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A STUDY ON FUZZY LOGIC CONTROL OF WASHING MACHINE

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Abstract

This work studies the fundamentals of fuzzy sets and fuzzy logic control of a washing machine. A fuzzy logic controller which consists of fuzzification, fuzzy arithmetic, applying criterion, and defuzzification is used to give one output which is the wash time.

Keywords: Fuzzy sets, fuzzy logic, fuzzification, defuzzification

1. Introduction

The concept of partial truth has been added to fuzzy logic, with the truth value ranging from entirely true to completely false. Fuzzy logic model the logic of human thought, which is far less rigorous than the calculations that computers typically execute. A large number of inputs are typically used in intelligent control strategies. The goal of fuzzy logic is to get a machine to think like humans. Fuzzy logic can deal with the ambiguity that is inherent in human thoughts and natural language, while also recognizing that it is not random. We might be able to teach machines to understand and respond to ambiguous human concepts like hot, cold, large, tiny and so on, using a fuzzy logic algorithm [1].

As a natural extension of classical set theory, the author in [2] researched fuzzy sets. A sharp set (also known as a crisp set) is defined by a double truth function that only accepts the values 0 and 1, implying that an element fully belongs to a set or not. We use intuition to decide which objects are members and which are not, just as we did with crisp sets; there is no formal basis for determining a fuzzy set’s membership [3].

The definition of a fuzzy set differs from that of a classical set in that membership values can range from 0 to 1, where the higher the value, the higher the membership. As a result, a classical set is a subset of a fuzzy set, with membership values limited to 0 and 1. Membership degrees or grades are the results of a membership function that clearly indicate how much an element belongs to a fuzzy set, or to the notion it represents.

Fuzzy logic has been successfully used in numerous fields such as, control system, engineering, image processing, industrial automation, etc. This branch of mathematics has given scientific fields that had been inert for a long-time fresh life [4]. The traffic problem is one of the most serious issues affecting many major cities around the world. The use of fuzzy logic controller to manage signal timings allows for the manipulation of linguistic and inexact traffic data [5, 6, 7, 8]. A fuzzy control system is a rule-based system that uses a fuzzy theory to define an expert’s control rules and a fuzzy inference to determine a control command. An example of the medical domain application is the detection system for heart disease [9, 10]. In essence, a symptom is an unreliable indicator of a phenomenon because it may or may not occur in conjunction with it. Patients’ inability to adequately express what has happened to them or how they are suffering might be sources of uncertainty. So, in order to construct a clinical decision system for heart disease diagnosis, soft computing techniques, particularly fuzzy logic techniques, are employed to estimate the risk level of heart disease in patients.

In [11], the author presented an enhanced controller microchip for washing machines with two inputs and one output, while in [12 , 13] the authors proposed three inputs and one output with different input data in their studies. The author in [11] conducted research on the design of an enhanced fuzzy logic-based control system for washing machines, which reveals that the system has a reduced washing time based on simulation findings [14].

In this paper, we studied [15] and modified the wash time.

We complete this section with basic definitions and fundamentals of fuzzy sets [2, 16, 17].

1.1 Fuzzy set: Let X be a nonempty *set.* A fuzzy set A in X is characterized by its membership function $\mu A: X \to [0, 1]$ and $\mu A(x)$ *is* interpreted *as the* degree *of* membership of element x in fuzzy set A for each $x \in X$.

It is clear that A is completely determined by the set of tuples.

$A = \{(u, \mu A(u)) \mid u \in X\}$.

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Subsequently we will write $A(x)$ instead of $\mu A(x)$. The family of all fuzzy sets in X is denoted by $F(X)$.
If $X = \{x1, . . ., xn\}$ is a finite set and A is a fuzzy set in X then we often use the notation
$A = \mu 1/x1 + \cdot \cdot \cdot + \mu n/xn$
Where the term $\mu i/xi$, $i = 1, . . ., n$ signifies that μi is the grade of membership of xi in A and the plus sign represents the union.

1.2 Support: Let A be a fuzzy subset of X; the support of A, denoted supp(A), is the crisp subset of X whose elements all have nonzero membership grades in A.
Supp (A) = $\{x \in X|A(x) > 0\}$.

1.3 Normal fuzzy set: A fuzzy subset A of a classical set X is called normal if there exists $x \in X$ such that $A(x) = 1$. Otherwise A is subnormal.

1.4 α-level: An α-level set of a fuzzy set A of X is a non-fuzzy set denoted by $[A]\alpha$ and is defined by$[A]\alpha = \{t \in X|A(t) \geq \alpha\}$ if $\alpha >0$cl(suppA) if $\alpha = 0$ where cl(suppA) denotes the closure of the support of A.

1.5 Universe of discourse: A fuzzy set is built from a reference set called universe of discourse. The reference set is never fuzzy. Assume that $U = \{x1,x2,...,xn\}$ is the universe of discourse, then a fuzzy set A in U ($A \subset U$) is denoted as a set of ordered pairs $\{(xi,\mu A(xi))\}$ where $xi \in U$, $\mu A : U \to [0,1]$ is the membership function of A and $\mu A(x) \in [0,1]$ is the degree of membership of x in A.
A fuzzy set B in a universe of discourse X is characterized by a membership function □x□□A~ □□which associates with each element x in X a real number in the interval □0,1□. The function value □x□□A~ μ□is termed the grade of membership of x in B.

1.6 Height of fuzzy set: The height of a fuzzy set is the largest membership grade attained by any element in that set. A fuzzy set *A* in the universe of discourse *X* is called normalized when the height of *A* is equal to 1.

1.7 Example: The membership function of the fuzzy set of real numbers "close to 1" can be defined as $A(t) = \exp(-\beta (t - 1)2)$ where β is a positive real number.

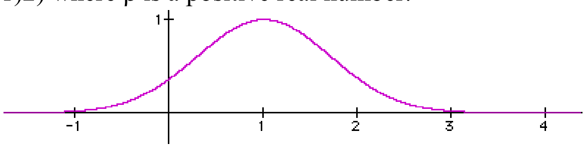

Figure 1.1 A membership function for" x is close to 1"

1.8 Example: Consider the universe of discourse U = {11, 12, 13, 14, 15, 16}. Then a fuzzy set G with the concept `large number' is represented below.
A = {(11,0), (12,0), (13,0.4), (14,0.6), (,15,0.9), (16,1)}
With the considered universe, the numbers 11 and 12 are not `large numbers', i.e. the membership degrees equal 0. Numbers 13 to 15 partially belong to the concept `large number' with a membership degree of 0.4, 0.6 and 0.9. Finally, number 16 is a large number with a full membership degree.

1.9 Convex fuzzy set: A fuzzy set A of X is called convex if $[A]\alpha$ is a convex subset of X $\forall \alpha \in [0, 1]$.

1.10 Fuzzy numbers: A fuzzy number is a fuzzy subset in the universe of discourse *X* that is both convex and normal.

1.11 Fuzzy matrix: A matrix D is called a fuzzy matrix if at least one element is a fuzzy number.

1.12 Quasi fuzzy number: A quasi fuzzy number A is a fuzzy set of the real line with a normal, fuzzy convex and continuous membership function satisfying the limit conditions

$$\lim_{t\to\infty} A(t) = 0 \ , \ \lim_{t\to-\infty} A(t) = 0$$

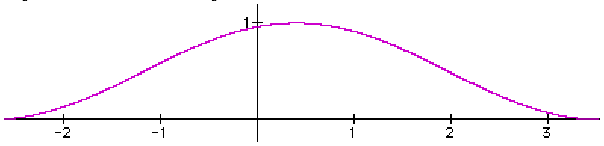

Figure 1.2 Fuzzy number

1.13 Subsethood: Let A and B be fuzzy subsets of a classical set X. We say that A is a subset of B if $A(t) \leq B(t)$, $\forall t \in X$.

1.14 Equality of fuzzy sets: Let A and B be fuzzy subsets of a classical set X. A and B are said to be equal, denoted A = B, if $A \subset B$ and $B \subset A$. We note that A = B if and only if $A(x) = B(x)$ for all $x \in X$.

1.15 Empty fuzzy set: The empty fuzzy subset of X is defined as the fuzzy subset $\emptyset$ of X such that $\emptyset(x) = 0$ for each $x \in X$.

2. Linguistic Inputs

In this section, we discuss the linguistic output and input of a washing machine. Fuzzy Logic Controller are made up of four Linguistic Inputs, these are:

1. Types-of-clothes
2. Type-of-dirt
3. Degree of dirt
4. Amount of clothes

All the above Linguistic input control the one Linguistic output (wash time).

2.1 Fuzzification: For the specifics of fuzzy logic controller, the assigned values for the input and output variables are determined in advanced by the operator. There is membership function to map the crisp input values to the fuzzy values and a required operation is applied. The procedure which converts crisp value to fuzzy value is fuzzification and fuzzifier is used for executing the fuzzification. The result given by fuzzy logic controller are obtained from fuzzy rules. The fuzzy rules are "IF" and "THEN" statements.

Input variables

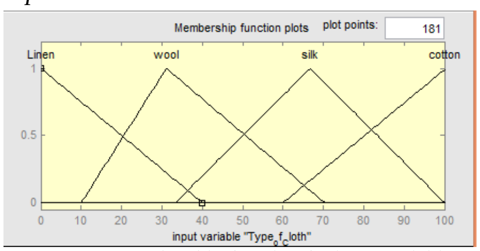

Figure 2.1 A membership function for input variable "Type of Cloth"

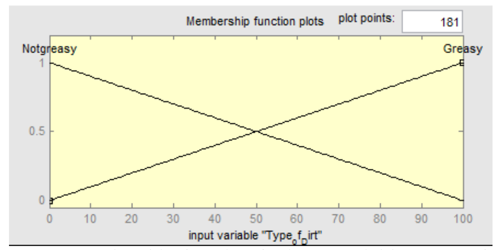

Figure 2.2 A membership function for input variable "Type of Dirt"

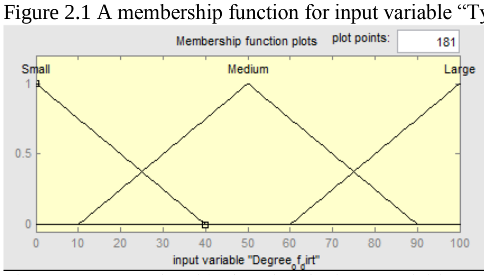

Figure 2.3 A membership function for input variable "Degree of dirt"

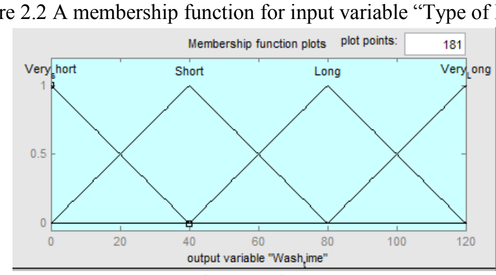

Figure 2.4 A membership function for output variable Wash time

Output variable

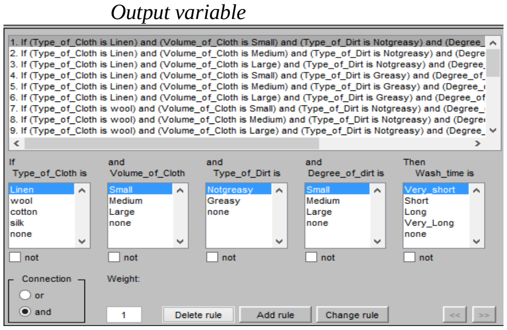

Figure 2.5 Rule base Interface

3. Fuzzy Inference Technique

The inference process of a Mamdani system is described in fuzzy inference technique which produced a quantifiable result i.e. the total time it takes to wash the clothes (Wash Time). Defuzzification is used to explain the membership degrees of the fuzzy sets in definite real value. When we use fuzzy logic control, we obtain a wash time for different type of dirt and different degree of dirt and different type of cloths. The typical method for the wash time for different cloths is determined by an individual. This process will be incorporated in the machine which will make the machine much more automatic and take appropriate decision.

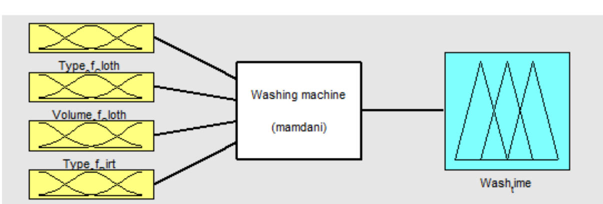

Figure 3.1 Washing machine Fuzzy interference system

3.1 Fuzzy Rules: The sets of rules used to derive the output are:

Rule Number	Linguistic Inputs				Linguistic Output
	Type Of Cloth	Amount of Cloth	Type of Dirt	Degree Of Dirt	Wash Time
1	Linen	Small	Not Greasy	Small	Very Short
2	Linen	Medium	Not Greasy	Medium	Short
3	Linen	Large	Not greasy	Large	Long
4	Linen	Small	Greasy	Small	Short
5	Linen	Medium	Greasy	Medium	Long
6	Linen	Large	Greasy	Large	Very Long
7	Wool	Small	Not Greasy	Small	Very Short
8	Wool	Medium	Not Greasy	Medium	Short
9	Wool	Large	Not greasy	Large	Long
10	Wool	Small	Greasy	Small	Short
11	Wool	Medium	Greasy	Medium	Long
12	Wool	Large	Greasy	Large	Very Long
13	Silk	Small	Not Greasy	Small	Very Short
14	Silk	Medium	Not Greasy	Medium	Short
15	Silk	Large	Not greasy	Large	Long
16	Silk	Small	Greasy	Small	Short
17	Silk	Medium	Greasy	Medium	Long
18	Silk	Large	Greasy	Large	Long
19	Cotton	Small	Not Greasy	Small	Very Short
20	Cotton	Medium	Not Greasy	Medium	Short
21	Cotton	Large	Not greasy	Large	Long
22	Cotton	Small	Greasy	Small	Long
23	Cotton	Medium	Greasy	Medium	Long
24	Cotton	Large	Greasy	Large	Very Long

Table 3.1 Rules for Fuzzy Wash Time Control

The results below show how it will response in distinct states. For instance, if we take, Type of Cloth=78, Amount of Cloth= 45, Type of dirt=67.4 and Degree of dirt=86.9 the wash time which the model output is equivalent to 79.2 mins. The input output relations is determined by the fuzzy interface unit.

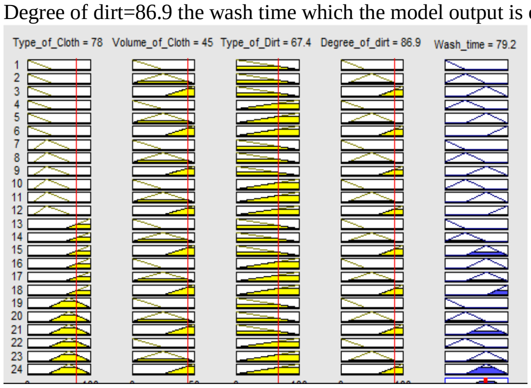

Figure 4.1 Rules of the System

4. Conclusion

The fuzzy logic controller presented works with four linguistic input consisting of: type of cloth, type of dirt, amount of cloth and degree of dirt. These inputs are fixed into the fuzzy controller which consist of fuzzification, fuzzy arithmetic and applying criterion and then defuzzification which gives wash time as output. With this, the wash time is less i.e. the method saves time and also conserves electricity as appropriate.

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