Global Journal of Pure and Applied Mathematics.
ISSN 0973-1768 Volume 11, Number 1 (2015), pp. 197-200

http://www.ripublication.com

Evaluation Of 2/2 Control Chart Through Monitoring Of Practical Process

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Abstract

To evaluate the performance of 2/2 control chart, a simulation was utilized to determine the average run length (ARL) then an industrial manufacturing process was also monitored to exhibit its efficiency. The result of simulation displayed the 2/2 control chart was more quickly capable detecting out-of-control states than the 1/1 control chart. In addition, the 2/2 control chart obviously indicated an upward shift in process mean and pointed to all existed signals earlier than the 1/1 control chart.

Keywords: 1/1 control chart, 2/2 control chart, ARL

Mathematics Subject Classification: 62-07, 62G35

Introduction

Control chart is one of powerful tools in statistical process control (SPC). It has been widely used for monitoring a manufacturing process. The $\bar{x}$ control chart, sometimes called the Shewhart $\bar{x}$ control chart, is the most popular traditional chart employed to examine the process mean developed by Dr. Water A. Shewhart. Although the Shewhart $\bar{x}$ control chart is efficient for detecting medium and large shifts, it is insensitive to small shift. The CUSUM and EWMA charts are the two alternatives to the Shewhart $\bar{x}$ control chart. However, these control charts are not simply utilized for practitioners because of their complicated calculation. Some researchers, for example; [1], [2], [3], [4] and [5], studied and then recommended the additional supplementary runs rules to solve this problem. Presently, Klein introduced two choices to the Shewhart $\bar{x}$ control charts. One is the two of two or 2/2 control chart and the other is two of three or 2/3 control chart [6]. Regard as this concept, the

Shewhart $\bar{x}$ control chart is known as the one of one or 1/1 control chart. In the same way, Khoo continually studied ARL performance of the 2/2, 2/3, 2/4, 3/3 and 3/4 control charts through a simulation [7].

The purpose of this study was (1) using a simulation to present only the ARL performance of 2/2 control chart which gave an out-of-control signal if either two consecutive points were plotted above the upper control limit or two consecutive points were plotted below the lower control limit and (2) applying the real data of industrial manufacturing process to investigate how well the 2/2 control chart could monitor the process mean shift also to compare its efficiency to the 1/1 control chart.

Materials And Methods

A simulation data would support the purpose of this study with Minitab Macro by assuming

(1) the in-control process mean (μ_0) with the quality characteristic

$$x_i \sim N\left(\mu_0 = 0, \sigma^2 = 1\right) \quad ; i = 1,2,\ldots,20 \text{, and}$$

(2) the out-of-control process mean (μ_1) with the quality characteristic

$$x_i \sim N\left(\mu_1, \sigma^2 = 1\right) \quad ; i = 21,22,\ldots,30$$

where $\mu_1 = \mu_0 + \delta\sigma$ and δ represents the process shift size.

In this study, the process shift size was roughly classified as 3 types: small shift ($\delta = 1$), medium shift ($\delta = 2$) and large shift ($\delta = 3$).

Once each of process iteration was operated, the run length was calculated. Then, finally the ARL was determined depended on all iterations.

An example of application was exemplified based on the data derived from [8]. This data contained 30 batch numbers of viscosity on aircraft primer paint. We are interested in applying the 1/1 and 2/2 control charts to investigate whether this industrial manufacturing process was in statistical control. The first 20 viscosity was assumed to be in-control state. The sample average ($\bar{x}$) and standard deviation (S) were computed as 33.546 and 0.3967, respectively.

The control limits for individual observations of traditional control chart defined as of Equation 1.

$$\begin{aligned} \text{Upper Control Limit } (UCL.) &= \mu_0 + k\sigma \\ \text{Center Line } (CL.) &= \mu_0 \\ \text{Lower Control Limit } (LCL.) &= \mu_0 - k\sigma \end{aligned} \tag{1}$$

where μ_0 and σ be the in-control process mean and standard deviation, respectively and k be the distance of the control limits from center line expressed in standard deviation unit. The approximation of μ_0 and σ are computed as $\bar{x}$ and S, respectively if these two parameters are unknown.

Control limits of the Shewhart chart are normally defined as three-sigma limits [8]. Since the 1/1 control chart is the traditional Shewhart chart, k is set up to 3 in accordance with the theoretical in-control ARL 370.4. While as the control limits of 2/2 control chart are modified by adding the sensitizing run rules for investigation of process change, k is then adjusted to 1.781 followed the recommendation of [9]. If any observation falls beyond the upper control limit or beneath the lower control limit, this process is identified in an out-of-control state.

Results

The out-of-control ARL of the 1/1 and 2/2 control charts were considered to compare the performance between these two charts as shown in Table 1. This table indicated the 2/2 control chart obtained smaller ARL values than of the 1/1 control chart in every process shift size. Furthermore, both of two charts most quickly detected when the process mean shifted to the large shift.

Table 1: ARL values for 1/1 and 2/2 control charts

Shift size	1/1 control chart	2/2 control chart
0	≈370.4	≈370.4
1σ	42.94	25.17
2σ	6.58	4.53
3σ	2.33	2.05

The 30 batch numbers of viscosity were plotted in Figure 1 with the control limits as 33.546±3(0.3967) and 33.546±1.781(0.3967) for the 1/1 and 2/2 control charts, respectively. There were 10 consecutive points above the control limit in the 2/2 control chart while only 4 points of 1/1 control chart were outside the upper control limit. However, both of two charts could illustrate that the viscosity data was out-of-control process.

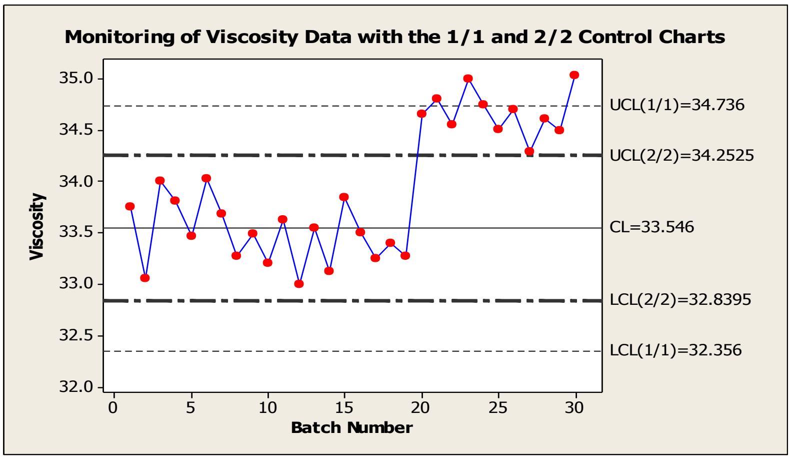

Figure 1: Monitoring of Viscosity Data with the 1/1 and 2/2 Control Charts

Discussion

The modified Shewhart or 2/2 control chart provided better performance than the traditional Shewhart or 1/1 control chart as seeing of the smaller ARL values for all process shift sizes. Also, both of these charts were still capably detected fast at the large shift in agreement of [9]. For the real data, the 2/2 control chart was not only able to detect 10 points were out-of-control but also exhibited an upward shift in viscosity mean had happened around batch number 20 or 21 because there was an apparent shift in process level pattern while the 1/1 could display only 4 points beyond the upper control limit. Therefore, adding the supplementary runs rules to the 2/2 control chart substantially aided to monitor changing of the process mean.

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