INTERGRATION OF CONTROL CHART AND PATTERN RECOGNIZER FOR BIVARIATE QUALITY CONTROL

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ABSTRACT

Monitoring and diagnosis of mean shifts in manufacturing processes become more challenging when involving two or more correlated variables. Unfortunately, most of the existing multivariate statistical process control schemes are only effective in rapid detection but suffer high false alarm. This is referred to as imbalanced performance monitoring. The problem becomes more complicated when dealing with small mean shift particularly in identifying the causable variables. In this research, a scheme that integrated the control charting and pattern recognition technique has been investigated toward improving the quality control (QC) performance. Design considerations involved extensive simulation experiments to select input representation based on raw data and statistical features, recognizer design structure based on individual and Statistical Features-ANN models, and monitoring-diagnosis approach based on single stage and two stages techniques. The study focuses on correlated process mean shifts for cross correlation function, ρ = 0.1, 0.5, 0.9, and mean shift, $\mu = \pm$ 0.75 ~ 3.00 standard deviations. Among the investigated design, an Integrated Multivariate Exponentially Weighted Moving Average with Artificial Neural Network scheme provides superior performance, namely the Average Run Length for grand average ARL_1 = 7.55~ 7.78 (for out-of-control) and ARL_0 = 491.03 (small mean shift) and 524.80 (large mean shift) in control process and the grand average for recognition accuracy (RA) = 96.36 ~ 98.74. This research has provided a new perspective in realizing balanced monitoring and accurate diagnosis of correlated process mean shifts.

ABSTRAK

Pemantauan dan diagnosis ke atas anjakan purata dalam proses pembuatan menjadi semakin mencabar apabila melibatkan dua atau lebih pembolehubah terkorelasi. Walau bagaimanapun, skema kawalan proses statistik pembolehubah berbilang yang sedia ada hanya berkesan bagi pemantauan secara deras tetapi memberikan amaran palsu yang tinggi. Ini merujuk kepada keupayaan pemantauan yang tidak seimbang. Masalah menjadi lebih rumit apabila melibatkan anjakan purata yang kecil terutama dalam mengenalpasti pembolehubah penyebab variasi. Dalam kajian ini, satu skim carta kawalan bersepadu dan teknik corak pengiktirafan yang telah disiasat kea rah meningkatkan prestasi kawalan kualiti (QC). Pertimbangan rekabentuk melibatkan ujikaji simulasi yang mendalam bagi memilih perwakilan masuk berasaskan kepada data mentah dan sifat-sifat statistik, rekabentuk struktur pengecam berasaskan kepada model-model individu dan Rangkaian Neural Tiruan ciri-ciri Statistik, serta pendekatan pemantauan- diagnosis berasaskan kepada teknik-teknik satu peringkat dan dua peringkat. Kajian ditumpukan ke atas anjakan purata proses terkorelasi pada fungsi korelasi rentas, ρ = 0.1, 0.5, 0.9 dan anjakan purata proses, μ = ± 0.7~3.00 sisihan piawai. Diantara rekabentuk-rekabentuk yang dikaji, skema tersepadu Purata Bergerak Pemberat Exponen Pembolehubah Berbilang bersama Rangkaian Neural Tiruan telah menghasilkan keputusan yang terbaik, iaitu purata panjang larian untuk purata besar, ARL_1 = 7.55~7.78 (untuk diluar kawalan). Manakala untuk purata panjang larian ARL_0 = 491.03 (anjakan min kecil) dan 524.80 (anjakan min besar) dalam proses kawalan dan untuk purata besar ketepatan pengiktirafan (RA) = 96.36~ 98.74. Kajian ini telah memberikan perspektif baru dalam merealisasikan pemantauan seimbang dan diagnosis tepat ke atas anjakan purata proses terkorelasi.

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ANN		Artificial neural network
ARL	-	Average run length
CUSUM	-	Cumulative sum
EWMA	-	Exponentially weighted moving average
MCUSUM	-	Multivariate cumulative sum
MEWMA	-	Multivariate exponentially weighted moving average
MPR	-	Multivariate pattern recognition
MSD	-	(Mean) x (standard deviation)
MSPC	-	Recognition accuracy
SPC	-	Statistical process control
SPCPR	-	Statistical process control pattern recognition
PR	-	Pattern Recognition
SF	-	Statistical Features
BQC	-	Bivariate quality control
QC	-	Quality control
BS	-	Baseline
SQE	-	Statistical quality engineering
MQC	-	Multivariate quality control

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Quality is define as the customer specification based customer experience with a product or service, measured against his needs - not specified or otherwise, conscious or merely felt, technical or operating entirely subjective - and always represent a moving target in a competitive market (Summers, 2007). Quality control (QC) is the name given to the collection of management techniques and tools used to manage, monitor, and control all steps in the production of quality products desire (Hansen and Prabhakar, 1987). Customer demand for quality products has increased carefully aligned with advances in communications and information technology. Customers want higher expectations and levels of satisfaction, higher quality, lower prices, timely delivery and they want better service than manufactured goods (Masood and Hassan, 2012).

In the manufacturing industry, remarkable process variation has become a major source of low-quality products (Masood and Hassan, 2012). Most manufacturers do not ever think to eliminate the function of QC of their production processes. Without QC, the number of defective products that need to be reworked, cancelled or refunded will dramatically increase. QC helps plant operators in checking all the processes to eliminate products that are not productive and damaged, maintain product quality, and reduce costs. Effect to minimize variation would lead to process stability in producing small scale, high capability and various models of products. Unpredictable changes of machine, material and employers are several contributors' unnatural process variation

The process of changing an important issue in quality control, to minimize the change process, statistical quality engineering (SQE) developed statistical process control (SPC). Statistical Process Control (SPC) has become an important approach for industrial processes or tools until today. Statistical process control (SPC) is a powerful and often a tool used to improve product quality by using statistical tools and techniques to monitor, control and improve the process. SPC goal is to achieve higher product quality and lower production costs due to the reduction of product defects. In fact, the manufacturing process involves two or more dependent variables, and therefore an appropriate scheme is required to monitor and identify those variables simultaneously. If this is the case, monitor their separate variables using univariate SPC will inevitably expose to high probability of false alarm occurrences and this can lead to making the wrong decision because of inaccurate data. Appropriate techniques that can be used in this case, known as multivariate Quality Control (MQC). It is basically an extension of simple univariate (one variable at a time) quality control.

1.2 Problem Statement

Quality control (QC) essential for continuous quality improvement and it became more challenging when involving two dependent variables (bivariate). An appropriate scheme is required to perform effective joint monitoring and diagnosis. The existing scheme are mainly designed using Artificial Neural Network (ANN) model recognizer with raw data input representation, which resulting in limited performance. MEWMA-ANN model is expected to perform better than one that uses the raw data as input representation. In this study, a scheme that integrate the control charting and pattern recognition technique will be investigated toward improving the QC performance.

1.3 Purpose of Research

The aim of this study is to design, build and test running a new scheme to enable accurate diagnosis of multivariate (bivariate) means the process of change. Features of this scheme are applicable to the bivariate process (data flow correlation) and conditions online (dynamic data flow). Diagnosis capability will be enhanced by using experimental design techniques in selecting its representative input.

1.4 Objective

I. To design the control charting and pattern recognition techniques in bivariate quality control (BQC). In particular, Statistical Features-ANN model is utilized for pattern recognizer.

II. To evaluate the monitoring and diagnosis performance of the proposed integrated scheme.

1.5 Scope of Study

I. Control charting is focus on MEWMA technique.

II. Pattern recognition is focus on Statistical Features- ANN technique.

III. The bivariate process variables are dependent to each other based on linear cross correlation (ρ).

IV. The predictable patterns of process variation are limited to sudden shifts (upward shift and downward shift).

V. Magnitudes of variation (sudden shifts) are limited within ± 3 standard deviations based on control limits of Shewhart control chart.

VI. Design and modelling of input data representation in training and pre-testing ANN-based model are based on Lehman (1977) model, whereas the validation tests are performed using actual manufacturing process data.

1.6 Definition of Term

The following terms are important and frequently used in this research:

I. Statistical Process Control (SPC).

Performance monitoring balanced in traditional SPC scheme is available for quality control bivariate (BQC) has been designed especially for the rapid detection of unusual changes with limited ability to prevent false alarms.

II. Multivariate Statistical Process Control (MSPC)

MSPC toward monitoring and diagnosis of multivariate process variation in mean shift/variances.

III. On-line Process Pattern

On-line process refers to in-process environment in manufacturing industries, that is, during manufacturing operation is running. Based on individual samples, continuous data streams patterns will be produced through automated measuring and inspection devices. An in-control process is represented by random/normal patterns, while an out-of-control process is represented by gradual trend or sudden shift pattern.

IV. Process monitoring and diagnosis

Monitoring means the identification of process status, example for monitoring is statistically stable state or in statistically unstable states. Diagnosing refers to identification of the source variation.

V. Bivariate Patterns

There are limited works reported on modeling of bivariate correlated process and pattern.

VI. Pattern recognition

In this study, it involves a bivariate pattern. According to (Haykin, 1999), Pattern Recognition is the operation of extracting information from an unknown process data stream or signal, and give to one of the specified class or category.

VII. Pattern recognition scheme

Research of (Hassan, 2002) describes a pattern recognition scheme refers to a set of related procedures formulated and presented in a way that unites to address the problem of control chart pattern recognition.

1.7 Expected Outcome

I. A representation scheme that consist of integration between Statistical Process Control (SPC) charting and pattern recognition (PR).

II. It is expected that the QC performance will be improved compared to the existing ANN-based PR scheme.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Quality control can be defined as a system that is used to maintain the desired level of quality in a product or service. In other words, is quality control activities to ensure that companies that produce products that meet the quality standards. In a study of existing research related to the subject of this thesis include general assessment of the change process that is known to be a source of low quality and then followed with the use of SPC to monitor changes in multivariate process. Also, limit multivariate quality control (MQC) and research work in multivariate statistical process control (SPC), and statistical pattern recognition process control scheme (SPCPR) are also reviewed.

2.2 Process Variation

In manufacturing and service industries, the goal of most processes is to produce products or provide services that exhibit little or no variation. Variation, where no two items or services are exactly the same, exists in all processes (Summers, 2006). Process variation and process precision are closely related, whereby a process with little variation is said to be 'precise'. Most processes are designed with controls that can be used to adjust the process mean, and hence increase the accuracy. Reducing the amount of process variation is usually a difficult task. As mentioned earlier, variation in manufacturing process environment causes the parts or products to be produced in different size and properties. Process variation as shown in Figure 2.1 can be influenced by chance causes (random error) and/or assignable causes (systematic errors). The figure shows that from initial time t_0 to period t_1, process mean (μ_0) and standard deviation (σ_0) are in-control. Disturbance due to assignable causes can be indicated in three situations. Firstly, at time t_1, an assignable cause may shift the process mean ($\mu_1 > \mu_0$) but maintain the dispersion (σ_0). Secondly, at time t_2, it may change the dispersion ($\sigma_2 > \sigma_0$) but maintain the mean (μ_0). Thirdly, at time t3, other assignable cause may effects both process mean and dispersion to be out-of-control, $\mu_3 < \mu_0$ and $\sigma_3 > \sigma_0$.

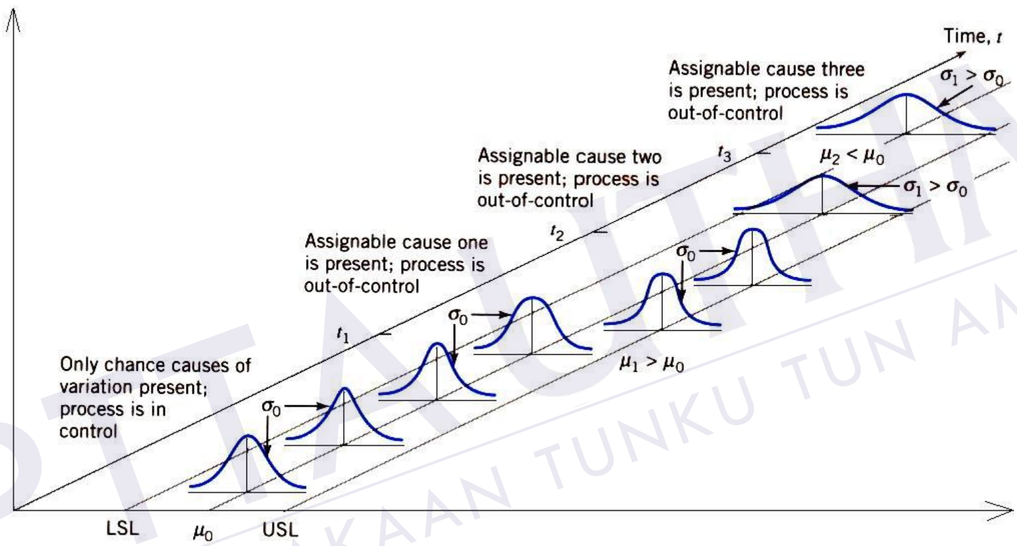

Figure 2.1: Process variation (Montgomery, 2005)

In order to maintain and achieve quality improvement, minimizing process variation in manufacturing environment has become a major issue in quality control. Statistical quality engineering (SQE) tools have been developed for systematically reducing variability in the key process variables or quality characteristics of the product (Montgomery, 2001). Statistical process control (SPC) charting is one of the SQE tools that useful for monitoring and diagnosing process variation.

2.3 Statistical Process Control (SPC)

A lot of thing can happen during manufacturing operations. Machine settings can fall out of adjustment, operators and assemblers can make mistakes and materials can be defective. Even under the most closely controlled process, there will always be variation in product output. The responsibility of production is to ensure that product specifications are met and that the final product performs as intended. In order to know what was happening during production, we need to collect and analyzing data from the process (Evans, 1991). Every problem occurs in the process need to be solved. The method that widely used to solve the problem is using statistical process control (SPC) tools. Before that, SPC used to improve the manufacturing process. SPC also used to monitor the process in order to assure that product have good quality. SPC means the application of appropriate statistical tool to process for continuous improvement in quality of product and service.

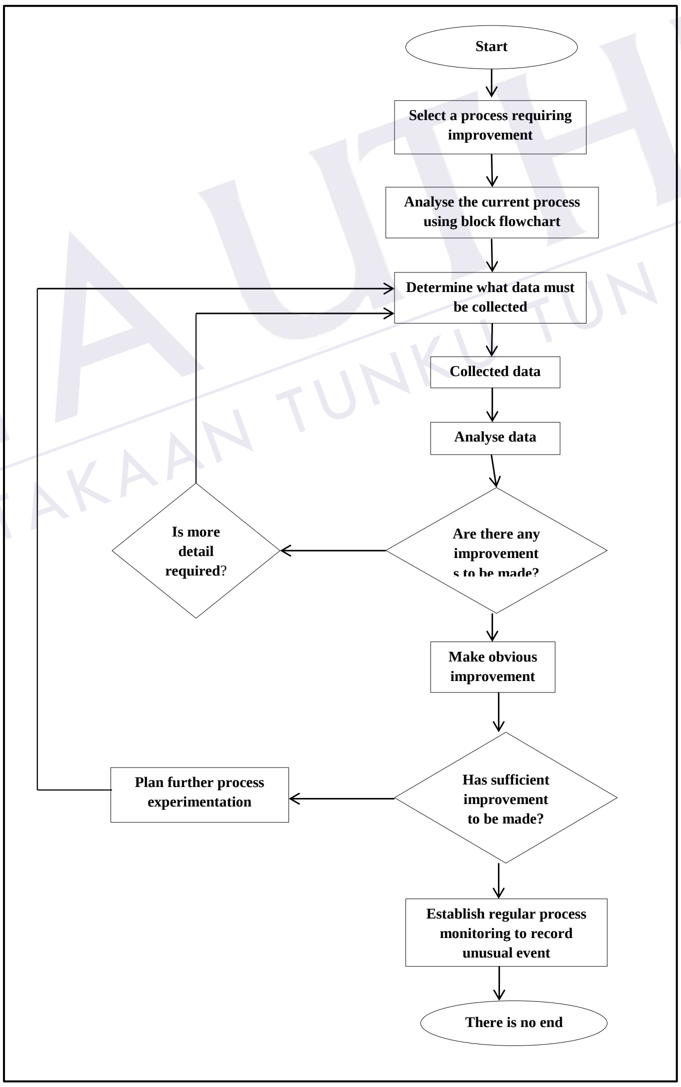

Figure 2.2: Step-To-Step Approach to Develop or Improve the Process (Evans, 1991)

Referring to Stevenson (2005), there are seven tools in SPC. The seven tools of SPC are state as below:

I. Check sheet
II. Pareto Chart
III. Cause and Effects Diagram
IV. Histogram
V. Scatter Diagram
VI. Control Chart
VII. Flowchart

2.3.1 Scatter Diagram

Scatter Diagram is the simplest way to determine if a cause and effect relationship exists between two variables. It is used to find the correlation between paired set data and supply the data to confirm a hypothesis that two variables are related. Figure 2.3 shows the types of Scatter diagram.

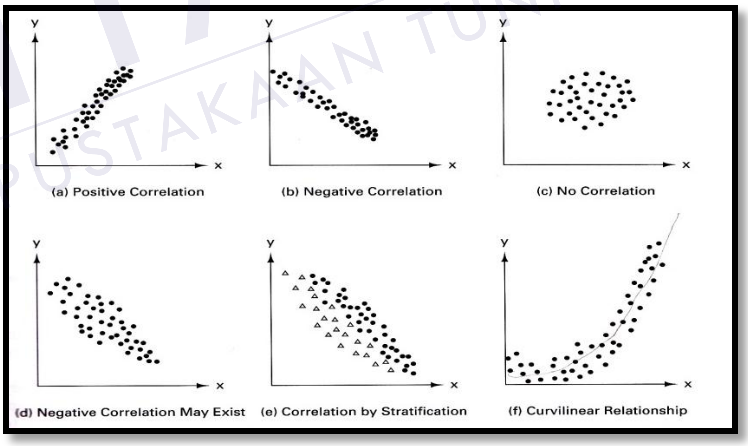

Figure 2.3: Scatter Diagram (Doty, 1996)

2.3.2 Control Chart

Control chart is a graphical record of quality of a particular characteristics and it is used to show whether the process is stable or not. The control chart is referring to $\bar{X}$

chart and it is used to record the variation. There is also the R charts. Figure 2.4 shows the example of control chart.

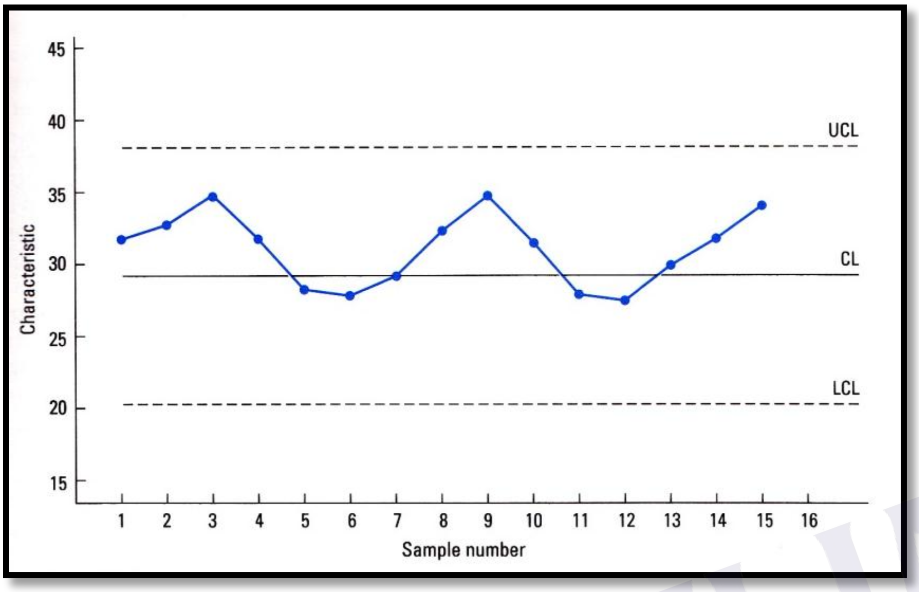

Figure 2.4: Control Chart (Besterfield, 1994)

2.3.3 Flowchart

Flow chart is an important thing to a product or service. Flow chart is a diagram that shows the flow of the product or service as it moves through the various processing station or operation. It is useful because this diagram will show the entire system and it will also locate the control activities. This diagram also will help people to understand more about the process. The improvement also can be made by eliminating and combining process. Figure 2.5 shows an example of flow chart diagram.

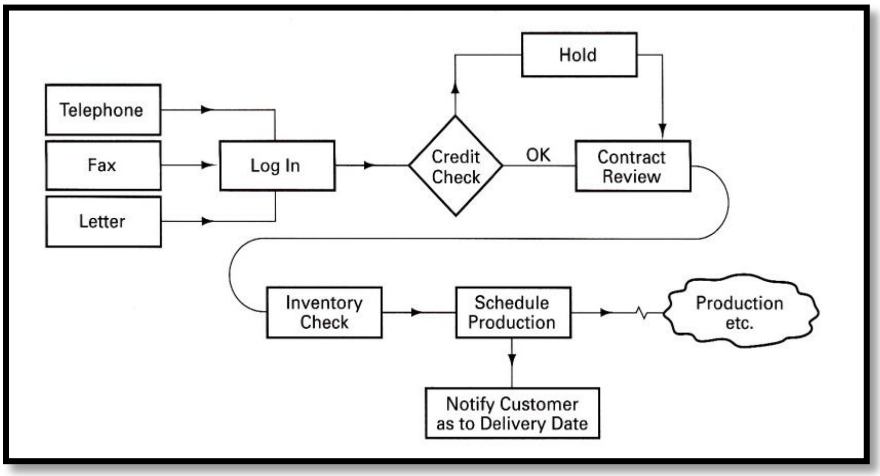

Figure 2.5: Flow Chart Diagram

2.4 SPC For Monitoring Multivariate Process Variation

The process of monitoring problems in several variables is called Multivariate Statistical Process Control (MSPC). One of the major disadvantages of a univariate monitoring scheme is that for a single process, many variables may be monitored and even controlled. The MSPC methods overcome this disadvantage by monitoring several variables simultaneously. Using multivariate statistical process control methods, engineers and manufacturers who monitor complex processes can monitor the stability of their process. In Figure 2.6 shows the advances in MSPC charting schemes.

There are two phases of objectives in multivariate control charts. The objectives are:

I. To identify the shifts in mean vector that might distort the estimation of the in-control mean vector and variance covariance matrix

II. To identify and eliminate multivariate outliers. (Williams *et al*. 2006)

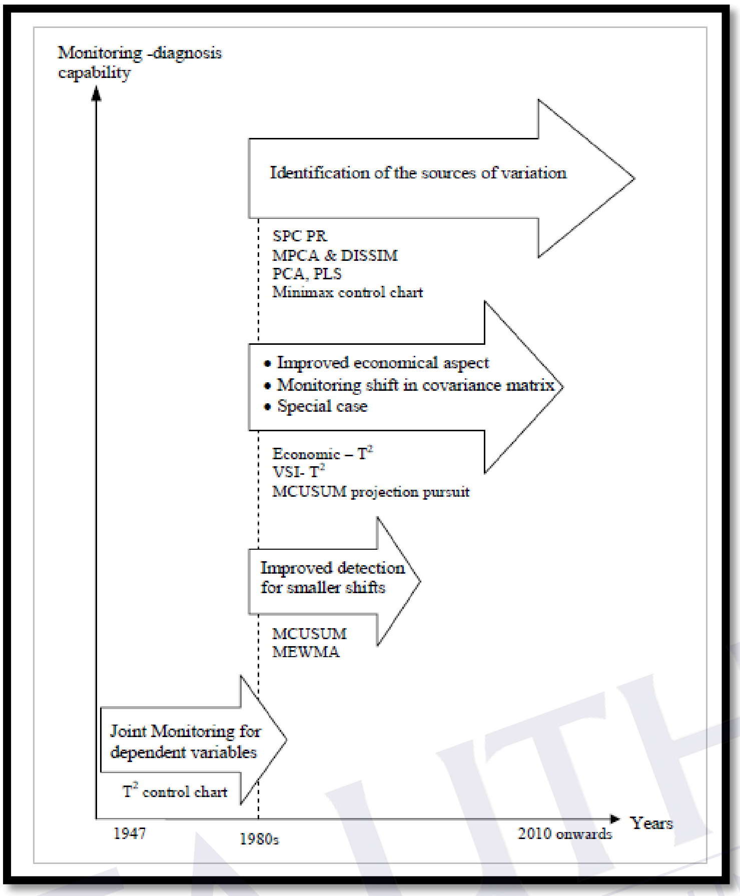

Figure 2.6: Advances in MSPC Charting Schemes (Montgometry, 1972)

2.4.1 Hotelling's T^2 Charts

The T^2 control chart is the multivariate version of the X chart (or the Individuals chart for individual observations). Its purpose is to assess whether several variables are simultaneously in control. For example, to monitor the quality of automobile tire casings, you can simultaneously measure three variables: weight, temperature, and percentage of polyester (Minitab 15 Statistical Software).

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