Unsupervised Learning

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Unsupervised Learning — Complete Explanation

1. What is Unsupervised Learning?

Unsupervised learning is a machine learning approach where the model learns patterns **without labeled output data**.

- No target variable (y)
- Only input features (X)
- Goal: discover hidden structure in data

Example:

You have a dataset of customer purchases but **no labels**.

Unsupervised learning helps you find **groups (clusters)** of similar customers.

Definition

> **Unsupervised learning is a machine learning technique that finds patterns, structures, or relationships in unlabeled data. It does not use target outputs; instead, it groups similar data points or reduces dimensionality to understand data structure.**

2. Why Unsupervised Learning?

Unsupervised learning is used when:

- Labeled data is unavailable or expensive
- We want to discover hidden patterns
- We want to explore data structure

3. Main Tasks in Unsupervised Learning

A. Clustering

Grouping similar data points.

- K-Means
- Hierarchical Clustering
- DBSCAN
- Gaussian Mixture Models

B. Dimensionality Reduction

Reducing number of features while preserving information.

- PCA (Principal Component Analysis)
- t-SNE
- UMAP

C. Association Rule Mining

Finding relationships between features.

- Apriori
- FP-Growth

Example: Market basket analysis

("Customers who buy bread often buy butter.")

D. Density Estimation

Estimating probability density of data.

- Kernel Density Estimation
- Gaussian Mixture Models

4. Characteristics of Unsupervised Learning

Feature	Description
No labeled data	Model finds patterns itself
Hidden structure discovery	Clusters, groups, relations
More difficult evaluation	No ground truth
Useful for exploratory analysis	Preprocessing and insights

5. Applications of Unsupervised Learning

1. Customer Segmentation

E-commerce, marketing, banking

2. Image Compression

PCA reduces dimensionality

3. Anomaly Detection

Detect fraud, faults, outliers

4. Topic Modeling

NLP – LDA groups similar documents

5. Recommendation Systems

Similarity-based suggestions

6. Genetic Data Analysis

Gene expression clustering

6. Advantages

- No need for labeled data
- Useful for understanding data structure
- Helps in preprocessing for supervised learning
- Handles big data analytics

7. Disadvantages

- Hard to evaluate accuracy
- Output may be unclear or subjective
- Sensitive to noise and outliers
- No guarantee clusters represent meaningful concepts

8. Common Algorithms

Category	Algorithms

Clustering	K-Means, Hierarchical, DBSCAN
Dimensionality Reduction	PCA, t-SNE
Association Rules	Apriori, FP-Growth
Density Methods	GMM, KDE