An NHPP SRGM with Change Point and Multiple Releases

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ABSTRACT

In an environment of intense competition, software upgrades have become the necessity for the survival in software industry. In this paper, the authors propose a discrete Software Reliability Growth Model (SRGM) for the software with successive releases by taking into consideration the realistic assumption that Fault Removal Rate (FRR) may not remain constant during the testing process, it changes due to severity of faults detected and due to change in strategies adapted by testing team and the time point where FRR changes is called the Change Point. Many researchers have developed SRGMs incorporating the concept of Change Point for single release software. The proposed model aims to present multi release software reliability modeling with change point. Discrete logistic distribution function has been used to model relationship between features enhancement and fault removal. It is helpful in developing a flexible SRGM, which is S-shaped in nature. In order to evaluate the proposed SRGM, parameter estimation is done using the real life data set for software with four releases and the goodness-of-fit of this model is analyzed.

KEYWORDS
Change Point, Discrete SRGM, Multiple Releases, Non-Homogeneous Poisson Process (NHPP), Software Reliability

INTRODUCTION

Over the years as time goes by, the technology change and evolve. These technologies provide an upgrade path for those too timid or wise to jump head-first into the latest wave of IT offerings. Realizing the great importance of current and future business needs, software developers offer latest version of their software through the addition of new functionality. To keep pace with the latest Software developments, the only way is to create great products through constant learning and improvement upon them, and thus release the software multiple times with added features and capabilities that enhance the functionality and usability of their software. Although these technologies and up-gradations of software application provides a smoother way toward a modern system, they often results to a complex and sometimes painful process that affects the entire working environment of organization. An upgrade of software is valuable if it results in increased reliability and reduced security risks. Reliability is the most important quality metric that is quantified in terms of the estimated number of faults remaining in the software system and is significantly used to measure the quality of software. Software reliability growth models (SRGMs) are used to predict the reliability and to assess software quantitatively. Many SRGMs have been developed in the last two decades that can describe the reliability growth during the testing phase of the software development (Kapur, Pham,
& Jha, 2011; Xie, Hu, Wu, & Ng, 2007). These models were proposed for the software in which no further enhancement is made and are released once into market. In today’s time there is a need for a modeling framework which presents a testing and debugging process of multi release software systems. Only a few attempts have been made to model multi-release software development process. In this paper we present a discrete modeling framework for multiple releases of software by considering the realistic assumption of having the change point in the testing time. During testing phase of software development process, the fault removal rate may not remain constant throughout but may change after some testing periods. Thus change point may appear notably when there is a non-monotonic increase or decrease in software failure intensity function. It happens due to changes in various factors such as operating environment, testing strategy, testing tools or techniques, nature of faults detected, defect density etc. In the next section, we briefly discuss the work done so far in this field.

**LITERATURE REVIEW**

One of the most important factors during testing process which affect the growth of software reliability is the fault removal rate (FRR). FRR helps in measuring the effectiveness of fault removal by test techniques and testing periods. Many researchers assumed a constant or monotonically increasing removal rate per fault in deriving their models (Goel & Okumoto, 1979; Yamada, Ohba, & Osaki, 1984, Kapur et al., 2011). However, in reality the FRR strongly depends on the skill of testing team, program size, defect density, testing efforts and software testability. In practice, stability of these factors cannot be guaranteed during the software testing and debugging process. Therefore, FRR may not be smooth and may change due to sudden changes in testing environment. The time at which change in FRR appear are known as change points. The pioneering work in this area was done by Zhao (1993). Chang (2001), Shyur (2003), Kapur, Gupta, Shatnawi, & Yadavalli (2006) and Lin & Huang (2006) made their contributions in this area by incorporating imperfect debugging and testing effort into the NHPP SRGM which is useful in solving the problems of many software projects and provides the flexibility to project managers to obtain the desired reliability level. All the models stated above were developed for single release software systems but in real life situation, to keep pace with the latest Software developments, organizations need to add new business models and adapt software applications to the new requirements and enterprise needs. Even if the present software version seems perfect, it needs to be upgraded to the latest version to improve its agility and to maintain innovation. Hence, there is an utmost need to model multi-releases in software development process. In recent years, many researchers have proposed a multi up-gradation reliability model. Hu, Peng, & Levitin (2012) studied the effects of multiple releases on the fault dynamics during the software development cycle and determined the expected number of remaining faults in each version. In this paper, we present a change point based discrete model for multi-release software systems to accommodate the sudden changes in FRR.

The rest of the paper is organized as follows: In the next section we present notations, assumptions and model development followed by discrete modeling of fault removal process for four release software system. Later on, in the paper we have validated the model on a real life 4-release-software fault data set to illustrate goodness of fit of the model to the data. Curves have been drawn, $R^2$ and MSE have been obtained to show how good the model is. Goodness of fit results of our model are compared with discrete logistic SRGM without change point due to Kapur, Aggarwal, & Nijhawan (2014). Finally, a conclusion is given and a list of references is enclosed at the end of the paper.

**NOTATIONS**

See Table 1.
Quality of Service Monitoring, Diagnosis, and Adaptation for Service Level Management
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