Approved in 44th BoA Meeting (24-11-2021)

Course number : **CS512**
Course Name : **Matrix Theory**
Credit Distribution : **2-0-0-2**
Intended for : **MTech (CSE), MS, PhD**
Prerequisite : **None**
Mutual Exclusion : **MA512, EE522**

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1. **Preamble:**

The main objective of this course is to provide students a basic foundation of linear algebra and let them understand its applicability in various AI/ML-related areas. Upon completion of this course, students should have the prerequisite background essentially required to appreciate the intricacies of AI/ML systems and can pursue Machine Learning and Data Science-related courses.

2. **Course Modules with quantitative lecture hours:**

   1. **Background and review:** Linear system of equations, and their solutions, Linear transformation, Matrices, Determinant, Rank, Linear Vector spaces, Basis, Dimensions, Subspaces, Inner product, and orthogonality, Range space and null space, Eigenvalues and eigenvectors. Application: Examples of linear transformation such as rotation, translation, scaling, and eigen analysis. **(5 hours)**
   2. **Norms for vectors and matrices:** Vector norms and their properties, Matrix norms, Error analysis in linear systems, Application: Examples of neural network optimization/regularizations. **(4 hours)**
   3. **Eigenvalue Problems:** Condition numbers, and their application, Generalized Eigenvalue problems, Rayleigh Quotient. Application: Physical significance of eigenvalues and vectors and its relationship with PCA and Face recognition. **(4 hours)**
   4. **Matrix factorization and Least square problems:** Singular value decomposition, generalized pseudoinverses, QR factorization, PCA, Least square problems. Application: Examples from dimensionality reduction and Clustering. **(5 hours)**
   5. **Sparse matrices, their analysis, and algorithms:** Graphs and matrices, Sparse

Gaussian elimination, Sparse eigenvalue, and singular value problems. Application: Relationship of sparse matrices with graph-based spectral clustering OR graph CNN's. **(4 hours)**

6. **Different types and matrices, their properties, and analysis:** Symmetric, stochastic, Random Matrices, Properties of positive definite matrices, Toeplitz, and Circulant matrices. Application: Toeplitz's relationship with convolution and deconvolution networks **OR** DSM based graph clustering **(6 hours)**

Laboratory/practical/tutorial Modules: NA

7. Text books:

1. Matrix Analysis, Roger A. Horn and Charles R. Johnson, Cambridge university press, 2012.
2. Matrix computations, Gene H. Golub and Charles F. Van Loan, 3ed Ed., John Hopkins University Press, 2012.

8. References:

1. Direct Methods for Sparse Linear Systems, T. A. Davis, SIAM, 2006
2. An Introduction to Matrix Concentration Inequalities, Joel Tropp, 2015
3. Topics in Random Matrix Theory, Terence Tao, AMS, 2012
4. Numerical linear algebra, Lloyd N. Trefethen and David Bau III, Siam, 1997.
5. Matrix analysis for scientists and engineers, Alan J. Laub, Siam, 2005.
6. Linear algebra in action, Harry Dym, American Mathematical Soc., 2013.
7. Linear Algebra and its application, Gilbert Strang, 4th Ed.,Cengage Learning
8. Matrix Analysis, Rajendra Bhatia, Springer 1997
9. Matrix Theory, David Lewis, 3rd edition, 2014, Allied Publishers

9. Similarity with the existing courses:
(Similarity content is declared as per the number of lecture hours on similar topics)

Course Code	Course Name	Overlap (%)
IC111	Linear Algebra	>30%
MA512	Linear Algebra	>30%
EE522	Matrix Theory	>30%

6. Justification of new course proposal if cumulative similarity content is >30%:

It is a subset of the existing course EE522 with topics relevant for MTech CSE. The 2 credit structure for this course is already approved in the senate document for CSE MTech.