📘 Fundamentals of Artificial Intelligence & Machine Learning

What you will study in this subject

🔹 Unit 1: Introduction to AI & Search Strategies

What is this unit about?

👉 Understanding how machines **think, decide, and solve problems**.

You will learn:

- What **intelligence** means (human vs machine)
- What **Artificial Intelligence (AI)** really is
- How AI evolved (history of AI)
- How a problem is given to a computer
- What are:
  - **States** (situations)
  - **Actions / Operators** (possible moves)
  - **State space** (all possible situations)
- How AI searches for solutions
- Smart search methods like:
  - **Best-First Search**
  - **A*** (used in maps, games, robotics)
- How AI plays games:
  - Perfect information games (Chess)
  - Imperfect information games (Poker)
  - How AI reduces unnecessary decisions (Alpha-Beta pruning)

📌 *In short:*

How AI thinks and finds solutions

🔹 Unit 2: Knowledge Representation & Planning

What is this unit about?
👉 Teaching machines **how to store knowledge and reason logically**.

You will learn:

- How knowledge is represented in AI
- Logic used by AI:
  - **Propositional logic**
  - **First-Order (Predicate) logic**
- How AI reasons:
  - **Forward chaining**
  - **Backward chaining**
- AI programming languages:
  - **LISP**
  - **PROLOG**
  - **CLIPS**
- Planning concepts:
  - How AI plans actions step-by-step
  - **Block world planning** (classic AI problem)

📌 *In short:*

How AI stores knowledge, thinks logically, and plans actions

🔹 Unit 3: Knowledge Inference & Expert Systems

What is this unit about?

👉 How AI handles **uncertainty and decision-making** like humans.

You will learn:

- Why uncertainty exists in real life
- Basics of:
  - **Probability**
  - **Bayes theorem**
- How AI predicts outcomes
- **Belief networks**
- **Fuzzy logic** (true/false is not always exact)
- Decision making using:
  - **Utility theory**
  - **Decision-theoretic expert systems**

📌 *In short:*

How AI makes decisions when information is incomplete

🔹 Unit 4: Introduction to Machine Learning (Supervised Learning)

What is this unit about?

👉 Teaching machines to **learn from data**.

You will learn:

- What **Machine Learning (ML)** is
- How machines learn from examples
- **Supervised learning**
- Algorithms like:
  - Linear regression
  - Logistic regression
  - Multi-class classification
- Concepts of:
  - Decision boundary
  - Cost function
  - Optimization
- Introduction to **Genetic Algorithms**

📌 *In short:*

How machines learn patterns from data

🔹 Unit 5: Unsupervised Learning & Clustering

What is this unit about?
👉 Finding **hidden patterns** without labels.

You will learn:

- **Unsupervised learning**
- **Clustering** techniques:
  - K-Means
  - Hierarchical clustering
  - DBSCAN
  - K-Medoids
  - Spectral clustering
- How AI groups similar data automatically

📌 *In short:*

How AI discovers structure in data without guidance

🎯 One-Line Summary for Students

This subject teaches **how machines think, learn, decide, and solve real-world problems using AI and Machine Learning techniques**.

🚀 AI Technology Roadmap (Past → 2050)

📌 1950s–1980s — Foundations & Early AI

Key Concepts Introduced

- **1950:** Turing Test (Alan Turing)
- **1956:** AI coined at Dartmouth
- **1960–70s:** Early symbolic AI & rule-based systems
- **1980s:** Expert systems, early neural networks

Impact

- Early research foundations
- Logic and rules dominate
- Hardware limits constrain progress

📌 1990s–2010 — Machine Learning & Early Data Era

Major Developments

- **1997:** Deep Blue beats chess champion
- **1998–2006:** SVMs, Bayesian models, ML frameworks
- **2006:** Deep Learning (Hinton) resurgence
- **2009:** Big Data era begins

Highlights

- Statistical learning becomes mainstream
- Neural networks return through deep architectures
- Better data and compute enable breakthroughs

📌 2010–2020 — Deep Learning & AI Growth

Key Milestones

- **2012:** AlexNet ignites DL in vision
- **2014:** GANs introduced
- **2016:** AlphaGo defeats human Go champion
- **2018–19:** Transformers introduced → NLP revolution

Technology State

- Deep learning dominates vision & language
- Early robotics, automation, early voice assistants

📌 2020–2025 — Generative AI & Ubiquitous AI

Defining Trends

- **GPT-3 / GPT-4 era** → broad adoption
- **Multimodal models** (text + image + audio)
- **AI as a service** (Cloud AI APIs, automation)
- **Ethics & governance frameworks** emerge

Examples of Tech

- ChatGPT, DALL-E, Stable Diffusion
- Real-time content generation
- Enterprise AI platforms

🌟 2025–2030 — AI Maturation & Augmented Intelligence

Expected Focus

- **Augmented AI** becomes mainstream
  Human + AI collaboration tools grow
- **AI Explainability & Trust** standards deployed
- **AI in Education & Personalized Learning**
- **Robotics + AI fusion** in manufacturing & services

Predictions

- AI accelerates 10× productivity
- AI-centric jobs increase alongside automation
- **Governance rules** begin global convergence

🌐 2030–2040 — Generalized & Cognitive AI

AI not just specialized intelligence — but versatile cognition

Key Tech Waves

- **Artificial General Intelligence (AGI) progression**

    - Not full human-level, but broad context understanding
- **Real-world perception & reasoning**
    - EU cognitive systems
- **Neuro-inspired & Bio-AI**
    - Brain-inspired computation
- **AI-embedded environments**
    - Smart cities, AI everywhere

Applications

- Autonomous transportation fleets
- Real-time predictive healthcare systems
- AI in governance & policy support

🚀 2040–2050 — Transformative & Cognitive Convergence

Future Fields

- **Deep Augmented Intelligence**
    - AI aids human thought and creativity
- **AI & Human Brain Interfaces**
    - Neural augmentation
- **AI-assisted science**
    - AI discovers new physics, medicine, materials
- **Ambient AI**
    - AI sensors everywhere, context-aware systems

Predicted Milestones

- AGI-level systems operational
- AI governance becomes standardized worldwide
- Ethical AI norms deeply integrated
- Humans collaborate with AI partners daily

📊 Layered Technology Map (By Area)

Field / Era	2000s	2010s	2020s	2030s	2040s	2050
Machine Learning	Classic ML	DL	Advanced DL	Reinforcement & Meta-learning	Cognitive ML	Ubiquitous AI
Generative AI	—	GANs	Transformers & Multimodal	Creative AI Assistants	Cognitive Creators	AI-Inventors
Augmented AI (Human + AI)	—	Emerging	Mainstream	Personal AI Co-workers	Neural augmentation	Cognitive augmentation
Robotics	Rule-based	Learning robots	Autonomous robots	Generalized robotics	Sentient systems	Adaptive intelligent robots
AI Governance & Ethics	—	Initial policy	Global frameworks	Regulation & compliance	Standardized ethics	Integrated AI law
AI + Society	Research	Adoption	Transformation	AI-driven industry	Smart civilization	Human-AI symbiosis

🧠 Key Terms Explained

🔹 Artificial Intelligence (AI)

Systems designed to perform tasks that require intelligence.

🔹 Machine Learning (ML)

AI subfield where systems improve from data.

🔹 Deep Learning (DL)

Neural networks with many layers for complex pattern recognition.

🔹 Generative AI

Models that **generate content** (text, image, audio).

🔹 Augmented AI

Human + AI collaboration tools — support, not replace.

🔹 Artificial General Intelligence (AGI)

AI capable of flexible, human-like reasoning across tasks.

UNIT 1: Introduction to Artificial Intelligence

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1. What is Intelligence?

Definition

Intelligence is the ability of an entity to **learn from experience, understand information, reason logically, solve problems, adapt to new situations, and make decisions to achieve goals**.

Key Characteristics of Intelligence

Aspect	Description
Learning	Acquiring knowledge from data or experience
Reasoning	Drawing conclusions using logic
Problem-solving	Finding solutions to complex situations
Adaptability	Adjusting to new or changing environments
Perception	Interpreting sensory input (vision, sound, etc.)
Decision-making	Choosing the best action among alternatives

Human Intelligence vs Machine Intelligence

Human Intelligence	Machine Intelligence
Emotional & creative	Logical & data-driven
Learns from experience naturally	Learns from data & algorithms
General-purpose	Mostly task-specific
Can understand context	Limited contextual understanding

Example

- **Human intelligence:** A doctor diagnosing a disease based on symptoms and experience.
- **Machine intelligence:** An AI system diagnosing diseases using medical data and patterns.

2. What is Artificial Intelligence (AI)?

Definition

Artificial Intelligence (AI) is a branch of computer science that focuses on creating machines capable of performing tasks that normally require **human intelligence**, such as learning, reasoning, problem-solving, perception, and language understanding.

Formal Definitions (Exam-Oriented)

- **John McCarthy (1956):**
  "Artificial Intelligence is the science and engineering of making intelligent machines."
- **Russell & Norvig:**
  "AI is the study of agents that perceive their environment and act rationally."

Goals of AI

- To create **intelligent agents**
- To automate intelligent tasks
- To simulate human thinking and behavior
- To improve efficiency and accuracy in decision-making

3. Foundations of Artificial Intelligence

AI is an **interdisciplinary field** built on multiple disciplines.

Major Foundations of AI

Discipline	Contribution to AI
Mathematics	Logic, probability, statistics, optimization
Computer Science	Algorithms, data structures, programming
Philosophy	Logic, reasoning, ethics
Psychology	Learning, cognition, behavior
Neuroscience	Brain functioning, neural networks
Linguistics	Natural Language Processing (NLP)
Control Theory	Robotics and automation
Economics	Decision theory, game theory

Example

- **Neural Networks** ← inspired by **human brain neurons**
- **Search algorithms** ← based on **logical reasoning**

4. History of Artificial Intelligence

Early Foundations (Before 1950)

- **Aristotle:** Formal logic and reasoning
- **Alan Turing (1950):** Proposed the **Turing Test** to measure machine intelligence

Birth of AI (1956)

- Term **"Artificial Intelligence"** coined by **John McCarthy**
- **Dartmouth Conference (1956)** marked the official beginning of AI

AI Timeline

Period	Key Developments
1950–1960	Logic-based programs, problem solving
1960–1970	Expert systems, symbolic AI
1970–1980	First AI Winter (lack of computing power)
1980–1990	Knowledge-based systems
1990–2000	Machine learning, data-driven approaches
2000–2010	Big data, statistical AI
2010–Present	Deep learning, generative AI

Key Milestones in AI

Year	Event
1950	Turing Test
1956	Dartmouth Conference
1997	IBM Deep Blue defeats Garry Kasparov
2011	IBM Watson wins Jeopardy
2012	Deep Learning breakthrough (ImageNet)
2020+	ChatGPT, Generative AI, Autonomous systems

5. Examples of AI in Real Life

Application	AI Use
Voice Assistants	Speech recognition & NLP
Recommendation Systems	ML-based predictions
Self-driving cars	Computer vision & decision-making
Healthcare	Disease diagnosis
Finance	Fraud detection

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6. Relationship Between AI, ML, and DL

Artificial Intelligence
└── Machine Learning
└── Deep Learning

- **AI:** Broad concept
- **ML:** Learning from data
- **DL:** Neural networks with many layers

Term	The Simple Goal	Real-World Example
Data Analytics	To explain **what happened** in the past.	"Our sales dropped by 10% last month because of the rain."
Data Science	To find **hidden insights** and build tools to solve problems.	Building a system that identifies which customers are likely to leave next month.
Big Data	To handle **massive amounts** of data that won't fit on one computer.	Processing the billions of transactions processed by Visa every day.
Machine Learning	To **predict** the future based on past data.	Netflix recommending a movie you might like.
Generative AI	To **create** something brand new.	Asking an AI to "Write a poem about a robot eating a taco."

Reels Ki Dunia

https://www.youtube.com/shorts/KYI3_HQYYtU

https://www.youtube.com/shorts/Teo0I9upE58

https://www.youtube.com/shorts/njAnYUuedLU

https://www.youtube.com/shorts/BAgJcz9ShX8

https://www.youtube.com/shorts/9fogzZ_6kR0

https://www.youtube.com/shorts/9bWqFHJxS7Y

https://www.youtube.com/shorts/DHV3Y0kRQp4

https://www.youtube.com/shorts/LV-Uu7GvpUo

https://www.youtube.com/shorts/fIkQ1fyUYNQ

No Worries

https://www.youtube.com/shorts/UN4hwsZ_z9Q

https://www.youtube.com/shorts/v9csjiPSyS0

📘 Lecture Notes: State Space Search (Fundamentals of AI & ML)

1. Introduction to State Space Search

What is State Space Search?

State space search is a **problem-solving technique in Artificial Intelligence** where:

- A problem is modeled as a **set of states**
- The AI system searches through these states to find a **goal state**
- Transitions between states are done using **operators (actions)**

👉 **Core Idea:**

"Problem solving = Searching for a path from initial state to goal state."

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2. Problem Solving as Search

In AI, a problem is defined by **five components**:

Component	Description
Initial State	Starting condition of the problem
State Space	All possible states reachable
Operators / Actions	Rules to move from one state to another
Goal State / Goal Test	Desired final condition
Path Cost	Cost of moving from one state to another

📌 *These five elements must be clearly defined before solving any AI problem.*

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3. State and State Space

🔹 State

A **state** is a **representation of the problem at a particular moment**.

✔ It describes *what the world looks like now*
✔ Usually represented using **tuples, arrays, or structures**

Example (Water Jug):

(4, 0)

Means:

- Jug A has 4 liters
- Jug B has 0 liters

🔹 State Space

The **state space** is:

The **set of all possible states** reachable from the initial state by applying operators.

✔ Can be:

- Finite (Tic-Tac-Toe)
- Infinite (Real-world planning problems)

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4. Operators (Actions)

What are Operators?

Operators are **actions that transform one state into another**.

✔ Must be **valid**
✔ Must follow **problem constraints**

Example Operators (Water Jug)

- Fill Jug A
- Fill Jug B
- Empty Jug A
- Empty Jug B
- Pour Jug A → Jug B
- Pour Jug B → Jug A

📌 *Operators define the edges in the state space graph.*

5. Search Tree vs State Space Graph

Search Tree	State Space Graph
Generated during search	Conceptual model
May contain repeated states	Each state appears once
Used by algorithms	Used for problem modeling

6. Water Jug Problem (Classic AI Problem)

Problem Statement

You have:

- Jug A: 4 liters
- Jug B: 3 liters
  Goal: **Measure exactly 2 liters of water**

Step 1: Define Problem Formally

Element	Definition
Initial State	(0, 0)
Goal State	(2, x) or (x, 2)
State Representation	(a, b)
Operators	Fill, Empty, Pour
Constraints	Jug capacities

Step 2: State Space Representation

Each state is a node:

(a, b) where $0 \le a \le 4$ and $0 \le b \le 3$

Step 3: Solution Path (Example)

(0,0)
→ (4,0)
→ (1,3)
→ (1,0)
→ (0,1)
→ (4,1)
→ (2,3)

✔ Goal achieved: 2 liters in Jug A

Why Water Jug is Important?

- Demonstrates **state modeling**
- Shows **operator design**
- Helps visualize **search trees**

7. Tic-Tac-Toe as State Space Search

Problem Overview

- Two-player game
- Turn-based
- Perfect information game

State Representation

A **3×3 board**:

X | O | -
- | X | -
- | - | O

Each cell ∈ {X, O, Empty}

Initial State

Empty board

Operators

- Place X or O in an empty cell

Goal State

- X wins OR
- O wins OR
- Draw

State Space Size

- Maximum possible states ≈ $\mathbf{3^9 = 19{,}683}$
- Actual valid game states are fewer

📌 *Good example to introduce Game Search later (Minimax).*

8. Other Classical State Space Problems (Mention Briefly)

1️⃣ 8-Puzzle Problem

- 3×3 grid
- One empty tile
- Goal: Arrange tiles in order

2️⃣ Missionaries and Cannibals

- Transport safely without violating constraints

3️⃣ Tower of Hanoi

- Recursive structure
- Clear state transition logic

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9. Types of Problems in State Space Search

Type	Example
Single-state	Water Jug
Multi-state	Sensor-based systems
Deterministic	Puzzle games
Non-deterministic	Real-world planning
Fully observable	Chess
Partially observable	Robot navigation

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10. What Should Be Added (Very Important for AI Foundations)

🔹 Goal Test vs Goal State

- **Goal State**: Exact condition
- **Goal Test**: Function that checks whether current state satisfies goal

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🔹 Path Cost

- Number of steps
- Time taken
- Resources used

Introduces idea of **optimal solutions**

🔹 Uninformed vs Informed Search *(Preview)*

You can end lecture by teasing next topic:

Uninformed	Informed
No heuristic	Uses heuristic
BFS, DFS	A*, Greedy
Blind search	Intelligent search

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11. Real-Life Analogy (For Student Engagement)

🎯 Google Maps Navigation

- State = current location
- Operators = move to next road
- Goal = destination
- Cost = distance/time
- Heuristic = estimated remaining distance

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12. Summary Slide (For Ending Lecture)

- AI problem solving = **Search**
- State space defines **all possibilities**
- Operators move between states
- Water Jug & Tic-Tac-Toe are **classical AI models**
- Foundation for **BFS, DFS, A*** and **Game Playing**

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13. Suggested Classroom Activities

- Draw **state space graph** of Water Jug
- Ask students to **define states for a new problem**
- Mini assignment: *Model 8-puzzle as state space*