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Fuzzy Logic as a Tool for Assessing Different Types of Four Wheeler Features using Defuzzification Centroid Method

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ABSTRACT
In this article we develop a fuzzy model for assessment or judge vehicle's groups according to their feature / parameter. Parameter under assessment (comfort, millage, maintenance, power and safety) which are represented as a fuzzy subset of the set of linguistic label parameters and consider some example of four wheeler vehicles like as different types of cars and its parameter are calculates. Defuzzification method is converting our fuzzy output to a crisp number [2, 3, 4]. In this paper, we apply Centroid defuzzification method and find the best vehicles performance. And also present the graph and example to illustrate the use of our result in practice.

Keywords: Fuzzy Logic, fuzzy set, defuzzification COG method, four wheeler vehicles.

1. Introduction

Vehicles are very important in our life. But one of the problems faced by customer is the assessment of their vehicles features. In fact our society demanded not only best vehicles mileage condition but also to classify the comfortable, maintenance, power and safety of the vehicles according to their performances being suitable or unsuitable for going from one place to another place. In this section, we introduce some basic concepts in fuzzy set theory and their rules and introduce centroid method which is used for selection of best vehicles and calculate their parameters. Fuzzy Logic, which is based on fuzzy set theory was introduced by Zadeh in 1965 [13, 14]. Fuzzy set theory proposed in terms of membership function operating over the range [0, 1] of real numbers. Fuzzy Logic resembles the human decision-making methodology. It deals with vague and imprecise information. Defuzzification process is converse of fuzzification process. It is performed by converting a fuzzy output to a crisp value. There are many types of techniques available in defuzzification method, but in this article we use center of gravity method. It's is also known as centroid method, developed by Takagi et al. in 1985 [8]. According to this method, first we determine the center of area of fuzzy set and returns the corresponding crisp value.

2. Definitions and Preliminaries

Definition 2.1. [12] Fuzzy set: - If X is a universe set of discourse and x is a particular element of X, then a fuzzy set Ã defined on X and can be written as a collection of ordered pairs

$$\tilde{A} = \{(x, \mu(x)), x \in X\}.$$

Definition 2.2. [12,3] Fuzzy logic: - Fuzzy logic is a form of many valued logic in which the truth values of variables may be any real number between 0 and 1 both inclusive.

Definition 2.3. [2] Defuzzification: - Defuzzification is such an inverse transformation process, which maps the output from the fuzzy domain back into the crisp domain.

Definition 2.4. [4] COG method: - COG method is basic concept to find the point x_C where a vertical line would slice the aggregate into two equal masses and μ_c is a membership function.

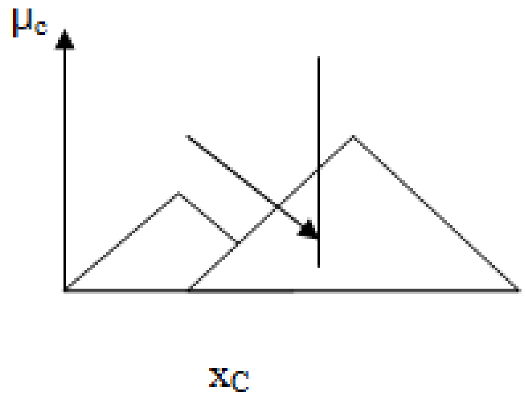

Figure 1: Membership function μ_c as a function of x_C.

3. Defuzzification Methodology

The Defuzzification process is performed by converting the fuzzy sets into a crisp value. In this article, we discuss new technique center of gravity method. It is used with an example.

3.1 The Centroid Method

A common and mostly useful defuzzification technique is the method of the center of gravity. The COG Defuzzification Technique is an Assessment Method which is one of the most popular method in fuzzy mathematics [2, 4].

Let as consider $\tilde{A} = \{(x, \mu(x)), x \in X\}$ as a fuzzy set determined the problem solution and U is a universal set of discourse $x \in U$, where U replace with a set of real intervals. Then we construct the graph *F* of the membership function $y = m(x)$. This is commonly used in FL approach to represent the system's fuzzy data by the coordinates (x_c, y_c) of the Center of gravity, say F_c, of the area *F*. Given below is the formula which is used to calculate x_c, and y_c which we calculated from Mechanical formula:

$$x_c = \frac{\iint_F x\,dx\,dy}{\iint_F dx\,dy},\quad y_c = \frac{\iint_F y\,dx\,dy}{\iint_F dx\,dy} \qquad \text{.................................... (1)}$$

In this article we shall apply the centroid method as a defuzzification technique for the different type of four wheeler vehicle groups like Alto car and Swift Desire car. Assessment model developed in this section. For this, we feature a vehicle's performance as comfort (a) if $y \in [0, 1)$, as millage (b) if $y \in [1, 2)$, as maintenance (c) if $y \in [2, 3)$, as power (d) if $y \in [3, 4)$ and as safety (e) if $y \in [4, 5)$ respectively. These observations are usually on the basic survey reports prepared by the customer during the survey on vehicles and the final results of the evaluate parameters in form of membership degree [5, 6, 7].

Consequently we have that $y_1 = m(x) = m(F)$ $\forall$ x in [0, 1), $y_2 = m(x) = m(D)$ $\forall$ x in [1,2), $y_3 = m(x) = m(C)$ $\forall$ x in [2,3), $y_4 = m(x) = m(B)$ $\forall$ x in [3,4), $y_5 = m(x) = m(A)$ $\forall$ x in [4,5).

In this case, the graph *F* of the membership function $y = m(x)$, corresponding fuzzy subset of *U* is
the bar graph of Figure 1 consisting of 5 rectangles, say S_i, i = 1, 2, 3, 4, 5 having the lengths of their sides on the x axis equal to 1.

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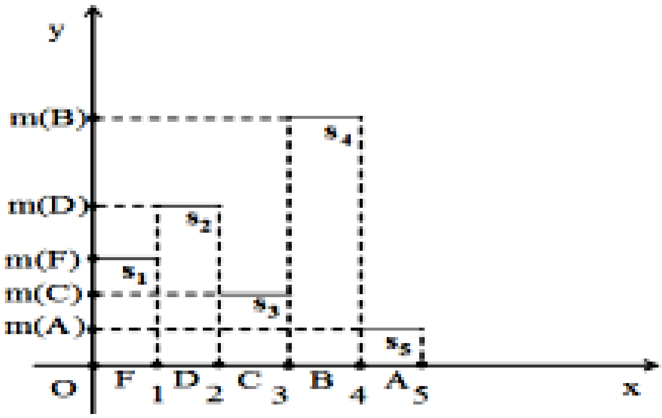

Figure 2: The graph of the COG method

Formulas (1) are transformed into the following form:

$$x_c = \frac{1}{2}\,\frac{(y_1 + 3y_2 + 5y_3 + 7y_4 + 9y_5)}{(y_1 + y_2 + y_3 + y_4 + y_5)}, \quad \textit{and} \quad y_c = \frac{1}{2}\,\frac{(y_1^2 + y_2^2 + y_3^2 + y_4^2 + y_5^2)}{(y_1 + y_2 + y_3 + y_4 + y_5)}. \quad (2,3)$$

Normalizing our fuzzy data by dividing each m(x), x ∈ U, with the sum of all membership degrees, we can assume without loss of the generality that y1 + y2 + y3 + y4 + y5 = 1. Therefore, we can write

$$x_c = \frac{1}{2}\,(y_1+3y_2+5y_3+7y_4+9y_5), \qquad \text{-----------------(4)}$$

$$y_c = \frac{1}{2}\,(y_1^2 + y_2^2 + y_3^2 + y_4^2 + y_5^2) \qquad \text{-------------------(5)}$$

with

$$yi = \frac{m(xi)}{\sum_{i=1}^{5} m(xi)=1}$$

where x_1 =F, x_2 =D, x_3 =C, x_4 =B, x_5 =A and i = 1, 2, 3, 4, 5. Note that the membership function *y= m(x),* as it usually happens with fuzzy sets, can be defined, according to the user's choice, in any compatible to the common logic way. We define here *y = m(x)* in terms of the frequencies, as in

$$\sum_{i=1}^{5} m(\mathrm{xi}) = 1.$$

But 0 □□$(y_i - y_j)^2 = y_i^2 + y_j^2 - 2y_iy_j$, therefore $y_i^2 + y_j^2$ □□2yiyj, with the equality holding if, and only if, $y_i = y_j$.
For i= 1 and j= 2. 0 □□$(y_1 - y_2)^2 = y_1^2 + y_2^2 - 2y_1y_2$, therefore $y_1^2 + y_2^2$ □□$2y_1y_2$, with the equality holding if, and only if, $y_1 = y_2$. In the same way one finds that $y_1^2+y_3^2$ □□$2y_1y_3$, and so on.
Hence it is easy to check that $(y_1 + y_2 + y_3 + y_4 + y_5)^2$ □□5, with the equality holding if, and only if $y_1= y_2= y_3 = y_4 = y_5$.
However, $y_1 + y_2 + y_3 + y_4 + y_5 =1$;
therefore, 1 □□$5(y_1^2 + y_2^2 + y_3^2 + y_4^2 + y_5^2)$ (3), with the equality holding if, and only if $y_1= y_2= y_3 = y_4 = y_5$= 1/ 5 In this case the first of Formulas (2) gives that $x_C = \frac{5}{2}$
Further, combining the Inequality (3) with the second of Formulas (3) one finds that 1 □□10y*c*, or
y_c □□□□□□□□Therefore,
In case 1 ($_{Fm}$) the unique minimum for corresponds to the center of gravity Fm ($\frac{5}{2}$, $\frac{1}{10}$).

In case 2 the ideal case (F_i) is when $y_1= y_2= y_3 = y_4 = 0$ and y = 1 Then from Formulas (2) we get that $x_c = \frac{9}{2}$ and $y_c = \frac{1}{2}$ Therefore the center of gravity in the ideal case is the point *Fi* $(\frac{9}{2}, \frac{1}{2})$
On the other hand the worst case (3) (F_w) is when y1 = 1 and y2 = y3 = y4 = y5 = 0. Then for formulas (2) we find that the center of gravity is the point $F_w(\frac{1}{2}, \frac{1}{2})$. Therefore, the area in which the COG F lies is the area of the triangle F_w, F_m, F_i (Figure 3).

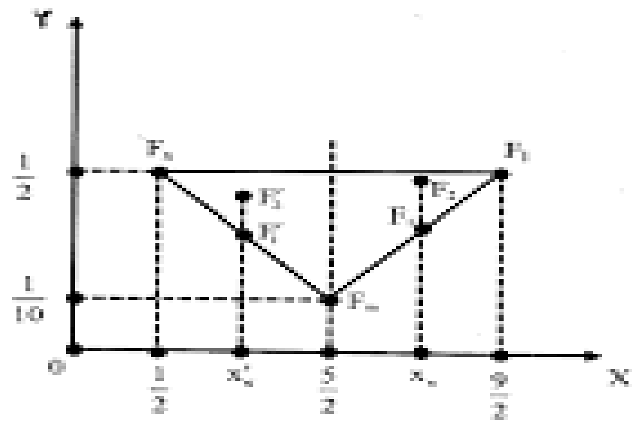

Figure 3: Graphical Representation of the “area” of the Center of gravity.

Using elementary algebraic inequalities and performing elementary geometric it follows that for two groups of vehicles observations (e.g. Section 3) one obtains the following assessment criterion:
1. Among two or more groups the group with the biggest x_c performs better.
2. If two or more groups have the same x_c $\geq$ 2.5, then the group with the higher y_c performs better.
3. If two or more groups have the same $x_c < 2.5$, then the group with the lower y_c performs better.

3.2 Procedure

The solution of a problem in terms of FL involves in general the following steps:
- Choice of the universal set U of the discourse.
- Fuzzifications of the problem’s data by defining the proper membership functions.
- Evaluation of the fuzzy data by applying rules and principles of Fuzzy Logic to obtain a unique fuzzy set, which determines the required solution.
- Defuzzification of the final outcomes in order to apply the solution found in terms of FL to the original, real world problem.

The graph *F* of the membership function *y* = m(x). There is a commonly used in FL approach to represent the system’s fuzzy data by the coordinates (x_c, y_c) of the Center of gravity, say F_c, of the area *F*. below given formula used to calculate x_c, and y_c.

3.3 A Fuzzy Model for Assessment Vehicles groups’ Performance

In this section, according to the standard method of assessment or evaluate a grade /present parameters value, express either with a numerical value within a given scale (example from 0 to 1) or with a letter (example from A to F) corresponding to the present of vehicles success, is assigned in ordered to parameters its performances. With the use of fuzzy logic as tool, we can easy assessment vehicles feature.
Let us consider a case of n vehicles n ≥1 and let us assume that the customer wants to assessment the following different type of four wheeler vehicles like as Alto car(s_1), and swift desire car (s_2). However the more one vehicles chose for

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assessment our model. Denote by a ,b, c, d and e the linguistic label (fuzzy expression) and it's parameters as comfort, millage, maintenance, power and safety denoted as membership function of a vehicles in each of the S_i and set U={a, b, c, d, e}[5, 6, 7].

Now we are going to attach to each vehicles S_i, i = 1, 2, 3 a fuzzy subset A_i of U where U is a universal set of X, and U replace with a set of real intervals.

Numerical Examples

The following data were obtained by assessing the mathematical skills of two groups of different type of vehicles of the survey in Indore by BHAWNA. Here first group obtained 20 four wheeler cars studies according to survey features with membership functions are given below:

A_{11} = {(a, 0.25), (b, 0.25), (c, 0.5), (d, 0), (e, 0),}
A_{12} = {(a, 0.5), (b, 0.25), (c, 0.5), (d, 0), (e, 0.25)}
A_{13} = {(a, 0.25), (b, 0.5), (c, 0.25), (d, 0.25), (e, 0)}

where A_{11} are the first groups of swift desire car, A_{12} are the groups of Ertiga car and A_{13} are the groups of wagon R car.

And here second group obtained 20 four wheeler cars studies according to survey features with membership function is given below

A_{21} = {(a, 0), (b, 0.5), (c, 0.25), (d, 0.25), (e, 0)},
A_{22}= {(a, 0.25), (b, 0.5), (c, 0.25), (d, 0), (e, 0.5)}
A_{23} = {(a, 0.25), (b, 0.5), (c, 0.5), (d, 0.25), (e, 0.25)}

where A_{21} are the second groups of Alto car, A_{22} are the groups of Maruti 800, A_{23} are the groups of Swift car.

According to the above notation the first index of A_{ij} denotes the group S_i (i = 1, 2) and the second index denotes the corresponding different type 4 wheeler vehicles feature S_j (j = 1, 2, 3) for compare between two groups Swift desire car and Alto car, we have

A_{11} ={(a, 0.25),(b, 0.5),(c, 0.5),(d, 0),(e, 0), and A_{21}= {(a, 0),(b, 0.5),(c, 0.25),(d, 0.25),(e, 0)} respectively

$$x_c = \frac{1}{2}(y1+3\,y2 + 5y3 + 7y4 + 9y5), \quad y\,c = \frac{1}{2}(y_1^2 + y_2^2 + y_3^2 + y_4^2 + y_5^2)$$

A_{11} = {(a,0.25),(b,0.5),(c, 0.5),(d, 0),(e,0}), A_{21} = {(a, 0),(b, 0.5),(c, 0.25),(d, 0.25),(e, 0)}

$x_{c11} = \frac{1}{2}$ (0.25+3×0.5+5×0.5+0+0) $\quad$ $y_{c21} = \frac{1}{2}$ (0+0.5×0.5+0.25×0.25+0.25×0.25+0)

$x_{c11} = \frac{4.25}{2}$ $\quad$ $y_{c21} = \frac{0.375}{2}$

x_{c11}= 2.125 $\quad$ y_{c21}= 0.1875.

Similarly for compare between two groups Ertiga car and Maruti 800, we have

A_{12} ={(a,0.5),(b,0.25),(c, 0.5),(d, 0),(e,0.25)}, A_{22}= {(a, 0.25),(b, 0.5),(c, 0.25),(d, 0),(e, 0.5)}

$xc_{12} = \frac{1}{2}$ (0.5+3×0.25+5×0.5+7×0+9×0.25), $\quad$ $y\,c_{22} = \frac{1}{2}$ (0.25+ 0.5×0.5+0.25×0.25+0×0+0.5×0.5),

$xc_{12}= \frac{6}{2}$ $yc_{22}=$ 0.8125/2

$xc_{12}= 3$ $yc_{22}= .40625$

Again similarly for comparison between two groups Wagon R car and Swift car, we have

A_{13} ={(a, 0.25),(b, 0.5),(c, 0.25),(d,0.25),(e,0)}, A23 = {(a 0),(b,0.5),(c, 0.5),(d, 0.25),(e, 0)}

$xc_{13} = \frac{1}{2}(0.25+3\times.05+5\times0.25+7\times0.25+0)$, $y\ c_{23} = \frac{1}{2}(0+0.5\times.05+0.5\times0.5+0.25\times0.25+0\times0)$

$xc_{13=} \frac{4.75}{2}$ $y\ c_{23} = \frac{0.5625}{2}$

$xc_{13=}$ 2.375 $y\ c_{23\ =}$ 0.28125

4. Results

Clearly the centroid defuzzification techniques give the result of the comparing different types of vehicles and their features assessment. (According as Section 3.1) one obtains the following assessment criterion: for A_{11} and A_{21} groups

1. Two or more groups the group with the biggest x_c performs better.
2. If two or more groups have the same x_C □□2.125, then the group with the higher y_c performs better.
3. If two or more groups have the same $x_C < 2.125$, then the group with the lower y_c performs better. Similarly apply this process in A12 and A22, also A13 and A23.

Similarly apply for A_{12}, A_{22} and A_{13}, A_{23} , calculate x_c and y_c and find result between two groups.

5. Conclusion

In this paper, a new technique using fuzzy logic is applied for the selection of different types of 4 wheeler vehicles assessment and generated different membership functions. Fuzzy logic, due to its nature of including multiple values, offers a wider field of resources for assessing the vehicles performance. We can easily calculate (x_c , y_c) and show first group cars (swift desire cars) are best performance of the groups using the fuzzy logic defuzzification technique.

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