Three Input – One Output Fuzzy logic control of Washing Machine

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Abstract
Fuzzy logic enables designers to control complex systems more effectively than traditional approaches. As it provides a simple way to arrive at definite conclusion upon ambiguous, imprecise or noisy information. In this paper we have proposed the design of fuzzy logic controller having three inputs to give correct wash time of washing machine. The objective is to save lot of time, electricity and water for washing the cloth. The paper describes the procedure that can be used to get a suitable washing time for different cloths. The process is based entirely on the principle of taking non-precise inputs from the sensors subjecting them to fuzzy arithmetic and obtaining a crisp value of washing time.

Keywords: *FIS Editor, Fuzzy Logic Controller, Matlab, Rules of the system, Response Surface of the Input Output relations*

I. Introduction

Washing machines are common house hold items and to have a washing machine that efficiently controls the wash time is vital. Conventional, proportional, integral and differential [PID] controllers have proven to be less capable in such control situations. In recent years there has been a growing interest in applying Fuzzy logic for control.

Fuzzy logic: In 1965 the concept of fuzzy logic was first conceived by Professor Lofti A. Zadeh University of California Berkely[1]. Fuzzy logic is used to monitor non linear systems which are difficult to deal mathematically. The non-probabilistic, uncertainties issues are monitored by fuzzy logic and fuzzy set theory[2]. The development of fuzzy logic theory now stimulated alternative ways to solve automatic control problems. Based on these basic ideas of fuzzy logic Mamdani and Assilian proposed fuzzy controllers which describe human control in linguistic form. Consequently the first applications of fuzzy control replaced a human operator[4]. Fuzzy logic controllers for Gas Heater was designed using behavioral modeling and then these modules are connected via structural VHDL to control "valve angle" [5].

For about 20 years, contributions on fuzzy control were presented at conferences and in the control literature, but the field of fuzzy control did not obtain high attention for a longer period. It is only recently about 1990 that the interest in fuzzy control has increased strongly because of successes and advertisement of applications in Japanese consumer products such as washing machines and camcorders. Moreover, successful fuzzy control of industrial processes, such as, e.g., a cement kiln in Denmark in train operation, or simulations for ship steering [3]. Since then, a controversial discussion has been going on concerning the merits of fuzzy control versus conventional control.

Fuzzy logic Controller for Washing Machine : In 2007, the fuzzy inference is used for determining wash time. In this design MF used was triangular; the inputs of fuzzy Controller were Change of turbidity and turbidity, the output was Washing Time [6]. In 2009, Pritesh Lohani, proposed "An improved Controller Microchip for washing machine" that comprises three inputs and one output [8].

In 2011, Manish Agarwal, proposed the fuzzy logic control for washing machine having two inputs and one output with the fuzzy inference engine which provides 9 rules for the FLC [7].

This paper aims at presenting the idea of controlling the washing time using fuzzy logic control. The paper describes the procedure that can be used to get suitable washing time for different types of cloths, dirtiness of clothes and amount of cloths. The process is based entirely on the principle of taking non-precise inputs from sensors, subjecting them to fuzzy arithmetic and obtaining a crisp value of the washing time. It is quite clear that from the paper itself that this method can be used in practice to further automate the washing machines.

II. Proposed Design

When one uses a washing machine, the person generally select the length of wash time based on the amount of clothes he/she wish to wash and the type and degree of dirt cloths have. Unfortunately, there is no easy way to formulate a precise mathematical relationship between volume of clothes and dirt and the length of wash time required.

Consequently, this problem has remained unsolved until very recently. Conventionally, people simply set wash times by hand and from personal trial and error experience. Washing machines were not as automatic as they could be. The users of washing machines 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. Most of the people find it very difficult to decide that which cloth needs what amount of washing time. To overcome these problems, Fuzzy based washing machine have the sensor based program which checks for the extents of dirt and grease, amount of detergent and water to add which accordingly adjust the wash time. In this paper, we have introduced three input variables and one output fuzzy logic controller to get correct wash time.

III. Principles of washing machine

To understand how a washing machine cleans, we must understand the components of washing machines

Important parts of the washing machine:

Water inlet control valve, Water pump, Tube (washer drum), Agitator, Motor, Door safety sensor, Detergent drawer, Drain pipe, Controller, Mechanical programmer.

Wash sensor (Optical sensor)

An optical sensor is a device that converts light rays into electronic signals. It measures the physical quantity of light and translates it into a form read by the instrument. The features of an optical sensor are its ability to measure the changes from one or more light beams.

A washing machine includes an optical sensor for detecting a light permeability of detergent solution and rinse water in a washer tank. The optical sensor includes a light emitting element and a light receiving element. A microprocessor (Fuzzy Controller) is provided for controlling a luminous intensity of the light emitted from the light emitting element.

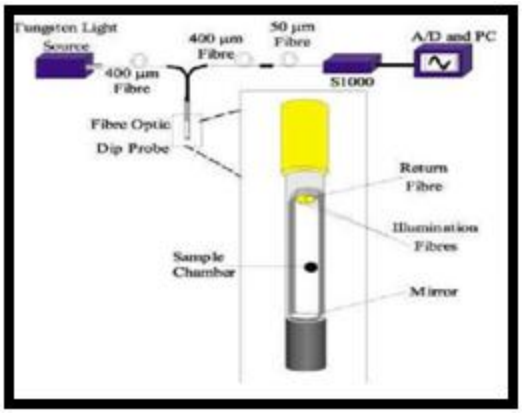

Fig. 1: Wash sensor

How Wash sensor work

The working of the sensors is not a matter of concern. We assume that we have these inputs at our hand.

1. **The degree of dirt** is determined by the transparency of the wash water. The dirtier the clothes, less transparent the water being analyzed by the sensors is.

2. **Type of dirt** determines the quality of dirt. Greasy cloths, for example, take longer for water transparency to reach transparency because grease is less soluble in water than other forms of dirt. Type of dirt is determined by the **time of saturation**.

Saturation is a point, at which there is no more appreciable change in the color of the water.

Unfortunately, there is no easy way to formulate a precise mathematical relationship between volume of clothes and dirt and the length of wash time required. Because the input/output relationship is not clear, the design of a washing machine controller has not in the past lent itself to traditional methods of control design. We address this design problem using fuzzy logic.

Fuzzy logic has been used because a fuzzy logic controlled washing machine controller gives the correct wash time even though a precise model of the input/output relationship is not available.

IV. Proposed Design

The proposed Fuzzy Logic Controller for washing machine consists of three Linguistic Inputs i.e.
Types-of-clothes

1. Type-of-dirt
2. Dirtiness-of-clothes

All the above LIs control the one LO i.e. wash time

The proposed Fuzzy Logic Controller inference engine is designed using 27 rules for Wash Time. The rules formed in this research are derived from the common sense and purely based on experience from a typical home use. Every Linguistic inputs and outputs has a set of membership functions. The MF used for all LIs and LOs is triangular MF.

The X-axis of all the MF graphs represents the LI values which are obtained from the sensors and it ranges from 0 to 1 up to first whereas the Y-axis of all MF graph denotes the degree of membership function.

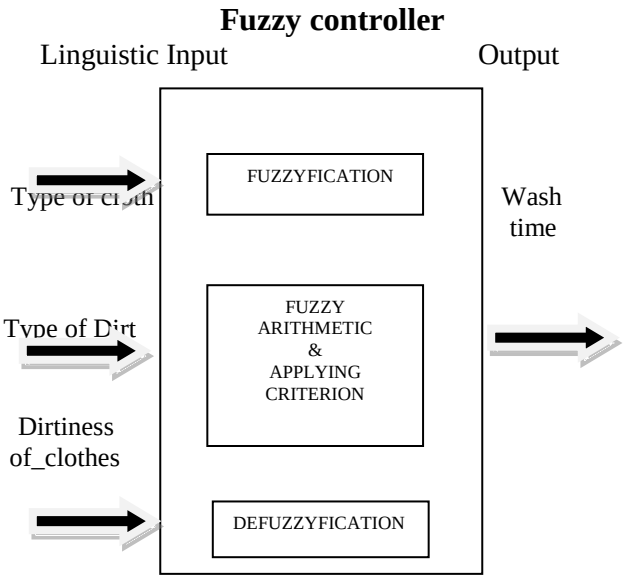

Fig 2: FLC for Washing machine

Fuzzy Logic Controller for Washing Machine consists of mainly three blocks i.e. Fuzzifier, Fuzzy Rule select and defuzzifier

V. Details about the set applied

Fuzzification: To deal with the details of fuzzy logic controller, the values for the input and output variables are determined in advanced. There is membership function which is used to map the crisp input values to the fuzzy values and after that suitable operation is applied on them.

The process which converts crisp value in fuzzy value is known as fuzzification and fuzzifier is used for performing the fuzzification. The decisions made by fuzzy logic controller are derived from the rules known as fuzzy rules. The fuzzy rules are the sets of "If" and "'then" statements Fuzzy rules are easy to understand since they are common English statements rules used in this research are derived from a typical home use the set of rules used in this paper are shown in table.

***Rules*:-**

The sets of rules used here to derive the output are:

Rule Number	Linguistic Inputs			Linguistic output
	Type of Cloth	Type of Dirt	Dirtiness of Cloth	Wash time
1	Silk	Not greasy	Small	Very Short
2	Silk	Not greasy	Medium	Short
3	Silk	Not greasy	Large	Medium
4	Silk	Medium	Small	Medium
5	Silk	Medium	Medium	Long
6	Silk	Medium	Large	Long
7	Silk	Greasy	Small	Medium
8	Silk	Greasy	Medium	Long
9	Silk	Greasy	Large	Very long
10	Woolen	Not greasy	Small	Short
11	Woolen	Not greasy	Medium	Medium
12	Woolen	Not greasy	Large	Long
13	Woolen	Medium	Small	Medium
14	Woolen	Medium	Medium	Medium
15	Woolen	Medium	Large	Long
16	Woolen	Greasy	Small	Long
17	Woolen	Greasy	Medium	Long
18	Woolen	Greasy	Large	Very Long
19	Cotton	Not greasy	Small	Short
20	Cotton	Not greasy	Medium	Medium
21	Cotton	Not greasy	Large	Long

Rule Number	Linguistic Inputs			Linguistic output
	Type of Cloth	Type of Dirt	Dirtiness of Cloth	Wash time
22	Cotton	Medium	Small	Medium
23	Cotton	Medium	Medium	Long
24	Cotton	Medium	Large	Very Long
25	Cotton	Greasy	Small	Long
26	Cotton	Greasy	Medium	Long
27	Cotton	Greasy	Large	Very Long

Table: Rules for Fuzzy Wash Time Control

The rules obtained in Table can be read in terms of IF and THEN statements as shown in below.

Rule 1:
IF (Type of Cloth is Silk) and (Type of Dirt is Not Greasy) and (Dirtiness of Cloth is Small) THEN (Wash time is Very Short)

Rule2:
IF (Type of Cloth is Silk) and (Type of Dirt is Not Greasy) and (Dirtiness of Cloth is Medium) THEN (Wash time is Short)
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……
……
……

Rule27:
IF(Type of Cloth is Cotton) and (Type of Dirt is Greasy) and (Dirtiness of Cloth is Large) THEN (Wash time is Very Long)

The rules too have been defined in imprecise sense and hence they too are not crisp but fuzzy values (see figure 3). The three input parameters after being read from the sensors are fuzzified as per the membership function of the respective variable these in additions with the membership function curve are utilized to come to a solution (using some criteria).

At last the crisp value of the wash_time is obtained as an answer.

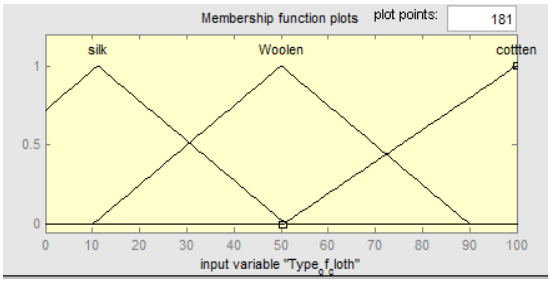

Fig : 3(a)

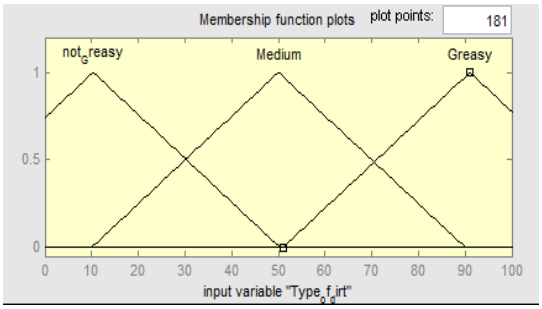

Fig : 3 (b)

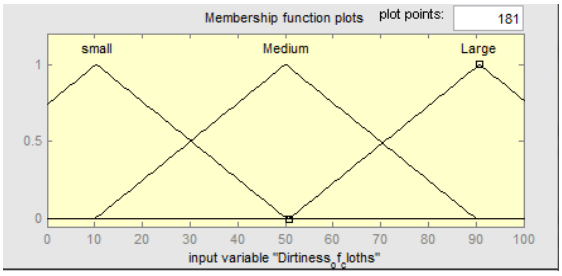

Fig: 3 (c)

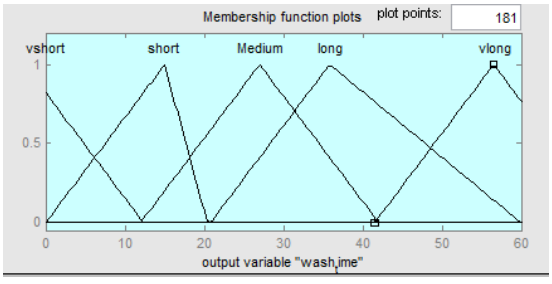

Fig: 3 (d)

Figure: 3 (a)
A membership for input variable Type of Cloth
Figure: 3 (b)
A membership for input variable Type of Dirt

Figure: 3 (c)
A membership for input variable Dirtiness of Cloths
Figure: 3 (d)
A membership for Output variable Wash Time

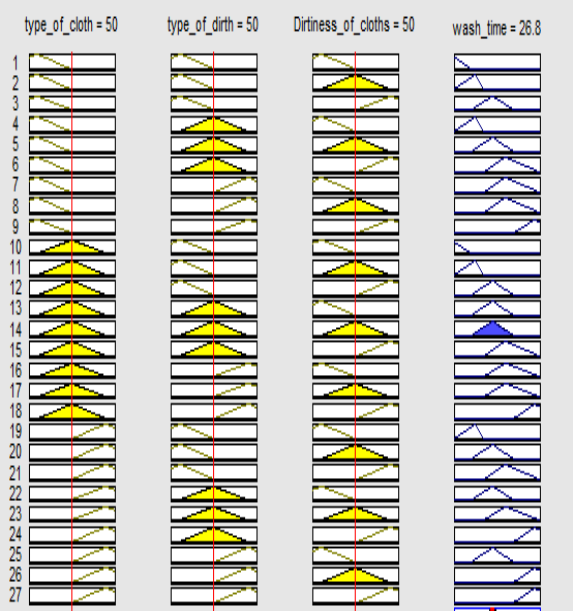

Fig:4 Rules of the System.

- **Defuzzification:** The result obtained from fuzzy inference technique is then processed to produce a quantifiable result i.e. the total time it takes to wash the clothes (Wash Time). Defuzzification process is used to interpret the membership degrees of the fuzzy sets in some specific real value (i.e. in crisp value opposite to that Fuzzification do). Centroid method is used for defuzzification to get a scalar output value for the actual duration of the wash cycle from the output function obtained.

$$\text{Wash time} = \bar{X}(centroid) = \frac{\sum_{1}^{60} x\mu(x)}{\sum_{1}^{60} \mu(x)}$$

= 26.8 minutes.

VI. Results and Discussion

By the use of fuzzy logic control we have been able to obtain a wash time for different type of dirt and different degree of dirt and different type of cloths. The conventional method required the human interruption to decide upon what should be the wash time for different cloths. In other words this situation analysis ability has been incorporated in the machine which makes the machine much more automatic and represents the decision taking power of the new arrangement.

Here the sensors sense the input values and using the above Model the inputs are fuzzyfied and then by using simple if-else rules and other simple fuzzy set operations the output fuzzy function is obtained and using the criteria the output value for wash time is obtained. Figure 5. shows the response surface of the input output relations as determined by fuzzy interface unit. This is the fundamental unit in which the application interface FIDE encodes controller information.

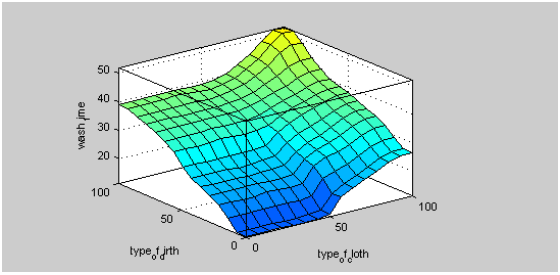

Fig: 5 Response surface of the input output relations

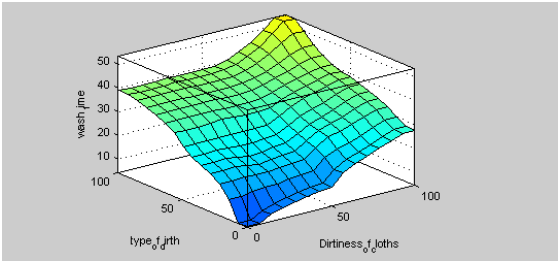

Fig .5: Response surface of the input output relations

The results (the above plot) shows the way the machine will response in different conditions. For example, if we take type of dirt and dirtiness of cloth value as 50, the wash time which the model output is equivalent to 26.8 mins. This is quite convincing and appropriate.

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