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A study of generalized bell-shaped membership function on Mamdani fuzzy inference system for Students' Performance Evaluation

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Abstract

This paper presents a Mamdani fuzzy inference system for evaluation of students' performance based on Generalized bell-shaped membership function $\left(i.e.\ \text{gbellmf}(x; a, b, c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \right)$. The objective of this research work is to study the control of parameter 'b' in the generalized bell-shaped membership function. Experimental Mamdani fuzzy inference systems will keep every condition identical except changing the parameter 'b' in the generalized bell-shaped membership function. Different values of parameter 'b' in generalized bell-shaped membership function using Mamdani fuzzy inference system have been proposed and the results are compared with a statistical tool.

Keywords: Fuzzy inference system; Mamdani fuzzy inference system; Generalized bell-shaped membership function.

1. Introduction

Fuzzy logic is a precise conceptual system of reasoning, deduction, and computation in which the objects of discourse and analysis are allowed to be, associated with imperfect information. Imperfect information is information which in one or more respects is uncertain, inadequate, unreliable or partially true [1]. The fuzzy logic was introduced by Zadeh (1965) [2]. Fuzzy logic is mostly associated with real-world problems, which usually involve a degree of uncertainty.

In today's competitive world, evaluation in the education system is the most required thing. There are many traditional ways for performance measurement are available. Conventional evaluation systems are representatives of structured systems that employ quantifiable and non-quantifiable measures of evaluation [3]. Academic administrators face many issues when trying to evaluate performance. Using soft computing techniques, effective measurement of performance is possible. To improve the effectiveness of performance evaluation, researchers all over the world are trying to use Fuzzy techniques. The fuzzy approach can be effectively utilized to handle imprecision and uncertainty[4]. In the fuzzy approach fuzzification is the most important part. Fuzzification is the method of transforming a crisp input value to a fuzzy value that is offered by the use of the information in the knowledge base. There are lots of verities for choosing the fuzzy membership function for this fuzzification process. Although various types of curves can be seen in literature, Gaussian, triangular, and trapezoidal membership functions are the most commonly used in the fuzzification process. These types of membership functions can easily be implemented by embedded controllers [5]. The last few years have been a lot of research that discusses the development of a model for the use of fuzzy logic in the evaluation process. In 1990, Dombi J. show the connections between the operators of the evaluation and membership functions, which gives the generalization of this concept in a more general form [6]. Pedrycz W. look at a certain theoretically sound motivation behind the common use of triangular (and trapezoidal) membership functions [7]. Some researcher also compared the different types of membership function for their effectiveness. The effectiveness of power system stabilizer (PSS) in providing damping and improving the dynamic response Gupta N. and Jain S investigated the result for trapezoidal,

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triangular and Gaussian membership functions of input and output variables [8]. Comparative to other generalized bell membership function is less selective by the researcher for their study. The generalized bell-shaped membership function (*gbellmf*) is a symmetrical shape similar to a bell[9]. Formulation of the generalized bell membership function is much complicated then triangular and trapezoidal membership function. In generalized bell membership function, there are three different parameters and among them, two parameters jointly effect impact the membership function. In this study, the effect of one parameter among the three parameters is checked. The main objective of this research work is to study the influence of parameter in the generalized bell-shaped membership function, while the evaluation of student's performance.

2. Generalized bell shaped membership function in Mamdani fuzzy inference system

2.1. Fuzzy logic

Fuzzy logic is mostly associated with real-world problems, which usually involve a degree of uncertainty.

A fuzzy set A in a universe of discourse X is defined as the following set of pairs [11]

$$A = \{(x, \mu_A(x)) : x \in X\} \quad [1]$$

Where, $\mu_A(x)$ is called the *"membership function"* of x in A and each pair $(x, \mu_A(x))$ is called a singleton.

2.2. Membership function

A membership function (MF) is a curve that define how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. There are many different forms of membership functions in fuzzy system. Triangular and Trapezoidal membership functions are widely used because of their simple formulas and computational efficiency, especially in real-time implementations. Triangular and Trapezoidal membership functions are formed with straight-line segments, they are not smooth at the corner points defined by the parameters. Gaussian and generalized bell membership functions are becoming increasingly popular for specifying fuzzy sets, Because of their smoothness and concise notation. Gaussian functions are well known in probability and statistics and Fourier. The generalized bell membership function has one more parameter than the Gaussian membership function. It has one more degree of freedom to adjust the steepness at the crossover points. A generalized bell membership function has three parameters: a – responsible for its width, c – responsible for its center and b – responsible for its slopes[10]. Mathematically,

$$gbellmf(x; a, b, c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \quad \text{..... [2]}$$

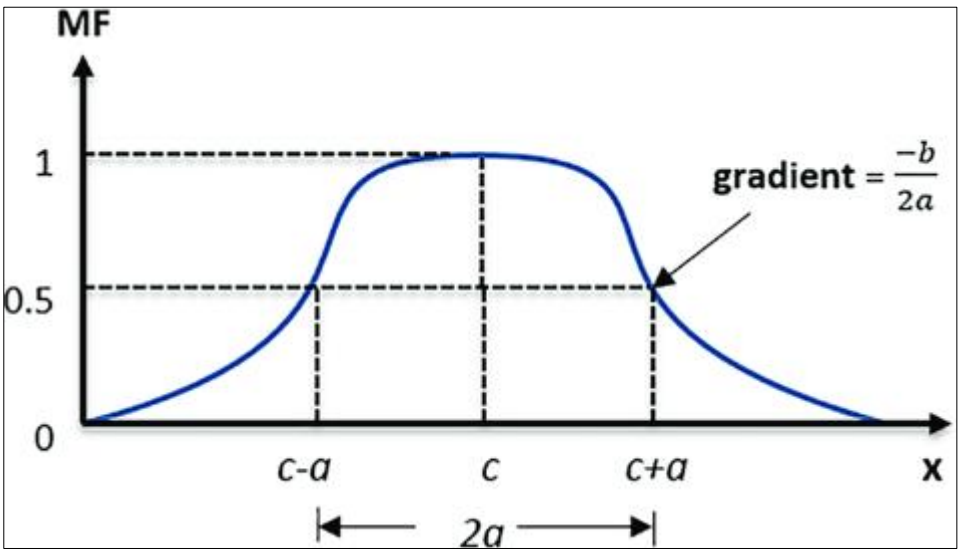

Figure 1 Generalized bell shaped membership function

2.3. Mamdani fuzzy inference system

Mamdani fuzzy inference was first introduced as a method to create a control system by synthesizing a set of linguistic control rules obtained from experienced human operators [11]. In Mamdani fuzzy inference have more intuitive and easier to understand rule bases, they are well-suited to expert system applications where the rules are created from human expert knowledge.

Mamdani-type fuzzy inference process consists of five steps[12]:

- Step 1: Fuzzify input variables
- Step 2: Apply fuzzy operator
- Step 3: Apply implication method
- Step 4: Apply aggregation method
- Step 5: Defuzzification

The main objective of this research work is to study the influence of parameter 'b' in generalized bell shaped membership function shown in equation 2. Experimental Mamdani fuzzy inference systems will keep every condition identical except changing the parameter 'b' in generalized bell shaped membership function.

3. Case study

The marks of two exams of 10 students were collected from College of Agriculture, Waghai, Gujarat. Here we consider both inputs have equal weights. Apply Mamdani fuzzy inference system with generalized bell shaped membership function. For each student both exam scores were calculated according to rule table. The output was calculated for different values of parameter 'b'. The following table shows the score of 10 students.

Table 1 Students exam marks

Sr. No.	Exam 1	Exam 2
(1)	(2)	(3)
1	38	70
2	50	60
3	52	42
4	45	65
5	11	15
6	30	25
7	25	40
8	70	90
9	28	30
10	82	70

The input value is mapped into the membership function graph to obtain the confidence value of the particular input variable. The real value that is supplied into the system is converted to linguistic variables. We assigned five linguistic variables to both exams, according to the input range value as Very poor(VP), Poor (P), Fair (F), Good (G) and Very good (VG) and only one output: student's performance with five membership functions have defined. For reasons of convenience, a output range is chosen between 0 and 1. Table 2 and Figure 3 shows the fuzzy membership range for students' performance.

Table 2 Fuzzy membership range for Student's performance

Linguistic Expression	Symbol	Interval
Poor	P	(0,0,0.10,0.30)
Satisfactory	S	(0.10,0.30,0.50)
Remarkable	R	(0.30,0.50,0.70)
Very Good	VG	(0.50,0.70,0.90)
Outstanding	O	(0.70,0.90,1.0,1.0)

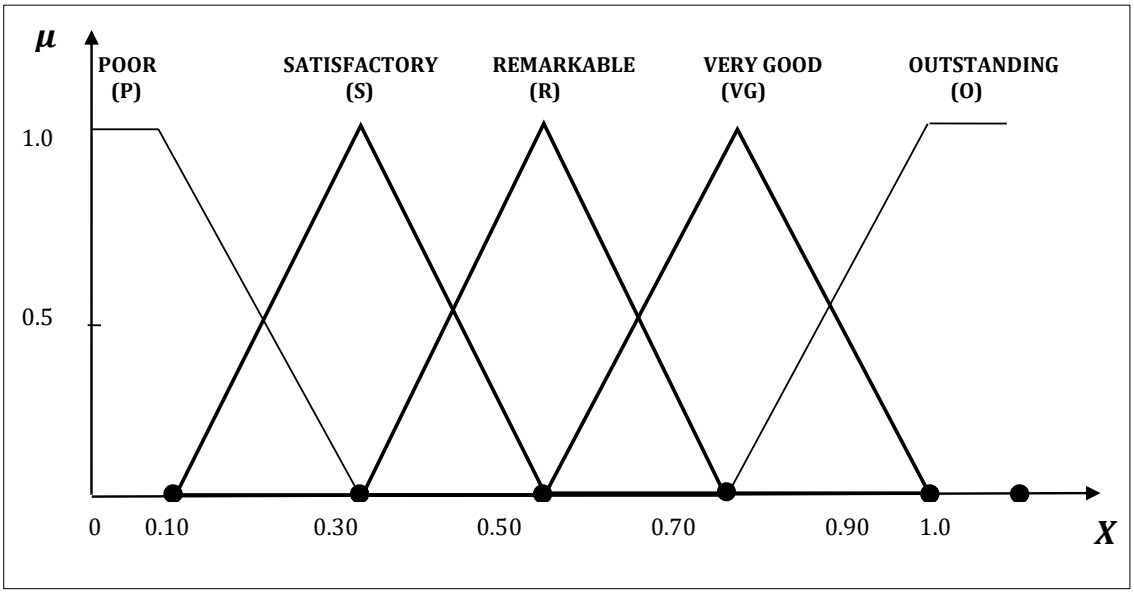

Figure 2 Fuzzy membership range for Student's performance

Fuzzy rule base modeling is important particularly where the relations between the components of the system are not exactly known, if there is insufficient statistical data for analysis and if the data is uncertain about particular things which the user needs. The rule based system was developed using many linguistic rules with "IF-THEN" rules. Fuzzy rules which used in this research are shown in table 3.

Table 3 Fuzzy Rules

Sr. No	Exam 1	Exam 2	Output	Sr. No	Exam 1	Exam 2	Out put	Sr. No	Exam 1	Exam 2	Out put
1	VP	VP	P	10	P	VG	R	19	G	G	VG
2	VP	P	P	11	F	VP	S	20	G	VG	O
3	VP	F	S	12	F	P	S	21	VG	VP	R
4	VP	G	S	13	F	F	R	22	VG	P	VG
5	VP	VG	R	14	F	G	VG	23	VG	F	VG
6	P	VP	P	15	F	VG	VG	24	VG	G	O
7	P	P	S	16	G	VP	S	25	VG	VG	O
8	P	F	S	17	G	P	R				
9	P	G	R	18	G	F	VG				

3.1. Evaluation of Student's Performance

In first trial following ranges for input membership function is used, which is shown in table 4 and Figure 3. After that in every trail, value of parameter 'b' is reduced by some ratio. Input membership functions for all the trials are shown in figure 3 to figure 7.

Table 4 Fuzzy membership range for Input

Linguistic Expression	Symbol	Interval
Very Poor	VP	[30 30 0]
Poor	P	[20 20 30]
Fair	F	[20 20 50]
Good	G	[20 20 70]
Very Good	VG	[30 30 100]

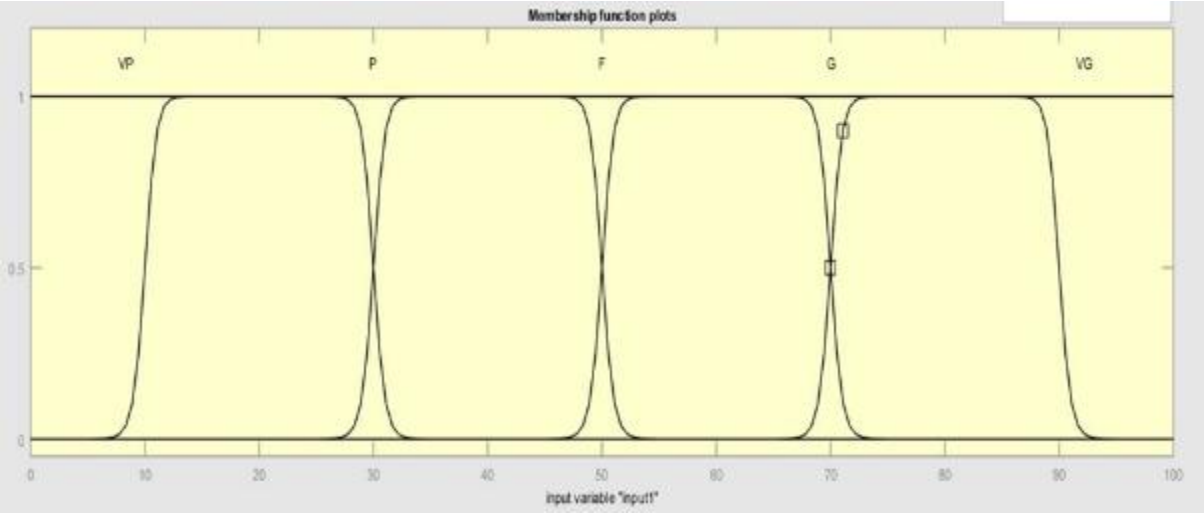

Figure 3 Membership range

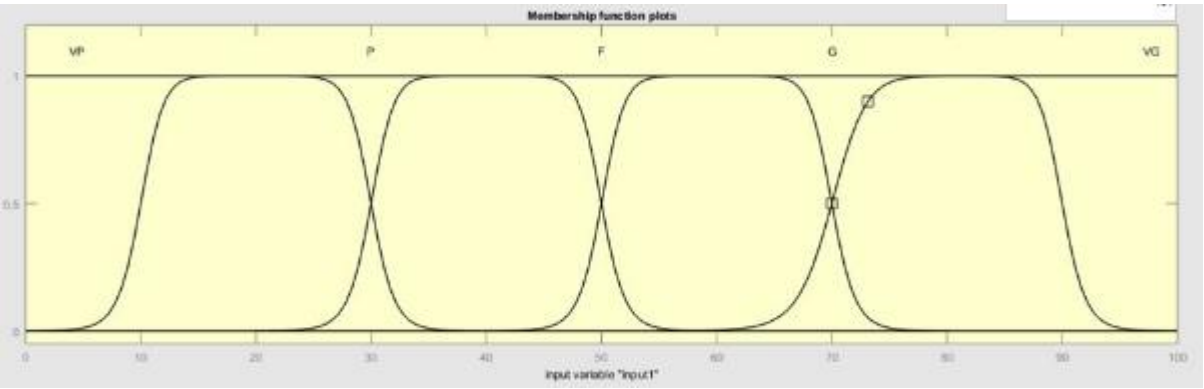

Figure 4 Membership range b'=b/2

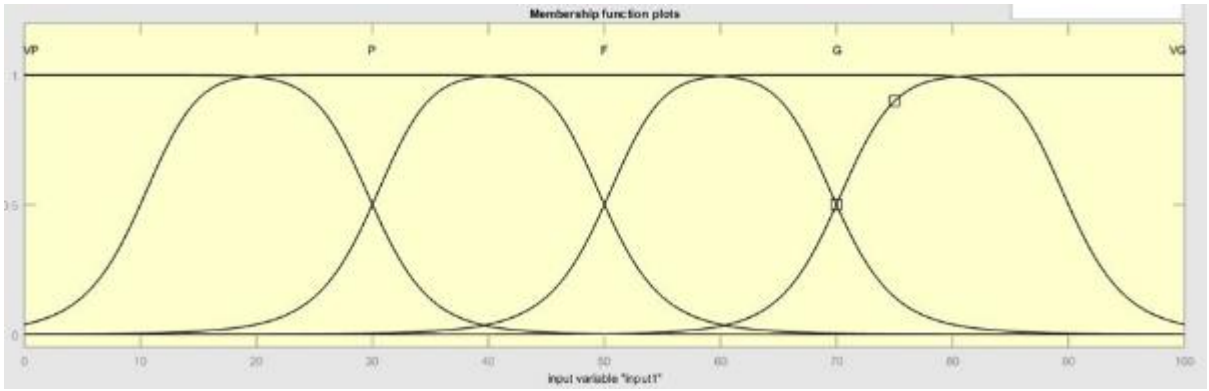

Figure 5 Membership range b'=b/5

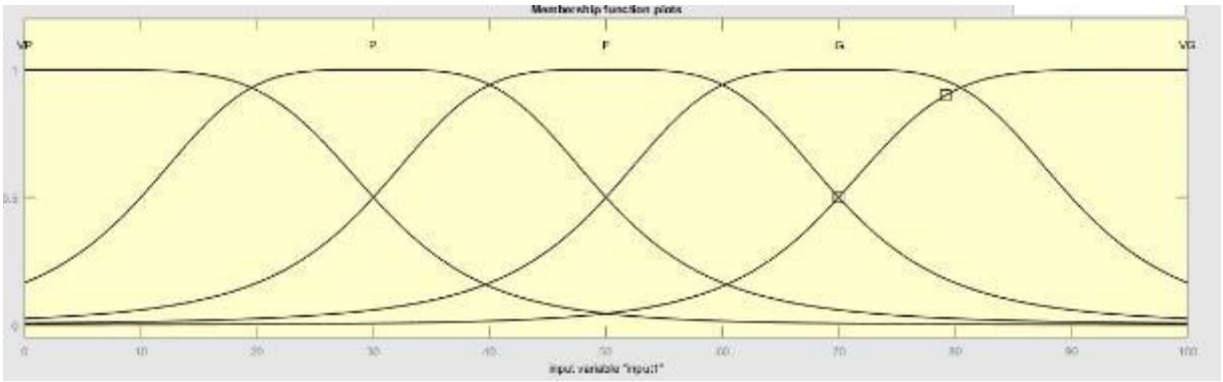

Figure 6 Membership range b'=b/10

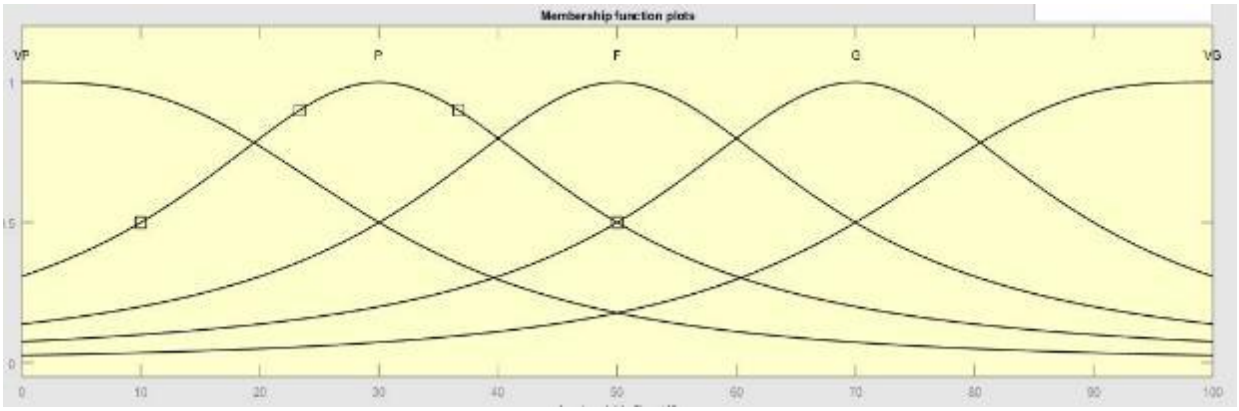

Figure 7 Membership range b'=b/20

4. Result and Discussion

The study compared the results of students' performance evaluation using generalized bell shaped membership function for different values of parameter 'b'. The evaluation results are noted in Table 5. Students performance in Trial 5 (i.e. b'=b/20) can find a better solution. Comparison of results with mean value by using correlation coefficient is shown in figure 9.

Table 5 Students' performance for different values of parameter 'b'

Sr. No.	Exam 1	Exam 2	Average	Trial:1 (b'=b)	Trial:2 (b'=b/2)	Trial:3 (b'=b/5)	Trial:4 (b'=b/10)	Trial:5 (b'=b/20)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	38	70	54	0.522	0.522	0.524	0.529	0.525
2	50	60	55	0.522	0.522	0.525	0.533	0.533
3	52	42	47	0.5	0.499	0.491	0.481	0.48
4	45	65	55	0.5	0.501	0.514	0.528	0.53
5	11	15	13	0.201	0.198	0.193	0.213	0.285
6	30	25	27.5	0.202	0.205	0.237	0.287	0.352
7	25	40	32.5	0.202	0.205	0.247	0.314	0.378
8	70	90	80	0.714	0.814	0.812	0.776	0.695
9	28	30	29	0.207	0.234	0.28	0.315	0.366
10	82	70	76	0.798	0.798	0.792	0.751	0.676
				0.959775	0.971817	0.983318	0.994199	0.998058

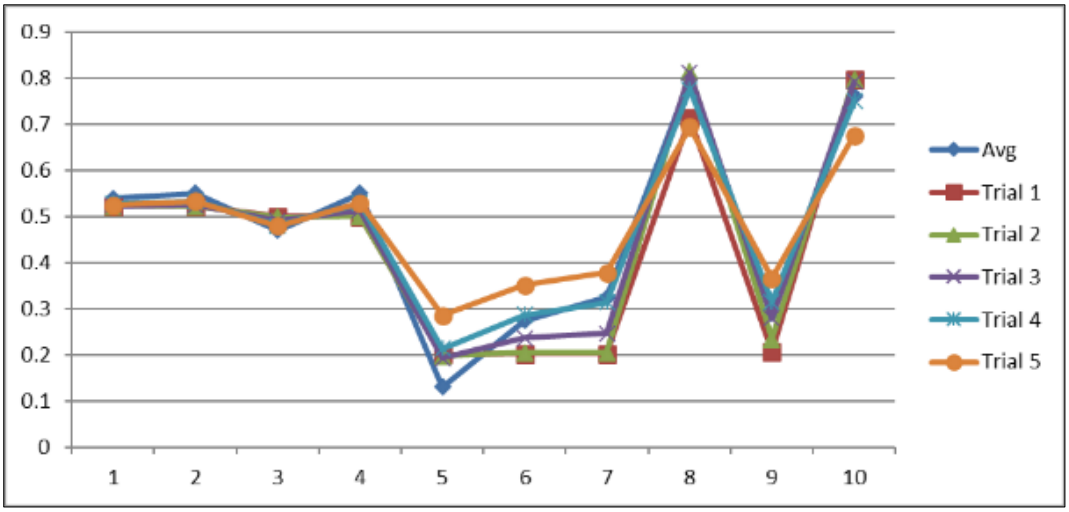

Figure 8 Comparison result of students' performance for different values of parameter 'b'

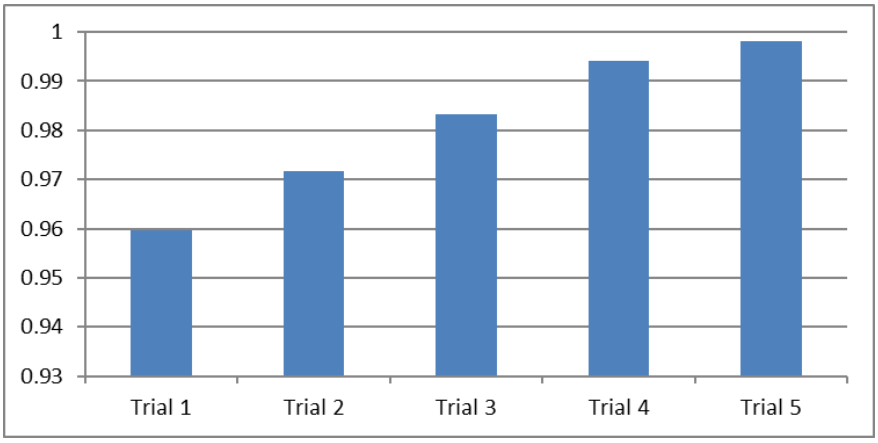

Figure 9 Correlation with statistical mean

5. Conclusion

In this paper, the impact of parameter 'b' from generalized bell shaped function has been discussed. Mamdani fuzzy inference method is used for this work. As the parameter 'b' controls the slops at the crossover points with parameter 'a', it is observed that as b decreasing, overall width of the membership function is enlarge, which gives better accuracy. Correlation of all the trials with statistical mean suggest that smaller value of parameter 'b' is give better accuracy.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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