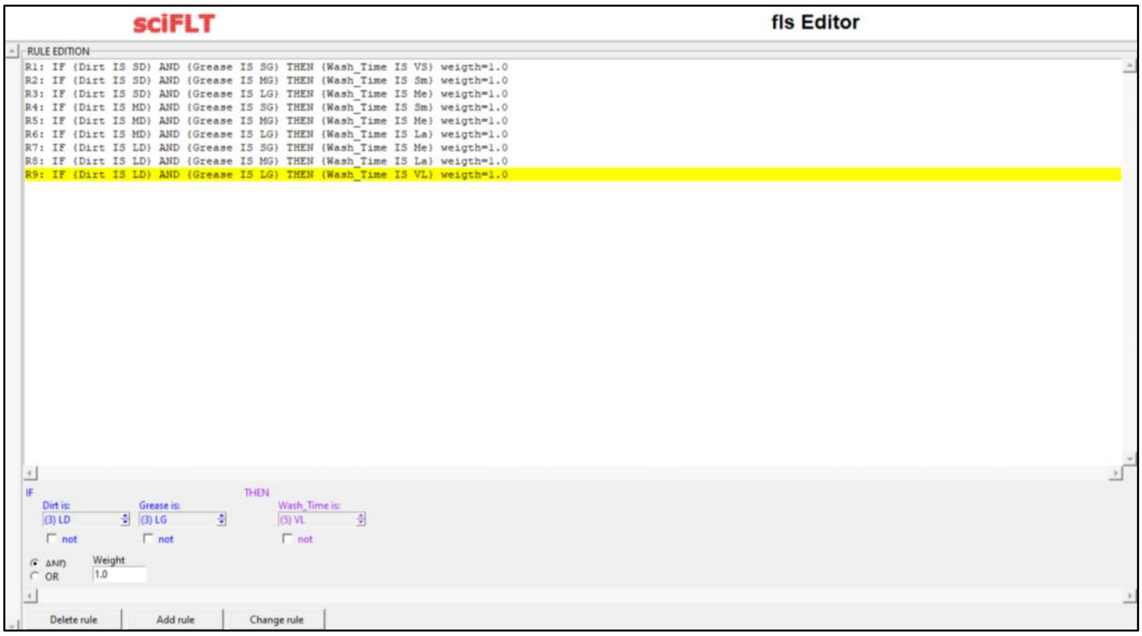
b. Grease



3. Output (Wash Time):

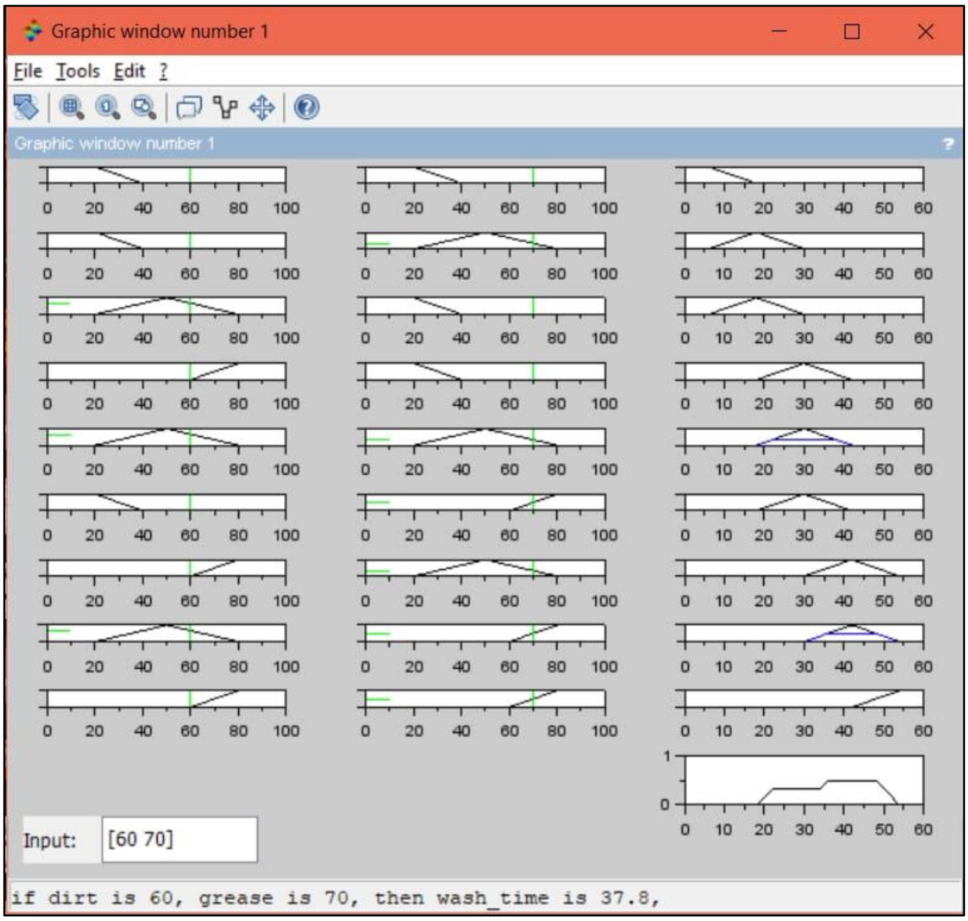


4. Rules:

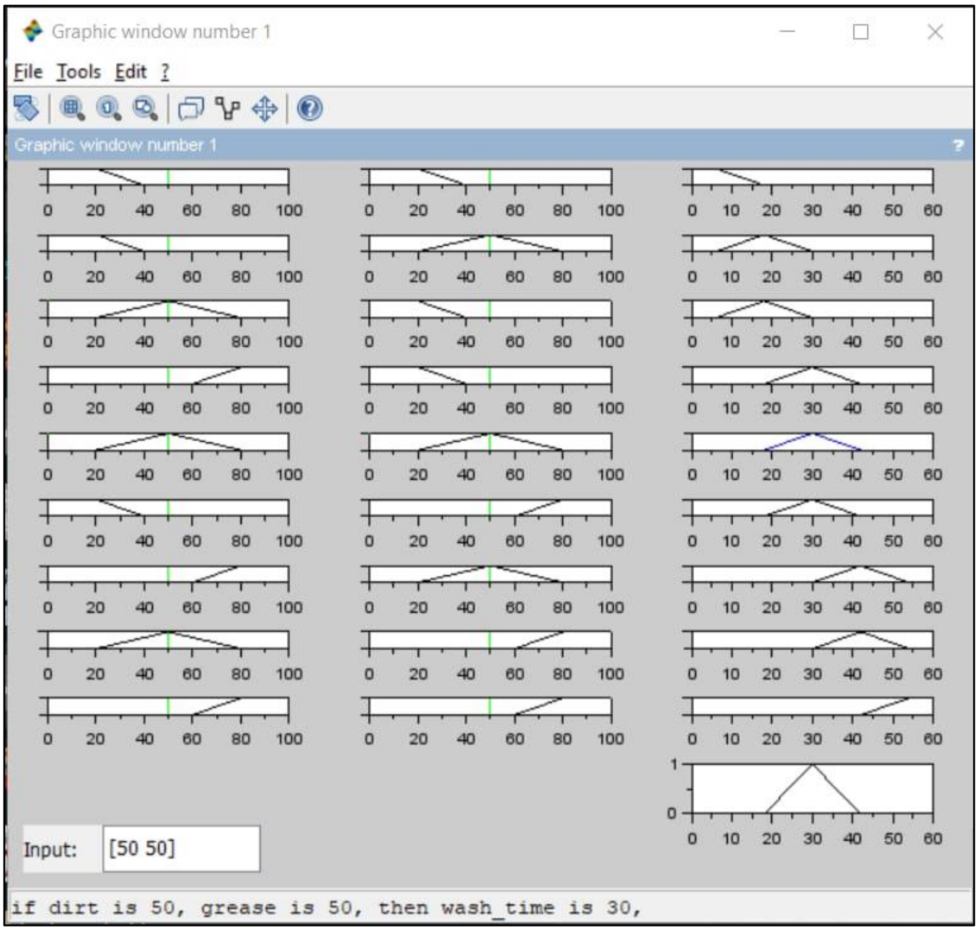


5. Waveforms:

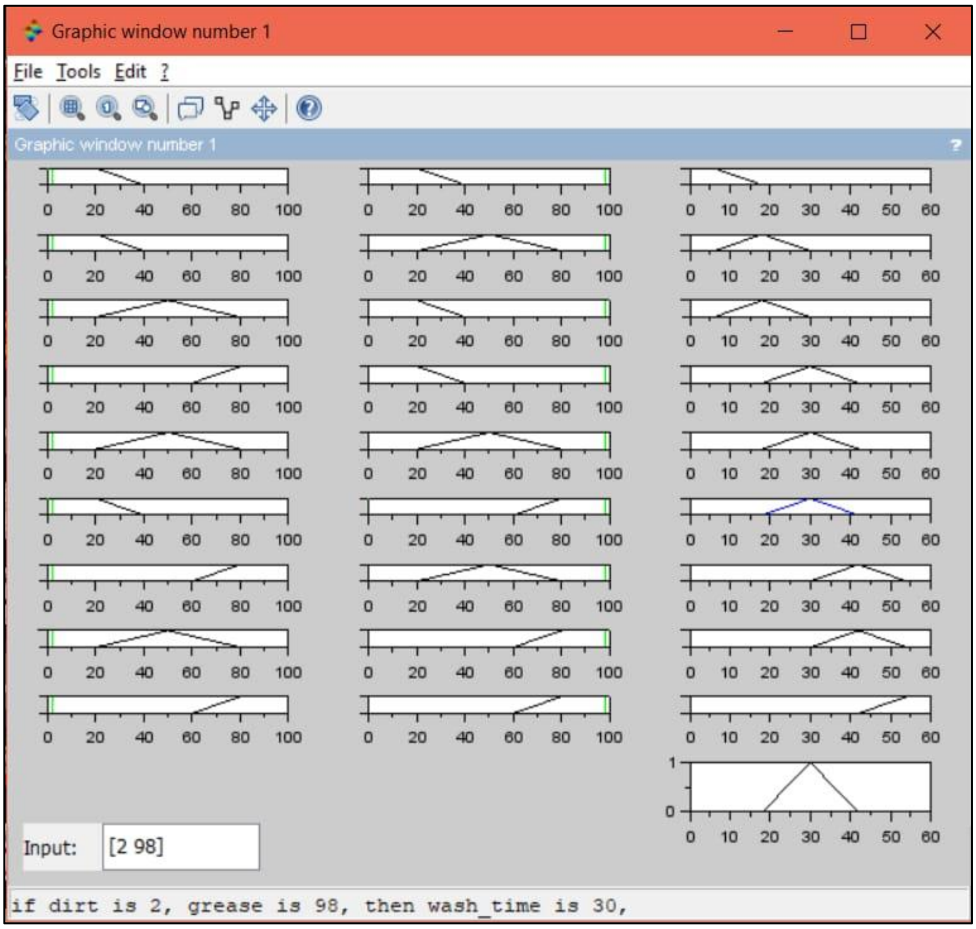
Dirt = 60% & Grease = 70%:



Dirt = 50% & Grease = 50%



Dirt = 2% & Grease = 98%:



Conclusion:

In this experiment, we used Mamdani style fuzzy interference to design a fuzzy inference system (FIS) for washing machine controller. We used the FLT Editor in Scilab for the simulation of the experiment. We gave two inputs and depending on the percentage of the inputs, calculated the output. The practical values of the output were compared by the theoretical values which were same. This proves the simulation was accurate and successful.