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A Fuzzy Logic-based Control System for Microwave Ovens

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Abstract. Conventional microwave ovens rely on users for their cooking time. In other words, the user must set the oven's cooking time manually. This paper aims to design a fuzzy logic-based controller to resolve the above-mentioned issue by determining the cooking time of the microwave oven automatically. The time determined depends on the quantity and type of food. During the fuzzy logic process, we used the Mamdani fuzzy model. This model involves determining the crisp input, fuzzification, rule evaluation, and defuzzification, to obtain the crisp output result. Input real variables used were the type of food and quantity of food, whereas the output variable used was cooking time. A fuzzy logic toolbox on MATLAB software was used to design and simulate the whole system. Considering the IF-THEN rules and functions, we used the value of food as 50, and the type of food as 50 and we obtained the cooking time as 25 minutes. The result showed that Fuzzy models are good at determining cooking time in Microwave ovens and that their cooking time depends on the inputs. Using fuzzy logic in microwave ovens helps to maintain food quality, saves users' time, and controls the energy used by the oven.

.

1. Introduction

A microwave oven is an electric appliance that cooks food by the use of electromagnetic waves.Today, microwave ovens are a common cooking feature used in homes and restaurants. They can be used for cooking raw food, warming cold food that has been removed from the fridge, and so many other cooking tasks. Microwave ovens are an appreciated feature because of their way of working, as they help users to save time and reduce the stress of cooking. These electric gadgets have continued to become an attractive feature in this modern generation. In industries, manufacturers also use them for heating processes. This is because of their bulk heating that comes up as a result of microwaves penetration [1]. This reliable heating helps users to reduce energy costs, which is a massive advantage of using microwave ovens.

However, since the modern microwave ovens require the user to set the cooking time, it means that the user sets the time by predicting adequate time that can be taken by the oven to cook the food regardless of the food type. However, different types and quantities of food require different time lengths to cook. It is, therefore, trying for the microwave oven user to estimate the right cooking time for the oven. Usually, regardless of the cooking mode, raw food takes a long time to cook. Half cooked food takes average time, and fully cooked food usually takes the least or short time to cook to the level of a well-known as a delicious dish. Thus, the goal of our study is to design a fuzzy logic controller that will determine the cooking time for the microwave ovens in an automatic manner, by using the Mamdani fuzzy inference system.

Fuzzy logic has become a common topic today in modern technology. In the current world, fuzzy logic can be used in different fields of study. In industries, manufacturers use fuzzy logic in their processes to test the reactions or strengths of their manufactured products, such as predicting the wear behavior of stainless steel in the steel industry [2]. When applied in washing machines, Fuzzy logic can do a very good task in control and simulation of the washing device. The model can reduce water wastage and maintain a good washing speed for different types of clothes [3].

Also, fuzzy logic can be used to design fuzzy reasoning systems that can detect fingerprint similarity. Such designed systems can be applied for use in situations when fingerprint authentication is required [4]. In the medical sector, fuzzy logic approaches can be used to diagnose diseases such as heart diseases, cancer, blood pressure, and so many others [5]. In the new technology, it has been used to modernize homes to smart homes through controlling home amenities such as water and electricity [6]. In addition to the above, in some drying processes, Fuzzy logic control systems can be used to control and monitor the temperatures of electric appliances [7]. Similarly, applying fuzzy control in microwave ovens for the cooking process, as expressed by one researcher, has many benefits of which include that it brings out a good texture in food and restores rehydration properties in case of dried foods. The food also maintains its color, thus, ensuring food quality [8]. Fuzzy logic systems are unique in a way that they do not actually require accurate mathematical models to carry out their functions. They have their own potential to deal with quite several complex issues and provide quick solutions. Manual prediction of cooking time for microwave ovens is an inaccurate method since it may result in a dish contrary to the desires of the user. Therefore, fuzzy logic can be used because it suits such complex problems.

2. Method and Materials

Fuzzy controller design began with the selection of input variables known as crisp inputs. In this paper of simulation of microwave ovens, we used two input variables i.e., the type of food and quantity of food. We decided these inputs after discussing with one of the chief cooks at one daily Restaurant in Yogyakarta, where they use microwave ovens daily at their restaurant and confessed that the cooking time estimation was a big challenge facing them. Due to this, they end up wasting much power and thus paying high bills because of the estimation of cooking time, since sometimes they set more time or less time than required.

The fuzzy inference process involves a few but essential steps. The first step (1) of the whole process is determining the real input variables, also known as the crisp input. After knowing the crisp input, step (2) is fuzzification. The role of fuzzification is to change the crisp input to linguistic variables using corresponding membership functions. Step (3) is the reasoning process, also commonly known as Rule evaluation. This process uses IF-THEN rules to transform fuzzy inputs to the fuzzy output. The last step (4) is defuzzification. It is at this step that the fuzzy output from the inference engine is changed to a crisp output result using membership function. At this stage, we get to know the cooking time of the microwave oven for its cooking process. The input-output mapping of the fuzzy Microwave oven controller is described as shown in the figure below.
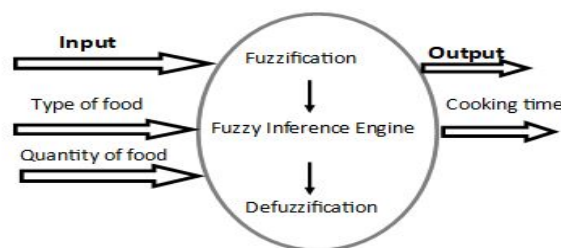
Figure 1. Design of the microwave oven controller

We used the Mamdani inference technique to design the controller system for microwave ovens. Mamdani fuzzy inference process is performed in four steps as we already explained above, namely-;
- Determine real inputs, Reasoning process, Rule evaluation, and Defuzzification to get a crisp output result.

To generate a Mamdani fuzzy model, the inference results from the input and output of a system must be obtained and considered. In this paper we used specific variables, thus to identify them, fuzzy inference regulations can be employed [9].

The standard Mamdani-type fuzzy model can be illustrated in Equation bellow;

$$if \ \ x_1 \ is \ A_i \ and \ x_2 \ is \ B_j, \ then \ \mu \ is \ C_{i,j} \ \ \ (i,j = 1,2,3, ..., 5) \tag{1}$$

μ represents the output of the fuzzy system

A_i and B_j are the input subsets and $C_{i,j}$ is the output subset.

The simulated design of the microwave oven on MATLAB is shown in figure 2 below;
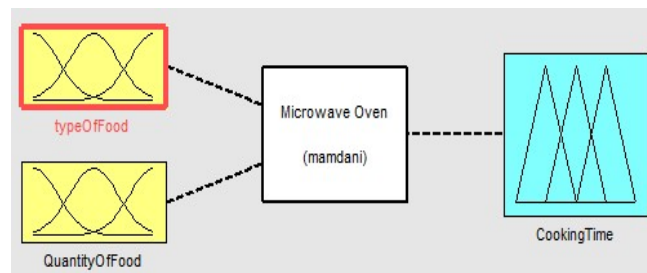
Figure 2. The design for Microwave Ovens on MATLAB

2.1. Fuzzification stage

Fuzzification is the stage at which the crisp inputs are converted to linguistic variables. In this paper, our crisp inputs are the type of food and quantity of food. We also consider output as the cooking time. We can use sensors to detect the type and quantity of food. We can then obtain the cooking time from the sensor readings. It is in this stage that the fuzzifier converts the crisp values into linguistic input values, and then the fuzzy inference rules are formed in the engine.

We indicate variable inputs, the membership value, and the range of membership in the table, as shown below.

Table 1. Variable input, value, and range of membership

Variable Inputs	Membership Value	Range of membership
Type of food	Raw Half cooked Fully cooked	[0 100]
Quantity of food	Little Medium Large	[0 100]

The table above shows the membership values of the type of food as raw, half-cooked, and fully cooked. The quantity of food can be classified as little, medium, and large. Below are the membership plots for the input variables i.e., type of food and quantity of food, respectively. Because of limited space, we did not put the non-membership plots in the paper.
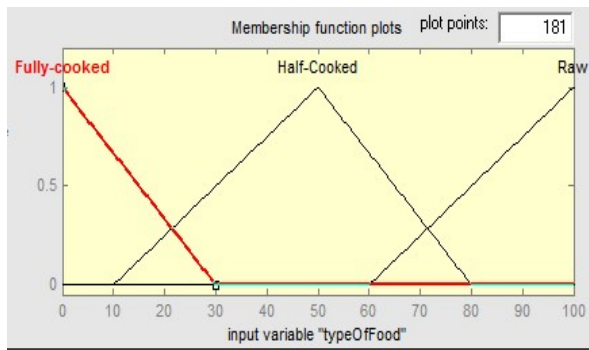
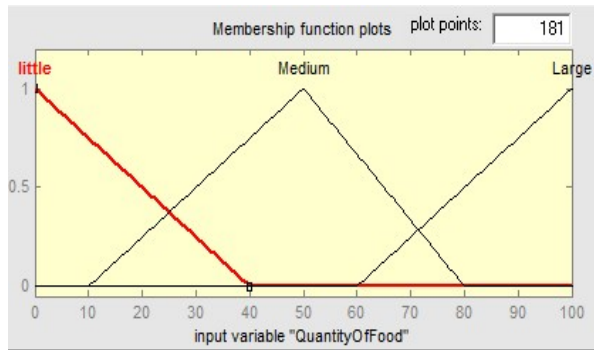**Figure 3.** Membership function for type of food**.**   **Figure 4.** Membership function plot for Quantity of food

Bellow is the membership plot for our output, which is the cooking time. We considered the highest cooking time as 60 minutes. (0 60). The classification of our cooking time is shown in the table below.

Table 2. Membership function plot for Type of food**.**

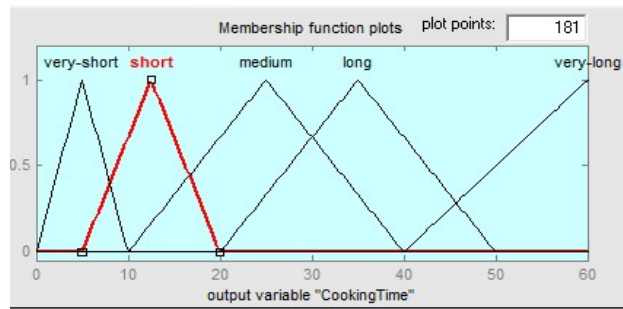| VARIABLE OUTPUT	MEMBERSHIP VALUE	MEMBERSHIP RANGE
COOKING TIME	0 - 10	Very-Short
	5 - 20	Short
	10 - 40	Medium
	20 - 50	Long
	40 - 60	Very-Long

Figure 5. Membership function plot for Cooking Time

2.2.   The Inference Engine

In the inference engine, linguistic variables are applied to the antecedents of the fuzzy rules. This is known as the reasoning process. In this case, we had more than one antecedent. Therefore, the AND operator was used to connect our antecedents and display the crisp output result.

Below are nine rules that were formed in the inference engine. These rules helped in determining the cooking time of the microwave oven.

1. If (TypeOfFood is Fully-cooked) and (QuantityOfFood is Little) then (cooking time is Very-Short)

2. If (TypeOfFood is Fully-cooked) and (QuantityOfFood is Medium) then (CookingTime is Short)

3. If (TypeOfFood is Fully-cooked) and (QuantityOfFood is Large) then (CookingTime is Medium)

4. If (TypeOfFood is Raw) and (QuantityOfFood is Little) then (CookingTime is Medium)

5. If (TypeOfFood is Raw) and (QuantityOfFood is Medium) then (CookingTime is Long)

6. If (TypeOfFood is Raw) and (QuantityOfFood is Large) then (CookingTime is Very-Long)

7. If (TypeOfFood is Half-Cooked) and (QuantityOfFood is Medium) then (CookingTime is Medium)

8. If (TypeOfFood is Half-Cooked) and (QuantityOfFood is Little) then (CookingTime is Short)

9. If (TypeOfFood is Half-Cooked) and (QuantityOfFood is Large) then (CookingTime is Long)

2.3. Defuzzification

The centroid of the area technique was used in this study for the defuzzification process. Defuzzification can be defined as a process by which crisp output results are obtained from any performance [10]
The point at which the vertical line cuts the set of aggregate into two equal parts is called the center of gravity. The centroid of the area method, therefore, aims at finding that point.

We can calculate the center of gravity (COG) using the equation below;

$$COG = \frac{\int_a^b \mu_A(x)x\,dx}{\int_a^b \mu_A(x)\,dx} \tag{2}$$

3.   Results and discussion

Fuzzy logic can be used to provide automated solutions to several hard situations. In this situation, it was found out that using fuzzy logic in microwave ovens to determine the cooking time undoubtedly helps to save time and save power (energy) used for cooking. It also helps to maintain food quality.
The output of the inference system in MATLAB software for determining the cooking time for microwave ovens is shown in figure 6 below. Following the rule viewer in the same figure indicates that results are obtained based on input variables. Using the result of the graph, we can now be able to predict the accurate cooking time of the oven.
Example: If the value of the inputs i.e., type of food, is 50, which is considered Half-cooked food, and the quantity of food is 50, which is considered as Medium-sized food, then the cooking time will be 25 minutes. This belongs to 'Medium' cooking time, according to our classification of membership range, as already shown in Table 2 in this paper.
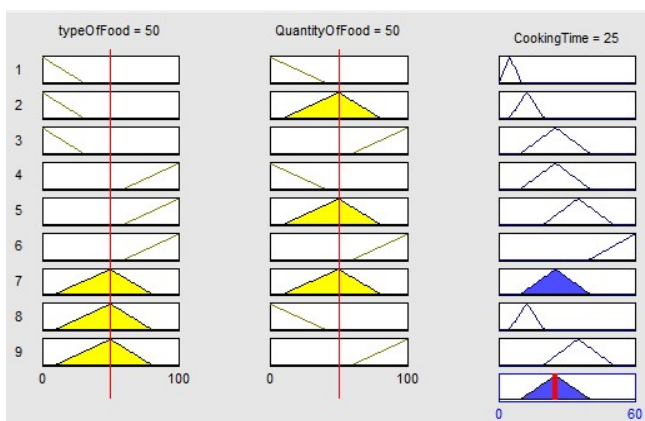

Figure 6. Cooking Time with Centroid Defuzzification
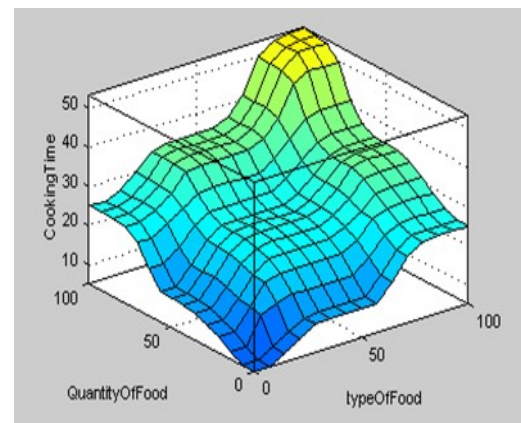

Figure 7. Surface graph

Following the above rule graph obtained from IF-THEN rules of the fuzzy logic tools box, we clearly note that the cooking time of the microwave oven depends on variable inputs, i.e., the type of food and quantity of food. Sensors can be used to automatically give variable output cooking time of the oven based on variable inputs.

The surface graph above in figure 7 shows the interaction of Input variables type of food, quantity of food, and output variable Cooking Time.

4.   Conclusion

We conclude by emphasizing the use of fuzzy logic controllers in microwave ovens since they give way to better control of the ovens, thereby saving time, energy, and maintaining food quality. The results of this study demonstrated that MATLAB software could be used for accurate prediction of cooking time in electric gadgets. MATLAB was also proved to be a reliable software able to generate all difficult relations between fuzzy input and output variables.

Researchers with related interests can also use the results from this study as a base of other studies on related subjects. Other researches can also be done focusing on other parameters. The proposed design can be improved by employing genetic algorithms for power efficiency optimization other than focusing on MATLAB alone to determine the cooking time.

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