

# CO327 Machine Learning

## Session 2023-24 (Winter)

### Lecture Plan

- Lecture 1: Announcement of methods of internal/class assessment and marking scheme, Syllabus, study material and resources, Motivation, Introduction to machine learning.
- Lecture 2: Review of Linear Algebra: Concept of feature vector representation, Norms of the vectors, vector and matrix operations, vector space, basis vectors, linear independence, orthogonality.
- Lecture 3: Vector sub-spaces, projection, Eigen vectors and Eigen values, properties of symmetric matrices.
- Lecture 4: Review of Probability Theory: Definitions, independent events, joint probability, marginal probability, conditional probability, sum rule, product rule, Bayes' theorem, concept of probability distribution, likelihood.
- Lecture 5: Random process and random variable: Definitions, continuous and discrete random variables, expectation, variance, covariance.
- Lecture 6: Classification and Regression: curve fitting, model selection, curse of dimensionality, loss function.
- Lecture 7: Evaluation of ML models: The train/test/validation split, under-fitting, overfitting, generalization, Bias vs Variance, validation curves.
- Lecture 8: Metrics: Confusion matrix, Accuracy, Precision, Recall, Specificity, F1 score Precision-Recall or PR curve, ROC (Receiver Operating Characteristics) curve, PR vs ROC curve.
- Lecture 9: Information Theory: Concept of information, Entropy, Information gain, relative and mutual information.
- Lecture 10: Classification using Decision Trees: Iterative Dichotomiser 3 (ID3), Greedy decision tree learning, selecting best feature for split, classification error, prediction with decision trees.
- Lecture 11: Decision trees with real valued features, threshold split in 1-D, threshold split in 2-D, finding optimal threshold split.
- Lecture 12: Overfitting in decision trees: Principle of *Occam's Razor*, complex and simpler decision trees, early stopping, Decision tree pruning.
- Lecture 13: CART, C4.5
- Lecture 14:  $K_n$ -nearest neighbor density estimation, K-nearest neighbor classifier (K-NN).
- Lecture 15: Naïve-Bayes Classifier
- Lecture 16: Linear discriminant functions, logistic discrimination, Linear separability, generalized linear discriminants.
- Lecture 17: Least-square techniques, gradient descent algorithms.

- Lecture 18: Supervise Learning-Linear Regression, linear regression with one variable, Derivative of cost function, gradient descent algorithm.
- Lecture 19: Logistic regression: Classification, learning parameters, cost function for logistic regression, gradient descent algorithm in logistic regression.
- Lecture 20: Artificial Neural Network (ANN): Introduction, Perceptron model, applications of linear model.
- Lecture 21: Perceptron learning, perceptron convergence theorem, limitations of perceptron.
- Lecture 22: Fisher's linear Discriminant-Linear discriminant analysis (LDA).
- Lecture 23: Multi-layer perceptron:
- Lecture 24: Error back-propagation
- Lecture 25: Support Vector Machine (SVM)
- Lecture 26: Unsupervised Learning: similarity measures, k-means clustering, k-means as coordinate descent algorithm, k-mean++
- Lecture 27: Convergence of k-means algorithm, limitations: uncertainty in cluster assignment, failure modes of k-means, mixture models.
- Lecture 28: Gaussian mixture models (GMM), Maximum likelihood estimation (MLE), Expectation Maximization, Inferring soft assignments with expectation maximization (EM), Convergence and overfitting of MLE
- Lecture 29: Hierarchal Clustering
- Lecture 30: Data representation and Dimension Reduction: change of basis vectors, principle component analysis (PCA).
- Lecture 31: Factor analysis, Manifold Learning
- Lecture 32: Reinforcement learning: Introduction, difference with supervised learning, Evaluative feedback: n-armed bandit problem, action-value methods, softmax action selection
- Lecture 33: The reinforcement learning problem: Agent-Environment interface, goals and rewards, returns, unified notation for episodic and continuing tasks, Markov property, Markov decision processes, value functions, optimal value functions.
- Lecture 34: Dynamic programming: policy evaluation, policy improvement, policy iteration.
- Lecture 35: Temporal-Difference Learning: TD prediction and advantages, Optimality of TD(0), Sarsa: On-Policy TD Control.
- Lecture 36: Q-Learning: Off-Policy TD Control, Actor-Critic Methods.