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Implementation and Analysis of Pizza Production Process Using Fuzzy Logic Based on Multi-Factors Criteria

Mr. Pankaj Kumar[1], Dr. Rajinder Singh Sodhi[2]

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Abstract: In contemporary food companies, whether it's a quick food supplier or a fixed restaurant, the waiting time significantly influences customer satisfaction. Extensive empirical evidence supports the notion that businesses in the food industries must compete primarily based on the speed of their food service. Within the food industry community, it is widely recognized that customers highly value promptness and accord it substantial importance in selecting their preferred food service provider. In this study I am introducing a scheduling system for the food industry, employing a fuzzy-based mechanism system. It specifically focuses on determining the necessary number of devices used in industry like ovens and workers for various tasks within the food manufacturing process, with a special emphasis on pizza production. The research considers factors such as reducing finances, enhancing the satisfaction of the customers, and elevating service quality. Implementation of the system was carried out using Matlab software, involving the development of code to achieve the desired outcomes.

Keywords*: Artificial intelligence, Fuzzy logic and set, Fuzzy inference system, food industry,*

1. Introduction

The success of a food industry organization's sales volume hinges on various factors, including their internal food processes and, most notably, the waiting times of competitors in their vicinity. Even a slight enhancement in waiting times can lead to an improved market share for a company, underscoring the food organization’s ongoing endeavors to minimize the time of wait for supply services [1].

The food organization is not only a thriving sector in the United States, with a value of $170 billion in 2010 [2], but also in other global regions. A primary objective of the food organization is to both hold existing customers and attract new ones. It's worth noting that acquiring upcoming customers is substantially more expensive, costing 5 to 9 times more than retaining existing ones. Therefore, maintaining excellent customer service is paramount.

In the food organization, customers primarily associate good customer service with speed. Satisfied customers tend to return, fostering loyalty, unless an event occurs that diminishes their satisfaction and prompts them to consider alternatives. Lower prices offered by competitors can sway even contented customers to explore other options. High sales volume, as previously mentioned, is closely tied to pricing and speed. To delve deeper into this, let's define customer satisfaction as the extent to which customers are receiving more value than their costs.. Let get the efficiency of the customer increases with their loyalty, a mere 5% boost in efficiency can result in a substantial 25-85% profit increase. Considering that retaining customers is more cost-effective than acquiring new ones, organizations should prioritize customer retention [3].

Hwang, Gao, and Jang also highlight the competitive aspect of wait times among organizations [4]. Restaurants, in particular, carefully select capacity levels that won't adversely affect their revenue or quality while simultaneously minimizing costs. Striking the right balance between service quality and cost minimization is crucial, not only in quick food delivery shops but also in traditional hotels. The waiting time and the price appear to be the primary factors influencing customers' restaurant choices. Achieving the right equilibrium between operational perspectives and marketing strategies is vital. Balancing service quality enhancement with cost reduction can lead to maximum profitability [4]. Given the increasing complexity of these balancing decisions, the fuzzy theory can offer valuable insights [5].

2. Literature Review

Jinping Niu and John Dartnall's study [6] introduces the concept of fuzzy-MRP-II, a method designed to address uncertainty and imprecision in decision-making. This technique provides decision-makers with comprehensive information, enabling them to consider all possible order scenarios.

Sanjoy Petrovic and Caroly Fayad's research [7] focuses on balancing the load for various heavy work (done by machine) with the use of job scheduling mechanism that

[1]Research Scholar, Department of Computer Science and Engineering, Om Sterling Global University, Hisar, Haryana-125001, pankaj.john11@gmail.com
[2]Associate Professor, Department of Computer Science and Engineering, Om Sterling Global University, Hisar, Haryana-125001, rajindersingh@osgu.ac.in

allocates work and divides them into all other similar machines. The primary objectives are to reduce total work time and enhance machine utilization.

Ripon Kumar Chakraborety et al. [8] explore an collaborative genetic algorithm based on a fuzzy, an approach to solving aggregate production planning for two products and two periods. This approach addresses various managerial challenges, including imprecise demands and variable manufacturing costs, by applying an algorithm based on inimitable genetic constraints to solve non deterministic polynomial problems.

In Manish's paper [9], the focus is on washing machines, which are commonplace in Indian households and highly valued as utility items. The paper proposes a fuzzy logic control system for regulating washing times for different types of clothes. This method relies on fuzzy arithmetic, considering imprecise sensor inputs to determine discrete washing times, offering practical automation possibilities for washing machines.

Paramot Srinol, Abrahim Shayan, and Fatmaeh Ghotb's research [10] presents a fuzzy-based scheduling model for addressing the problem in the parts routing. This design selects the best another route through multi-measures scheduling using the principles of fuzzy logic.

Ziaul Hassan Serneabat et al. research [11] focuses on simulating Flexible Manufacturing Systems (FMS). The model prioritizes tasks and selects optimal routes through multi-criteria scheduling, employing fuzzy logic principles and rule-based approaches to sequence jobs efficiently.

Dusan Teodornic's study [12] The paper explores classification techniques and examines outcomes obtained through the utilization of fuzzy logic in modeling intricate traffic and transportation processes. The Fuzzy logic demonstrates promise as a mathematical approach for modeling systems characterized by ambiguity, subjectivity, imprecision, and uncertainty.

Based on prior studies, it is clear that the application of fuzzy logic-based scheduling system in the food organization has been limited thus far. This paper aims to introduce a distinctive technique that holds the potential to produce more accurate outcomes compared to previous research efforts.

This paper specifically concentrates on the pizza production industry and reduces waste, enhances customer satisfaction, and improves service quality by using a fuzzy-based control system. This study aims to define the question by implementing a fuzzy-based control system using Matlab software to find the optimal number of workers and ovens needed for various scenarios. Waste reduction results from efficiently scheduling only the necessary workers and ovens. Shorter wait times lead to improved customer satisfaction, and the overall service quality is enhanced.

3. Fuzzy Logic and Set

In the year 1965, Zadeh introduced Fuzzy sets to manipulate or represent the data and the information possessed in the non-analytical uncertainties.

Fuzzy logic was specifically developed to characterize uncertainty mathematically and provide dignified apparatuses for addressing the inherent imprecision in such problems. However, fuzzy logic predates the formalization of fuzzy sets by quite some time.

Several fundamental aspects of fuzzy logic are as follows:

1. In fuzzy logic, precise reasoning is viewed as a particular kind of approximation reasoning.
2. In fuzzy logic, everything is a question of degree.
3. The concept of fuzzy knowledge is understood as a collection of flexible or equivalent fuzzy restrictions on diverse variables.
4. The steps of propagating flexible restrictions are referred to as implications.
5. 5. Any logical system can benefit from fuzzy logic.

Two primary characteristics distinguish fuzzy systems, making them superior to traditional sets. The two different notations samples of crisp sets are illustrated below:

- Fuzzy systems find their niche in uncertain or approximate reasoning, especially when dealing with systems that are challenging to formulate mathematically.
- Fuzzy logic facilitates decision-making by accommodating estimated values in situations characterized by incomplete or uncertain information.

To comprehend the paper's implementation in the context of the pizza restaurant, it is crucial to grasp the fundamentals of fuzzy sets and fuzzy logic. This segment will elucidate both fuzzy set theories and crisp and furnish a few fuzzy sets, in addition to an illustration of a fuzzy inference system.

Given that the implementation will involve a fuzzy inference system, the forthcoming section's detailed example will aid in grasping the concept.

These words, entities, numbers, letters and similar elements included a crisp set. It may involve a random variety of these components or may be defined according to a rule defined by the individual as a whole. Below, we can achieve the crisp sets representation in two different notations:

$$P = \{ pk, kp, dk, ds, dj \}$$
$$C = \{ i \mid 1 \le i \le 5 \}$$

Whereas a crisp set of people is denoted by Set P and C is denoted by numbers between 1 and 5, inclusive. A different circumstance of a fuzzy set is known as crisp set.

In any language usage or calculation, if a degree of uncertainties is available then it can be used as Fuzzy. Identifying situations where fuzzy sets are applicable is straightforward; they often involve vague terms like "cold", "hot", "short," "tall", "thin" or "fat". The inherent ambiguity found in spoken language underscores the necessity of employing fuzzy inference systems and fuzzy sets.

Let's describe a fuzzy set of all tall people in a set, if familiarity'. Let's describe the heights for all tall people like pk (6'3"), kp (5'6"), dk (5'3"), ds (5'2"), and dj (5'9"), in a fuzzy set which is described below:

Assume S = tall people set of all

$$S = \frac{0.5}{pk} + \frac{0.7}{kp} + \frac{0.5}{dk} + \frac{0.4}{ds} + \frac{1}{dj}$$

This is known as the membership grade allocated to each member within a fuzzy set and the difference between a crisp set and a fuzzy set.

The value in between 0 and 1 will be used as membership grades. Each data in the given set will describe the level of membership. The above values are demonstrated based on the people's knowledge of all and the opinions formed about them.

Numerous fuzzy terms exist in the English language and these terms can all be subjected to fuzzy principles, allowing for a more nuanced description when referring to someone as tall or short, for instance. Take the earlier example: Bill stands at five feet, seven inches tall. This description doesn't categorize him as unequivocally tall; rather, it implies a degree of tallness, in this case, 0.8. This finding shows that a set of crisp, where all membership values equal 1, indicates a separate scenario within a fuzzy set.

When it comes to graphically defining fuzzy sets, this understanding becomes crucial, particularly in the context of designing Fuzzy Inference Systems. For instance, consider defining multiple age sets spanning the range of 0-100 years old, as illustrated in Fig 1.

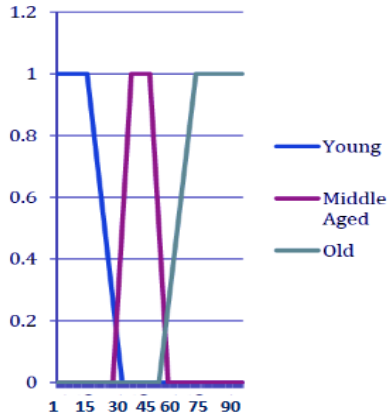


Fig 1: In Graphical notation fuzzy set

As per above Figure 1, the graphical representation of the 3 sets - Old, Middle, and Young aged- spans a 100-year range. In this visual representation, when the lines on the diagram maintain a horizontal position at 1, it indicates that X-axis possesses the data point with full membership in the corresponding set of fuzzy. Conversely, when the slope ranging from zero to one line exhibit , membership grades within the fuzzy set will signify this data point. This graphical method is the most commonly used approach for illustrating fuzzy sets due to its clarity and its significant utility in crafting fuzzy inference systems, the implementation section of this paper demonstrates.

4. Fuzzy Logic and Fuzzy Set

The fuzzy set theory is used by fuzzy inference systems to convert hazy inputs into accurate results. These systems excel at accommodating the inherently uncertain nature of our world. Given the increasing ambiguity in contemporary inputs, these systems offer a high degree of accuracy and appeal. Their main goal is to take advantage of the ambiguity that exists in many facets of life and turn it into an insightful answer to a system's issue.

Traditionally, systems like washing machines operate with a set of well-defined inputs and produce corresponding outputs. However, when a fuzzy inference system is integrated, it allows for a much broader range of input levels and output possibilities to be analyzed. This enhanced flexibility can significantly improve a system's efficiency and the accuracy of its calculations.

Describing a fuzzy inference system can be simplified into four distinct steps: Fuzzification of Inputs, the Fuzzy Inference Process, Fuzzy Quantification, and the Conversion of Fuzzy Outputs into Precise Outputs.

5. Inputs Fuzzification

In the initial process of Fuzzification, we consider the input as linguistic, numerical, or crisp & transform these inputs into linguistic, fuzzy. This phase relies heavily on well-defined fuzzy set descriptions, which play a pivotal role. For every input, a comprehensive set of fuzzy sets is established across the entire spectrum of potential inputs, typically depicted graphically. Each input can be categorized into multiple levels, ranging from two to several, each corresponding to various system outputs. To illustrate, if we have a numeric crisp input of temperature, say 60 degrees in Fahrenheit, and we process to change it into an input of fuzzy multi lingual, hence we delineate sets in fuzzy, representing different temperature ranges and portray them graphically in fig 2.

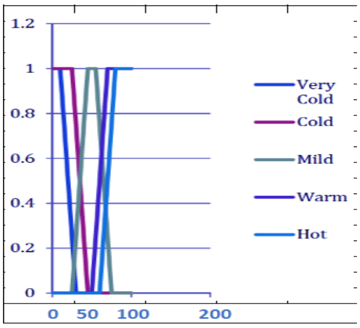


Fig 2: Different levels of temperature representation

The graph depicted above illustrates various temperature levels, each associated with fuzzy linguistic terms representing the inputs. When we have a specific temperature, such as 40 degrees Fahrenheit, we can convert it into a fuzzy input using a straightforward process. This involves intersecting the vertical line upward by placing the value of 40 degrees on the graph, By doing this, we determine the values of the function of membership for input fuzzy. The entire process will be seen in the above graph and resulting function of fuzzy membership is shown below:

$$Heat' = \frac{0.5}{hot} + \frac{0.75}{normal}$$

6. The Inference Fuzzy

Now, convert into fuzzy output using the center of gravity method for all produced fuzzy input in the initial process. To achieve this, we need to establish a series of rules that define the relationship between two inputs. For example, let's consider a scenario where the input in fuzzy represents the speed of air, classified into four levels at different stages like: low, moderate, high, and extreme. The corresponds output to the amount of rainfall occurring in the area, which is classified into levels: low, moderate, extreme and flood level.

$$WindSpeed' = \frac{0.76}{extreme} + \frac{0.24}{moderate}$$

Based on the above outputs and inputs, for the Center of Gravity method, we can create a matrix, which can then be utilized to create an output as fuzzy linguistic. Please refer to Tabular representation 1.

Utilizing the Gravity Method for the center, we will calculate membership derived as follows:

$$precipation' = \frac{0.24}{moderate} + \frac{0.76}{extreme}$$

Now, the output of fuzzy linguistic will processed in the next step.

7. Quantification Fuzzy

In this step, the function defined for fuzzy output is used. These functions are usually best represented graphically. The graph below shows the spread output level.

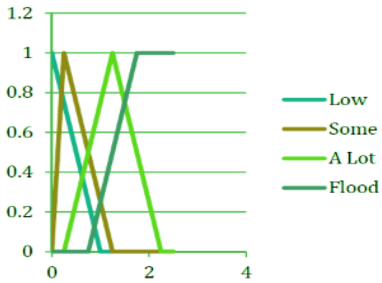


Fig 3. The output of fuzzy at different levels

By using the above graph, see Figure 3, the fuzzy output can be quantified in below:

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

8. Crisp Outputs in Turning Fuzzy

In the last step, a crisp and numeric output will be generated and used for the linguistic fuzzy output. With help of a form of average weighted it will be calculated. The example is shown below:

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

$$precipation = Round\left(\frac{2.5}{2}\right) = 1$$

In this fuzzy inference, we have four steps and it is possible to obtain a degradation value of 1 based on the fuzzy multi-lingual input. In any decision support system (DSS) application proves to be very effective in the fuzzy estimation system. Typically, such systems are developed using smart knowledge in a specific field, which in this case relates to pizza production.

Many factors come into play when creating a system in pizza production. Building an accurate model that includes all relevant variables is a competitive endeavor. Fortunately, there are several pizza makers in the world who have the smart knowledge needed to build the solid fuzzy estimation process. Such experiences are useful for designing the sets of fuzzy which drive the interpretation system.

DSS were created in a manner that is generally recognized as being knowledge-based. Such a method excels at giving approximations for solutions to queries, particularly when it is based on professional knowledge from many sources. Since the purpose of DSS is to provide precise answers to questions, such as determining the oven numbers and staff numbers needed to prepare a specific quantity of pizzas within a certain period, This system exceptionally effective.

9. Implementations Fuzzy

In this research article, fuzzy logic control will be implemented. Below you will find fuzzy relations definitions for both input & output.

In input: NP represents the Pizza numbers and ST represents the work time to deliver

In output: NO represents the Oven numbers and WS represents the Worker numbers

The fuzzy sets or fuzzy relations are shown in the Figures 4, 5, 6, 7, 8.

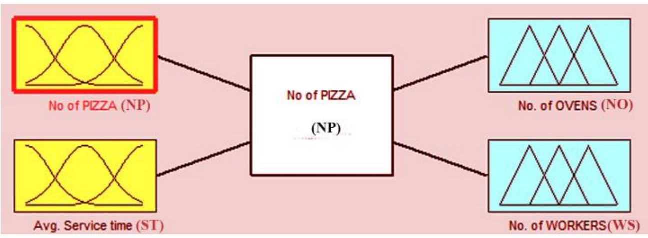


Fig 4: input and output of fuzzy relation

Fig 5: input1 RST of fuzzy relation

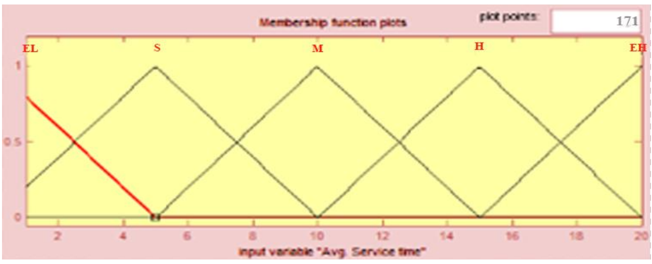


Fig 6: input1 R of fuzzy relation

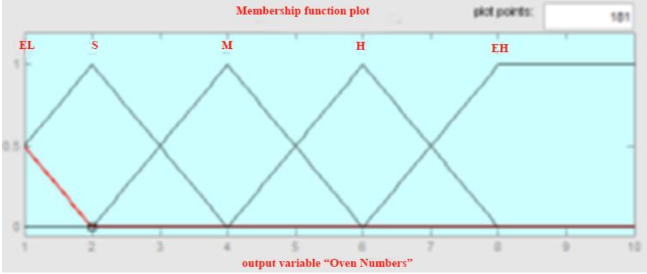


Fig 7: input1 RNO of fuzzy relation

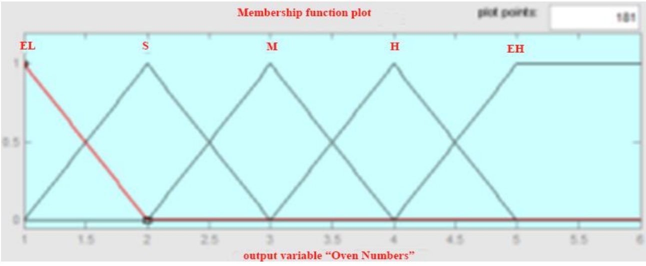


Fig 8: input1 RWS of fuzzy relation

In all fuzzy relations like RNP, RST, RNO, RWS Triangular membership functions are used. The output rules will be produced based on control of the heuristic knowledge. For the following output the calculation to be applied:

1. Calculate required total Number of ovens

2. For the number of the prescribed ovens required on workers number.

The workers number is shown in below Tabular representations 2 and 3.

Numbers of Pizza	The processing time required for Service Time					
		EL	S	M	H	EH
	S	S	S	S	S	S
	EL	M	M	S	EH	M
	H	S	S	H	H	H
	S	H	S	H	H	H
	EH	H	M	S	S	EL

Table 2: – For the Ovens Number Output

Numbers of Pizza	The processing time required for Service Time					
		EH	S	M	H	EH
	S	S	S	S	S	S
	EL	M	M	S	EH	M
	H	S	S	H	H	H

	S	H	L	H	H	H
	EH	H	M	S	S	EH

Table 2: –for the workers Number Output

The workers number and the ovens number are closely interconnected. In this context, the similar inputs used for outputs regarding the ovens number imply a significant dependence of the output for the number of workers on the number of ovens.

To design the controller, the Matlab application software is used do develop a fuzzy inference system. There are four important steps involved in the Fuzzy inference system. Those are:

1. Inputs Fuzzification: in this input will be converted from arithmetic values into language terms. In the the triangular fuzzy function the membership function is utilized for this purpose by substituting the appropriate values for s1, s2, s3. After this step, the input will be represented as T' = 0.6/L + 0.3/M + 0.2/E, and so forth.
2. Output Fuzzification: From the input, output is calculated in terms of fuzzy linguistic terms.
3. Transferring Fuzzy Subsets: In this stage, a collection of linguistic phrases representing the output's fuzzy subset are transformed into a set of numerical values.
4. The Max-Min Rule is used in fuzzy composition to accomplish this. The following is a breakdown of how to express the Max-Min Rule in the context of our particular scenario [15][16][17].

The control design is displayed in the fig 9 in four processes.

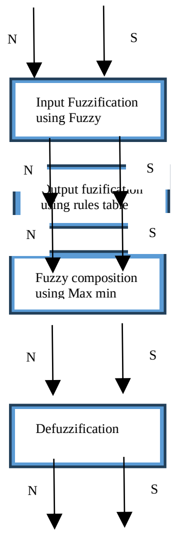
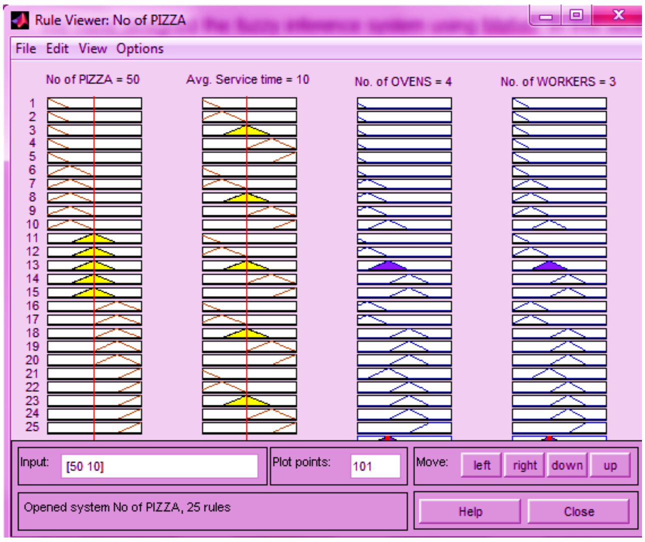


Fig 9: fuzzy inference system design steps

This design has created by Matlab application software for fuzzy inference system. Here few outputs for several input setting has displayed in the below Figures 10.



10. Future work & Conclusion

In this paper, we introduce a system in which fuzzy designs for scheduling within the food organization, with the potential for application in various manufacturing and industrial domains. The primary objectives of this research have been successfully accomplished by determining the required oven numbers and workers numbers on specific tasks within food manufacturing unit, particularly in the context of pizza production. This approach not only reduces financial waste but also enhances customer satisfaction. The implementation phase of this study leveraged Matlab software, where code was developed to attain the desired outcomes.

For future endeavors, the utilization of fuzzy-based control systems holds promise in improving the performance of production lines across different manufacturing sectors using an intuitionistic fuzzy set. The complexity of such systems makes fuzzy control an advantageous approach compared to other methods. Extending the application of this paper to diverse industries has the potential to yield high levels of precision and efficiency.

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Author contributions

Mr. Pankaj Kumar[1]: Conceptualization, Methodology, Software, Field study, Writing-Original draft preparation, Software, Validation., Field study **Dr. Rajinder Singh Sodhi[2]:** Reviewing, Data curation and Investigation.

Conflicts of interest

The authors declare no conflicts of interest.

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