APPLIED LINEAR ALGEBRA FOR SIGNAL PROCESSING, DATA ANALYTICS AND MACHINE LEARNING

PROF ADITYA K. JAGANNATHAM
Department of Electrical Engineering
IIT Kanpur

INTENDED AUDIENCE :

• Students in Electrical Engineering, Electronics and Communication Engineering, Mathematics, Economics, Computer Science
• Practicing engineers • Technical and Non-technical managers of Telecomm companies • Students preparing for Competitive Exams with focus on Wireless Communication, Signal Processing, Machine Learning
• Students pursuing projects or research in Machine Learning, Data Analytics and Signal Processing/ Communication

INDUSTRIES APPLICABLE TO : Qualcomm, Intel, Samsung, Google and other technology companies

COURSE OUTLINE :

This course aims to introduce students to all the basic and advanced concepts in Linear Algebra with a strong focus on applications. Linear Algebra is one of the fundamental tools that has applications in diverse fields such as Machine Learning, Data Analytics, Signal Processing, Wireless Communication, Operations Research, Control and Finance. The various topics and applications that will be covered in different areas are as follows:

- **Wireless**: MIMO/ OFDM systems, Beamforming, Channel Estimation
- **Machine Learning:** Regression, Clustering, EM Algorithm, Perceptron, SVM/ Kernel SVM, Principal Component Analysis (PCA), Face recognition
- **Signal Processing:** Signal Estimation, Regularization, Compressive Sensing, Image Compression, Robotics and Dynamical systems
- **Data Analytics:** Recommender systems, Data completion, Data prediction, forecasting, Optimal Estimation, Financial models
- **Operations Resarch:** Markov chains, inventory management, supply chain management
- **Miscellaneous Applications:** Electrical circuits, Graph models and social networks, Traffic flow management

The course is suitable for all UG/PG students and practicing engineers/ scientists/ managers from the diverse fields mentioned above and interested in learning about the novel cutting edge applications of linear algebra in various fields such as Machine Learning, Data Analytics, Signal Processing, Wireless Communication.

ABOUT INSTRUCTOR :

Prof. Aditya K. Jagannatham received his Bachelors degree from the Indian Institute of Technology, Bombay and M.S. and Ph.D. degrees from the University of California, San Diego, U.S.A. From April '07 to May'09 he was employed as a senior wireless systems engineer at Qualcomm Inc., San Diego, California, where he was a part of the Qualcomm CDMA technologies (QCT) division. His research interests are in the area of next-generation wireless cellular and WiFi networks, with special emphasis on various 5G technologies such as massive MIMO, mmWave MIMO, FBMC, NOMA, Full Duplex and others. He has contributed to the 802.11n high throughput wireless LAN standard and has published extensively in leading international journals and conferences. He was awarded the CAL(IT)2 fellowship at the University of California San Diego and the Upendra Patel Achievement Award at Qualcomm.

He is currently a Professor in the Electrical Engineering department at IIT Kanpur, where he holds the Arun Kumar Chair Professorship, and is also associated with the BSNL-IITK Telecom Center of Excellence(BITCOE). He has been twice awarded the P.K. Kelkar Young Faculty Research Fellowship for excellence in research, the Qualcomm Innovation Fellowship (QInF) and the IIT Kanpur Excellence in Teaching Award. His popular video lectures for the NPTEL(National Programme on Technology Enhanced Learning) course on Advanced 3G and 4G Wireless Mobile Communications can found at the following YouTube link (NPTEL 3G/4G). He has also successfully conducted several Massive Open Online Courses (MOOCs) on various topics such as Applied Game Theory, MIMO OFDM Wireless Systems, Probability and Random Processes, Signals and Systems, Principles of Communication Systems, which have been widely adopted and appreciated. A book authored by him titled Principles of Modern Wireless Communications Systems has been published by McGraw Hill Education and comprehensively covers several key aspects of modern wireless technologies.

COURSE PLAN :

Week 1: Introduction to vectors, properties and applications

Week 2: Introduction to matrices and Applications Circuits, Graphs, Social Networks, Traffic flow

Week 3: Eigenvalue decomposition, properties and Applications Principal component analysis (PCA), Eigenfaces for facial recognition

Week 4: Singular value decomposition (SVD) and Applications Beamforming in MIMO, Dimensionality reduction, Rate maximization in wireless, MUSIC algorithm

Week 5: Linear regression and Least Squares. Applications: System identification, linear regression, Support vector machines (SVM), kernel SVMs

Week 6: Optimal linear MMSE estimation. Applications MMSE Receiver, Market prediction and forecasting, ARMA models

Week 7: Data analytics: Recommender systems, user rating prediction, NETFLIX problem

Week 8: Structure of FFT/ IFFT matrices, properties, System model for OFDM/ SC-FDMA, Signal processing in OFDM systems

Week 9: Modeling of Dynamical systems Examples: Robots, Chemical plants. Solution of autonomous linear dynamical systems (LDS), solution of with inputs and outputs

Week 10: Unsupervised learning: Centroid based clustering, probabilistic model based clustering and EM algorithm

Week 11: Linear perceptron. Training a perceptron stochastic gradient. Compressive sensing, orthogonal matching pursuit for sparse signal estimation

Week 12: Discrete time Markov chains Applications: supply chain management, forecasting, Operations research - resource and inventory management.