An Overview of Fuzzy Inference Algorithms

Omid Feizollahzade

Department of Electrical Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran, omidfeizollahzade@gmail.com

Abstract

A fuzzy inference system is a mapping of input-to-output space implemented using membership functions and fuzzy rules. Intelligent, control and decision making is one of the most important fuzzy inference algorithms. Mamdani and Sugno fuzzy inference algorithms are examined and their advantages and disadvantages are stated.

Keywords: Fuzzy logic, fuzzy inference system, Mamdani inference algorithm, Takagi Sugeno inference algorithm
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1. Introduction

The real world is complex, and this complexity stems entirely from its uncertainty. Man, because of his power of thought, is able to comprehend ambiguities and complexities. Many real-world problems cannot be solved by the theory of classical sets. In classical set theory, either an element is a member of a set, or it is not, or it is zero, or one. The opposite point is the theory of the classical set of fuzzy theory. [1]. Fuzzy set theory is a powerful tool for dealing with uncertainty due to ambiguity. Although fuzzy systems describe uncertain phenomena, fuzzy theory itself is an accurate theory [2]. Familiarity with fuzzy inference system, their advantages and disadvantages can be effective in designing fuzzy expert systems and output estimated by the system.

2. Fuzzy logic

Fuzzy logic was introduced by Prof. Lotfizadeh in a treatise called "Fuzzy Sets Information and Control" [3] in 1691 and in the 1691 decade it was developed and put into practice, the biggest events of this decade of control production Fuzzy logic was for real systems. Fuzzy logic is one of the most successful applications of fuzzy sets in which the variables are linguistic rather than numerical. Fuzzy logic is opposed to binary or Aristotelian logic, which says yes to everything in only two ways. No, he sees black and white, zero and one, this logic changes in the interval between zero and one. [4]

Among the advantages of fuzzy logic are the following:
Fuzzy logic is close to human thinking and logic.

- Programs designed with fuzzy logic are fast and inexpensive.
- Can be easily modeled.
- Widely used in decision control and forecasting systems.
- Used to describe uncertain phenomena.
- Disadvantages of fuzzy logic include the following:
- The rules of fuzzy logic are determined by expert experience.
- A system with fuzzy logic is difficult to analyze, meaning it cannot be estimated before the reaction.
- Functions are identified by trial and error that are time consuming.

3. Fuzzy inference systems

Figure 1 shows the architecture of the fuzzy inference system. As can be seen, the fuzzy inference system is generally made up of the following components:

- Fuzzy maker
- Fuzzy inference engine
- Defuzzy maker

The process of converting explicit variables to linguistic variables is called fuzzy. The inference engine evaluates and inferred the rules using

inference algorithms, and after aggregating the output rules by the storage unit, it becomes an explicit or numerical value [1]. A variety of decomposition methods is included:

- The Area center of gravity $(COA)^2$
- Nimsaz area$(BOA)^3$
- The smallest maximum$(SOM)^4$
- Maximum $(LOM)^5$
- Mean maximum $(MOM)^6$
- Weight average$(WA)^7$،
- Total weight$(WS)^8$

COA and WA have the most applications in general [9].

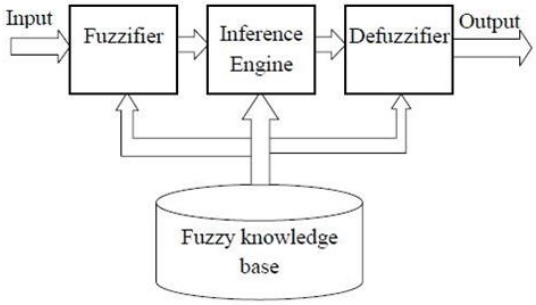

Fig. 1. Fuzzy inference system

The use of fuzzy systems has expanded day by day and its application in various fields such as fuzzy expert systems [9] Decision support systems [8] Estimation of potential project cost using risk analysis [6], control systems, image processing, Communications, trade, medicine, military and training, robots, power system and nuclear reactor, automotive engineering were used. One of the first products to use fuzzy systems was the washing machine introduced by Matsu Shita in Japan in 1661, in which a fuzzy system was used to automatically adjust the appropriate number of cycles, depending on the type, amount of dirt and volume of clothing. used. Sendai metro fuzzy control system is another application of fuzzy system that considers four parameters, safety, passenger comfort, reaching the desired speed, and braking accuracy at the same time.

Today, the fuzzy system is also used in digital image stabilization in cameras and in areas such as engine, transmission, braking in cars, automatic gear changes, water purification.

4. Types of fuzzy inference algorithms

A) Mamdani inference algorithm

The Mamdani inference system was proposed by Mamdani and Asilian in 1691. Due to the visual nature and interpretation of the rules, these systems can be widely used in decision support systems. They also have high expressive power and can be both multi-input and multi-output $(MIMO)^{11}$and multi-input and one. Output $(MISO)^{12}$ is implemented. The general diagram of Mamdani fuzzy inference system is shown in Figure 2. Mamdani inference system uses fuzzy sets as the result of the law and the output of each law is nonlinear and fuzzy. It is also different from other inference systems in terms of decomposition method. Disposal methods in Mamdani inference system are BOA, COA, SOM, LOM, MOM [10], [5].

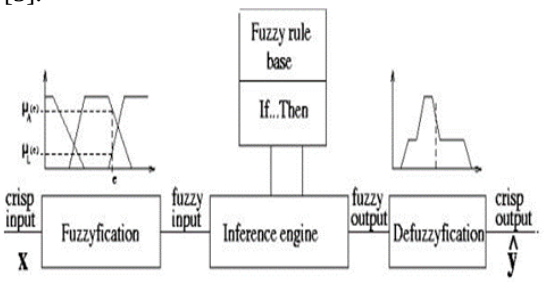

Fig. 2. General diagram of a Mamdani fuzzy inference system

The general form of the rules in the Mamdani system is shown in Figure 3. The results of each rule are denoted by the values of c1 and c2. It is obtained numerically.

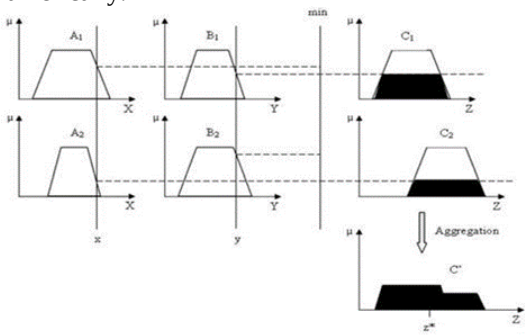

Fig. 3. General form of law enforcement in Mamdani inference system

B) Takagi Sugeno inference algorithm

The Takagi Sugeno inference system was proposed by Takagi and Mishio Sugno in 2002 to develop a systematic approach to the production of fuzzy rules. This inference system is mostly used in control systems and in areas that require mathematical calculations. Figure 4 shows a diagram of a Sugeno inference system.

The output of the Sugeno inference algorithm uses a first-order polynomial of input variables as a result of the law, and the decomposition method in it is of the WA, WS decomposition methods. Implement the MIMO form [11], [5].

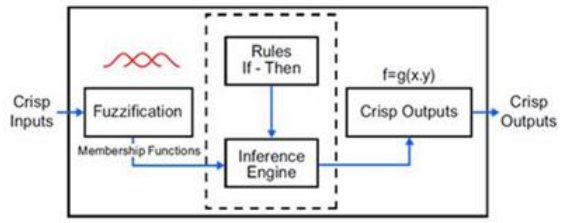

Fig. 4. Diagram of a Sugeno inference system

An overview of rule evaluation using the Sugeno method is shown in Figure 5. As it turns out, the results of the law in Sugeno's inference system are explicit and linear.

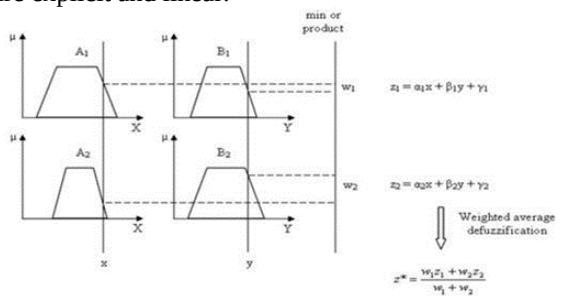

Fig. 5. An overview of the implementation of the rules in the Sugeno inference system

5. Comparison of Mamdani and Sugno fuzzy inference algorithms

Table (1) shows a comparison between Mamdani and Sugno inference algorithms [6], [12]. Sugeno inference algorithm is mostly used in control systems and systems that require mathematical calculations, but in Mamdani inference algorithm logical results are expressed with a relatively simple structure and are mostly used in decision support systems and systems that can interpret the rules. The output of the Mamdani inference algorithm is nonlinear and fuzzy, but the output of the Sugno inference system is linear[13] And it is computationally more efficient than Mamdani, because the process of defragmentation requires less computational time, but only works better for linear analysis of MISO control systems [14], [11].

6. Conclusion

Today, fuzzy applications in the design of various uncertain systems indicate the high performance and rapid growth of these systems. Although the performance of fuzzy inference algorithms are similar, but observing their differences in the design of fuzzy systems can be effective in system output. Sugeno inference algorithm is used in the design of sensitive and control systems due to its high accuracy and flexibility, but Mamdani systems are mostly used in human systems due to their interpretive nature and fuzzy output of rules.

Table.1.
Comparison between Mamdani and Sugno fuzzy inference algorithms

Mamdani	***Sugeno***
The output of the rules is a function of membership	The output of the rules is not a function of membership
The output is distributed	Its output is not distributed and The result is a mathematical combination of power
The output level is not continuous	The output level is continues
In the form of MIMO, MISO	Only in the form of MISO
Expressive power and interpretation of laws	Low interpretive power
Type of defuzzy COA, SOM, LOM, MOM, BOA	defuzzy type WA, WS
Low flexibility in design system	High flexibility in design system

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