Types of Machine Learning

Core Foundations for Machine Learning

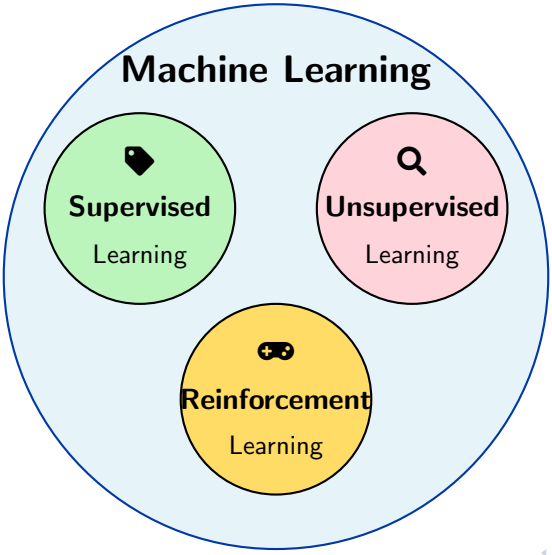
Sarwan Ali

Department of Computer Science
Georgia State University

Today's Learning Journey

1. Introduction to ML Types
2. Supervised Learning
3. Unsupervised Learning
4. Reinforcement Learning
5. Comparison and Summary

The Machine Learning Universe



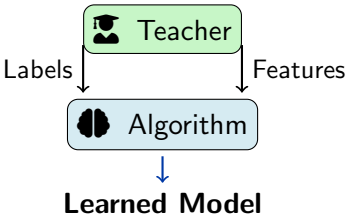
Supervised Learning: Learning with a Teacher

Key Characteristics

- **Labeled Training Data**: Input-output pairs
- **Goal**: Learn mapping function $f : X \to Y$
- **Evaluation**: Performance on unseen test data
- **Feedback**: Immediate error correction

Mathematical Framework

Given training set: $\{(x_1, y_1), (x_2, y_2), \ldots, (x_n, y_n)\}$
Find function $\hat{f}$ such that $\hat{f}(x) \approx y$



Types of Supervised Learning

Classification

Discrete Output Variables

- Predict categories/classes
- Binary or multi-class
- Examples:
  - Email spam detection
  - Image recognition
  - Medical diagnosis

Algorithms: Decision Trees, SVM, NN

Regression

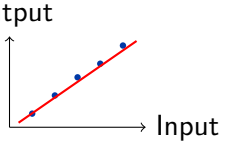
Continuous Output Variables

- Predict numerical values
- Real-valued outputs
- Examples:
  - House price prediction
  - Stock market forecasting
  - Temperature prediction

Algorithms: Linear Regression, RF, NN

Classification

Regression



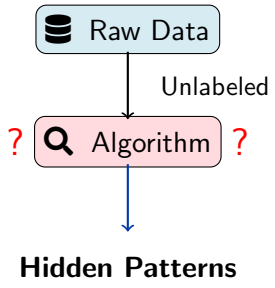
Unsupervised Learning: Discovering Hidden Patterns

Key Characteristics

- **No Labeled Data**: Only input features X
- **Goal**: Find hidden structure in data
- **Exploration**: Pattern discovery and data understanding
- **Challenge**: No direct performance measure

Mathematical Framework

Given data: $\{x_1, x_2, \ldots, x_n\}$
Find patterns, structures, or representations in X



Types of Unsupervised Learning

Clustering

Group Similar Data

- Find natural groupings
- Similar items together
- Examples:
  - Customer segmentation
  - Gene sequencing
  - Market research

Algorithms: K-means, Hierarchical

Dimensionality Reduction

Reduce Feature Space

- Remove redundancy
- Preserve information
- Examples:
  - Data visualization
  - Feature extraction
  - Noise reduction

Algorithms: PCA, t-SNE

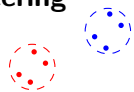
Anomaly Detection

Find Unusual Patterns

- Identify outliers
- Detect abnormalities
- Examples:
  - Fraud detection
  - Network security
  - Quality control

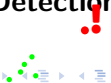
Algorithms: Isolation Forest, One-Class SVM

Clustering



Dim. Reduction

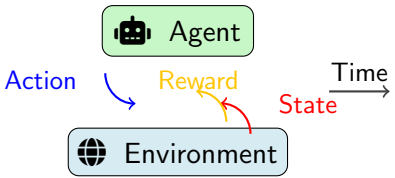
Anomaly Detection



Reinforcement Learning: Learning through Interaction

Key Characteristics

- **Agent-Environment Interaction**
- **Sequential Decision Making**
- **Reward/Penalty Feedback**
- **Goal**: Maximize cumulative reward
- **Exploration vs Exploitation Trade-off**



Mathematical Framework

Markov Decision Process (MDP):

- States: S, Actions: A, Rewards: R
- Policy: $\pi(a|s)$
- Goal: max $\sum_{t=0}^{\infty} \gamma^t r_t$

Reinforcement Learning: Key Concepts

Core Components

- **Agent**: Decision maker
- **Environment**: External system
- **State**: Current situation
- **Action**: Agent's choice
- **Reward**: Feedback signal
- **Policy**: Decision strategy

Applications

- **Game Playing**: Chess, Go, Video games
- **Robotics**: Navigation, manipulation
- **Autonomous Vehicles**: Path planning
- **Finance**: Algorithmic trading
- **Healthcare**: Treatment optimization
- **Recommendation Systems**

Key Challenge

Exploration vs Exploitation

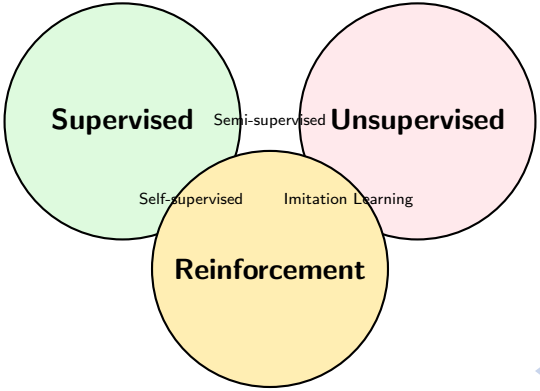
- Explore: Try new actions
- Exploit: Use known good actions
- Balance for optimal learning

Algorithms

- Q-Learning
- Deep Q-Networks (DQN)
- Policy Gradient Methods
- Actor-Critic Methods

Comparing the Three Paradigms

Aspect	Supervised	Unsupervised	Reinforcement
Data Type	Labeled	Unlabeled	Interactive
Feedback	Immediate	None	Delayed
Goal	Prediction	Discovery	Optimization
Learning	From examples	From patterns	From interaction
Evaluation	Test accuracy	Domain knowledge	Cumulative reward
Example Task	Classification	Clustering	Game playing



When to Use Each Approach?

Use Supervised Learning When:

- You have labeled data
- Clear input-output relationship
- Prediction is the goal
- Historical examples available

Examples:

- Medical diagnosis
- Email classification
- Price prediction

Use Unsupervised Learning When:

- No labeled data available
- Exploratory data analysis
- Pattern discovery needed
- Data understanding required

Examples:

- Market segmentation
- Data visualization
- Anomaly detection

Use Reinforcement Learning When:

- Sequential decisions needed
- Learning from interaction
- Long-term optimization
- Dynamic environment

Examples:

- Game playing
- Robot control
- Trading strategies

Key Takeaways

Machine Learning is a Diverse Field

Remember:

- Each paradigm solves different problems
- Choice depends on available data and goals
- Hybrid approaches often work best
- Understanding the problem is crucial

Next Steps:

- Deep dive into each paradigm
- Learn specific algorithms
- Practice with real datasets
- Understand evaluation metrics

The journey of a thousand miles begins with understanding the map!

Questions?

Discussion Time

sali85@student.gsu.edu