Foreword
Software Reliability

READERS of this TRANSACTIONS are well aware of the importance of software reliability. While they may differ about the ways to measure it or about the ways to achieve it, they would certainly agree about the need to ensure the presence of this attribute in a software system. The two parts of this special issue on Software Reliability (December 1985 and January 1986) address several aspects relevant to this critical software characteristic. The current issue deals with software reliability estimation, new modeling techniques, management issues, testing and verification, and fault-tolerant programs.

Software reliability can be viewed as the probability that a given program will operate correctly in a specified environment for a specified duration. Pursuant to this view, several models have been proposed for estimating the reliability of programs. These can be broadly categorized as software reliability growth models and statistical models. The former attempt to predict the reliability of a program on the basis of its error history while the latter estimate it by determining the response (success/failure) of a program to a random sample of test cases, without correcting any errors which may be discovered during this process. A survey of these models appears in the paper by Goel. This paper discusses the appropriateness of the assumptions underlying these models as well as their applicability during the software development cycle. It also gives a step-by-step procedure for developing a software reliability model from available failure data.

One important application of software reliability theory is to provide feedback regarding the amount of testing necessary in order to achieve a reliability objective. The paper by Okumoto develops an approach for monitoring, controlling, and predicting the quality of a program as it proceeds through the testing phase. The theory is illustrated using data from a real-time command and control system. The next paper by Yamada and Osaki discusses a class of software reliability growth models based on the nonhomogeneous Poisson process. These models are applied to data gathered from two software projects. The results indicate that the models provide a satisfactory empirical description of the underlying failure phenomenon.

In spite of the large number of models proposed to date, there are various factors which have so far not been extensively dealt with in the literature. Iyer and Rossetti discuss the effect of workload characteristics on the reliability of operating systems. They provide measurements which indicate that the system workload has a strong impact on software reliability. Their observations indicate that the probability of software failure increases nonlinearly with the amount of interactive processing. They discuss possible reasons for the strong correlation between workload and software failures based on a detailed analysis of failure data.

The paper by Cavano describes a set of expectations which managers of large scale software projects have from research in this area. He discusses a framework for characterizing software products and processes across eight dimensions and emphasizes that the reliability of a software product must be monitored continuously over its life cycle. The paper proposes a set of software reliability numbers which can be used for this purpose.

The next three papers deal with different approaches to estimating software reliability. Singpurwalla and Soyer use a random coefficient autoregressive process to estimate software reliability growth or decay. They propose four types of models based on this approach and illustrate them via execution time failure data from a medium-sized project. The paper by Jewell presents a Bayesian extension of the Jelinski-Moranda model and investigates a number of theoretical issues concerning this model. A numerical example is used to illustrate the estimation of model parameters. Finally, the paper by Ross proposes a model for determining whether a program has been adequately tested. Simulation results which indicate close agreement with the theory are also presented.

Testing is intimately related to the assessment of the reliability of programs. Richardson and Clarke provide an in-depth discussion of the partition analysis approach to software validation. An important feature of their approach is the combination of testing and verification so as to obtain the most favorable characteristics of both these techniques. A carefully selected example is used to demonstrate the applicability of the theory.

One method of developing high reliability programs is to incorporate mechanisms which attempt to mask out the occurrences of software faults. There are three papers in this issue which address methods of providing fault-tolerant capabilities in programs. These techniques include forward error recovery such as exception handlers, backward error recovery such as checkpoint/rollback recovery, and redundancy in data structures and algorithms such as N-version programming.

The paper by Avizienis presents a discussion of the motivation and evolution of the N-version programming approach to the tolerance of design faults and describes an environment for the execution of N-version software. The author also raises the possibility that this approach may facilitate the development of reliable programs using simplified development methods. Anderson, Barret, Halliwell, and Moulding present an experimental assessment of the effectiveness of the recovery block approach to providing software fault tolerance. They applied this technique to a realistic implementation of a real-time system. Their results indicate that the use of this fault tolerance approach yielded a substantial improvement in system reliability. The final paper by Eckhardt and Lee attempts to
evaluate a fundamental assumption of N-version programming, namely, that the probability of independently designed versions of a program containing similar errors is small. They explore the effect of such coincident errors in N-version programming from a theoretical point of view.

**ACKNOWLEDGMENT**

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Guest Editors

**Amrit L. Goel** (M’75) received the B.S. degree from Agra University, Agra, India, the B. Engr. degree from the University of Roorkee, Roorkee, India, and the M.S. and Ph.D. degrees from the University of Wisconsin, Madison.

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Dr. Goel was a Guest Editor for the *Journal of Systems and Software*. He has been a member of several technical program committees, including the Sixth International Conference on Software Engineering and COMPSAC. Currently, he serves on the Executive Committee of the IEEE-CS Technical Committee on Software Engineering and on the Editorial Board of *Computer*. He is a member of the Association for Computing Machinery, the American Statistical Association, the Institute of Mathematical Statistics, and Sigma Xi, and is a Fellow of the Royal Statistical Society, England. He was the recipient of the P. K. McElroy best technical paper awards of the IEEE Reliability Society in 1979 and 1980.

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**List of Referees**

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