Unit I – Introduction to Artificial Intelligence (AI)

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1. Introduction to AI

What is Artificial Intelligence (AI)?

AI is the **branch of computer science** that focuses on creating **machines that can think, learn, and act intelligently** — like humans.

Definition:
Artificial Intelligence is the ability of a machine to **perform tasks that normally require human intelligence**, such as reasoning, learning, perception, and decision-making.

Examples of AI

- Voice Assistants (Siri, Alexa, Google Assistant)
- Self-driving Cars
- Chatbots
- Recommendation Systems (YouTube, Netflix)

Advantages of AI

1. **Accuracy:** Less error compared to humans.
2. **Speed:** Can perform tasks faster.
3. **No Fatigue:** Works continuously without breaks.
4. **Automation:** Reduces human effort.
5. **Data Handling:** Can analyze large data efficiently.

Disadvantages of AI

1. **High Cost:** Expensive to develop and maintain.
2. **No Emotions:** Cannot replace human empathy.
3. **Job Loss:** Replaces human workers.
4. **Dependence:** Humans become dependent on machines.
5. **Lack of Creativity:** Cannot think beyond data patterns.

Types of AI

Type	Description	Example
1. Reactive Machines	No memory, only reacts to current input	Chess Game AI
2. Limited Memory	Can use past experiences for current decisions	Self-driving Cars
3. Theory of Mind	Understands human emotions (still developing)	Advanced Robots
4. Self-aware AI	Has its own consciousness (future concept)	Not yet developed

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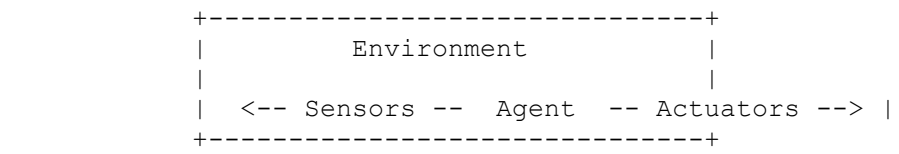
2. Intelligent Agents

What is an Agent?

An **agent** is an entity that **perceives** its environment through **sensors** and **acts** upon it through **actuators**.

Agent = Sensors + Actuators

Figure: Structure of an Agent



Types of Agents

Type	Description
1. Simple Reflex Agent	Acts based on current perception.
2. Model-based Reflex Agent	Uses internal model to track the world.
3. Goal-based Agent	Chooses actions that achieve goals.
4. Utility-based Agent	Maximizes overall happiness (utility).
5. Learning Agent	Learns from experience to improve.

Agent and Environment

- **Environment:** Everything outside the agent that it interacts with.
- **Example:** In a self-driving car — road, traffic, pedestrians, etc.

Concept of Rationality

A **rational agent** is one that **does the right thing** to maximize performance based on:

1. Performance measure
2. Agent's knowledge
3. Possible actions
4. Percept sequence (observations)

Nature of the Environment

Property	Type
Observable	Fully / Partially
Agents	Single / Multi
Deterministic	Deterministic / Stochastic
Episodes	Episodic / Sequential
Dynamic	Static / Dynamic
Discrete	Discrete / Continuous

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3. Problem Solving and Search

Problem-Solving Agent

A **problem-solving agent** uses search to find a solution (sequence of actions) that leads to the goal.

Steps:

1. **Formulate Goal**
2. **Formulate Problem**
3. **Search for Solution**
4. **Execute Solution**

Example: Path finding in a maze.

Uninformed Search Strategies (Blind Search)

Do not use any information about the goal beyond problem definition.

1. Breadth First Search (BFS)

- Explores nodes **level by level**.
- **Uses Queue (FIFO).**

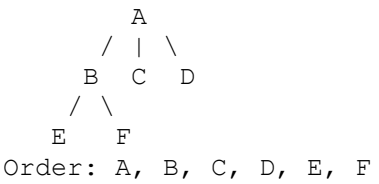
Advantages:

- Finds shortest path.

Disadvantages:

- High memory use.

Figure:



Order: A, B, C, D, E, F

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2. Depth First Search (DFS)

- Explores as deep as possible before backtracking.
- **Uses Stack (LIFO).**

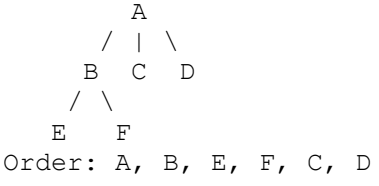
Advantages:

- Low memory.

Disadvantages:

- May get stuck in infinite path.

Figure:



Order: A, B, E, F, C, D

Informed Search Strategies (Heuristic Search)

Use **heuristics (estimates)** to reach the goal faster.

1. Best First Search

- Selects the node with the **lowest heuristic cost (h(n))**.

Example: Greedy Search – always expands node closest to goal.

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2. A* Search

- Uses both cost so far and estimated cost:

  f(n) = g(n) + h(n)
  where
  g(n) = cost so far,
  h(n) = estimated cost to goal.

Advantages:

- Optimal and complete if h(n) is admissible.

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3. AO* Search

- Used for **AND-OR graphs** (problems with multiple sub-goals).
- Finds the least-cost combination of sub-solutions.

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4. Means-End Analysis

- Used in **problem reduction**.
- Tries to minimize the difference between **current state** and **goal state**.

Example:
If goal = "reach school," current = "at home,"
then means = "ride bicycle."

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4. Adversarial Search and Games

Used in **two-player games** (like Chess, Tic-Tac-Toe).

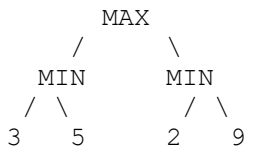
Two-Player Zero-Sum Games

- **One player's gain = other player's loss.**
- Players: **MAX** and **MIN**.

Minimax Algorithm

- Used to choose the **best move** for the MAX player, assuming the opponent plays optimally.

Figure:




```
Best Move for MAX = 5
```

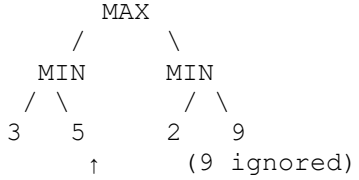
Alpha-Beta Pruning

- Improves Minimax by **cutting off unnecessary branches** (does not affect final result).

Advantages:

- Faster search.
- Less memory usage.

Figure:



□ Summary Table

Topic	Key Idea	Type/Example
AI	Machine intelligence	Chatbots, Cars
Agents	Sense & Act	Reflex, Learning

Topic	Key Idea	Type/Example
Search	Finding solutions	BFS, DFS, A*
Heuristic	Use of knowledge	Best-First
Games	Competitive search	Minimax, Alpha-Beta

Unit II – Knowledge-Based Agents and Learning

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1. Knowledge-Based Agents

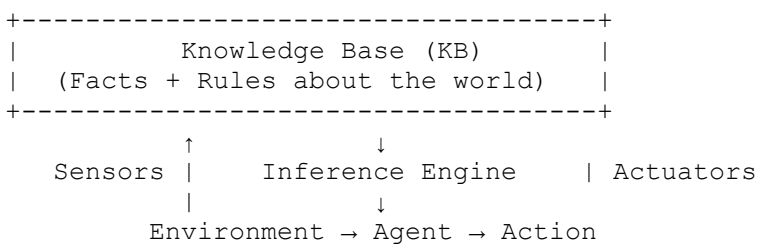
Definition:

A **knowledge-based agent** is an intelligent agent that **uses knowledge and reasoning** to make decisions.
It stores information about the world in a **knowledge base (KB)** and uses **inference** to derive new facts.

Components of Knowledge-Based Agent

1. **Knowledge Base (KB):** Stores facts and rules.
2. **Inference Engine:** Applies logical reasoning to derive new facts.
3. **Percept Sequence:** Records observations.
4. **Actuator:** Executes actions.

Figure: Structure of a Knowledge-Based Agent



Advantages

 Can reason and make logical decisions
 Flexible and general-purpose
 Can explain reasoning (transparency)

Disadvantages

 Requires large knowledge base
 Reasoning may be slow
 Hard to update or maintain knowledge

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2. The Wumpus World

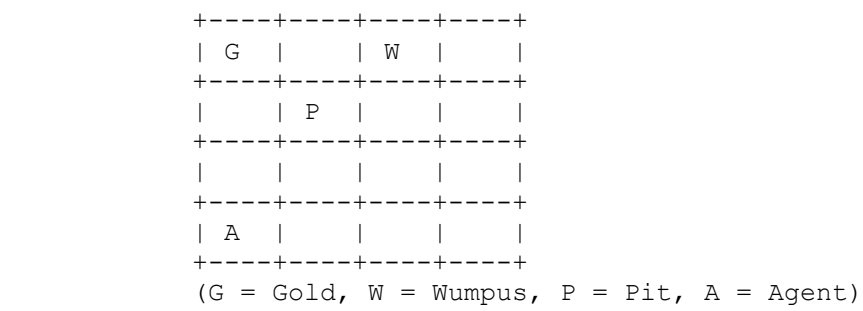
What is the Wumpus World?

A **grid-based environment** used to illustrate reasoning in AI.
The agent's goal: **find gold** and **avoid pits and the Wumpus (monster)**.

Features:

- **Percepts:** Breeze (near pit), Stench (near Wumpus), Glitter (gold nearby)
- **Actions:** Move forward, Turn, Grab, Shoot, Climb
- **Environment:** Partially observable, stochastic

Figure: Wumpus World Layout



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3. Logic in AI

Logic is the language of reasoning. It helps represent **knowledge** and **derive conclusions**.

Types of Logic:

1. **Propositional Logic**

2. **First-Order Predicate Logic (FOPL)**

Propositional Logic

- Deals with **statements that are true or false.**
- Example:
  - “It is raining.” (True/False)
  - “The Wumpus is dead.”

Connectives:
¬ (NOT), ∧ (AND), ∨ (OR), ⇒ (Implication), ⇔ (Biconditional)

Example:

```
If it rains, then road is wet:
R → W
```

Advantages

 Easy to understand and implement
 Foundation of logical reasoning

Disadvantages

 Cannot represent relationships or objects
 Limited expressiveness

First-Order Predicate Logic (FOPL)

- Extends propositional logic by using **quantifiers and predicates**.
- Can represent **relationships** between objects.

Example:

```
∀x (Human(x) → Mortal(x))
Human(Socrates)
∴ Mortal(Socrates)
```

Advantages

 Can express complex relationships
 Used in real-world reasoning

Disadvantages

 Computationally expensive
 Complex syntax

Propositional vs. First-Order Logic

Feature	Propositional Logic	First-Order Logic
Representation	Facts only	Objects + Relations
Expressiveness	Limited	High
Example	R → W	Human(x) → Mortal(x)

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4. Inference Techniques

Unification and Lifting

- **Unification:** Process of making two logical expressions identical by substituting variables.
  Example:
  `Knows(John, x)` and `Knows(John, Mary)` → x = Mary
- **Lifting:** Applying unification at predicate (generalized) level.

Forward Chaining

- Data-driven reasoning (from facts → conclusion)
- Uses **Modus Ponens**:
- `If A → B and A is true → then B is true.`
- Example:
  If “It rains” → “Road wet”; It rains → Road wet.

Figure:

```
Facts → Rules → New Facts → Goal
```

Backward Chaining

- Goal-driven reasoning (from goal → facts)
- Example:
  Want to prove: Road wet?
  Check: Does "It rains"? Yes → True.

Figure:

```
Goal → Supporting Rules → Known Facts
```

Resolution

- Inference rule used for **propositional and predicate logic**.
- Works by converting statements into **clause form (CNF)** and resolving contradictions to prove truth.

Truth Maintenance Systems (TMS)

- Keep track of beliefs and justifications.
- Automatically update beliefs when new information contradicts old facts.

Example:
If "It is sunny" was believed but later "It is raining" comes true, TMS updates and removes the old belief.

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5. Knowledge in Learning

What is Learning?

Learning is the process by which an agent **improves its performance** over time based on experience.

Figure:

```
Experience → Knowledge Update → Improved Performance
```

Advantages

 Improves over time
 Adapts to changes
 Reduces human intervention

Disadvantages

 Requires large data
 Can learn wrong patterns
 Needs computation power

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6. Types of Learning

1. Rote Learning

- Simple memorization.
- No understanding, just recall.

Example: Learning multiplication tables.

Advantage: Fast recall
Disadvantage: No generalization

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2. Learning by Taking Advice

- Learning from an external source (teacher or system).
- Example: A chatbot updated with new grammar rules.

Advantage: Fast, reliable
Disadvantage: Dependent on advice quality

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3. Learning in Problem Solving

- Learns how to solve similar problems more efficiently.

Example: Solving puzzles repeatedly improves strategy.

Advantage: Experience-based improvement
Disadvantage: May overfit to similar problems only

---

4. Learning from Examples

- Learning general rules from specific examples.

Example: Spam mail classification.

Advantage: Data-driven
Disadvantage: Requires many examples

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5. Winston's Learning Program

- Classic AI experiment for **concept learning**.
- Learns geometric concepts (like "arch") from examples and non-examples.

Process:

1. Positive Example → Add features
2. Negative Example → Remove conflicting features

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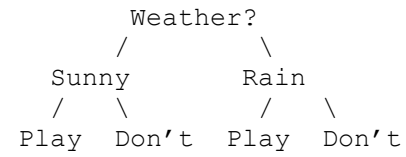
6. Decision Tree Learning

- Tree structure for decision-making.

Figure:



Advantages:
 Easy to understand
 Handles categorical data

Disadvantages:
 Prone to overfitting
 Inefficient with continuous data

□ Summary Table

Topic	Concept	Key Point

Topic	Concept	Key Point
Knowledge-Based Agent	Uses knowledge base	Logic + Inference
Wumpus World	Example world	Gold, Pits, Wumpus
Logic	Basis of reasoning	Propositional, FOPL
Inference	Deriving new facts	Forward, Backward, Resolution
Learning	Improves over time	Example-based, Decision Trees

Artificial Intelligence – Unit IV

Introduction to Planning

What is Planning in AI?

Planning is the process of deciding a sequence of actions that will lead from the initial state to a desired goal state.
It allows an AI system (like a robot or intelligent agent) to **think ahead** before acting.

1. Blocks World Problem

A **classical planning problem** used to illustrate AI planning concepts.

- The world consists of a **table and blocks (A, B, C...)** that can be stacked on each other.
- The goal might be, for example: *to stack block A on block B and block B on block C.*

Figure (Textual Representation):

```
Initial State:  A on Table, B on Table, C on Table
Goal State:     A on B, B on C
```

Advantages:

- Easy to model planning problems.
- Helps understand how AI forms and executes plans.

Disadvantages:

- Simplified; real-world planning is far more complex.

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2. STRIPS (Stanford Research Institute Problem Solver)

STRIPS is a formal language used to describe **actions** in AI planning.

Each action has:

- **Preconditions:** What must be true before the action.
- **Add list:** What becomes true after the action.
- **Delete list:** What becomes false after the action.

Example:

```
Action: Stack(A, B)
Precondition: Clear(A), Clear(B), OnTable(A)
Add list: On(A, B)
Delete list: OnTable(A)
```

Advantages:

- Simplifies representation of actions.
- Widely used in planning algorithms.

Disadvantages:

- Not suitable for dynamic or uncertain environments.

□ Handling Uncertainties

AI systems often operate in uncertain environments where outcomes are not guaranteed.

1. Non-Monotonic Reasoning

- Logic where adding new information can **invalidate old conclusions**.
- Example: “Birds can fly” → later learn “Penguins are birds but can’t fly.”

Advantages:

- Models real-world reasoning.
- Supports flexible decision-making.

Disadvantages:

- Complex to implement logically.
- Hard to maintain consistency.

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2. Probabilistic Reasoning

- Deals with **uncertain or incomplete information** using probability.
- Example: A doctor predicting disease likelihood based on symptoms.

Techniques:

- **Bayesian Networks**
- **Markov Models**

Advantages:

- Mathematically sound.
- Works well with noisy data.

Disadvantages:

- Requires large data for accurate results.
- Computation can be intensive.

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3. Fuzzy Logic

- Allows reasoning with **degrees of truth** instead of binary true/false.
- Example: “The water is warm” (not just hot or cold).

Figure (Conceptual):

```
Temperature (°C) → [0     25     50     75     100]
Fuzzy Values     → Cold   Warm   Hot
```

Advantages:

- Handles vague or imprecise information.
- Widely used in control systems (ACs, washing machines).

Disadvantages:

- Designing fuzzy rules requires expert knowledge.
- Can be less precise than probabilistic methods.

□ Robotics

1. Fundamentals of Robotics

Robotics combines AI, mechanical engineering, and electronics to design and control robots.

Key Components:

- **Sensors:** To perceive environment.
- **Actuators:** To perform movements.
- **Controllers:** To process data and make decisions.

Advantages:

- High precision and consistency.
- Useful in hazardous environments.

Disadvantages:

- High cost.
- Limited adaptability in unknown environments.

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2. Robot Kinematics

- The study of motion of robots without considering forces.
- It includes:
  - **Forward Kinematics:** Finding position from joint angles.
  - **Inverse Kinematics:** Finding joint angles for desired position.

Figure (Textual Representation):

```
Robot Arm:
Base → Joint 1 → Joint 2 → End Effector (Gripper)
```

Advantages:

- Crucial for robot control and motion planning.
- Used in industrial and surgical robots.

Disadvantages:

- Inverse kinematics can have multiple or no solutions.

👁 Computer Vision

1. Introduction to Image Processing

- Involves **analyzing and transforming images** to extract useful information.
- Steps include:
  - Image acquisition
  - Filtering / Enhancement
  - Edge detection
  - Segmentation

Advantages:

- Enables automatic image understanding.
- Used in security, healthcare, and self-driving cars.

Disadvantages:

- High computational power needed.
- Sensitive to lighting and background.

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2. Image Classification

- The process of labeling images into categories (e.g., cat, dog, car).

Techniques:

- **Traditional:** Feature extraction + classifier (SVM, KNN)
- **Modern:** Deep learning (CNNs)

Advantages:

- Accurate recognition.
- Automates large-scale image analysis.

Disadvantages:

- Needs large labeled datasets.
- May fail on unseen image types.

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3. Object Detection

- Identifies **what objects** are present and **where** they are located in an image.

Figure (Textual Representation):

```
Image → [Person] [Car] [Dog]
Boxes drawn around detected objects
```

Advantages:

- Helps in surveillance, autonomous driving, and robotics.

Disadvantages:

- Computation-heavy.
- Requires training with large datasets.

□ Summary Table

Topic	Types	Advantages	Disadvantages
Planning	Classical, Conditional, Probabilistic	Structured decision-making	Hard in dynamic environments
Uncertainty Handling	Non-monotonic, Probabilistic, Fuzzy	Real-world modeling	Complex computations
Robotics	Manipulators, Mobile, Humanoid	Precision, safety	Costly
Computer Vision	Image Processing, Classification, Detection	Automation	High computational needs

Fundamentals of Machine Learning

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1. Introduction to Machine Learning (ML)

Definition:
Machine Learning is a subset of Artificial Intelligence that enables computers to **learn from data** and improve performance without being explicitly programmed.

Importance of ML:

- Automates decision-making.
- Handles large-scale data efficiently.
- Powers real-world applications like recommendation systems, self-driving cars, fraud detection, and speech recognition.

Figure (Conceptual):

```
Data → Machine Learning Model → Prediction/Decision → Feedback → Improved Model
```

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2. Types of Machine Learning

2.1 Supervised Learning

- Learns from **labeled data** (input-output pairs).
- Predicts outcomes for new, unseen data.

Examples:

- Predicting house prices (Regression).
- Email spam detection (Classification).

Popular Algorithms:

- Linear Regression
- Logistic Regression
- Decision Trees
- k-Nearest Neighbors (k-NN)

Advantages:
 Accurate predictions when data is labeled
 Easy to evaluate performance

Disadvantages:
 Requires large labeled datasets
 Cannot handle unseen patterns outside training data

2.2 Unsupervised Learning

- Learns from **unlabeled data** (no explicit output labels).
- Finds hidden patterns or structures in data.

Examples:

- Customer segmentation
- Market basket analysis

Popular Algorithms:

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

Advantages:
 Finds hidden patterns
 Reduces data dimensionality

Disadvantages:
 Hard to evaluate performance
 May produce meaningless clusters if features are poor

2.3 Reinforcement Learning (RL)

- Learns by **trial and error** through interaction with the environment.
- Receives **rewards or penalties** and aims to maximize cumulative reward.

Examples:

- Self-driving cars
- Game playing (e.g., AlphaGo)

Popular Algorithms:

- Q-Learning
- Deep Q Networks (DQN)

- Policy Gradient Methods

Advantages:
 Learns complex strategies
 Adapts to dynamic environments

Disadvantages:
 Requires many interactions
 Computationally expensive

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3. Basic Concepts in Machine Learning

Term	Definition
Feature	Input variable used to make predictions (e.g., age, income)
Label/Target	Output variable to predict (e.g., price, category)
Training Data	Data used to train the ML model
Test Data	Data used to evaluate model performance
Model	Function or algorithm that maps inputs to outputs

Figure (Conceptual):

```
Training Data → ML Algorithm → Trained Model → Test Data → Predictions
```

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4. Popular Machine Learning Algorithms

4.1 Linear Regression

- Predicts continuous output using a linear relationship between input and output.
- Equation: `y = mx + b`

Advantages:
 Simple and interpretable
 Fast to train

Disadvantages:
 Cannot model complex relationships

4.2 Logistic Regression

- Predicts categorical outcomes (e.g., Yes/No).
- Outputs probability using the sigmoid function.

Advantages:
 Interpretable
 Works well with binary classification

Disadvantages:
 Limited to linear decision boundaries

4.3 Decision Trees

- Splits data based on features to predict output.
- Tree structure: nodes → branches → leaves

Advantages:
 Easy to visualize
 Handles both numerical and categorical data

Disadvantages:
 Prone to overfitting
 Can be unstable to small changes in data

4.4 k-Nearest Neighbors (k-NN)

- Predicts output based on **closest training examples** in feature space.

Advantages:
 Simple and effective
 No assumption about data distribution

Disadvantages:
 Slow for large datasets
 Sensitive to irrelevant features

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5. Evaluation Metrics for ML Models

Metric	Definition	Formula / Notes
Accuracy	Proportion of correct predictions	`(TP + TN) / (TP + TN + FP + FN)`

Metric	Definition	Formula / Notes
Precision	Correct positive predictions out of predicted positives	`TP / (TP + FP)`
Recall (Sensitivity)	Correct positive predictions out of actual positives	`TP / (TP + FN)`
F1-Score	Harmonic mean of Precision and Recall	`2 * (Precision * Recall) / (Precision + Recall)`
Confusion Matrix	Table showing TP, TN, FP, FN	Used to calculate other metrics

Figure (Confusion Matrix Concept):

```
             Predicted
            Yes   No
Actual Yes   TP    FN
       No    FP    TN
```

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6. Advantages of Machine Learning

- Automates decision-making.
- Handles large-scale and complex data.
- Improves over time with more data.
- Detects patterns humans may miss.

7. Disadvantages of Machine Learning

- Requires large and high-quality datasets.
- Can be biased if training data is biased.
- Computationally expensive.
- Hard to interpret complex models (e.g., deep learning).