



## RPMME

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e-ISSN : 2773-4765

# Identification of Trend and Shift Variation in Bivariate Process Using Pattern Recognition Scheme

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DOI: <https://doi.org/10.30880/rpmme.2022.03.01.115>

Received 01 Dec 2021; Accepted 01 April 2022; Available online 30 July 2022

**Abstract:** In advance manufacturing industry, quality control is an important to meet and achieve customer requirement. Statistical Process Control (SPC) is a tool that used in quality control to monitor and diagnosis the manufacturing process. In real production system there is challenging to monitoring and identifying unnatural process variation (UPV) when it composed two correlated quality variables (bivariate). Meanwhile, most of previous research are focusing on the pattern recognition technique. However, research on the findings of unnatural variation is still not many and it is limited to certain pattern such as sudden shifts pattern. In this study, the pattern recognition for unnatural variation is focusing to identify trend and shifts pattern in bivariate process. The framework of scheme was constructed using Artificial Neural Network (ANN) recognizer and window size will be determined using a different size to achieve 99% recognition accuracy. Thus, performance of the proposed framework able to identify the nine category of control chart pattern that focus on trend and shift pattern. The result demonstrates the proposed approach can recognize control chart pattern effectively. In previous research, it was proven that double stage algorithm able to detect and identify the five basic control chart patterns. The outcome of this study will be helpful for quality practitioner in industry that dealing with a multiple variable in their manufacturing process for realizing accurate monitoring and diagnosis the process.

**Keywords:** Unnatural Process Variation, Trend And Shift, Bivariate Process, ANN Recognizer

## 1. Introduction

In manufacturing system there is difficult to avoid from having a disturbance that affected from natural variation or unnatural variation. This unnatural process variation has become a major source of poor quality in industrial manufacturing process. It is becoming more challenging when two correlated variables (bivariate) are involved. Variation source identification is targeting at diagnosing the root causes of quality related problems in manufacturing processes for directing counteractive

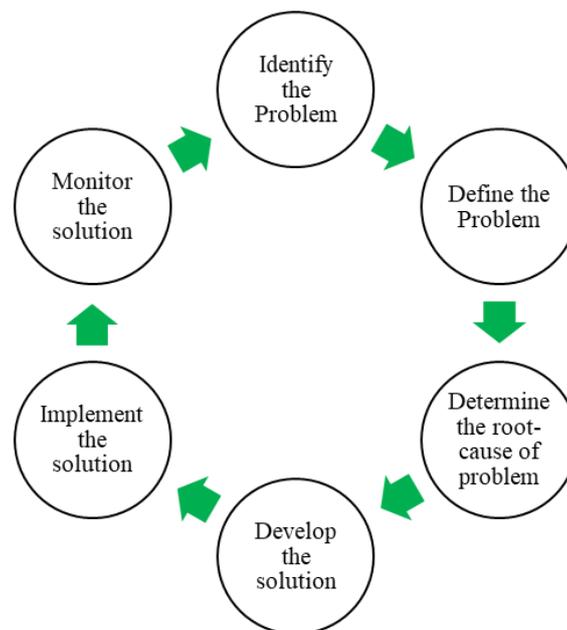
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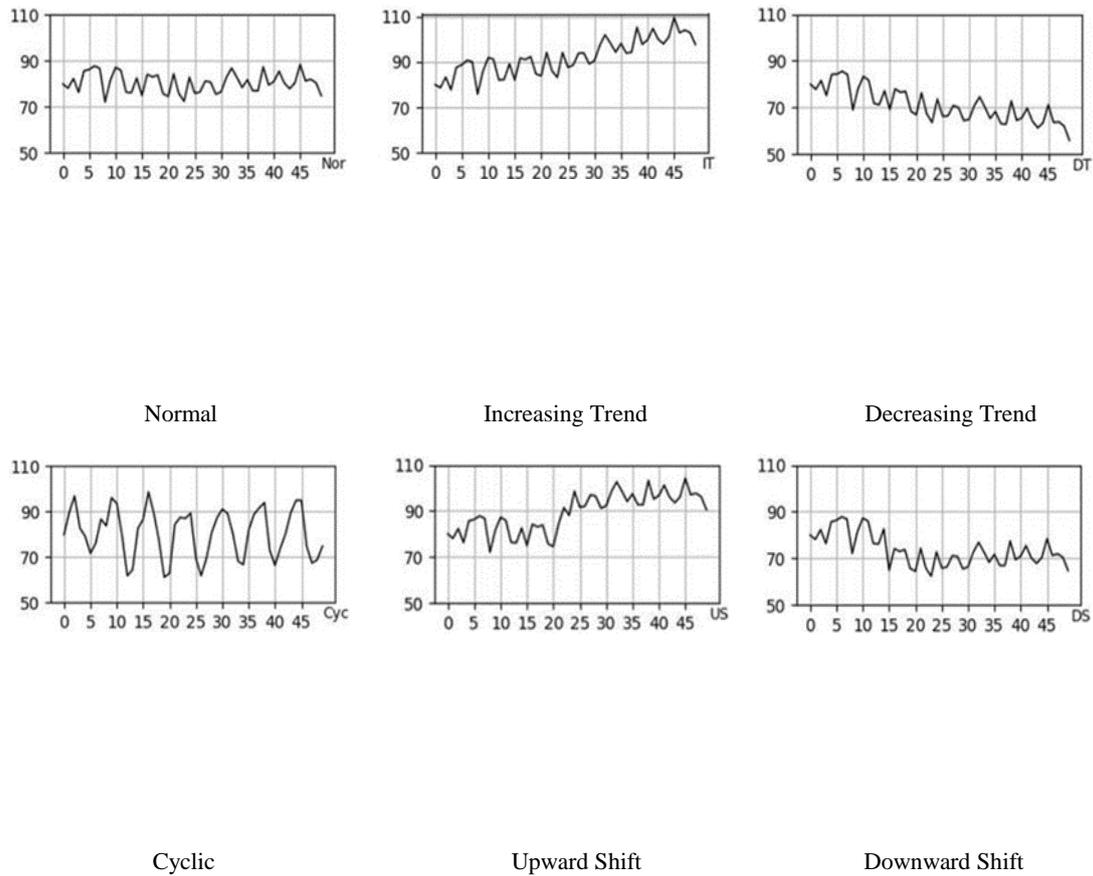
actions (Rooney & Heuvel 2004), and it is a key issue to achieve closed-loop quality control. In addressing this issue, the conventional multivariate SPC charts such as Chi-square, multivariate cumulative sum (MCUSUM), and multivariate exponentially weighted moving average (MEWMA) were designed based on monitoring approach to detect the presence of unnatural variation and it were constantly being improved to be more sensitive for triggering small shifts. This unnatural variation is contributed to process deterioration towards out-of-control during manufacturing process at production line. After a long period of research and review, most unnatural variation patterns can be classified in six abnormal patterns, including upward shift (US), downward shift (DS), increasing trend (IT), decreasing trend (DT), Cyclic (Cyc) and Systematic (Sys) (Zhao et.al., 2016). Normally, process monitoring refers to the identification of process stability either process condition in a statistically in-control or out-of-control with minimum false alarm. Meanwhile process diagnosis refers to the identification of the source variable for out-of-control condition. Statistical Process Control (SPC) is common industrial tool that used in manufacturing industry to monitor the data stream pattern of production. Because of that, it is necessary for the quality practitioner to have a skill and knowledge in SPC to identify the root-cause when there is disturbance during manufacturing of product. The Quality practitioner in industry must having a problem-solving skill to find the solution when unnatural variation appears in manufacturing process. Therefore, SPC is one of the methods in problem solving closed loop to identify the solution as shown in Figure 1.



**Figure 1: Problem Solving Closed Loop**

### 1.1 The Quality Pattern Recognition

There are many quality patterns in the industrial manufacturing process. The Western Electric Rules and Nelson Run Rules were established to identify the pattern out of control. Western Electric has studied the quality anomaly patterns and six basic quality patterns have been defined, which cover the common quality patterns in the intelligent manufacturing process. The six typical patterns in the actual production process are shown as normal pattern (N), increasing trend pattern (IT), decreasing trend pattern (DT), cyclic pattern (Cyc), upward shift pattern (US) and downward shift pattern (DS) as illustrated in Figure 2. The rest of the anomaly patterns can be obtained from the combination of these six basic patterns (Guh, 2013).



**Figure 2: Six Typical Pattern (Guh, 2013)**

Previous research has identified shift patterns in autocorrelated univariate. Recognizing and classifying a whole host of shift patterns as well as all the other possible abnormal patterns as already successfully accomplished in univariate SPC can provide a much deeper understanding of the mechanisms involved in the process (Zorriasatine, Tannock & Brien, 2003). Previous research has identified shift patterns in autocorrelated univariate. Recognizing and classifying a whole host of shift patterns as well as all the other possible abnormal patterns as already successfully accomplished in univariate SPC can provide a much deeper understanding of the mechanisms involved in the process (Zorriasatine, Tannock & Brien, 2003). In related study, there is research use a statistical correlation coefficient to create a simple mechanism for recognizing single and concurrent unnatural patterns where a change point from normal to abnormal may occur in control charts (Yang & Yang, 2005).

## 1.2 Artificial Neural Network

Artificial Neural Network (ANN) is a machine learning technology that has appeared because of this evolution and it becomes one of the most important networks applied in many research. The ANN recognizer was designed based on the Multi-layered Perceptron (MLP) model trained with Back-propagation Network (BPN) algorithm. Most of the ANN models have been successfully utilized as pattern recognizer in classifying abnormal patterns and in estimating the shifts magnitude of quality variables (Sohaimi et.al., 2017). Numerous ANN-based models have been investigated, i.e., novelty detector, modular-ANN, ensemble-ANN and multi-module-ANN. Most of the ANN models have been successfully utilized as pattern recognizer in classifying abnormal patterns and in estimating the shifts magnitude of quality variables (Sohaimi et.al., 2017). The neural network, with a strong self-learning ability and aiming at the empirical risk minimization, its practical application will be limited while training a large and complex sample. Those reported work that used ANN are success to identifying

the normal, upward shift, downward shift, upward trend, downward trend and cyclic patterns (Shaban & Shalaby, 2010).

## **2. Methodology**

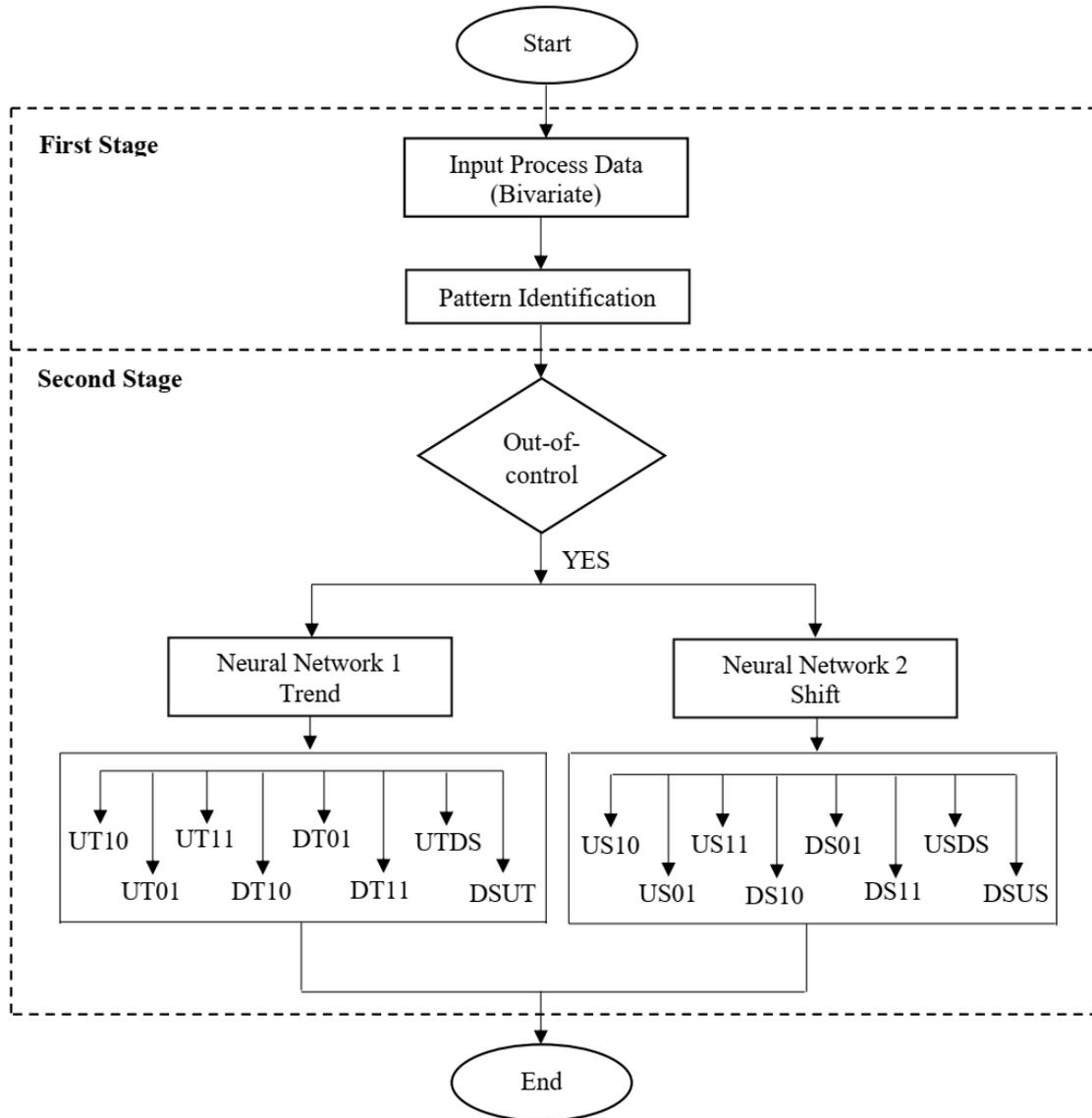
The design of scheme consists of two general phases as shown in Figure 3.

### *First Stage:*

- Monitoring process to identify the process status either in statistically in-control or out-of-control states, whereas process diagnosis refers to the identification of the source variables of out-of-control state. Pattern identification in this stage is to identify the abnormal pattern. In this research, a design methodology to establish a framework using an original SPC samples has been proposed.

### *Second Stage:*

- Classifying process of the bivariate pattern and to meet this target and the ANN-recognizer will be established. In analysis and classification of bivariate patterns, the sources of unnatural variation are represented by two main pattern that is shift and trend pattern. Each main pattern will be dividing in eight sub-patterns and total for pattern generate are 18 patterns.



**Figure 3: General phase of scheme**

## 2.2 Framework of Scheme for Identification Trend and Shift Pattern

Figure 4 shows the detail of proposed scheme for identification of trend and shift pattern in bivariate process. The development of scheme involves five main steps: (i) identification of pattern scheme (ii) design of pattern recognizer, (iii) design of input representation, (iv) training and pre-testing, and (v) validation test.

### Identification of Pattern Scheme

- Extraction and classification bivariate pattern. The unnatural variation pattern is represented by trend and shift pattern. Therefore, trend and shift pattern are divided in eight (8) pattern categories. Trend patterns are: UT10, UT01, UT11, DT10, DT01, DT11, UTDS and DSUT. Shift pattern are: US10, US01, US11, DS10, DS01, DS11, USDS and DSUS.

### Design of Pattern Recognizer

- ANN recognizer was designed by using the multilayer perceptron (MLP) model and trained with back-propagation (BPN) algorithm. ANN with back propagation network (BPN) has

been used widely in most applications in the field of neural network. The MLP model basically comprises an input layer, one or more hidden layers and an output layer. Each component has its own influence on ANN recognizer performance.

#### Design of Input Representation

- In designing the input representation, it is important to provide a strong influence on ANN recognizer performance. Raw data-based that was used in novelty detector recognizer (Zorriassatine et al. 2003) is the basic approach to represent input data. The observations of dynamic data are transformed by using common pre-processing techniques, namely standardization and normalization (Hwang and Hubele, 1993). Standardization is a procedure to linear the sample ( $X_t$ ) into standard normal variates ( $Z_t$ ). It can be performed by using the following equation (Nelson, L.S. 1989):  $Z_t = (X_t - \mu) / \sigma$ . Besides, features-based is original samples are extracted to shape features, summary statistics or statistical features.

#### Training and Pre-Testing

- The target performance for the scheme was determined at normal (N)=  $\geq 99\%$ , trends (T)=  $\geq 95\%$  and shifts (S)=  $\geq 95\%$ .

#### Validation

- Three performance measures were used: (i) Average Run Length 0 (ARL0) - measures the ability to prevent false alarms, (ii) Average Run Length 1 (ARL1) - measures the value of how fast scheme it can detect unnatural changes, and (iii) Recognition Accuracy (RA) – measures the accuracy for pattern classification.

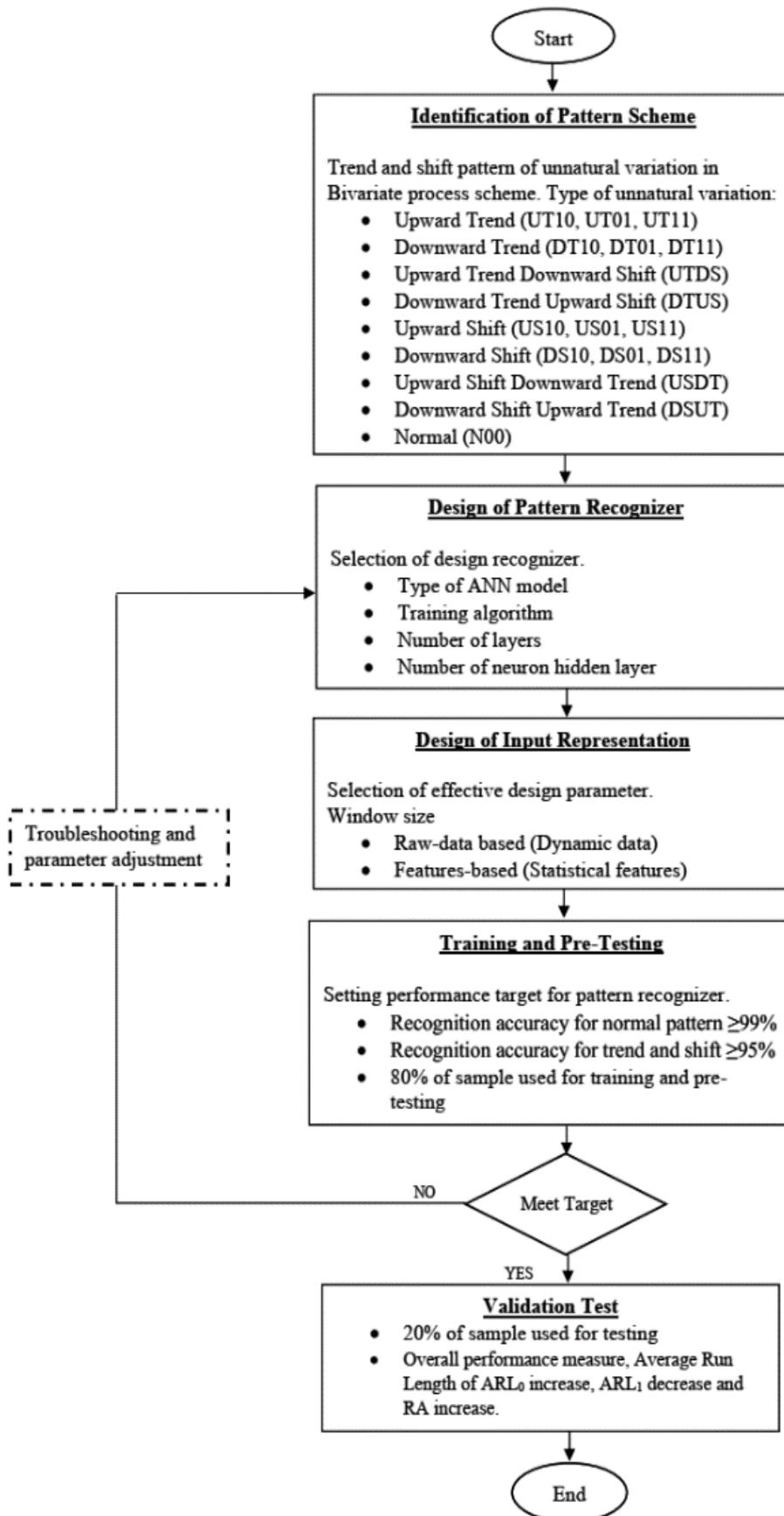


Figure 4: Framework of Scheme for Identification Trend and Shift

### 3. Result and Discussion

The result was represented by comparison from the framework that established by previous research. A double neural network approach effective to detect and identify five basic control chart patterns namely, natural, upward shift, downward shift, upward trend and downward trend (Shaban & Shalaby, 2010). This framework consists of double stages; the first stage is to identify the upward shift and upward trend of process mean. Second stage is to identify downward shift and downward trend. Besides that, there is research uses the Artificial Neural Networks to recognize set of subclasses of multivariate abnormal patterns, identify the responsible variable on the occurrence of abnormal pattern and classify the abnormal pattern parameters (El-Midany, El-Baz & Abd-Elwahed, 2010). The framework able to identify three basic pattern that is normal, trend and shift. Meanwhile, shift pattern will be considered as an example for training and applying the proposed framework. It consists of separated three neural network works simultaneously. This ANN frameworks are named EVD1, EVD2, and EVD3 (EVD Errant Variate Detector). *One errant variate only*: Only one of the variates is subjected to the abnormal pattern. *Two errant variates*: Two of the variates are subjected to the abnormal pattern (signal) while the other variate remains normally distributed. *All Three errant variates*: All the variates are subjected to the same pattern magnitude. Hence a great variety of patterns could be obtained (El-Midany, El-Baz & Abd-Elwahed, 2010). Each framework is shown in Figure 5 and Figure 6.

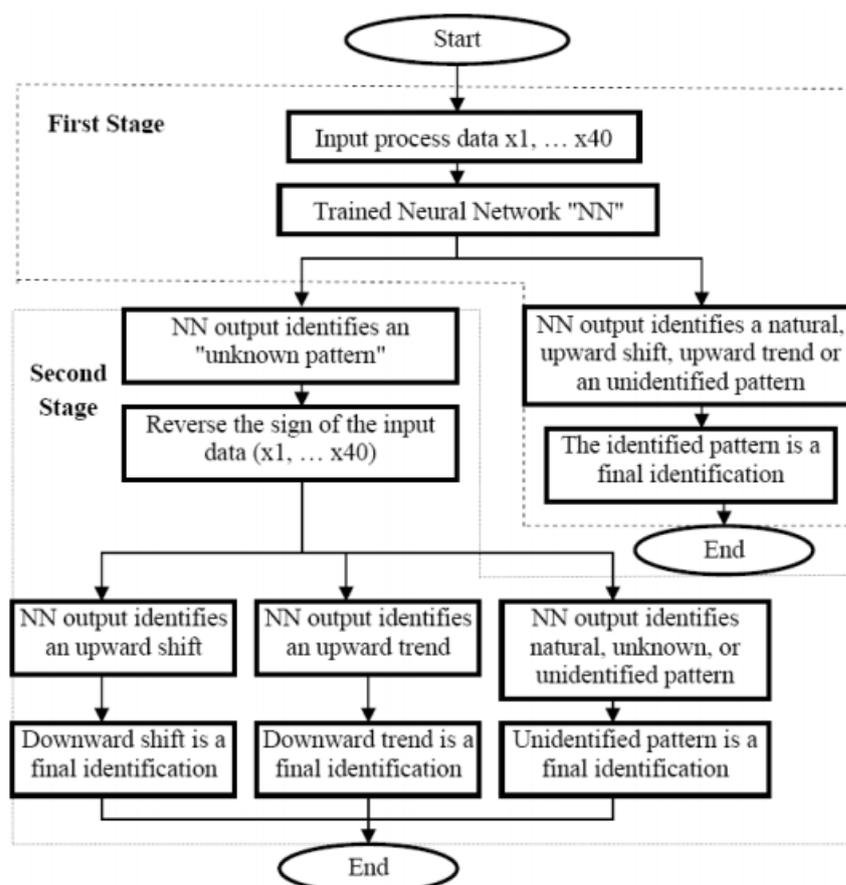
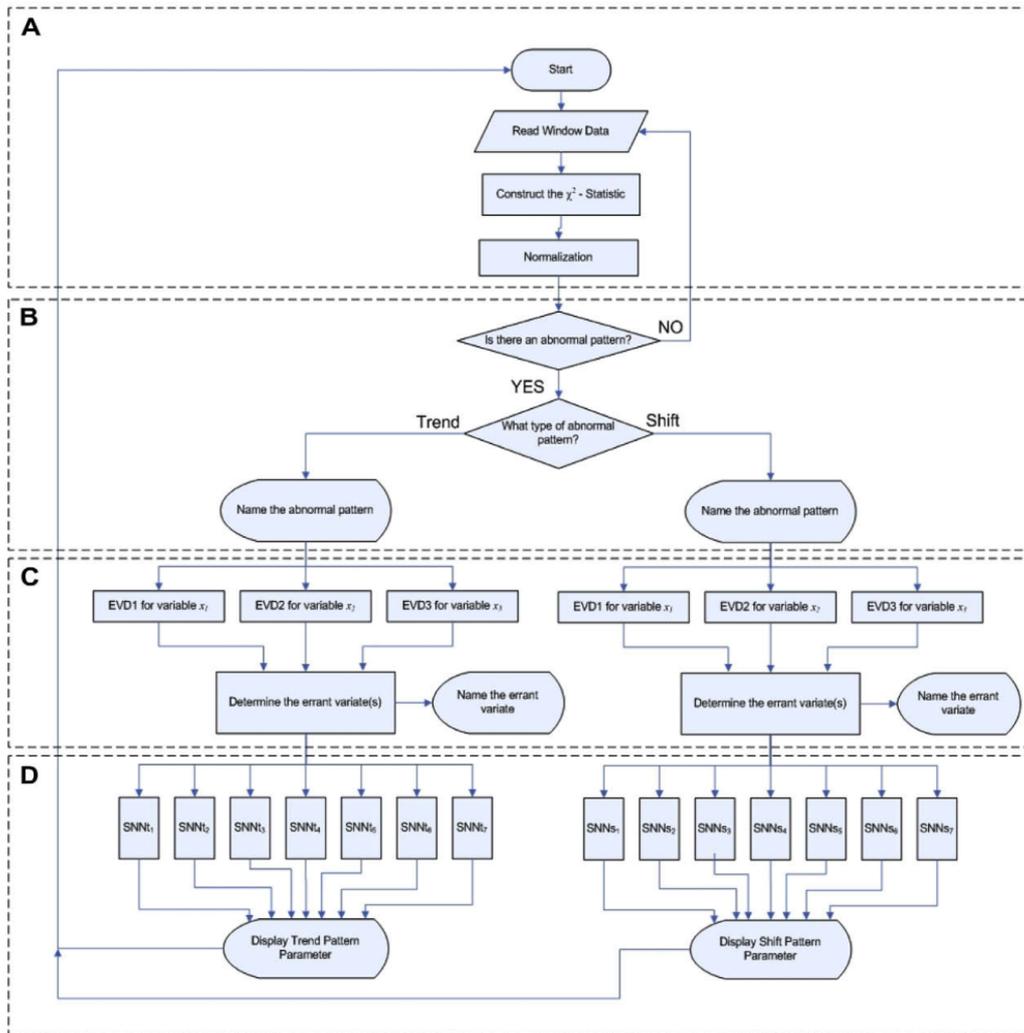


Figure 5: A Double Neural Network Approach Framework (Shaban & Shalaby, 2010)



**Figure 6: Artificial Neural Networks to recognize set of subclasses of multivariate abnormal patterns (El-Midany, El-Baz & Abd-Elwahed, 2010)**

The proposed framework is extended from the previous research. Basic trend and shift pattern are still the main pattern. However, from these two patterns there will be expanded to eight patterns to detect and identify unnatural variation. The key success factors for the framework are strongly dependent on a proper design of input representation, recognizer model and training and pre-testing algorithm. ANN model is also expected to overcome the problem of high false alarm rate because it does not depend on any statistical tests that are usually required for the traditional methods.

**4. Conclusion**

The purpose of this study is to address some of the deficiencies in the existing control chart scheme for unnatural variation in bivariate correlated data. The aim of this scheme is to enhance monitoring and diagnosis of unnatural variation in manufacturing industrial that consists of many variables. Specifically, this framework should be able to identify the trend and shift pattern with minimum false alarm.

**Acknowledgement**

The authors would also like to thank the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia for its support.

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