A new strategy for phase I analysis in SPC

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1.Introduction

- The purpose of this paper is to propose and study a new strategy for Phase I analysis.

- In statistical process control (SPC), control chart applications are often distinguished into Phase I and Phase II.
- In Phase I, process data are collected and analyzed with the goals to bring the process to a state of statistical control, and then to model the in-control process so that reliable control limits of the control chart can be established for online process monitoring later in Phase II.

- The conventional practice for Phase I analysis is an iterative procedure described below:

- (i) First, use the data to set up a set of initial *trial* control limits for the monitoring statistic, such as *X*, *R*, or *S*, to identity potential ‘out-of-control’ points.For simplicity, we only consider the charted points that exceed the control limits as the ‘out-of-control’ points in this study.

- (ii) If some samples signal ‘out-of-control’, then the operators or process engineers should investigate the process to see if there exist any assignable causes to explain why these points are out-of-control.

- (iii) Repeat the above screening steps based on the remaining data set until no more ‘out-of-control’ points can be found.

- Statistically, in any control charting, there are possibilities that some in-control samples may get wrongly discarded and some out-of-control samples may remain undetected, which are similar to committing Type I and Type II errors in hypothesis testing, respectively.

- In this paper, we study this procedure and find surprisingly that the discard-all practice tends to mistakenly screen out too many (i.e. more than expected) in-control data points.

- To overcome this drawback, we propose a more effective iterative procedure for collecting in-control data by simply discarding, instead of *all*, but only *one* ‘out-of-control’ point (the most extreme one) and then updating the trial control limits at each iteration.

- This procedure will be referred to as the one-at-a-time (OAAT) procedure hereafter.

- To fit the purpose of Phase I analysis better, we suggest using simultaneously the rate of correctly rejected samples and the rate of wrongly rejected samples as the comparison criteria.
- The former measures the detecting power (true-alarm rate) and the latter measures the false-alarm rate.

- With a fixed individual false-alarm rate, the overall false-alarm rate gets larger when the number of samples *m* gets larger.

2. The conventional method

- *2.1. Estimating process parameters*
- *2.2. Phase I Shewhart control chart*
- *2.3. The individual and overall false-alarm rates*

2.1. Estimating process parameters

$$\mathrm{Var}\left(\frac{\overline{V}^{1/2}}{c_{4,m}}\right) \leq \mathrm{Var}\left(\frac{\overline{S}}{c_4}\right) \leq \mathrm{Var}\left(\frac{\overline{R}}{d_2}\right)$$

2.2. Phase I Shewhart control chart

$$LCL = \hat{\mu}_0 - k\frac{\hat{\sigma}_0}{\sqrt{n}}, \quad CL = \hat{\mu}_0 \quad \text{and} \quad UCL = \hat{\mu}_0 + k\frac{\hat{\sigma}_0}{\sqrt{n}}$$

2.3. The individual and overall false-alarm rates

$$\alpha^* = 2\left(1 - F_{t_{m(n-1)}}\left(\frac{k\sqrt{m}}{c_{4,m}\sqrt{m-1}}\right)\right)$$

3. New strategy and the OAAT method for Phase I analysis

- *3.1. Criteria for performance evaluation*
- *3.2. A new strategy on when to inspect*
- *3.3. An illustrative simulation study of discard-all practice*
- *3.4. The OAAT method*

3.1. Criteria for performance evaluation

- Note that when the historical data set contains a mixture of in-control and out-of-control data (i.e. when $m>m1>0$), then the signal probability (denoted by P) is not the overall false alarm rate (unless $m1=0$) nor the detecting power (unless $m1=m$), and out-of-control signals can be triggered by either true or false alarms.

3.2. A new strategy on when to inspect

- Here we suggest a new strategy: run through the whole iterative procedure and then perform the inspection for assignable causes for all of the ‘out-of-control’ points at the end. This new strategy should be able to reduce the frequency of stop-and-inspect actions.

3.3. An illustrative simulation study of discard-all practice

- By examining the simulation results of the discard-all practice, it is noted that the number of false alarms is higher than we would expect.

3.4. The OAAT method

- *Step 1*. Construct the trial control limits with all collected data.
- *Step 2*. If no ‘out-of-control’ samples are identified with the control limits, stop iterating and go to Step 4; otherwise, discard the most extreme sample.
- *Step 3*. Construct the trial control limits with the remaining samples; go to Step 2.
- *Step 4*. If there is no sample discarded, claim the process is in control; otherwise collect all the samples discarded in the above iterations and inspect the process for assignable causes.

4. The performance of the OAAT procedure

- *4.1. Controlling the individual false-alarm rate*
- *4.2. Controlling the overall false-alarm rate*

其中有四個因素會影響此研究結果:

- 樣品的數量(m)
- 組的大小(*n*)
- 樣本比例(p)
- size of the process shift(δ).

4.1. Controlling the individual false-alarm rate

- P值的增加，失控點的比例會更明顯
- OAAT較少出現signals false alarms
- 當 m，n或p很大時，在許多實驗中所有程序方面的假警報率是非常大的
- 當n增加時，OAAT比傳統做法的錯誤警報率更小

4.2. Controlling the overall false-alarm rate

- OAAT遠比其他傳統方法在每個實驗上假警報率非常的小。

5. Summary and concluding remarks

- 此方法可節省龐大的企業成本
- 當程序不穩定時，OAAT可明顯的降低假警報率發生
- OAAT可應用於其他管制圖上

END