

# Machine Learning Foundations and Applications (AI42001)



[Home](#) / [My courses](#) / [Machine Learning Foundations and Applications \(AI42001\) - Spring 2024](#)

Turn editing on

## [Announcements](#)

### [Theory: Course Logistics and Discussion](#)

#### **[Course Logistics](#) (8-9 AM, Tue, 2-1-2024)**

*Teachers:* Sudheshna Sarkar, Somdyuti Paul, Mahesh Mohan M R

##### *References*

- Introduction to Machine Learning, Ethem Alpaydin, MIT Press (available online)
- Machine Learning, Tom M Mitchell, Mc Graw Hill Education (available online)

##### *Theory*

- Monday – 11:00-11:55 AM, Tuesday – 8:00-9:55 AM
- Evaluation: Class Test-1, Midsem, Class Test-2, and Endsem (5%+20%+5%+30%)

##### *Laboratory*

- Thursday – 02:00 - 05:00 PM
- Demo + Assignment Discussion + Problem solving
- Evaluation:
  1. 12-15 program assignments (20%)
  2. [Midsem Lab Test](#) + Endsem Lab Test (10% +10%)

Plagiarism: No tolerance policy. Binary marking (both parties).

Attendance: Compulsory to avoid deregistration.

#### **Class Discussion: Applications of ML in Different Fields (9:05-9:55 AM, Tue, 2-1-2024)**

Robotic arm based manufacturing

Drone for package delivery and agricultural pesticide spraying

Banking -- Loan allotment rules based on Decision tree

Medical Field -- Smart phone based tele-medicine and cancer detection from CT

Captcha

Recommendation systems

Production line to detect faulty products

## [Course Logistics](#)

### [Lab: Introduction to Python Programming](#)

#### **Introduction to Python (2-5 PM, Thu, 4-1-2024)**

Python: Fun to Use


Intro to Google Collab

Intro to Numpy: Matrices/Vectors and Mathematical Manipulations

Intro to Pandas: Dataset structure and easy analysis

Intro to Matplotlib: Plotting Data

## [Slides: Intro to Python](#)

 [Class Tutorial: Intro to Python](#)

 [Lab Assignment 1: Intro to Python](#)

## [Theory: Introduction to Machine Learning](#)

### **Intro to ML: Part 1 (11-11:55 AM, Mon, 8-1-2024)**

Motivations of ML. Why ML is trending now?

Classification of ML: Supervised, Unsupervised and Reinforcement Learning

Algorithm and its ineffectiveness for problems intuitive to humans (e.g., digit classification)

Basics of Supervised Learning

### **Intro to ML: Part 2 (8-9:15 AM and 9:20 AM to 9:55 AM, Tue, 9-1-2024)**

Basics of Supervised Learning (contd): Labelled Data, Model, Loss, and Parameter Optimization

Basics of Unsupervised Learning: Clustering and Association

Basics of Reinforcement Learning: Optimal sequence of steps to an objective based on states

**Reading Exercise** : A very detailed and informative account on the Introduction to ML can be found in Secs 1.1 and 1.2 of the Ethem Alpaydin's text book (i.e., our first reference text)!

 [Intro to ML: Part 1](#)

 [Intro to ML: Part 2](#)

 [Practice Problems: Intro to ML](#)

## [Theory + Lab: K Nearest Neighbor](#)

### **K Nearest Neighbor (Theory: 2:15 PM to 3:55 PM)**

KNN basics

Weighted KNN

Different Distance Metrics: Euclidian, Manhattan, Chebyshev, Cosine and Hamming.

Normalization: Min-max and Z-score normalization

Drawbacks: Curse of Dimensionality, Expensive and Storage Need

### **Lab Tutorial: 4 - 4:55 PM**

Intro to Scikit Learn

KNN Tutorial using Scikit Learn

**Reading Exercise:** Sections 8.1 and 8.2 of the Tom Mitchell Text Book (second reference). More important, it contains the equations that we presented in the class, but not included in the slide.

 [K-NN Theory](#)

 [K-NN Lab Tutorial](#)

 [Lab Assignment 2: K-Nearest Neighbor](#)

## [Linear Algebra for Machine Learning](#)

Basic Vector/Matrix operations

Addition and scaling

Product: Hadamard product, Inner product, Outer Product

Vector-Vector Multiplication --- Inner product and Outer product interpretation

Matrix-Vector Multiplication --- ""

Matrix-Matrix Multiplication --- ""

Interpreting Neural Network using Linear Algebra: What do network weights convey?

Single-Output Linear Network via Vector-Vector Inner product

Multi-Output Linear Network via Matrix-Vector Inner product

Special Matrices and Eigen values/vectors

Diagonal and Identity Matrices

Inverse and Pseudo-Inverse Matrices

Matrix transformations and their use in Image dataset augmentation (translation, rotation, scaling, sheering, etc)

Determinant & Systems of algebraic equations

Eigen values and vectors. Their calculation.

**Reading exercise:** [https://minireference.com/static/tutorials/linear\\_algebra\\_in\\_4\\_pages.pdf](https://minireference.com/static/tutorials/linear_algebra_in_4_pages.pdf)



[Linear Algebra Slides](#)

## [Theory + Lab: Linear Models for Classification and Regression](#)

### **Linear Models (Theory: 2:10 PM to 3:25 PM)**

Linear Classifier

Linear Mapping

Signum function for binary class

Threshold for multiple classes

Linear Regressor or Perceptron Algorithm

Linear Mapping (no thresholds)

Importance of Bias

Optimizing parameters of (Incrementally) Linear Mapping

Closed form solution

Gradient Descent

### **Linear Models Tutorial (Theory: 3:35 PM to 4:55 PM)**

Linear Classifier using Scikit Learn

Linear Regressor using Scikit Learn

**Reading Exercise :** Chapter 10.1-10.6 of the Ethem Alpaydin's text book!



[Slides: Theory](#)



[Linear Regression Lab Tutorial](#)



[Lab Assignment 3: Linear Regression](#)



[Linear Models \(Pre- and Post- Inner product\)](#)

## [Probability for ML and Naive Bayes Model](#)

Basics of Probability

Probability and Random Variables

Probability Distribution (Joint, Marginal, and Conditional)

Bayes' Theorem

Independence

Mean, Variance, and Covariance

Naive Bayes' Model

Main assumption: Independence. Why?

Naive Bayes' training

Numerical Stability

Merits and Demerits

**Reading Exercise** : Appendix and Secs 3.1 and 3.4 of the Ethem Alpaydin's text book! Also for Naive Bayes, refer to Sec. 6.9 and Sec 6.10 of Tom M Mitchell's text book.



[Probability\\_naivebayes](#)



[Naive\\_bayes\\_tutorial](#)



[Naive\\_Bayes Assignment](#)

---

## Bias-Variance Tradeoff

Bias Variance Tradeoff

Derivation of MSE in terms of Variance and Bias<sup>2</sup>

Implications: Underfitting and Overfitting

Lasso and Ridge Regression

Ridge: Optimization via Closed form and Gradient Descent

Lasso: Optimization via Gradient Descent

Intro to Boosting and Bagging

**Reading Exercise** : Secs 4.6 and 4.9 of the Ethem Alpaydin's text book!



[Bias\\_variance\\_tradeoff\\_ons](#)



[Bagging and Boosting](#)



[Bias-variance tradeoff detailed proof](#)

---

## Decision Tree

Decision Tree for Classification

Motivation for Decision Tree: Interpretability

Elements of Decision Tree: Root, Nodes, and Leaves

When to Split a Node?

Concept of Impurity -- Which feature to consider in a given node

Entropy Measure

Dealing with categorical as well as numerical features

Rule Extraction from Decision Trees

Other Impurity Measures

**Reading Exercise**: Chapter 9, Ethem Alpaydin.



[Decision Tree - Part 1](#)



[Decision Tree - Part 2](#)



[Decision tree Tutorial](#)

---

## MLE and MAP



[MLE\\_MAP](#)

---

## Midsem Lab Test

<https://www.kaggle.com/datasets/uciml/pima-indians-diabetes-database?resource=download>



[Midsem Lab Test](#)

---

## Support Vector Machines

Intuition for maximal margin classifiers  
Functional and geometric margins  
Deriving maximal margin classifier  
Primal forms  
Lagrange duality and KKT conditions  
Dual form  
Solution in the form of support vectors  
Non-linear SVMs  
Kernel trick  
Commonly used kernels  
Kernel SVM  
Soft-margin SVMs



[Lecture slides: SVM](#)



[Jupyter notebook on support vector machines](#)



[Lab Assignment: Support Vector Machines](#)

---

## Feedforward Neural Networks

Artificial neurons as building blocks of neural networks  
The perceptron algorithm  
Limitation of single layer perceptron and multi-layer perceptrons'  
Representation power of multi-layer perceptron and need for deeper network architectures  
Activation functions  
Feedforward neural networks as universal function approximators  
Learning network parameters through backpropagation



[Lecture slides: Feedforward Neural Networks](#)



[Jupyter notebook for feedforward neural networks](#)

---

## Convolutional and Recurrent Neural Networks

Early Motivations for CNNs  
Precursors to modern CNNs  
Feature design vs. feature learning  
Convolutional filters and convolutional layers  
Pooling layers  
Hierarchical abstractions learned by CNNs  
Applications of CNNs  
Modeling sequential data with RNNs  
Vanilla RNNs  
Backpropagation through time (BPTT)  
Vanishing and exploding gradient issues in BPTT  
Long-short term memory (LSTM)  
Bidirectional RNNs



[Lecture slides: Convolutional and Recurrent Neural Networks](#)

[Jupyter notebook on CNN implementation](#)[Lab Assignment - Neural Networks](#)

---

## Ensemble Learning

Introduction  
Error analysis with ensembling  
Bagging  
Bias-variance trade-off with bagging  
Random Forests  
Out-of-bag error and feature importance  
Boosting  
Adaptive Boosting (Adaboost)  
Face detection with Adaboost

[Lecture slides: Ensemble learning](#)[Jupyter notebook on ensemble learning](#)[Lab Assignment: Ensemble Learning](#)

---

## Clustering

Introduction to Clustering  
Kmeans algorithm  
Evaluation of Clustering  
Agglomerative Hierarchical Clustering  
Gaussian Mixture Model and EM Algorithm

[Slide: Introduction to Clustering and kmeans](#)[Slide: Evaluation of Clustering](#)[Slide: Agglomerative Hierarchical Clustering](#)[Slide: Gaussian Mixture Model and EM Algorithm](#)

---

## PCA and LDA

[Principal Component Analysis](#)[PCA and LDA](#)

---

## Final Lab Test

[Final Lab Test](#)

---

## Hidden Markov Model

Definition, Components  
Evaluation problem and details  
Decoding problem and Viterbi algorithm

Brief overview of Learning Task



[Hidden Markov Model](#)

**Hidden from students**



[Hidden Markov Model Updated Slides](#)

---

## [Large Language Model Introduction](#)

Not in endsem syllabus



[LLM and Chatgpt](#)

---

## [Class Test Scores](#)



[Class Test 1 Scores](#)



[Class Test 2 Scores](#)

 [Moodle Docs for this page](#)

You are logged in as [Dr. Mahesh Mohan MR](#) ([Log out](#))

[Home](#)

[Data retention summary](#)