Proposal for Senior Project

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Course Title:	Mathematics for Machine Learning with Applications to Electric Load Forecasting
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Course Description

This course connects undergraduate studies in probability, statistics, linear algebra, numerical analysis and vector calculus to modern machine learning methods including Singular Value Decomposition, Linear Regression, Logistic Regression, Support Vector Machine, Principal Component Analysis, Expectation Maximization, Stochastic Gradient Descent, and Deep Neural Networks. After studying their mathematical preliminaries, the student will develop Applications of these machine learning methods in the domain of electric load forecasting.

Summary

My primary motivation for matriculating at IUE was to develop the mathematical literacy necessary to become a machine learning practitioner. To achieve that goal, I propose the following plan of study which I believe captures the intent of MATH-M 499 in its breadth and connections back to my coursework at IUE.

I will study many foundational machine learning techniques and their mathematical preliminaries. In a series of Labs, I will apply these techniques to the problem of electric load forecasting using publicly available data from my employer. The selection of electric load forecasting as the domain of inquiry allows me to leverage knowledge gained from industry experience. My aim is to bridge my mathematics education with my professional aspirations, not to progress the state of the art in electric load forecasting.

Therefore, I will develop an ensemble of machine learning models without consulting current research specific to the application of machine learning to electric load forecasting in a series of Applications and Labs. The results of these Labs will be documented in a term paper. After graduation this Spring, I will work with Dr. You to develop a research paper that builds on my results with the intention to submit to a journal.

Plan of Study

The chief organizing principle of this plan of study is to complete roughly one chapter a week from the textbook Mathematics for Machine Learning [DFO20]. This is reflected in the Readings alongside complementary materials that enrich the primary reading or serve as a reference for implementation of the Application. The Application column refers to software I will develop in python or Julia. The code will be made available publicly via my GitHub account. In addition to this work, I will complete relevant chapter exercises from the textbook [DFO20].

Week Ending	Topic	Readings	Application
16-Jan	Linear Algebra Review	[DFO20] §1-2 [Str16] §1-3, 11.1 [BFB16] §6.2	Gaussian Elimination with Partial Pivoting
23-Jan	Analytic Geometry	[DFO20] §3 [Str16] §4, 11.2 [BV18] §3,5 [BFB16] §9.1-9.2	Orthogonalization with Gram-Schmidt

30-Jan	Eigenvalue Decomposition	[DFO20] §4.1-4.4 [Str16] §6, 11.3 [BFB16] §9.4-9.5 [GBC16] §4	Householder + QR Method
6-Feb	Singular Value Decomposition (SVD)	[DFO20] §4.5-4.8 [GBC16] §2.1-2.9 [BK19] §1.1-1.8	SVD for positive definite matrices
13-Feb	SVD / pseudoinverse / least squares	[Str16] §7 [BFB16] §9.6	Lab 1: Load Prediction via Naive Linear Model
20-Feb	Vector Calculus Review	[DFO20] §5 [Str16] §8	Derive and Implement Logistic Regression (LR)
27-Feb	Probability	[DFO20] §6 [Str16] §12 [GBC16] §3 [BFB16] §6.6	Sampling Gaussian using Cholesky Factorization
6-Mar	ML Models / Linear Regression	[DFO20] §8-9 [BK19] §4 [GBC16] §5.1-5.6 [BFB16] §8.1-8.2	Lab 2: Improved Linear Model
13-Mar	Principal Component Analysis	[DFO20] §10 [BK19] §1.5 [GBC16] §2.12, 5.8.1	Implement PCA / Notes on derivation of PCA from SVD / first-principles
20-Mar	Support Vector Machines	[DFO20] §12 [BK19] §5.7 [GBC16] §5.7.2	Unsupervised classification of bids with SVM / Notes on derivation of SVM from LR
27-Mar	Density Estimation	[DFO20] §11 [BK19] §5.3-5.5	Lab 3: Expectation Maximization
3-Apr	Continuous Optimization	[DFO20] §7 [GBC16] §4 [BK19] §6.4	Stochastic Gradient Descent
10-Apr	Neural Networks	[GBC16] §6-8 [BK19] §6.1-6.3	Lab 4: NN model for MTLF
17-Apr	Convolutional Neural Networks	[GBC16] §9 [BK19] §6.5	Lab 5: CNN to predict load from weather
24-Apr	Recurrent Neural Networks	[GBC16] §10	Lab 6: LSTM for MTLF
1-May	Draft Term Paper Submitted		
5-May	Term Paper Finalized		

Resources

In addition to the texts listed in the References, the following online courses will be utilized.

- MIT 18.06 Linear Algebra
- MIT 18.065 Matrix Methods in Data Analysis, Signal Processing, and Machine Learning
- DeepLearning.AI Deep Learning Specialization
- Machine Learning Specialization (Unversity of Washington)

References

[BFB16] Richard L. Burden, J. Douglas Faires, and Annette M. Burden. *Numerical Analysis, Tenth Edition*. Cengage Learning, Inc., 2016. ISBN: 9781305253667.

[BK19] Steven L. Brunton and J. Nathan Kutz. *Data-Driven Science and Engineering: Machine Learning, Dynamical Systems, and Control*. http://www.databookuw.com/. Cambridge University Press, 2019. ISBN: 9781108422093.

[BV18] Stephen Boyd and Lieven Vandenberghe. *Introduction to Applied Linear Algebra: Vectors, Matrices, and Least Squares*. https://web.stanford.edu/~boyd/vmls. Cambridge University Press, 2018. ISBN: 9781316518960.

[DFO20] Marc Peter Deisenroth, A. Aldo Faisal, and Cheng Soon Ong. *Mathematics for Machine Learning*. https://mml-book.com. Cambridge University Press, 2020. ISBN: 9781108455145.

[GBC16] Ian Goodfellow, Yoshua Bengio, and Aaron Courville. *Deep Learning*. http://www.deeplearningbook.org. MIT Press, 2016.

[Str16] Gilbert Strang. *Introduction to Linear Algebra, 5th Edition*. https://math.mit.edu/linearalgebra. Wellesley - Cambridge Press, 2016. ISBN: 9780980232776.