Faculty of Engineering Sciences, GIK Institute
Advanced Linear Algebra (ES304)
Project: Complex Engineering Problem

Section: ES304	**Instructor:** Dr. Babar Zaman
Semester: Fall 2024	**Weightage: 10%**

Concerned CLOs:

- ✓ CLO4 - Analyze and solve applied engineering problems requiring tools from advanced linear algebra. PLO-4 (Investigation)
- ✓ CLO5 - Efficiently work in a team to investigate and solve problems related to applied linear algebra. PLO-9 (Individual and Teamwork)

Title: **Application of Linear Algebra in Control Charts for Process Monitoring**

1. Objective:

The primary objective of this project is to demonstrate the integration of linear algebra techniques—such as singular value decomposition (SVD), quadratic forms, and constrained optimization—with classical control charts (Shewhart, EWMA, CUSUM) for enhancing multivariate process monitoring. Using real-world datasets, the project will explore how these techniques can improve sensitivity and accuracy in detecting shifts and anomalies across multiple channels or variables, as seen in fields like multichannel image processing and quality control. The project will showcase the critical role of linear algebra and control charts in high-dimensional data contexts, presenting methods to visualize and interpret out-of-control signals more effectively.

2. Background:

In quality control and process monitoring, classical control charts (e.g., Shewhart, EWMA, and CUSUM) are widely used to detect shifts in the process mean or variance. However, in multivariate settings, where multiple interrelated variables must be monitored simultaneously, these charts often need enhancement for optimal performance. Linear algebra offers a powerful foundation for tackling these complexities. Techniques like SVD and constrained optimization allow us to extract key features, reduce dimensionality, and handle multichannel data (e.g., image processing, sensor data). This project will investigate how integrating linear algebra methods with classical control charts can enhance process monitoring in multivariate scenarios. Applications will include tasks such as multichannel image processing and statistical anomaly detection, where these mathematical tools and control charts work together to capture critical data patterns.

Milestones and Deadlines

Milestone 1: Group Formation and Data Selection

- Objective: Form groups of 4 students, select a dataset (e.g., from Kaggle, UCI), and submit team details.
- Deliverable: Group members' names, registration numbers, group number, and dataset choice.

Due Date: 20/11/2023

Milestone 2: Source Code and Report Submission

- Objective: Submit project code and report, following formatting guidelines.
- Deliverable: A zip file containing the source code (well-commented, executable) and a 5-page report using IEEE format.

Due Date: 13/12/2023

Milestone 3: Project Demonstration and Viva

- Objective: Demonstrate the project and answer questions in an oral examination.
- Due Date: To be scheduled by the instructor.

4. Tips for Successful Project Completion:

- Understand the Problem: Define objectives and required model outcomes.
- Data Preprocessing and Analysis: Ensure high-quality data and handle outliers, missing values, etc.
- Experiment with Linear Algebra Techniques: Explore multiple linear algebra concepts (SVD, quadratic forms) and control charts (EWMA, CUSUM).
- Document Everything: Maintain clear, organized documentation for reproducibility.

Project Outline

Title: XXXXXXXXXXXXXXXXX

Provide a concise summary of the project's objectives, methods, and anticipated insights.

1. Introduction

- Overview of control charts and multivariate process monitoring.
- Importance of linear algebra and classical control charts in quality control.
- Project objectives.

2. Literature Review

Review linear algebra techniques and control charts:

- Linear Algebra: SVD, diagonalization, quadratic forms, constrained optimization.
- Control Charts: Shewhart, EWMA, CUSUM.
- Applications: Explore applications in multichannel image processing and quality monitoring.

3. Dataset Selection

- Choose a dataset (e.g., multichannel images or quality control data).
- Describe the dataset's structure and relevance to process monitoring.

4. Data Preprocessing

- Data cleaning, handling missing values, and normalizing features.
- Representing data as matrices and vectors.

5. Tasks and Implementation (Select any two methods):

Task I: Singular Value Decomposition (SVD)

- Apply SVD for dimensionality reduction or data compression.
- Integrate results with control charts to identify patterns.

Task II: Quadratic Forms

- Use quadratic forms to analyze variance-covariance structures.
- Examine how these structures affect the sensitivity of control charts.

Task III: Constrained Optimization

- Implement constrained optimization to improve model stability.

- Apply optimization results in conjunction with control charts.

Task IV: Control Charts (Shewhart, EWMA, CUSUM)

- Design and implement control charts based on multivariate statistics.
- Integrate these with linear algebra techniques to enhance anomaly detection.

6. Results and Analysis

- Present results from each technique.
- Discuss insights, interpret control charts, and analyze the effectiveness of linear algebra integrations.

7. Conclusion

- Summarize key findings and their implications for quality control.
- Reflect on future applications and potential project extensions.

8. References

List all academic and technical resources used during the project.