Subject Code: 01CT2510

Subject Name: Applied Linear Algebra

B. Tech. Year – III (Semester V)

Objectives:

Linear Algebra is the study of vector spaces and linear transformations on vector spaces. Linear Algebra is central to both pure and applied mathematics. Techniques from linear algebra are also used in analytic geometry, engineering, physics, natural science, computer science, and the social sciences. Topics include the use and application of matrices in the solution of systems of linear equations, determinants, real n-dimensional vector spaces, abstract vector spaces and their axioms, linear independence, span and bases for vector spaces, linear transformations, eigenvalues and eigenvectors, matrix factorizations, and orthogonality. Computer explorations using MATLAB or Python is an integral component of this course.

Credits Earned: 04 Credits

Course Outcomes: After completion of this course, student will be able to:

1. Understand the use of matrices in solving linear systems of equations (Understand).
2. Determine the approximate solution of any system of linear equations using projection (Apply).
3. Matrix representations of linear transformations and use them in applied problems (Apply).
4. Applying the concept of eigenvalues, eigenvectors to solve real life problems (Apply).
5. Study and analyze various matrix factorization techniques (Analyze).

Pre-requisite of course: Understanding of elementary linear algebra, MATLAB/PYTHON

Examination Scheme:

Teaching Scheme (Hours)			Credits	Theory Marks			Tutorial / Practical Marks		Total Marks
				E	I		V	T	
Theory	Tutorial	Practical		ESE	IA	CSE	Viva	Term Work	
3	0	2	4	50	30	20	25	25	150

Contents:

Unit	Topics	Content Hours
1	**Vectors and vector spaces** Scalars: real numbers, complex numbers, examples of vector spaces, linear independence, span, basis vectors, rank, subspace, the null space of A: solving Ax = 0 and Rx = 0, the Complete Solution to Ax = b	04

2	**Linear Transformations** Matrix representation, change of basis, products of linear maps, null space, range, fundamental subspaces, rank-nullity theorem, invertibility, isomorphism, operators, invertible linear maps, change of basis for a linear map/operator, simplifying linear operators by changing basis	14
3	**Eigenvalues and eigenvectors of linear operators** Characteristic polynomial, eigenvalues/eigenvectors, generalized eigenvectors/eigenspaces, similaritytransformation, diagonalization, determinant, applications of eigen values: convolution and DFT, stability, finding expressions for A^k - fibonacci, counting paths in graphs, google search - popularity measures in a network	09
4	**Projection and least squares** Projection to a subspace, distance from a subspace and projection least squares solution to a linear equation, application: MMSE estimation application: linear regression in machine learning	08
5	**Singular value decompositions** Singular values and singular vectors, singular value decomposition, application: MIMO communications, low-rank approximations, recommendation systems	07
	Total Hours	**42**

Suggested Text books / Reference books:

1. Gilbert Strang, Introduction to Linear Algebra Fifth Edition (2016), Wellesley-Cambridge Press
2. Stephen Boyd and Lieven Vandenberghe, Introduction to Applied Linear Algebra – Vectors,Matrices, and Least Squares First Edition (2018), Cambridge University Press
3. Sheldon Axler, Linear Algebra Done Right third edition (2015), Springer
4. Gilbert Strang, Linear Algebra for Everyone, First Edition (2020), Wellesley-Cambridge Press
5. Gilbert Strang, Linear Algebra and Learning from Data, First Edition (2019), Wellesley-Cambridge Press

Suggested Theory distribution:

The suggested theory distribution as per Bloom's taxonomy is as per follows. This distribution serves asguidelines for teachers and students to achieve effective teaching-learning process.

Distribution of Theory for course delivery and evaluation					
Remember	Understand	Apply	Analyze	Evaluate	Create
10%	10%	40%	20%	10%	10%

Suggested List of Experiments:

1. Solving the maze using set of vectors to reach from start to end using restricted movements
2. Image Filtering using Convolution operation
3. Image Rotation using Matrix operations
4. Encryption and Decryption of secret messages using cryptography
5. Correct or recover the codes that have been tampered with while transmission or processing
6. Determining the word representation based on embeddings of different words using word2vec
7. Solving the system of Linear Equations for exact solution
8. Solving the system of Linear Equations for Approximate solution
9. Using QR decomposition for solving linear equations
10. Find the equation of hypothesis to fit the set of datapoints
11. Obtain the linearly transformed image/structure of a given image/structure
12. Application of Radiography images using Projection
13. Calculating the matrix-power using matrix diagonalization
14. Ranking algorithm in search engines using eigenvalues
15. Dimensionality Reduction using Eigenvalues and Eigenvectors
16. Finding the Fibonacci series using eigenvalues and eigenvectors
17. Image compression using Matrix Factorization
18. Content Based Filtering Recommendation system using Singular Value Decomposition
19. Merging multiple images using linear algebra to look as natural image

Instructional Method:

1. The course delivery method will depend upon the requirement of content and need of students. The teacher in addition to conventional teaching method by black board, may also use any of tools such as demonstration, role play, Quiz, brainstorming, MOOCs etc.
2. The internal evaluation will be done on the basis of continuous evaluation of students in the laboratory and class-room.
3. Practical examination will be conducted at the end of semester for evaluation of performance of students in laboratory.
4. Students will use supplementary resources such as online videos, NPTEL videos, e-courses, Virtual Laboratory

Supplementary Resources:

1. https://math.mit.edu/~gs/linearalgebra/
2. https://web.stanford.edu/~boyd/vmls/
3. https://clas.ucdenver.edu/mathematical-and-statistical-sciences/applied-linear-algebra- preliminary-exam-syllabus
4. http://www.cs.lewisu.edu/~harsyram/Linear_Algebra_Note_Packet_2020.pdf