PERFORMANCES EVALUATION AND COMPARISON OF TWO ALGORITHMS FOR FUZZY LOGIC RICE COOKING SYSTEM

(MATLAB FUZZY LOGIC TOOLBOX AND FUZZY TECH)

MOHD SHAHRIEEL MOHD ARAS
FADILAH ABDUL AZIS
FARA ASHIKIN ALI
SYED MOHAMAD SHAZALI SYED ABDUL HAMID
MOHD FARRIZ HJ MD BASAR

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(MATLAB Fuzzy Logic Toolbox and FuzzyTECH)

Mohd Shahrieel Mohd Aras
Department of Mechatronics, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
shahrieel@utem.edu.my

Fadilah Abdul Azis
Department of Mechatronics, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
fadilah@utem.edu.my

Fara Ashikin Ali
Department of Mechatronics, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
fara@utem.edu.my

Syed Mohamad Shazali Syed Abdul Hamid
Department of Mechatronics, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
syedshazali@utem.edu.my

Mohd Farriz Hj Md Basar
Department of Electrical, Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
mfarriz@utem.edu.my

Abstract – This paper presents an evaluation of performances rice cooking system with using Intelligent Controller that is Fuzzy Logic Controller (FLC) to meet the special requirements and some limitations of the rice cooking system. A new inference scheme is given to estimate the amount of rice and water to be used, and the temperature will be controlled according to the amount of rice and the time while cooking. The FLC system is designed by using two types of simulation software which are MATLAB Fuzzy Logic Toolbox and FuzzyTECH. The results obtained from the both simulation software are given in this paper. The differences the between both simulation also will be discussed. MATLAB Toolbox gives more specific results compared FuzzyTECH software. The both software meet the special requirements because is not much differ between each other.

Keywords: Fuzzy Logic Controller; MATLAB Fuzzy Logic Toolbox; FuzzyTECH; Temperature

I. INTRODUCTION

The objective of this paper is to present a simple design of a FLC for a rice cooker with do a simulation by using MATLAB Fuzzy Logic Toolbox and FuzzyTECH. The performances of both software's will discussed detail in this paper respectively to choose which one is more intelligent and suitable to implemented in real-time process control.

This paper will cover the controller configuration detail for the inputs and outputs as well as the parameters used. The rules of the fuzzy models also will be covered and the process of choosing the rules will be included. All the results from the simulation will be reported together with the conclusion of this project. The controller designed will be implemented in real-time process by using the results of the selected software so that will be known better performance in real-time process.

As we know a rice cooker or rice steamer is a device that used primarily for cooking rice. The preparation of rice has traditionally been a cooking process which requires attention to ensure the rice is cooked properly. Rice cookers simplify the process by automatically controlling the heat and timing, and at the same time freeing up a heating element on the range. Based on the results we can estimate the best and suitable software to implement in rice cooker.

II. FUZZY LOGIC CONTROL SYSTEM

Fuzzy logic controller or FLC is also introduced to the system for estimate temperature to be set when the load varies. Fuzzy logic is a technique to embody human-like thinking into a control system [1]. A fuzzy controller can be designed to emulate human deductive thinking, that is, the process people use to infer conclusions from what they know. Fuzzy control has been primarily applied to the control of processes through fuzzy linguistic descriptions [1].

Fuzzy logic is widely used in machine control. It has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller. The basic concept of the fuzzy matrix theory is that mathematical matrices can be applied to social and natural situation to predict the outcomes. This theory use uses algorithms and algebra to analyze data [1].

III. RICE COOKER SYSTEM

The principle of rice cooker is the three major components which are rice bowl, heater and thermostat. A spring pushes thermostat against the bottom bowl, for good thermal contact to ensure accurate temperature measurement. At the end of cooking, some of the water added will have been absorbed by the rice and the rest is boiled off. Once the heating continues past the boiling point, the thermostat then trips, switching the rice cooker to low power "warming" mode [2].

From the basic principle of rice cooker as mention before, a fuzzy controller can be designed so that more robust and sophisticated rice cooker system can be produced. The fuzzy controller design need a well define inputs variables and also the yielding of outputs variables.

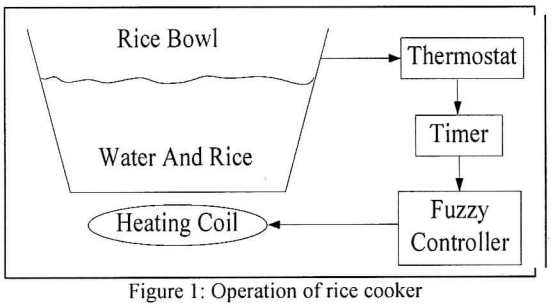


Figure 1: Operation of rice cooker

Referring to Figure 1, the fuzzy logic controller has 2 inputs which are time and amount of rice while 1 output which is temperature. The 2 inputs are used for accessing the current conditions of the process such that the necessary action can be taken by providing the correct control signal for output. The Table 1 shows the amount of rice and the time needed to cook for HITACHI RZ-BM18/CM18 rice cooker [3].

TABLE 1
Amount of Rice And Time Elapse for Cooking

Amount of rice	*Time elapse*
1 Cup	20 minutes
2 Cups	22 minutes
3 Cups	24 minutes
4 Cups	26 minutes
5 Cups	28 minutes

Based on Table 1, the new design of fuzzy rice cooker will finish cooking as the time mentioned according to the amount of rice, then the rice cooker will keep the rice in warm temperature which is 47.6°C. The design and the result will be shown in MATLAB and FuzzyTECH software.

Simulation 1: Fuzzy Logic Control System Designed By Using MATLAB

Fuzzy Inference System (FIS) Toolbox in MATLAB is the powerful Graphical User Interface (GUI) to design a fuzzy controller system. The FIS type design in MATLAB is Mamdani inference engine.

- *Fuzzification and Knowledge Base*

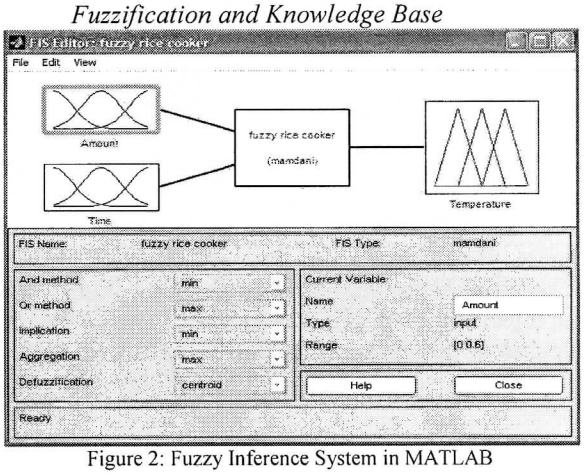


Figure 2: Fuzzy Inference System in MATLAB

The Fuzzy Inference System for rice cooker is shown in Figure 2. The inputs are amount and time; and the output is temperature. Inference engine in this project used Mamdani technique.

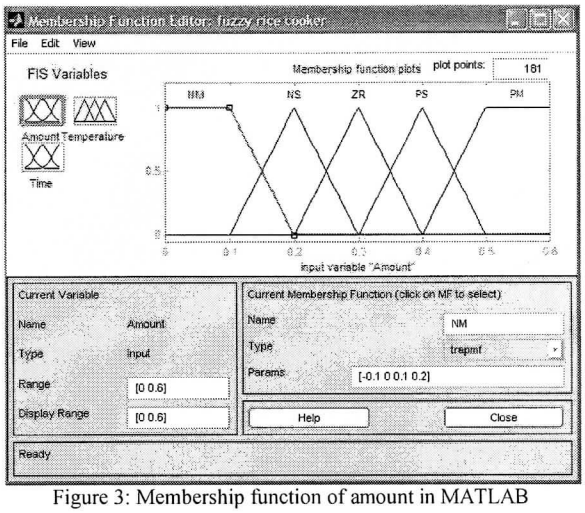


Figure 3: Membership function of amount in MATLAB

Figure 3 shows the membership function of the amount of rice. The range is set at 0.0 to 0.6 which mean 0 cup to 6 cups in real quantity, the ratio for normalization is 1:0.1. The fuzzy set of amount is quantizing (partition) the inputs such that each has 5 fuzzy sets which included Negative Medium (NM), Negative Small (NS), Zero (ZR), Positive Small (PS) and Positive Medium (PM). For the 2 input variables, use triangular waveforms for the middle fuzzy sets and trapezoidal functions on the sides.

MF1='NM':'trapmf' [-0.1 0 0.1 0.2]
MF2='NS':'trimf' [0.1 0.2 0.3]
MF3='ZR':'trimf' [0.2 0.3 0.4]
MF4='PS':'trimf' [0.3 0.4 0.5]
MF5='PM':'trapmf' [0.4 0.5 0.6 0.7]

Where,

NM = Negative Medium;
NS = Negative Small;
ZR = Zero,
PS = Positive Small
PM =Positive Medium.

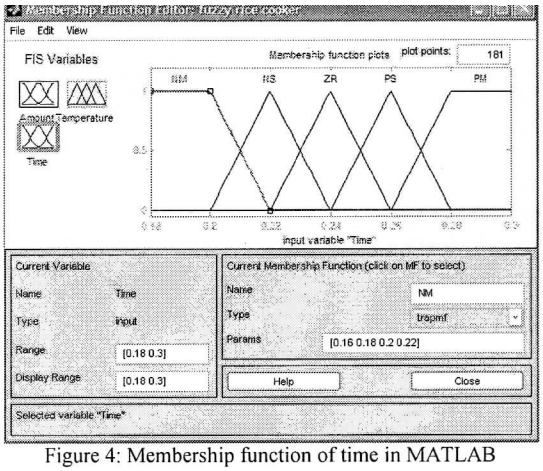


Figure 4: Membership function of time in MATLAB

Figure 4 shows the membership function of time elapse for cooking the rice. The range is set at 0.18 to 0.30 which means 18 minutes to 30 minutes in real time, the ratio for normalization is 10:0.1. The fuzzy set of time contains 5 membership functions which included NM, NS, ZR, PS and PM.

MF1='NM':'trapmf' [0.16 0.18 0.2 0.22]
MF2='NS':'trimf' [0.2 0.22 0.24]
MF3='ZR':'trimf' [0.22 0.24 0.26]
MF4='PS':'trimf' [0.24 0.26 0.28]
MF5='PM':'trapmf' [0.26 0.28 0.3 0.32]

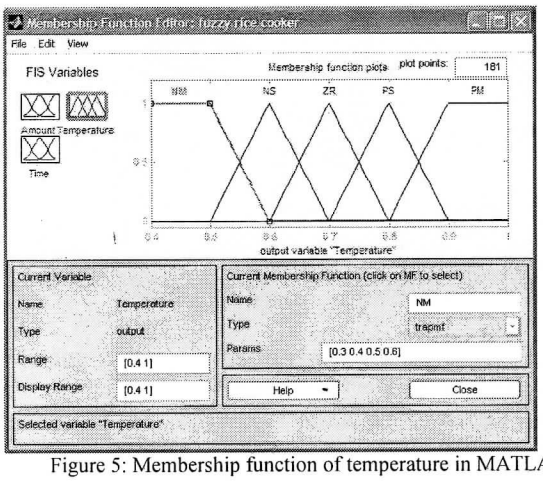


Figure 5: Membership function of temperature in MATLAB

Figure 5 shows the membership function of temperature controlled according to the amount of rice and time elapse for cooking the rice. The range is set at 0.4 to 1.0 which means 40°C to 100°C in real temperature, the ratio for normalization is 100:1. The fuzzy set of time contains 5 membership functions which included NM, NS, ZR, PS and PM.

MF1='NM':'trapmf' [0.3 0.4 0.5 0.6]
MF2='NS':'trimf' [0.5 0.6 0.7]
MF3='ZR':'trimf' [0.6 0.7 0.8]
MF4='PS':'trimf' [0.7 0.8 0.9]
MF5='PM':'trapmf' [0.8 0.9 1 1.1]

- *Fuzzy Control Rules*

The Fuzzy control rules are set as shown in Table 2 and Figure 6 shows the rules editor in MATLAB. The concept to design the rules is based on to the inputs which are amount of rice and time elapse. For example, when 2 cups of rice (about NS in amount) is cooked until 20 minutes (about NM in time) the output temperature is PS (about 70°C-90°C), when the time cooking until 22 minutes (about NS in time), the output temperature will be ZR (60°C-80°C) and then keep reducing the temperature until the time ZR (about 22 minutes-26 minutes) or later, the temperature will be kept in NM (about 40°C-60°C) which called as 'warm' condition.

TABLE 2:
Rules of Membership Function

Amount of rice \ Time elapsed	NM	NS	ZR	PS	PM
NM	ZR	NS	NM	NM	NM
NS	PS	ZR	NS	NM	NM
ZR	PM	PS	ZR	NS	NM
PS	PM	PM	PS	ZR	NS
PM	PM	PM	PM	PS	ZR

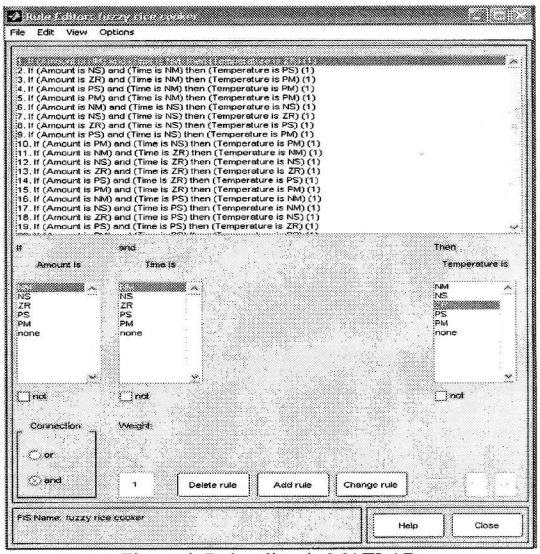


Figure 6: Rule editor in MATLAB

- *Inference Mechanism and Defuzzification*

Figure 7 shows the rule viewer in MATLAB which consists the inference mechanism and the value of defuzzification. The fuzzy interference mechanism is using Mamdani's max-min compositional operator and the defuzzification is using centroid method or center of gravity method.

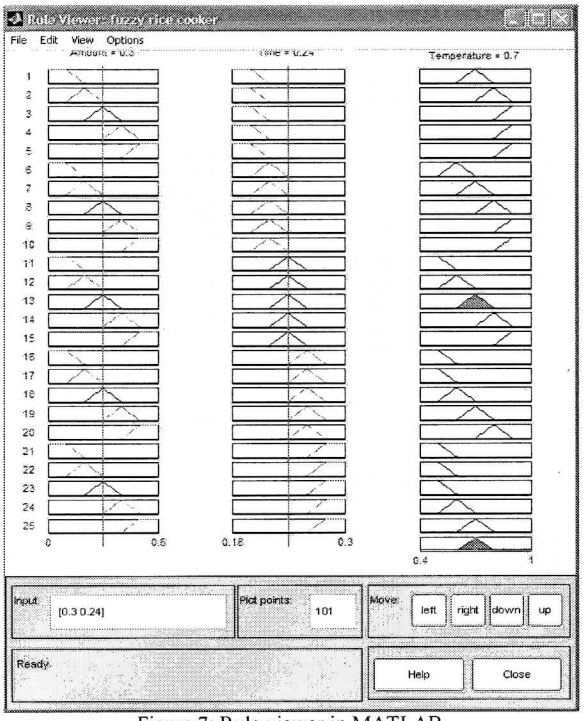


Figure 7: Rule viewer in MATLAB

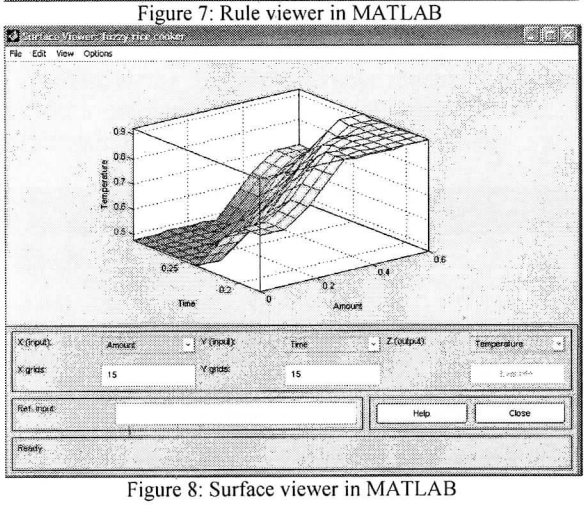


Figure 8: Surface viewer in MATLAB

The Figure 8 shows the surface viewer in MATLAB which concludes the response of output (temperature) regarding to inputs (amount of rice and time elapse).

Simulation 2: Fuzzy Logic Control System Designed By Using FuzzyTECH

FuzzyTECH is a software which can design and simulate the result same as FIS Toolbox in MATLAB. Furthermore, FuzzyTECH can compiles the fuzzy control system to C-code, Java code and FTR code. The C-code can also generated by FuzzyTECH for fuzzy rice cooker system.

- *Fuzzification and Knowledge Base*

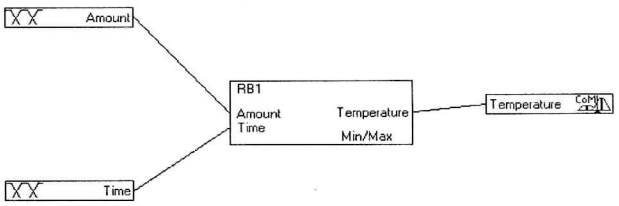


Figure 9: Fuzzy Inference System in FuzzyTECH

There are 2 inputs which are amount and time and 1 output which is temperature as shown in Figure 9.

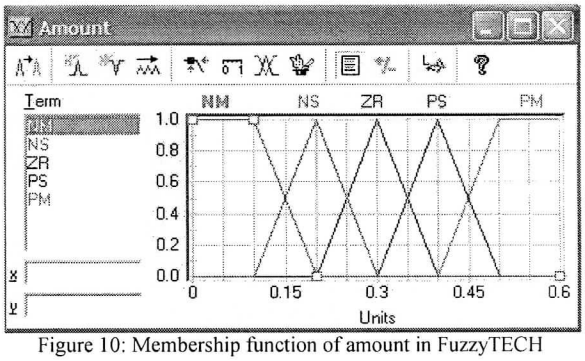


Figure 10: Membership function of amount in FuzzyTECH

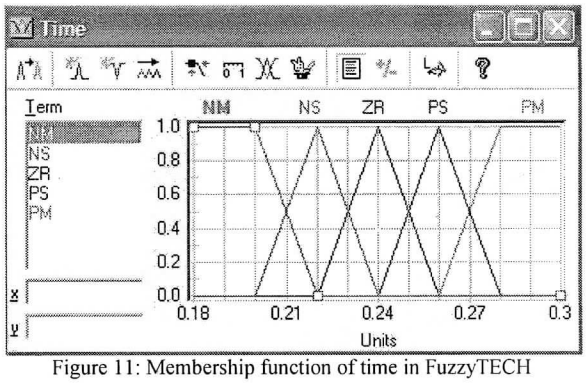


Figure 11: Membership function of time in FuzzyTECH

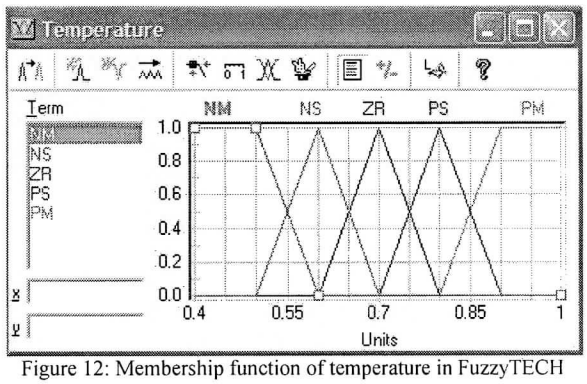
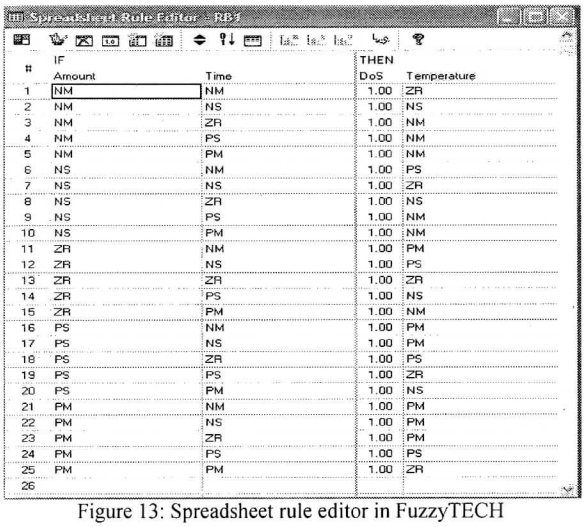


Figure 12: Membership function of temperature in FuzzyTECH

Figure 10, Figure 11 and Figure 12 show the membership function of amount of rice, time elapse and temperature controlled respectively. The setting of all fuzzy sets is similar with the MATLAB design that mentioned in MATLAB implementation section.

- *Fuzzy Control Rules*



#	IF Amount	Time	THEN DoS	Temperature
1	NM	NM	1.00	ZR
2	NM	NS	1.00	NS
3	NM	ZR	1.00	NM
4	NM	PS	1.00	NM
5	NM	PM	1.00	NM
6	NS	NM	1.00	PS
7	NS	NS	1.00	ZR
8	NS	ZR	1.00	NS
9	NS	PS	1.00	NM
10	NS	PM	1.00	NM
11	ZR	NM	1.00	PM
12	ZR	NS	1.00	PS
13	ZR	ZR	1.00	ZR
14	ZR	PS	1.00	NS
15	ZR	PM	1.00	NM
16	PS	NM	1.00	PM
17	PS	NS	1.00	PM
18	PS	ZR	1.00	PS
19	PS	PS	1.00	ZR
20	PS	PM	1.00	NS
21	PM	NM	1.00	PM
22	PM	NS	1.00	PM
23	PM	ZR	1.00	PM
24	PM	PS	1.00	PS
25	PM	PM	1.00	ZR
26				

Figure 13: Spreadsheet rule editor in FuzzyTECH

Figure 13 is the spreadsheet rule editor in FuzzyTECH; all the rules are set same as in Table 2.

- *Inference Mechanism and Defuzzification*

In FuzzyTECH, the fuzzy interference mechanism is using Mamdani's max-min compositional operator and the defuzzification is using center of gravity method.

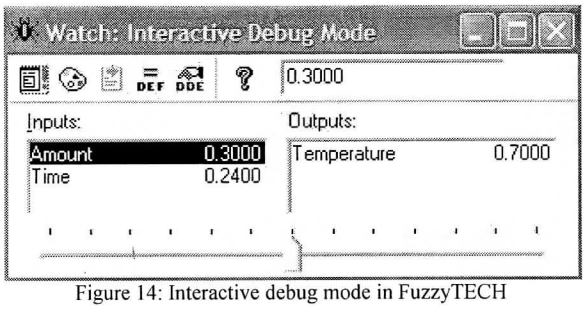


Figure 14: Interactive debug mode in FuzzyTECH

Figure 14 shows the interactive debug mode in FuzzyTECH. The defuzzification value of output temperature is calculated according to the values set in inputs amount and time. Referring to Figure 13, the amount is set to 0.3 and time is sets to 0.24 then the defuzzifcation value of temperature is 0.7 which calculated by using center of gravity method.

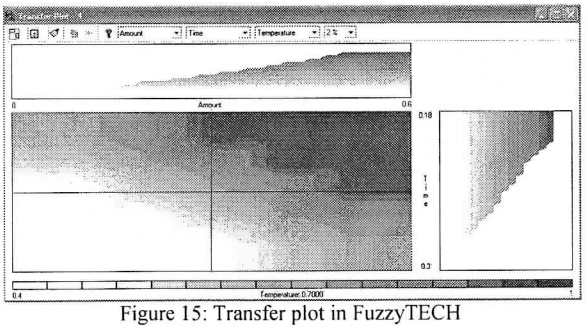


Figure 15: Transfer plot in FuzzyTECH

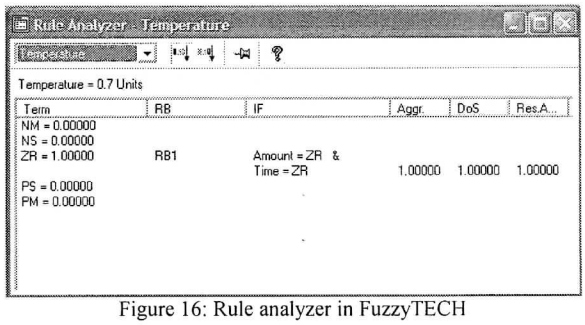


Figure 16: Rule analyzer in FuzzyTECH

Figure 15 and Figure 16 show the transfer plot and rule analyzer in FuzzyTECH respectively which analyze the response of output by referring to inputs and rules set.

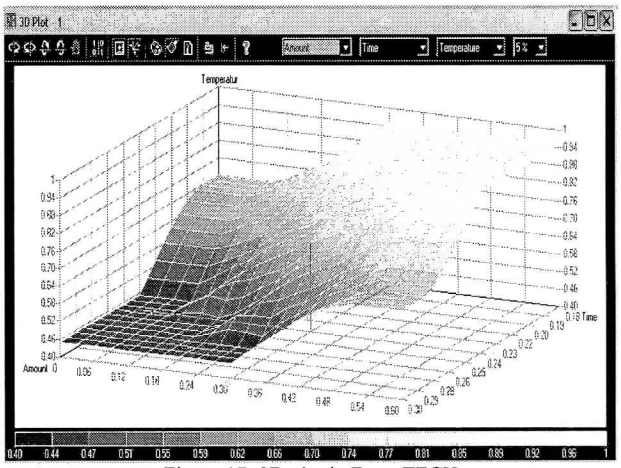


Figure 17: 3D plot in FuzzyTECH

Figure 17 shows 3D plot in FuzzyTECH which concludes the response of output temperature regarding to inputs amount of rice and time elapse.

IV. DISCUSSION

Table 3 and Table 4 are the simulation results obtained from MATLAB and FuzzyTECH respectively which fix the amount of rice equal to 3 cups and vary the time between 18 minutes to 30 minutes.

TABLE 3:
Simulation Result obtained from Rule Viewer In MATLAB

Input		*Output*
Amount	Time	Temperature
0.3	0.18	0.924
0.3	0.20	0.924
0.3	0.22	0.8
0.3	0.24	0.7
0.3	0.26	0.6
0.3	0.28	0.476
0.3	0.3	0.476

TABLE 4
Simulation Result obtained from Interactive Debug Mode in FUZZYTECH

Input		*Output*
Amount	Time	Temperature
0.3	0.18	0.95
0.3	0.20	0.95
0.3	0.22	0.8
0.3	0.24	0.7
0.3	0.26	0.6
0.3	0.28	0.45
0.3	0.3	0.45

Referring to Table 3 and Table 4, the amount of rice is equal to 3 cups, and the rice is cooked once the start button is ON until 20th minutes which the temperature is 92.4°C and 95°C in MATLAB and FuzzyTECH respectively. Then the heat is reduced from 22nd minute until 28th minute and maintains the temperature in 'warm' condition which the temperature is 47.6°C shown in MATLAB and 45°C shown in FuzzyTECH. Figure 18 shows graph of the comparison between MATLAB and FuzzyTECH software with amount of rise is 3 cups. From graph in Figure 18 not much difference between both software and results from MATLAB more specific compared with FuzzyTECH in-term of decimals point. When time 22 until 26 minutes the results of both software shown the same results. In Figure 19 shows the surface viewer for the both software. Both surface viewer look likes same surface view.

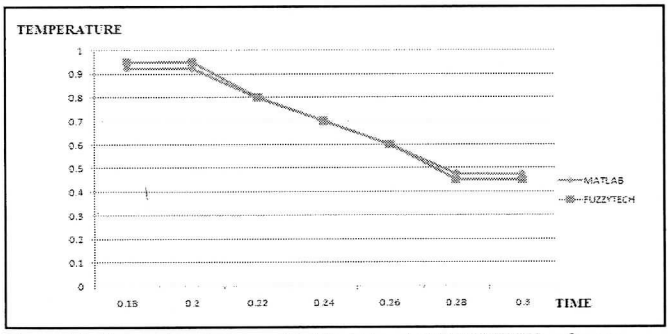


Figure 18: Comparison between MATLAB and FUZZYTECH software

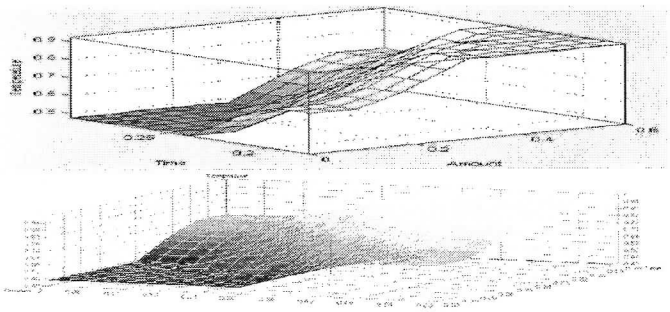


Figure 19: Comparison surface viewer of MATLAB and FuzzyTECH

V. CONCLUSION

The fuzzy rice cooker system had been designed to control the temperature while the rice is cooked by regarding to the amount of rice and the time elapse. Every input (amount of rice and time elapse) and output (temperature controlled) consists of 5 membership functions which called NM, NS, ZR, PS and PM. The type of membership function for NM and PM are trapezoidal while the type of membership function for the others is triangular. The fuzzy control system consists of 25 rules. The simulation had been done by using MATLAB FIS Toolbox and FuzzyTECH. A C-code of fuzzy rice cooker is compiled by using FuzzyTECH. The both simulation gives the comparable performances. MATLAB gives more specific values of output temperature. But for implementation on real time application FuzzyTECH look like easier compared MATLAB.

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