Defuzzification in a Fuzzy Logic Controller: Automatic Washing Machine

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ABSTRACT
The purpose of this paper is to compare the various defuzzification techniques for the application of an automatic washing machine control design to predict the error difference between different methods. An automatic washing machine with for domestic applications is considered. The input parameters are considered to be the amount of dirt and grease on clothes. Depending upon the amount of inputs the wash time is to be decided as the output by various defuzzification techniques. The problem is supported by MATLAB simulation to assess the various techniques.

Keywords
Fuzzy logic controller, defuzzification techniques, fuzzy rule base, MATLAB simulation

1. INTRODUCTION
Washing machines are one of the most common household appliances found today. The essence of such a machine is to reduce the workload and effectively provide cleaner clothes. In terms to prove the cleanliness of clothes the washing machine manufacturers are striving towards a fully automated sensor operated machines which can completely sense the amount of wash load, the amount of dirtiness of the clothes and the type of material in the current wash cycle so as to directly predict the wash time required. The wash sensor can be a simple optical sensor used to measure the physical quantity of light, passed through a glass tube, which can then be converted to electrical signals to predict the amount of dirtiness[1]. A fuzzy logic controller (FLC) based washing machine is to be designed

2. PROBLEM STATEMENT
A fuzzy logic controller (FLC) based washing machine is to be designed for two input parameters,

1. The degree of dirt present on the clothes and

2. The amount of grease present on the clothes.

Each of the inputs have three descriptors each and are to be presented on a scale from 0% to 100%.

The output is to predict the wash time required for a certain amount of both inputs and are classified under five descriptors. The total amount of wash time is to be estimated between 0 to 60 minutes. The membership functions are to be designed for all the input as well as output parameters and depending on these membership functions a rule base is developed.

3. BLOCK DIAGRAM

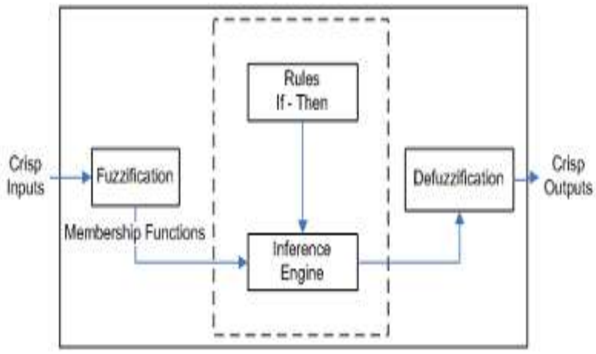

Fig 1: Basic block diagram of a Fuzzy Logic Controller (FLC)

Fuzzification : Defining the inuts and the outputs for a given problem statement and deciding their range of operation so as to assign the proper membership functions to each is the process of fuzzification.

Rule Base : Depending on the types of inputs and the required outputs rules are developed to predict the possible outputs status.

Inference Engine : It infers from the rules applied to it and depending upon the inputs derives the output for the desired applied input.

Defuzzification : The derivation of the crisp output for the specific inputs applied is the process of defuzzification.

4. DEFUZZIFICATION TECHNIQUES
The fuzzification process produces an output depending upon the developed rule base and inference engine. This process generates an output, from the precise values available at the input, in the fuzzified form. Usually the fuzzification process involves union of two or more fuzzy sets applied as inputs and defined over the universe of discourse.

The process of converting the fuzzy rule base output to a final crisp value, suitable to be useful for applications for which a system is designed, is called as "Defuzzification". The defuzzification method cannot be chosen systematically depending upon the applications. It depends on the need of the application.

4.1 Centroid method

The most familiar and commonly used technique for defuzzification is the "Centroid method" also called as "center of gravity" or "center of area" method. It clips the area into smaller regions and then the union operation is performed to get the final output. It is given by the expression[7],

$$x = \frac{\sum_{i=1}^{n} x_i . \mu(x_i)}{\sum_{i=1}^{n} \mu(x_i)}$$

Here n represents the number of elements in the sample, i.e., x_i are the elements and $\mu(x_i)$ are their corresponding membership functions.

4.2 Bisector method

The bisector method or bisector of area method divides the area into two regions with the same area. It may or may not coincide with the centroid line of the given area.

4.3 Middle of maxima (MOM) method

The simplest method of defuzzification is to take the crisp value with the highest degree of membership function. The mean of maxima is the arithmetic average of mean values of all intervals contained in the fuzzy set including zero length intervals. The equation of the defuzzified value is given by[7],

$$x = \frac{\sum_{x_i \in M} x_i}{|M|}$$

where M = height of the fuzzy set

$|M|$ = cardinality of the fuzzy set M

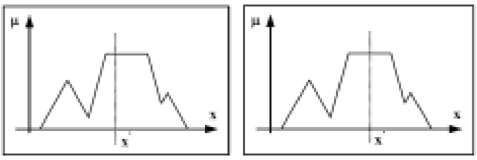

Fig 2: comparing the Centroid and MOM methods

5. SYSTEM IMPLEMENTATION

The automatic washing machine for a domestic household use is considered with two inputs and one output. The first input is the degree of dirt present on the clothes. It has three descriptors as – small, moderate and large. The second input is the amount of grease present on the clothes with three descriptors as – small amount of grease (SGr), medium amount of grease (MGr) and large amount of grease (LGr).

The output of this washing machine is to decide the wash time required for the specific inputs and is divided between five descriptors as – very short time-period, short time-period, moderate time-period, large time-period and very large time-period. Depending upon the type of inputs a rule base is developed to predict the wash time.

Table 1. Rule base for the washing machine FLC

	NGr	MGr	LGr
SD	VS	S	M
MD	S	M	L
LD	M	L	VL

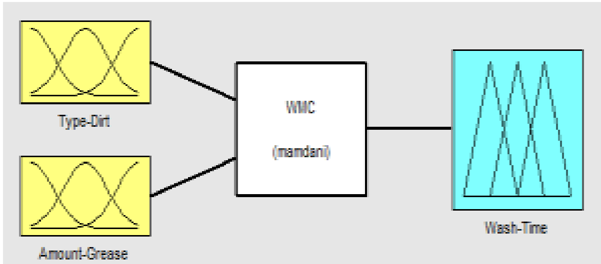

Fig 3: FLC for an automatic domestic washing machine

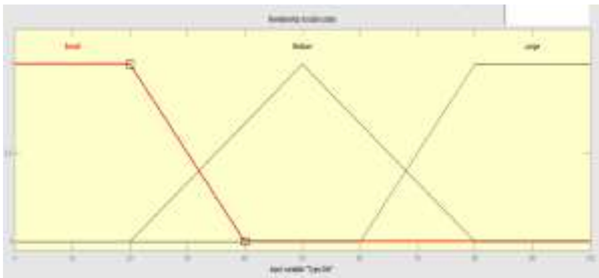

Fig 4: Input of FLC "Type-Dirt" with three descriptors

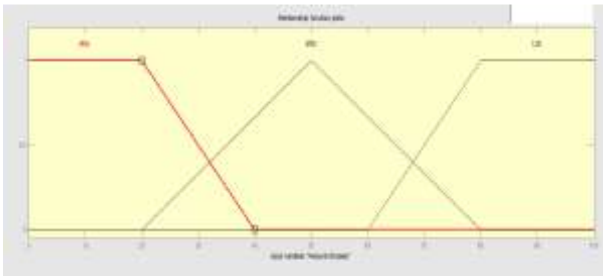

Fig 5: Input of FLC "Amount-Grease" with three descriptors

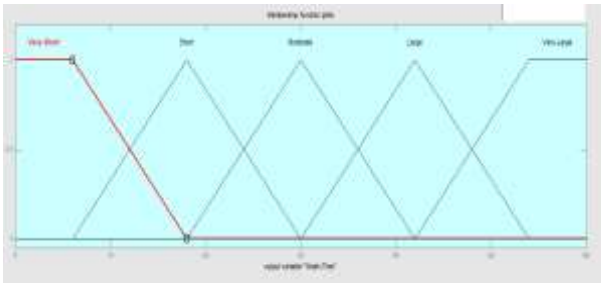

Fig 6: Output of FLC – "Wash-Time" with five descriptors

5.1 Surface Plots

The three defuzzification techniques used – the centroid method, the bisector method and the mean of maxima (MOM) method - for the above system implementation gives the surface plots [5] as shown below

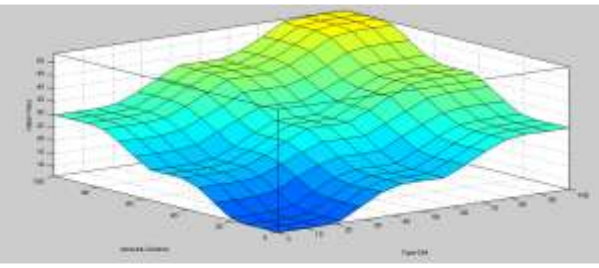

Fig 7: Surface plot for FLC using the Centroid method

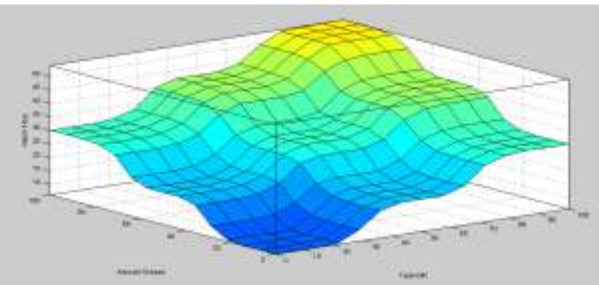

Fig 8 Surface plot for FLC using the Bisector method

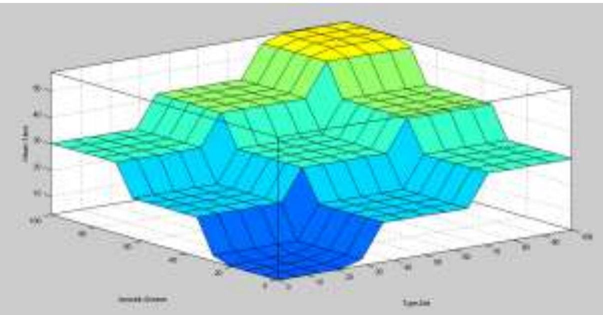

Fig 9: Surface plot for FLC using the MOM method

5.2 Results

Table 2. Wash time output for varying input parameters

Type-Dirt (%)	Amount-Grease (%)	Wash-Time Centroid	Wash-Time Bisector	Wash-Time MOM
20	40	18	18	18
20	80	30	30	30
40	50	30	30	30
50	50	30	30	30
50	40	30	30	30
60	80	42	42	42
80	60	42	42	42
50	30	22.9	22.2	18
60	70	37.1	37.8	42
80	90	53.7	54	57

Looking at the above results table it can be shown that depending upon the amount of grease and dirt present on the clothes the respective methods will have different wash time. This analysis can be carried out for more number of values of dirt and grease to and check the difference between the three methods of comparison. From the above table it is observed that the three techniques used for comparison gives a wash time output of nearby values hence acknowledging that the wash cycle will provide the desired output. Thus the above fuzzy model for defuzzification of washing machine output can be modified by changing the simple if – then rules and performing any one defuzzification technique the output can be verified. Any modification in the rule base model will require to modify the if – then rules to get a corrected output.

Fig 10: Defuzzification output for FLC using the Centroid method

Fig 11: Defuzzification output for FLC using the Bisector method

Fig 12: Defuzzification output for FLC using the MOM method

The fuzzy model can also be modified in future to incorporate more no of input variables[2], like incorporating type of clothes or volume of clothes, to get an output depending upon all the parameters. Also, analysis of other defuzzification techniques to compare the output wash time can be incorporated.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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