FOUR INPUTS – ONE OUTPUT FUZZY LOGIC SYSTEM FOR WASHING MACHINE

by

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IN THE NAME OF ALLAH, THE MOST GRACIOUS, THE MOST MERCIFUL

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LIST OF ABBREVIATIONS

AIFNN	Adaptive intuitionistic fuzzy neural network
ANFIS	Adaptive neuro – fuzzy inference system
FIU	Fuzzy interface unit
FLS	Fuzzy logic system
MATLAB	Matrix laboratory
PID	Proportional, integral and differential

LIST OF SYMBOLS

α	Alpha-cut
$\in$	Element of
$\mathbb{R}$	Real number
μ	Membership function
$\cap$	Intersection
$\cup$	Union

Empat Input – Satu Output Sistem Logik Kabur Untuk Mesin Basuh

ABSTRAK

Mesin basuh merupakan salah satu peralatan elektrik yang menggunakan teknologi yang canggih. Mesin basuh yang digunakan pada masa sekarang bukan sahaja menjimatkan tenaga, malah mampu untuk membasuh beban yang banyak. Oleh itu, pereka mesin basuh telah mencadangkan penggunaan sistem logik kabur untuk mesin basuh kerana sistem ini membolehkan mesin untuk melakukan kerja secara efektif berbanding kaedah tradisional. Dalam kajian ini, empat input dan satu output dipertimbangkan. Input-input tersebut ialah jenis fabrik, jenis kekotoran, darjah kekotoran bagi fabrik dan berat beban, manakala satu output ialah masa basuhan. Lapan puluh satu (81) peraturan dibangunkan dengan menggabungkan kesemua input menggunakan operasi *AND*. Inferens enjin Mamdani digunakan dalam kajian ini untuk mencari nilai nyata bagi output. Proses pengkaburan digunakan bagi menentukan input kabur untuk setiap input yang digunakan dengan menetapkan nilai nyata terlebih dahulu. Nilai nyata yang ditetapkan untuk jenis fabrik, jenis kekotoran, darjah kekotoran bagi fabrik dan berat beban masing-masing adalah 32, 55, 48 dan 7. Merujuk kepada inferens enjin Mamdani, fungsi keahlian yang minima dari input memangkas kepada output untuk setiap peraturan. Proses dinyahkabur melibatkan pengambilan fungsi keahlian yang maksima bagi output dari setiap peraturan dan dilukis dalam satu graf. Sentroid merupakan salah satu kaedah yang digunakan untuk mencari nilai nyata bagi output mesin basuh. Pakej logik kabur yang terdapat dalam perisian MATLAB digunakan dengan memasukkan kesemua data yang ada didalamnya. Berdasarkan simulasi yang ditunjukkan oleh MATLAB, masa basuhan bagi empat input dan satu output adalah 35.5 minit. Seterusnya, masa basuhan bagi empat input dibandingkan dengan masa basuhan bagi tiga input. Proses yang sama digunakan seperti empat input dengan 27 peraturan dibangunkan berdasarkan hasil gabungan ketiga-tiga input. Merujuk kepada simulasi MATLAB, masa basuhan bagi tiga input adalah 34.4 minit dimana terdapat perbezaan masa yang sedikit di antara dua perbandingan ini. Oleh itu, simulasi yang dihasilkan oleh MATLAB adalah setanding dengan masa basuhan yang dihasilkan oleh mesin basuh sendiri. Apabila terdapat pertambahan dalam bilangan peraturan, masa basuhan yang dihasilkan adalah meningkat dengan kadar yang sedikit. Secara kesimpulannya, apabila bilangan input bertambah, terdapat banyak pilihan yang boleh dibuat kerana simulasi yang dijalankan melibatkan semua peraturan yang ada.

Four Inputs – One Output Fuzzy Logic System for Washing Machine

ABSTRACT

Washing machine is one of the electrical appliances that use sophisticated technology. Washing machines that are used today not only saving energy, but it is able to wash a lot of load. Therefore, the designers of washing machine have suggested the usage of fuzzy logic system for washing machine because this system allows the machine to perform effectively compared to the traditional method. In this study, four input and one output variables are considered. The input variables are type of fabric, type of dirt, dirtiness of fabric and weight of load, while the output variable is washing time. Eighty one (81) possible rules are developed by combining all the inputs using *AND* operator. Mamdani inference engine is used in this study to find the crisp output. Fuzzification process is used to determine the fuzzy input by setting up a crisp input first. The crisp input for type of fabric, type of dirt, dirtiness of fabric and weight of load are 32, 55, 48 and 7, respectively. Referring to the Mamdani inference engine, a minimum membership function from the input parts is truncated to the output for each rule. Defuzzification involved the process of taking the maximum membership function of the output from each rule and drawn in a single graph. The centroid is one of the methods that used to find the crisp output of washing machine. The package of fuzzy logic that contained in MATLAB software is used by inserting all the data available therein. Based on the simulation shown by MATLAB, the washing time for four input and one output variables is 35.5 minutes. Next, the result of washing time for four input variables is compared with the washing time for three input variables. The same process is used like before by developing 27 possible rules based on the combination all the three input variables. Referring to the simulation in MATLAB, the washing time for the input variables is 34.3 minutes where there is a slightly difference in timing between these two comparisons. Hence, the simulation produced by MATLAB is comparable to the washing time that generate by washing machine itself. When there is an increase in the number of rules, the washing time increase slightly. In conclusion, as the number of inputs increases, there are many options that can be made because the simulation conducted involves all the existing rules.

CHAPTER 1 : INTRODUCTION

1.1 Background

Fuzzy logic was first introduced by Zadeh (1965). It is a part of artificial intelligence which resembles human behaviour that helps computers in making decisions. Fuzzy logic is difficult to deal mathematically especially when dealing with non-linear systems. This concept used to monitor non probabilistic and uncertainties issues (Hatagar & Halase, 2015b).

Yen and Langari (2004) presented that the fuzzy logic was accepted as the basis for at least two decades ago since its elaboration as an emerging technology, ranging from consumer products, to automotive application and to industrial process control. Kumari (2013) stated that there were a great number of researchers that interested in dealing with fuzzy logic to solve the real world issues. The fuzzy logic enables designers to control complex systems effectively because it was proven that proportional, integral and differential (PID) controllers were less capable (Ahmed & Toki, 2016).

The application of fuzzy logic can be found in few of electrical equipment such as washing machine, vacuum cleaner and air conditioner. In the past, the users faced the problems in cleaning the clothes, where they need to put the amount of water and soap needed, the length of wash cycle and also the spin period. Therefore, the designers of washing machine overcome these problems by implementing the fuzzy logic system into washing machine that makes the machine becomes fully-automated. The controllers

that set up in the washing machine can sense the quantity of the wash load, the quantity of dirtiness of the cloths and the type of material within the current wash cycle to directly predict the washing time needed. Today, an automatic washing machine has been created with more advantages of performance, simplicity, less cost and productivity. Washing time is one of the factors that need to be considered when designing the washing machine. Most of the researchers aimed washing time as an output of washing machine (Alhanjouri & Alhaddad, 2013; Kumar & Haider, 2013; Habib & Akram, 2015).

In this study, the methods that have been proposed by the previous researchers are further explored in order to find the best washing time of washing machine. Fuzzy logic toolbox is used based on the propose inputs and output by creating the fuzzy IF-THEN rules and fuzzy logic system is suggested to solve the problem starting from fuzzification, fuzzy inference engine and finally defuzzification.

1.2 Problem Statement

The study of washing time has gained an attention among the researchers due to various usage in industrial and home. This encouraged the researchers to do a research to obtain the value of output variable of washing machine which is washing time. In literature, most of the researchers have suggested whether type of cloth, type of dirt or dirtiness of cloth as input variables (Agarwal, 2007; Alhanjouri & Alhaddad, 2013; Akram, Habib & Javed, 2014; Hatagar & Halase, 2015b; Habib & Akram, 2015). However, not many paper published the weight of load together with the existing three input variables. Therefore, in this study, the weight of load is included and fuzzy logic

system as an alternative to conventional method are used in order to estimate the best washing time.

1.3 Objectives

The objectives of this study are as follows:

i) To propose fuzzy logic system for washing machine based on four input variables.

ii) To estimate the washing time based on the fuzzy logic system developed in (i).

iii) To compare the result obtained from four input variables with three input variables.

1.4 Scope of Study

In this study, the washing time of top loading washing machine is represented. According to Bansal, Vineyard and Abdelaziz (2011), this type of washing machine is most popular in United States, Latin America, Canada and Australasia. It is widely used in housing units whilst it saves electricity and the user does not require bending to load or unload the clothes. In determining the washing time, the input variables must be considered first. Four inputs with their linguistic variables are identified which are type of fabric, type of dirt, dirtiness of fabric and weight of load. The triangular and trapezoidal fuzzy numbers are used to represent the graph of the membership functions for each of the input and output variables. All the data of membership functions are inserted into the fuzzy logic toolbox in MATLAB and the result of washing time is

obtained at the rule viewer part through the calculation of the centroid method where this method is set up first as a defuzzification.

1.5 Significant of Study

The findings of this study contribute to the benefit of society considering that mathematics plays an important role in science and technology. Washing machines that use the concept of fuzzy logic system provide a lot of benefits to human being. A few of its benefits are it can be easily modified, more inputs and outputs can be used and the clothes that wash by using washing machine become more cleanliness compared to the traditional method. By using the washing machine with fuzzy logic system, the working people especially can save their time in washing the cloths and do not need a lot of energy to brush the cloths. In a large industry, for example hospital, they can use the fuzzy washing machine in cleaning all the clothes and blankets that have been used by the patients and all the process can be done effectively. Therefore, the users can choose the washing machine that use the concept of fuzzy logic as an alternative to ease their work compared to the traditional method.

1.6 Dissertation Organisation

This dissertation consists of five chapters, where all the work has been organised accordingly. Chapter 1 begins with the background of the dissertation, followed by problem statement, objectives, scope of study, significant of study, dissertation organisation and summary. Chapter 2 reviews the types of washing machine and the previous work about fuzzy logic system that has been proposed by the researchers in

order to find the relevance and significance with the fuzzy logic system for washing machine. In Chapter 3, it describes the methodology of this dissertation. The preliminaries related with this dissertation are also discussed to give a framework of the study. Chapter 4 explains the steps involved based on the chosen method and the expected results also discussed. Chapter 5 comprises of contribution of the dissertation and recommendation for future work.

1.7 Summary

This chapter ended by highlighting the background of the dissertation, problem statement, objectives, scope of study, significant of study and the dissertation organisation. In the next chapter, the types of washing machine available are presented and the previous works of the researchers are reviewed.

CHAPTER 2 : LITERATURE REVIEW

2.1 Introduction

This chapter is discussed about the creation of washing machine and the types of washing machines available are presented. Besides, the advantages of fuzzy logic system are included to show what the users obtain when they use the washing machine with fuzzy logic. The two methods that have been proposed by the previous researchers are presented on how these methods relates with washing machine. Next, the other applications based on engineering that used fuzzy logic system are studied.

2.2 Types of Washing Machine

According to Malave, Arun, Chandrakant, Suresh and Lalaso (2017), the clothes dryers are first being invented in France and England in the early 1800s. The first clothes dryers is the ventilator, that is built by a Frenchman named Pochon. The ventilator had holes that came in a barrel – shaped and it is turned by human over a fire. The creation of washing machine is getting sophisticated from day to day. In 1937, a first automatic washing machine with more advancement is introduced by Bendix Corporation where this machine is connected to a water supply.

Before the creation of an automatic washer, a manual washing machine was created without using a fuzzy logic system as shown in Figure 2.1. This manual washer has two tubs where it can be divided into washing tub and drying tub. The user needs to add water into the washing tub before washing the clothes and set their own time for the clothes to be rinsed with soap. The water must be removed from the washing machine

after the rinsing process is completed and all the clothes must be diverted into drying tub for the drying process. All of these processes require human intervention from the process of washing up to the drying process.

Today, an automatic washing machine with fuzzy logic system has been created to facilitate human work. This type of washing machine can be divided into two which are top loading and front loading washing machine, and it comes with different weights. The automatic washing machine works as a washer, rinser and dryer in one tab where all washing activities are done by the washing machine without human intervention.

Top loading washing machine is a washer unit that many of human are familiar with and this washer is most popular in United States, Latin America, Canada and Australasia. This washing machine has benefits that the human can get, which it has a wide selection of options and it is available in a wide variety of efficiency and conventional styles. The top loading washing machine are easy and affordable to fix when it broken. The advantages of top loading washing machine are the user can add the clothes midway through the wash cycle and suitable for those who have a back pain because the user does not require bending to load or unload the clothes.

Front loading washing machine is popular in Europe and Middle East as mention by Bansal et al. (2011). It is also designed for efficiency where it required less water and detergent, less energy and it can handle large loads. This front loading washing machine remove more stains on fabric where there is a water heater to ensure that the temperature of the water is exact and correct. Those who have this washer can see that the washing quality is excellent and this washer can be placed in a small space since its lid is located in front of the machine.

Figure 2.1: Manual washing machine

(a) (b)

Figure 2.2: (a) Top loading washing machine, (b) Front loading washing machine

2.3 Fuzzy Logic System

A numerous studies had been performed by the researchers based on the application of fuzzy set theory. A fuzzy logic system (FLS) provides other approaches in controlling the operations. Fuzzy logic systems have a few advantages to the users. First, creating a fuzzy logic system is more cost-effective than creating a model-based or other controller with same performance. Second, a wider range of operating conditions is covered by fuzzy logic system compared with traditional control. Third, fuzzy logic system is easy to understand and the rules easy to modified. In engineering area, fuzzy set theory is one of the greatest successes for controlling the systems. One of the successes in this area is washing machine, in which the production of washing machine is determined by fuzzy logic system (Shuaibu, 2016).

There are two common inference methods have been proposed in the literature; Mamdani (Mamdani & Assilian, 1975) and Takagi-Sugeno-Kang methods (Sugeno, 1985). In this chapter, the types of washing machine and these two methods are reviewed by considering both input and output variables.

2.4 Mamdani Method

Mamdani method is widely utilised in more applications because the output variable can be easily converted into linguistic form. To find the crisp output variables, the defuzzification technique is used by using fuzzy logic toolbox in MATLAB (Blej & Azizi, 2016).

Agarwal (2007) presented the idea of fuzzy logic system that control the washing time for different cloths. In this paper, the author proposed two input variables which are degree of dirt and type of dirt with three linguistic variables respectively. Nine rules were developed to see the relationship between the input and output variables. Hence, fuzzy interface unit (FIU) in MATLAB determined the washing time based on the input variables declared. For future, the new inputs can be considered such as type of cloth and weight of load in order to find the best washing time.

Alhanjouri and Alhaddad (2013) introduced two input variables which are degree of dirt and type of dirt in their article entitled Optimize Wash Time of Washing Machine Using Fuzzy Logic. The authors described the concept of base ten minutes to decide the best washing time for different input variables with nine rules were developed. By using fuzzy logic toolbox, the if-then rules were created and output variables were aggregated, hence the washing time was obtained. However, the washing time is not up to the users' expectations since the washing machine did not specify the type of cloth. Therefore, the input variables which are type of cloth and weight of load can be considered, so that the washing process becomes more efficient.

Kumar and Haider (2013) proposed a fuzzy logic based control system for washing machines. The authors presented two input parameters which are quantity of cloths and dirtiness of cloths. The sensors in washing machine would take the input variables and subjecting them to fuzzy arithmetic, hence the washing time could be determined. The membership functions need to identify first before developing if-then rules in MATLAB. By using fuzzy logic toolbox, the washing time is obtained based on quantities of cloths and the dirtiness of cloths. However, these two input variables not

enough to determine the cleanliness of cloths. To ensure that the washing process becomes more efficient, other input variables can be added which are type of cloth and type of dirt.

Virkhare and Jasutkar (2014) proposed a neuro-fuzzy controller based washing machine. The authors aimed to find the spin time as an output variable with four input parameters were presented such as type of cloths, dirtiness of cloths, amount of detergent and water. In fact, the neuro-fuzzy and fuzzy techniques helped the system to take its own decisions like the amount of washing powder needed by each cloth and time taken to release the water. The result of output variable had been analysed by using MATLAB software and algorithm was developed too. However, this paper only focuses on spin time and the authors did not mention about the washing time. Therefore, the washing time can be considered as an output variable for washing machine besides the weight of load can be added into the input variable.

Hatagar and Halase (2015b) presented their idea on article entitled Three Inputs-One Output Fuzzy Logic Control in Washing Machine. The objectives of the authors are to save electricity, save water when washing the clothes and save time. They proposed three input variables which are types of cloth, type of dirt and dirtiness of cloth in order to find the washing time. Three linguistic variables were determined for each input; hence 27 if-then rules were designed for the washing time. By using the Mamdani method, the centroid method was used to find the washing time in the defuzzification process. Hence, the washing time for different inputs could be obtained. Even though this paper mentioned all the three inputs needed, the weight of load can be considered as new input for further research.