論　文　の　要　旨

題　目　　A Study on Markov Process Modeling for Software Reliability Assessment
（ソフトウェア信頼性評価のためのマルコフ過程モデリングに関する研究）

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In the typical waterfall development model, the software development process consists of 5 steps: (i) requirement/specification analysis, (ii) preliminary and detailed design, (iii) coding, (iv) testing/verification, and (v) maintenance. In the testing phase especially, software faults are detected and removed as much as possible to meet high software reliability requirements. In other words, the success of software testing leads to guaranteeing the quality of software. Since software reliability is considered as one of the most fundamental and significant attributes of software quality, considerable attention has been paid to improving software testing. At the same time, since software testing is quite expensive, the quantification of software reliability is also another important issue in the verification phase. The quantitative software reliability is generally defined as the probability that software failures caused by faults do not occur in a given time interval after the release, it is common to describe the probabilistic behavior of the fault-detection process in testing phases by any stochastic counting process. The software reliability defined in the above cannot be measured directly in the field, so that stochastic models, which are called software reliability models (SRMs), can be utilized to assess the quantitative software reliability. In fact, a great number of SRMs have been developed to control/monitor software testing processes as well as to evaluate the quantitative software reliability during the last four decades.

In this thesis, we propose numerous novel SRMs, based on the homogeneous Markov process (HMP) and non-homogeneous Markov process (NHMP). We formulate the maximum likelihood (ML) estimation of our SRMs and perform the software reliability analysis with the fault count time-interval data, fault count time-domain data (group data), and time-dependent software metrics data, which can be observed in the software industry. By comparing our SRMs with the representative existing SRMs, we evaluate the performances of models comprehensively.

In Chapter 1, we introduce the definition of HMP and NHMP-based software reliability modeling, including the well-known non-homogeneous Poisson process (NHPP)-based modeling framework.

In Chapter 2, we utilize the pure birth process (HMP) to describe software fault counts and propose geometric de-eutrophication SRM. We provide some useful results to handle the software fault count group data. Two types of SRMs are considered; Moranda SRM (1975) and Gaudoin-Soler SRM (1992), where the former is a modification of the well-known Jelinski-Moranda SRM (1972) having a software fault detection rate with geometrically decreasing reduction, the latter is an extension of Moranda SRM having another software fault detection rate with exponential decay.

Chapter 3 primarily focuses on the finite-failure (type-I) NHPP-based SRMs and infinite-

failure (type-II) NHPP-based SRMs. For describing the software fault-detection time distribution, we postulate 29 representative probability distribution functions that can be categorized into the generalized exponential distribution family, the extreme-value distribution family, the Burr-type distribution family, and the Lindley-type distribution family. To verify the usefulness of our considered type-I and type-II NHPP-based SRMs and confirm how well they make decisions in software reliability assessment, We compare the goodness-of-fit and predictive performances with the representative existing NHPP-based SRMs.

In Chapter 4, we propose local polynomial SRMs, which can be categorized into a semi-parametric modeling framework. Our models belong to the common NHPP-based SRMs but possess a flexible structure to approximate an arbitrary mean value function by controlling the polynomial degree. More specifically, we develop two types of local polynomial NHPP-based SRMs; finite-failure and infinite-failure SRMs, which are substantial extensions of the existing NHPP-based SRMs in a similar category.

Chapter 5 focuses on the so-called proportional intensity-based software reliability models (PI-SRMs), which are extensions of the common NHPP-based SRMs, and describe the probabilistic behavior of software fault-detection process by incorporating the time-dependent software metrics data observed in the development process.

In Chapter 6, we focus on NHMPs, which are generalizations of the well-known HMPs and NHPPs, and compare two SRMs that can be classified into a generalized binomial process (GBP) and a generalized Polya process (GPP). GBP and GPP are also characterized respectively as a Markov inverse death process and a Markov birth process, with state- and time-dependent transition rates. We develop a unified software reliability modeling framework based on the NHMPs and apply it to the software reliability prediction. Throughout numerical examples with the fault count data observed in actual closed-source software (CSS) and open-source software (OSS) development projects, we compare two SRMs (GBP and GPP) in terms of the goodness-of-fit and predictive performances, in addition to the quantitative software reliability assessment. We also consider software release problems with these generalized SRMs and investigate the impact on the software release decision. Finally, some conclusions and remarks are given in Chapter 7.