Machine Learning for Data Science and AI (2/2023)

CPE 393. MEE 673.

King Mongkut's University of Technology, Thonburi

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Time: *Lecture:* Saturdays 13:00 - 16:00. Room 1115. Engineering Building.

Lab/Self Study/Projects: Average of 7 hours/week (more if not a strong programmer)

Links:
Course LMS: https://app.leb2.org/class/514766/new-plan (we use CPE 393 S1)
Facebook for discussions: https://www.facebook.com/groups/922570172552621
Instant Messaging / Chats: https://www.facebook.com/groups/922570172552621/chats

Course Description. A hands-on approach to introduce students to machine learning (ML) algorithms with the goal of building a foundation for further self-learning in this vast field. Applications of ML in data science, artificial intelligence, and computer vision will be covered. The mathematics used to power each ML algorithm will also be covered so that students have a deep understanding and a strong foundation.

Programming Background Expectations. In this course, we won't have traditional exams. Instead, you'll learn by doing class assignments, which involve basic programming tasks. You don't need to be an expert programmer; we often use ready-made programming tools. If you're not skilled in programming, it might take a bit more time, but by the end of the course, you should become a better programmer. On the other hand, if you're already comfortable with programming, this course should be easier for you. We'll mainly use Python for programming. If you're not familiar with it, don't worry; it's quite easy to learn, especially if you already know another programming language.

Mathematical Background Expectations. You should have taken some calculus and linear algebra. If you have forgotten most of it, don't worry. The instructor will review the underlying mathematics for each algorithm.

Course Description

This course will cover the following *applications* and related *Machine Learning and supporting algorithms*:

Week 1

- Course Overview. Learning Outcomes. An Introduction to Machine Learning.
- Intro to Image Processing. Convolution, Gaussian filtering, Template matching. K nearest neighbor (KNN) algorithm for classification.
- *Assignment 1.* Image match using (KNN), Image Convolution, Gaussian Convolution Masks.

Weeks 2

- Image features and image classification using such features. Edges, Histogram of Gradients, SIFT image features. Simple image segmentation. Character recognition (OCR).

- *Assignment 2.* Handwritten digit recognition using KNN with grayscale features and HOG features.

Week 3

- Naive Bayes for classification. Test on Iris and Cancer dataset. Dataset normalization. Test on wine and digits dataset. Confusion Matrix, false positive, false negative.
- *Assignment 3.* Code Naive Bayes. Normalize the dataset. Try Naive Bayes & KNN on datasets.

Weeks 4

- Introduction to Optimization. Minimizing cost functions. Pseudo-inverse, linear regression, gradient descent, Gauss-Newton method.
- *Assignment 4.* Curve fitting using gradient descent. Use numerical estimates for gradient. Use pseudo-inverse linear regression instead of gradient descent. Try Gauss-Newton method.

Week 5

- Stochastic Gradient Descent and Simulated Annealing. Evolutionary Algorithms for optimal garment placement. Linear Regression on the diabetes dataset and gasoline consumption dataset. Discrete gradient descent and continuous gradient descent for image restoration. Using optimization libraries for gradient descent, Nedler-Mead method, BFGS (with Jacobian matrix).
- Logistic Regression. Use on the employee attrition prediction dataset.
- *Assignment 5.* Linear Regression to make predictions using 1-D data and multi-dimensional data. Image processing using Continuous and Discrete Gradient Descent. Use Logistic Regression on a dataset. Logistic regression using your own program with BFGS minimization.

Week 6

- Principal Component Analysis (PCA). Dimension reduction for feature transformations. Convert various datasets to 2 features and test that classification algorithms still work after feature reduction. Explained variance preserved in the Eigenvalues of PCA. Apply feature reduction to handwriting recognition to see it works even better. Eigenfaces - application of PCA to face recognition.
- *Assignment 6.* PCA to reduce a dataset to 2 features. Try logistic regression. Plot decision boundary.

Week 7

- Classification based on multiple weak features to form a strong feature. Haar Cascade, Adaboost.
- Handling outliers in your dataset. RANSAC Regression.
- Recommender system using the MovieLens dataset for movies. Recommender Systems (People who bought this book also bought X, You may also like these movies ...). Algorithms: simple recommenders (score-based), content filtering (location, age, gender), collaborative filtering previous behavior, similar users), matrix decomposition, clustering, and deep learning.
- Decision Trees and forests. Application to IRIS classification.

- *Assignment 7.* Haar cascade and adaboost for face detection. RANSAC for curve fitting with outlier data points. K-means clustering on the IRIS dataset. Decision tree on IRIS dataset. PCA + K-means clustering.

Week 8

- Introduction to Neural Networks. Perceptrons and multi-layer perceptrons (MLP). Apply them to handwriting dataset and diabetes dataset. Activation functions.
- *Assignment 8.* Perceptron using Or, And. Try XOR. Linear Regression using MLP in a dataset. Try MLP for MNIST digits dataset. Classify Iris with PCA using MLP. Apply standard scalar transform.

Weeks 9-14

- Advanced Neural Network architectures:
    - Convolutional NN (CNN). Ideal for data with grid-like topology: images, video.
    - Recurrent NN (RNN). Ideal for language translation, speech recognition, text generation.
    - Transformer NN (TNN). Ideal for sequential data such as natural language; eg., ChatGPT.
    - Generative Pretrained Transformers (GPTs).
    - LLMs (Large Language Models) and LVM (Large Visual Models).
- Convolution Neural Networks (CNN) and their variants such as YOLO, VGG16, ResNet. Application to classification of faces. F-1 scores and precision metrics. Application to object recognition such as RNN, Deep Feed-forward neural networks (DFFNN), and other models for prediction to "buy", "sell" or "hold" for commodities trading. Application to Cart Pole balancing.
- Reinforcement Learning, Deep Nets.
- *Assignment 9.* For eigenfaces, find dimensions required to preserve variances of 50, 60, ..., 95%. For each graph the F-1 score for SVM classification. Use CNN on Eigenfaces to classify 7 faces.
- *Assignment 10.* Create a predictor of whether to buy or sell using a neural network model RNN, DFFNN, or others. Try using reinforcement learning for the cart pole balancing simulation.
- *Assignment 11.* Reinforcement Learning lab.
- *Assignment 12.* Understanding Transformers in ChatGPT.

Reference Textbook

- All the ML material can be found on the internet. The instructor will provide references on the relevant topics with each lecture's notes.

Course Evaluation

1. Learning Exercises as Programming Assignments (10-12) 85%
2. Pitch a Machine Learning Project to seek Funding 15%