MACHINE LEARNING PROGRAM
College of Engineering
University of the Philippines Diliman, Quezon City

AI 211 (COMPUTATIONAL LINEAR ALGEBRA FOR AI)

A. Course Catalogue Description

1. **Course Number:** AI 211
2. **Course Title:** Computational Linear Algebra for AI
3. **Course Description:** Mathematical and Computational Methods for AI
4. **Prerequisite:** COI
5. **Semester Offered:** First Year, First Semester
6. **Course Credit:** 3u
7. **Number of Hours:** 3h lec
8. **Meeting Type:** Lecture
9. **Course Goals:** To train students in the fundamentals of linear algebra and to show examples in Data Analysis and Machine Learning.

B. Course Outline

1. **Course Outcomes (CO)**
   Upon completion of the course, students must be able to:
   - **CO 1.** Demonstrate the understanding of the six fundamental decompositions in linear algebra;
   - **CO 2.** Identify example applications of linear algebra in machine learning such as optimizations, regression, neural networks, vector calculus, etc.;
   - **CO 3.** Implement algorithms that calculate essential quantities such as eigenvalues, determinants, matrix multiplication and perform the fundamental decompositions; and
   - **CO 4.** Create linear algebra-based models that are used in artificial intelligence and machine learning.

Course Outcomes and Relationship to Program Objectives
I (introduced), ***D*** (demonstrated), or ***R*** (reinforced)

Course Outcomes	Program Objectives*				
	A	B	C	D	E
CO 1. Demonstrate the understanding of the six fundamental decompositions in linear algebra	***I***			***I***	
CO 2. Identify example applications of linear algebra in machine learning such as optimizations, regression, neural networks, vector calculus, etc.	***I***			***I***	
CO 3. Implement algorithms that calculate essential quantities such as eigenvalues, determinants, matrix multiplication and perform the fundamental decompositions	***I***			***I, D***	***I***

CO 4. Create and evaluate linear algebra-based models that are used in artificial intelligence and machine learning	***I***			***I, D***	***I***

* **A** Conduct directed research projects that addresses questions of significance in a particular subject area in artificial intelligence.
B Communicate effectively, artificial intelligence concepts and systems in oral and written communication formats to stakeholders.
C Investigate current state-of-the art research in artificial intelligence.
D Deploy artificial intelligence systems to solve real world problems.
E Practice ethical standards in research, teaching, and professional service.

2. Course Content

Lecture Topics	**No. of Hours**
Basics of Linear Algebra 1. Vectors and Vector Spaces a. Solutions to $Ax = b$ as Linear combination of Vectors b. Vector Spaces and Basis Vectors c. Matrix Multiplication from Linear combination of Vectors 2. $A = CR$ a. Elimination and pivots b. C and the Column Space of A c. R and the Row Space of A d. C and R, rank, and their relationship 3. $Ax = 0$ a. The null space and left null space of A. b. Solutions of x to Ax = b as a particular solution. 4. $A = LU$ a. Elimination and LU decomposition b. Permutation Matrix c. $PA = LU$ d. Ranks and Determinants 5. Orthogonal Matrices a. $A = QR$ b. Orthonormal Vectors c. Gram-Schmidt d. Orthogonal Basis Vectors e. Projections and Curve Fitting	9
Long Exam 1	3
Eigenvalues, Eigenvectors and Singular Value Decomposition 1. $A = S\Lambda S^{-1}$ a. Soving for the eigenvalues and Eigenvectors b. Eigenvalue Decomposition c. Jordan Matrices and Jordan Decomposition d. Similar Matrices e. e^{At} f. Fast Fourier Transform 2. Positive Definite Matrices a. Definitions and Properties b. Symmetric Matrices in Eigenvalue Decomposition c. $S = AA^{*}$	9

3. Singular Value Decomposition a. $A = U\Sigma V^*$ b. Calculation c. Intuition	
Long Exam 2	3
Matrix Calculations for Machine Learning 1. Vector and Matrix Calculus (Differentiation) a. Derivatives of vectors and matrices with respect to scalars b. Derivative of scalars with respect to matrices (1D and 2D) c. Tensors d. Derivatives of vectors and matrices with respect to vectors/matrices 2. Matrices in Neural Networks a. Forward and Back Propagation b. Gradient Descent c. Computational Graphs	12
Machine Problem	
3. Optimization a. Norms, Least-Squares and Minimizing with Ax=b constraints b. Intro to Linear Programming (Matrix Formulation) c. Quadratic Programming 4. Other Topics a. Distance Matrices b. Clustering c. Stability and Conditioning d. Randomized Matrix Multiplication e. Conjugate Gradient Method GMRES and MINRES	12
Long Exam 3	

3. Grading

1.00	1.25	1.50	1.75	2.00	2.25	2.5	2.75	3.00	5.00
[92,100]	[88,92)	[84,88)	[80,84)	[76,80)	[72,76)	[68,72)	[64,68)	[60,64)	[0,60)

4. Course Assessment

Long Exams	50%
Machine Problem	20%
Homework/Classwork.	30%

5. Class Policies

a. **Attendance:** University rules on attendance applies. Attendance is encouraged since this will be the opportunity for students to get clarifications for any misunderstanding that they may have to the lesson at hand.

b. **Homework/Classwork:** Late homework/classwork will be subject to appropriate penalties. No make-up activities will be given for these. These may be done together with your classmates but each individual must make his/her own submission. Sessions may have synchronous activities that will transition into homework.

c. **Long Exams/Machine Problem:** Strictly individual work unless otherwise specified – do not discuss your solutions with your classmates. Make-up exams / machine problems will be given in extraordinary circumstances. These exams will be scheduled on the week at the end of each section.

d. **Others:** University rules on absences, cheating, dropping, and filing of LOA apply. No removal/comprehensive exams will be given.

C. References:

1. Deisenroth, M. P., Faisal, A. A, Ong, C. S. (2020). Mathematics for machine learning. Cambridge University Press.
2. Strang, G. (2019). Linear algebra and learning from data. Cambridge: Wellesley-Cambridge Press.
3. Golub, G. H., & Van Loan, C. F. (2013). Matrix computations.
4. Lay, D. C., McDonald, J. J., Lay, S. R. (2020). Linear Algebra and Its Applications. 6th ed. Pearson.
5. Trefethen, L. N., & Bau III, D. (1997). Numerical linear algebra.

D. Teacher Information

Miguel Francisco M. Remolona
mmremolona@up.edu.ph
A303 Chemical Engineering Building / Interactive Learning Center Diliman