ISEN-614 ADVANCED QUALITY CONTROL

FALL-2018

PROJECT: **Phase-I analysis for Manufacturing Process Control**

Team 06
Nitesh Kumar (UIN: 327003765)
Vasu Kumar (UIN: 427007395)

APPROACH

Preliminary Analysis:
- Understand the type of data set for Manufacturing process
- Understanding the distribution, dimensions and trend

Signal-Noise Ratio Improvement:
- Dimension Reduction
- Correlation Matrix (since data dimensions not provided)
- Principal Components
- Analysis of Pareto, MDL and SCREE Plots

Control Charting (for Phase 1 Analysis):
- Multivariate Univariate Control Charts
- T2 Control Charts to remove spike type of data changes
- M-EWMA to remove sustained mean shifts of statistical distance 3
- Estimate in control parameters and control limits

Chart Performance:
- Determination of ARL for Multivariate Univariate, T2 and m-EWMA control charts

PRELIMINARY ANALYSIS

- 552 Observations of 209 Variables i.e n=552 and p= 209
- Cyclic Manufacturing Process
- Continuous profile
- Normal Distribution of individual variables
- High Dimension dataset
- Units of variables not given

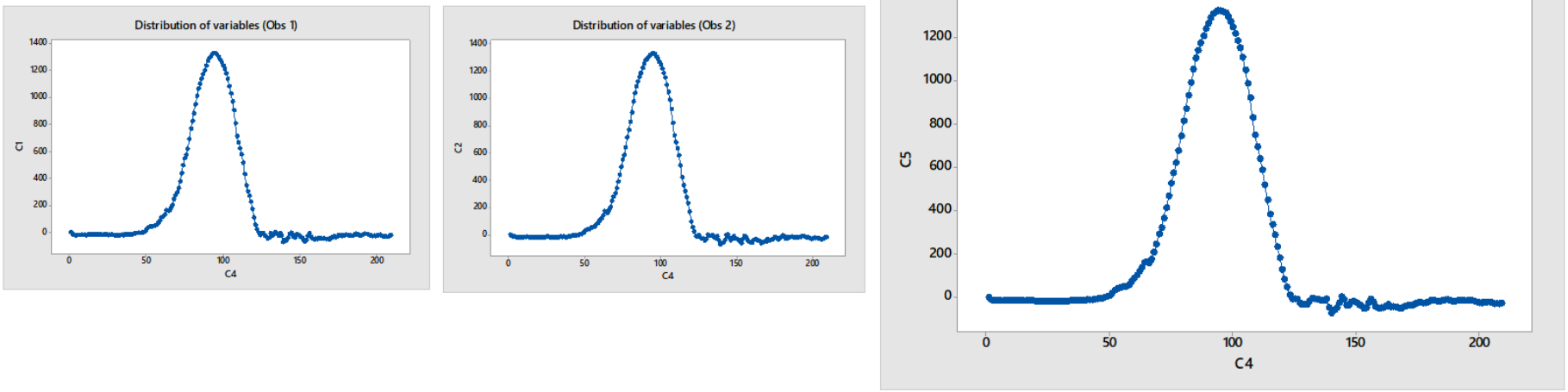

Figure 1. Data distribution and mean distribution

Analysis 1: Minimum Description Length

- MDL value minimum at 30 i.e. 30 principal components to be selected
- 30 PCAs are considered large in dimension for analysis

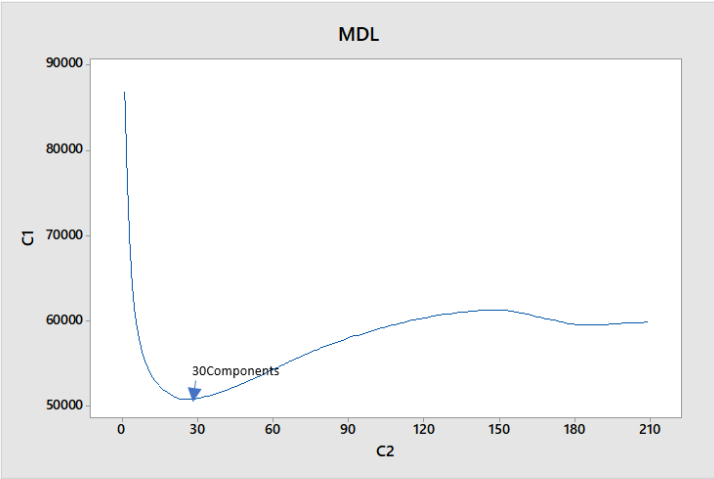

Figure 2. MDL Plot

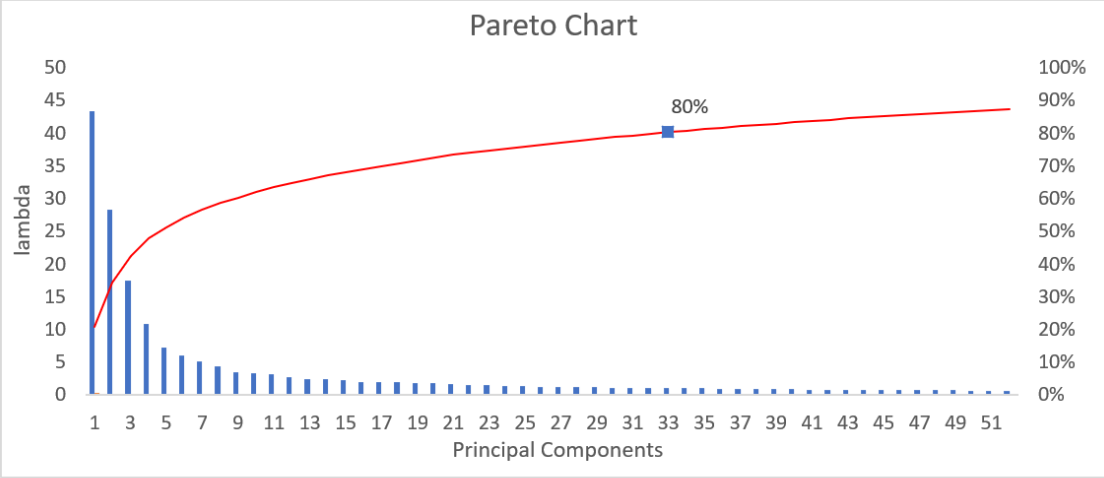

Figure 3. Pareto Plot

Analysis 2: Pareto Chart

- 80% of variance explained at 33PCAs
- Still a high dimension
- Need for a new analysis

Analysis 3: Scree Plot

- Plot of eigenvalues against number of principal components
- Elbow found at PC=09
- Final Selection of principal components = 09

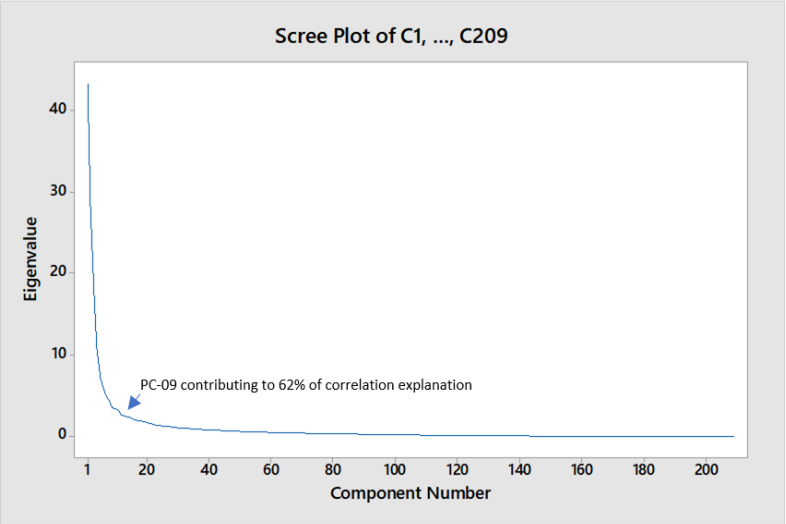

Figure 4. Scree Plot

The i^{th} principal component of data can be calculated using:

$$y_i = (\mathbf{e}_i^{\rho})^T(\mathbf{V}^{-\frac{1}{2}})(\mathbf{x} - \mu_x) \quad \text{i=1...9}$$

where $\mathbf{V} = \begin{pmatrix} \sigma_{11} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sigma_{pp} \end{pmatrix}$ is the matrix having the diagonal elements from $\mathbf{\Sigma}$ and

$$\mathbf{V}^{-\frac{1}{2}} = \begin{pmatrix} \frac{1}{\sqrt{\sigma_{11}}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \frac{1}{\sqrt{\sigma_{pp}}} \end{pmatrix}.$$

PHASE-1 ANALYSIS

Multivariate Univariate Control Chart

- Achieved in control data points in 4 steps
- 29 data points removed
- Performed on PC1 to PC09

Table 1. Principal components removed after iterations (for Multivariate Univariate Chart)

Phase-I Analysis	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
After 0 Iteration	11	3	1	0	0	0	0	1	3
After 1st Iteration	4	4	0	0	0	0	0	0	0
After 2nd Iteration	0	2	0	0	0	0	0	0	0
After 3rd Iteration	0	0	0	0	0	0	0	0	0

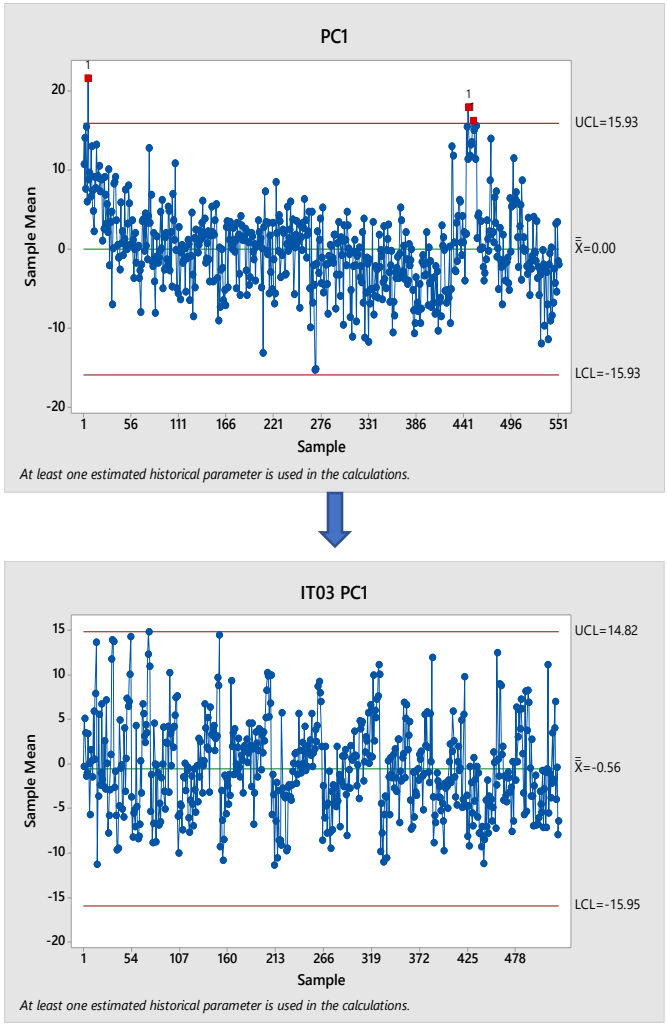

Figure 5: Iteration 0 to 03 (for PC1)

PHASE-1 ANALYSIS

T2 Control Chart

- Achieved in-control data points at 5th Iteration
- 80 Data points removed after PCA step
- UCL: 37.04 unit
- Next Step: apply m-EWMA to identify sustained mean shift out of control points

Table 2. Data points removed after iterations (for T^2 Charts)

Phase-I Analysis	Total Data points identified as outliers
After 0 Iteration	59
After 1st Iteration	9
After 2nd Iteration	5
After 3rd Iteration	4
After 4th Iteration	3
After 5th Iteration	0

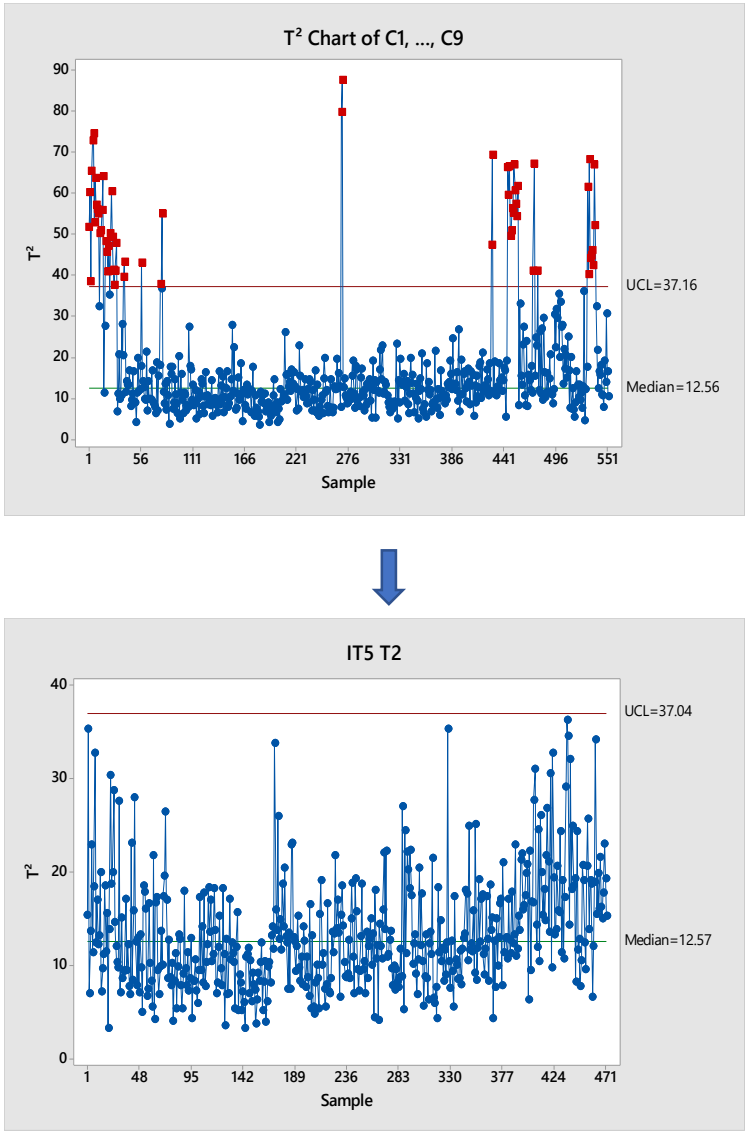

Figure 6: Iteration 0 to 05

m-EWMA Control Chart

- Applied in conjunction with T2 control chart
- Used for detection of data points contributing to sustained mean shift
- No point identified out of control
- Can be used for Phase-2 Analysis

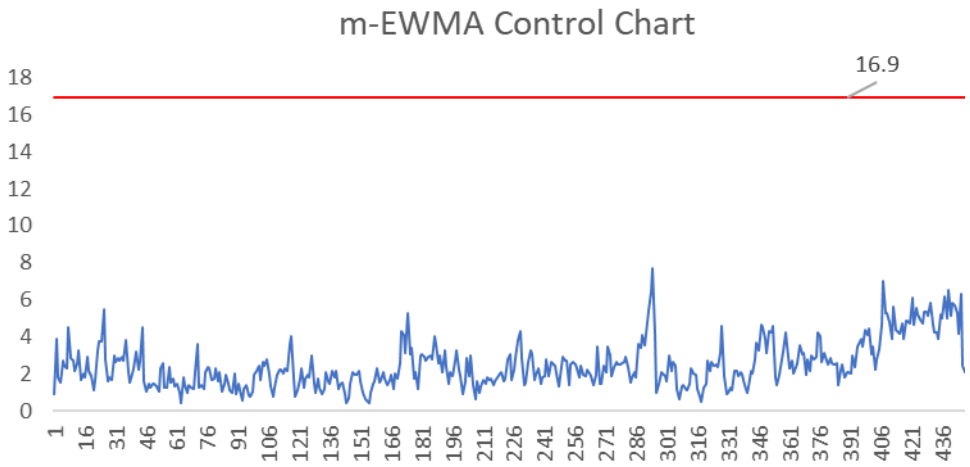

Figure 7: m-EWMA Iteration

PERFORMANCE ON FUTURE DATA

- For 3-sigma industry, composite alpha – 0.0243(using 9 PCA) and the corresponding ARLo for multivariate univariate chart is 41.3.
- For T2 control chart and m-EWMA it is estimated via Monte Carlo Simulation
- The first univariate chart analysis on PCAs lead to the removal of 29 variables and the subsequent T2 control chart eliminated 80 out of control data points leaving us with 446 data points

Table 3. Control limits from Multivariate Univariate in PCA, T2 and m-EWMA control charts

Multivariate Univariate Control Chart (PCAs)		
PC1	UCL : 14.82	LCL: -15.95
PC2	UCL : 14.26	LCL: -14.63
PC3	UCL : 12.07	LCL: -12.47
PC4	UCL : 9.88	LCL: -9.95
PC5	UCL : 8.15	LCL: -8.05
PC6	UCL : 7.07	LCL: -7.3
PC7	UCL : 6.75	LCL: -6.79
PC8	UCL : 6.19	LCL: -6.17
PC9	UCL : 5.42	LCL: -5.38
T2 Control Chart	UCL : 37.04	LCL: 0
m-EWMA	UCL : 16.9	LCL: 0

KEY LEARNINGS & TAKEAWAYS

- Effective understanding and implementation of statistical quality control techniques such as Principal Component Analysis (PCA), T2 Control Chart, m-EWMA Control Chart, m-CUSUM Control Chart, Multivariate Univariate Control charts for PCAs.
- High dimensional manufacturing data set quite insightful for Phase-1 analysis
- Based on eigen values, PCAs represent the data set effectively
- Multivariate Univariate Analysis on PCAs effective in determining the out of control values
- T2 Control chart effective in determining spike type of changes
- m-EWMA effective in detection of sustained mean shift
- Softwares used: MATLAB, Minitab, R and Excel

-THANK YOU-