Applied Linear Algebra
Course Code: MATH-816

Course Description

The abstract concepts of linear algebra are given meaning through demonstration in select application problems in optimization, control, machine learning robotics and signal processing. After revisiting the fundamental concepts, the importance of null space is explained in the context of inverse-kinematics for control of robotic manipulators and consensus in multi-agent robots, the range space and its orthogonal complements through controllable and uncontrollable subspaces, the four fundamental subspaces using Kalman decomposition for minimal realizations, the eigenvalues and eigenvalue decompositions for stability and solutions of linear dynamical systems, singular values and singular value decomposition through matrix norms, principal component analysis, model order reduction and image compression, projections through least squares solutions and minimum norm solutions using matrix calculus and optimization, followed by machine learning applications like classification, regression and deep neural networks.

Text Book:

1. Stephen Boyd and Lieven Vandenberghe, Introduction to Applied Linear Algebra, CUP, 2018

2. Gilbert Strang, Introduction to Linear Algebra, Wellesley-Cambridge Press, 2023

Reference Book:
1. Carl D. Meyer, Matrix Analysis and Applied Linear Algebra, SIAM, 2023

Prerequisites
Undergraduate Linear Algebra, MATLAB/Python

ASSESSMENT SYSTEM

Quizzes	10%
Assignments	10%
Mid Terms	35%
ESE	45%

Teaching Plan

Week No	Topics	Learning Outcomes
1-4	Linear Algebra Fundamentals	Vectors Spaces and Subspaces, Norms, Inner Products, Orthogonality, Gram-Schmidt Algorithm and QR factorization, Solution of Linear System of Equations, Linear Independence, Basis and Dimension, Null Space, Range Space, Fundamental Theorem of Linear Algebra, Singular and Nonsingular Matrices, Eigen Values and Eigen Vectors, Eigen Value Decomposition
5-8	Applications in Control Theory and Robotics	Linear Dynamical Systems, Representations, Solutions, Stability, Controllability and Observability, Kalman Decomposition, Model Order Reduction, Control Design, Graph Theory and Consensus in Multi-robot Systems*, Rotation Matrices in Robotics and Computer Vision*
MID TERM IN WEEK 9		
10-13	Matrix Calculus and Optimization	Positive Definite Matrices, Least Squares Solutions, Multi-objective Least Squares, Constrained Least Squares, Nonlinear Least Squares*, Constrained Nonlinear Least Squares*, Gauss-Newton and Levenberg-Marquardt Algorithms
14-17	Applications in Machine Learning and Signal Processing	Regression, Clustering, Classification, Deep Neural Networks*, Singular Value Decomposition, Principal Component Analysis, Dimensionality Reduction, Image Compression.
END SEMESTER EXAM IN WEEK 18		