COT 5615
Math for Intelligent Systems
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Prerequisites: STA 4321 (Mathematical Statistics), MAC 231 (Multivariate Calculus), MAS 3114 or MAS 4105 (Linear Algebra), or consent of instructor. Knowledge of high-level programming language such as MATLAB, Python, or R. A pre-test is available <here>.

Overview: Intelligent Systems is a broad term that refers to a variety of computer programs. Roughly speaking, these programs generally appear to use intelligence. The philosophical question of whether machines can possess true intellgience is not addressed in this course. The focus is on useful mathematical techniques commonly used in specific ways in this field.

Topics: The course covers mathematical concepts commonly used in several areas of Intelligent Systems, including Computer Vision, Cybersecruity, Big Data / Data Science, Environmental Data Analysis, Human Centered Computing, Image and Signal Analysis, Machine Learning, Micro- and Macro- Biology, Neural Networks/Deep Learning, Sensor Networks, and Social Networks.

Linear Algebra is covered first with the goal of understanding diagonalization of positive-definite matrices and the relationships of such matrices and related transformations to Intelligent Systems. Following that, **Probability and Statistics** will be studied with emphasis multivariate Gaussian, or Normal, distributions as well as Mixtures of multivariate Gaussians. The Beta, Binomial, Gamma, and Dirichlet distributions will also be introduced. A brief overview of **Lagrange Multipliers and Optimization** will be given. Finally, **Information Theory** will be discussed from the perspective of intelligent systems.

Topic Outline
All these topics are widely used in Intelligent Systems

1 Linear Algebra

- 1.1 Vector Spaces
- 1.2 Norms and Distances
- 1.3 Linear Transformations and Matrices
- 1.4 Change of Bases
- 1.5 Singular Value Decomposition
- 1.6 Eigenvalues and Eigenvectors
- 1.7 Symmetric, Positive-Definite Matrices (SPDM)
- 1.8 Diagonalization
- 1.9 Simultaneous Diagonalization
- 1.10 Quadratic Forms
- 1.11 Numerical Issues

2 Probability and Statistics

- 2.1 Random Variables
- 2.2 Probability Distributions
- 2.3 Probability Density Functions (pdf's)
- 2.4 Gaussian pdfs
- 2.5 Expected Values and Higher Order Moments
- 2.6 Gaussian pdfs and SPDM
- 2.7 Gaussian pdfs and Least Squares
- 2.8 Maximum Likelihood Estimates
- 2.9 Bayesian methods
- 2.10 Dirichlet and Multinomial Distributions
- 2.11 Maximum A-Posteriori Estimates
- 2.12 Mixture models

3 Lagrange Multipliers and Optimization

4 Information Theory

- 4.1 Shannon's Entropy
- 4.2 Mutual Information
- 4.3 KL-divergence
- 4.4 Renyi Entropy
- 4.5 Fisher Information