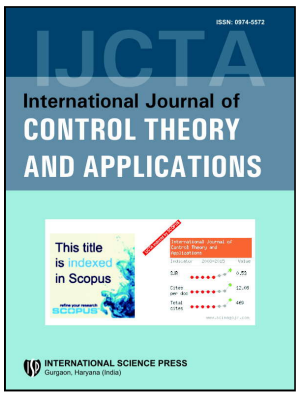

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Software Operational Profile based Test Case Prioritization using Fuzzy Logic

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Abstract: Testing is considered as an expensive part of the development. There can be number of test cases to design, select and execute. However, it will be of no use to first execute test cases, having less priority. Priority can be decided based on certain criteria like its ability to detect maximum number of faults, severity caused by faults and total time involved etc. There will be number of test cases, whose priority should be given higher in execution process as either they can detect maximum number of fault or can cover maximum aspect of a software. Therefore, decision makers should make their decision based on the priority of test cases, which will help in reducing cost, increasing reliability as well as helps in resource optimization. Test case prioritization helps in ordering the test case in such an order, so that higher priority test case will execute first. Test cases will be prioritized by their operational profile. Operational profile is defined in terms of weightage given to particular test cases. Operational Profile is considered as best practice for finding the most used or higher order operation. Therefore, we are using here operational profile as a measure, to order all test cases in an effective way. However, it will be beneficial if we prioritize all test cases before its actual run. Therefore, fuzzy logic has been used to provide early estimate of all test cases.

Keywords: Operational profile, test cases, fuzzy logic, weightage

1. INTRODUCTION

With the growing complexity, it is required to develop a quality product with low cost, less time and improved user satisfaction. For producing a quality product, there have been so many techniques to improve every phase of software development life cycle. Testing and maintenance are the most time taking phases. Testing is considered an important activity in software development as test cases are allotted to operations. User's and developer's confidence about the quality of product is based on its testing process. Testing can be simply understood in terms of execution of software system with controlled input, in order to evaluate its quality and identifying potential problems into it [1]. There are different activities involved in testing process like test case selection, test case allocation, test case prioritization and many more. If we want to improve testing process, it is required to provide weightage to those test cases that have higher impact or can detect more faults. Test case prioritization mainly helps to improve effectiveness in regression testing in which test cases are executed several times. Regression testing is an expensive testing process used to validate modified software

and detect whether new faults have been introduced into previously tested code[9,10,11,12,13]. Moreover, test case selection is used to reduce the number of test cases in test suite, while test case prioritization helps to order test cases in such a way so that higher weightage test case will execute first. Test case prioritization technique organizes the test cases in test suit to make testing more effective. Test cases can be prioritized based on some criteria. So according to that criteria, highest priority test case will execute first. Test case prioritization removes the drawback of test case selection, by ordering of test cases instead of minimizing test suite. Benefit of test case prioritization can be understood in terms of its effectiveness in ordering test cases. It can be used to increase the likelihood of detecting faults earlier in many runs of regression testing. It can be used to reveal regression error due to some changes in code in earlier phases. It can be used to detect high risk impact fault early and finding its location based on its severity. It can be used to increase confidence in reliability level by testing at more rapid rate. This paper presents test case prioritization technique based on its operational profile criteria. Operational profile is defined as quantitative characterization of how a system will be used [2]. It can be defined in terms of weightage of a component, function or operation. Higher the operational profile has higher the weightage of test case. However, prioritization will be useful if done early. Fuzzy logic is used in order to provide linguistic opinion about the criteria of test cases. Three criteria severity, time and number of fault is taken as input for test cases and output will be test case's operational profile. Based on operational profile, test cases will be prioritized. Therefore this paper presents a methodology, in which based on operational profile, test cases will be prioritized. Section II will present proposed methodology. Section III will present case study and results, Section IV will present comparison between prioritized and non-prioritized test cases and finally section V will present conclusion.

2. PROPOSED METHODOLOGY

The proposed methodology takes severity, number of faults and time of test cases as input and produces operational profile for test cases. These are input parameters taken in order to prioritize test cases based on their operational profile. A fuzzy system is developed for test case prioritization. Membership function will be assigned to all three input variables and output variable. This methodology can be helpful for normal testing process as well as in regression testing. In case of normal testing process, experts have to decide the linguistic states of these variables based on some historical data. In case of regression testing process, test cases have to be executed several times. Therefore, test case prioritization will help to reorder test cases in such a way, so that most needed test case will execute first in several runs. Figure 1 shows the proposed methodology.

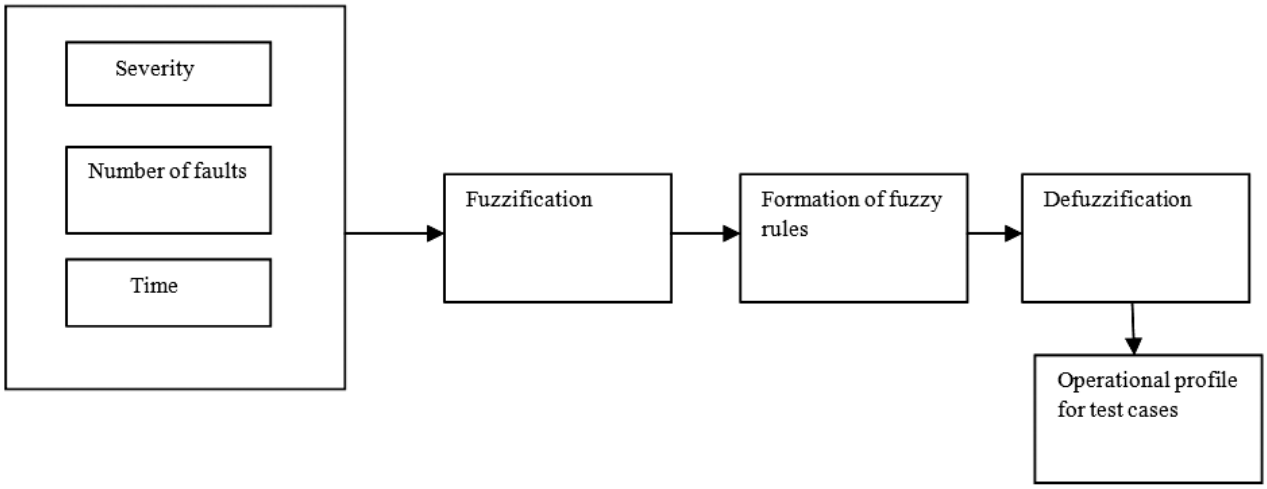

Figure 1: Proposed methodology

2.1. Defining membership functions for input and output variable

Fuzzification is the process of making crisp quantity into fuzzy [3]. It is performed to take care of uncertainty, vagueness and ambiguity. There can be situation, in which we assume data to be crisp and deterministic. However it may or may not be deterministic. They can carry uncertainty. In that case, to avoid uncertainty and ambiguity, variable is treated as fuzzy. In the proposed method, we want to compute the input variables in early phase. With the help of expert opinion, early estimation is possible. Figure 2 is showing the generalized profile for input variable number of faults. It is defined by 3 linguistic variables i.e. L, M and H and it ranges from 1-5. Figure 3 is showing the generalized profile for time and is defined by 3 linguistic variables L, M & H, ranges from 1-20. Figure 4 is showing generalized profile for input variable severity and is defined by 3 linguistic variables L, M & H, ranges from 1-22. Figure 5 is showing generalized profile for output variable operational profile and is defined by 5 linguistic variable VL, L, M, H & VH, ranges from 1-14.

2.2. Formation of fuzzy rules

Number of rules is decided on the basis of number of input variables and the number of linguistic variables associated with input variables. If number of linguistic variables is same for all input variable, then total number of fuzzy rules are defined by

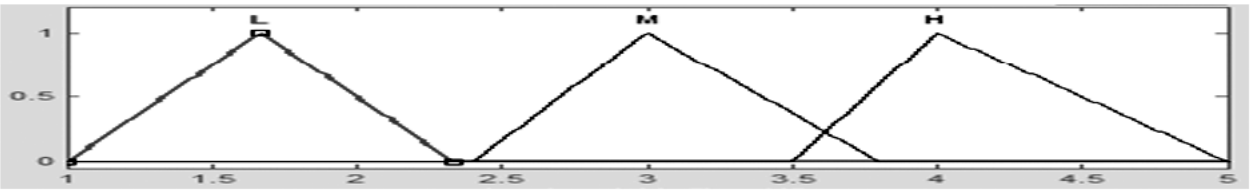

Figure 2: Membership function for input variable number of faults

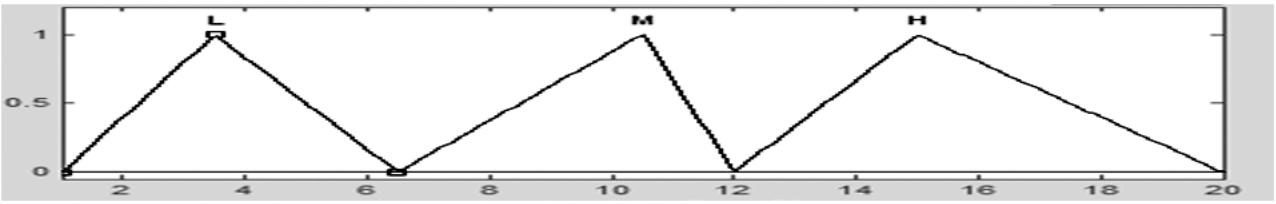

Figure 3: Membership function for input variable time

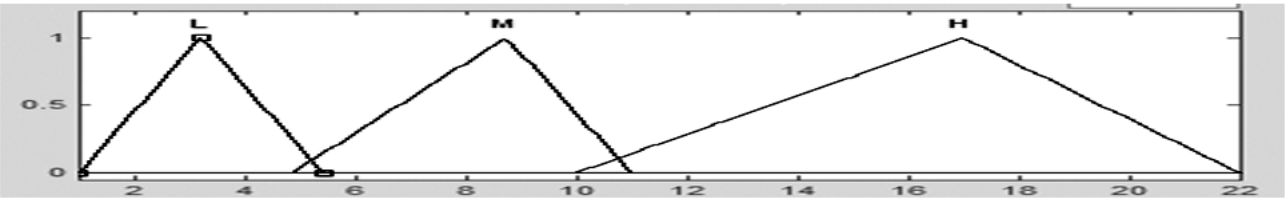

Figure 4: Membership function for input variable severity

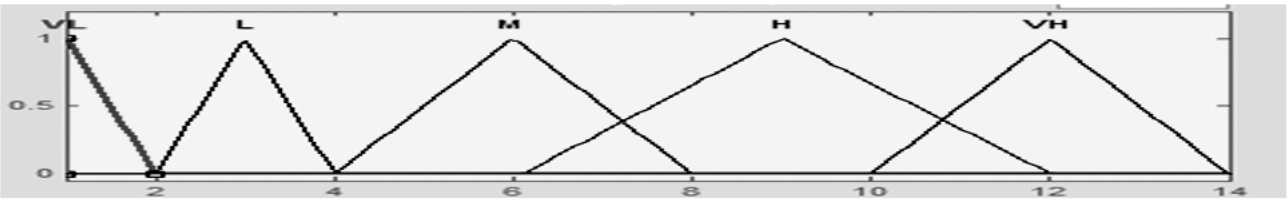

Figure 5: Membership function for output variable operational profile

Number of fuzzy rules = (Number of input variables) $^{(\text{Number of linguistic variable})}$

However, if number of linguistic variables is different than total number of fuzzy rules is given by the multiplication of linguistic variables. In the proposed model, antecedent part is the combination of input variables number of faults, time and severity and consequents are operational profile. Therefore, total number of rules will be 3^3 i.e total number of rules will be 27.

2.3. Defuzzification

Defuzzification is the translation of a fuzzy quantity to a crisp quantity, just as fuzzification is the conversion of a crisp quantity to a fuzzy quantity. Various methods are available for defuzzification, which are max-membership principle, centroids method, weighted average, mean max, centre of sums and centre of largest area. Centroids method of defuzzification is used in the proposed model. This method is the most common and physically appealing of all the defuzzification methods [7]

3. CASE STUDY & RESULTS

In 2010, a framework has been presented by R. Kavitha for the prioritization of test cases. This framework was not based on early estimation. We have taken three input parameters i.e. Number of faults, time and severity of the test case. According to the values of input parameters, it is clear that operational profile changes according to severity of the test cases mainly. However, all three parameters have effect over operational profile of test cases. We calculated operational profile for test case prioritization using fuzzy logic. The outcome of using proposed model is shown in table 1. For making firm decision about test case prioritization, fuzzy values are defuzzified. Table 2 is presented for the comparison between [1] and proposed model.

Table 1
Proposed model estimated values

Number of test cases	*Number of faults*	*Time*	*Severity*	*Operational profile by proposed model*
T1	2	9	6	5.99
T2	2	8	6	5.99
T3	2	14	6	4.99
T4	3	9	10	8.98
T5	2	12	8	5.19
T6	3	14	10	7.55
T7	1	11	4	2.42
T8	4	10	20	12
T9	2	10	12	7.95
T10	2	13	6	5.09

From [6,7], it is clear that normalization is required in order to get optimal operational profile. Therefore, here we have given final result obtained by proposed model and its comparison with [1] in table2. Relative Difference (RD) and Mean of Square Difference (MSD) has been used as a measure of estimation.

Table 2
Comparison between Kavitha Model and Proposed Model

Number of test cases	*Operational profile by [1]*	*Operational profile by proposed model*	*Relative Difference*	*SRD*
T1	0.0794	0.0905	-0.1397	0.01951
T2	0.0837	0.0905	-0.0812	0.0065
T3	0.0673	0.0754	-0.1203	0.0144
T4	0.1267	0.1358	-0.0718	0.0051
T5	0.0861	0.0784	0.0894	0.0079
T6	0.1086	0.1141	-0.0506	0.0025
T7	0.0441	0.0366	0.1700	0.0289
T8	0.2130	0.1811	0.1497	0.0224
T9	0.1217	0.1201	0.0131	0.0001
T10	0.0690	0.0769	-0.1144	0.0130

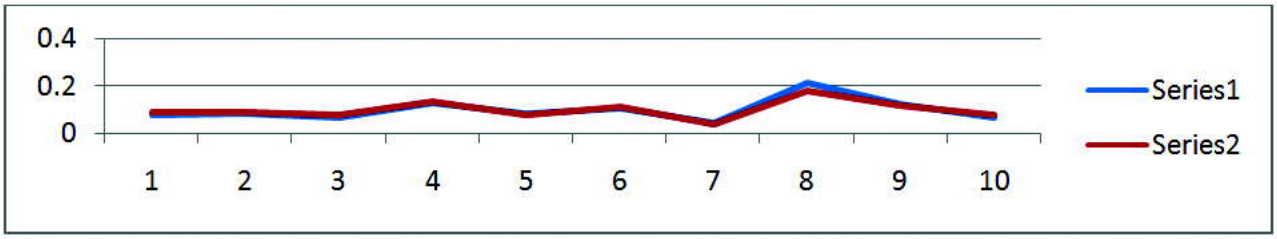

Figure 6: Comparison between [1] and proposed model

Results obtained from [1] and proposed model has been shown in table 2. MSD obtained is 0.01203. Mean square derivation gives the minimum difference obtained from estimator and estimation. The least MSD is desirable. MSD obtained from above calculation is satisfactory. Also from figure 6, it has been observed that there is not much difference between the original result and result obtained using fuzzy. Therefore, fuzzy can be used in order to get early estimation or in the case where we cannot predict the actual values for the operational profile of test cases. It is calculated by domain expert. Hence, small variability is assumed. Moreover, degree of priority is same for highest order and lowest order test cases. Now, we have benefit of having these values for reducing the testing effort.

4. COMPARISON BETWEEN PRIORITIZED AND NON-PRIORITIZED TEST CASES

This section presents a comparison between prioritized and non-prioritized test cases. This will add the confidence for the necessity for the prioritized test cases. Many of the metrics are used to measure the prioritization of test cases. APFD (Average Percentage of Fault Detection) metric is one of important metric to measure the test cases prioritization based on the fault detection. It was developed by Elbaum [5]. It can be only used when number of faults is known. The APFD is calculated by taking the weighted average of faults detected over the life of the test suits. It varies from 0 to 100. Higher number simplify faster detection rate. For ex there are n number of test cases and m number of faults. Formula for calculating APFD is shown below:

$$APFD = 1 - \frac{(TF1 + TF2 + TF3.....TFm)}{nm} + \frac{1}{2n} \quad (1)$$

Where n- number of test cases, m- number of faults, TFi- first test case in T which reveals fault i

Here we are using APFD metric, in order to show that there is difference between prioritized and non-prioritized test cases. Here table 3 shows the number of faults detected by a test case in a test suite.

Table 3
Number of test cases and number of faults

	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
F1								*	*	
F2		*	*		*					
F3				*		*				*
F4		*	*							
F5								*		
F6								*	*	
F7				*	*		*			
F8	*					*				
F9				*		*				*
F10	*							*		

m= 10 n=10

For non-prioritized test case-

$$APFD = 1 - \frac{(8+2+4+2+8+8+4+1+4+1)}{10*10} + \frac{1}{20} = 0.63$$

For prioritized test cases-

$$APFD = 1 - \frac{(1+5+2+5+1+1+2+6+2+6)}{10*10} + \frac{1}{20} = 0.74$$

It has been clear that APFD value for prioritized test case is higher than obtained from APFD obtained from non-prioritized test case. Hence prioritized test cases will detect higher number of faults in minimum time.

5. CONCLUSION

Test case prioritization is used in mainly regression testing, where it is needed to test several times. Our proposed method is based on expert opinion, which will help to predict test case prioritization. Once an estimate is obtained, similar type of test cases can be prioritized based on expert opinion. Prioritization means to schedule (or) order the execution of the test cases. It improves the software quality and Rate of fault detection. Prioritization is used to reduce the time, cost and to improve the effectiveness.

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