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A Novel Interval Type-2 Fuzzy Software Effort Estimation Using Takagi-Sugeno Fuzzy Controller

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Abstract: *Software effort estimation is the process of estimating the cost and time required for the development of software system. Resource allocation and bidding are major parts of planning in software projects. The main objective of the plan is to scout for the future and diagnose the attributes the consummation of successful projects. So, to meet the challenges of cost estimation time in the software development, effective software is required. This paper introduces a novel model of fuzzy logic estimation effort in software development. My paper touches up on MATLAB for tuning parameters of famous various cost estimation models. It also uses published software projects data, performance of the model and the comparison between my novel model and existing ubiquitous models.*

Key words: *Fuzzy Logic, Effort Estimation, KLOC, COCOMO, Fuzziness, Membership Function.*

I. Introduction

Software estimation is the process of predicting the amount of time (effort) that is required to build a software system. The cost benefit analysis is performed with cost estimation process which is achieved in terms as person-months (PM) and can be translated in to actual dolor cost. Estimation carries inherent obscurity risks. The concept of software cost estimation has been growing rapidly these days. Due to globalization, people expect high quality software with a low cost though so many models came into existence like COCOMO81, COCOMOII, SLIM, FP, Delphi, Halsted Equation, Bailey-Basili, Doty, and Anish Mittal Models. Recent surveys repeat says that software projects overrun the cost estimation, which is found in the actual data.
COCOMO II is the model is used to estimate the cost as products in many software companies but in vain due to the some variations in models [2], [5-10]. We also can find several problems like unrealistic over-optimum, complexity, and overlooked tasks [11], [12]. So, to overcome all these problems in software development, new models are approached which researchers showed attention in 1990's. They are artificial neural networks, fuzzy logic models and genetic algorithms. Out of these models fuzzy logic is the best powerful linguistic representation with exact inputs and outputs. It is also based on model building with logic concepts introduced by Lofti A. Zadeh [3], [4], [13].

1.1Membership Functions

Fuzzy numbers are 3 types they are 1) Triangular fuzzy number 2) Trapezoidal fuzzy number 3) Bell shaped fuzzy number. Fuzzy numbers are used to describe the vague data obscurity and imprecision. A fuzzy number is a extension of a regular number that does not refer to one single value but connected to set of possible values which weights between '0' and '1'. This weight is called the membership function. It increases towards the mean and decreases away from it.
Membership function is characterized by fuzziness in a fuzzy set. It is a curve that defines how each point in the input space is mapped to a membership value between 0 and 1. It may exists different graphical representations but they are certain restrictions regarding shaped to be considered effectively.

Gaussian Bell shape (Figure 1)
It is defined by its mid value m and the value of k>0. The greater k is, the narrower the bell.
G(x)= e^(⟦-k(x-m)⟧^2) … (1)

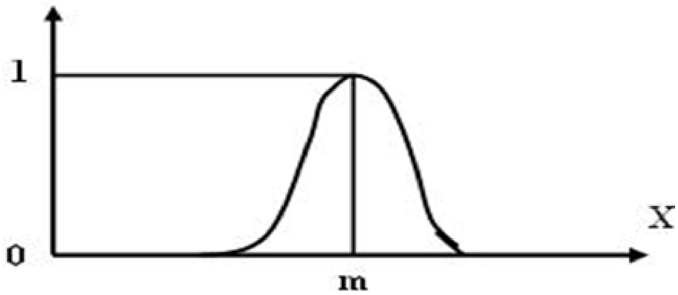

Fig 1: **Gaussian Bell Shape**

II. COST ESTIMATION MODELS LITERATURE REVIEW

Within last few decades, to improve the accuracy of cost estimation many software cost estimation models [2], [6-10] were introduced. It seems to be impractical because of the inherent obscurity in software development projects and the impact of software development cost use. Still, it is likely that the estimation can be improved because software development cost estimates are systematically overoptimistic and very inconsistent. The primary objective of the software engineers has been to develop required models using which software cost can be accurately estimated. Estimation models use KDLOC (Thousands of Delivered Lines of Code) as the primary input. This input is not sufficient for accurately estimating the cost of products. Several other parameters have to be considered.

2.3 Doty: [1]

Effort = 5.288(KLOC)1.047 … (2)
Halsted Equation:
Effort = 5.2 (KLOC)1.50 …(3)
Bailey-Basili:
Effort = 5.5 + 0.73 (KLOC)1.16 … (4)

2.4 Mittal Model: [1]

2.5 Harish model1

Fuzzification: u(E) =

$$\begin{cases} 0 & \text{if } E \le a\alpha^b \\ \frac{\left(\frac{E}{a}\right)^{1/b} - \alpha}{m - \alpha} & \text{if } a\alpha^b \le E \le am^b \\ \frac{\beta - \left(\frac{E}{a}\right)^{\frac{1}{b}}}{\beta - m} & \text{if } am^b \le E \le a\beta^b \\ 0 & \text{if } E \ge a\beta^b \end{cases} \quad ..(5)$$

Defuzzification: $E = \frac{\left(w1\left(a\alpha^b\right) + w2\left(am^b\right) + w3\left(a\beta^b\right)\right)}{(w1 + w2 + w3)}$ … (6)

2. 5 Harish model1

$$Effort\ (E) = \frac{w_1\left(a\alpha^b\right) + w_1\left(am^b\right) + w_1\left(a\beta^b\right)}{w_1 + w_2 + w_3} \quad \ldots(7)$$

Where a=3.41, b=0.795, m represents size in KLOC

$\alpha = \left(1 - \frac{2KF}{k+1}\right)$*m

$\beta = \left(1 + \frac{2F}{k+1}\right)$*m

K,f,w1,w2 and w3 are arbitrary constants.

The effort is obtained in man months (MM). optimization of effort for an application is done by a suitable choice of arbitrary constants.

Harish model2

$$Effort\ (E) = \frac{w_1\left(a\alpha^b\right) + w_1\left(am^b\right) + w_1\left(a\beta^b\right)}{w_1 + w_2 + w_3} + c(ME) + d \quad \ldots (8)$$

Where a=3.41, b=0.795, m represents size in KLOC

$\alpha = \left(1 - \frac{2KF}{k+1}\right)$*m

$\beta = \left(1 + \frac{2F}{k+1}\right)$*m

K,f,w1,w2 ,w3, c and d are arbitrary constants.

ME is methodology of the project.

The effort is obtained in man months (MM). optimization of effort for an application is done by a suitable choice of arbitrary constants.

III. Proposed Model

Interval Type-2 GMF (A,M,B) Firing Intervals:

$J_{PX} = [\frac{\mu PL_1 + \mu PL_2}{2}, \frac{\mu PR_1 + \mu PR_2}{2}]$

$= [\mu_p(x_i). \mu_p(x_i)]$ … (9)

$J_{Nx} = [\frac{\mu NL_1 + \mu NL_2}{2}, \frac{\mu NR_1 + \mu NR_2}{2}]$ …(10)

$= [\mu_N(x_i). \mu_N(x_i)]$

Defuzzification:

In this model we considered centroid method (weights average), which is of the form [11]

$$C = \frac{\sum_{i=1}^{N} w_i\, \mu_i}{\sum_{i=1}^{N} w_i} \quad \ldots (11)$$

.

IV. EXPERIMENTAL STUDY:

For the membership functions the L value is the mean of the input sizes i.e. 207.3385 and stddev() is 186.3325 (L1=393.671, L2= 21.006). By applying exponential regression [www.xuru.org] analysis for the input sizes and effort we obtained a=70.737 and b=0.004.

By applying Gaussian membership function for the membership functions the left and right boundaries are [μ_P (α, m, β), μ_N(α, m, β)] measured with α=0.9m and β=1.1m.

Foot print of uncertainty intervals for the μ_P is [0.501212 to 0.612593] for left hand side i.e LMF and [0.9 to 1.1] for right hand side i.e UMF. Foot print of uncertainty intervals for the μ_N is [0.13737 to 0.167896] for left hand side i.e LMF and [0.206148 to 0.251959] for right hand side i.e UMF. The means of FOU intervals is taken as firing strength.

JPx = [μ_p (X_i), μ_p (X_i)] =[0.556903, 1]

JNx= [μ_N (X_i), μ_N (X_i)] =[0.152633, 0.229054]

The type reducer action by using the Guassian membership function and defuzzification is done through centroid method and results shown in the table II.

V. Research Methodology

The performance of proposed software effort estimation model is evaluated by comparing against various software cost estimation models. The methodology used in empirical evaluation is described as follows:

- For each model, using MRE we evaluate the impact of estimation accuracy using (MARE, VARE) evaluation criteria.
- Criterion for measurement of software effort estimation model performance.

MARE (%) =

mean ($\sum_{i=1}^{n}(\left|\frac{estimate_i - actual_i}{actual_i}\right|)$)* 100 … (12)

VARE (%) =

var ($\sum_{i=1}^{n}(\left|\frac{estimate_i - actual_i}{actual_i}\right|)$)*100 … (13)

Where $estimate_i$ is the estimated effort (E) from the model, $actual_i$ ($\hat{E}$) is the actual effort and n is the number of projects.

VI. Model Results & Discussion

S.No	Size	Actual Effort	Doty Model	Baili-Basili Model	Walston Felix	Harish Model1	Harish Model2	Mittal Model	Hari Model	Swarup Model3
1	39	72	245	56.663212	19.632103	71.792824	84.542824	68.34707	59.566984	77.778217
2	40.5	82.5	254.9	58.952828	20.318054	71.803662	84.553662	70.08411	61.080874	78.070043
3	50	84	317.8	73.753993	24.612784	71.86421	84.61421	80.62635	70.268827	79.956785
4	128.6	230.7	854.4	209.69372	58.144323	72.13628	84.88628	151.11487	131.70216	98.438093
5	161.4	157	1083.8	271.26082	71.497401	72.201861	84.951861	175.7591	153.18051	107.92207
6	164.8	246.9	1107.8	277.76588	72.8667	72.207882	84.957882	178.21264	155.31886	108.97411
7	200	130.3	1356.7	346.31418	86.903113	72.263817	85.013817	202.69681	176.65771	120.70049
8	214.4	86.9	1459.1	374.93974	92.579022	72.283916	85.033916	212.28849	185.01721	125.96762
9	253.6	287	1739.5	454.38593	107.86334	72.332483	85.082483	237.36748	206.87447	141.85708
10	254.2	258.7	1743.9	455.61812	108.09554	72.333167	85.083167	237.74079	207.19983	142.11919
11	289	116	1994.6	527.85332	121.48288	72.370299	85.120299	258.91608	225.65487	158.39588
12	449.9	336.3	3170.3	878.34557	181.73292	72.498537	85.248537	347.52344	302.87943	269.58085
13	450	1107.31	3171.1	878.57062	181.76967	72.498601	85.248601	347.5748	302.9242	269.67358

Table 1: Effort of various models

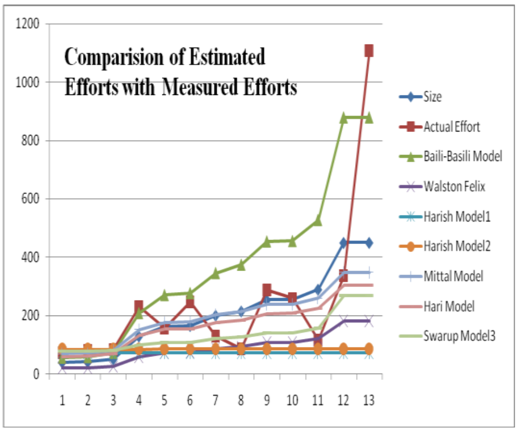

Fig 2: Measured Effort Vs Estimated Efforts of various Models

Comparison of various models on the basis of various performance criterions for software cost estimation is given in below Table 2. Figure 6 below shows the Mean Absolute Relative Error (%) comparison of various models.

Table 2: Various Models MARE % Values

Model Type	MARE %
Doty Model	8186.1
Bailey-Basili	1325
Walston-felix	713.3
Harish Model1	638.8
Harish Model2	563.3
Mittal Model	518.7
Hari Model	515.3
Swarup Model3	442.7

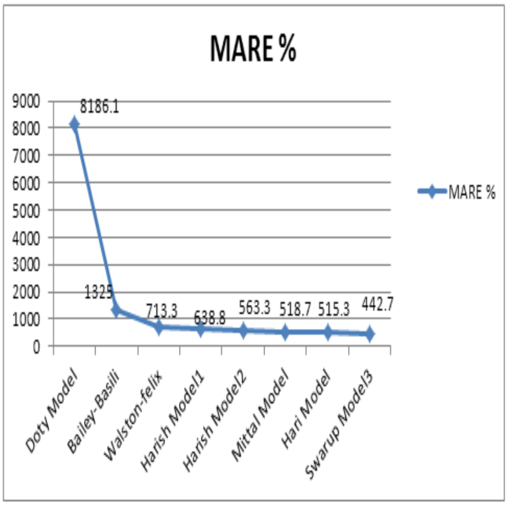

Fig 3: MARE (%) Comparison of various models

VII. Conclusion

Software development life cycle is important for project managers are to estimate the accuracy and reliability at the early stages of software development. This paper postulates about the fuzzy software cost estimation model and with other popular software cost estimation models. It concludes by empirical evaluation of better software effort with proposed and traditional estimation models by MARE evaluation criteria. To identify the problem of obscurity and vagueness that are existed in software effort drivers' fuzzy logic methods are applied. This proves the fuzzy logic application is used in software engineering successfully.

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