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ORIGINAL ARTICLE

An integrated MEWMA-ANN scheme towards balanced monitoring and accurate diagnosis of bivariate process mean shifts

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Abstract Various artificial neural networks (ANN)-based pattern recognition schemes have been developed for monitoring and diagnosis of bivariate process variation in mean shifts. In comparison with the traditional multivariate statistical process control (MSPC) charts, these advanced schemes generally perform better in identifying process mean shifts and provide more effective information towards diagnosing the root causes. However, it seemly less effective for multivariate quality control (MQC) application due to disadvantages in reference bivariate patterns and imbalanced monitoring performance. To achieve 'balanced monitoring and accurate diagnosis', this study proposes an integrated multivariate exponentially weighted moving average (MEWMA)-ANN scheme for two-stages monitoring and diagnosis of some reference bivariate patterns. Raw data and statistical features input representations were applied into training of the Synergistic-ANN recognizer for improving patterns discrimination capability. The proposed scheme has resulted in better monitoring – diagnosis performances with smaller false alarm, quick mean shift detection and higher diagnosis accuracy compared to the basic scheme.

1. Introduction

In manufacturing industries, process variation has become a major source of poor quality. Manufacturing process may involve two or more correlated variables and an appropriate procedure is required to monitor these variables simultaneously. This issue is sometimes called multivariate quality control (MQC). It has led to extensive research in the field of multivariate statistical process control (MSPC) towards monitoring and diagnosis of multivariate process variation in mean shifts/variances. Further discussions on this issue can be found in Lowry and Montgomery (1995), Kourti and MacGregor (1996), Mason et al. (1997) and Bersimis et al. (2007).

Development in soft computing technology have motivated researchers to explore the use of artificial intelligence techniques such as artificial neural networks (ANN), among others

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for automatically and intelligently recognizing patterns in relation to MSPC charting. Identification of these patterns coupled with engineering knowledge of the process would lead to more specific diagnosis and troubleshooting. Various ANN-based pattern recognition schemes have been proposed such as MSPC-ANN (Chen and Wang, 2004; Niaki and Abbasi, 2005; Cheng and Cheng, 2008; Yu et al., 2009), novelty detector (Zorriassatine et al., 2003), modular-ANN (Guh, 2007), ensemble-ANN (Yu and Xi, 2009) and multi-module-structure-ANN (El-Midany et al., 2010). The MSPC-ANN schemes combined the MSPC charts (for monitoring any mean/variance shifts in multivariate processes) with ANN recognizer (for diagnosing the source variable(s) that responsible for mean/variance shifts). The other schemes such as novelty detector, modular-ANN, ensemble-ANN and multi-module-structure-ANN were designed to perform continuous monitoring and diagnosis simultaneously. Further discussion on these schemes can be found in Masood and Hassan (2010).

In this study, these ANN-based schemes are referred as bivariate pattern recognition (BPR) since the investigations are mainly focused on two correlated variables. In comparison with the traditional MSPC charts, these schemes have shown faster detection of mean shifts and provided a more detail information of the source variable(s) towards effective diagnosis. Nevertheless, they revealed some disadvantages in terms of:

1.1. Reference bivariate patterns

In MQC, the joint effect (cross correlation) between two dependent variables should be taken into account. Monitoring-diagnostic using Shewhart control chart patterns may provides useful meaning about univariate process mean shifts but it would lead to a higher false alarm than assumed. On the other hand, monitoring-diagnosis using χ^2 control chart patterns would result in lack of diagnosis (unable to identify the source variables). Generally, there are limited works reported on modeling of bivariate correlated process and patterns.

1.2. Imbalanced monitoring

In monitoring aspect, the existing BPR schemes are generally effective to quickly detect mean shifts. Unfortunately, they are mainly limited to a short ARL_0 ($\approx$200), that is inadequate to reduce false alarm towards an original SPC level ($ARL_0 \approx 370$ based on Shewhart control chart). It is critical for a practitioner to conduct unnecessary troubleshooting due to wrong identification of stable process as unstable. In this study, this situation is called 'imbalanced monitoring'.

In order to overcome the above disadvantages, an integrated MEWMA-ANN scheme was developed towards 'balance monitoring and accurate diagnosis' for some reference bivariate patterns. The proposed scheme aims for a reduced false alarm, faster mean shift detection and a more accurate diagnosis. Details discussion is organized as follows. Section 2 presents an integrated MEWMA-ANN scheme. Section 3 then provides performance comparison between an integrated MEWMA-ANN scheme and the Basic scheme. Section 4 finally outlines some conclusions.

2. An integrated MEWMA-ANN scheme

An integrated MEWMA-ANN scheme was developed based on two-stages monitoring and diagnosis approach as shown in Fig. 1. Process monitoring refers to the identification of process status either in a statistically stable or unstable state, whereas process diagnosis refers to the identification of the source variable(s) of an unstable process. In the first stage monitoring, the MEWMA control chart is used for triggering mean shifts based on 'one point out-of-control'. Once the mean shift is triggered, the Synergistic-ANN recognizer is then used to perform second stage monitoring and diagnosis by recognizing data stream pattern contained point(s) out-of-control as truly unstable or not.

2.1. Modeling of bivariate process and patterns

Let $X_{1i} = (X_{1-1}, \ldots, X_{1-24})$ and $X_{2i} = (X_{2-1}, \ldots, X_{2-24})$ represent bivariate process data streams based on window size = 24. Observation windows for both variables start with samples ith = (1, ..., 24). It is followed by (ith + 1), (ith + 2) and so on.

In a statistically stable state, samples for both variables are identically and independently distributed with zero mean ($\mu_0 = 0$), unity standard deviation ($\sigma_0 = 1$) and zero cross correlation ($\rho = 0$). They yield random patterns when plotted

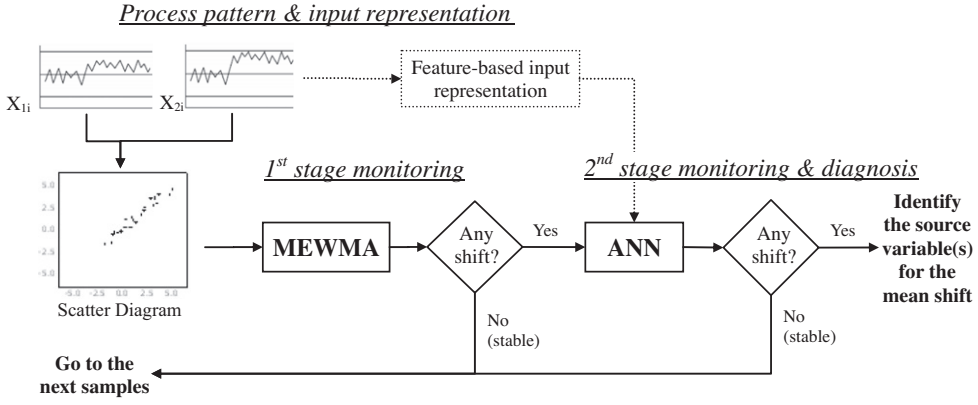

Figure 1 Conceptual diagram of an integrated MEWMA-ANN scheme.