UNIVERSITY OF MISSOURI-COLUMBIA
COLLEGE OF ENGINEERING
DEPARTMENT OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE

CS 8050 – DESIGN AND ANALYSIS OF ALGORITHMS II

Fall 2025

ASSIGNMENT 5: EXPLORING DIVERSE MACHINE LEARNING ALGORITHMS

Due Date: Wednesday Dec 10th, 2025, at 5:00 pm

(100 points)

Goals

This assignment requires students to examine machine learning algorithms from an algorithmic and complexity-theoretic perspective. Students must analyze selected algorithms focusing on computational structure, time and space complexity, convergence behavior, scalability, and theoretical bounds.

Key Areas of Investigation:

You must select one algorithm from each of the following five categories.

1. **Supervised Learning Algorithms:**
    - Linear Regression (Normal Equation vs. Gradient Descent)
    - Decision Trees (ID3, CART)
    - Support Vector Machines (primal vs. dual, kernel dependence)
    - Feedforward Neural Networks (one-hidden-layer MLP)
2. **Unsupervised Learning Algorithms:**
    - k-Means Clustering
    - Hierarchical Clustering (agglomerative)
    - Principal Component Analysis (SVD-based)
3. **Reinforcement Learning Algorithms:**
    - Q-Learning
    - SARSA
    - Policy Gradient (REINFORCE)
    - Deep Q-Networks (DQN)
4. **Ensemble Learning Algorithms:**
    - Random Forests
    - Gradient Boosting Machines (GBM or XGBoost)
    - Bagging or Stacking
5. **Neural Network Architectures:**
    - Convolutional Neural Networks (CNN)
    - Recurrent Neural Networks (RNN, LSTM)
    - Transformer Encoder Block

Required Analysis for Each Algorithm:

- Algorithm Description (Theoretical): Definition, pseudocode, data structures.
- Time Complexity: Worst-case, best-case, and average-case; expressed in terms such as; n (number of training samples), d (number of features per sample), k (number of clusters/classes/components/trees, depending on algorithm), p (number of model parameters (e.g., weights in a neural network)).
- Space Complexity: Memory footprint, model storage, workspace usage.
- Convergence and Termination Analysis: Guarantees, rates, and failure cases.
- Data-Dependent Complexity: Effects of dimensionality, sparsity, depth, kernel selection, etc.
- Algorithmic Strengths and Weaknesses: Scalability, bottlenecks, and computational trade-offs.
- Comparative Analysis Across Algorithms: Efficiency, scalability, and complexity-based trade-offs.

Submission Format

File Type	Description
PDF Report (Mandatory)	Your professionally formatted and finalized 12–18-page report (including figures and references).
Code Folder (Optional)	Scripts, notebooks, datasets used.
Any Extra Figures/Diagrams	If not embedded in the report, attach separately.

Assignment Grading Rubric (Total: 100 Points)

Category	Criteria	Description of Expectations	Points
A. Literature Review	Coverage of Foundations	Explains theoretical basis, algorithm structure, and key concepts with accuracy and depth.	5
	Use of Academic Sources	Integrates high-quality research papers and authoritative ML/algorithmic references.	5
	Critical Understanding	Demonstrates synthesis, not just description; compares viewpoints where relevant.	5
Subtotal			**15**
B. Algorithmic & Complexity Analysis	Time Complexity	Correct derivation of worst, best, and average-case time complexities using variables such as *n, d, k, p, T*.	10
	Space Complexity	Clear understanding of memory usage, model storage, and runtime workspace.	5
	Case-Based Behavior	Discusses how runtime changes with data conditions, dimensionality, initialization, or structure.	10
	Convergence Analysis	Includes mathematical or conceptual discussion of convergence conditions and iteration bounds.	5
	Data-Dependent Complexity	Evaluates how sparsity, feature size, model width, or sampling strategy affects runtime.	5
	Correct Pseudocode	Provides accurate algorithmic pseudocode with appropriate notation.	5
Subtotal			**40**
C. Experimental / Theoretical Demonstration	Methodology	Clearly explains experimental or theoretical setup used to study computational behavior.	5
	Evidence of Complexity Trends	Provides charts/tables/time measurements or analysis supporting theoretical claims.	5
	Interpretation	Connects empirical results to theoretical complexity and explains discrepancies.	5
Subtotal			**15**
D. Comparative Analysis	Cross-Algorithm Comparison	Compares algorithms based on complexity, scalability, and computational structure.	6
	Bottleneck Discussion	Identifies which operations dominate runtime and under what data conditions.	6
	Insightful Conclusions	Draws meaningful conclusions about algorithm suitability across scenarios.	3
Subtotal			**15**
E. Writing, Formatting & Presentation	Organization & Clarity	Logical flow, proper section labeling, readability.	5
	Tables, Figures & Diagrams	Uses visuals to communicate complexity, architecture, or results effectively.	5
	Academic Style & Citation	Proper citation of all sources, no plagiarism, polished grammar.	5
Subtotal			**15**
		TOTAL	**100**