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Prediction of Software Quality Using Hierarchical Fuzzy Rule Based System

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Abstrac : A field of study known as Software Quality Estimation analyses qualities based on estimates of comparable products from the past. It is necessary for these estimation methods to account for ambiguity and imprecision. As a result, soft computing methodologies are becoming increasingly prevalent. The results of a hierarchical fuzzy rules-based system that attempts to eliminate the need for fuzzy rules and conventional multiple regression are detailed in this article. It describes the process of generating personal estimates using initiatives. With the intention of diminishing the reliance on fuzzy rules and traditional multiple regression, Land presents the results obtained from a hierarchical fuzzy rule-based system .MMRE employing multiple regression produces a result that is lower in magnitude than MMRE employing a hierarchical fuzzy rule-based system; however, MMRE employing the latter produces a value that is higher in magnitude. When it comes to predicting the quality of software, fuzzy principles have been demonstrated to be a feasible option. The simulation results regarding the proposed method's effectiveness. MATLAB procedures have been executed utilizing a system based on hierarchical fuzzy rules. This illustrates that the quality of the software closely resembles that of the actual product.

Keywords: Software Quality Estimation, Fuzzy Rule based System , Hierarchical Fuzzy Rule based SystemMultiple Regressions.

I. . INTRODUCTION

Software Quality Prediction has been identified as one of the major difficulties in computer science [1][3]. Any one estimation approach or model should not be chosen over the others. Fuzzy logic could be a useful tool for estimating software development quality [2]. [4]. Several academics have employed soft computing approaches such as fuzzy logic and case based reasoning to estimate development cost and time in Software Engineering[5-19]

A hierarchical fuzzy rule-based system for software quality prediction is presented in this research study. Multiple Regression and Fuzzy Logic is used to compare the results further. Three metrics were used to create the model: Graphical User Interface (GUI), Meaningful Error Message (MEM), and User Manual (UM). The dataset was acquired from projects developed by Birla Institute of Technology postgraduate students.

A.Multiple-Regressions:

Multiple-regressions are defined as a linear equation with three unique variables as defined below.

$$y= b0+ b_1x_1 + b_2x_2 +b_3x_3 \quad (1)$$

whereb0, b1, b2 and b3 are constants; x1, x2 and x3 are the autonomous variables, and y is thedependent variable. The values of the multiple regressions Equation's b0, b1, b2, and b3 can be found by solving the following system of linear equations [26].

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

$$\Sigma x_1y = b_0(\Sigma x_1) + b_1(\Sigma_{x1}^2) + b_2(\Sigma x_1x_2) + b_3(\Sigma x_1x_{3)} \quad (3)$$

$$\Sigma x_2y = b_0(\Sigma x_2) + b_1(\Sigma x_1x_{2)} + b_2(\Sigma x_2^2) + b_3(\Sigma x_2x_3) \quad (4)$$

$$\Sigma x_3y = b_0(\Sigma x_3) + b_1(\Sigma x1x3) + b_2(\Sigma x_2x_3) + b_3(\Sigma x_3^2) \quad (5)$$

B. Fuzzy Rule Based System:

A fuzzy logic rule basedsystem is intended to govern a process with n inputs, such as I1, I2,...,In, and its input-output connection (fuzzy rules) can be defined by a function[12].

O=f(I1, I2,,…….,In)

Let us assume that each variable is represented by a 'm' number of fuzzy sets. Therefore, m^n fuzzy rules are to be designed to construct the Fuzzy rule based system[8][19]. It is observed that as the number of rules increases exponentially with the number of variables, complexity of an algorithm and difficulties associated with controlling a process will increase. This problem of rule explosion becomes difficult to develop Fuzzy rule based system for solving complex real world problems having many variables. Wecan resolve this problem by using Hierarchical Fuzzy Rule Based System[20][22].The proposed fuzzy rule based system has three fuzzy inputs, namely Graphical User Interface (GUI), Meaningful Error Message (MEM), and User Manual (UM), and one output, Software Quality (SQ), as illustrated in "Fig 1."

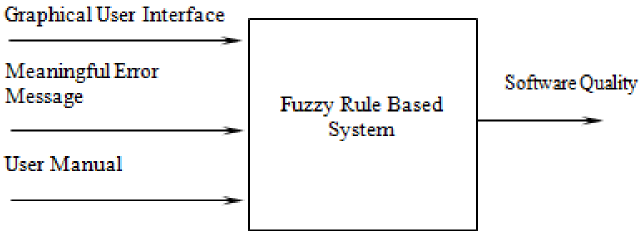

Fig.1. Fuzzy Rule Based System

C.Hierarchical Fuzzy Rule Based System:

In Hierarchical Fuzzy Rule Based System high dimensional fuzzy rule base systems (FLS) are to be designed by combination of low dimensional fuzzy rule base systems as represented in below"Fig 2".

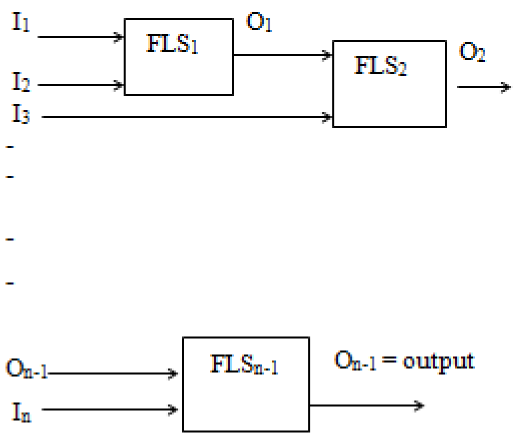

Fig 2. Hierarchical fuzz rule based system

There are 'n' input variables and (n- 1) fuzzy rule base systems. Two inputs I1 and I2are fed into FLS1 to get output O1. This output O1 and another input variable I3 are fed into FLS2 to get output O2. This process is continued until all inputs are consumed. Here, we consider two input variables for each FLS and each variable has a 'm' number of fuzzy sets, hence $1.m^2$ fuzzy rules used for the first FLS. Thus $(n-1)m^2$ fuzzy rules are required to design complexity of FLS, which indicates that number of rules of hierarchical FLS increases linearly in the number of variables entered as input.

There are three fuzzy inputs for a proposed hierarchical fuzzy rule based system (1)Graphical User Interface (GUI), (2)Meaningful Error Message (MEM) (3)User Manual (UM) and One output Software Quality (SQ)[23][24] as displayed in" Fig 3".

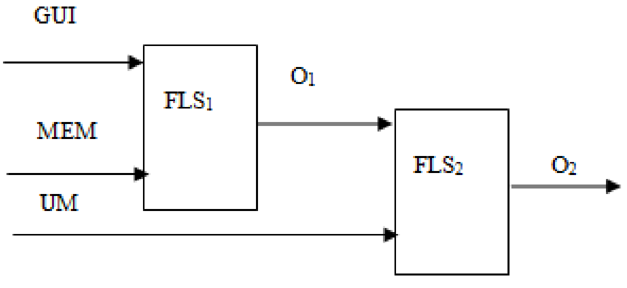

Fig. 3. Proposed hierarchical fuzzy rule based system

D. Evalua tion Criteria:

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

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

Where the quality is predicted, the MRE value of each observation is determined. The use of the Mean MRE (MMRE) as shown below can be used to combine MRE over several observations (N):

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

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, is a complementing criterion[10]. As a result, Pred (25) and Pred (5) represent the percentage of projects anticipated with an MRE of less than or equal to 0.25 and 0.05, respectively

The rest of the paper is organized as follows: Section II gives the Research Method Section III presents the Experimental Results Section IV presents the Conclusion and. Section V acknowledgement

II. RESEARCH METHOD

A. Metrics Used

Portability, usability, reusability, correctness, maintainability and other software quality components can be specified. This work focuses on software usability and metrics that were designed and/or adapted from Pal and Bhattacherjee [8][19][23], who built a Fuzzy Logic System for software quality prediction[24].

Description of metrics:

1. *GUI (Graphical User Interface):*The number of forms that were clearly shown by the software was measured on a scale of 0 to 10 for GUI.

2. *MEM (Meaningful Error Message*): On a scale of 0 to 1, MEM was defined as the number of serious error messages displayed by the software..

3. *UM (User Manual*):The completeness of the user manual or help file was rated on a scale of 1 to 20.

The quality of the end product (projects) was assessed by a group of three experts who graded the various projects on a scale of 50 to 100 to determine whether they delivered the expected results [23].

B. Data Collected

The hundred and ten projects are used to collect the data. A snapshot of the dataset related to them is depicted in Table 1.

TABLE1 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	P 1	0	0.5	9	75
2	P22	5	0.5	14	80
3	P 33	1	0.4	8	72
4	P41	7	0.7	12	82
5	P 52	7	0.7	16	82
6	P 60	6	0.6	14	83
7	P71	7	0.8	18	91
8	P 82	1	0.2	9	62
9	P 93	7	0.5	14	82
10	P100	8	0.8	17	92
11	P 101	7	0.5	15	90
12	P 102	5	0.8	18	89
13	P103	5	0.4	11	75
14	P 104	2	0.2	12	61
15	P 105	5	0.2	12	75
16	P106	1	0.4	7	59
17	P 107	9	0.5	14	89
18	P 108	6	0.4	12	81
19	P 109	9	0.8	18	91
20	P110	3	0.6	13	76

Input and output Membership Functions (MF) [25]are portrayed in Table 2.

TABLE 2: MEMBERSHIP FUNCTION CHARACTERISTICS

Inputs

Variable Name	Range	MF	Parameters		
			a	b	c
Graphics 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

Outputs

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

C. Multiple Regression

Using three independent variables and data from Table 1 to solve the system of linear equations(2), (3), (4) and (5),the equation (1) gives

$$SQ' = 134.3 + 11.35*GUI - 69.32*MEM - 5.37*UM \quad (6)$$

As a result, GUI, MEM, and UM.metrics can all be used to forecast software quality in a project.

D. Fuzzy Rules

Mamdani-type fuzzy rule based system is used in this research paper. 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)

The initial fuzzy rule base consists of $3^3 = 27$ rules.[9]In this paper usingHierarchical fuzzy rule based system ,we have obtained 18((3-1)*3²) fuzzy rules as follows:

Rule 1: If GUI is low, MEM is low and UM is Small then SQ is low.

Rule 2: If GUI is low, MEM is low and UM is medium then SQ is low.

.Rule 3: If GUI is low, MEM is averageand UM is small then SQ is low.

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Rule 16: If GUI is average, MEM is low and UM is small then SQ is low.

Rule 17: If GUI is average, MEM is low and UM is medium then SQ is low.

Rule 18: : If GUI is high, MEM is low and UM is medium then SQ is average.

III. EXPERIMENTAL RESULTS

On the same data subset, multiple regressions (equation 6) and Hierarchical fuzzy Rule based System are used. Table 3 shows the outcomes of the MRE.

TABLE 3: MRE COMPARISON BETWEEN ESTIMATION MODELS

Project Id	Actual SQ	Multiple Regression		Hierarchicalfuzzy Rule based System	
		SQ'	MRE	SQ'	MRE
P1	75	51.31	0.315	75.6	0.008
P22	80	81.21	0.015	80.3	0.004
P33	72	74.97	0.041	71.6	0.005
P41	82	100.81	0.229	82	**0.000**
P52	82	79.33	0.032	81.96	0.0005
P60	83	85.63	0.032	82.5	0.006
P71	91	61.69	0.322	90	0.010
P82	62	83.46	0.346	61.25	0.004
P93	82	103.91	0.267	81.96	0.0005
P100	92	78.36	0.148	91.5	0.005
P101	90	60.89	0.323	90	**0.000**
P102	89	60.72	0.318	89	**0.000**
P103	75	51.31	0.315	75.6	0.008
P104	61	82.66	0.355	60.76	0.004
P105	75	51.31	0.315	75.6	0.008
P106	59	81.89	0.388	59	**0.000**
P107	89	60.72	0.318	89	**0.000**
P108	81	78.98	0.025	81	**0.000**
P109	91	61.69	0.322	90	0.010
P110	76	52.65	0.307	76.4	0.005

Further, we have compared our proposed method with the existing method[19] as shown in Table4.

TABLE4: COMPARISION BETWEEN CONVENTIONAl FUZZY RULE BASED SYSTEM AND HIRARCHICAL FUZZY RULE BASED SYSTEM

Project Id	Actual SQ	Conventional Fuzzy Rule based System		Hirarchical Fuzzy Rule based System	
		SQ'	MRE	SQ'	MRE
P1	75	75.6	0.008	75.6	0.008
P22	80	80.3	0.004	80.3	0.004
P33	72	71.6	0.005	71.6	0.005
P41	82	82	**0.000**	82	**0.000**
P52	82	81.96	0.0005	81.96	0.0005
P60	83	82.5	0.006	82.5	0.006
P71	91	90	0.010	90	0.010
P82	62	61.25	0.004	61.25	0.004
P93	82	81.96	0.0005	81.96	0.0005
P100	92	91.5	0.005	91.5	0.005
P101	90	89.6	0.004	90	**0.000**
P102	89	88.86	0.002	89	**0.000**
P103	75	75.6	0.008	75.6	0.008
P104	61	61	**0.000**	60.76	0.004
P105	75	75.6	0.008	75.6	0.008
P106	59	59	**0.000**	59	**0.000**
P107	89	88.79	0.002	89	**0.000**
P108	81	79.89	0.014	81	**0.000**
P109	91	90	0.010	90	0.010
P110	76	75.81	0.007	76.4	0.005

Moreover, the pred (5), pred (25) and MMRE as given in Table5.

TABLE5: PREDICTION RESULTS

	Multiple Regression	Conventional Fuzzy Rule based System	Hirarchical Fuzzy Rule based System
MMRE	0.2367	0.0049	0.0039
Pred(5)	0..25	0.15	0.1
Pred(25)	0.35	1.0	1.0

IV.CONCLUSION

This study uses minor projects to demonstrate that in a traditional fuzzy rule based system, if there are 'n' input variables and each variable has m fuzzy sets, the number of fuzzy rules is m^n, however in a hierarchical fuzzy rule based system, the number of fuzzy rules is (n-1)m2. The results show that a hierarchical fuzzy rule-based system can be utilized to estimate software quality as an alternative. Also, because the number of fuzzy rules is minimized, we may reduce the complexity of the design of the fuzzy rule based system by adopting our proposed Hierarchical fuzzy rule based system.

The value of MMRE using Hierarchical Fuzzy Rule based System is lower than that of MMRE using multiple regression and Conventional Fuzzy Rule based System, while the value of Pred(25) and Pred(5) using Hierarchical Fuzzy Rule based System is higher than that of Pred(25) and Pred(5) using multiple regression. Furthermore, utilizing the Hierarchical Fuzzy Rule Based System, six of the twenty MRE are equivalent to zero (as shown in bold font in Table 4). Additional parameters from future study would be added in our future measures, allowing for more precise prediction..

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