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Fuzzy Logic based Software Reliability Quantification Framework: Early Stage Perspective (^{FL}SRQF)

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Abstract

Today, the influence of information technology has been spreading exponentially, from high level research going on in top labs of the world to the home appliances. Such a huge demand is compelling developers to develop more software to meet the user expectations. As a result reliability has come up as a critical quality factor that cannot be compromised. Therefore, researchers are continuously making efforts to meet this challenge. With this spirit, authors of the paper have proposed a highly structured framework that guides the process of quantifying software reliability, before the coding of the software start. Before presenting the framework, to realize its need and significance, the paper has presented the state-of-the-art on software reliability quantification. The strength of fuzzy set theory has been utilized to prevail over the limitation of subjectivity of requirements stage measures. Salient features of the framework are also highlighted at the end of the paper.

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1. Introduction

The role of software has been increasing in our life day by day. Earlier it was limited to desktops only, but now has reached to the devices that can easily accommodate in our pockets. Nobody can think about a life without the devices controlled by software[1]. Such dependence as well as trust on software compels the software industry to be more conscious and attentive while developing software, so that delivered software became successful in their operational life[2]. On the other hand, it has also been noticed that, in industry most of the development activity is carried out in labor-intensive manner[3]. System developers are also struggling to deliver software with acceptable level of quality, within given resources and time. Such a pressure on the software professionals cannot be ignored as one of the key factor for software whose reliability is not up to mark[4].

A lot of unfortunate events had already occurred in the defense and health sectors due to the unreliability of corresponding software applications[5]. After realizing reliability as one the key quality attribute, its prediction cannot be delayed or ignored. Therefore, there is an emergent need to ensure reliability of developing software as early as

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possible. So that developers can take suitable corrective measure before they start writing the actual code. In the last two decades, a large number of models for predicting the reliability have been proposed. But still, this domain of software engineering has been attracting more researchers to contribute further. It is evident from the review of the literature that reliability has been estimated or predicted through a variety of techniques like, formal methods, neural network, cause-effect graph analysis, multiple linear regressions, fuzzy logic, and many more. But prediction at early stage was rarely discussed[6]. The researchers had put their best efforts, but still there are a number of theoretical and practical issues noticed in many studies, that undermine the strength as well as validity of most models. Appropriate validation process is a necessity for the success of every effort. But majority of the models lack quality validation.

Even though, it is a universally accepted statistic that 70–80% of all the faults in software are get introduced during the requirements phase, this phase of the SDLC had not been given importance while quantifying the reliability. Majority of existing reliability models are applicable only in the later stages of development, and helping developers either by the end of coding phase or in the testing stage[7]. That becomes too late for developers to take corrective measure to improve its reliability. Despite the obvious variety of software reliability quantification, a prospect to design a comprehensive framework that can be followed by industry personnel and researchers to quantify reliability on the basis of requirement and design stage measures appears highly advantageous and significant. The remaining of the paper is structured as follows; Section 2 presents a comprehensive review of the literature and concludes with a summary of critical findings. Section 3 describes different phases of the proposed reliability quantification framework. A summary of the key features of the framework is listed in Section 4, while the paper finishes off in Section 5.

2. Related Work

Research in a specific dimension needs a highly structured review and study of literature related to that theme. A critical review of the literature make available information regarding, what has been done so for in the area, leading to a significant exploration. Comprehensive and careful reviews of the researchers also endorse better understanding of the selected topic, approach, procedure, method and algorithms and facilitate to frame useful hypothesis[8].

Software reliability quantification has attracted immense interest from researchers as well as software practitioners since the early 1990's. Traditional methods for quantifying the software-reliability such as reliability growth models estimates reliability on the basis of the defects observed during validation testing, where operational patterns represent how actually the product would be used. However, quantifying software reliability in an early stage has been a tricky research topic that many researchers have attempted to resolve with limited success[9]. Unfortunately, absence of failure data in early stages of software makes it challenging to measure the reliability. So there are just a few attempts, addressing the concept of early software reliability assessment or prediction.

During the review of literature it is commonly observed that software metrics has been playing a prominent role in fault identification[10–13]. In a study[14] authors had focused on the selection of an appropriate metrics suite to develop a prediction model. The study also demonstrates that how this selection impact on the fault prediction accuracy. While, Maa *et al.*,[15] had proposed a reliability prediction model, that highlighted the potential of requirement and design metrics in defect prediction at the early stage of development. In another effort, the concept of bayesian networks was used by Okutan and Yildiz,[16] to publicize the relationship between software metrics and defect proneness. In[10] authors supported the role of method-level metrics in predicting defects of application software. While the efforts had done by Radjenovic *et al.*,[12] drawn attention towards the potential of Chidamber and Kemerer's object-oriented metrics in predicting defects. The study also concluded that these metrics are not only the most frequently used metrics but also used twice than other conventional metrics. Another work in the area of defect prediction[17] has considered the role of process maturity with software metrics, while developing a defect prediction model. The study had developed fuzzy profiles for different metrics followed by the fuzzy inference process, but the criteria behind these profiles were not justified properly. In a study Olga Georgieva *et al.*,[18] have used the fuzzy logic approach for measuring software reliability, and concluded that participation of fuzzy logic has overcome the limitations of probability based reliability models. Another fuzzy based model proposed by Yadav *et al.*,[6] that predicts the residual faults during the testing stage. Another well known work done by Pandey and Goyal,[19] where, a data mining technique (classification) was used with fuzzy logic to categorized software modules as fault prone or not. While, the research[20] had demonstrated, how fuzzy logic can solve the modeling issue of reliability? The study had developed a fuzzy based reliability growth model