Groups

- Group 1: Bobbie Seppelt and Josh Hoffman
- Group 2: Qingyu Yang and Yulan Liang
- Group 3: Shan Bao and Birsen Donmez
- Group 4: Shan Li and Alaa Elwany
- Group 5: Ivy Donaldson and Policarpio Soberanis
- Group 6: Debbie Lotz and Carlos Ray
- Group 7: Zhe Song

Title: On-line monitoring when the process yields a linear profile

Author(s): Kang L, Albin SL


Abstract: Control charts monitor processes where performance is measured by one or multiple quality characteristics. Some processes, however, are characterized by a profile or a function. Here we focus on monitoring a process in semiconductor manufacturing that is characterized by a linear function. While the linear function is the simplest, it occurs frequently, for example in calibration studies. Two monitoring approaches are proposed: (1) monitor parameters, slope and intercept, with multivariate T-2 and (2) monitor average residuals between sample and reference lines with EWMA and R charts. Simulation studies indicate that both methods work well. Both methods are extendable to complex functions.
Title: MULTIVARIATE QUALITY-CONTROL BASED ON REGRESSION-ADJUSTED VARIABLES

Author(s): HAWKINS DM

Source: TECHNOMETRICS 33 (1): 61-75 FEB 1991

Abstract: When performing quality control in a situation in which measures are made of several possibly related variables, it is desirable to use methods that capitalize on the relationship between the variables to provide controls more sensitive than those that may be made on the variables individually. The most common methods of multivariate quality control that assess the vector of variables as a whole are those based on the Hotelling T2 between the variables and the specification vector. Although T2 is the optimal single-test statistic for a general multivariate shift in the mean vector, it is not optimal for more structured mean shifts—for example, shifts in only some of the variables. Measures based on quadratic forms (like T2) also confound mean shifts with variance shifts and require quite extensive analysis following a signal to determine the nature of the shift. This article proposes Shewhart and cumulative sum (CUSUM) controls based on the vector Z of scaled residuals from the regression of each variable on all others. Each component of Z is the (Neyman-Pearson) optimal single-test statistic for testing whether that variable is shifted in mean. The Shewhart charts plot the components of Z, and the CUSUM charts are based on accumulation of components of Z, leading one to anticipate good performance by the charts. This is verified by some average run length calculations. The vector Z also has the valuable interpretive property that signals given are for shifts in the mean, or shifts in the variance, of particular variables rather than global signals indicating some unspecified departure from control.

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Multivariate profile charts for statistical process control

Fuchs, Camil (Tel Aviv); Benjamini, Yoav

Source: Technometrics, v 36, n 2, May, 1994, p 182-195

Abstract: The multivariate profile (MP) chart is a new control chart for simultaneous display of univariate and multivariate statistics. It is designed to analyze and display extended structures of statistical process control data for various cases of grouping, reference distribution, and use of nominal specifications. For each group of observations, the scaled deviations from reference values are portrayed together as a modified profile plot symbol. The vertical location of the symbol is determined by the multivariate distance of the vector of means from the reference values. The graphical display in the MP chart enjoys improved visual characteristics as compared with previously suggested methods. Moreover, the perceptual tasks required by the use of the MP chart provide higher accuracy in retrieving the quantitative information. This graphical display is used to display other combined univariate and multivariate statistics, such as measures of dispersion, principal components, and cumulative sums.
**Paper 4**

**Title:** A factor-analysis method for diagnosing variability in multivariate manufacturing processes  
**Author(s):** Apley DW, Shi JJ  
**Source:** TECHNOMETRICS 43 (1): 84-95 FEB 2001  
**Abstract:** In many modern manufacturing processes, large quantities of multivariate process-measurement data are available through automated in-process sensing. This article presents a statistical technique for extracting and interpreting information from the data for the purpose of diagnosing root causes of process variability. The method is related to principal components analysis and factor analysis but makes more explicit use of a model describing the relationship between process faults and process variability. Statistical properties of the diagnostic method are discussed, and illustrative examples from autobody assembly are provided.

**Paper 5**

- **Title:** Phase I analysis of linear profiles with calibration applications  
- **Author(s):** Mahmoud MA, Woodall WH  
- **Source:** TECHNOMETRICS 46 (4): 380-391 NOV 2004  
- **Abstract:** We study the phase I analysis of data when the quality of a process or product is characterized by a linear function. We assume that simple linear regression data are available for a fixed number of samples collected over time, a situation common in calibration applications. Using a simulation study, we compare the performance of some of the recommended approaches used to assess the stability of the process. We also propose a method based on using indicator variables in a multiple regression model. We show that this method has competitive performance relative to other methods in terms of the probability of a signal for certain types of parameter shifts within the set of historical process data. We also show that two methods proposed in the literature are ineffective in detecting shifts in the process parameters. Finally, we apply some of the proposed methods to a calibration example.
Title: Real-time process monitoring for changing inputs
Author(s): Grimshaw SD, Shellman SD, Hurwitz AM
Abstract: A method is presented for statistical process control using real-time data in applications with finite processing times. This extends existing methods that monitor process behavior, assuming constant inputs and process conditions. Summary scores constructed from linear combinations of the realtime data are monitored both in real time and at the end of processing. The summary scores have a minimal loss of information due to the high dimensionality and correlated nature of real-time data. A multivariate regression model relates the inputs and initial conditions to the summary variables. This permits prediction of summary scores for different inputs and initial conditions. Large deviations from the predicted summary variables, Measured by process monitor statistics, signal abnormal behavior. Diagnostic tools identify the patterns in the real-time variable(s) that cause the signals.

Title: Designing a multivariate EWMA control chart
Author(s): Prabhu SS, Runger GC
Abstract: A multivariate exponentially weighted moving average control chart can be used to improve the detection of small shifts in multivariate statistical process control. Recommendations are provided for the selection of parameters for such a chart. The recommendations are based on performance distributions and average run lengths for zero-state, steady-state, and worst-state cases that are obtained from a Markov chain analysis of the scheme.
NOTE ON MULTIVARIATE CUSUM PROCEDURES.
Abstract: Cumulative sum (CUSUM) procedures are among the most powerful tools for detecting a shift from a good quality distribution to a bad quality distribution. This article discusses the natural application of CUSUM procedures to the multivariate normal distribution. It discusses two cases, detecting a shift in the mean vector and detecting a shift in the covariance matrix. As an example, the procedure is applied to measurements taken on optical fibers. (19 refs.) (Author abstract)

Multivariate SPC charts for monitoring batch processes
Nomikos, Paul (McMaster Univ); MacGregor, John F. Source: Technometrics, v 37, n 1, Feb, 1995, p 41-59
Abstract: The problem of using time-varying trajectory data measured on many process variables over the finite duration of a batch process is considered. Multiway principal-component analysis is used to compress the information contained in the data trajectories into low-dimensional spaces that describe the operation of past batches. This approach facilitates the analysis of operational and quality-control problems in past batches and allows for the development of multivariate statistical process control charts for on-line monitoring of the progress of new batches. Control limits for the proposed charts are developed using information from the historical reference distribution of past successful batches. The method is applied to data collected from an industrial batch polymerization reactor. (Author abstract)
Identifying spatial variation patterns in multivariate manufacturing processes: A blind separation approach

Apley, Daniel W. (Department of Industrial Engineering, Texas A and M University); Lee, Ho Young. Source: Technometrics, v 45, n 3, August, 2003, p 220-234

Abstract: Large sets of multivariate measurement data are now routinely available through automated in-process measurement in many manufacturing industries. These data typically contain valuable information regarding the nature of each major source of process variability. In this article we assume that each variation source causes a distinct spatial variation pattern in the measurement data. The model that we use to represent the variation patterns is of identical structure to one widely used in the so-called "blind source separation" problem that arises in many sensor-array signal processing applications. We argue that methods developed for blind source separation can be used to identify spatial variation patterns in manufacturing data. We also discuss basic blind source separation concepts and their applicability to diagnosing manufacturing variation. (22 refs.)

Schedule and Requirements

- Paper selection: FCFS – send me email as soon as your group decides your paper (one paper for each group). I will then forward your selection to the class so that the other groups cannot select the same paper.
  - Do not use papers you have discussed with your advisor or used in other classes
- Presentation: the last two weeks (starting from the week after Thanksgiving). Present the paper in the same way as you present your own work at a research conference. Try to incorporate as much of your own understanding as possible (same as in report).
- Discussion meeting with me before presentation
- Report due on December 9th
  - Not exceeding 5 pages (double-space)
  - Emphasize on strengths and weakness of the models and approaches in the paper, the applicability to other problems not mentioned in the paper (e.g., problems in your research area), and potential extension/improvement.