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Shewhart-EWMA chart for monitoring binomial data subject to shifts of random amounts

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ABSTRACT

Attribute charts are used widely for monitoring binary events in manufacturing, service, and healthcare processes. While Shewhart type charts are efficacious in detecting large or sudden shifts in a nonconforming rate *p*, exponentially weighted moving average (EWMA) type charts tend to be more powerful for detecting smaller or gradual shifts. Since many processes can shift by various amounts, this paper proposes a combined optimized Shewhart-EWMA dual chart that combines the strengths of both charts to quickly detect shifts of any random magnitude within a defined range. The performance of this combined Shewhart-EWMA chart is optimized by allocating total detection power between the Shewhart chart element and EWMA chart element in a manner that yields the best overall effectiveness while maintaining the false alarm rate at a specified desired level. In numeric analysis under a range of settings, the detection speed of this combined Shewhart-EWMA chart is found to outperform individual Shewhart and EWMA charts, with up to 499% and 31% fewer average number of defective items respectively until process shifts of random sizes are detected. It also demonstrates enhanced overall efficacy when compared to synthetic, cumulative sum, combined Shewhart-synthetic, and combined Shewhart-CUSUM charts.

1. Introduction

In organizations, statistical process control tools are utilized to produce high quality products and processes as well as maintain its stability (Mahmood et al., 2023). A common attribute control chart employed for monitoring and tracking the number of nonconforming items within a sample, *d*, in the most recent specimen from a process is called the Shewhart np chart (Leoni & Costa, 2018; Chowdhury et al., 2022). As alternatives, Cumulative Sum (CUSUM) chart as well as Exponentially Weighted Moving Average (EWMA) chart also incorporate information from all past observed values of *d* (Lucas, 1985; Wu et al., 2021; Xue et al., 2023), and by so doing increase their ability to detect smaller process changes faster (Ajibade et al., 2023). They are called memory control charts (Mohamadkhani & Amiri, 2022). EWMA and CUSUM charts have quite similar operating characteristics (Reynolds & Stoumbos, 2004, Mahmood & Erem, 2023) and tend to be faster than their Shewhart counterparts when detecting minor shifts but lengthier for larger process shifts (Radaelli, 1994; Kapatou, 1996; White et al., 1997; Aradhye et al., 2003; Abbas et al., 2011; Yang et al., 2012). For continuous variables, Reynolds and Stoumbos (2004) and Vera do Carmo et al. (2004) performed comparisons related to the CUSUM versus EWMA control charts' performance, and Reynolds and Stoumbos (2005) demonstrated that the integration of either of these methods with a Shewhart chart effectively detects large or minor shifts in both the mean and variance of a process (Haq & Awais, 2018; Haq & Munir, 2021).

EWMA and CUSUM charts both use the idea of collecting information through time as their foundation, but they take different approaches to collecting information as well as allocating weight to earlier observations. In CUSUM scheme, equal weights are used in a running total, whereas in EWMA, exponentially decreasing weights are applied in a running weighted average. Additionally, the integration of either EWMA or CUSUM chart into the framework of the Shewhart control chart enhances its capacity to discern large as well as small shifts in process means, thereby elevating the chart's overall sensitivity (Mahmood et al., 2023). These two chart types have been extensively utilized and studied

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