Comparative Analysis of Membership Function on Mamdani Fuzzy Inference System for Decision Making

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Abstract. Membership function is a curve that shows mapping the input data points into the value or degree of membership which has an interval between 0 and 1. One way to get membership value is through a function approach. There are some membership functions can be used on mamdani fuzzy inference system. They are triangular, trapezoid, singleton, sigmoid, Gaussian, etc. In this paper only discuss three membership functions, are triangular, trapezoid and Gaussian. These three membership functions will be compared to see the difference in parameter values and results obtained. For case study in this paper is admission of students at popular school. There are three variable can be used, they are students’ report, IQ score and parents’ income. Which will then be created if-then rules.

1. Introduction

Fuzzy logic is a methodology of problem-solving control systems, suitable for implementation on systems, from simple systems, small systems, embedded systems, PC networks, multi-channel or workstations based data acquisition, and control systems. This methodology can be applied to hardware, software, or a combination of both. In a more specific sense, Fuzzy logic is an extension of multivalued logic whose objective is approximate reasoning rather than exact solution [1].

Unlike traditional Crisp Logic, such as Binary Logic where variables may only take on truth values true and false represented by 1 and 0 respectively, the variables in fuzzy logic may have a truth value that ranges in degree between 0 and 1. Instead of describing absolute yes or no, the truth value, or membership in fuzzy logic explains a matter of degree. 0 shows completely false, while 1 expresses completely true, and any value within the range indicates the degree of true. Furthermore, the concept of membership in fuzzy logic is close to human words and intuition, so the number and variety of applications of fuzzy logic have increased significantly in recent years [4].

Membership function is a graph which represents the magnitude of the degree of membership of each input variable that is in the interval between 0 and 1. The degree of membership of a variable x is denoted by the symbol \( \mu(x) \). The rules use the value of membership as a weighting factor to determine its effect when making inferences to draw conclusions [1].

In this paper will only discuss the comparison of three membership functions so that it can determine decisions in the determination of students accepted or rejected at favorite schools. To get
the output value is done the main approach of fuzzy by taking the input variable consisting of the if-then rule. The If-Then rules are expressed directly by human words, and each of the word is regarded as a fuzzy set.

2. Theory
A. Logical Operation
Because the standard binary logic is a special case of fuzzy logic where the membership values are always 1 (completely true) or 0 (completely false), fuzzy logic must hold the consistent logical operations as the standard logical operations. The most foundational logical operations are AND, OR and NOT. Unlike standard logical operation, the operands A and B are membership values within the interval [0, 1]. In fuzzy logical operations, logical AND is expressed by function min, so the statement A AND B is equal to min (A, B). Logical OR is defined by function max, thus A OR B becomes equivalent to max (A, B). And logical NOT makes operation NOT A become the operation 1 – A [2][3].

B. Fuzzy Inference and Mamdani-Type Fuzzy Inference
Fuzzy Inferece System has 3 basic structure that is Rule Base which is used to do selection to fuzzy rule. The database, this component is used to define the membership value of the fuzzy set and the reasoning mechanism used to generate the output of the operations performed on the fuzzy set. Basically the input given on the fuzzy inference system is in the form of a firm set and will produce the output of a fuzzy set depending on the situation where the fuzzy inference system is used [1].

Generally, there are three types of fuzzy inference system, they are Mamdani, Sugeno, and Tsukamoto. All of these three methods can be divided into two processes. The first process is fuzzifying the crisp values of input variables into membership values according to appropriate fuzzy sets, and these three methods are exactly the same in this process[5]. While the differences occur in the second process when the results of all rules are integrated into a single precise value for output. Mamdani is often known as the Max-min method. This method was introduced by Ebrahim Mamdani in 1975. To get the output required 4 stages are the establishment of the fuzzy set: definition of the fuzzy set and the determination of the degree of membership of the input crisp on a fuzzy set, application function implication: evaluation of rules fuzzy to generate output from each rule, composition rule: aggregation or combination of outputs of all rules, defuzzification: calculation of output crisp. The reasoning with the Sugeno method is almost the same as the Mamdani method, only the output system is not a fuzzy set, but rather a constant or a linear equation[6]. Then a weighting mechanism is implemented to work out the final crisp output [2].

3. Result and Discussion
In this section will be explained result of comparison three membership functions are triangular, trapezoid, and Gaussian. Samples of data taken from a school by input student’s report score, IQ score and parents’ income in order to get a decision whether the student is accepted or rejected at the popular school. Only three data samples of students are used to see the comparison parameters of each membership functions. The following is result of three membership functions use matlab:
A. Triangular Variable of Students’ Report
   Triangular variable of students’s report has 3 parameters, are low, middle and high.
   - low parameter : 55, 55, 70
   - middle parameter : 60, 77, 95
   - high parameter : 85, 100,100
B. Triangular Variable of IQ
Triangular variable of IQ has 3 parameters, are low, middle and high.
- low parameter : 90, 90, 100
- middle parameter : 90, 110, 130
- high parameter : 120, 130, 130

C. Triangular Variable of Income
Triangular variable of Income has 3 parameters, are low, middle and high.
- low parameter : 0, 1000000, 4000000
- middle parameter : 2000000, 5500000, 9000000
- high parameter : 7000000, 10000000, 10000000

The result use matlab as follows:

Output Triangular Curve
The output of the triangle curve in the form of rejection and acceptance of prospective students in popular schools by including data that become the reference assessment such as report score, IQ and income parents. Data input is as follows:

| Report | IQ  | Income   |
|--------|-----|----------|
| 81.65  | 90  | 5000000  |
| 90.45  | 120 | 2000000  |
| 74.91  | 90  | 10000000 |

Result of data input use matlab as follows:
D. Trapezoid Variable of Students’ Report  
Trapezoid variable of students’ report has 3 parameters, are low, middle and high.  
- low parameter : 55, 55, 56.5, 68.5  
- middle parameter : 61.7, 75.3, 78.8, 93.2  
- high parameter : 86.5, 98.5, 100, 100  

E. Trapezoid Variable of IQ  
Trapezoid variable of IQ has 3 parameters, are low, middle and high.  
- low parameter : 90, 90, 91, 99  
- middle parameter : 92.11, 108.1, 112.1, 128.1  
- high parameter : 121, 129, 130, 130  

F. Trapezoid Variable of Income  
Trapezoid variable of Income has 3 parameters, are low, middle and high.  
- low parameter : 100000, 900000, 1300000, 3700000  
- middle parameter : 2350000, 5150000, 5850000, 8650000  
- high parameter : 7300000, 9700000, 10000000, 10000000  

The result use matlab as follows:

Output Trapezoid Curve  
The output of the trapezoid curve in the form of rejection and acceptance of prospective students in popular schools by including data that become the reference assessment such as report score, IQ and income parents. Data input is as follows:

| Report | IQ  | Income  |
|--------|-----|---------|
| 81.65  | 90  | 5000000 |
| 90.45  | 120 | 2000000 |
| 74.91  | 90  | 10000000|

Result of data input use matlab as follows:
G. Gaussian Variable of Students’ Report
Gaussian variable of students’ report has 3 parameters, are low, middle and high.
- low parameter : 7.644, 55
- middle parameter : 7.644, 77
- high parameter : 7.644, 100

H. Gaussian Variable of IQ
Gaussian variable of IQ has 3 parameters, are low, middle and high.
- low parameter : 7.644, 90
- middle parameter : 7.644, 110
- high parameter : 7.644, 130

I. Gaussian Variable of Income
Gaussian variable of Income has 3 parameters, are low, middle and high.
- low parameter : 1.147000, 1000000
- middle parameter : 1.147000, 5000000
- high parameter : 1.147000, 10000000

The result use matlab as follows:

![Figure 9. Report](image1)
![Figure 10. IQ](image2)
![Figure 11. Income](image3)

Output Gaussian Curve

The output of the gaussian curve in the form of rejection and acceptance of prospective students in popular schools by including data that become the reference assessment such as report score, IQ and income parents. Data input is as follows:

| Report | IQ  | Income |
|--------|-----|--------|
| 81.65  | 90  | 5000000|
| 90.45  | 120 | 2000000|
| 74.91  | 90  | 10000000|

Result of data input use matlab as follows:

![Figure 12. Rejected and Accepted Output of Gaussian](image4)
4. Conclusion

Based on experiments conducted in this paper it can be concluded that three of membership functions are triangular, trapezoid, and Gaussian have the same result. But the parameters of them are different. For decision making case in popular school, three of membership functions are equally good. But for taking parameter values, triangular membership function is easier than trapezoid and Gaussian. So the three of membership functions have the disadvantages and advantages depending on the case study conducted.

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