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A Novel Approach for Early Software Operational Profile Estimation

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Abstract

One of the important features of any software system is its operational profile. Software operational profile is an important facet of software testing. Software operational profile is used to test most used functions/operations and provide them prior testing. Therefore it is required to proper estimate it. Moreover Software Operational Profile requires huge amount of data for estimation. Also it could be available only in later phase. To improve performance in software testing process, this article presents a novel approach for software operational profile estimation in early phase. This estimation requires usage profile and criticality profile for optimal function prioritization. We need to calculate theses parameters prior to testing. Function's usage is defined by membership function based on human intuition and user's opinion is defined by linguistic approach. Usage profile is calculated by aggregating support among users. Function's criticality is calculated by aggregating expert's opinion for input variables. These variables are multiplied and defuzzified to obtain crisp criticality profile. User's opinion of function's usage is combined with expert opinion of function's criticality to obtain software operational profile. Proposed work is validated with existing literature. Validation is satisfactory.

Keywords: Reliabiity; software operational profile; functions; usage profile; criticality

INTRODUCTION

Software reliability is defined as the probability of failure free operation of a program within a specified time limit under a specified set of operating conditions [1]. It is required to check reliability of system by testing the software product under virtual field use conditions. Software Operational Profile (SOP) is a quantitative characterization of software field usage. SOP performs testing of the function with maximum occurrence probability. Moreover, intelligent testing is required due to frequent functional usage and criticality of faults in product. SOP can be estimated based on operation's criticality and usage frequency. It is desirable to produce a quality product. Effective estimation of SOP is required for quality product.

Previously user's involvement is not of much concern [2]. However, this has been changed now days and user's perceptions are now considered as one of the aspects for quality. SOP is the way to specify the user's perception of quality. SOP considers most used operations [3]. It offers great benefit in increasing productivity, speeding up development and increasing reliability [4]. SOP is useful in order to provide the certain level of reliability [5]. Along with reliability, it will satisfy cost and time constraint with satisfying user requirement.

Function's usage could be calculated by analyzing its usage pattern. For ex. usage of the functions can be understood by calculating the percentage usage per CPU time as if a function F1 has value 0.5 and F2 has value 0.03 in the operational profile, it means 50% usage of F1 per CPU time and 3% usage of F2 per CPU time. According to usage pattern, F2 is less used function than F1.

For new product it is often difficult to analyze usage pattern. Some researchers have investigated that reliability estimation is not much affected by errors in operational profile. Musa [6] analyzed that reliability estimate is not much affected by errors in SOP. Andreas [7] and Adams [8] also provided the same concept about effect of errors in SOP over reliability estimate.

Previously, a SOP estimation methodology was given by Aggrawal et.al [2].He considered occurrence probability of operations to prioritize operations. However, he has not provided any specification about how users will give opinion on function's usage. In [5] author presented a framework for the allocation of test cases using operational profile. He has considered occurrence probability and criticality for test case allocation. He also mentioned that, operations falls in four categories: Frequent and critical operation, Infrequent and critical operation, Frequent and non-critical operation, In-frequent and non-critical operation. Moreover, he has not mentioned any procedure for obtaining criticality of functions/operations. In [9, 10] it is described that SOP depends on occurrence probability and criticality.

Here is some example of safety critical system. A modern heart pacemaker is a computer with specialized peripherals, the U.S. Air Force's F22 fighter relies heavily on a computer network as does a modern car, and many defense facilities are actually distributed computer systems. There are critical operations, which may or may not be highly used. Also, for applications like web usage mining, there is need to focus on usage of operations rather than considering its criticality. Therefore, it is required to consider both parameters in SOP estimation.

This paper aims to combine user's opinion of function's usage and expert's view of function's criticality. Any person could be an expert who has direct or indirect impact on development process or some outsider having experience in related project. For complex projects it is very difficult for a decision maker to consider all aspects. It necessitates the participation of multiple experts and users. .A group decision-making process can be defined as a decision situation where there are two or more individuals have different preferences but the same access to information, each characterized by his/her own perceptions, attitudes, motivations, and personalities[11].To obtain function's criticality value, a team is organized consisting of field experts[12]. Team consisting of three team members. Moreover, usage of functions could be predicted with a group of users. It is previously considered that users are the ultimate judge of quality. Also they only know how the product will be used throughout their requirement. Giving subjective information and by using linguistic approach usage of functions are calculated. Therefore this paper presents a novel approach for SOP estimation on the basis of function's performance parameters.

The remainder of this paper is organized as follows. The proposed methodology is described in section 2. Section 3 presented proposed methodology with appropriate example. Subsequently results analysis and validation is presented in section 4. Conclusion with future scope is presented in section 5

PROPOSED METHODOLOGY

In this section we have presented steps for proposed methodology. Usage probability and criticality is calculated in early stage. For an application where it is not mandatory to consider safety requirement then SOP will be based on usage profile only. One can use usage profile based approach for SOP calculation, in that usage percentage of each function will be calculated. For an application where safety is mandatory condition rather than its occurrence then criticality profile can be used. However, there may arise different situations, in which operations may have low usage and high criticality. This kind of scenario should not be ignored as these can lead to some catastrophic situations, sometimes related to human lives also. If an application considers operations having high occurrence probability as well as high criticality then a combined profile is required for SOP estimation. Steps for proposed methodology are given below:

Step 1: Prepare a report consisting of all functions based on user's opinion

Step 2: Perform calculation from step 4 to step 6 for function's usage calculation.

Step 3: For function's criticality calculation perform calculation from step 7 to step 10.

Step 4: Membership function is constructed for each function and linguistic variables are assigned based on user's opinion of usage.

Step 5: Graded mean integration is calculated for each fuzzy number $\tilde{F}$ = (k, l, m) associated with functions

$$P(G) = \frac{1}{6}(k + 4*l + m) \quad (1)$$

Step 5: Difference and support among function's usage are calculated using equations below:

$$\text{if } m_{p1} \xrightarrow{d1} m_{p2} \;\&\; n_{p1} \xrightarrow{d2} n_{q2} \qquad \alpha_{m,n} = 0 \quad (2)$$

$$\text{if } m_{p1} \xrightarrow{d1} m_{p2} \;\&\; n_{p2} \xrightarrow{d2} n_{p1} \qquad \alpha_{m,n} = |d1 + d2| \quad (3)$$

$$\text{if } m_{p1} \xrightarrow{d1} m_{p2} \;\&\; n_{p1} \xrightarrow{d2} n_{p2} \qquad \alpha_{m,n} = |d1 - d2| \quad (4)$$

$$S_{m,n} = 1 - \alpha_{m,n} \quad (5)$$

Where $\alpha_{m,n}$ = (1/2n) $\sum T_{(m,n)}^{(p1,p2)}$

Step 6: User's usage profile is calculated based on support among users.

Step 7: Membership function is constructed for occurrence, severity and detection and linguistic variables are assigned based on three team member's opinion.

Step 8: Team member's opinion is aggregated for each input variables.

Step 9: Using fuzzy multiplication criticality value is computed for each functions.

Step 10: Defuzzify and normalize it to obtain crisp value of function's criticality

Step 11: Now we have function's usage profile as well as criticality profile. Function's weightage (SOP) is calculated by following formula:

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$$\text{Wop} = \frac{Fupi * Fcpi}{\sum_{i=1}^{3} Fcpi * Fupi} \qquad (6)$$

ILLUSTRATION OF PROPOSED MODEL WITH AN EXAMPLE

This section explains step by step methodology with the help of a numerical example. It has been assumed that, three functions are required for software. According to our methodology, function list is collected at the starting of the SOP estimation process. These functions are decided based on user's requirement. We have to find criticality value and usage profile value for all functions in order to get total operational profile. Usage profile is obtained by collecting information based on expected function's usage. It is decided by group of users. For criticality profile a group of team members are organized. Team members collectively give their opinion about occurrence, severity and detecting capability of possible faults in system. These experts can be either developers or person having experience of related project or having past records. In fig1, fig 2, fig 3 membership functions for function's usage is illustrated. Every function's usage has been decided by group of users.

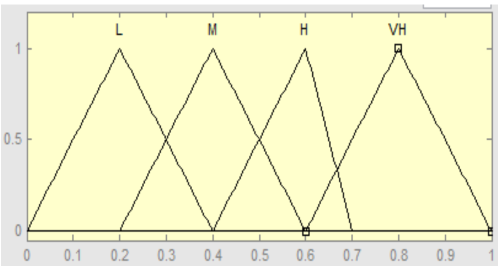

Figure 1: Membership function for usage of F1

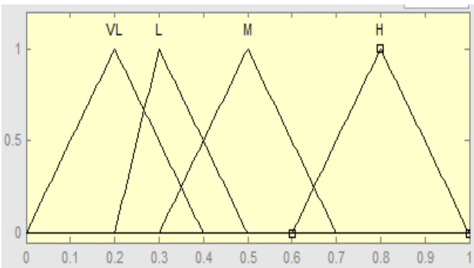

Figure 2: Membership function for usage of F2

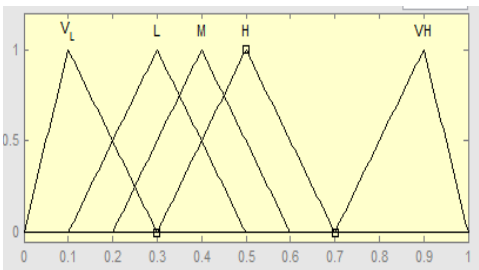

Figure 3: Membership function for usage of F3

By linguistic approach, linguistic variables are assigned.

	U1	U2	U3
F1	H	VL	M
F2	L	M	VL
F3	VL	L	M

	U1	U2	U3
F1	(0.4, 0.6,0.7)	(0,0.2,0.4)	(0.2,0.4,0.6)
F2	(0.2,0.3,0.5)	(0.3,0.5,0.7)	(0,0.2,0.4)
F3	(0,0.1,0.3)	(0.1,0.3,0.5)	(0.2,0.4,0.6)

Now, Graded mean integration is calculated for each fuzzy number using eq (1).

	U1	U2	U3
F1	0.58	0.2	0.266
F2	0.31	0.5	0.2
F3	0.116	0.3	0.4

Distances among functions are calculated as:

d(U1, U2) = 0.188, d(U2, U3) = 0.134, d(U1, U3) = 0.2

S(U1,U2)= 1-0.188=0.812

S(U2,U3)=1-0.134=0.866

S(U1,U3)=1-0.02=0.98

Support matrix is shown below

	U1	U2	U3
F1	1	0.812	0.98
F2	0.812	1	0.866
F3	0.98	0.866	1

Total usage according to users is given below:

U(U1)= 1/3(1+0.812+0.98)= 0.93066

U(U2)=1/3(0.812+1+0.866)= 0.8926

U(U3)=1/3(0.98+0.866+1)= 0.94866

Step 3.2.13

Estimated usage profile for F1= 0.93066

Estimated usage profile for F2= 0.8926

Estimated usage profile F3= 0.94866

After normalization usage profile for F1, F2, F3 is 0.33574, 0.322015, 0.34223.

Suppose there are n functions to be prioritized by m team members. Let $R_{ij}^{O}= (R_{ijl}^{O}, R_{ijm}^{O}, R_{ijh}^{O})$, $R_{ij}^{S}= (R_{ijl}^{S}, R_{ijm}^{S}, R_{ijh}^{S})$, $R_{ij}^{D}= (R_{ijl}^{D}, R_{ijm}^{D}, R_{ijh}^{D})$ be the fuzzy rating of occurrence, severity and detection and h_j be the relative weight of m team members, satisfying $\sum hj=1$ for all (j=1…m). Different team members have presented different opinion for function's risk values. Range for occurrence, severity and detection has been given in [12]. These values are normalized in this paper for simplicity and shown in table 1.

Generalized membership function has been used for all factors of each function and is illustrated in fig. 4. However, for obtaining total fuzzy rating of risk values for all functions, it will be required to aggregate the opinion of all members. Equation (7) - (9) will be used for aggregating the opinion of all team members.

$$\tilde{O}_i = \sum_{j=1}^{m} hj\,\tilde{O}ij$$

$$= \left(\sum_{j=1}^{m} hjOijl\ ,\ \sum_{j=1}^{m} hjOijm\ \sum_{j=1}^{m} hjOijr\right) \tag{7}$$

$$\tilde{S}i = \sum_{j=1}^{m} hj\,\tilde{S}ij$$

$$= \left(\sum_{j=1}^{m} hjSijl\ ,,\ \sum_{j=1}^{m} hjSijm\ \sum_{j=1}^{m} hjSijr\right) \tag{8}$$

$$\tilde{D} = \sum_{j=1}^{m} hj\,\tilde{D}ij$$

$$= \left(\sum_{j=1}^{m} hjDijl\ ,\ \sum_{j=1}^{m} hjDijm\ ,\ \sum_{j=1}^{m} hjDijr\right) \tag{9}$$

Table 1: Normalized fuzzy rating for occurrence, severity and detection

Ratings	Rating for occurrence	Rating for severity	Rating for detection	Fuzzy number
VL	Failures are unlikely	Function operate with degraded performances	Very remote chance	(0.0, 0.1, 0.3)
L	Relatively few failures	Functions operate without damage	Remote chance	(0.0, 0.2, 0.4)
M	Occasional failures	Operation with minor damage	Low chance	(0.2, 0.4, 0.6)
H	Repeated failure	Operation with some damage	Moderately high chance	(0.3, 0.5, 0.7)
VH	High repeated failures	Function inoperable with severe damage	Very high chance	(0.4, 0.6, 0.7)
EH	Failure is inevitable	Function inoperable with destructive failure	Almost certainty	(0.7, 0.9, 1)

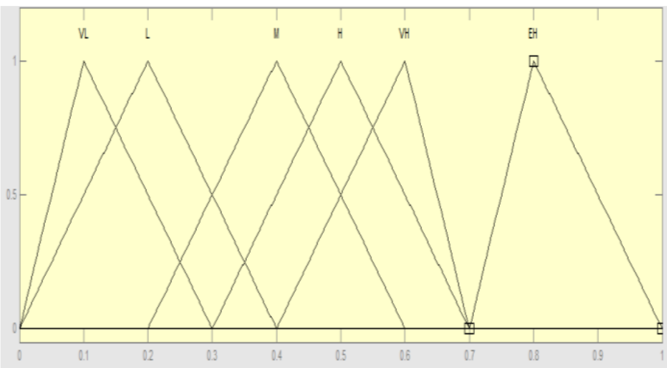

Figure 4: Generalized Membership functions for input variables

Table 2: Expert opinion based Allocation information for O, S, D

F1	**Occurrence**	**Severity**	**Detection**
TM1(45%)	H	VH	H
TM2(25%)	M	H	M
TM3(30%)	M	M	VH
F2			
TM1(45%)	VH	VH	H
TM2(25%)	H	H	VH
TM3(30%)	VH	H	M
F3			
TM1(45%)	H	H	VH
TM2(25%)	M	VH	M
TM3(30%)	H	M	H

Table 3: Aggregated fuzzy evolution information

Functions	O	S	D
F1	(0.245,0.445, 0.645)	(0.315,0.515, 0.67)	(0.275,0.475,0.665)
F2	(0.375, 0.575, 0.7)	(0.345, 0.545, 0.7)	(0.375, 0.575, 0.7)
F3	(0.275,0.475,0.675)	(0.245, 0.495, 0.67)	(0.275,0.475,0.675)

Table 4: Evaluation of criticality value

	Fuzzy RPN	Defuzzification	Normalization
F1	0.02122, 0.10885, 0.28737	0.13914	0.2930
F2	0.04851, 0.180190, 0.343	0.190566	0.40130
F3	0.018528,0.11168, 0.30526	0.145156	0.30567

Weight is calculated using equation (6)

$Wop_1 = 0.29606$, $Wop_2 = 0.38891$, $Wop_3 = 0.31503$

RESULT ANALYSIS

Results are shown in table 5. We are prioritizing functions based on usage profile and criticality profile. It is clear that criticality profile for function 2 is highest among all. F3 (usage profile) is ranked second in the priority list. As we are estimating SOP on the basis of usage profile and criticality profile, therefore ranking of final SOP will be based on it. It is clear from the table that SOP of F2 is highest. F3 is ranked after F2 in priority list.

Table 5: OP estimation based on criteria weightage

Functions	Criticality profile	Usage profile	Estimated SOP
F1	0.2930	0.33574,	0.29606
F2	0.40130	0.322015,	0.38891
F3	0.30567	0.34223	0.31503

Result validaion

Here we will compare operational profile obtained by Aggrawal [2] and our proposed method.

Table 6: comparison of different models

Functions	Aggrawal model	Proposed model
F1	0.52311	0.29606
F2	0.25366	0.38891
F3	0.22096	0.31503
∑	1	1

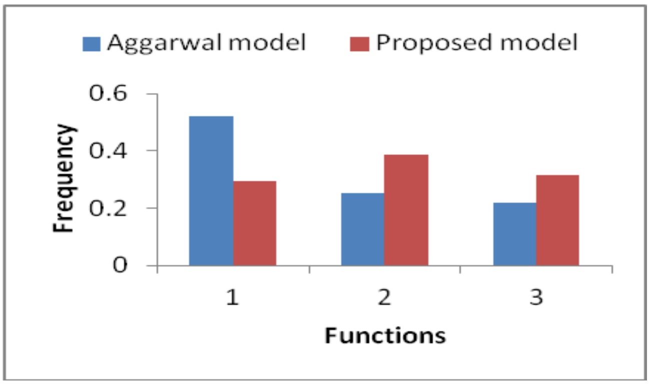

Figure 5: Comparison between proposed model and Aggrawal model

Aggarwal et.al calculated SOP based on operation's occurrence probability. In our proposed model, we calculated SOP based on criticality and usage profile. For function F1 SOP is decreased while for F2 & F3 SOP has been increased. Also according to [5], final SOP is normalized. Fig. 5 shows pictorial representation for comparison between models. When SOP is calculated using Aggrawal model, it does not consider function criticality. Therefore, difference between these models can be justified by the presence of parameters. By defining membership function based on human intuition together with the suitable selection of linguistic variables, variation in parameter estimates are taken into consideration.

CONCLUSION

A novel approach for SOP estimation has been presented in this paper. Two important performance parameters are considered for estimation. It is known that functions can be either most used or critical or both. In every scenario it is required to estimate accordingly. Functions are prioritized based on profiles. If usage probability is high and operation is less critical, operational profile will be according to usage profile and if operation is highly critical but less used then operational profile will be according to criticality profile. Therefore, this paper brings criticality with usage probability together to estimate accurate operational profile and it will be useful for predicting software reliability also. We will try to automate our approach in future by adding some other engineering parameters.

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