Mathematics of Machine Learning and Signal Recognition
COMS W4995

Instructor:
Prof. Homayoon Beigi <beigi@recotechnologies.com> (hb87@columbia.edu)

Textbooks:
Required:
H. Beigi, "Fundamentals of Speaker Recognition, Springer, New York, 2011.

Reference Books:
H. Beigi, "Fundamentals of Speaker Recognition," Springer, New York, 2nd Edition, 2024.
H. Beigi, "Mathematics of Machine Learning and Signal Recognition, Springer, New York, 2024.
K.P. Murphy, "Machine Learning, A Probabilistic Perspective," The MIT Press, Cambridge, MA, 2012.
M. Loève, "*Probability Theory*," Springer, New York, 4th Edition, 1977.
P.R. Halmos, "Measure Theory," Springer, New York, 1974.
I.T. Jolliffe, "Principal Component Analysis," Springer, New York, 2nd Edition, 2002.
R. Courant and D. Hilbert, "Methods of Mathematical Physics," John Wiley & Sons, New York, 1989.
C. F. Gerald and P. O. Wheatley, "Applied Numerical Analysis," Pearson College Div., 7th Edition, New York, 2003.
G.J. McLachlen and T. Krishnan, "The EM Algorithm and Extensions," John Wiley & Sons, 2nd Edition, New York, 2008.
W.E. Boyce and R.C. DiPrima, "Elementary Differential Equations and Boundary Value Problems," John Wiley & Sons, 11th Edition, New York, 2017.
P.W. Berg and J.L. McGregor, "Elementary Partial Differential Equations," Holden Day, San Francisco, 1966.
R. Fletcher, "Practical Methods of Optimization," John Wiley & Sons, 2nd Edition, New York, 2000.

Grading:

Homework (20%):	Problems and coding assignments.
Midterm (20%):	Coding assignment and Problems.
Project Proposal (10%):	2-page proposal, including state of the art and proposed methodology.
Final Project (50%):	35% - Report of the methodology and resultts and 15% - Code.

Course Description:
Mathematics of Machine Learning and Signal Recognition provides the mathematical background for addressing in-depth problems in machine learning, as well as the treatment of signals, especially time-dependent signals, specifically non-stationary time-dependent signals – although spatial signals such as images are also considered. The course will provides the essentials of several mathematical disciplines which are used in the formulation and solution of the problems in the above fields. These disciplines include Linear Algebra and Numerical Methods, Complex Variable Theory, Measure and Probability Theory (as well as statistics), Information Theory, Metrics and Divergences, Linear Ordinary and Separable Partial Differential Equations of Interest, Integral Transforms, Decision Theory, Transformations, Nonlinear Optimization Theory, and Neural Network Learning Theory. There will be in-depth coverage of many Neural Network Architectures, with in-depth coverage of CNN, TDNN, RNN/LSTM, Transformer, and Conformer architectures. The requirements are Advanced Calculus and Linear Algebra. Knowledge of Differential Equations would be helpful.

See Syllabus for detailed weekly topics.