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Research in reliability and quality control covering topics in software certification and testing, tracking (software) reliability growth, Bayesian acceptance sampling and life testing, accelerated life testing and the setting of optimum warranties.

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FINAL TECHNICAL REPORT

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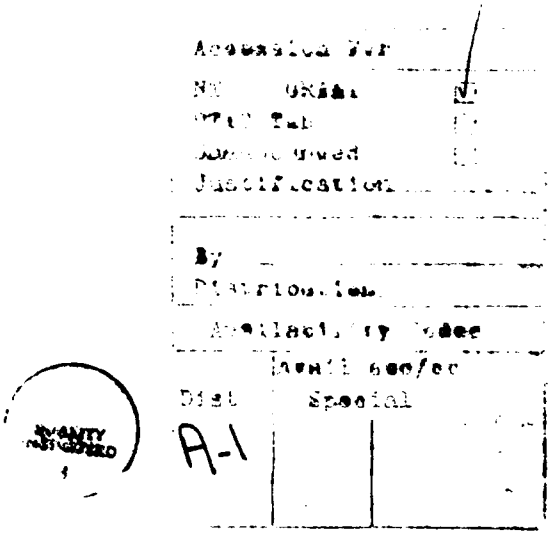
September 25, 1991



FINAL TECHNICAL REPORT

Grant AFOSR-89-0381
Nozer D. Singpurwalla, Principal Investigator

Overview:

Research under the above grant deals with the general area of reliability theory and quality control. An emphasis here is on problems emanating from the area of software engineering, especially software reliability and software testing. In all 6 papers have been published or accepted for publication in the open literature, and 2 are currently under review. In the latter category, one of the papers deals with the topic of *warranties*, an issue which is relatively less formally researched but which appears to be growing in importance with respect to both military and commercial systems (to include both hardware and software).

1. Software Certification and Reliability Growth.

In the general area of software reliability 2 papers (see references 2 and 5) have been written, one of which has appeared in print and the other accepted for publication. The first one deals with the important problem of how much testing needs to be done to a piece of software before it is released for use. The problem is formulated as one involving decision under uncertainty and a mathematical expression for obtaining the optimum test time has been developed. The approach has been codified for use on a personal computer and this software is included in a package of programs for reliability analysis that is currently being developed. A use of this approach calls for a specification of the costs of testing and the costs of failure during operation. Unfortunately, only the case of single stage testing has been rigorously addressed. The more realistic case of sequential testing poses horrendous technical difficulties and remains to be addressed. Work on this topic continues.

The second paper deals with the topic of monitoring the growth in reliability of a system, say a piece of software. A new model for reliability growth is proposed; this is based on the *power law* relationship, and a Bayesian approach for inference about the model parameters and tracking the future failure times is developed. The model reduces to a nonhomogeneous autoregressive process which under certain circumstances can be addressed via a *Kalman Filter* algorithm, and which under other circumstances can be addressed via an adaptive Kalman Filter algorithm, for which a new solution is proposed. The solution of the latter involves an approximation due to Lindley. Thus this work makes a contribution to 3 topics, software reliability growth (the approach is illustrated via data on software testing), time series analysis, and adaptive Kalman Filtering.

It is anticipated that the proposed model and ensuing approach will also be useful for the optimum testing of software, but this remains to be explored.

2. Adversarial Life Testing and Acceptance Sampling

Military standards, for quality control and reliability, such as MIL-STD-1051 and MIL-STD-781C, are routinely used by government (particularly the DOD) and by industry. These have been severely criticized in the literature on grounds of uncoherence; see for example the writings of Deming. A Bayesian approach to the above would rectify the above concern, but the choice of a prior which is acceptance to both the producer and the consumer has been an obstacle. As a way of obviating this difficulty a new approach to the above plans has been proposed and developed under the aegis of this grant; see references 4 and 7. The approach allows the consumer and the producer to assume their own, possibly different, priors and develops suitable formulae for the accept/reject regions and the necessary sample sizes. The word adversarial is used to indicate the fact that the producer and the consumer are adversaries, and each is trying to maximize the underlying expected utilities. It is hoped that the above development will be picked up by the DOD (which is the caretaker of the MIL STD

plans) and implemented for use.

3. Accelerated Life Testing

Accelerated life testing is routinely done in reliability assessment. The existing procedures for inference from accelerated tests are predominantly non-Bayesian; their disadvantage has been an inability to incorporate engineering judgment into the analysis of data from accelerated tests. The use of such judgments is the operating norm in practical applications of accelerated tests. Viewing an accelerated test as an operation in filtering, with suitable priors to reflect engineering judgment offers hope, and a proposal to do the above was advocated by the PI. An implementation of this approach to some real live data from a biological context was undertaken under the aegis of this grant; see reference 3. The aim here was to demonstrate the feasibility of the proposed approach and to describe the practical nuances that occur when one attempts to undertake it.

4. Dependence in Reliability

The notion of dependence is central to the current research in reliability theory; the usual assumption of independence has resulted in unsatisfactory assessments. The fact that dependence is a *conditional* notion has not been explicated in the literature in reliability. Under the aegis of this grant (see reference 1), such conditioning is emphasized and the idea is further explored by making the conditioning parameter random. This work is of a foundational nature.

5. Warranties

Whereas consumers are used to acquiring products that are warranted by the manufacturer, the government, particularly DOD, may soon be moving more aggressively in that direction. It is very

likely that warranties may be mandated in the future procurement activities of the DOD. The problem of optimum warranties is a multi-disciplinary one, which involves among other things, issue of reliability and renewal theory. Under the aegis of this grant the problem of warranties has been scoped out (see references 6 and 8) and specific issues germane to the problem addressed. Of particular interest is the need to develop a new class of failure models that are indexed by two scales, time and usage. Work in this area is currently in progress. The topic of warranties promises to become a full-fledged multidisciplinary research area in the mathematical sciences.

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