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SCHEDULING FOOD INDUSTRY SYSTEM USING FUZZY LOGIC

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ABSTRACT

In today's food industry, regardless if it is fast food or a sit down restaurant, wait time has a huge effect on customer satisfaction. It has been empirically proven that different firms compete with one another based on how fast their service is and it is also very well known in the food industry community that customers value speed of service highly and weigh it heavily when deciding who the preferred provider is. This paper presents a scheduling food industry using fuzzy based control system and focuses on determining the number of the ovens and workers needs for a certain job in food manufacturing system specially the pizza production industry. The reduction in money waste, increase in customer satisfaction, and the increase in the quality of the service were considered in this paper. Matlab software was used for the implementation stage and code was developed to achieve the final results.

Keywords*: Fuzzy Logic, Fuzzy Inference Systems, Control Theory, Artificial Intelligence*

1. INTRODUCTION

Education Sales volume of a certain food industry organization depends on all process of food within the region of their location and most importantly the waiting time of all the other competitors within the region. Market shares of an organization can also be improved by the just slight improvement in waiting time so it is of no surprise that the food industry has continuing efforts to reduce waiting time [1].

The food industry is a growing field not only in the United Sates, $170 billion in 2010 [2], but also in other regions of the world. One of the main goals of food industry is to retain old customers and obtain new customers. Although new customers cost 5 to 9 times more to obtain than just to keep the old customers. What better way to keep the old customers by having great customer service.

What customers associate with good customer service than anything else when it comes to the food industry is speed. If a customer is kept happy they will continue to keep coming back, until there is an event that brings down their satisfaction and the competition then steps in. When a competitor offers a lower price, even if the customer is happy going to the current location or organization they will give some thought to the idea of a new place. Lower costs can be achieved by high sales volume, which stated above has a lot to do with price and speed. Before we go any further let us define customer satisfaction is customer receiving benefits that outweigh their costs. Because customer loyalty is increased by efficiency, only a 5% increase in efficiency will yield a 25-85% increase in profit. With this and the fact that keeping customers is less expensive than gaining new ones, the organization should focus on maintaining the customers it currently has [3].

Hwang, Gao, and Jang also emphasize the competitiveness between organizations between wait times [4]. Restaurants are known for choosing capacity levels that will not affect the system revenue or quality but that make sure to minimize the system costs as well. The right balance must be found between quality of service and the minimization of costs. Not only in fast food but also in restaurants the price and waiting time seems to be the leading factors in the decision of a customer to choose a restaurant. This is where the right balance of operations perspectives and marketing must be embraced. The balance between improving the service quality and minimizing the costs can yield maximum profit [4]. Because these balancing decisions that must be made are becoming more and more complex, this is where the fuzzy theory can be of use [5].

2. LITERATURE REVIEW

The study of Jinping Niu, John Dartnall. [6] provides the idea of fuzzy –mrp-ii deals with uncertainty and imprecision. This technique shows all information for the decision makers allowing them to consider all possibilities of the orders.

Sanjoy Petrovic and Caroly Fayad [7] This study deals with the load balancing of a specific task (m/c) in a real-world job scheduling algorithm that allocates jobs, splits into lots on identical m/c. However, the main objectives of this paper are to reduce job total throughput time and to improve m/c utilization.

Another paper of Ripon Kumar Chakraborety and A. Akhtar Hassen. [8] their work explained the interactive fuzzy based genetic algorithmic approach solving two products and two period aggregate production planning with some different vulnerable managerial contraries such as imprecise demands, variable manufacture cost, authors applied some unique genetic algorithm parameters accurately to solve non-deterministic polynomials problem.

Manish Agrawal.[9] Here in this paper, it was mentioned that the washing machine is common item today at Indian household and considered as one of the most important utility customer can buy. this paper represents the idea of controlling the washing time using fuzzy logic control and describes the produce that can be used to get the suitable time for different types of cloths. the process is based entirely on principle of having no precise inputs from the sensor, subjecting them to fuzzy arithmetic and obtaining discrete value of washing time. It is quite clear from the paper that this method can be used in practice to further automates the washing machines.

Another paper of Paramot Srinol, Abrahim Shayan, Fatmaeh Ghotb [10]. In this paper, the authors present research project under taken as Witchburne industrial institutes in the area of fuzzy scheduling. The authors represented fuzzy based schedule model dealing with the parts routing problem. Model with select best alternative route with multi-criteria scheduling through fuzzy logic approach.

Ziaul Hassan Serneabat, Nabila Choudhury, A.K.M.Masud[11]. This paper concentrates on the simulation study of FMS. FMS is the production system containing of identical multi-purpose numerically controlled m/cs. the model that built in this paper prioritizes the task and select the best alternative route with multi-criteria scheduling through an approach based on fuzzy logic and with the help of rules the sequence of the jobs are done and the best route is selected.

Dusan Teodornic.[12]. This paper presents the classification techniques and analysis the results that achieved using fuzzy logic to build a model of complex traffic and transportation process system. Fuzzy logic is shown to be very promising mathematically approach to modeling traffic and transportation process characterized by subjectivity, ambiguity, uncertainty and imprecision.

From the previous studies, it can be concluded that very limited researches have used fuzzy based control system in the field of food manufacturing system, this paper will apply a unique technique that may give more accurate results comparing with other researches.

This paper focuses on the pizza production industry and tries to answer the question of fuzzy based control system can reduce in money waste, increase in customer satisfaction, and the increase in the quality of the service? This paper will answer this question by applying fuzzy based control system using MatLab to determine how many workers and ovens are needed to run. A schedule will be set for different scenarios. The reduction in waste will come from not having ideal workers or ovens running that don’t need to be running. The customer satisfaction will come with the short wait because of the efficient schedule and the improved quality.

3. FUZZY SETS AND FUZZY LOGIC

Fuzzy sets were introduced by Zadeh in 1965 [13] to represent/manipulate data and information possessing non-statistical uncertainties.

It was specially designed to mathematically represent uncertainty and to provide formalized tools to deal with the imprecision intrinsic to such problems. However, fuzzy logic started much more earlier before fuzzy sets.

Some of the basics features of fuzzy logic relate to the following [14]

- In fuzzy logic, exact reasoning is viewed as a limiting case of approximate reasoning.
- In fuzzy logic, everything is a matter of degree.
- In fuzzy logic, knowledge is interpreted a collection of elastic or, equivalently, fuzzy constraint on a collection of variables.
- Inference is viewed as a process of propagation of elastic constraints.
- Any logical system can be fuzzified.

There are two main characteristics of fuzzy systems that give them better performance for specific applications [15].

- Fuzzy systems are suitable for uncertain or approximate reasoning, especially for the system with a mathematical model that is difficult to derive.
- Fuzzy logic allows decision making with estimated values under incomplete or uncertain in- formation.

It is very important to understand the nature of fuzzy sets and fuzzy logic to fully understand the implementation of this paper with the pizza restaurant. This section will describe crisp and fuzzy set theory and provide an example of fuzzy sets along with an example of a Mamdani style fuzzy inference system.

Since Mamdani style fuzzy inference system will be used in the implementation part, the detailed example provided within the next section will help the understanding the concept. The concept of fuzzy sets begins with a complete understanding of the concept of crisp sets.

A crisp set is a set of letters, numbers, entities, words, etc. It can be a random grouping of any of these things, or it can be based on a rule determined by the person that is defining the set. Some examples of crisp sets in two different notations are shown below:

$F = \{Andy, Bill, Carol, Ginger, Ed\}$

$N = \{x | 1 \le x \le 5\}$

Set F is a crisp set of people. Set N is a crisp set of the numbers between 1 and 5, inclusive. A crisp set is nothing more than a special case of a fuzzy set.

Fuzzy sets are usually used when there is any sort of uncertainty in the calculations to be done, or the language used. One can easily identify a case in which fuzzy sets should be used by looking for ambiguous words such as hot, cold, tall, short, fat, or thin. The inherent ambiguity of spoken language creates the need for fuzzy sets and fuzzy inference systems.

To define a set of tall friends using a fuzzy set, if acquaintances' heights are as follows: Andy (6'4"), Bill (5'7"), Carol (5'4"), Ginger (5'3"), and Ed (6'0"), it can be defined a fuzzy set as shown below:

$Let\ T = Set\ of\ Tall\ Friends$

$$T = \frac{1}{Andy} + \frac{0.8}{Bill} + \frac{0.6}{Carol} + \frac{0.5}{Ginger} + \frac{0.9}{Ed}$$

What it calls a membership grade is assigned to each person in a set fuzzy set. This is the distinction between a crisp set and a fuzzy set. All membership grades are values between 0 and 1. They represent the level of membership of each data point in the set. These values are defined based on knowledge and opinions formed about these people".

There are many "fuzzy" terms in the English language such as: tall, short, rich, poor, smart, dumb, athletic, lazy, fat, and thin. All of these terms can have fuzzy principles applied to them and fuzzy sets allow to more accurately describing what it means when call someone tall, or short. The example earlier, Bill is five feet, seven inches tall. This not considers him to be absolutely tall, but it considers him to be tall to a degree of 0.8. After seeing this, we can understand that a crisp set is just a special case of a fuzzy set, where all of the membership values are equal to 1.

In term of defining fuzzy sets in a graphical notion. This will become important later when dealing with designing the Mamdani style Fuzzy Inference Systems. To define several sets of age over the range of 0-100 years old, see Figure 1.

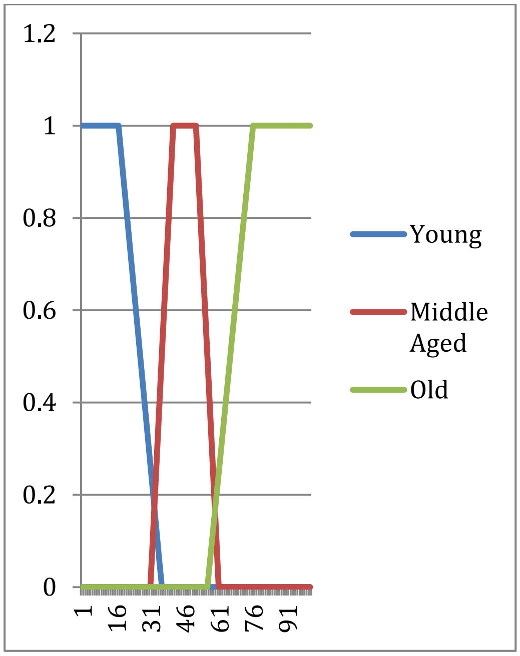

Figure 1: Definition of fuzzy sets in a graphical notion

As shown in Figure 1, the three sets Young, Middle Aged, and Old are defined in a graphical manner over a period of 100 years. When the lines in the graph are flat at 1, it can be considered the data point on the X-axis to have full membership in the fuzzy set. When the lines are sloped between zero and one, it can be read the membership grades of the data point in the fuzzy set. Fuzzy sets are most commonly represented in this fashion because it is extremely clear and very useful in creating fuzzy inference systems, which is what has been created in the implementation section of this paper.

4. FUZZY INFERENCE SYSTEMS

Fuzzy inference systems take fuzzy inputs and turn them into crisp outputs using fuzzy set theory. These systems are very capable of taking into account the stochastic nature of our world. Because of the ambiguous nature of many inputs these days, these systems can be very accurate and desirable to use. These systems are specifically set up to be able to take the fuzzy aspects of life and transform those into a meaningful and accurate answer to a systems problem. Normally, a system such as a washing machine has a set of crisp inputs that produces a set of crisp outputs. When a fuzzy inference system is applied, a much wider variety of levels of input and levels of output can be analyzed. This can provide much more flexibility to a system and can result in much more efficient and accurate calculations. The simplest way to describe a fuzzy inference system seems to be to describe it in four separate steps. The steps are as follows: Fuzzification of Inputs, the Fuzzy Inference, The Fuzzy Quantification, and Turning Fuzzy Outputs into Crisp Outputs.

2.1 Fuzzification of Inputs

Artificial In this step, crisp, numerical or linguistic inputs have been taken and turn them into fuzzy, linguistic inputs. This stage is when the fuzzy set definitions are extremely useful. For each input, it must define fuzzy sets over the range of possible inputs. Usually it is represented in graphical form. For each input, it can be defined anywhere from two to several different levels, which will relate to the outputs of the system. So, if it is a crisp, numerical temperature input of 60 degrees Fahrenheit and it needs to be change to a fuzzy linguistic input, it must define fuzzy sets of temperatures and represent them in graphical form. See Figure 2.

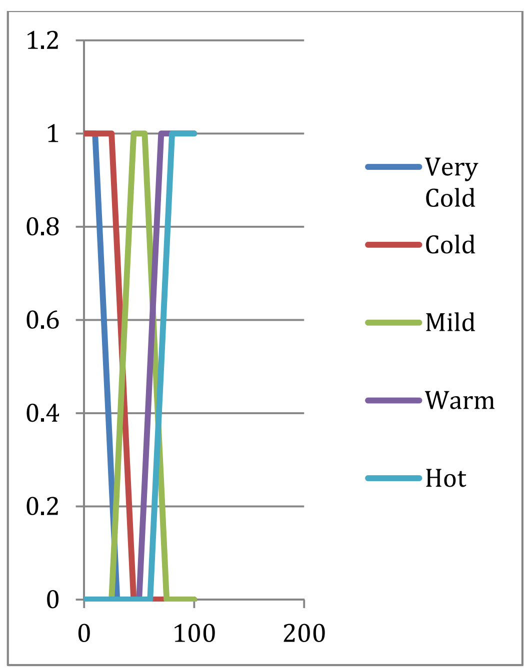

Figure 2: Representation of the different levels of temperature

The graph above is a representation of the different levels of temperature. These are the fuzzy, linguistic terms for the inputs. Now, if 60 degrees Fahrenheit has been taken, it can be converted it to fuzzy inputs. This can be done by placing 60 degrees on the graph and drawing a vertical line upwards and seeing which fuzzy sets it intersects with and therefore determining the membership function values for the fuzzy input. It can be sees completed on the graph above and the fuzzy membership function is shown below:

$$Temp' = \frac{0.75}{Mild} + \frac{0.5}{Warm}$$

2.2 The Fuzzy Inference

Now, let's turn the fuzzy inputs which generated in the first step into fuzzy outputs using the center of gravity method. To complete this step, a matrix of the rules that relate the two inputs to one another must be created. Assume that the fuzzy input being wind speed, with four different levels: Low, Medium, High, Hurricane, and an output of how much precipitation the area in question will receive with levels: Low, Medium, Excessive, Flood-Level.

$$Wind\ Speed' = \frac{0.25}{Medium} + \frac{0.75}{High}$$

From these inputs and outputs, matrix can be created If the Center of Gravity method has been created, and matrix can be used to generate a fuzzy, linguistic output. See Table 1.
From the Center of Gravity Method, membership function will be:

$$Precipitation' = \frac{0.25}{Medium} + \frac{0.75}{Excessive}$$

Now, fuzzy, linguistic output is ready to proceed to the next step.

2.3 Fuzzy Quantification

After In this step, the functions that defined for the fuzzy outputs have been used. These are most easily defined in a graphical manner. The graph for the levels of the fuzzy output is shown below.

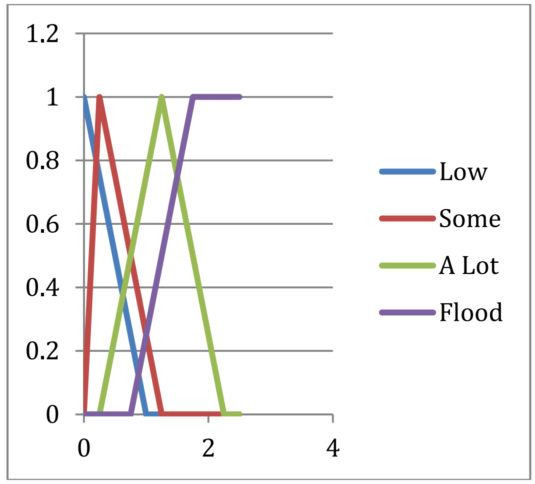

Figure 3: Representation of the different levels fuzzy outputs

Using the graph, see Figure 3, it can quantify the fuzzy output as below:

$$Precipitation'' = 0.25/0.5 + 0.75/1 + 0.75/1.5 + 0.25/2$$

2.4 Turning Fuzzy Outputs into Crisp Outputs

In the final step, linguistic fuzzy output will be used to generate a crisp, numerical output. This will be done with a form of weighted average. Below is an example to do so.

$$Precipitation = Round\left(\frac{0.25(0.5) + 0.75(1) + 0.75(1.5) + 0.25(2)}{0.25 + 0.75 + 0.75 + 0.25}\right)$$

$$Precipitation = Round\left(\frac{2.5}{2}\right)$$

$$Precipitation = 1''$$

From the four steps of the fuzzy inference system, it can be obtained a value of 1" of precipitation from the fuzzy linguistic inputs.
This type of fuzzy inference system is very effective in Decision Support System applications. These systems are typically designed using expert knowledge of the subject matter; which is pizza production in this case.
In the case of pizza production, there are many factors to build the system and it is very competitive to create an accurate model that encompasses all of the pertinent factors. There are many experienced pizza makers in the industry that have the expert knowledge that is required to form a fuzzy inference system. This expert knowledge is used to design the fuzzy sets that are used to power the inference system. A Decision Support System designed in this manner is commonly known as a Knowledge Driven DSS. These systems are very effective in providing

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accurate answers to the questions asked, especially when expert knowledge is used from multiple sources. Since the goal of a DSS is to provide an accurate answer to a question, which in this case is how many ovens and employees are required to produce a given number of pizzas in a given amount of time, a Mamdani Style Fuzzy Inference System is an extremely effective approach to use.

5. FUZZY IMPLEMENTATIONS

In the implementation part in this paper, fuzzy logic control will be used based on Mamdani fuzzy logic inference system. However, below are the definitions of the fuzzy relations for the inputs and outputs.

The inputs: Number of Pizza (P) and service time (T)

The outputs: Number of Ovens (O) and number of Workers (W)

The fuzzy relations or fuzzy sets can be seen in Figures 4, 5, 6, 7, 8.

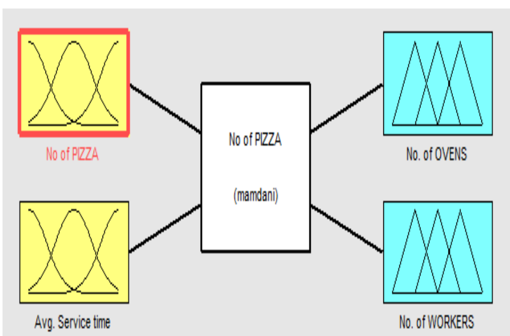

Figure 4: Fuzzy relation for inputs and outputs

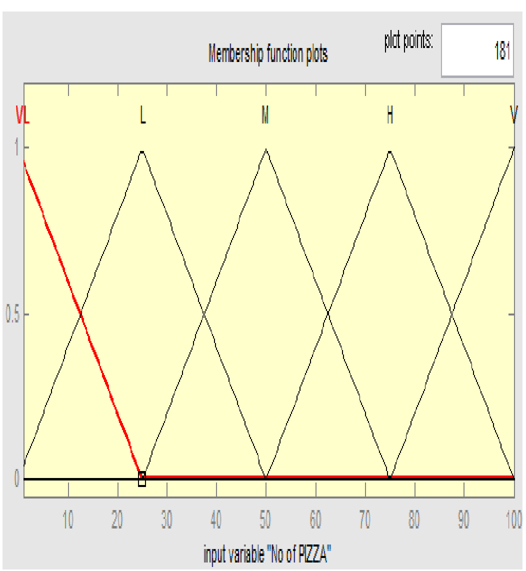

Figure 5: Fuzzy relation for input1 R_P

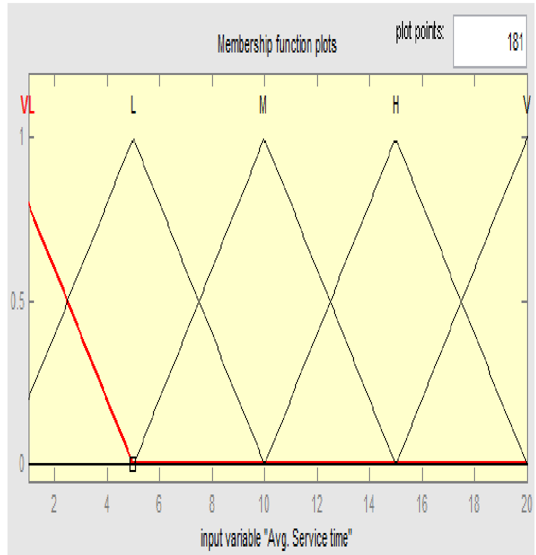

Figure 6: Fuzzy relation for input2 R_S

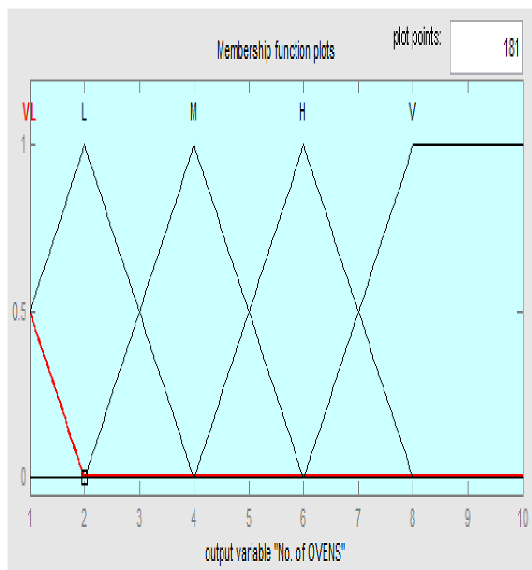

Figure 7: Fuzzy relation for output1 R_O

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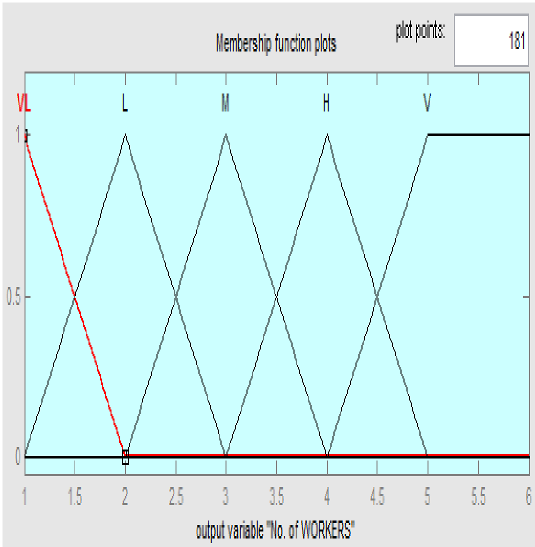

Figure 8: Fuzzy relation for output2 R_W

Triangular membership functions have been used in all the fuzzy relations (R_P, R_S, R_O, R_W), as shown above. However, to control the output, the rules should be generated; these rules will follow the logic or the heuristic knowledge.

The calculation will be applied for the following outputs:

1. Number of ovens required
2. Number of workers required for the prescribed amount of ovens.

Number of ovens and workers can be seen in Tables 2 and 3

Number of Pizzas	Service Time required for the processing					
		VL	L	M	H	VH
	VL	VL	VL	VL	VL	VL
	L	VL	L	L	L	M
	M	VL	L	M	H	H
	H	L	L	H	H	H
	VH	M	H	H	H	VH

Table 2: Output 1. – Number of Ovens

Number of Pizzas	Service Time required for the processing					
		VL	L	M	H	VH
	VL	VL	VL	VL	VL	VL
	L	VL	L	L	L	M
	M	VL	L	M	H	H
	H	L	L	H	H	H
	VH	M	H	H	H	VH

Table 3: Output 2- Number of Workers

The number of workers has a deep co-relation with the number of ovens; here it has taken the same inputs as in the output for the number of ovens and it can be concluded that the output table of the number of workers is very much dependent on the number of ovens.

Mamdani fuzzy inference system will be used to design the controller. However, Matlab toolbox will be used for this purpose.

Mamdani Fuzzy inference system consists of four steps:

1. Fuzzification of the inputs: the input is transformed from numerical value into linguistic term. the membership function for the triangular fuzzy function given before can be used to do so, substituting the right values for a_1,a_2,a_3

After this step the input will looks like N'=.6/L+.3/M+.2/H…etc.

2. Fuzzification of the output: the output is calculated from the inputs in terms of fuzzy linguistics term.

3- Transfer the fuzzy subset of the set of linguistic terms for the output to a fuzzy subset of the set of numerical values. In order to do this it needs to use fuzzy composition using the Max-Min Rule.

Expressing the max-min Rule as it relates to our specific example as the following. [15][16][17].

$$\begin{bmatrix} \mu_{M''}(y) = \underset{t \in T_M}{\text{Max}} \{\min [\mu_{M'}(t), \mu_M(t, y)]\} \\ \text{for all } y \in Y_M \end{bmatrix}$$

In the design for the first output Y_M takes all the real numbers [1,10], also The same equation has been applied for the second output with changing M into P, however the second output Y_P takes all the real numbers [1,6].

4. Defuzzification: Transforming the fuzzy set of the output in one numerical value.

$$M = \frac{\int_1^{60} Y \times \mu_{M''}\, dY}{\int_1^{60} \mu_{M''}\, dY}$$

See Figure 9 for summarize the four steps used for this control design

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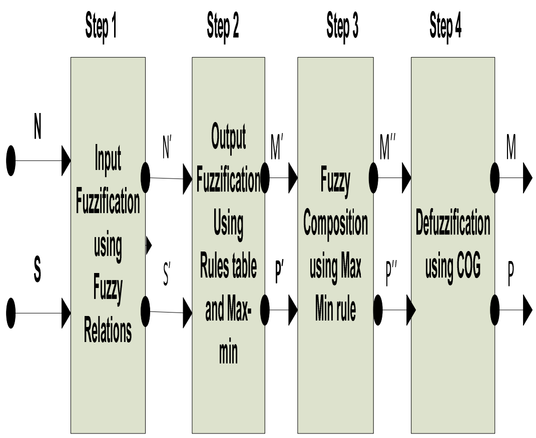

Figure 9: Design steps using Mamdani fuzzy inference system

The fuzzy inference system has been designed using Matlab software. In this section some outputs for different input setting will be shown in Figures 10 and 11:

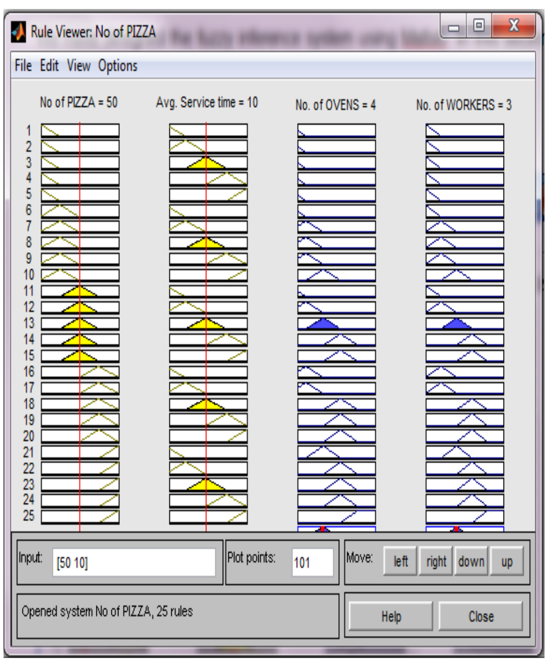

Figure 10: Example1- Outputs for different input setting

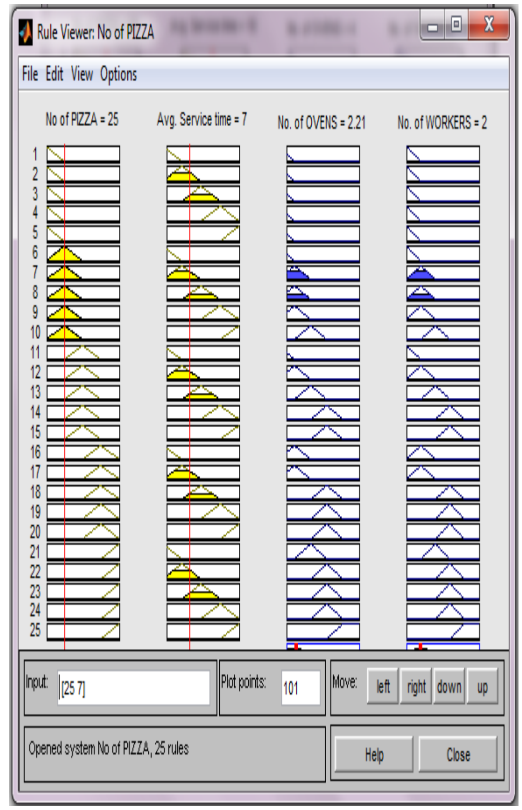

Figure 11: Example2- Outputs for different input setting

Matlab program will allow the user to adjust the two inputs continuously and the output will change corresponding to the change in the inputs.
As mentioned in the above figures when the input was 50 Pizzas and the service time was 10 minutes, then the number of ovens needed was 4 and the number of the workers was 3. From the second output screen when the number of pizzas has been changed to 25 and the service time to 7, the output to finish this job was almost 2 ovens and 2 workers.

6. CONCLUSIONS AND FUTURE WORK

In this paper, fuzzy based control system has been designed for scheduling food industry system which also can be used in different field of manufacturing and industry.

The objectives of this paper has been achieved by determining the number of the Ovens and workers needs for a certain job in food manufacturing system specially the pizza production, which will reduce the waste in money and give a better customer satisfaction. Matlab software has been used for the implementation stage and code has been developed to achieve the final results.

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For future work, fuzzy based control system could be useful for other manufacturing systems and can be applied to increase the performance of production lines. However, using fuzzy control might be helpful for complex systems comparing with other methods and applying this method for other industries would give high accuracy.

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APPENDIX

Matlab code:

```
% input 1
  c=newfis
('No of PIZZA');
  c=addvar
(c,'input','No of PIZZA',[1 100]);
  c=addmf(c,'input',1,'VL','trimf',
[-1000000000 0 25]);
  c=addmf
(c,'input',1,'L','trimf',[0 25 50]);
  c=addmf
(c,'input',1,'M','trimf',[25  50 75]);
  c=addmf
(c,'input',1,'H','trimf',[50 75 100]);
  c=addmf
(c,'input',1,'V','trimf',
[75 100 100000000]);

% input 2
  c=addvar
(c,'input','Avg. Service time',[1 20]);
  c=addmf
(c,'input',2,'VL','trimf',
[-1000000000 0 5]);
  c=addmf
(c,'input',2,'L','trimf',[0 5 10]);
  c=addmf
(c,'input',2,'M','trimf',[5  10 15]);
  c=addmf
(c,'input',2,'H','trimf',[10 15 20]);
  c=addmf
(c,'input',2,'V','trimf',
[15 20 1000000000]);

% output 1
  c=addvar
(c,'output','No. of OVENS',[1 10]);
  c=addmf
(c,'output',1,'VL','trimf',
[-10000000000 0 2]);
  c=addmf
(c,'output',1,'L','trimf',[0 2 4]);
  c=addmf
(c,'output',1,'M','trimf',[2 4 6]);
  c=addmf
(c,'output',1,'H','trimf',[4 6 8]);
  c=addmf
(c,'output',1,'V','trimf',
[6 8 10000000000]);

% output 2
  c=addvar
(c,'output','No. of WORKERS',[1 6]);
  c=addmf
(c,'output',2,'VL','trimf',
[-10000000000 1 2]);
  c=addmf
(c,'output',2,'L','trimf',[1 2 3]);
  c=addmf
(c,'output',2,'M','trimf',[2 3 4]);
  c=addmf
(c,'output',2,'H','trimf',[3 4 5]);
  c=addmf
(c,'output',2,'V','trimf',
[4 5 10000000000]);

%rules[1-No of PIZZA 2-service time  3-No. of OVENS 4-No. of WORKERS ]
 ruleList=
[
 1 1 1 1 1 1
 1 2 1 1 1 1
 1 3 1 1 1 1
 1 4 1 1 1 1
 1 5 1 1 1 1
 2 1 1 1 1 1
 2 2 2 2 1 1
 2 3 2 2 1 1
 2 4 2 2 1 1
 2 5 3 3 1 1
 3 1 1 1 1 1
 3 2 2 2 1 1
 3 3 3 3 1 1
 3 4 4 4 1 1
 3 5 4 4 1 1
 4 1 2 2 1 1
 4 2 2 2 1 1
 4 3 4 4 1 1
 4 4 4 4 1 1
 4 5 4 4 1 1
 5 1 3 3 1 1
 5 2 4 4 1 1
 5 3 4 4 1 1
 5 4 4 4 1 1
 5 5 5 5 1 1
 ];

%evaluate rules
c = addrule
(c,ruleList);
showrule(c)
ruleview(c)
```

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Matrix To Generate A Fuzzy, Linguistic Output

	Low	**0.25 Medium**	**0.75 High**	**Hurricane**
Very Cold	Low	Medium	Medium	Excessive
Cold	Low	Medium	Excessive	Flood-Level
Mild	Medium	0.25 Medium	0.75 Excessive	Flood-Level
Warm	Medium	0.25 Excessive	0.5 Excessive	Flood-Level
Hot	Medium	Excessive	Flood-Level	Flood-Level