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Comparison of Defuzzification Methods from a Real World Problem

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ABSTRACT

Fuzzy logic is a method to formalize the human capacity of imprecise reasoning. Fuzzy logic react how people think. It tries to make our sense of words and our decision making. As a result, it is making to human intelligent systems. There are three basic steps for fuzzy logic system i.e. Fuzzification, Rule evaluation and Defuzzification. In this paper I discuss a real life problem in which different results of same survey were presented. The survey data represent vague values in the form of fuzzy sets. To solve this problem we applied defuzzification methods to get the best result from surveys. I represent the most commonly used defuzzification methods and made comparison to choose the best one.

KEYWORDS: *Fuzzification, Defuzzification, Centroid method, weighted average method, center of sums method*

A. INTRODUCTION

With introduction of fuzzy sets by Lotfi Zadeh in 1965, it had a profound influence on the thinking about uncertainty because it challenged not only probability theory as the sole representation for uncertainty, but the very foundations upon which probability theory was based: classical binary (two-valued) logic.

Fuzzy logic is the theory of fuzzy sets, sets that calibrate vagueness. Fuzzy logic is based on the idea that all things admit of degrees. Temperature, height, speed, distance, beauty – all comes on a sliding scale.

Fuzzy Set Theory

Fuzzy logic measures the degree of correctness to which the proposition is correct. Many terms/fuzzy sets, such as 'tall,' 'rich,' 'famous' or 'full,' are valid only to a certain degree when applied to a particular individual or situation. Fuzzy logic tries to measure that degree and to allow computers to manipulate such information. Membership is a real number with a range [0, 1]. Membership functions are commonly triangular or Gaussian because ease of computation. Utility comes from overlapping membership functions – a value can belong to more than one set.

The classical example in fuzzy sets "tall men" is defined in Table I. The elements of the fuzzy set "tall men" are all men, but their degrees of membership depend on their height. Tall men are above 180cm and not tall men are below 180cm. Crisp and fuzzy sets of "tall men" are illustrated in Fig. 2 and Fig. 3.

There are three main methods or steps of fuzzy system as given in Fig. 1.

The ultimate goal of fuzzy logic is to form the theoretical foundation for reasoning about imprecise propositions; such reasoning has been referred to as approximate reasoning. Approximate reasoning is analogous to classical logic for reasoning with precise propositions and hence is an extension of classical propositional calculus that deals with partial truths. A rule-based format to represent fuzzy information: IF x is A THEN y is B, where A and B represent fuzzy propositions (sets).

Defuzzification is the conversion of a fuzzy quantity to a precise quantity. The output of a fuzzy process can be the logical union of two or more fuzzy membership functions defined on the universe of discourse of the output variable. This paper includes three sections. The first section is basics of fuzzy set theory, the second section includes different defuzzificaiton methods and the third section includes a real world problem which applies defuzzification techniques.

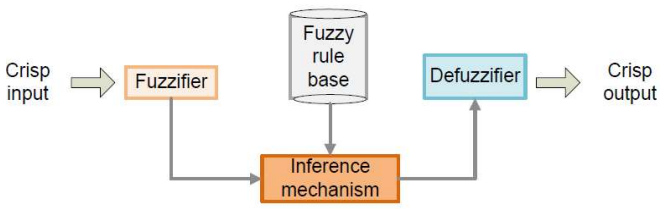

Fig. 1 Fuzzy System

Table I.

Name	Height, cm	Degree of Membership	
		Crisp	Fuzzy
Kyaw Kyaw	204	1	1.00
Zaw Zaw	199	1	0.98
Mi Mi	183	1	0.83
Maw Maw	166	0	0.15
Aye Aye	154	0	0.01
Aung Aung	151	0	0.00

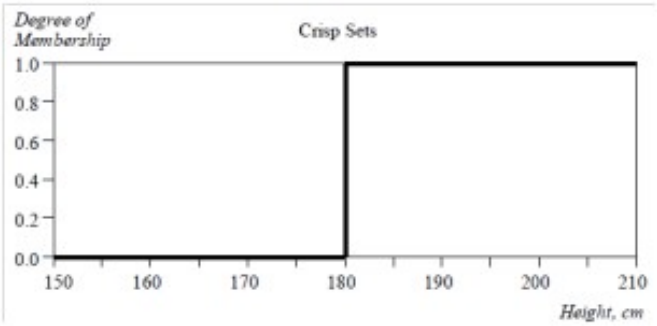

Fig. 2 Crisp set for "tall men"

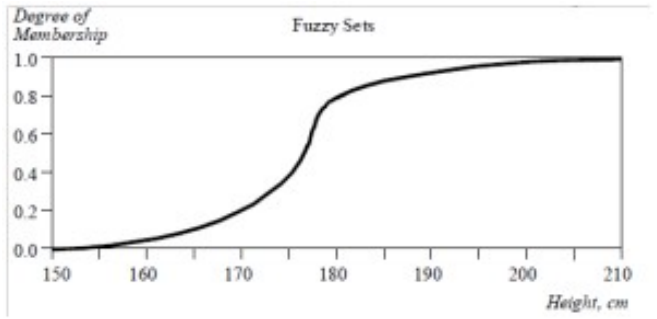

Fig. 3 Fuzzy Set for "tall men"

B. Membership Function

Membership function - A function that specifies the degree to which a given input belongs to a set.

- Degree of membership - The output is always limited to between 0 and 1.
- Membership functions are used in fuzzification and defuzzification steps.

There are six basic types of fuzzy membership functions:
Gaussian
Triangular
Trapezoidal
Sigmoid
Z-shape
S-shape

Some fuzzy membership functions are illustrated in Fig. 4 and Fig. 5.

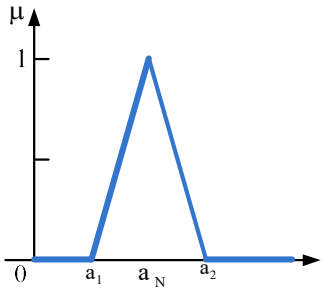

Fig. 4 Triangular Fuzzy Membership Function

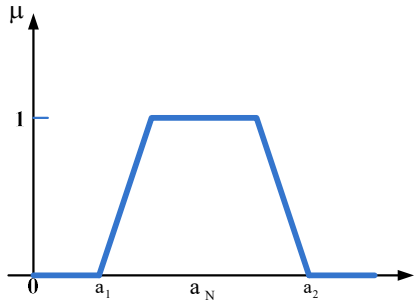

Fig. 5 Trapezoidal Fuzzy Membership Function

Features of Fuzzy Membership Function

- **Core:**

region of the universe that is characterized by complete and full membership in the set.

- **Support:**

region of the universe that is characterized by nonzero membership in the set.

- **Boundary**:

region of the universe containing elements that have a nonzero membership but not a complete membership.
These features are shown in Fig. 6.

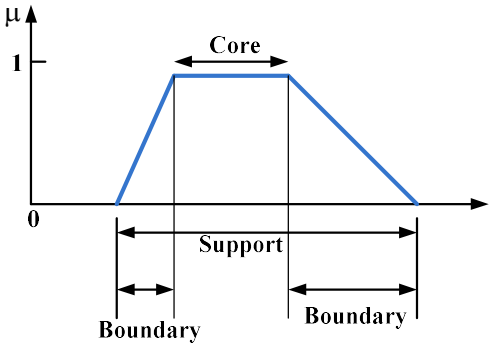

Fig. 6 Features of Fuzzy Membership Function

The simplest membership functions are formed using straight lines. These straight line membership functions have more simplicity. Let Triangular membership function as trimf and Trapezoidal membership function as trapmf.

I use Triangular membership function to represent my problem.

Triangular: Define by lower limit a and upper limit c, and lower and upper limits of its nucleus, b respectively.

$$T(x) = \begin{cases} 0 & \text{if } (x \le a) \text{ or } (x \ge c) \\ (x-a)/(b-a) & \text{if } x \in (a,b) \\ 1 & \text{if } x = b \\ (c-x)/(c-b) & \text{if } x \in (b,c) \end{cases}$$

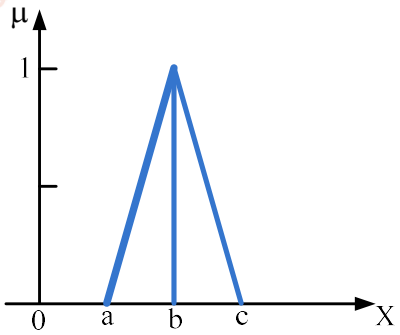

Fig. 7 Triangular Function

C. Defuzzification Methods

The last step in the fuzzy inference process is defuzzification. Fuzziness helps to evaluate the rules, but the final output of a fuzzy system has to be a crisp number. The input for the defuzzification process is the aggregate output fuzzy set and the output is a single number. There are many defuzzification methods: Centroid method, weighted average method, Center of Largest Area, Center of Sums etc.

Centroid Method:

This method is the most prevalent and physically appealing of all the defuzzification methods; it can be expressed as

$$z^* = \frac{\int \mu_C(z).z\,dz}{\int \mu_C(z)dz}$$

z^* is the defuzzzified value and $\int$ denotes an algebraic integration.

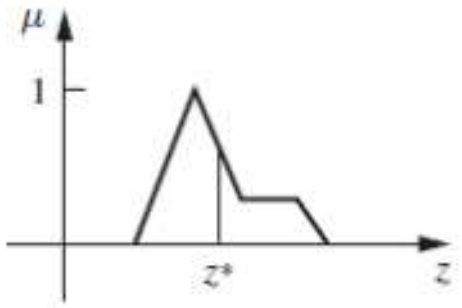

Fig. 8 Illustration of Centroid Method

Weighted Average Method

The weighted average method is the most frequently used in fuzzy applications since it is one of the more computationally efficient methods. But it is usually restricted to symmetrical output membership functions. This method can be expressed as

$$z^* = \frac{\sum \mu_C(\bar{z}).\bar{z}}{\sum \mu_C(\bar{z})}$$

$\sum$ denotes the algebraic sum and $\bar{z}$ is the centroid of each symmetric membership function.

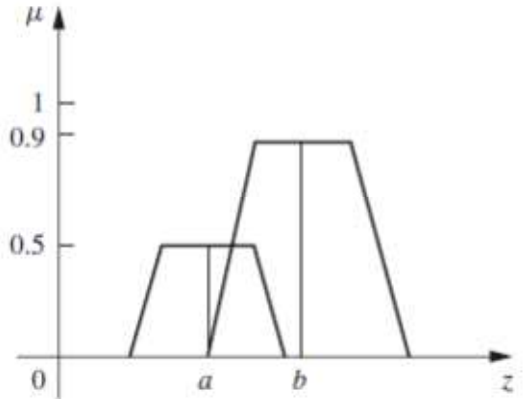

Fig. 9 Illustration of Weighted Average Method

Center of Sums Method

This method is faster than many defuzzification methods that are currently in use and the method is not restricted to symmetric membership functions. This method has two drawbacks that the intersecting areas are added twice and the method also involves finding the centroids of the individual membership functions. This method can be expressed as

$$z^* = \frac{\sum_{k=1}^{n} \mu_{C_k}(z) \int_z \bar{z}\,dz}{\sum_{k=1}^{n} \mu_{C_k}(z) \int_z dz}$$

D. A Real World Problem

A railroad company intends to lay a new rail line in a particular part of a county. The whole area through which the new line is passing must be purchased for right-of-way considerations. It is surveyed in three stretches, and the data are collected for analysis.

For the railroad to purchase the land, it must have an assessment of the amount of land to be bought. The three surveys on right-of-way width are ambiguous, however, because some of the land along the proposed railway route is already public domain and will not need to be purchased. Additionally, the original surveys are so old that some ambiguity exists on boundaries and public right-of-way for old utility lines and old roads. The three fuzzy sets Z1, Z2 and Z3 which represent the uncertainty in each survey as to the membership of right-of-way width, in meters, in privately owned land.

E. Implementation

I use different function on Software MATLAB for calculating results. I calculate defuzzified value by using the five defuzzification methods.

I use degree of membership value for all fuzzy sets for 1. The three fuzzy sets are shown in Fig. 10, 11, 12 and union of these fuzzy sets is shown in Fig 13.

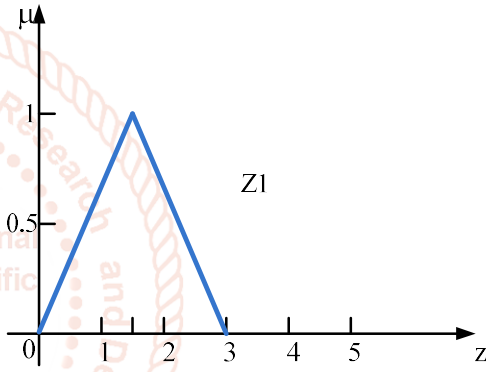

Fig. 10 First Fuzzy Set

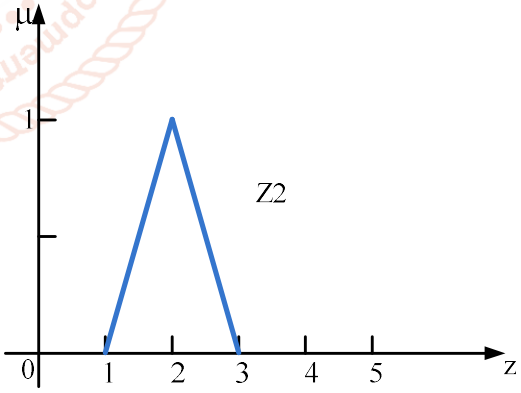

Fig. 11 Second Fuzzy Set

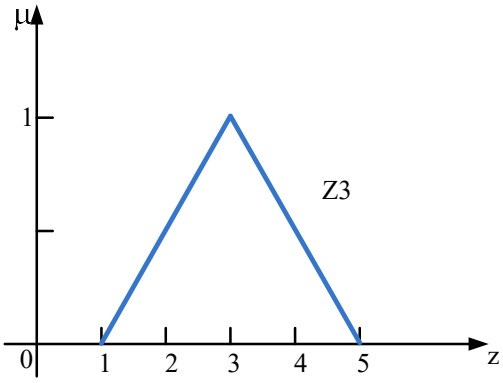

Fig. 12 Third Fuzzy Set

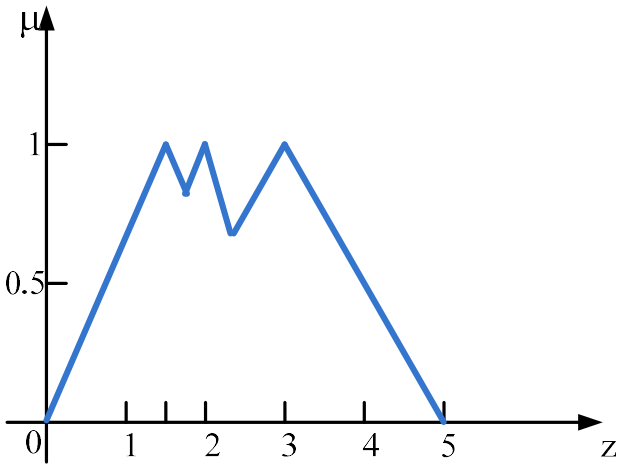

Fig. 13 Union of Three Fuzzy Sets

Table II : Comparison Table

Defuzzification Method	Defuzzified Value
Centroid	2.5
Weighted Average	2.25
Center of Sums	2.3
Center of Largest Area	3.3
First of Maxima	1.5
Last of Maxima	3

According to the comparison table, centroid method is the best one which is definitely center point in this problem. Other methods are variable depend on problem.

Conclusion

This paper presents different defuzzification techniques to get an appropriate result. The results are shown in Table II. In this table, there are different six defuzzification methods. From this, weighted average method and center of sums are approximately the same result. First of maxima and last of maxima are variable depend on the problem because they calculate the smallest convex and largest convex fuzzy sets. Centeroid method obtains the center of the three fuzzy sets.

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