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Abstract. This paper aims to model and simulate washing machine based on user expert knowledge using fuzzy logic. Fuzzy logic inference process to control washing machine in this study use Mamdani method. The method has four steps Fuzzification of linguistic variable, rule evaluation (based on expert experience), aggregation of the rules outputs and final defuzzification. Input linguistic variable used are dirtiness of the clothes, type of fabric, type of dirt and amount of the clothes and the output variable is washing time, washing speed, water intake and water temperature. The system is designed and simulated using Fuzzy logic toolbox on MATLAB. Result show that the washing machine inference relate to user expert perception. The main advantage of using fuzzy logic in washing machine is that it reduce water and electricity consumption also good time management.

1. Introduction

Fuzzy logic use the method of reasoning that mimic human ways of reasoning and interpreting things. Fuzzy logic control provide way to model user expert knowledge in a computer program by automating reasoning process[1]. Washing machine is the most used home appliance and it helps to wash the clothes in effortless way. Conventional washing machine needs human intervention based on experiences and user manual to operate[2]. In order to automate the washing machine using fuzzy logic, human knowledge is captured using Mamdani method. The method has four steps which are fuzzification of linguistic variable, rule evolution, aggregation of the rule, and defuzzification. Washing machine base on fuzzy logic provide the following to the user: high performance, lower operational cost and simplicity of using machine[3]. Fuzzy logic control system outweighs PID (Proportional Integral-derivative Controllers) and traditional control system due to low cost of implementation and its high effectiveness in using.

In recent years, fuzzy logic has well proved its broad potential in building automated application in industry and other discipline. To control the consumer product fuzzy logic is used in washing machine to automatically determine rinse period, washing speed, washing time respectively[4-5]. In rice cooker fuzzy logic is used to determine cooking time based on the amount of rice and water. For the case of air condition fuzzy logic is used to determine compressor speed, fan speed, fan direction and mode of operation based on temperature and humidity of the room[6]. In medical arena fuzzy logic is used to

modulate the body inclination in order to adjust the cardiovascular variables heart rate (HR), or systolic or diastolic blood pressures (sBP, dBP) for patients with prolonged bed rest[7].

Conventional washing machine need experienced user to operate the machine. For the case of unexperienced users, they need to read user manual which is time consuming process. This paper proposes the design of the fuzzy logic controller to automatically determine water intake, water temperature, washing time and washing speed[8]. The design involve selection of input variable, membership function definition, rule definition the result of the rule is then mapped into membership function and true value to get the output variable of the system[9]. Proposed system gives good water and electricity management also optimize the lifespan of the washing machine[10].

2. Method

Fuzzy controllers design consist of a selection of input variable the so-called linguistic variable. In this automatic washing machine the input variable used is Dirtiness of the clothes, type of fabric, type of dirt and volume of the clothes. That variable is obtained from a discussion with a user of the washing machine in one of the laundry in Yogyakarta and literature review. At the input stage, the value maps sensor information to the appropriate membership function and truth values of the variable also known as Fuzzification process. After that variable is processed using the appropriate rule in the form of IF-THEN statement and generate the results of each rule. The output is obtained by converting the result of the rules back to output value also known as Defuzzification. Figure 1 below shows the input-output mapping of this fuzzy washing machine controller
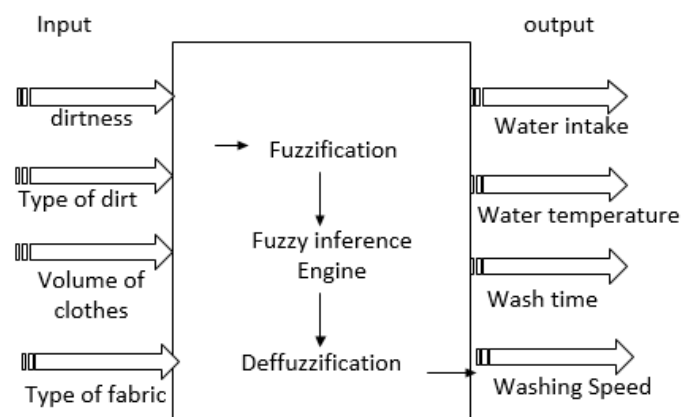

Figure1. Show the design of the controller for washing machine.

The washing machine inference techniques used to design the controller system is Mamdani method, with triangular membership function. The Mamdani style of fuzzy inference process is performed in four steps as follow fuzzification of the input variable, Rule evaluation (Inference engine), aggregation of the rule outputs (composition) and defuzzification to get the output (Rosyara, Vromman, & Duveiller, 2008). Figure 2 shows the simulated design on the MATLAB.
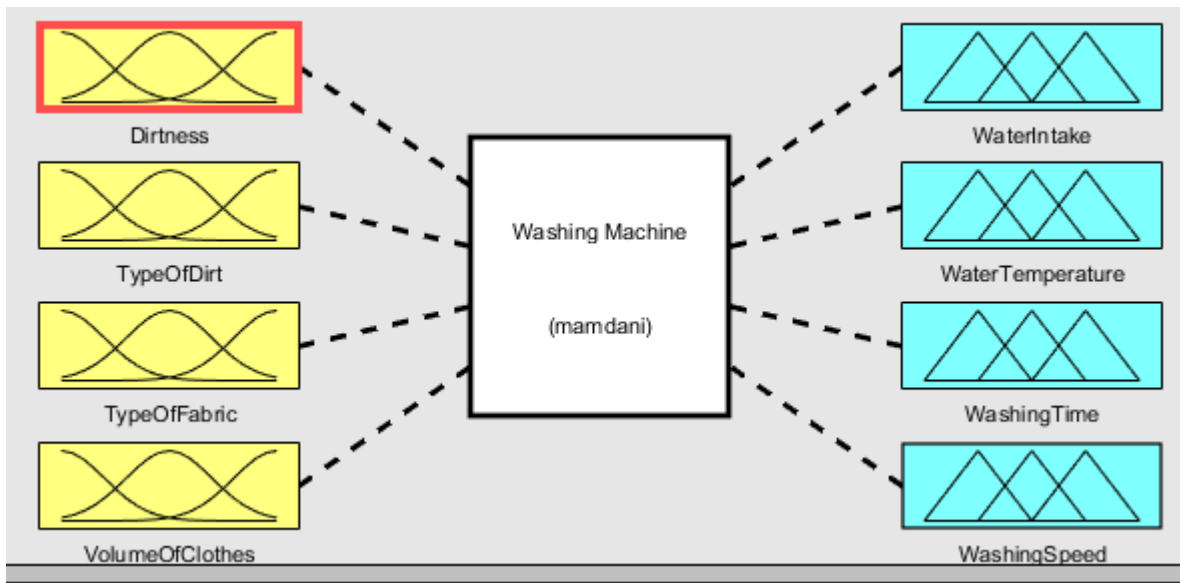
Figure 2. show the simulated washing machine on MATLAB

2.1 Fuzzification

At this step take the crisp inputs, the dirtiness of the clothes, type of dirt, the volume of clothes, type of fabric used to make clothes to determine the degree to which these inputs belong to each of the appropriate fuzzy sets. The membership value and range are shown in Table 1 below.

Table 1. show the input variable and membership

INPUT VARIABLE	MEMBERSHIP VALUE	MEMBERSHIP RANGE
Dirtiness of clothes	[Small,Medium, Large]	[0 100]
Type of Dirt	[Notgreasy, Medium, Greasy]	[0 100]
Type Of fabric	[Silk, Woolen, Cotton]	[0 100]
Volume of Clothes	[Small, Medium, Large]	[0 100]

After knowing the membership of each input variable and the output variable as shown in Table 2 below, then the inference engine is created.

2.2 Inference Engine

At this step, the Fuzzified inputs above are taken and apply them to the antecedents of the fuzzy rules. Because there are multiple antecedents AND operator is used to connecting and obtaining the single number that represents the result. Because of space here is the list of the example of the rule created to determine the washing speed.

1. If (Dirtiness is Small) and (TypeOfDirt is Not greasy) and (TypeOfFabric is Silk) and (volume of clothes is Small) then (WashingSpeed is VeySlow)
2. If (Dirtiness is Large) and (TypeOfDirt is Greasy) and (TypeOfFabric is Cotton) and (volume of clothes is Large) then (WashingSpeed is very fast)

3. If (Dirtiness is Large) and (TypeOfDirt is Not greasy) and (TypeOfFabric is Woolen) and (volume of clothes is Medium) then (WashingSpeed is Medium)

The rule that applies is fired, using the membership functions and truth values obtained from the inputs, to determine the result of the rule.

2.3 Diffuzification

The results are combined to give a crisp answer that means the actual washing speed, washing time, water intake and water temperature from the rule the process is called deffuzifaction. The defuzzification method used is the centroid technique, which finds the point where a vertical line would slice the aggregate set into two equal masses known as the center of gravity (COG) (Mamdani, 1974). Mathematically can be expressed as.

$$COG = \frac{\int_a^b \mu_A(x)\,x\,dx}{\int_a^b \mu_A(x)\,dx}$$

(1)

The output variable and their range are as shown below

Table 2. The Output variable

OUTPUT VARIABLE	MEMBERSHIP VALUE	MEMBERSHIP RANGE
Washing Time	[Veryshort, Short, Medium, Long, VeryLong]	[0 100]
Washing Speed	[VeryLow, Slow, Medium, Fast, VeryFast]	[0 1200]
Water Intake	[Little, Normal, A lot Of]	[0 100]
Water Temperature	[Low, Normal, High]	[0 80]

3. Result And Discussion

Fuzzy logic offers an absolutely different means of dealing with a control system when compared to the conventional method. These techniques focus on what the control system should do rather than trying to understand how it works. Fuzzy logic mimics what should be done by an expert or experienced personnel. To design the control system concentration is on how to solve the problem rather than to model the system in mathematical expressions. The designed washing machine prove to give simplicity, productivity, less cost and high performance to the user which is difficult to get when using the conventional washing machine[9].

The rule graph shows how the washing time is obtained based on the input variable. For example when the type of clothes is 21.5 which is between silk and woolen, type of dirty is 20.8 which is between Nongressy and medium, Dirtiness of Clothes is 50 which is medium and volume of clothes is 28 the output value washing time is 57 min which is the range of medium. The result is obtained based on fuzzy if-then rule base which is better than relying on human intuitive decision[11].
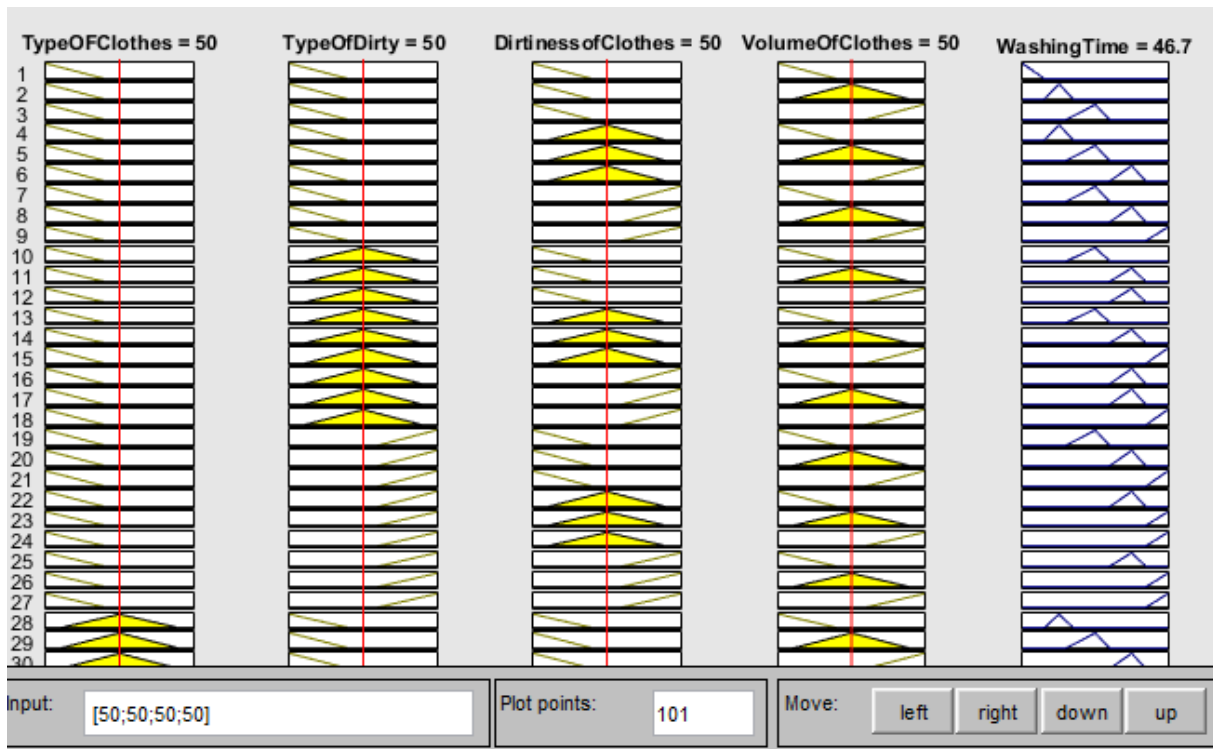
Figure 3. show the rule viewer which is obtained based on if –then of the fuzzy logic tools box.

Based on Figures 3 and 4 below which show surface graph relationship between Input variable type of dirty and dirtiness of clothes to the output variable washing time, the graph shows that time of washing roughly depends on those input variable so using the sensor to automatic give the output washing time based on input is the ideal solution.
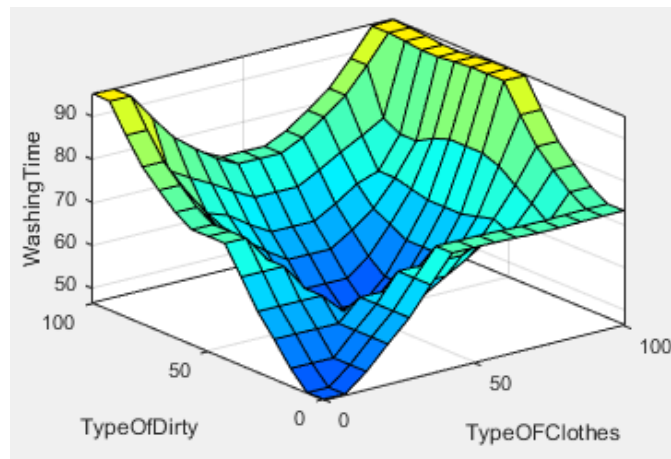

Figure 4. Show the surface relationship between input variable type of Dirty and type of clothes with output variable washing time
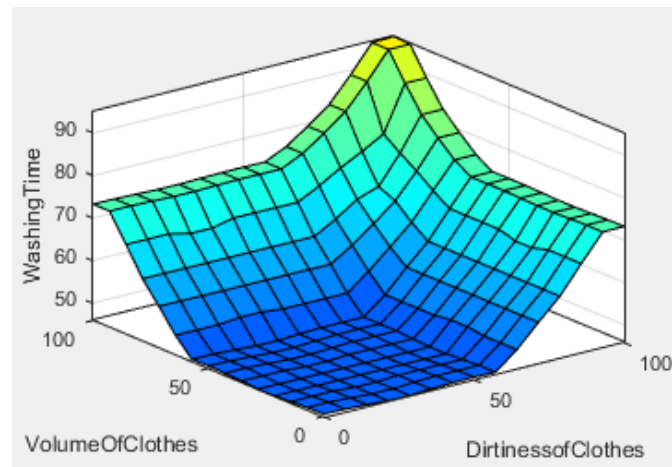
Figure 5. Show the surface relationship between input variable volume of clothes and dirtiness of clothes to the output washing time.

4. Conclusion

The fuzzy logic controller provides better control of the washing machine while giving good electricity and water management. This optimizes the lifespan of the washing machine because now the washing machine is able to weigh the required amount of clothes to avoid overloading the machine and adjust the required amount of water. A conventional washing machine which needs human intervention to set the washing speed and decide the amount of water based on the experience is outdated in this technological era. In the future, the washing machine that learns from the past experience and adjusting automatically to the given task is the ideal design which can minimize the running costs. The paper focus on the design and simulation of a washing machine on MATLAB. There is a room of designing the circuit board which will show how those sensor work to automate the washing machine in the future.

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