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Software Effort Estimation Based on Use Case Point (Fuzzy Logic)

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***Abstract*— Software cost estimation is a crucial part of the software project initiation process.**
Cost estimation plays an important role in the bidding/budgeting and help managers to use their resources at the maximum output level. Software Project failure rate is very high in case the project cost estimation is not done by taking all the important factors into the consideration. So finding the cost at the initial level is an important and challenging task and need great attention. Software cost estimation help in the risk analysis task and also avoids the underestimation/overestimation of the projects. It saves projects from late delivery or further cancelation.

This paper discusses an improved method of finding cost, based on Use Case Point (UCP) and using the soft computing method called the fuzzy logic. Here it is also applied on a live project to show the estimation improvement.

***Keywords*- Cost Estimation; budgeting; Use Case Point (UCP); Fuzzy Logic; Soft Computing**

I. INTRODUCTION AND BACKGROUND

Day by day the role of software is becoming vital in the every sector of the society. Now the interaction is getting invoked through the software only and for every small or big service we all have to use the software. As the use of software is increasing the need of fast, accurate and cost effective way of software development is required. More and more people are opting the software development as a profession and so providing a cost effective and timeline based software estimation to the client at the initial level is very crucial for the business.
Project management will be better if the estimation task is done at the early stage of the software development life cycle.

For better project management early estimation is required but the accuracy of the estimation is again very crucial. If the estimation work is not done correctly it may led to the project overestimation/underestimation. Both overestimation and underestimation of the project assure great chance of the project failure. There is so many examples found where million of dollar and time wasted due to incorrect estimation of the project.

The International Society of Parametric Analysis (ISPA) [1] and the Standish Group International [2] identified poor estimation as one of the main culprits behind software failure.

Due to the importance of the cost estimation at the early stage of the software development there are so many methods available to find the estimation at the initial stage.

This paper discuss the fuzzy logic approach [3] and apply it to find if the fuzzy logic approach is proved to be a more improved approach of finding cost estimation at the early stage of software development life cycle using Use Case Point (UCP) .

The one of the method proposed by Karner[4] which is based on the use case diagram called Use Case Point (UCP). In this method the estimation is based on the count of number of use cases and actors which are multiplied by their complexity weights.
The complexity of any use case is find by the total number of transaction in the success and extension scenarios of the use case. Table 1 and Table 2 respectively shows the complexity rates of the use case and actors.

The UCP is calculated through two stages: Unadjusted Use Case points **(UUCP)** and the Adjusted Use Case Points **(UCP)**. The formula for UCCP given in the Equation [1]

$$UUCP = \sum_{i=1}^{6} n_i * w_i \qquad \text{Equation [1]}$$

Here n_i is either Actor or Use Case and w_i is the respective weight.
For calculating the UCP, Technical Factors (**TFs**) and Environmental factors (**EFs**) has to be calculated.
TF is the measure of the degree of the complexity and EF indicate the degree of the efficiency of the system.
Table 3 and Table 4 shows the TF and EF.
Formula for calculating TF is as follows in the Equation [2]:

$$TF = C1 + C2 \sum_{i=1}^{13} F_i * W_i$$ Equation [2]

Where C1 = 0.6, C2 = 0.01 and F_i is a factor that range between 0 and 5. If the value is “0” then the factors is completely irrelevant but if it is “5” then it is the essential one. If the value is “3” then it is the average factor i.e. not essential nor irrelevant.

Formula for calculating EF is as follows in the Equation [3]:

$$TF = C1 + C2 \sum_{i=1}^{8} F_i * W_i$$ Equation [3]

Where C1 = 1.4, C2 = -0.03 and F_i is the same as explained above in the formula of EF.

Calculation for the adjusted use case points (UCP) is as follows in the Equation [4]:

UCP = UUCP × TF × EF Equation [4]

TF can have the maximum value 1.3, if the value of all technical factors is set to 5.

As per Karner, the software effort is calculated as follows in the Equation [5]:

Effort = Size × 20 Equation [5]

Where size: Calculated software size in UCP and the effort is measured in person-hours.

Table 1: Weighted Use Cases

Use Case Complexity	Weight	Number of Transactions
Simple	3 or fewer	5
Average	4 to 7	10
Complex	More than 7	15

Table 2: Weighted Actors

Actor Complexity	Description	Weight
Simple	Through an API	1
Average	Through a text-based user interface	2
Complex	Through a GUI	2

Table 3: Technical Factors

Fi	Factors contributing to complexity	Wi
F1	Distributed systems	2
F2	Application performance objectives	1
F3	End user efficiency	1
F4	Complex internal processing	1
F5	Reusability	1
F6	Easy installation	0.5
F7	Usability	0.5
F8	Portability	2
F9	Changeability	1
F10	Concurrency	1
F11	Special security features	1
F12	Direct access for third parties	1
F13	Special user training facilities	1

Table 4: Environmental Factors

Fi	Factors contributing to efficiency	Wi
F1	Familiar with Object	1.5
F2	Stable requirements	2
F3	Analyst capability	0.5
F4	Application experience	0.5
F5	Object oriented experience	1
F6	Motivation	1
F7	Difficult programming language	-1
F8	Part-time workers	-1

II. Problem Definition

The estimation approach given by the karner however has some limitation or drawbacks.

The main drawback of this approach is that the graduation is completely avoided while assigning/classifying complexity to the use case. It can be understood by taking an e.g. like if the number of transaction in a use case is 3 then it is classified as simple which carry the weight 5 but if the number of transaction in a use case exceed just by one transaction which is 4 then the classification changes from simple

to average and the weight shifted from 5 to 10. In a simple practical example if any project1 having 5 use case each of three transaction and there is another project2 having 5 use case each of four transaction then the size of project 2 will be double then the size of project1 which is practically not true.
In the similar way the use case of 8 transactions have the same complexity factor of any use case of 21 transactions which is again practically not acceptable.

A new approach was given by Ali Bou Nassif [3] to overcome this limitation of the UCP.
The use case will be classified as ux, such as x∈ [1, 10] where x represents the number of transactions.
This concludes that there will be ten degrees of complexity for use cases (u1, u2, u3, etc.).
Applying this approach facilitate taking the weight value falling in the classified range of Simple, average and complex. This approach gives more realistic estimation.

III. Related Work, Implementation and Evaluation

Fuzzy Logic: The one of the soft computing approach Fuzy logic which is derived from the fuzzy set theory which was proposed by Lotfi Zadeh [5].

The fuzzy logic is different from the conventional binary logic. In the binary approach the value can be either True(1) or False(0) but in fuzzy approach the value between 1 and 0 is considered including 1 and 0.

It may be explained as the one element can completely belong to one particular set or may not completely belong to a set or may partially belong to a set. So all the three situation is possible in fuzzy logic approach which is not possible in binary approach where the element can either completely belong to a set or may not completely belong to a set. The mid way is not possible.

A fuzzy set A can be represented mathematically by a membership function as follows in Equation [6]

$$FZ[x \in A] = \mu_A(x): R \rightarrow [0,1] \quad \text{Equation [6]}$$

Where μ_x = Degree of the membership of element x in the fuzzy set A.

The knowledge based in fuzzy logic is represented by if-then rule. Fuzzy rule applied to make inferences and associations among members in different groups.
The fuzzy logic rule for the use case is given below and the weight shown in the Table5.

Fuzzy Logic Rules:

If Input = 2 transactions then output = 5
If Input = 6 transactions then output = 10
If input = 10 transactions then output = 15

Table5 : Weight Table

Use case contains	Karner's weight	Adjusted weight
1 transaction	5	5
2 transactions	5	5
3 transactions	5	6.45
4 transactions	10	7.5
5 transactions	10	8.55
6 transactions	10	10
7 transactions	10	11.4
8 transactions	15	12.5
9 transactions	15	13.6
10 transactions	15	15

Evaluation Criteria and Implementation

Mean of the Magnitude of Relative Error (MMRE)
MMRE: This is a very common criterion used to evaluate software cost estimation models [6]. The Magnitude of Relative Error (MRE) for each observation i can be obtained as Equation [7]

$$MRE_i = \frac{|\text{Actual } Effort_i - \text{Predicted Effort}_i|}{\text{Actual Effort}_i}$$

Equation [7]

MMRE can be achieved by summing up MRE over N observations as given in Equation [8]:

$$MMRE = \frac{1}{N}\sum_{1}^{N} MRE_i \quad \text{Equation [8]}$$

Mean of Magnitude of error Relative to the Estimate (MMER)

MMER: MMER is another method for cost estimation models evaluation [7]. MER is similar to MRE with a difference that the denominator is the predicted effort instead of the actual effort. Consequently, the equations for MER and MMER are Equation [9] and Equation [10] respectively:

$$\mathrm{MER_i} = \frac{|\mathrm{Actual}\ Effort_i - \mathrm{Predicted\ Effort_i}|}{\mathrm{Predicted\ Effort_i}}$$

Equation [9]

$$\mathrm{MMER} = \frac{1}{N}\sum_{1}^{N} \mathrm{MER_i}$$

Equation [10]

When using the MMRE and the MMER in evaluation, good results are implied by lower values of MMRE and MMER.

Mean Error with Standard Deviation
Although MMRE and MMER have been used for a long time, both methods might lack accuracy. If the actual effort was small, MMRE would be high. On the other hand, if the predicted effort was low, MMER would also be high. Foss et al. argued that MMRE should not be used when comparing cost estimation models and using the standard deviation would be better [8]. The standard deviation method was first proposed by Karl Pearson [9]. The equation for the mean error for each observation i and total number of observations N is given as in Equation [11]:

$$\bar{\mathrm{x}} = \frac{1}{N}\sum_{i=1}^{N} x_i$$

Equation [11]

Where

$$x_i = (\mathrm{Actual}\ Effort_i - \mathrm{Predicted\ Effort_i})$$

The equation for standard deviation is given as Equation [12]:

$$\mathrm{SD}=\sqrt{\frac{1}{N-1}\sum_{i-1}^{N}(x_i-\bar{x})^2}$$

Equation [12]

The mean error with standard deviation can be represented as Equation [13]:

$$\bar{x} \pm SD$$

Equation [13]

The implementation is done on a live online tender publication software project.

The use case for the project can be given as below:

Use Case Title: Online publication of Tender

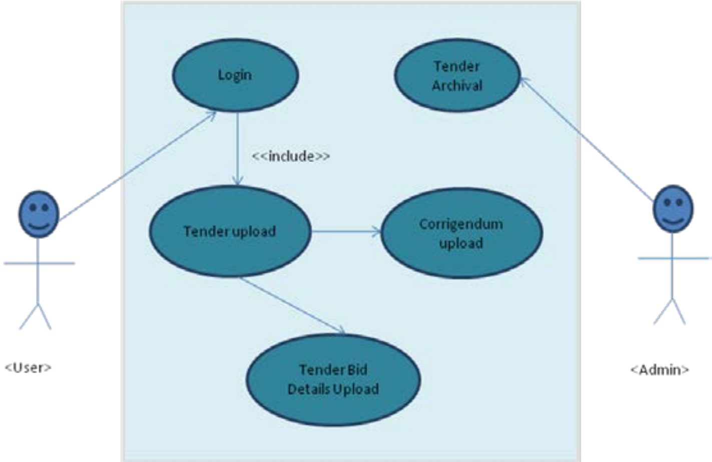
Actors: Registered User, Administrator

Precondition: The user must have submitted the registration form and it is approved by the authority and allotted the userid and password for login on Tender Portal for publishing Tender.

Main Success Scenario (Main Flow):
1. The registered user login into the portal and fill all the detail regarding the tender for eg. tender location, tender value, start date of application, end date of application etc
2. Systems validate all the fields entered.
3. The registered user successfully published the tender

Extensions (Alternative)
2a: The user is not registered on the portal
2a1: Notify the user to contact the administrator
2b: The last date of tender submission has been passed or the tender value is not correct or any other field has not received the allowed value

Post condition: The registered user published the tender on the tender portal



Figure[1] : Use case Diagram for online Tender Publishing System

In the figure[1] use case diagram for for online tender publication has been shown. The 7 different module of online tender portal has been taken into account and the UUCP and MMRE has been calculated using the karners method and the proposed fuzzy method using the weight Table [6].

Table [6]: Implementation Data

Project	Actual Size UUCP	Karner's Estimation	Proposed Model (Fuzzy)	MRE Karner	MRE Fuzzy Logic	MER Karner	MER Fuzzy Logic	Error Karner (Karner–Actual)	Error Fuzzy (Fuzzy – Actual)
Tender Module 1	72.44	128.96	104.98	0.78	0.45	0.44	0.31	56.52	32.54
Tender Module 2	74.33	128.54	108.65	0.73	0.46	0.42	0.32	54.21	34.32
Tender Module 3	55.5	51	48.7	0.08	0.12	0.09	0.14	-4.5	-6.8
Tender Module 4	68	108.5	92.4	0.6	0.36	0.37	0.26	40.5	24.4
Tender Module 5	48.75	74.25	61.25	0.52	0.26	0.34	0.2	25.5	12.5
Tender Module 6	94.5	168.75	144	0.79	0.52	0.44	0.34	74.25	49.5
Tender Module 7	72.5	108.41	92.44	0.5	0.28	0.33	0.22	35.91	19.94
Mean				0.57	0.35	0.35	0.26	40.34	23.77
Standard Dev								25.33	17
Improvement				+22%	+9%				

This experiment shows that the proposed Fuzzy model is gaining advantage over the Karner's estimation technique.

IV. Conclusion and Future Work

The use case Points estimation model has been widely used as this is simple, fast, near to accuracy and can be made automated up to some extent.

By using fuzzy logic it is been observed that the estimation accuracy can be improved up to 22%.

Future work will focus on the improved use case model which allows including "extend" and "include" use cases.

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