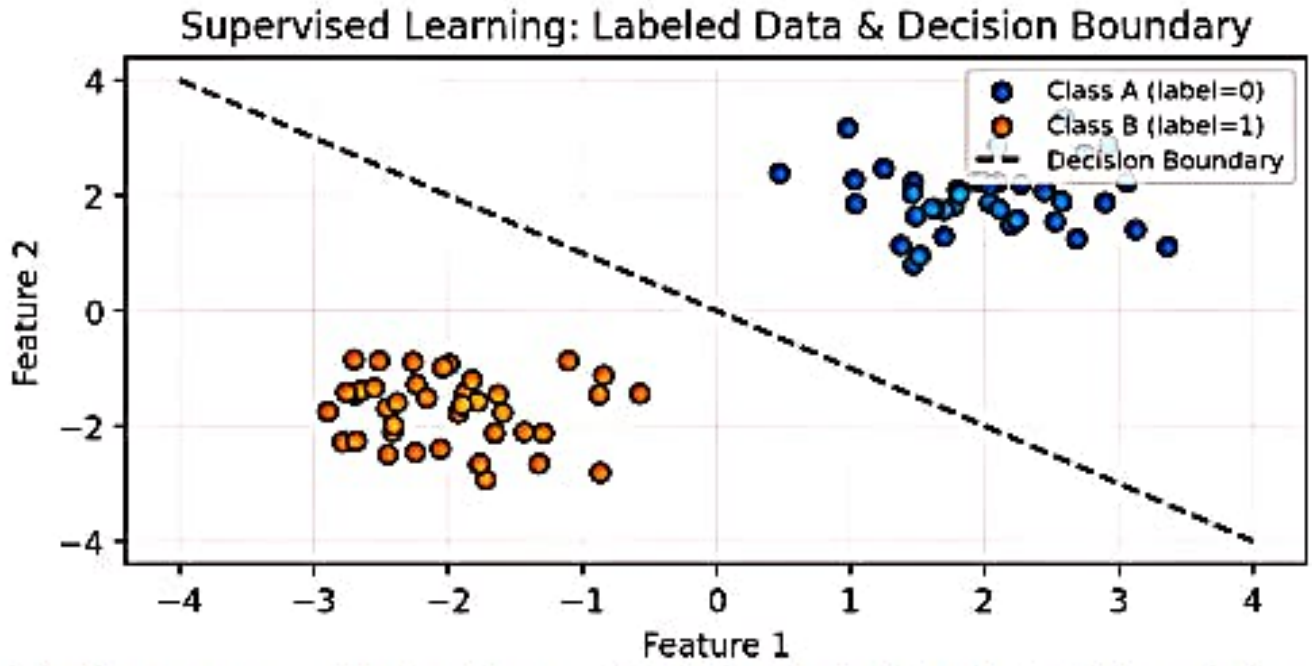
1. What is Machine Learning?

Machine Learning (ML) is a field of AI that learns patterns from data to make predictions, decisions, or representations. Instead of hard-coded rules, ML algorithms optimize objectives such as predictive accuracy, cluster separation, or expected reward. This guide focuses on the most common paradigms and how they differ in data needs, objectives, and outputs.

2. Supervised Learning

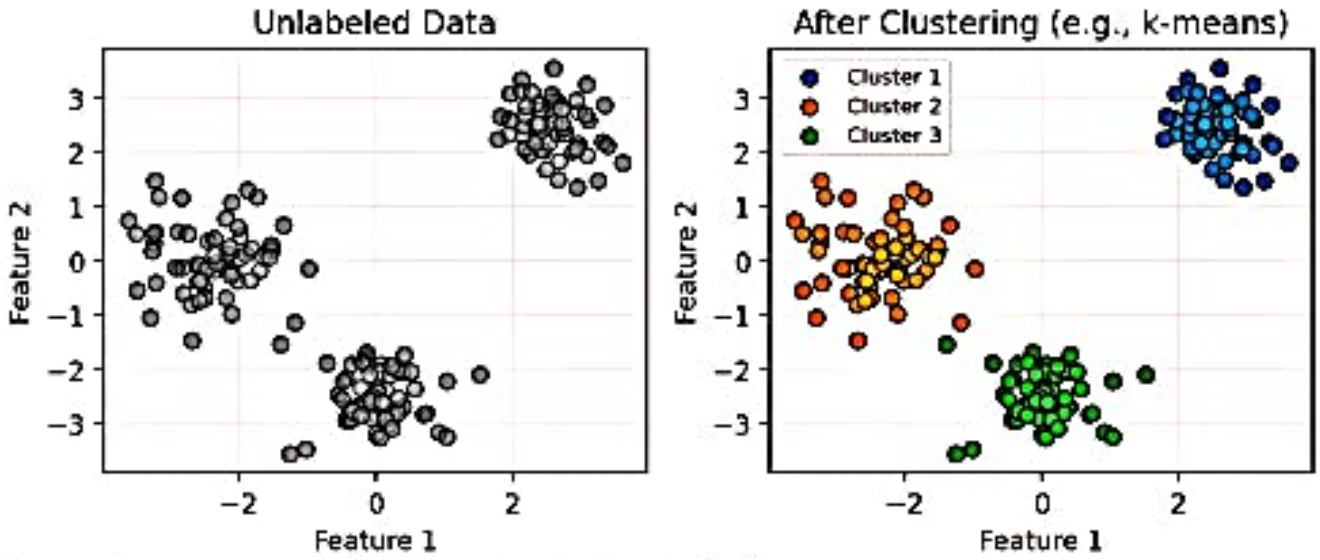
Goal: Learn a mapping from inputs X to targets y using labeled examples. Typical tasks include classification (e.g., spam detection) and regression (e.g., price prediction).
Common algorithms: Linear/Logistic Regression, Support Vector Machines (SVM), Decision Trees/Random Forests, Gradient Boosting, k-Nearest Neighbors, Neural Networks.
Key ideas: train/validation/test splits, loss functions (e.g., cross-entropy, MSE), regularization, overfitting/underfitting.



Evaluation: accuracy, precision/recall, F1, ROC-AUC (classification); MAE/MSE/R^2 (regression).
Examples: email spam filtering, credit risk scoring, medical diagnosis from imaging.

3. Unsupervised Learning

Goal: Discover structure in unlabeled data. Tasks include clustering (grouping similar items), density estimation, and dimensionality reduction (DR) for visualization or preprocessing. Common algorithms: k-means, Gaussian Mixture Models (GMM), DBSCAN, Hierarchical Clustering, PCA, t-SNE/UMAP (for visualization).



Uses: customer segmentation, anomaly detection, topic discovery.
Tip: choose the number of clusters with methods like elbow/silhouette; standardize features before distance-based clustering.

4. Reinforcement Learning

Goal: Learn a policy that maximizes expected cumulative reward by interacting with an environment. Elements: states, actions, rewards, transitions.
Methods: value-based (Q-learning, DQN), policy-based (REINFORCE), actor-critic (A2C/A3C, PPO).
Applications: robotics, recommendation, game-playing.

Key challenges: exploration vs exploitation, credit assignment, sample efficiency.

5. Deep Learning

Deep Learning uses neural networks with many layers to learn hierarchical features from raw data (images, audio, text).
Architectures: CNNs (vision), RNNs/LSTMs (sequences), Transformers (attention-based, dominant in vision and NLP).
Tricks: batch normalization, residual connections, dropout, optimizers (Adam, SGD with momentum).

Deep Learning: Multi-layer Neural Network