

# Lecture 2

## Fundamentals of Machine Learning

Artificial Intelligence Programming

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Level: 2nd Year

### 1. Introduction

Machine Learning (ML) is a core subfield of Artificial Intelligence that focuses on enabling computer systems to learn from data and improve their performance over time without being explicitly programmed for every task. Instead of relying on fixed rules, machine learning systems identify patterns, relationships, and structures within data to make predictions or decisions.

Machine learning has become a fundamental technology behind many modern AI applications, including recommendation systems, speech recognition, medical diagnosis, autonomous vehicles, and intelligent industrial systems.

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### 2. Definition of Machine Learning

One of the most widely accepted definitions of machine learning was introduced by Tom Mitchell:

*A computer program is said to learn from experience  $E$  with respect to some task  $T$  and performance measure  $P$  if its performance at task  $T$ , as measured by  $P$ , improves with experience  $E$ .*

This definition highlights three essential components of any machine learning system:

- **Task (T):** What the system is expected to do
  - **Experience (E):** The data used for learning
  - **Performance Measure (P):** How success is evaluated
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### 3. Why Machine Learning is Needed

Traditional programming requires explicit rules defined by humans. However, many real-world problems are too complex, dynamic, or data-driven to be solved using fixed rules alone.

Machine learning is preferred when:

- The problem domain is complex or poorly understood
  - Data is abundant but explicit rules are difficult to define
  - The system must adapt to changes over time
  - High accuracy is required in uncertain environments
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## 4. Types of Machine Learning

Machine learning algorithms are generally classified into three main categories based on the nature of the learning process.

### 4.1 Supervised Learning

Supervised learning involves training a model using labeled data, where both input features and correct output labels are provided.

#### Common Tasks:

- Classification
- Regression

#### Examples:

- Email spam detection
- Medical diagnosis
- Student performance prediction

#### Popular Algorithms:

- Linear Regression
  - Logistic Regression
  - k-Nearest Neighbors (k-NN)
  - Support Vector Machines (SVM)
  - Decision Trees
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### 4.2 Unsupervised Learning

Unsupervised learning deals with unlabeled data. The goal is to discover hidden patterns or structures within the data.

### Common Tasks:

- Clustering
- Dimensionality reduction

### Examples:

- Customer segmentation
- Market analysis
- Anomaly detection

### Popular Algorithms:

- k-Means Clustering
- Hierarchical Clustering
- Principal Component Analysis (PCA)

## Example 3 Explanation – K-Means Clustering (Customer Segmentation)

In this practical example, K-Means is used to automatically group customers based on their spending behavior and visit frequency. No labels are provided because the model's purpose is to **discover patterns on its own**.

### Scenario:

- Features: [Annual Spending, Visit Frequency]
- Each row represents a customer.
- Goal: Separate customers into two groups for marketing analysis.

### Python Code:

```
from sklearn.cluster import KMeans

X = [
    [200, 5],
    [220, 6],
    [800, 20],
    [820, 22],
    [300, 7],
    [900, 25]
]

model = KMeans(n_clusters=2, random_state=0)
```

```
model.fit(X)

print("Cluster labels:", model.labels_)
```

### Explanation:

- The output labels (0 or 1) indicate the cluster assignment for each customer.
- Cluster 0 might represent customers with lower spending and fewer visits.
- Cluster 1 might represent high-value, frequent customers.
- This method **does not predict a specific outcome** but organizes data into meaningful groups for further analysis.

### Educational Takeaway:

K-Means demonstrates how AI can explore data without supervision, making it essential for tasks like marketing segmentation, anomaly detection, and industrial process optimization.

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## 4.3 Reinforcement Learning

Reinforcement learning is based on interaction with an environment. An agent learns by performing actions and receiving rewards or penalties.

### Key Components:

- Agent
- Environment
- Actions
- Rewards

### Examples:

- Game playing (Chess, Go)
  - Robotics
  - Autonomous navigation
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## 5. Machine Learning Workflow

A typical machine learning pipeline consists of several stages:

1. Data collection
2. Data preprocessing

3. Feature selection and extraction
4. Model selection
5. Training the model
6. Model evaluation
7. Deployment and monitoring

Each stage plays a crucial role in determining the effectiveness of the final system.

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## 6. Training Data and Features

Data is the foundation of any machine learning system. The quality and relevance of training data directly affect model performance.

- **Features:** Input variables used by the model
  - **Labels:** Target outputs in supervised learning
  - **Training set:** Used to train the model
  - **Testing set:** Used to evaluate performance
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## 7. Overfitting and Underfitting

- **Overfitting:** The model learns noise and performs well on training data but poorly on new data.
- **Underfitting:** The model is too simple and fails to capture underlying patterns.

Achieving a balance between these two is essential for good generalization.

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## 8. Practical Machine Learning Examples Using Python

To bridge theory and practice, this section presents simple and illustrative Python-based examples using well-known machine learning models. These examples are designed for educational purposes and do not require advanced mathematical background.

### Example 1: Linear Regression – Predicting Student Performance

```
from sklearn.linear_model import LinearRegression
X = [[1], [2], [3], [4], [5]]
y = [50, 55, 65, 70, 80]
```

```
model = LinearRegression()
model.fit(X, y)
prediction = model.predict([[3.5]])
print("Predicted Score:", prediction[0])
```

## Example 2: Medical Diagnosis – Disease Prediction Using Logistic Regression

```
from sklearn.linear_model import LogisticRegression
X = [[25, 120], [30, 130], [45, 140], [50, 150], [60, 160], [65, 170]]
y = [0, 0, 1, 1, 1, 1]
model = LogisticRegression()
model.fit(X, y)
result = model.predict([[48, 145]])
print("At Risk" if result[0] == 1 else "Healthy")
```

## Example 3: Unsupervised Learning – Customer Segmentation Using K-Means

Explanation added above.

## Example 4: Simple Neural Network Using scikit-learn

```
from sklearn.neural_network import MLPClassifier
X = [[0, 0], [0, 1], [1, 0], [1, 1]]
y = [0, 1, 1, 0]
model = MLPClassifier(hidden_layer_sizes=(4,), max_iter=2000)
model.fit(X, y)
print(model.predict([[1, 0]]))
```

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## 9. Summary

This lecture introduced the fundamental concepts of machine learning and demonstrated how theoretical ideas translate into practical implementations using Python. Understanding these basics is essential before advancing to deep learning, computer vision, and natural language processing.