Economic Design of a Screening and Process Monitoring Procedure for Normal Model

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Abstract

An economic process monitoring procedure is presented using a surrogate variable for the case where performance variable is dichotomous. Every item is inspected with a surrogate variable and determined whether it should be accepted or rejected. When an item is rejected, the number of preceding accepted items is compared with a predetermined number r to decide whether there is shift in fraction nonconforming or not. The conditional distribution of the surrogate variable given the performance variable is assumed to be normal. A cost model is constructed which includes costs of inspection, misclassification, illegal signal, undetected out-of-control state, and correction. Methods of finding the optimum number r and screening limit are provided. Numerical studies on the effects of cost coefficients are also performed.

Due to the recent advances in inspection systems and the increasing requirements of the marketplace, 100% inspection (screening) becomes very popular at one or more stages of the manufacturing process. The inspection is frequently based on a surrogate variable instead of the major quality characteristic of interest (performance variable). For example, in the manufacturing process of the nozzle of the fuel injection equipment, every item is inspected by measuring the amount of air flow through the nozzle instead of testing whether the injection system equipped with each nozzle is functioning or not. There have been a number of studies concerning the screening procedure. For detailed literature review, see Tang and Tang[1]. For more recent works, see Boys et al.[2] and Greenshtein and Rabinowitz[3].

The objective of screening procedures may be either improving the outgoing quality or minimizing the total cost relevant. This, however, may not be achieved if the process is unstable. For attainment of a state of statistical stability of a process, a wide variety of Shewhart control charts and their modifications have been developed for different types of situations. Economic design of control charts was also studied by many authors. See Montgomery[4] for literature review and Das et al.[5] and Das and Jain[6] for recent works. The control charts are usually based on samples taken over fixed or variable time intervals. Under 100% inspection, however, sampling is not necessary and the inspection data can be used. For this situation, Bourke[7] suggested a run-length control chart to detect a shift in fraction nonconforming. Hui[8] studied a complete inspection plan with feedback control when the performance variable is continuous. These two works used the performance variable for designing the process monitoring scheme.

In many situations, a surrogate variable is used instead of the performance variable for 100% inspection. In the screening procedure, the screening limits are determined assuming a stable production process. This, however, is not likely to be true in the practical situation of industries. When the process is unstable, it will be reasonable to use a screening procedure together with a process control scheme. In this paper, we combined a screening procedure with a process monitoring scheme when a surrogate variable is used instead of the dichotomous performance variable. The surrogate variable is assumed to be normally distributed given the performance variable. Every item is determined to be accepted or rejected based on the observed value of the surrogate variable. When an item is rejected, the number of preceding accepted items is compared with a predetermined number r to decide whether there is a shift in fraction nonconforming or not. A cost model is constructed on the basis of the costs of inspection, misclassification, illegal signal, undetected out-of-control state and correction. The optimum number r and screening limit are provided. A numerical example is given and the effects of cost coefficients are studied.

Numerical analyses based on an example show that the screening limit depends mainly on the costs of the type I and type II misclassification errors. And γ^* is affected by λ and the relative magnitude of p_1 against p_0. If λ becomes large, which implies the process becomes unstable, γ^* takes a larger value and thus the process is subject to more frequent investigation for change. As for the effect of cost coefficients, if the cost of undetected out-of-control state increases, γ^* increases. These numerical results agree with our intuition. The expected total cost per unit time is pretty robust to the estimation error of the means when the percentage error is smaller than about 4%.