Course Title: Mathematical Foundations of Data Science

MATH 4931/MSSC 5931*. Topics in Mathematics or Statistics. 3 cr. hrs.

Linear algebra techniques are primary keys for creating and understanding machine learning algorithms, especially as applied to neural networks and deep learning. This course reviews linear algebra with applications to probability and statistics and optimization – and above all, a full explanation of deep learning.

This course can be seen as a second course in linear algebra, focusing on the background and computational methods necessary in data science. This will be a useful class for senior undergraduate students and graduate students in the MSSC department or other STEM disciplines.

Course Description:

The second course in linear algebra, focusing on topics that are the most essential for data science. In general, this topic course introduces computational and numerical methods required for large data-sets and machine learning. Some of those methods include LU, QR, spectral and singular-value decompositions; conditioning and stability; the DFT and filters; basic probability and statistics; linear regression; dimension reduction and principal component analysis; optimization; K-means and hierarchical clustering; classification with support vector machine; deep learning; fully connected and convolutional neural nets.

Potential Textbooks:

- *Mathematics for Machine Learning* by Deisenroth et al., Cambridge Univ. Press; 1st Ed. (2020) URL: http://www.mml-book.com/
- *Linear Algebra and Learning from Data* by Gilbert Strang, Cambridge Univ. Press; 1st Ed. (2019) URL: https://math.mit.edu/~gs/learningfromdata/
- *Pro Deep Learning with TensorFlow: A Mathematical Approach to Advanced Artificial Intelligence in Python* by Santanu Pattanayak; 1st Ed. (2017) URL: https://www.apress.com/gp/book/9781484230954

Potential Topics to cover:

- Review of basic Linear Algebra
- Matrices, linear transformations
- Systems of equations, Introduction to least squares, LU decomposition
- Inner products, orthogonality, QR decomposition, Eigenvalues, eigenvectors
- Singular value decomposition, best low-rank approximation
- Fourier Series and Discrete Fourier Transform, convolution
- Probability and statistics, probability distributions, moments, covariance matrix, weighted least squares
- Dimensionality reduction with principal component analysis
- Classification with support vector machines
- Optimization, Levenberg-Marquardt, Gradient Descent
- Deep learning, Layers, Learning and loss functions
- Fully connected and Convolutional Neural Nets (CNN)
- Backpropagation and chain rule, stochastic descent
- Natural Language Processing using Recurrent Neural Networks
- Unsupervised Learning with Restricted Boltzmann Machines and Auto-encoders

Prereq: COSC 1010, MATH 3100, and MATH 4720 or the equivalents.

* Students enrolled in MSSC 5931 will have additional theoretical and computational assignments.