Software Matrices Selection for a SDLC Based Software Reliability Prediction Model

Neha Yadav, Vibhash Yadav, Prashant Kumar Mishra

Abstract: ***Software reliability is one of the essential factors of quality in software engineering like other quality attributes as functionality, usability, maintainability, performance, serviceability, documentation etc. From last few years, several software reliability models have been developed. There is lack of relevant literature which focuses on processes related to SDLC. A SDLC based structure for measurement of reliability has been proposed. Identified software reliability measures which are majorly take place in all levels of early software development phase of SDLC. Considering all measures for reliability estimation will be costly and time taking. So measures are identified which are taking place at each development phase and have high synthetic weight according to selecting criteria based on expert judgment and multi criteria decision making technique. Based on the grading, top ranked measures like completeness, error distribution, fault density etc are identified. Use of recommended metrics will make software reliability estimation more effective and reliable.***

Keywords: ***multi criteria decision making, reliability measurement, reliability metrics, reliability techniques, selecting criteria***

I. INTRODUCTION

Software has an important role in our daily life. So development of quality software is an important concern. Software quality measurement is important field of software engineering. Quality of software systems is described by different attributes like performance, functionality, usability, maintainability etc. Reliability is also an important quality factors. According to ISO/IEC 9126 reliability is a collection of attributes that have the ability of to maintain level of software performance in given conditions for a given period of time. Reliability is estimated for reducing the fault occurrence and failure of software. Reliability measurement use mathematical as well as statistical models to quantitatively review for the software reliability prediction. Reliability metrics are useful to predict the current reliability of software.

There are measures which mainly focusing on estimate reliability in testing and operation phases but these models avoid the early phases of SDLC. It is required to cover all the phases. Values of metrics which belong to software reliability at early levels of SDLC are affected by many factors or attributes. IEEE Std 982.2. Propose many measures related to reliability. There are 31 reliability measures which are taking place in early stages of SDLC. If all the metrics are considered for reliability estimation then it will include huge calculation and take large time and cost. It is required to decide the metrics effecting most to the software reliability. So there is a need to rank all these measures in systematic manner with respect to their capability at predicting software reliability. For doing this, weights of all the matrices are identified and according to that top ranked measures are found. This weight can be set with the help of any multi criteria decision making techniques. MCDM is a decision making technique for factors considering different criteria. All the metrics are not equally weighted; it depends on the criteria which we are considering. SDLC based framework is introduced in Section3. In Section 4, introduction of all selected measures is given. As all the measures are not related to all the early phase of SDLC, availability of each measure is given in section5.A value 1 represents that the measure is available and a value 0 represents that measure is not available at that particular phase. Once the measures are selected then there is a need of selection of measures which are playing more important role in estimation of software reliability. In section6, the grading of each measure is given on the basis of expert's judgment for decided selecting criteria and then given the weight of each metric using multi criteria decision making technique (AHP). Finally measures with top weights are recommended and analyzed.

II. LITRATURE SURVEY

In last few years, several studied have been done related to software reliability estimation using measures related to that. For measuring software reliability, there are many metrics related in the requirements phase. Metrics can be identified in all SDLC phases; possible areas of problems are also identified which may create problems. Requirements give the features and functionality of the final software that must be included. To collect the requirement without nay misinterpretation is a very critical task. Wrong interpretation causes the mismatch between the understanding of developer and the client. Complex modules are complicated to recognize and there is a higher possibility of defects. Prediction of the reliability of the software has different dependencies on different modules that will depend on complexity of particular software or module (Rosenberg et al., 1998). As the main objective is to produce software with high reliability so Amara et al.(2017) proposed a new framework on the basis of reliability measures in which all early phase of SDLC are considered to predict the reliability. Metrics are included from requirement, design, implementation and testing phase in a SDLC.

Reliability models found dependency of failure process and main factors which affects it use in

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geometric methods in operation phase and testing phase (Farooq et al., 2011, 2012).

According to Jatain and Mehta (2014), all the factors of software reliability as well as all aspect associated with these factors should be analyzed.

In Kumar and Misra (2008), Reliability metrics are useful for prediction of the reliability of a software product and also to predict that how it will behave in future. Lawrence Livermore National Laboratory research team has performed a research work on reliability metrics. They identified all the software metrics which were directly or indirectly related to software reliability and also suitable for the study of digital I&C systems. It is properly documented initially that what are the ranking criteria. That was a set of 78 measures which was reduced to 30 using structural and importance considerations by Amara et al.(2017).

An approach for software reliability prediction is proposed. Results of metrics measurement are linked to quantitative reliability estimation during defect information. The given approach is used in software deployed in nuclear power plant. Result shown that this method can be applied for different software metrics at different phases of the SDLC. That's why the approach could direct the development process and helpful in making design decisions. Experiences learned from the applications are also discussed (Shi Ying et al., 2016). User quality objectives should influence the system design and serve as criteria both for intermediate verification and for system validation and acceptance. The defend user quality objectives give the most direct means for fault search and detection. Examples of user quality objectives are ease-of-use for a word processor; ultra-high reliability for a telephone exchange plant; reliability and security for a banking application; safety and robustness for a nuclear power plant. According to Gall et al. (2008) through software maintenance, semantic measures calculated from early in design; which gave consistent types of metrics collected through the software lifecycle.

Definitions of all the software metrics and their history of this field are introduced. Complete survey of the metrics is given for related attributes. Some of the basic metrics are discussed and complexity metrics methods considered, as McCabe complexity metrics and object oriented metrics. Comparison and how these metrics related to each other are also are given (Saini et al., 2014).

Reliability is estimated so that the fault occurrence can be reduced and software failures. Reliability metrics are useful to predict the current reliability of software. In Saini et al. (2014), used metrics base estimation models to predict software reliability and for that matrices related to reliability have to be identified. Software Metrics give a measurement for the software and the process of software production.

Norman and Bieman (2014) present several attributes related to Software quality which are classified in two main categories: Internal attributes and external attribute. Internal attributes are those which can be directly measured from the program syntax and External attributes are those which are visible to the users of the system. Reliability is an external attribute of software quality (ISO/IEC 25010, 2011).

Smidts C. and Li M. (2000) identified all the metrics correlated to software reliability. Then ranking criteria and metrics weights of all the criteria are identified. For considering the weights of each measure, different methods are available. They used expert opinion. Linear additive scheme was used as an aggregation scheme. According to all ranking criteria and their weights, top-ranked measures of each phase were identified individually. Use of selected metrics in each SDLC phase can show the way to a more reliable estimation of software reliability.

Li Haifeng (2006) proposed a model for selection of software reliability metrics with the help of MCDM technique (there are many techniques here AHP is considered) and expert judgment. Metrics and selecting criteria were identified. Early SDLC phase as requirement phase, design phase, coding phase and testing phase were considered then the grading of the metrics related to these phase was measured according to every criterion by experts. Synthetically analyze these to find the weights with the help of AHP. Metrics having highest weights are top-ranked and recommended.

III. FRAMEWORK BASED ON SDLC

A new process has been proposed based on the techniques and metrics included from requirement phase to testing phase (early phases) in SDLC. In new framework, steps are subdivided into two main phases:

The Requirement phase, Design phase and Coding phase: Design phase is one of the fundamental phases in SDLC and in the design phase activity system break into modules. It is requirement of software engineers to accomplish the desired qualities of the software in ISO/IEC CD 25010. (2011).In these phases verity of different reliability techniques can be implementing and many metrics can be identified.

Implementation and testing phase: These phases include the implementation of all the modules as integrated and testing of this. It includes use of reliability models, semantic and syntactic metrics. It also consists of testing phase which is used to estimate the fault density and the reliability of the program. For effectiveness of prediction of reliability of the system it is also beneficial to include metrics related to these phases.

Reliability validation: The new framework includes this step which verify that the system is verify the reliability objective or not. If the project is not releases yet then this validation step is repeated until the system will not achieve the desired reliability.

Saravana et al., (2016) proposed framework is in-depth description that in SDLC what are the key element of software reliability measures and ho we will achieve this. The existing models are improved by developing required specification from the requirement phase and that will avoid unwanted tests. So it will be possible to do the correction and in less time and cost. Even in testing phase, now reliability models, software metrics, and techniques are using in parallel which will improve the measurement and also

reduce the cost and effort needed for corrections and improvements.

Role of reliability measurement in SDLC should be identified like models and metrics. This enhanced model also gives a state to shrink the phase suppression of errors in each of the early phases of software life cycle. Initially the objective of reliability is finalized and both the phases that will validate that the desired objective is achieving or not. If validation results fail then there is a need to repeat the exercise of that phase it will minimize the time and cost effectively.

IV. MEASURE SELECTION

Measure selection is on the basis of high utility value of measures which should also relevant to reliability, so that the ability to predict software reliability is very high. As the proposed model of software reliability estimation is based on the metrics related to each SDLC phase so there is a need to identify metrics which are related to each phase. As all the metrics are not equally important so there will be also the requirement of their ranking Criteria and Levels Definition. Lawrence Livermore National Laboratory (LLNL) research team has performed a research work on reliability metrics. They identified all the software metrics which were directly or indirectly related to software reliability. It is properly documented initially that what are the ranking criteria. That was a set of 78 measures which was reduced to 31 using structural and importance considerations. Selection criteria of these matrices are experience, cost benefit, validation, credibility, repeatability, and reliability. This set of 31 measures was the basis for further consideration. These 31 measures give out with the help of expert opinion elicitation, aggregation, and ranking. Important metrics which are taking place at all early phases of SDLC and have significant weight are briefly described.

V. PHASE-BASED MEASURES' AVAILABILITY

All the software measures are not applicable to a development phase like Cyclomatic complexity cannot be planned until the design phase. Once these primitives are available, they remain available in the later phases of the life-cycle. So measure is defined as related to a phase if the primitives required to calculate the measure are available in that particular phase. Availability of all the related measures which take place in the prediction of software reliability is defined in IEEE Std. Rates has been given by the experts is used to reflect the availability of the metrics during the phase.

Information of any measures is given in Table 1. A value 1 represents that the measure is available and a value 0 represents that measure is not available. This information is useful for elimination or retention of any particular measures from the corresponding phases. A measure specifically defined to capture the software's design character is available from design phase till the end of the software life cycle. It is to be noted that the phase-based availability of metrics is given in Table 1 which is extracted from IEEE Std 982.2. (1988).

We can consider all the metrics given in this list but it will be time taking so for further consideration only those metrics are considered which are having high weight. For section of weight of each metrics at each level of SDLC there are many different methods. Here expert opinion is taking place for weight adjustment of each metrics according to different criteria and Multi criteria decision making is used to finalize the ranking of all these metrics according to considered criteria.

VI. ANALYSIS

As in all 31 measures are not taking part in all four phases of SDLC. Consider all matrices and analyze that which are common matrices in all four levels as well as find matrices has maximum weight in its level. For example data flow complexity is the matrices which are not at

requirement level but from design to testing it is at all three levels. Finally compress the list of 31 matrices to 10 matrices which have an important role in estimating software reliability in all four early phase of SDLC. Table 3 is shown this proposed model of shortlisted matrices.

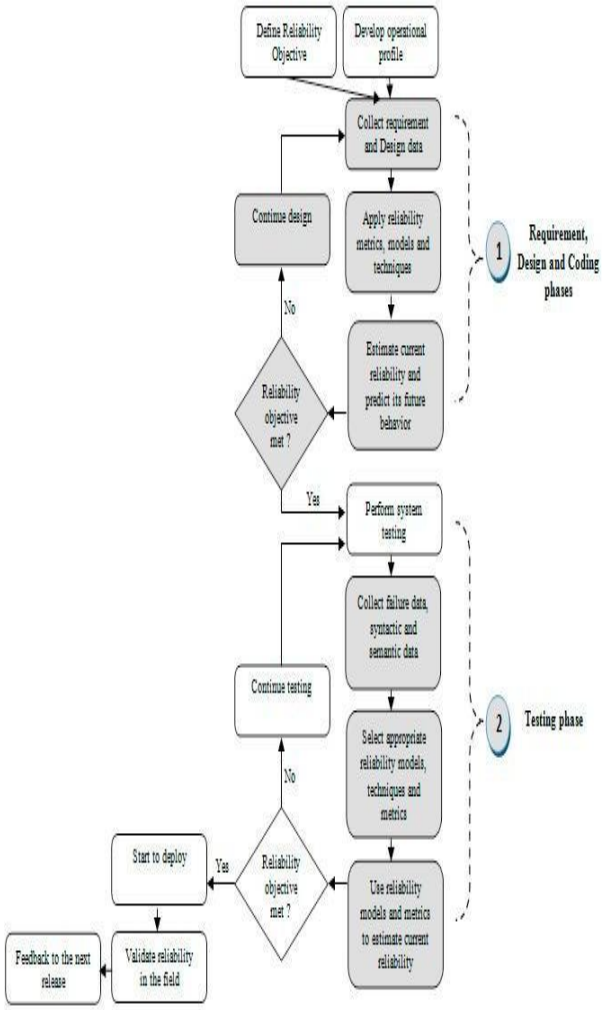

Table 1: lists the phase-by phase available 31 measures.

Software Reliability Measures	Development Phase			
	Requirements	Design	Implementation	Testing
Completeness	1	1	1	1
Number of conflicting requirements	1	1	0	0
Requirements traceability	0	1	0	0
Defect Indices	1	1	1	1
Failure Avoidance	0	1	1	1
Incorrect operation avoidance	0	1	1	1
Man hour per major defect detected	0	1	1	1
Number of entries per module	0	1	1	0
Software Science measures	0	0	1	1
Cyclomatic complexity	0	1	1	1
Data flow complexity	0	1	1	1
Fault Density	1	1	1	1
Software Maturity index	0	1	0	1
Mean time to failure	0	0	0	1
Failure rate	0	0	0	1
Mean down time	0	0	0	1
Defect density	0	1	1	1
Cumulative failure profile	0	0	0	1
Cause and effect graphing	1	1	1	1
Error distribution	1	1	1	1
Fault days numbers	1	1	1	1
Test coverage	1	1	1	1
Graph complexity	0	1	1	1
Number of fault remaining	1	1	1	1
Requirements compliance	1	1	1	1
Test Sufficiency	0	0	0	1
Test Maturity	0	0	0	1
MTTR	0	0	0	1
Minimal unit test case determination	0	0	1	1
Test Accuracy	0	0	0	1
Restorability	0	0	0	1

A. Software reliability metrics selection

Considering all metrics for reliability estimation will make task difficult and even all the metrics at all level are not equally important. Even many metrics selection will cost more resource and workloads. So there is a need to prioritize the metrics so that we can ignore measures having least priority.

Garg R. K. et al. (2011) propose ranking of the software engineering metrics on the basis of many criteria creates a multi-criteria decision-making problem. Values of given selection criteria are repeatedly imprecisely measured or qualitatively described. Significance of each criterion may also vary under different requirements and situations.

It can consider all the metrics given in this list but it will be time taking and costly so for selecting the small set of metrics from these 31 metrics we are taking weights of all the metrics at all levels. Method for selecting suitable software reliability metrics is AHP which is one of the decision-making processes which evaluates applicability of every metric in each development phase.

B. Selecting Criteria

Selecting criteria are the different attributes which are the basis for metrics selection and metrics can be compared. Following five criteria are considered.

1. Relevance: It reflects how much the metrics is related the software reliability.

2. Experience: It reflects the level to which given metric has been used and recognized.

3. Correctness: It includes the input and results of this metric can't be easily influenced.

4. Practicality: Give how much this particular metric is necessary in development.

5. Feasibility: The formula of this metric should be understood easily, and supported by tools, data collection should be easily; the results of this metric can be evaluated and confirmed conveniently.

C. Weights of Selecting Criteria

For selecting the weight of each criterion expert judgment is used by considering five software experts as judges. Weighted of all the judgment sheet is taking equal. Experts obtain relative importance scale for each criterion by common comparisons. A comparison matrix for criteria is constructed.

Relevance	Experience	Correctness	Practicality	Feasibility
0.4	0.135	0.07	0.26	0.135

TABLE 2: LISTS THE WEIGHTS OF THE FIVE CRITERIA UNDER STUDY

D. Final Results

Expert give the grading for every metric by each selecting criterion based on their experience and combined grading of each metrics by every expert.

Measures	Requirements Phase	Design Phase	Implementation Phase	Testing Phase
Fault density	0.1162*	0.0566*	0.0624*	0.0415
Defect Indices	0.1095*	0.0526	0.0566	0.0379
Error distribution	0.0979	0.0469	0.0466	0.0302
Cause and effect graphing	0.1011*	0.0439	0.0439	0.0331
Requirement Compliance	0.0965	0.0464	0.0487	0.0324
Test Coverage	0.1088*	0.0543	0.0610	0.0419
Number of fault remaining	0.0916	0.0437	0.0501	0.0345
Completeness	0.0985	0.0504	0.0502	0.0308
Defect density		0.0599*	0.06259*	0.0434*
Cyclomatic Complexity		0.0588*	0.0613*	0.0391
Mean time to failure				0.0420*
Failure rate				0.0436*

Table 3: list of top ranked measures with their weight

To calculate synthetic weight of each metrics we are using root method. Equation 5 is for weight estimation. Metric with high Wi(∅) will be consider.

$$Wi(\emptyset) = \sum_{k=1}^{k} w_i(k,\emptyset) * W_k \quad (5)$$

$$w_i(k,\emptyset) = {}^{b_i}\Big/_{\sum_{i=1}^{M_\emptyset} b_i}$$

Where: and

$$b_i = M_\emptyset \sqrt{b_{i1} \ldots . b_{iM_\emptyset}}$$

According to every selecting criterion, experts proposed their grading of each metric in each phase based on their experience. Synthetic weight of each metric in each phase is calculated according to these grading results. Metrics having less weight at all the levels have been eliminated. Now top 10 metrics according to their weight is given in table 3. High weighted measures are marked as (*) in table and these are recommended.

VII. CONCLUSION

In this paper, basics of reliability measurement in the have been illustrated which covers techniques, models and metrics. As existing reliability measurement process focused only on using reliability models in measurement step in testing phase. So there is need to identified measures of reliability prediction which can be useful earlier in the SDLC. Therefore, frame is given which is covering all of these elements and consider reliability estimation in early phases is considered for further consideration. Identified measures which are majorly take place in early levels in each software development phase. There are 31 metrics which are related to software reliability prediction in early phase of SDLC. If all the metrics will considered then it will be costly and time taking. So there was a need to minimize the list of metrics. Common measures are identified which are taking place at early levels and have high weight according to selecting criteria based on expert judgment and multi criteria decision making technique. Selection criteria are given by experts and their weights are given. Grading of experts is analyzed by AHP. Metrics having least weight at all levels are not considered as Fault day's number. Finally ten major metrics like completeness, error distribution, fault density etc are considered which collectively test the reliability of a software product. These are the selected measures which will make software reliability estimation more effective and reliable. In future, sensitivity of this method needs to analyze to strengthen the feasibility of this method.

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