Data Analytics and Monitoring of the Tennessee Eastman Process

CHE 599 Process Data Analytics and Machine Learning

Instructor: Dr. S. Joe Qin, Spring 2017

Group 1

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Outline

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    - Fault detection
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Introduction

- In this project, we build PCA model on normal quality and process data.
- Then calculate T^2 and Q control limit which are used as fault detection control limits to partition potential disturbances from the distorted data sets.
- After grouping the observations based on the PCA results, LDA is used to separate one from the other, the classification outcome needs be assessed.
- Further, using the CCCA to monitor the input and output of process with disturbances.

Methodology

- PCA, LDA and CCCA are employed in R and MATLAB to modeling on both the quality and process datasets of the Tennessee Eastman Process.
- Plots are drawn to demonstrate the modeling results and analyses are presented.
- In LDA, results are used to decide which observation belongs to normal region or the other way around. Different combinations of variables are implemented to evaluate the appropriation of LDA in our cases.

PCA for Quality Data

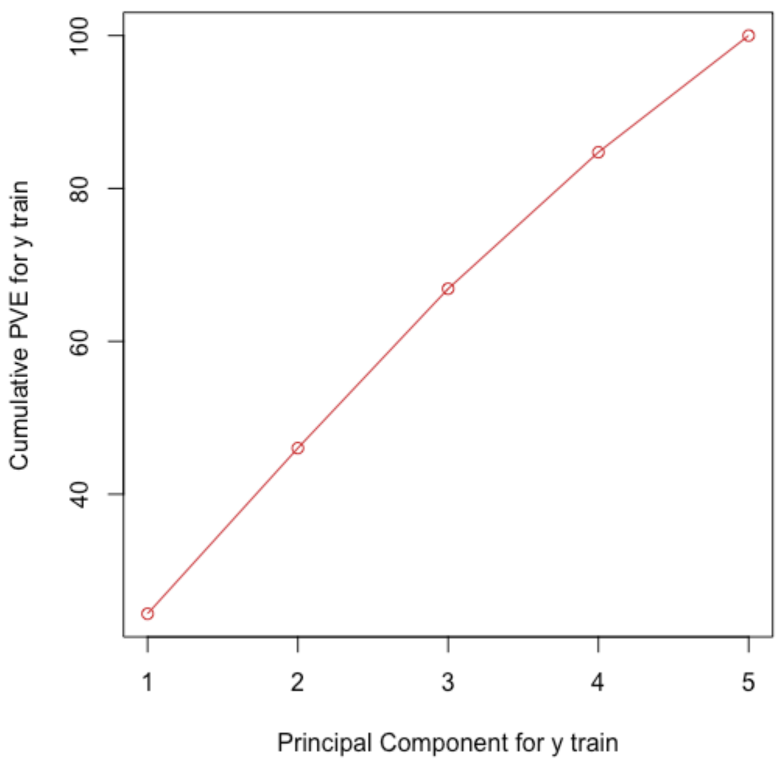


Fig 1. variance explained by components for IDV (0)

Choose 5 PCs

Product D analysis (stream 11)	XMEAS(37)
Product E analysis (stream 11)	XMEAS(38)
Product F analysis (stream 11)	XMEAS(39)
Product G analysis (stream 11)	XMEAS(40)
Product H analysis (stream 11)	XMEAS(41)

No SPE limit

T^2 control limit = 11.07

Fault Detection

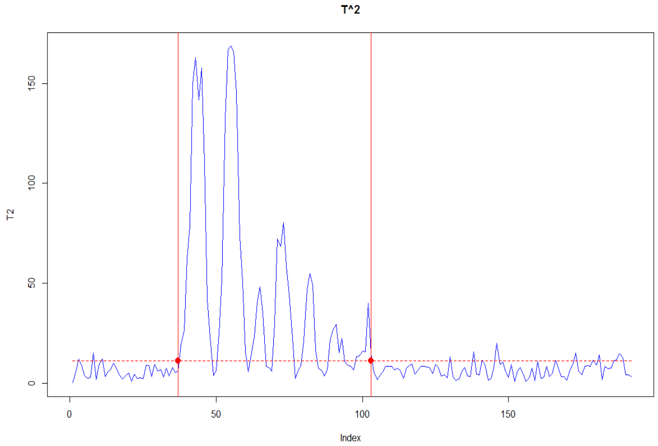


Fig.2. PCA-based monitoring result for IDV (1)

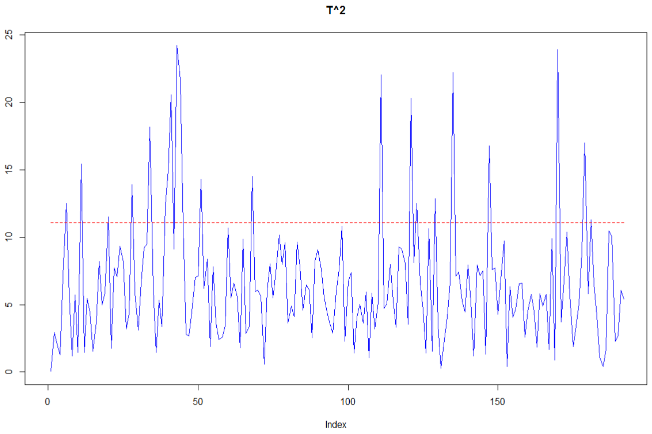


Fig.3. PCA-based monitoring result for IDV (3)

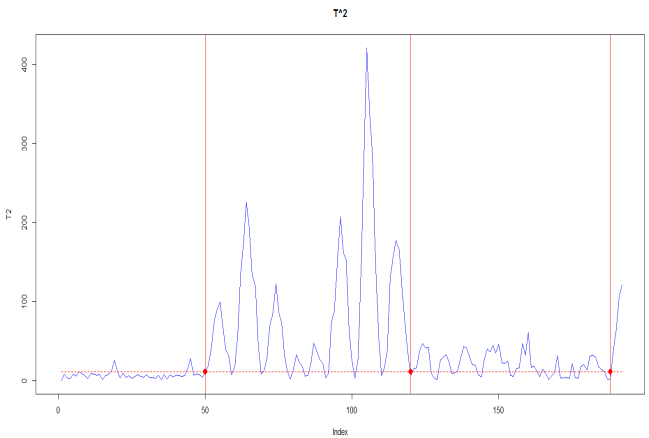


Fig.4. PCA-based monitoring result for IDV (8)

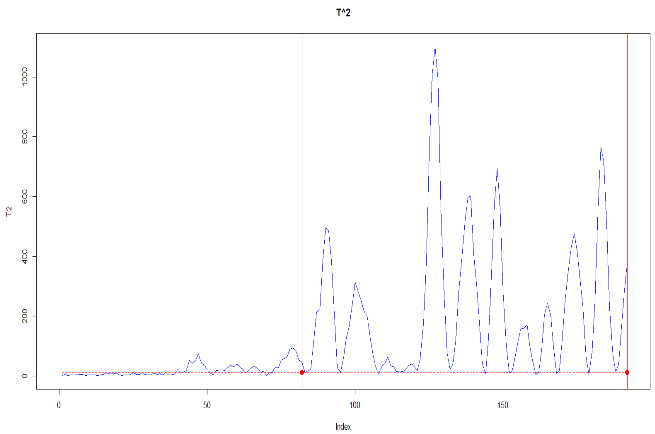


Fig.5. PCA-based monitoring result for IDV (13)

Fault Detection

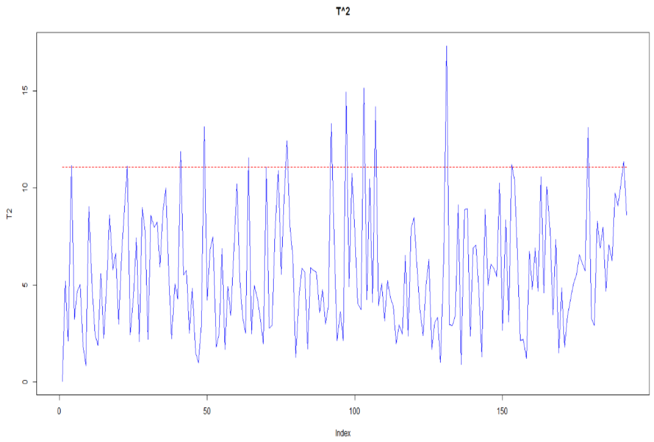


Fig.6. PCA-based monitoring result for IDV (14)

Compare the classification

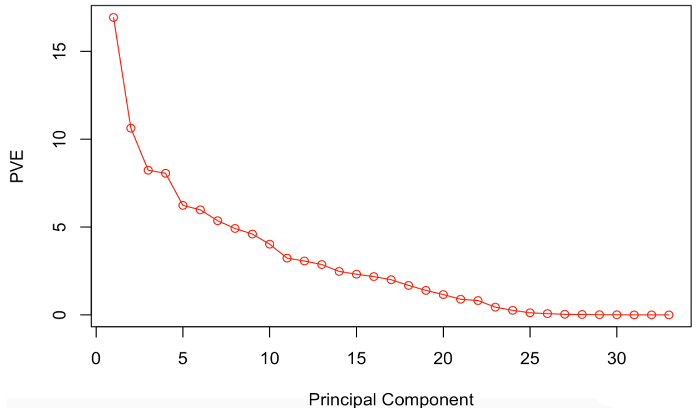
AGREE

Table 1. Comparison table

Test	% of Samples Beyond T^2 limit	Number of Samples Beyond T^2 limit	Total Number of Samples	Classification in paper
IDV (1)	34.375	66		Quality-Relevant
IDV (3)	10.938	21		Quality-Irrelevant
IDV (8)	71.875	138	192	Quality-Relevant
IDV (13)	57.291	110		Quality-Relevant
IDV (14)	7.8125	15		Quality-Irrelevant

<15%
Quality-Irrelevant

PCA for Process Data Monitoring



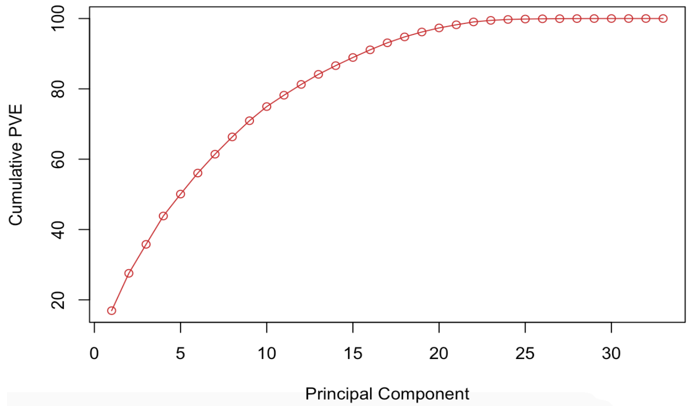


Fig 2.1. variance explained by components

PC	PC17	PC18	PC19	PC20
CUMPVE	93.1	94.77	96.17	97.32

Choose 19 PCs

SPE limit＝2.84
T2 limit＝30.14

Fault Detection

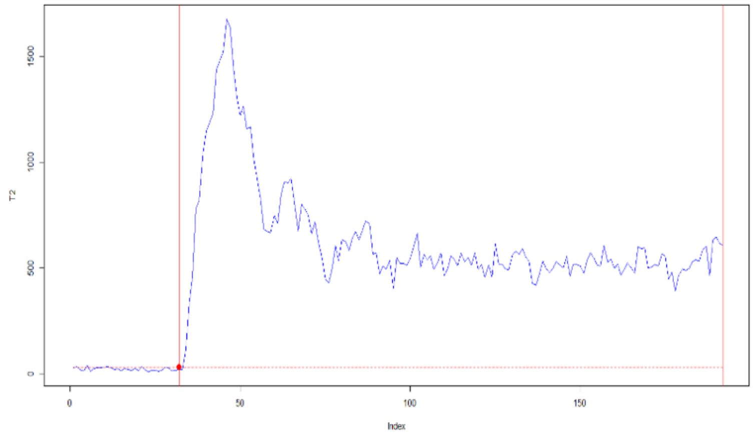


Fig.7. PCA – based process modeling result for IDV(1)

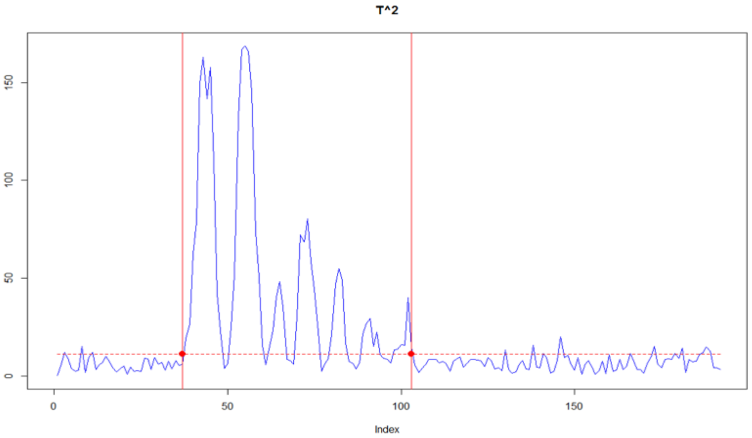


Fig.8. PCA – based quality monitoring result for IDV(1)

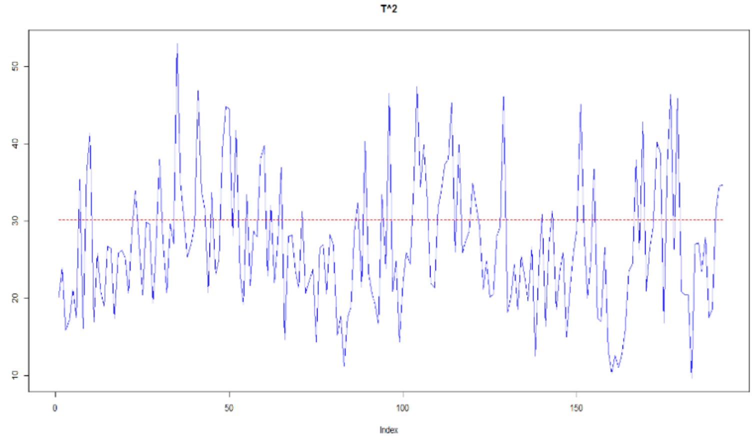


Fig.9. PCA – based process modeling result for IDV(3)

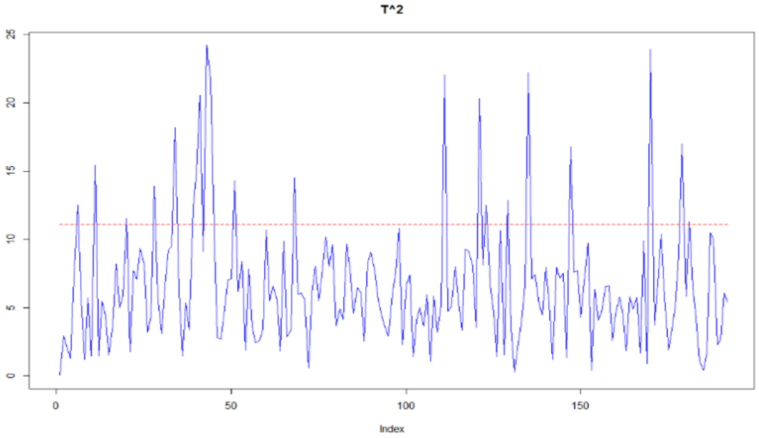


Fig.10. PCA – based quality monitoring result for IDV(3)

Fault Detection

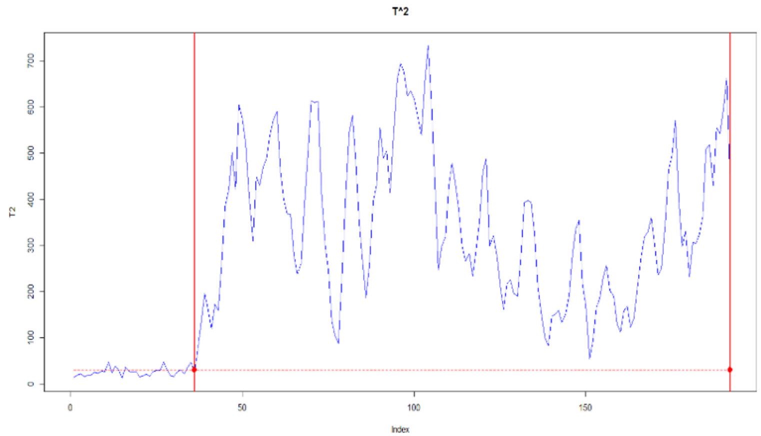


Fig.11. PCA – based process modeling result for IDV(8)

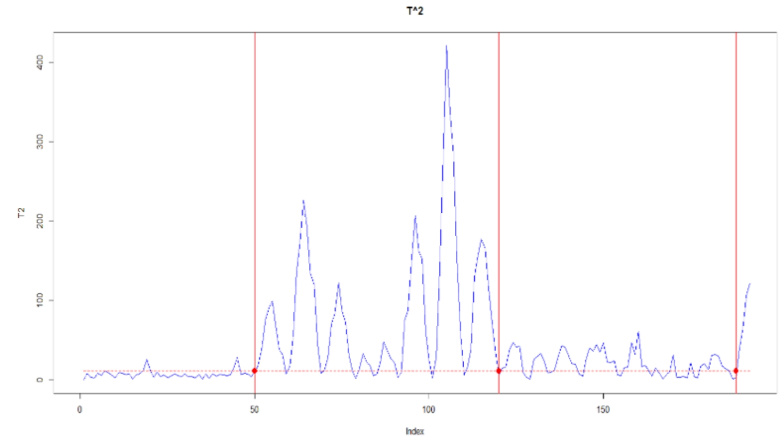


Fig.12. PCA – based quality monitoring result for IDV(8)

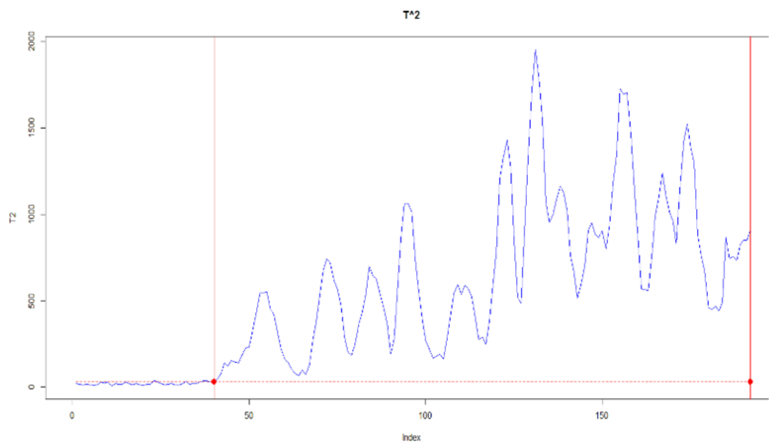


Fig.13. PCA – based process modeling result for IDV(13)

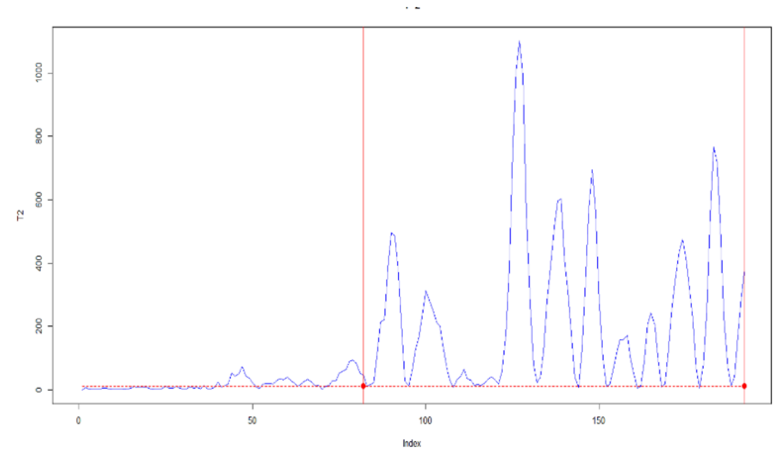


Fig.14. PCA – based quality monitoring result for IDV(13)

Fault Detection

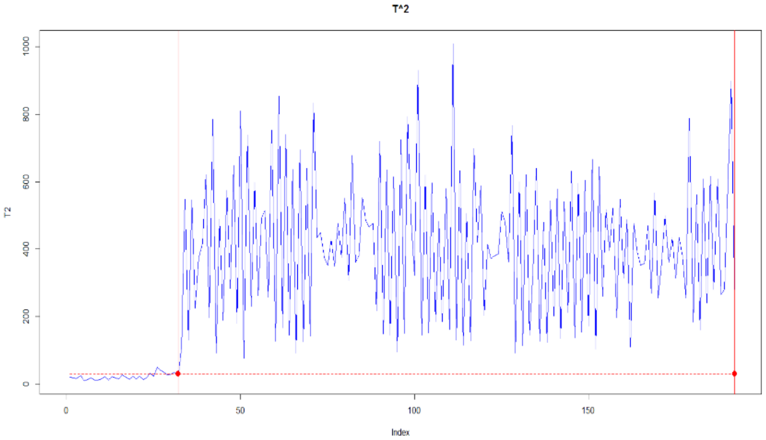


Fig.15. PCA – based process modeling result for IDV(14)

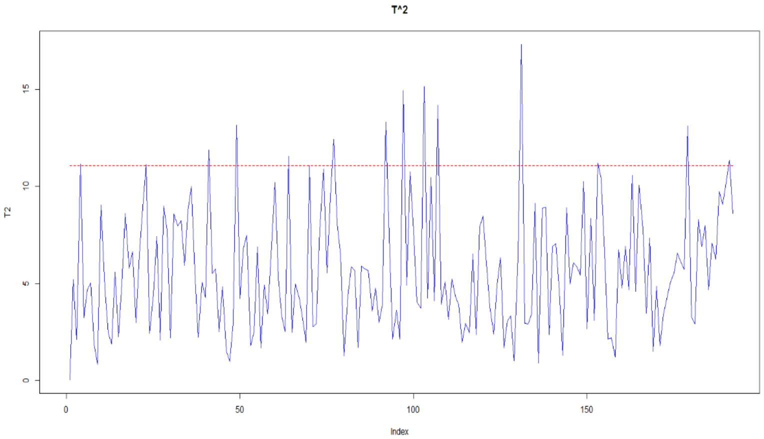


Fig.16. PCA – based quality monitoring result for IDV(14)

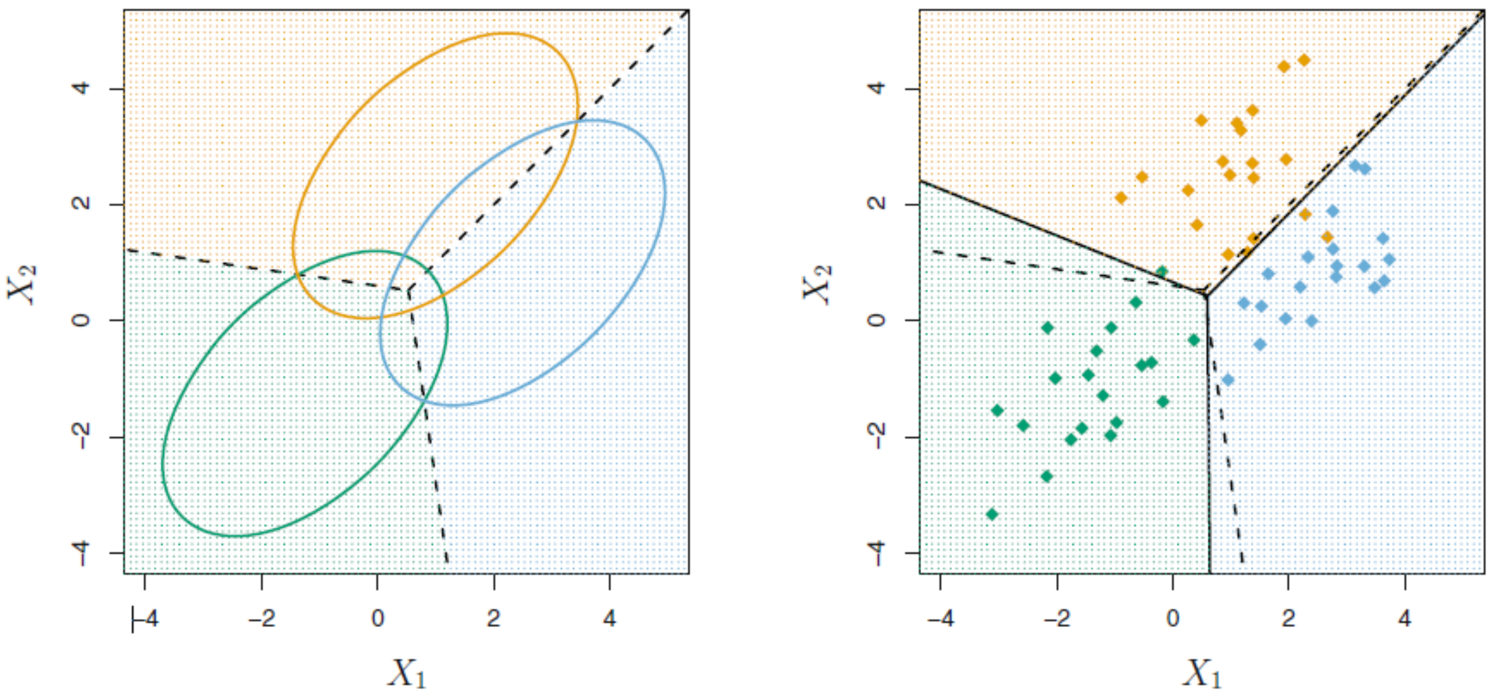
Fault Detection

Table 2. False Alarming and Miss Detecting Rates

Disturbances	FAR	MDR
IDV (1)	75%	0.00%
IDV (3)	/	/
IDV (8)	70%	0.00%
IDV (13)	51%	0.00%
IDV (14)	83%	0.00%

LDA

the *discriminant functions* $\delta k(x)$ are linear functions of x



LDA

a stacked histogram for quality monitoring

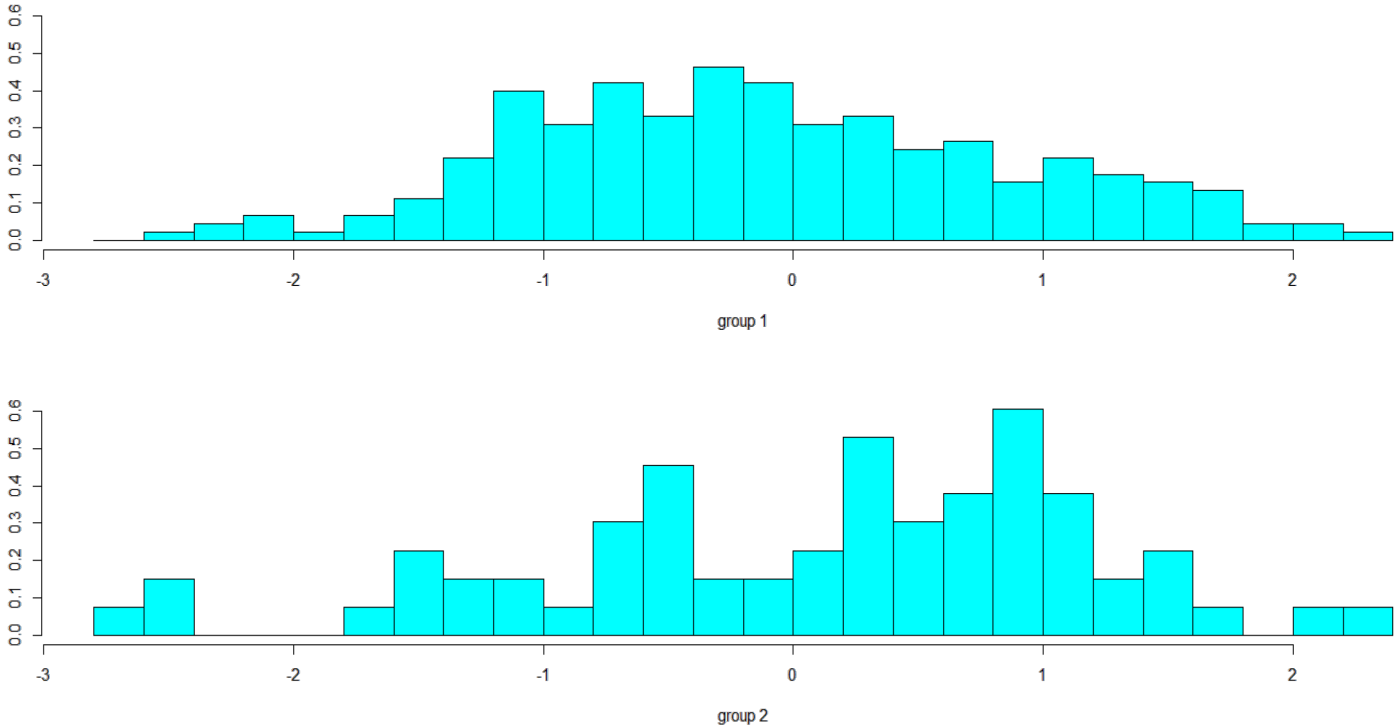


Fig.17. LDA- based classification result for IDV (1)

LDA

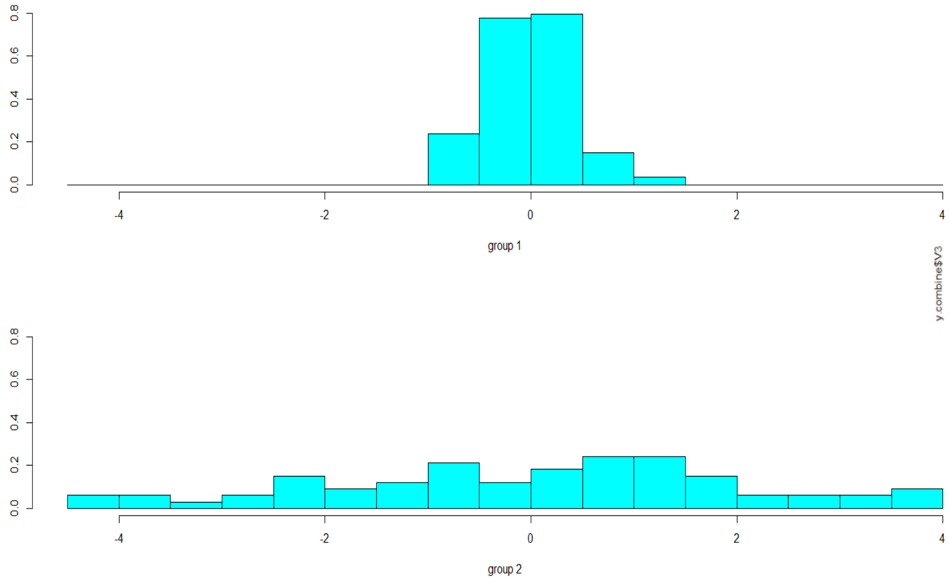


Fig.18. stacked histogram of V2 verse V3 for IDV (1)

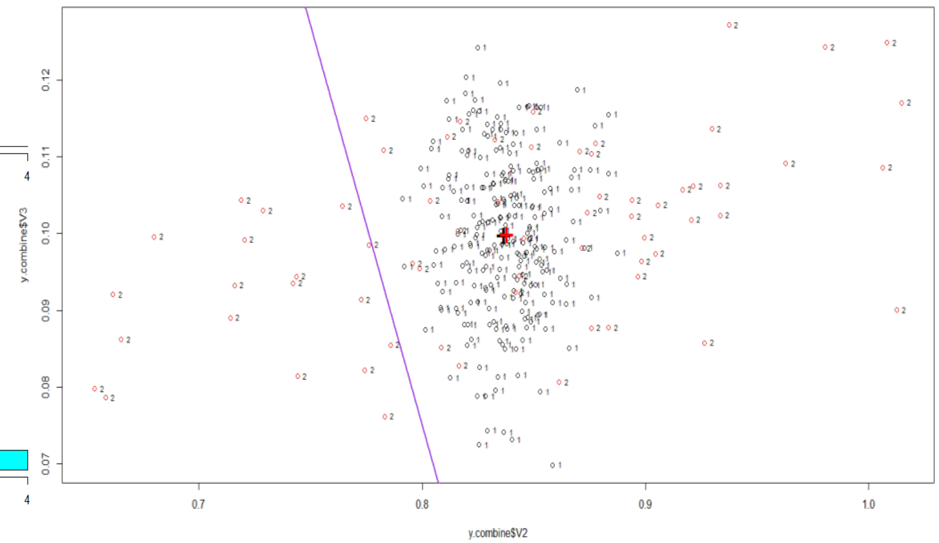


Fig.19. scatterplot of V2 verse V3 for IDV(1)

LDA

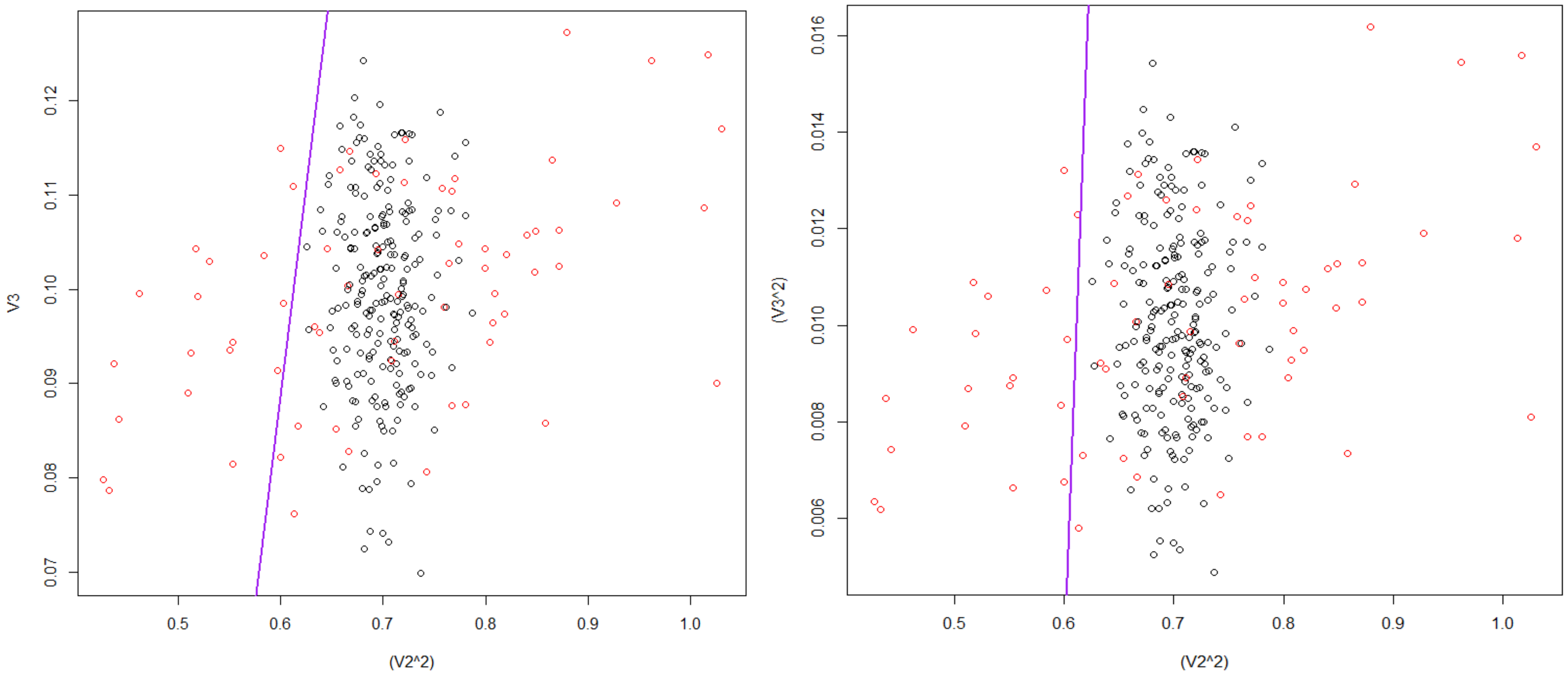


Fig.20. scatterplots for using quadratic terms in LDA

LDA

Processing monitoring result

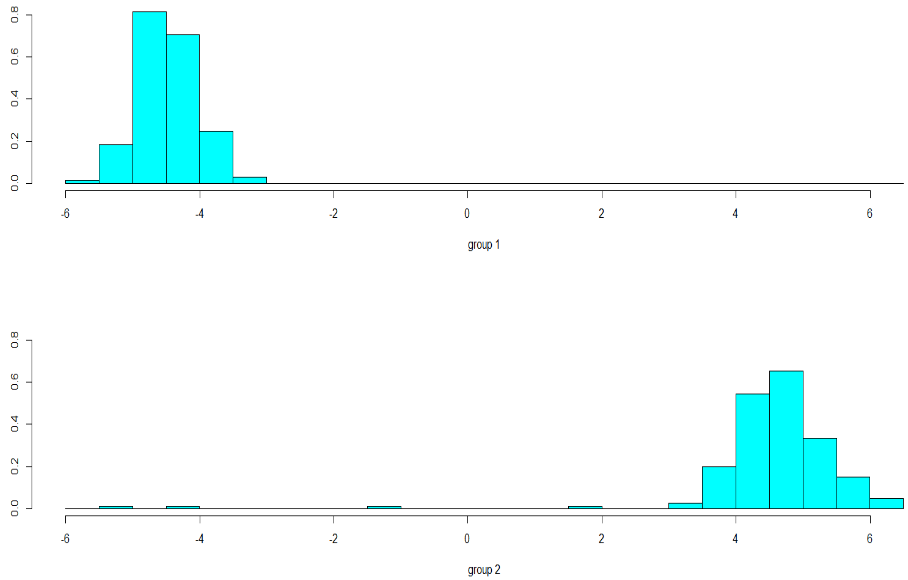


Fig.21. LDA- based process modeling result for IDV (1)

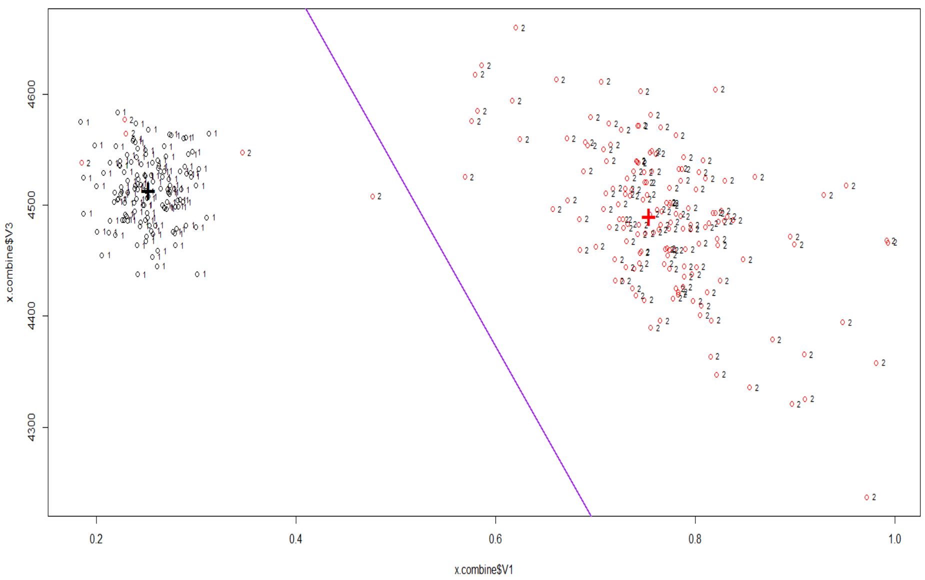


Fig.22. LDA scatterplot of V1 verse V3 for IDV(1)

LDA

Processing monitoring result

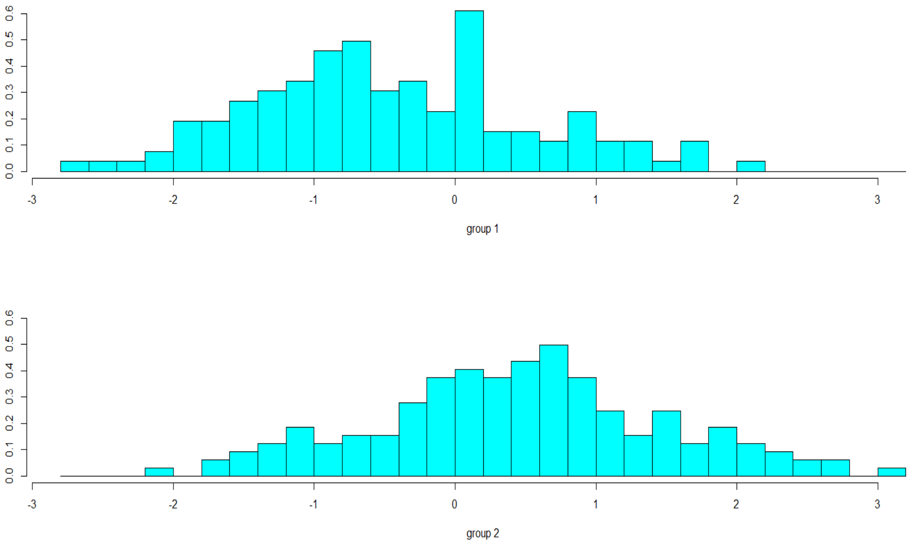


Fig.23. stacked histogram for IDV(14)

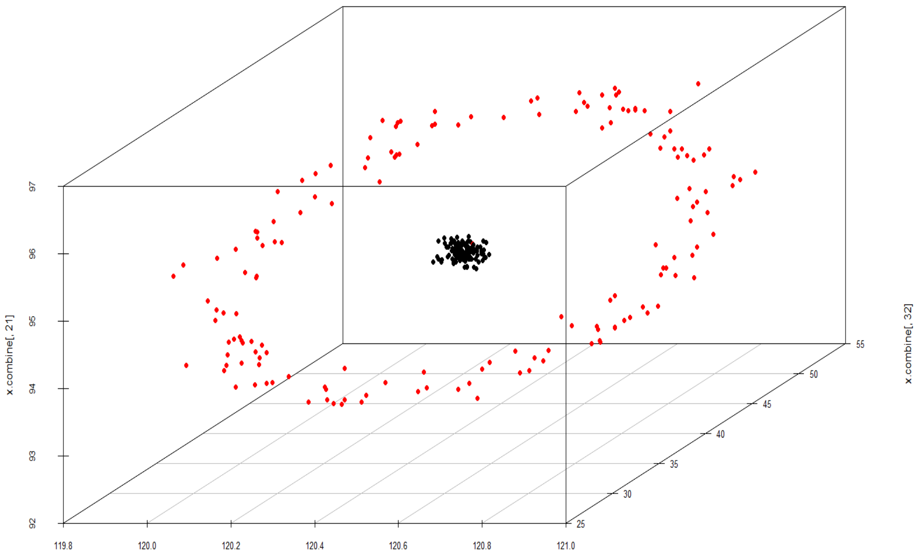


Fig.24. 3-D scatterplot in direction (V21, V9, V32) for IDV (14)

Concurrent CCA Monitoring

IDV (1): Step Change in A/C feed Ratio and B Composition Constant

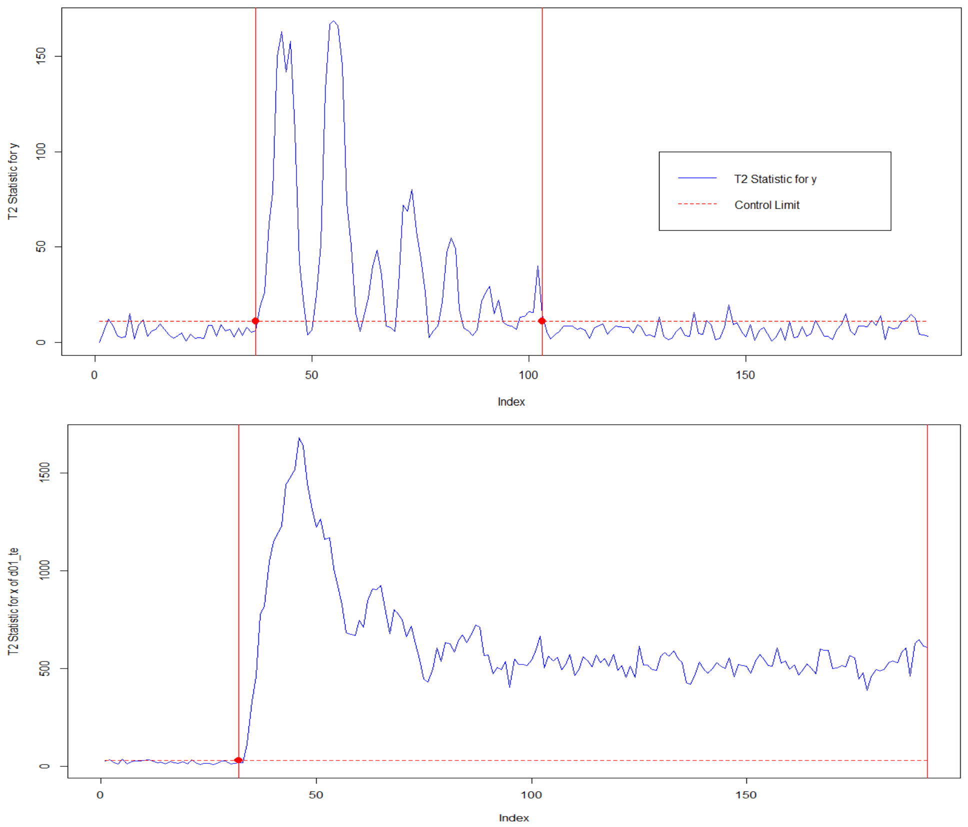


Fig.25. PCA Modeling for IDV(1)

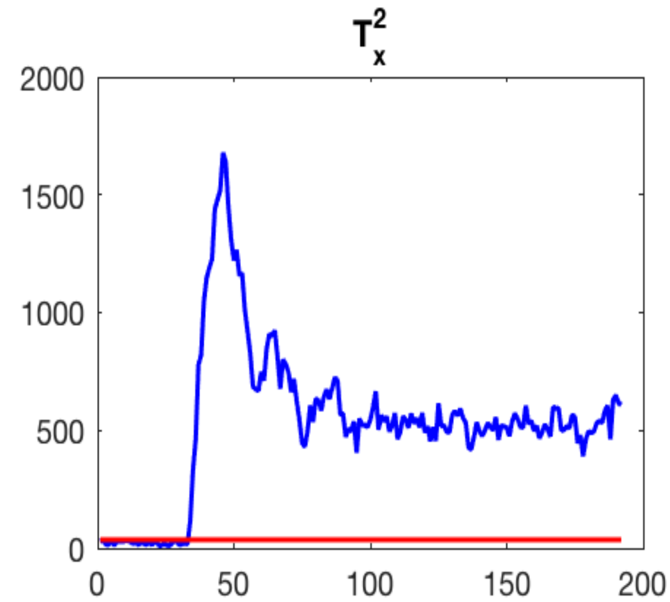


Fig.26. T_X^2 plot for IDV(1)

Concurrent CCA Monitoring

IDV (1): Step Change in A/C Ratio and B Composition Constant

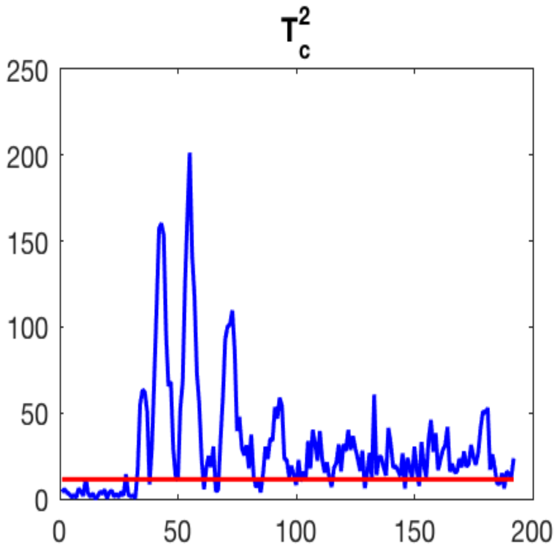


Fig.27. T_c^2 plot for IDV(1)

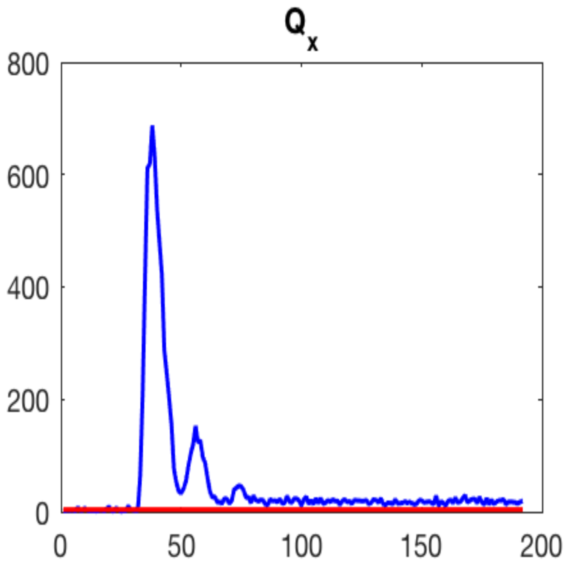


Fig.28. Q_X^2 plot for IDV(1)

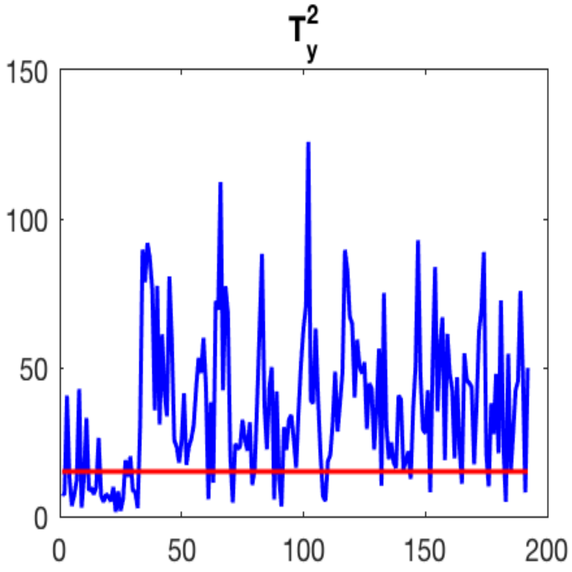


Fig.29. T_y^2 plot for IDV(1)

Concurrent CCA Monitoring

IDV (3): Step Change in D Feed Temperature

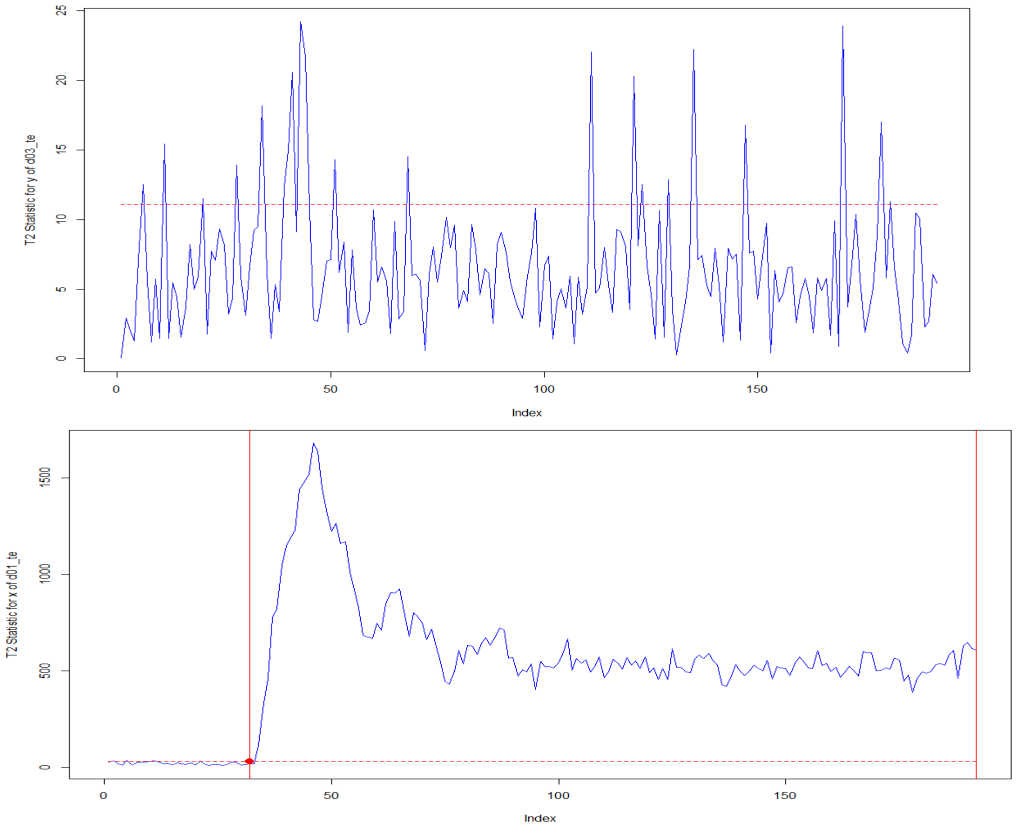


Fig.30. PCA Modeling for IDV(3)

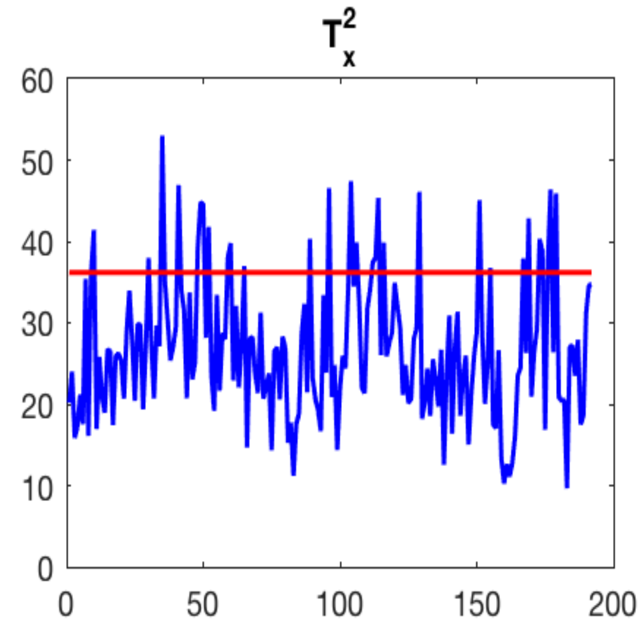


Fig.31. T_X^2 plot for IDV(3)

Concurrent CCA Monitoring

IDV (3): Step Change in D Feed Temperature

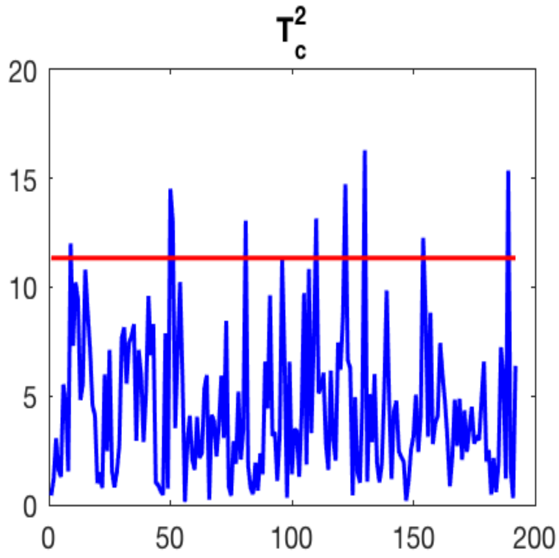


Fig.32. T_c^2 plot for IDV(3)

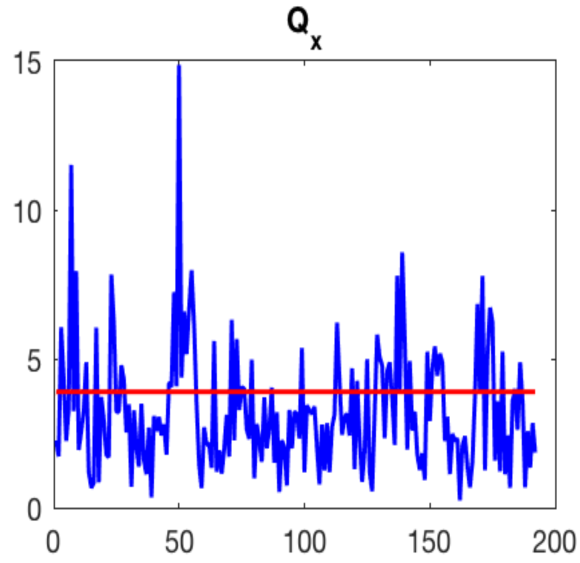


Fig.33. Q_X^2 plot for IDV(3)

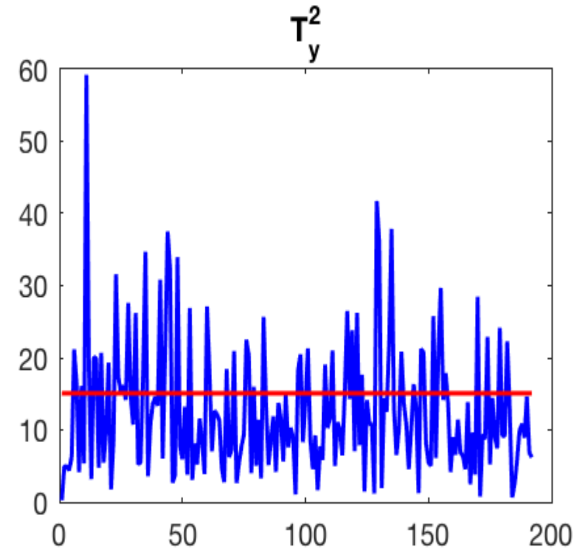


Fig.34. T_y^2 plot for IDV(3)

Concurrent CCA Monitoring

IDV (8): Random Variation in A,B,C Feed Composition

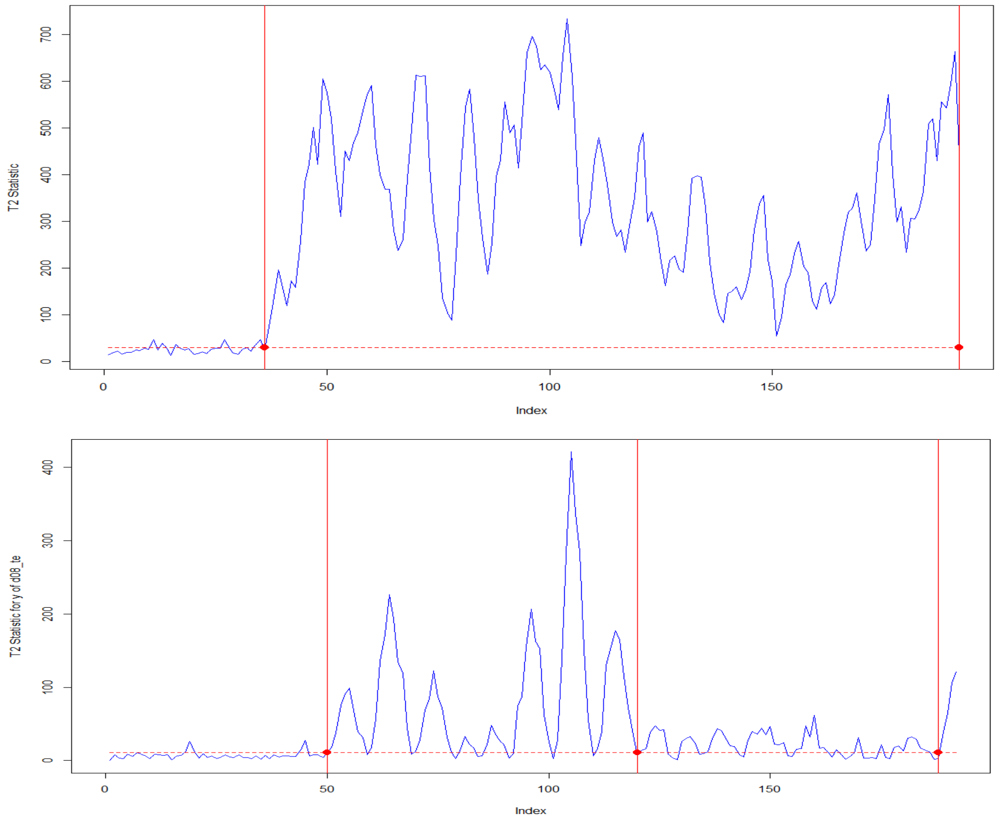


Fig.35. PCA Modeling for IDV(8)

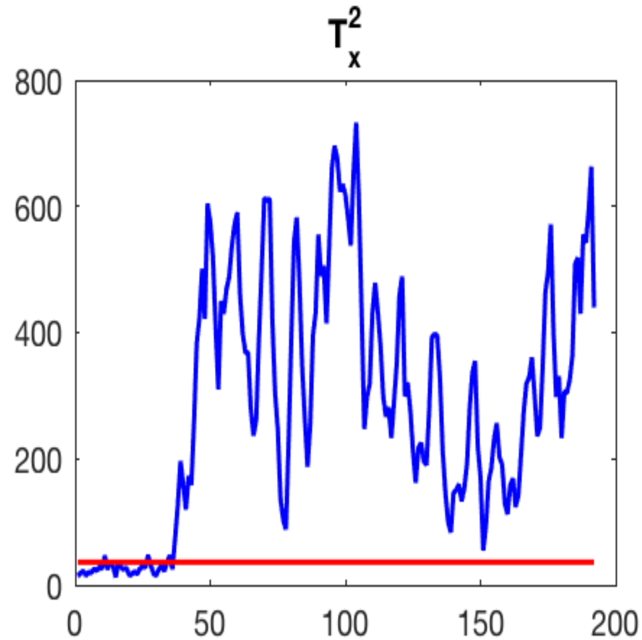


Fig.36. T_X^2 plot for IDV(8)

Concurrent CCA Monitoring

IDV (8): Random Variation in A,B,C Feed Composition

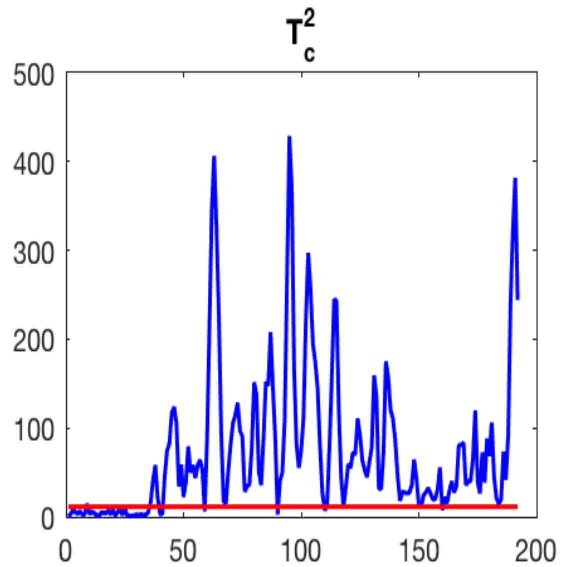


Fig.37. T_c^2 plot for IDV(8)

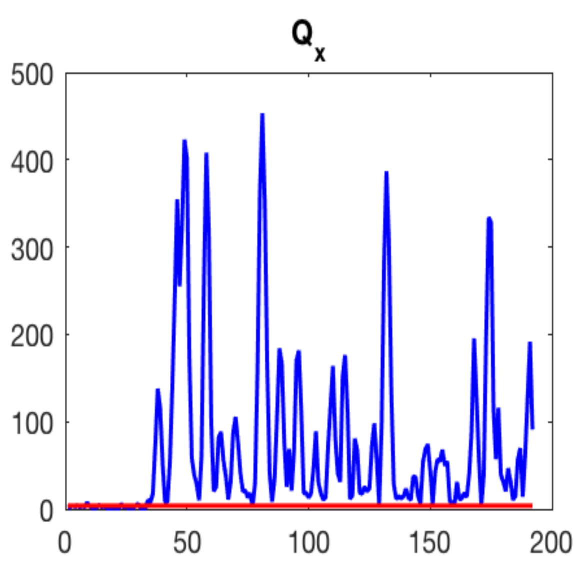


Fig.38. Q_X^2 plot for IDV(8)

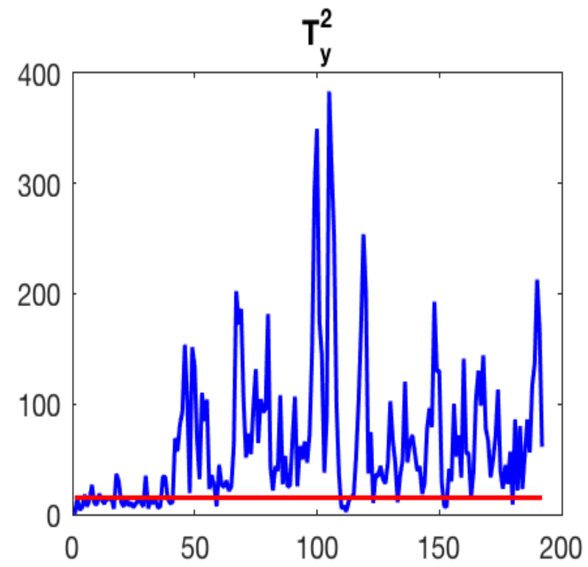


Fig.39. T_y^2 plot for IDV(8)

Concurrent CCA Monitoring

IDV (13): Slow Drift in Reaction Kinetics

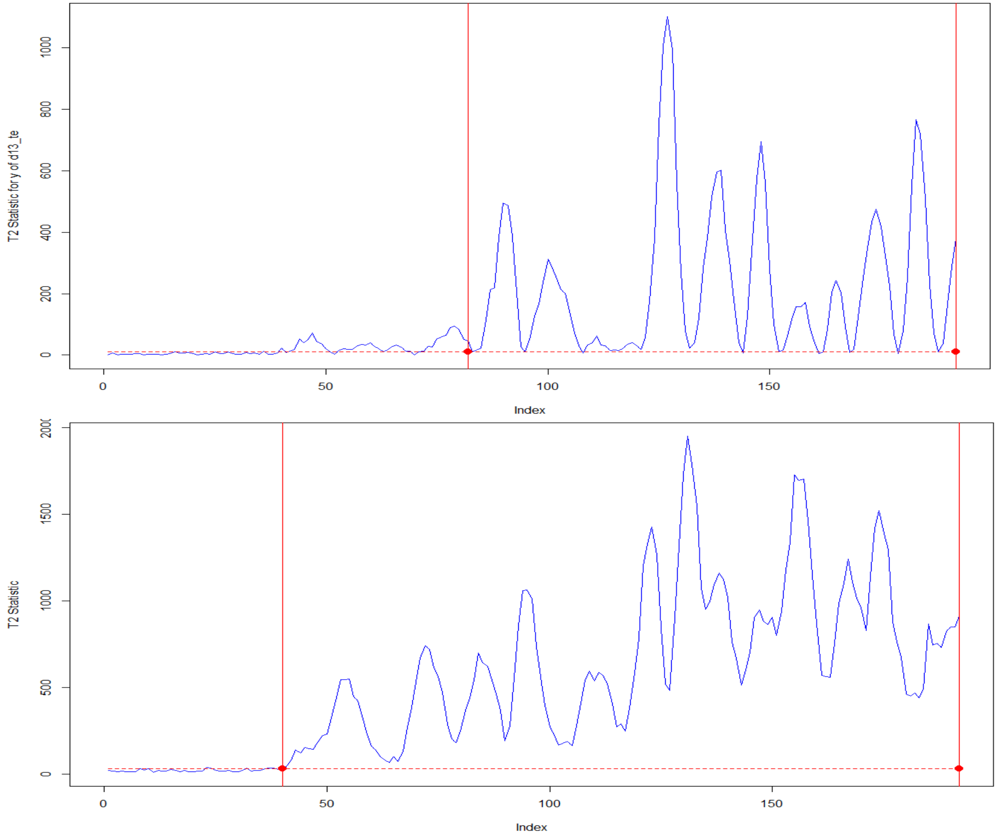


Fig.40. PCA Modeling for IDV(13)

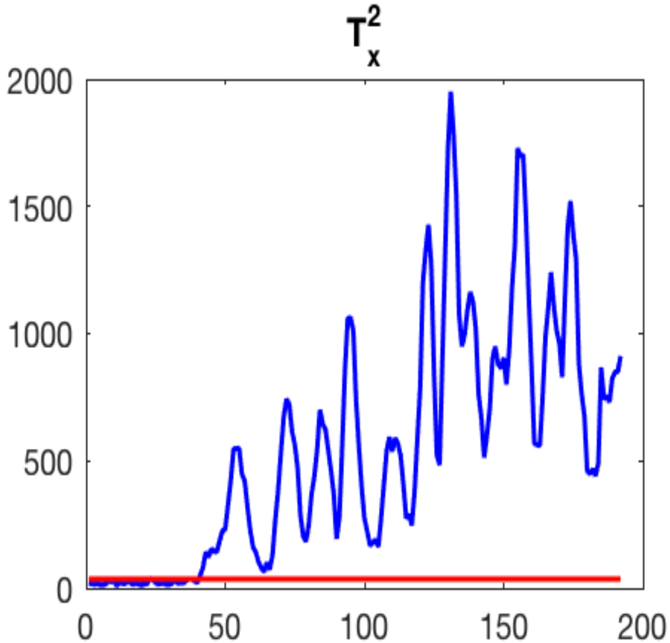


Fig.41. T_X^2 plot for IDV(13)

Concurrent CCA Monitoring

IDV (13): Slow Drift in Reaction Kinetics

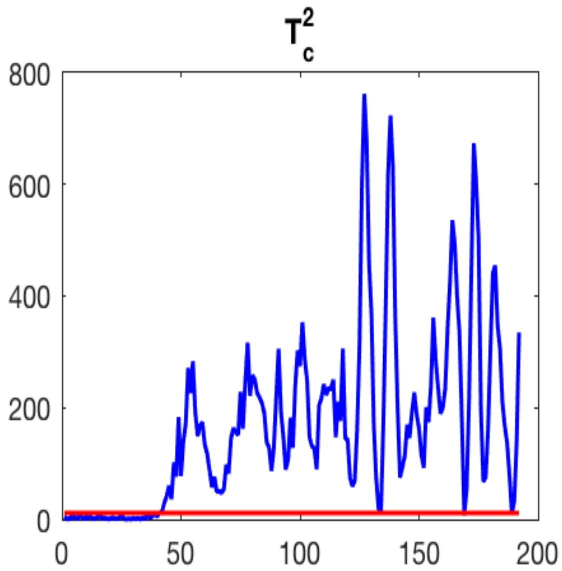


Fig.42. T_c^2 plot for IDV(13)

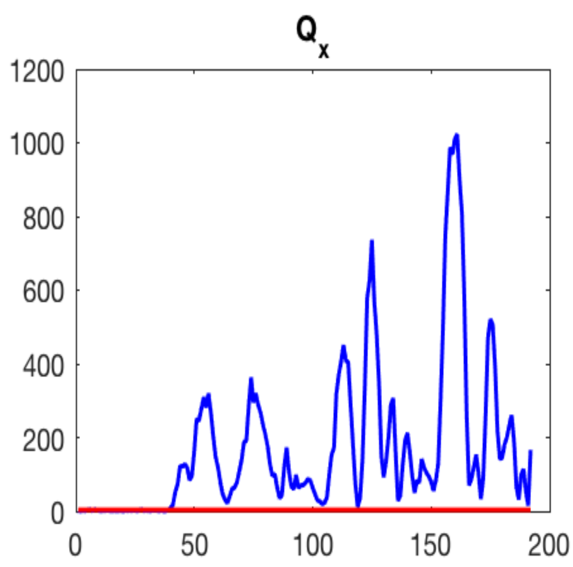


Fig.43. Q_X^2 plot for IDV(13)

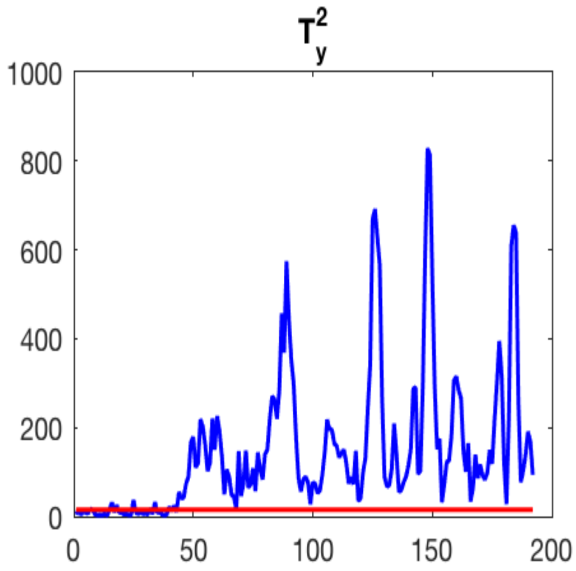


Fig.44. T_y^2 plot for IDV(13)

Concurrent CCA Monitoring

IDV (14): Sticking in Reactor Cooling Water Valve

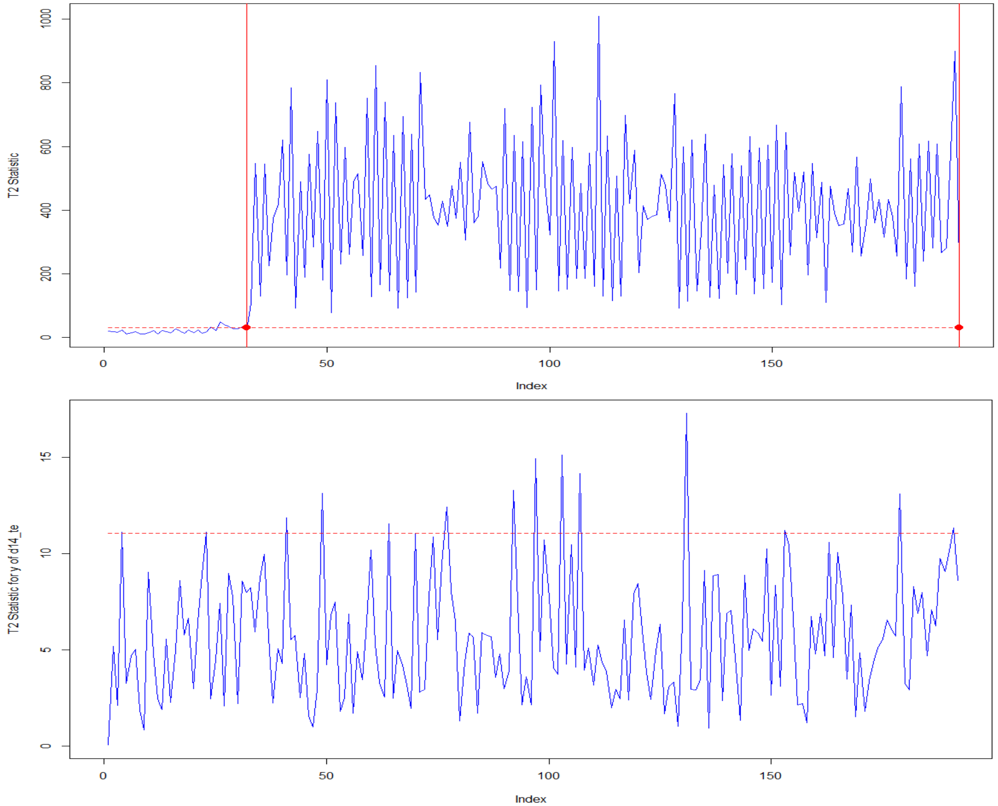


Fig.45. PCA Modeling for IDV(14)

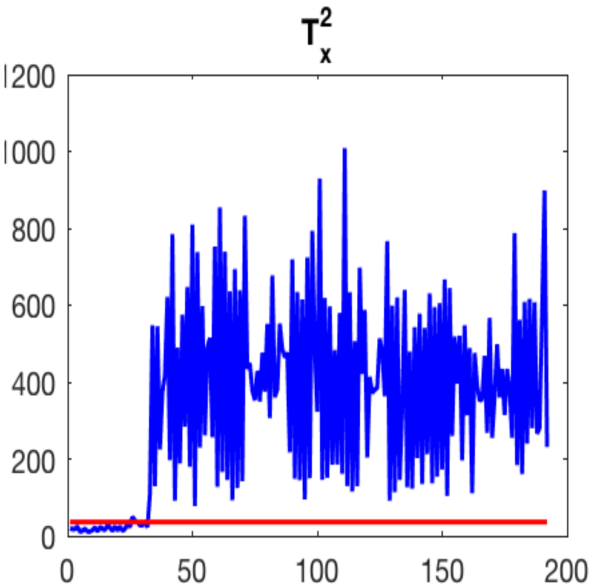


Fig.46. T_X^2 plot for IDV(14)

Concurrent CCA Monitoring

IDV (14): Sticking in Reactor Cooling Water Valve

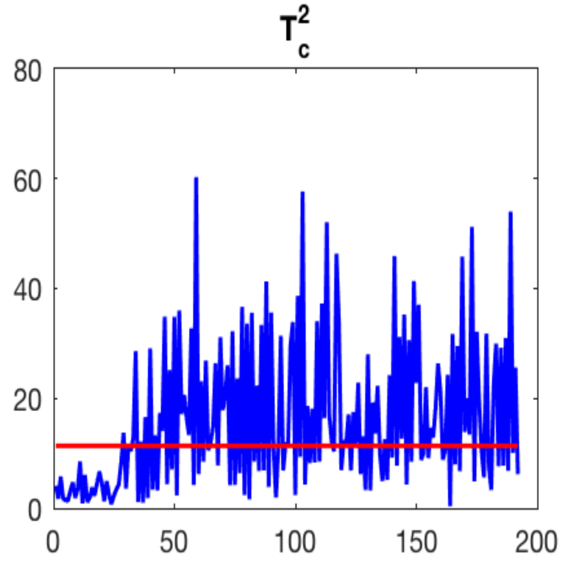


Fig.47. T_c^2 plot for IDV(13)

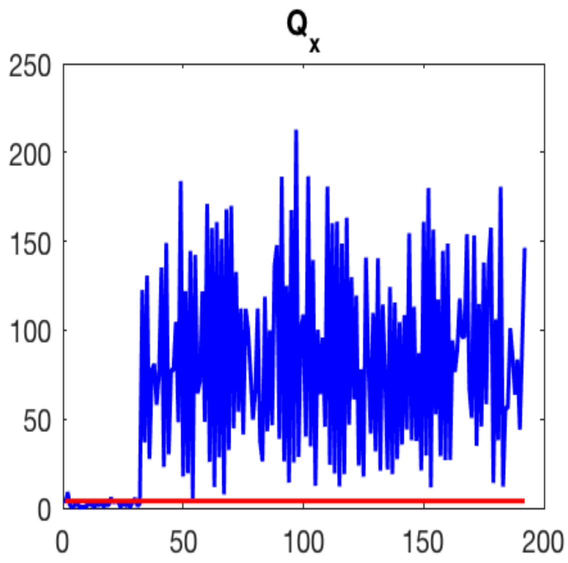


Fig.48. Q_X^2 plot for IDV(13)

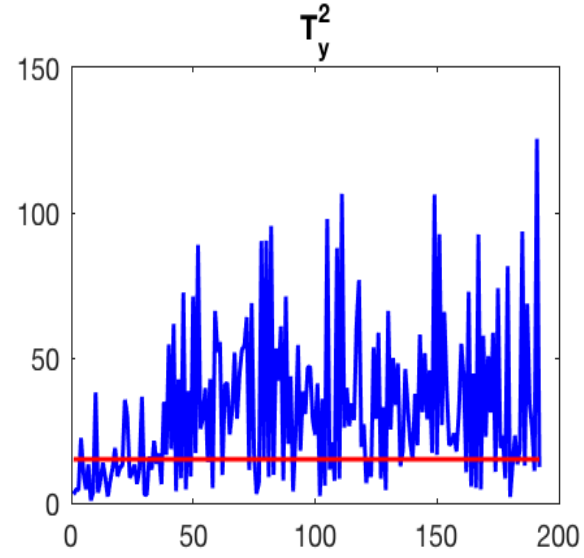


Fig.49. T_y^2 plot for IDV(13)

Thank You