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Improved method of estimating the product quality after multiple inspections

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A complex product is often inspected more than once in a sequential manner to ensure the product's quality. Based on the number of defects discovered during each round of inspection process, we can estimate the number of defects still remaining in the product. For each defect, the probability that the defect will be detected during each inspection cycle is usually assumed to be a known 'constant'. However, in many practical situations, some defects are easily detected, while others are much more difficult to identify. In this paper, we propose a 'beta-geometric' inspection model in which the heterogeneity in detection probability is described by a beta distribution. In a numerical study, we show that our more realistic inspection model clearly outperforms traditional estimation methods that are based on the assumption of a constant detection probability.

Keywords: inspection; product quality; reliability; maximum likelihood estimation

1. Introduction

Although inspection is one of the most important and effective tools in assuring product quality, the 'inspection error' is inevitable in any inspection process (Yang and Cho 2014). Due to human error and technical problems, not every defect (or non-conformity) is detected during a single round of inspection. That is why some complex products (e.g. software system) are inspected multiple times in a sequential manner in order to improve the outgoing quality.

As an example of multiple inspection, consider a software system that contains an unknown number of 'faults', N. A complete test and correction cycle is referred to as a 'review' as in Rallis and Lansdowne (2001), and the software system will be reviewed more than once in a sequential manner. For each fault, the 'detection probability' is p, which is the probability that the fault will be detected, if not detected earlier, during the current review cycle. After each review, the number of faults x_i detected during the review cycle i is recorded, and those faults are removed or corrected prior to the next review.

After a series of k independent reviews, we have a record $\mathbf{x} = \{x_1, x_2, \cdots, x_k\}$ of the number of faults detected and corrected during each review cycle. Based on the inspection results $\mathbf{x} = \{x_1, x_2, \cdots, x_k\}$, we need to estimate the total number of faults N or, equivalently, the number of faults R_k $(=N - x_1 - x_2 - \cdots - x_k)$ still remaining in the software system (Chun 2009). Conversely, we also want to determine the number of multiple inspections k that ought to be conducted to achieve a certain level of outgoing quality (Jaraiedi, Kochhar, and Jaisingh 1987).

Such multiple inspection plans have attracted considerable attention recently under various names: repetitive testing (Greenberg and Stokes 1995; Ding, Greenberg, and Matsuo 1998; Quinino and Ho 2004; Ding and Gong 2008; Gong 2012; Wu, Wu, and Chen 2015), sequential defect removal sampling (Bonett and Woodward 1994), repeat inspection (Duffuaa 1996; Duffuaa and Khan 2002, 2005; Elshafei, Khan, and Duffuaa 2006), repeated screening (Gasparini, Nusser, and Eisele 2004), and sequential review or inspection (Yao and Zheng 1999; Rallis and Lansdowne 2001).

In most articles, however, the detection probability p of a fault is assumed to be a 'constant' – either a known constant that is given a priori or an unknown constant that ought to be estimated. For example, assuming that the detection probability p is a known constant, Rallis and Lansdowne (2001) treated the total number of defects N as a Poisson random variable. As a prior distribution of N, Chun (2009) and Chun and Sumichrast (2007) proposed a negative binomial distribution, and developed a Bayesian model to determine the number of inspections that is needed to achieve a certain level of product quality.

Assuming that both N and p are unknown constants, Chun (2005) proposed the maximum likelihood estimators. Bonett and Woodward (1994) also treated both N and p as unknown parameters that can be estimated by a non-linear

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