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Improving product quality by multiple inspections: Prior and posterior planning of serial inspection procedures

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In many practical situations, a complex product is inspected more than once in a sequential manner to further improve its quality. In this paper, the problem of designing the *multiple* inspection plan via a Bayesian method is considered. As a prior distribution in the Bayesian model, a negative binomial distribution that has many desirable properties is used. Two types of design problem are considered. In *prior* planning of a serial inspection procedure, the number of inspections necessary to achieve a desired level of quality must be determined prior to starting the inspection process. In *posterior* planning, the inspection process can be terminated if the product meets a given level of quality. In both cases, the improved level of quality is measured in this paper either by the expected number of undetected errors still remaining in the product or by the probability of no undetected errors in the product.

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1. Introduction

Inspection is one of the proven approaches to ensuring the quality of a complex product. A highly effective inspection procedure in quality control must ensure that most of the detectable faults in the product are, indeed, detected. However, *inspection errors* are inevitable in most inspection procedures, and the effectiveness of inspections can vary widely among different inspectors and various inspection methods. Thus, a product is often inspected independently by multiple inspectors, or examined with different inspection methods, to further improve its quality. In this paper, we consider the problem of designing a "serial" inspection procedure, in which a product is inspected repeatedly by a single inspector or sequentially by multiple inspectors.

The total number of faults Z in a product is obviously unknown, but the inspector may have subjective knowledge about Z prior to conducting a series of inspections. Thus, the problem of designing a serial inspection plan can be approached from a Bayesian point of view. Recently, Rallis and Lansdowne (2001) developed a Bayesian model for the serial inspection procedure. They proposed a Poisson prior, assuming that the number of faults still remaining undetected in a software system is *independent* of the numbers of faults discovered during a series of inspection cycles. This assumption is not generally acceptable in many practical situations. As the votes are counted in the "ballot problem," for example, the probability that the next vote is for Candidate A is *positively* related to the number of votes he or she has received so far.

As an alternative to their Poisson prior, we propose in this paper a *negative binomial prior* with parameters α and β, which has many desirable properties. For example, by changing the parameter values, we can represent a wide variety of prior distributions with different location, dispersion, shape and the like, including not only the Rallis–Lansdowne Poisson prior as a special case, but also the non-informative or vague prior of Z. Using the Bayesian model with a negative binomial prior, we can easily estimate: (i) the number of faults still remaining in the product; (ii) the probability that all the faults have been successfully detected; and (iii) the probability that no more faults will be detected during the *next* inspection cycle.

The Bayesian model with the negative binomial prior is then used to design a sequential inspection procedure at two different planning stages: (i) prior planning; and (ii) posterior planning. Prior to starting the inspection process, we need to determine the number of inspection cycles necessary to achieve a certain quality level. During the *prior planning* stage, the only information available is our prior information on Z; the inspection results are not yet available.