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RESEARCH ARTICLE

SOFTWARE QUALITY PREDICTION USING FUZZY RULE BASED SYSTEM

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ABSTRACT

Development of software quality, development effort etc is a common application of software metrics. A new tool as Fuzzy Logic offers a good technique for building models for software quality prediction. This paper illustrates the practice of estimation at a personal level using projects and presents the results obtained with a fuzzy rule based system and an ordinary multiple regression. Result shows that the value of MMRE applying fuzzy logic is smaller than MMRE applying multiple regression; while the value of Pred (0.25) and Pred (0.05) applying fuzzy logic is higher than Pred (0.25) and Pred (0.05) applying multiple regression. Thus Results demonstrate that fuzzy logic can be used as alternative for predicting the software quality.

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INTRODUCTION

Software Quality Prediction has been identified as one of the major challenges for computer science (Fredrick and Brooks, 2003). No method or model of estimation should be preferred over all others. Fuzzy logic may be used as a convenient tool for software development quality estimation (Witold Pedrycz, 2002; Briand and Wieczorek, 1996).

Soft computing technique likes fuzzy logic, case based reasoning have been used by several researchers for estimation of development cost and time in Software Engineering (Musflek *et al*., 2000; Huang *et al*., 2004; Idri *et al*., 2001; Idri *et al*., 2002; Gray *et al*., 1997; Braz *et al*., 2004) (Bhattacherjee and Kumar, 2006; Bhattacherjee, 2006; Viraj and Bhattacherjee, 2009 Bhattacherjee *et al*., 2008; Bhattacherjee *et al*., 2009). In this research paper a fuzzy logic system for software quality prediction has been developed. Further this paper compares estimations obtained with Multiple Regression and Fuzzy Logic. For developing the model, three quality metrics have been gathered for dataset collected from the projects developed by postgraduate students of Birla Institute of Technology, Mesra, Ranchi, India. These metrics are Graphical User Interface (GUI), Meaningful Error Message (MEM) and User Manual (UM).

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Multiple regressions

A linear equation with three independent variables (multiple regressions) may be expressed as:

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 \qquad \ldots\ldots (1)$$

Where b0, b1, b2 and b3 are constants; x1, x2 and x3 are the independent variables, and y is the dependent variable. The values of b0, b1, b2 and b3 of the multiple regressions Equation may be obtained solving the following system of linear equations

$$\Sigma y = nb_0 + b_1(\Sigma x_1) + b_2(\Sigma x_2) + b_3(\Sigma x_3) \qquad \ldots\ldots (2)$$

$$\Sigma x_1 y = b_0(\Sigma x_1) + b_1(\Sigma x_1^2) + b_2(\Sigma x_1x_2) + b_3(\Sigma x_1x_3) \qquad \ldots\ldots (3)$$

$$\Sigma x_2 y = b_0(\Sigma x_2) + b_1(\Sigma x_1x_2) + b_2(\Sigma x_2^2) + b_3(\Sigma x_2x_3) \qquad \ldots\ldots (4)$$

$$\Sigma x_3 y = b_0(\Sigma x_3) + b_1(\Sigma x1x3) + b_2(\Sigma x_2x_3) + b_3(\Sigma x_3^2) \qquad \ldots\ldots (5)$$

Fuzzy logic

Intelligent Systems provide alternative paradigms aimed at facilitating the representation and manipulation of uncertain, incomplete, imprecise or noisy data. Specifically, Fuzzy Logic offers a particularly convenient way to generate a keen mapping between input and output spaces thanks to fuzzy rules' natural expression (12). This paper presents a fuzzy rule based system having three fuzzy inputs, namely Graphical User Interface (GUI), Meaningful Error Message (MEM) and User Manual (UM) and one output Software Quality (SQ) as shown in Figure 1.

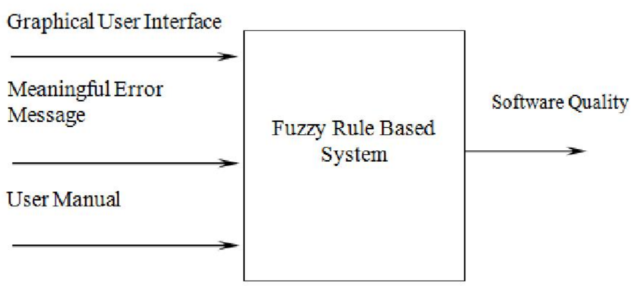
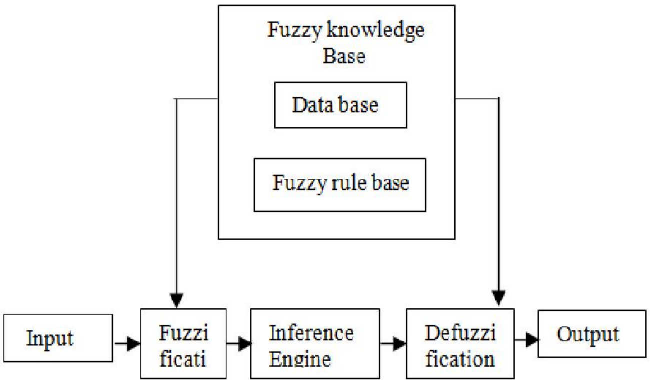


Figure 1. Proposed Fuzzy Rule Based System

Fuzzy rule based system

A typical fuzzy logic system consists of four main components as shown in Figure.



1. Fuzzification: that contains predefined set of linguistic values. It converts non-fuzzy (Deterministic) inputs of fuzzy system into fuzzy inputs for inferencing mechanism.

2. Knowledge base: that consists of two parts: **database** that defines linguistic variables conditional statements (Fuzzy sets, and **rule base** that represents the mapping of fuzzy input set into a fuzzy output set. Rules are fuzzy implications). Fuzzy sets, and **rule base** that represents the mapping of fuzzy input set into a fuzzy output set. Rules are fuzzy conditional statements (implications).

3. Decision logic: that simulates human decision making based on fuzzy concepts. Conclusion of certain condition is derived by decision making logic.

4. Defuzzification: that converts rule base fuzzy outputs into non-fuzzy (.numerical) values.

Fuzzy inferencing rules generally connect **m** conditional variables $X1,\dots, Xm$ to **n** consequent variables $Y1,\dots, Yn$ in form of:

IF (**X1** is A1 and ……….Xm is Am) **THEN** (**Y1** is B1 and ... Yn is Bn).

Where $A1,\dots, Am$ and $B1,\dots, Bn$ are linguistic terms of linguistic variables $X1,\dots,Xm$ and $Y1,\dots, Yn$, respectively.

The **IF** part is called the "antecedent" and the **THEN** part is called the "consequent". To make a decision based on a set of rules, a rules-based system follows these steps:

1. All the rules that apply are invoked, using the membership functions and truth values obtained from the inputs (by a process called **fuzzification),** to determine the result of the antecedent.

2. This result in turn will be mapped into a membership function and truth value controlling the output variable. This process is known as **implication**. Two of the more common implication functions are: clipping (the fuzzy set is clipped to a value given by the level of activation of the input variables) and scaling (the fuzzy set is multiplied by a value given by the level of activation of the input variables).

3. These results are combined by a process called **aggregation.** One common approach for the aggregation involves using the "maximum" of the implicated sets.

4. Finally, a process known as defuzzification is used to compute a single value that is representative of the aggregated fuzzy set. A typical defuzzification approach .

Evaluation criteria

A common criterion for the prediction of software quality model is the Magnitude of Relative Error (MRE) which is defined as follows:

$$MRE = \frac{|\text{ Actual quality} - \text{Predicted quality }|}{\text{Actual quality}}$$

The MRE value is calculated for each observation *whose* quality is predicted. The aggregation of MRE over multiple observations (N), can be achieved through the Mean MRE (MMRE) as follows:

$$MMRE = \frac{1}{N} \sum_{i}^{N} MRE$$

A complementary criterion is the prediction at level *l*, Pred (*l*) = k/N, where *k* is the number of observations where MRE is less than or equal to *l*, and *N* is the total number of observations. Thus, Pred (25) and Pred (5) gives the percentage of projects which were predicted with a MRE less or equal than 0.25 and 0.05 respectively.

RESEARCH METHODS

Metrics used

Software quality of a product is measured in terms of "fitness of purpose" (3) (12). That is, the more a product conforms to the requirements laid down in SRS document, the greater is its quality. The metrics have been used GUI, MEM and UM which served as input to the Fuzzy Logic System (19).

Description of metrics

1. GUI (Graphical User Interface): GUI was measured as the relative number of forms which were clearly displayed, on a scale of 0-10.

2. MEM (Meaningful Error Message): MEM was measured as the relative number of meaningful error messages displayed by the software, on a scale of 0-1.

3. ***UM (User Manual):*** UM was measured as the completeness of the user manual or help file, on a scale of 1-20.

The quality of the ultimate product (projects) has been judged by team of three experts who ranked the various projects on a scale of 50-100 and this served as the predicted output.

Data Gathered

The hundred and ten project developed by Post Graduate students during their final semester were evaluated for quality metrics. The snapshot of the projects are depicted in Table 1.

Table 1. Projects Id and metrics, Graphical User Interface (GUI): Meaningful Error Message (MEM), User Manual (UM), Software Quality (SQ) (ranks)

Sl No.	Project Id	GUI	MEM	UM	SQ
1	P1	0	0.5	9	75
2	P2	5	0.5	14	80
3	P3	1	0.4	8	72
4	P4	7	0.7	12	82
5	P5	7	0.7	16	82
6	P6	6	0.6	14	83
7	P7	7	0.8	18	91
8	P8	1	0.2	9	62
9	P9	7	0.5	14	82
10	P10	8	0.8	17	92

Multiple regression equation

Solving the System of linear equations (2),(3),(4) and (5) using three independent variables and data from Table 1 the equation (1) gives

SQ'=134.3 +11.35*GUI-69.32*MEM–5.37*UM ………. (6)

Therefore GUI, MEM as well as UM metrics are all useful to predict the software quality per project.

Fuzzy rules

The term fuzzy identification usually refers to the techniques and algorithms for constructing fuzzy models from data. The expert knowledge in a verbal form is translated into a set of **if–then rules.** A certain model structure can be created, and parameters of this structure, such as membership functions and weights of rules, can be tuned using input and output data. For our application, we have used the **Mamdani- type** fuzzy rule based system. Here a general rule has following format:

R_K : If(x_1 is A_{1k}) & (x_2 is A_{2k}) &…& (x_n is A_{nk}) then (y is B_k)

Where R_K is the k-th rule in the fuzzy rule base (k=1, 2,…k). Here A_{jk} and B_k are fuzzy sets on appropriate domains (j=1, 2,….,n)

This paper is based on the following fuzzy rules:

Rule 1: If GUI is low and UM is Small then SQ is low.
Rule 2: If GUI is average and UM is medium then SQ is Average.
Rule 3: If GUI is high and UM is big then SQ is high.
Rule 4: If MEM is low then SQ is low.
Rule 5: If MEM is average then SQ is average.
Rule 6: If MEM is high then SQ is high.

Input and output Membership Functions (MF) are depicted in Table 2. All are triangular and their scalar parameters (a, b, c) are defined as follows:

$$MF(x) = 0 \text{ if } x < a$$
$$MF(x) = 1 \text{ if } x = b$$
$$MF(x) = 0 \text{ if } x > c$$

Table 2. Membership Function Characteristics

Inputs

Variable Name	Range	MF	Parameters		
			a	b	c
Graphical User Interface	0-10	Low	0	2	4
		Average	2	4	6
		High	4	7	10
Meaningful Error Message	0-1	Low	0.1	0.25	0.4
		Average	0.3	0.5	0.7
		High	0.5	0.85	1
User Manual	1-20	Small	2	6	10
		Medium	8	11	14
		Big	12	16	20

Output

Variable Name	Range	MF	Parameters		
			a	b	c
Software Quality	50-100	Low	50	60	70
		Average	60	80	90
		High	80	90	100

The membership function plots corresponding to Table 2 are shown in Figures 2(a), 2(b), 2(c) and 2(d).

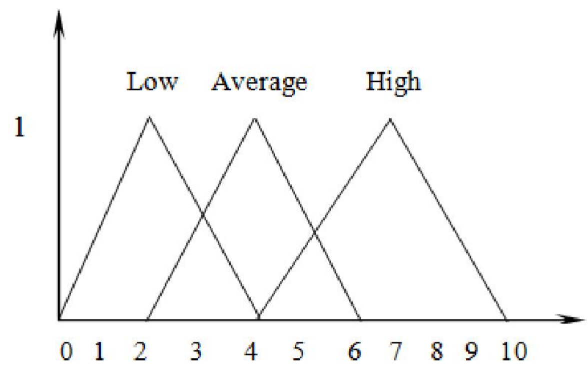


Figure (a). Graphical User Interface (input)

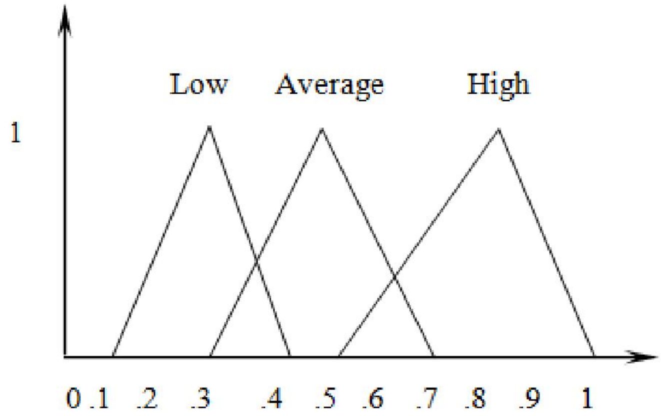


Figure (b). Meaningful Error Message (input)

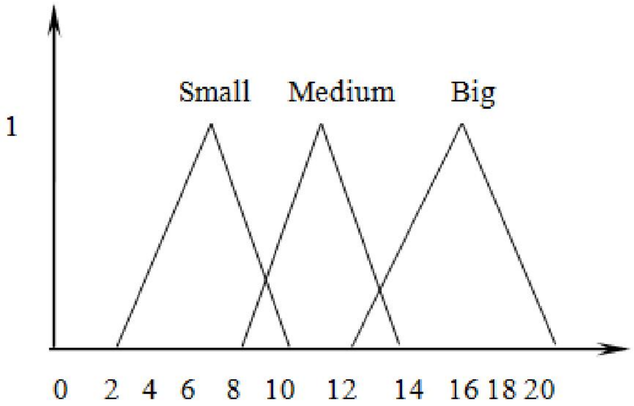


Figure (c). User Manual (input)

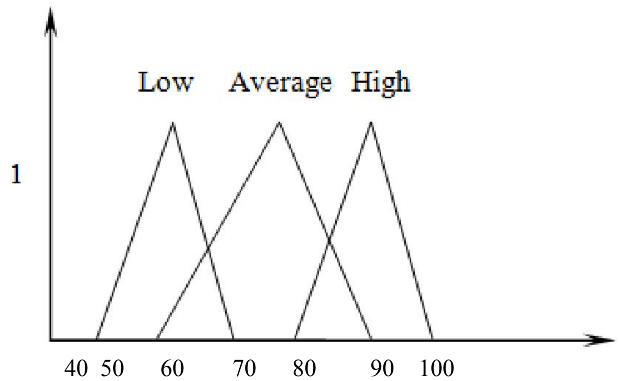


Figure (d). Software Quality (output)

Figure 2. Membership Function plots

Experimental results

Both multiple regressions (equation 6) and these fuzzy rules Systems are applied to same data subset. The **MRE** results are depicted in Table3.

Conclusion

This paper illustrates the practice of estimation at a personal level using small projects and presents the results obtained with a fuzzy logic system and an ordinary multiple regression. Results demonstrate that fuzzy logic can be used as alternative for estimating the software quality.

Table 3. **MRE comparison between estimation models**

Project Id	Actual SQ	Multiple Regression		Fuzzy Logic	
		SQ'	MRE	SQ'	MRE
P1	75	51.31	0.315	75.6	0.008
P2	80	81.21	0.015	80.3	0.004
P3	72	74.97	0.041	71.6	0.005
P4	82	100.81	0.229	82	0.000
P5	82	79.33	0.032	81.96	0.0005
P6	83	85.63	0.032	82.5	0.006
P7	91	61.69	0.322	90	0.010
P8	62	83.46	0.346	61.25	0.004
P9	82	103.91	0.267	81.96	0.0005
P10	92	78.36	0.148	91.5	0.005

Moreover, the pred (5), pred (25) and MMRE as given in Table4:

Table 4. Prediction Results

	Multiple Regression	Fuzzy Logic
MMRE	0.1747	0.0043
Pred(5)	0.4	1.0
Pred(25)	0.6	1.0

Result showed that the value of MMRE applying fuzzy logic is smaller than MMRE applying multiple regression; while the value of Pred (25) and Pred (5) applying fuzzy logic is higher than Pred (25) and Pred (5) applying multiple regression. Moreover one of the 10 MRE equal to zero using Fuzzy Logic(as shown in bold font in Table3).

Future research involves in collecting more data to serve as the basis of a generalized fuzzy tool for quality prediction. Additional parameters would be included in our future metrics for facilitating more accurate prediction.

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