Intuitionistic Fuzzy Logic Control for Microwave Ovens

Afshan, Assistant Professor ,
Toc H Engineering College Arakkunnam,

Shiny Jose, Associate Professor in Mathematics,
St. George's College Aruvithura, Kerala, India.

Abstract

In this paper, we describe the use of intuitionistic fuzzy logic control technique for the working of microwave ovens. Intuitionistic fuzzy inference systems and defuzzification techniques which are already in literature are used to obtain crisp output (i.e., cooking time of the oven) from an intuitionistic fuzzy input (i.e., type of food and quantity of food). We calculate the output value (cooking time) from the inferred intuitionistic fuzzy inputs.

Key words

Defuzzification, Intuitionistic Fuzzy Logic, Intuitionistic Fuzzy Logic Controller, Intuitionistic Fuzzy Sets

1. Introduction

L.A. Zadeh introduced fuzzy set theory in 1965. It was extended to Intuitionistic fuzzy set theory by K.T. Atanassov in 1983[2]. Intuitionistic fuzzy theory deals with uncertainity and vagueness, using degree of membership and degree of non membership.

Microwave Ovens are a common feature today. The most important use of ovens are that time and effort for cooking can be saved. Each food item requires specific time to get cooked and that depends on the type of food and quantity of food placed in the oven. It is not easy to determine the exact time required by each food item and so the common practice is to set the time by trial method. Through this paper, an intuitionistic fuzzy logic controller is designed that itself sets the time required for the food placed in the oven depending on its type and quantity. Intuitionistic fuzzy inference systems and defuzzification techniques are developed to obtain crisp output (i.e., cooking time of the oven) from an intuitionistic fuzzy input (i.e., type of food and quantity of food). We calculate the output value (cooking time) from the inferred intuitionistic fuzzy sets.

Mamdani controller and Takagi Sugeno controller are the two most frequently used fuzzy logic controllers. We have applied Takagi Sugeno controller[1] in this paper.

2. Preliminaries

Definition 2.1[2] Let X be a given set. An Intuitionistic fuzzy set A in X is given by,

$$\mathrm{A} = \{(x,\ \mu_A(x),\ \nu_A(x)) \mid\ x\ \in\ X\}$$

where $\mu_A, \nu_A : X \to [0,1]$, and $0 \leq \mu_A(x) + \nu_A(x) \leq 1$. $\mu_A(x)$ is the degree of membership of the element x in A and $\nu_A(x)$ is the degree of non membership of x in A.
For each $x \in X$, $\pi_A(x)\ =\ 1 - \mu_A(x) - \nu_A(x)$ is called the degree of hesitation.

Definition 2.2[3] **Intuitionistic Fuzzy Number**: An IFN denoted by $\tilde{A}^i$, is defined as follows:

(1) an intuitionistic fuzzy subset of the real line

(2) normal, i.e., there is any $x_0 \epsilon$ R such that $\mu_{\tilde{A}^i}(x_0)$=1 (so $\nu_{\tilde{A}^i}(x_0)$=0)

(3) a convex set for the membership function $\mu_{\tilde{A}^i}$(x), i.e.,
$\mu_{\tilde{A}^i}(\lambda x_1$ +(1-λ)$x_2) \geq \min(\mu_{\tilde{A}^i}(x_1),\ \mu_{\tilde{A}^i}(x_2))x_1,\ x_2\ \epsilon$ R, $\lambda\epsilon$[0,1]

(4) a concave set for the membership function $\nu_{\tilde{A}^i}$(x), i.e.,
$\nu_{\tilde{A}^i}$ (λx_1 + (1-λ)x_2) $\leq$ max ($\nu_{\tilde{A}^i}(x_1)$,$\nu_{\tilde{A}^i}(x_2)$) $x_2,\ x_1\ \epsilon$ R, $\lambda\epsilon$[0,1]

Definition 2.3 [5] Triangular Intuitionistic Fuzzy Number: A TIFN $\mu_{\tilde{A}^i}$ is a subset of IFS in R with following membership function and non-membership function as follows:

$$\mu_{\tilde{A}^i} = \begin{cases} \frac{x-a_1}{a_2-a_1} & \text{for} a_1 \leq x \leq a_2 \\ \frac{a_3-x}{a_3-a_2} & \text{for} a_2 \leq x \leq a_3 \\ 0, & \text{otherwise} \end{cases} \tag{0.1}$$

Definition 2.4[1] **Takagi Sugeno Formula**: Let x be an element in intuitionistic fuzzy set A, and μ_A and ν_A are degree of membership and non- membership of x in A. If M are few sample spaces in A, x^j represents the jth sample space in M. If a number of rules give same output membership function, then we take minimum out of all membership value, and maximum out of all non- membership values. Takagi Sugeno's formula is given by

$$x = \frac{\sum_{j=1}^{M} x^j \left((1 - \pi_{A^j})\mu_{A^j} + \mu_{A^j}\pi_{A^j} \right)}{\sum_{j=1}^{M}\left((1 - \pi_{A^j})\mu_{A^j} + \mu_{A^j}\pi_{A^j} \right)}$$

3. Outline of the Proposed Model

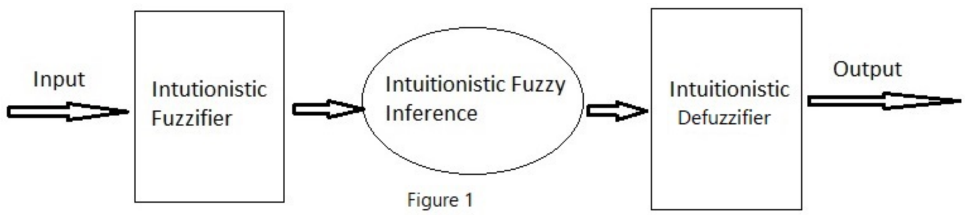

Figure 1

The main aim of the intuitionistic fuzzy logic controller is to find a crisp control action from a set of crisp inputs using intuitionistic fuzzy rule base. The input variables called the parameters (type of food and quantity of food) goes through the intuitionistic fuzzy inference system to provide the output(cooking time).

3.1 Algorithm for the Intuitionistic Fuzzy Controller

Now we will use the above described method of intuitionistic fuzzy rule based inference to decide the cooking time of the Microwave Oven.
The following algorithm needs to be fulfilled to implement the intuitionistic fuzzy techniques

- Linguistic variables of the input (type of food and quantity of food) and output (cooking time) are defined.
- Linguistic variables are assigned membership (μ) and non membership(ν) degree.
- Application of intuitionistic fuzzy logic rules and calculating the output fuzzy sets inferred from the input sets.
- Defuzzificate the output variables of the satisfied rules to receive the crisp value of the cooking time required by the oven.

3.2 The Proposed Intuitionistic Fuzzy Inference System

The main units are

- Intutitionistic fuzzifier
- Intutitionistic fuzzy Inference Rules
- Intutitionistic defuzzifier

3.2.1 Intutitionistic fuzzifier

Here we consider the type of food and quantity of food as the inputs to the fuzzy controller. Cooking time is considered as its output. To identify the type and quantity of the food, sensors can be used and from the sensor readings, the cooking time can be obtained. Intuitionistic fuzzifier converts the crisp values into linguistic input values. Rules are formed in the intuitionistic fuzzy inference engine. Type of food can be classified as three sets- raw, semi-cooked and fully cooked. Also quantity of food can be classified as regular, medium and large. Membership functions and non membership functions for the type of food and quantity of food are given in figure 2,3,4 and 5.

There are five triangular intutionistic fuzzy sets for the cooking time of the oven. The range is from 0-60 minutes. They are termed as very short (0-10), short (5-20), medium (10-40), long (20-60), very long (40-60). Their membership and non membership values are given in figure 6 and 7.

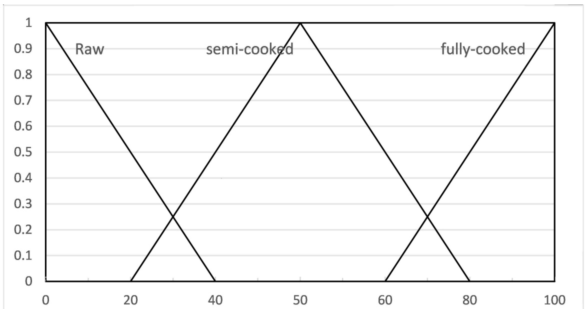

Figure 2 : Membership function of type of food

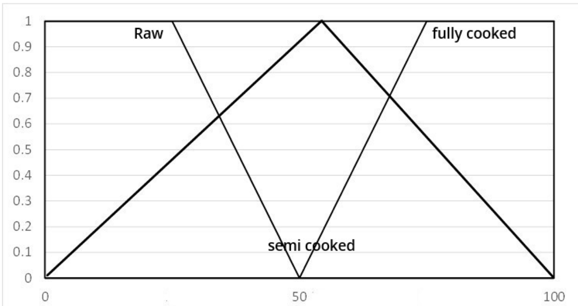

Figure 3 :Non-membership function of type of food

We will explain the working of the controller with an example. Let the input for the type of food and quantity of food be 65 and 75 respectively. Lets fuzzify these values using membership and non membership functions of both inputs.

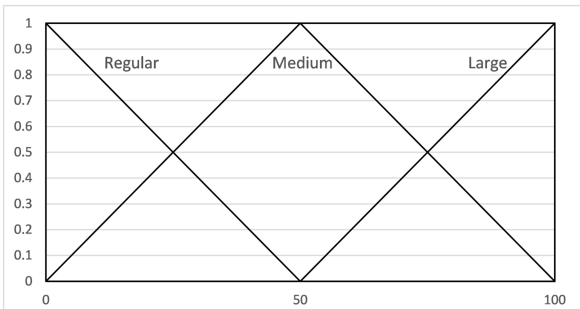

Figure 4: Membership function of quantity of food

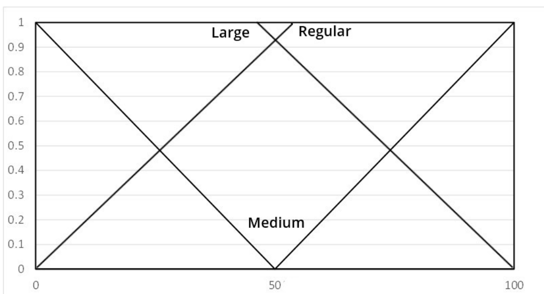

Figure 5: Non Membership function of quantity of food

$$\mu_{raw}(x) = 0 \ ,\mu_{semi-cooked}(x) = 0.38, \ \mu_{fully-cooked}(x) = 0.15$$
$$\nu_{raw}(x) = 0 \ , \ \nu_{semi-cooked}(x) = 0.5, \ \nu_{fully-cooked}(x) = 0.8$$
$$\mu_{regular}(x) = 0 \ , \ \mu_{medium}(x) = 0.55 \ , \ \mu_{large}(x) = 0.45$$
$$\nu_{regular}(x) = 1, \ \nu_{medium}(x) = 0.5 \ , \ \mu_{large}(x) = 0.5$$

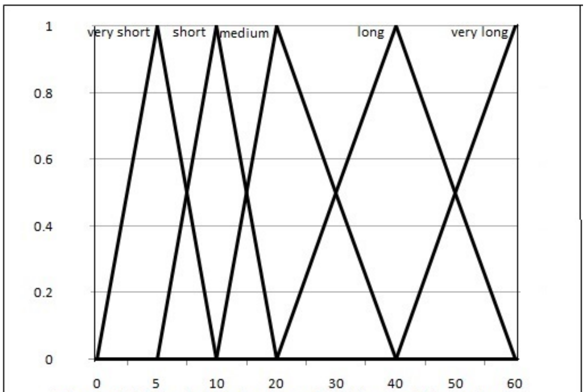

Figure 6 Membership function for cooking time

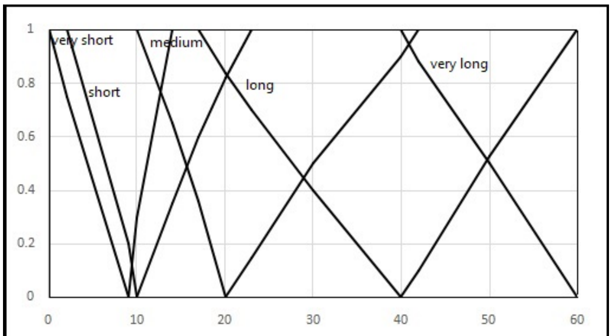

Figure 7 Non Membership functions for cooking time

3.2.2 Intutionistic Fuzzy Inference Rules

Following are the 9 (if-then) type intuitionistic fuzzy rules applied.

Rule 1- If the type of food is raw and the quantity of food is large, then cooking time is very long.

Rule 2- If the type of food is raw and the quantity of food is medium, then cooking time is long.

Rule 3- If the type of food is raw and the quantity of food is regular, then cooking time is very medium.

Rule 4- If the type of food is semi- cooked and the quantity of food is large, then cooking time is long.

Rule 5- If the type of food is semi- cooked and the quantity of food is medium, then cooking time is medium.

Rule 6- If the type of food is semi- cooked and the quantity of food is regular, then cooking time is medium.

Rule 7- If the type of food is fully cooked and the quantity of food is large, then cooking time is medium.

Rule 8- If the type of food is fully cooked and the quantity of food is medium, then cooking time is short.

Rule 9- If the type of food is fully cooked and the quantity of food is regular, then cooking time is very short.

Since the rules 4,5,7,8 gives a membership and non- membership values from (0,1) and the remaining rules gives membership value 0 and non membership value 1, we skip rules 1,2,3,6,9.

3.2.3 Defuzzification

Now let's defuzzify linguistic value to crisp value using Takagi Sugeno formula given in definition 2.4.

According to Rule 4 cooking time will be long

$$\mu_{long}(\text{x})= \tfrac{x-20}{20} = 0.36$$
$$x = 27.2$$
$$\mu_{long}(\text{x})= \tfrac{60-x}{20} = 0.36$$
$$x = 52.8$$
$$\nu_{long}(\text{x})= \tfrac{40-x}{23} = 0.19$$
$$x = 35.63$$
$$\nu_{long}(\text{x})= \tfrac{x-40}{20} = 0.19$$
$$x = 43.8$$

According to Rule 5 cooking time will be medium

$$\mu_{medium}(\text{x})= \tfrac{x-10}{10} = 0.36$$
$$x = 13.6$$
$$\mu_{medium}(\text{x})= \tfrac{40-x}{20} = 0.36$$
$$x = 32.8$$
$$\nu_{medium}(\text{x})= \tfrac{20-x}{10} = 0.19$$
$$x = 21.9$$
$$\nu_{medium}(\text{x})= \tfrac{x-20}{22} = 0.19$$
$$x = 24.18$$

According to Rule 7 cooking time will be medium

$$\mu_{medium}(\text{x})= \tfrac{x-10}{10} = 0.14$$
$$x = 11.4$$
$$\mu_{medium}(\text{x})= \tfrac{40-x}{20} = 0.14$$
$$x = 37.2$$
$$\nu_{medium}(\text{x})= \tfrac{20-x}{10} = 0.31$$
$$x = 16.9$$

$$\nu_{medium}(\mathrm{x}) = \frac{x-20}{22} = 0.31$$
$$x = 26.82$$

According to Rule 8 cooking time will be medium

$$\mu_{short}(\mathrm{x}) = \frac{x-5}{5} = 0.14$$
$$x = 5.7$$
$$\mu_{short}(\mathrm{x}) = \frac{20-x}{10} = 0.14$$
$$x = 18.6$$
$$\nu_{short}(\mathrm{x}) = \frac{10-x}{8} = 0.31$$
$$x = 7.52$$
$$\nu_{short}(\mathrm{x}) = \frac{x-10}{13} = 0.31$$
$$x = 14.03$$

TABLE 1. Membership and Non Membership values of medium cooking time(rule 5)

Sample space(x)	μ_x	ν_x
10	0	0.19
13.6	0.36	0.19
15	0.36	0.19
20	0.36	0.19
21.9	0.36	0.19
24.18	0.36	0.19
25	0.36	0.19
30	0.36	0.19
32.8	0.36	0.19
35	0.25	0.19
40	0	0.19
42	0	0.19
45	0	0.19

TABLE 2. Membership and Non Membership values of medium cooking time (Rule7)

Sample space(x)	μ_x	ν_x
10	0	0.31
11.4	0.14	0.31
15	0.14	0.31
16.9	0.14	0.31
20	0.14	0
25	0.14	0.23
26.82	0.14	0.31
30	0.14	0.31
35	0.14	0.31
37.2	0.14	0.31
40	0	0.31
42	0	0.31
45	0	0.31

TABLE 3. Defuzzification of medium cooking time using TS formula

Sample Space (x)	μ_x	ν_x	π_x	A=(1-π_x)μ_x	B=π_x μ_x	A+B	(A+B)x
10	0	0.31	0.69	0	0	0	0
15	0.14	0.31	0.55	0.063	0.077	0.14	2.1
20	0.14	0.19	0.67	0.046	0.0938	0.14	2.8
25	0.14	0.23	0.63	0.0518	0.0882	0.14	3.5
30	0.14	0.31	0.55	0.063	0.077	0.14	4.2
35	0.14	0.31	0.55	0.063	0.077	0.14	4.9
40	0	0.31	0.69	0	0	0	0
45	0	0.31	0.69	0	0	0	0
						$\sum(A+B) = 0.7$	$\sum(A+B)x$ =17.5

TABLE 4. Defuzzification of long cooking time using TS formula

Sample Space (x)	μ_x	ν_x	π_x	A=(1-π_x)μ_x	B=π_x μ_x	A+B	(A+B)x
10	0	0.19	0.81	0	0	0	0
15	0	0.19	0.81	0	0	0	0
17	0	0.19	0.81	0	0	0	0
20	0	0.19	0.81	0	0	0	0
25	0.25	0.19	0.56	0.11	0.14	0.25	6.25
27.2	0.36	0.19	0.45	0.198	0.162	0.36	9.8
30	0.36	0.19	0.45	0.198	0.162	0.36	10.8
35	0.36	0.19	0.45	0.198	0.162	0.36	12.6
35.63	0.36	0.19	0.45	0.198	0.162	0.36	12.83
40	0.36	0	0.64	0.13	0.23	0.23	14.4
43.8	0.36	0.19	0.45	0.198	0.162	0.36	15.77
45	0.36	0.19	0.45	0.198	0.162	0.36	16.2
50	0.36	0.19	0.45	0.198	0.162	0.36	18
52.8	0.36	0.19	0.45	0.198	0.162	0.36	19
55	0.25	0.19	0.56	0.11	0.14	0.25	13.75
60	0	0.19	0.81	0	0	0	0
						$\sum(A+B) = 3.74$	$\sum(A+B)x = 149.4$

TABLE 5. Defuzzification of short cooking time using TS formula

Sample Space (x)	μ_x	ν_x	π_x	A=(1-π_x)μ_x	B=π_x μ_x	A+B	(A+B)x
2	0	0.31	0.69	0	0	0	0
5	0	0.31	0.69	0	0	0	0
5.7	0.14	0.31	0.55	0.063	0.077	0.14	0.798
7.52	0.14	0.31	0.55	0.063	0.077	0.14	1.0528
10	0.14	0	0.86	0.02	0.12	0.14	1.4
14.03	0.14	0.31	0.55	0.063	0.077	0.14	1.96
15	0.14	0.31	0.55	0.063	0.077	0.14	2.1
18.6	0.14	0.31	0.55	0.063	0.077	0.14	2.6
20	0	0.31	0.69	0	0	0	0
23	0	0.31	0.69	0	0	0	0
						$\sum(A+B)$ =0.84	$\sum(A+B)x$ =9.9108

Table 1 and 2 determines membership and non membership values for medium cooking time according to rule 5 and 7 respectively. Table 3,4,5 shows the defuzzification of medium, long and short cooking time respectively. The result for medium cooking time is $\frac{17.5}{0.7} = 25$ whereas for long cooking time the result is $\frac{149.4}{3.74} = 40$. The result for short cooking time is $\frac{9.9108}{0.84} = 11.8$.

4. Conclusion

Currently fuzzy logic is applied in the functioning of washing machine and microwave oven. However intuitionistic fuzzy logic is a better option. In this study we show how we can apply intuitionistic fuzzy logic control to make a fully automatic microwave oven.

References

[1] Muhammad Akram, Shaista Habib and Imran Javed, Intutitonistic Fuzzy Logic Control for Washing Machines, *Indian Journal of Science and Technology*, Vol7(5), 654-661(2014).

[2] Jaydip Bhattacharya, A few more on intutitonistic Fuzzy set, *Journal of Fuzzy Set Valued Analysis*, No.3, 214-222(2016).

[3] G.S Mahapatra, T. K Roy, Intuitionistic Fuzzy Number and its Arithmetic Operation with Application on System Failure. *Journal of Uncertain Systems*, Vol 7, No.2(2013), 92-107.

[4] Muhammad Akram, Saadia Shahzad, Arif Butt, Abdul Khaliq, Intuitionistic Fuzzy Logic Control for heater fans, *Mathematics in Computer Science*, Vol 7, No.2(2013).

[5] Adrian I Ban and Oelia ,Trapezoidal/ Triangular intuitionistic fuzzy number versus interval valued trapezoidal/triangular fuzzy number and applications to multicriteria decision making methods, *Notes on Intuitionistic Fuzzy Sets*, Vol 20, No.2(2014), 43-51.