USC Viterbi School of Engineering

EE460: Machine Learning for Engineers (Spring 2024)

Units: 4

Instructor: Antonio Ortega
EEB 436
213-740-2320 (Voice)
aortega@usc.edu

Office Hours: TBD

TA / Grader: TBD

Lecture: Monday, Wednesday, 4:00 – 5:50 PM in DMC 157

Discussion/Lab: TBD

Prereq: EE151L Introduction to Programming for Electrical Engineers
Or one of BME 210, CE 108, CHE 305, CSCI 103, ISE 150,
ITP 115, ITP 165, ITP 168
(or equivalent proficiency, e.g., C++, Matlab, Python)
E141L Applied Linear Algebra for Engineering (or MATH 225 or MATH 235)
EE364 Probability and Statistics for EE/CS (or MATH 407)

Useful, but not required: EE301L

Other Requirements: Basic computer skills (e.g., plotting, Python or Matlab or other).

Grading:

30% Homework
10% Quiz 1
10% Quiz 2
20% Midterm Exam
30% Final Project

Learning Objectives: Upon successful completion of this course a student will

- Be able to identify machine learning according to the taxonomy of supervised, unsupervised, reinforcement learning, etc.
- Apply methods of linear and nonlinear methods of regression or classification to data sets
- Apply principle component analysis to datasets and determine a reasonable amount of dimensionality reduction
- Select appropriate methods of optimization to train machine learning systems
- Apply data engineering concepts, such as cleaning, labeling, augmentation, to design and improve data sets for machine learning applications

- Be able to use Python-based machine learning tools, such as scikit-learn, Tensorflow, PyTorch to design machine learning solutions and evaluate the associated performance

Exam Dates:

- **Quiz 1:** TBD
- **Quiz 2:** TBD
- **Midterm Exam:** TBD
- **Final Project Presentation/Report:** Wednesday, May 1, 4:30 – 6:30 (university final exam slot)

Textbooks:

- **Required Textbooks:**
  - Jeremy Watt, Reza Borhani, Aggelos Katsaggelos, *Machine Learning Refined, 2nd Ed.*, Cambridge University Press.
- **Optional Textbooks:**
  - Ethem Alpaydin, *Introduction to Machine Learning, 3rd Ed.*, MIT Press.
  - Christopher Bishop, *Pattern Recognition and Machine Learning*, Springer, 2016.
  - Michael Nielsen, Neural Networks and Deep Learning
  - Kevin P. Murphy, *Machine Learning: A Probabilistic Perspective*, The MIT Press, 2012.
  - Tensorflow online documentation and examples

Course Outline

1. Introduction and Motivation **[Watt Chapters 1 and 2]**
   (a) ML definitions, problem statements, and tools
   (b) Global/Local Optimization, Curse of Dimensionality
   (c) Comparison to inference methods based on statistical models
   (d) Applications of ML
2. Overview of Optimization Methods **[Watt Chapters 2.1-2.5, 3.1-3.5, 4.1, 4.3]**
   (a) Global/Local Optimization, Curse of Dimensionality
   (b) Zero order methods
   (c) Gradient decent
   (d) Second order methods
   (e) Autograd tools in Python
3. Regression **[Watt Chapters 3.1-3.5, 5.1-5.2, 5.6]**
   (a) Linear regression
   (b) Linear regression review from EE364 and EE141L
   (c) Multiple-output regression
   (d) Alternative loss functions
4. Introduction to Data Engineering **[Watt Chapters 11.1-4, 11.7-11.8, 11.10]**
   (a) Over-fitting
   (b) Under-fitting
   (c) Regularization
   (d) Cross-validation
   (e) augmentation
   (f) Data formats and common data sets.
5. Classification **[Watt Chapters 6.1-6.4, 7.1-7.4, 7.6]**
   (a) Linear regression for 2-class classification
   (b) Logistic regression and the perceptron
   (c) Cross-entropy loss
   (d) Multi-class classification
   (e) Example: digital modulation classification

   QUIZ 1
6. Features and Unsupervised ML **[Watt Chapters 8.1-8.3, 8.5, 9.2, 9.7]**
   (a) Sufficient statistics and features
   (b) Principle Component Analysis

   (c) K-mean clustering
   (d) Example: common features in audio signal processing

7. Introduction to Nonlinear Methods **[Watt Chapters 10.1-10.2, 10.4]**
   (a) Nonlinear regression
   (b) Nonlinear classifiers
8. Introduction to Kernel Machine **[Watt Chapter 12]**
   (a) Universal approximation property
   (b) Kernel trick
   (c) Optimization and learning methods

QUIZ 2

9. Introduction to Neural Networks **[Watt Chapter 13, Neilson]**
   (a) Multilayer perceptions (MLPs)
   (b) Activation functions
   (c) Backpropogation learning
10. Decision Trees **[Watt Chapter 14.1-14.4, 14.6]**
   (a) Regression trees
   (b) Classification trees
   (c) Random forests
11. Deep Learning (Neural Networks) **[Slides, Tensorflow tutorials/docs]**
   (a) Optimizers
   (b) Regularizers
   (c) Training and evaluation of MLPs in TensorFlow

MIDTERM

12. Convolutional Neural Networks **[Slides, Tensorflow tutorials/docs]**
   (a) CNN architectures and conventions
   (b) Applications to computer vision problems
13. Recurrent Neural Networks **[Slides, Tensorflow tutorials/docs]**
   (a) RNN architectures and conventions
   (b) Applications to nonlinear filtering
14. Attention mechanisms **[Slides, Tensorflow tutorials/docs]**
   (a) Attention as an alternative to state
   (b) Introduction to transformers

(c) Example capabilities of Large Language Models (LLMs)

15. Selected Advanced Topics (time allowing) **[Slides, Tensorflow tutorials/docs]**

(a) Introduction to reinforcement learning

(b) Introduction to generative models (GANs, diffusion)

(c) Example capabilities of text-to-image systems and deep fakes

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Plagiarism: presenting someone else's ideas as your own, either verbatim or recast in your own words is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct.

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