COMP 5230/6230: FOUNDATIONS OF AI

Course Description: This course introduces the mathematical foundations underlying modern Artificial Intelligence and Machine Learning systems. The course emphasizes intuitive and application-driven understanding of linear algebra, probability, statistics, optimization, and calculus through hands-on AI and data-centric examples. Students will develop the mathematical fluency needed to analyze, interpret, and build foundational AI/ML models and algorithms.

Prerequisites: None. Beginner Python programming recommended.

Credit Hours: 3

Objectives: By the end of this course, students will be able to:

1. Understand the mathematical foundations that power modern AI systems.
2. Reason about data, similarity, uncertainty, and optimization using mathematical tools.
3. Interpret how vectors, matrices, probability, and calculus are used in machine learning and deep learning models.
4. Analyze the behavior of AI systems through mathematical and geometric intuition.
5. Apply mathematical thinking to practical AI tasks including prediction, classification, embeddings, and neural networks.
6. Use computational tools to explore and visualize mathematical concepts in AI.
7. Build confidence in reading, understanding, and implementing mathematical ideas used in AI/ML coursework and research.

Tentative Course Outline:

Week 1: Mathematical Thinking for AI, Data Representations, Geometry of Data

Week 2: Scalars, Vectors, and Vector Operations, Similarity and Distance Metrics, Assignment 1

Week 3: Matrices, Matrix Multiplication, Linear Transformations, Systems of Equations

Week 4: Eigenvalues, Eigenvectors, Dimensionality Reduction Intuition, Embeddings, Assignment 2

Week 5: Probability Fundamentals, Conditional Probability, Bayes' Rule, Uncertainty

Week 6: Random Variables, Common Distributions, Expectation, Variance, Correlation, Assignment 3

Week 7: Statistics for Machine Learning, Sampling, Hypothesis Testing, Evaluation

Week 8: Midterm Review and Midterm Examination

Week 9: Functions, Derivatives, Partial Derivatives, Optimization Intuition, Assignment 4

Week 10: Gradient Descent, Loss Functions, Convexity, Training ML Models

Week 11: Linear Regression, Logistic Regression, Classification Intuition

Week 12: Neural Network Mathematics, Activation Functions, Backpropagation Intuition, Assignment 5

Week 13: Information Theory, Entropy, Cross-Entropy Loss, Representation Learning

Week 14: Applications in AL – Neural Networks, Generative Models

Week 15: Fairness, Bias, and Ethical Considerations in Mathematical Models for AI

Week 16: Course Review and Final Exam