UNIT-I: Introduction to Artificial Intelligence and Intelligent Agents

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1. Introduction: AI Problems and Foundation

What is Artificial Intelligence?

Artificial Intelligence is concerned with the design of intelligence in an artificial device. The term was coined by John McCarthy in 1956[1].

Artificial Intelligence exists when a machine can have human-based skills such as learning, reasoning, and solving problems[2]. According to Sudhakar Atchala and Mahesh Huddar's lectures, AI is fundamentally about creating systems that can perceive their environment and take rational actions to achieve specific goals[3][4].

AI Problems

Definition of Problems in AI:

A problem in artificial intelligence is a particular task or challenge that calls for decision-making or solution-finding. These tasks can range from straightforward mathematical problems to intricate decision-making situations such as image recognition, natural language processing, gameplay, and optimization[5].

Every problem has:

- A defined set of initial states
- A goal state that must be attained
- Potential actions or moves available[5]

Characteristics of AI Problems:

According to GeeksforGeeks, when dealing with AI, problem-solving involves creating algorithms and methods that empower machines to imitate humans' capabilities of logical and reasonable thinking in certain situations[5].

Key characteristics include:

- **Search Space:** Refers to the area where an agent involved in the problem-solving process can examine all possible states or settings with the hope of discovering a solution. It covers a gamut of options that the agent might select for arriving at the same destination[5].
- **Problem Complexity:** The difficulty level of finding the optimal or satisfactory solution within the search space.
- **Domain Specificity:** Different problems require different approaches and solutions.
- **Constraints:** Limitations and restrictions within which solutions must be found.

YouTube Reference (Problem Solving by Mahesh Huddar):

Dr. Mahesh Huddar discusses the steps to solve problems in AI in his lecture "Tasks in AI | Steps to Solve Problem". The fundamental approach involves defining the problem accurately first, then proceeding with solution strategies[6].

URL: https://www.youtube.com/watch?v=YnFwyHfS67I

Foundation of AI

The foundation of artificial intelligence rests on several key principles:

1. **Perception and Sensing:** Agents must be able to perceive their environment through sensors.
2. **Decision-Making:** Based on perceptions, agents must make rational decisions about their actions.
3. **Action and Execution:** Agents must execute actions that affect their environment.
4. **Learning:** Many AI systems learn from past experiences to improve performance.
5. **Goal Achievement:** All AI systems are designed to achieve specific predefined objectives[3][4].

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2. History of Artificial Intelligence

The history of AI spans several decades of development and innovation:

- **1956:** The term "Artificial Intelligence" was coined by John McCarthy at the Dartmouth Conference[2].
- **Early Era:** Initial development focused on problem-solving and game-playing AI.
- **Expert Systems Era:** Development of systems that captured human expertise in specific domains.
- **Modern Era:** Emergence of machine learning, deep learning, and neural networks.
- **Current Trends:** Development of intelligent agents, reinforcement learning, and advanced AI systems capable of complex reasoning[2].

According to Sudhakar Atchala's lectures on YouTube, the evolution of AI has been marked by increasing complexity and capability, from simple reflex agents to sophisticated learning systems[3].

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3. Intelligent Agents: Agents and Environments

Definition of Agents

An agent is anything that can be viewed as perceiving the environment with the help of sensors[7]. More formally, an artificial intelligence (AI) agent is a software program that can interact with its environment, collect data and use that data to perform self-directed tasks that meet predetermined goals[8].

Key Characteristics of AI Agents (GeeksforGeeks):

- **Autonomous:** Act without constant human input and decide next steps from past data.
- **Goal-driven:** Optimize for defined objectives.
- **Perceptive:** Gather information from sensors, inputs or APIs.
- **Adaptable:** Adjust strategies when situations change.
- **Collaborative:** Work with humans or other agents toward shared goals[8].

Mahesh Huddar's Definition:

According to Mahesh Huddar, an agent is a system that:

1. Perceives the environment with the help of sensors
2. Acts on the environment with the help of actuators based on its knowledge
3. Can make decisions independently to achieve its goals[7]

Definition of Environments

Everything external to the agent that the agent interacts with is called the environment. This includes all the conditions, contexts, and dynamics that the agent must respond to[9].

The presence of continuous interaction between agent and environment allows:

- The agent to select actions
- The environment to respond to those actions
- A new situation to be presented to the agent
- Rewards to be provided (typically in numerical values) for the agent to maximize[9]

Agent-Environment Interaction

The Basic Cycle (Mahesh Huddar's Explanation):

The agent-environment interaction follows this cycle:

1. The agent perceives the current environment through sensors
2. Based on the current environment status, the agent acts on the environment through actuators
3. The environment responds to the agent's action
4. A new state of the environment is perceived by the agent
5. The cycle continues[7].

Example: Robotic Vacuum Cleaner

Mahesh Huddar uses the robotic vacuum cleaner as an example:

- There are two locations: Location A and Location B
- The robot senses the environment through sensors
- If a location is dirty, it cleans it
- If a location is clean, it moves to the other location
- This process continues based on the current state and actions[7]

URL: https://www.youtube.com/watch?v=fCSvGlhl7sA (Agents & Environments by Mahesh Huddar)

GeeksforGeeks Perspective:

The agent-environment interface in reinforcement learning focuses on how agents should behave in environments to maximize cumulative rewards[9].

Components of Agent-Environment Interface:

- **Perception:** The agent gathers information about the environment at each time step t, denoted as S_t
- **Action:** Based on the state S_t, the agent chooses an appropriate action A_t from the set of possible actions A(S_t)
- **Feedback:** After taking an action, the agent receives new states (S_{t+1}) and rewards (R_{t+1})[9].

Reference: https://www.geeksforgeeks.org/artificial-intelligence/agent-environment-interface-in-ai/

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4. The Concept of Rationality

Definition of Rational Agent

An agent is said to be rational if it does the right thing. **The definition of a rational agent:**

"For each possible percept sequence, a rational agent should select an action that is expected to maximize its performance measure, given the evidence provided by the percept sequence and whatever built-in knowledge the agent has."[10]

What Does It Mean to Do the Right Thing?

According to Mahesh Huddar's video lecture on rationality[10]:

To say that an agent is doing the right thing, there must be criteria to evaluate this. When an agent is put into the environment:

1. It generates a sequence of actions according to the percepts it receives through sensors
2. When it performs those actions through actuators, the environment goes through a sequence of states
3. If this sequence of state is desirable (starts from initial state and reaches the goal state), the agent is rational

Performance Measure

Definition: The performance measure is the criteria used to evaluate whether an agent is behaving rationally[10].

Important Points:

- The performance measure is not fixed for all tasks and agents
- Different agents and tasks require different performance measures
- The agent has to select an action in such a way that it will maximize the performance measure[10].

Example: Automated Taxi Driver

According to Mahesh Huddar, the performance measure for an automated taxi driver includes:

- Getting to the destination
- Minimizing time and fuel consumption
- Providing a comfortable and safe ride
- Following traffic laws
- Maximizing profits[10]

An agent that achieves all these objectives within constraints is considered rational.

YouTube Reference:

Mahesh Huddar - "Concept of Rationality Rational Agent Irrational Agent"
URL: https://www.youtube.com/watch?v=ETd_zGQzoUo

Sudhakar Atchala - "AI Basics - What is a Rational Agent?"
URL: https://www.youtube.com/watch?v=B99VVFCTzik

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5. The Nature of Environments

Task Environment Properties

According to Mahesh Huddar's lecture on task environments[11], there are seven main properties that characterize task environments:

1. Fully Observable vs. Partially Observable

- **Fully Observable:** The agent can perceive the complete state of the environment at each moment through its sensors. The agent has access to all information needed to make decisions.
- **Partially Observable:** The agent can only perceive partial information about the environment. Some aspects of the environment remain hidden or unobservable.

Example: A fully observable environment is a board game where all pieces are visible. A partially observable environment is a poker game where cards in opponents' hands are hidden[11].

2. Single-Agent vs. Multi-Agent

- **Single-Agent Environment:** Only one agent interacts with the environment.
- **Multi-Agent Environment:** Multiple agents interact with the same environment, potentially cooperating or competing.

Example: A robot solving a puzzle alone is single-agent. Multiple robots working in a warehouse is multi-agent[8].

3. Deterministic vs. Stochastic

- **Deterministic:** The next state of the environment is completely determined by the current state and the agent's action.
- **Stochastic:** The next state is not completely determined; there is uncertainty and randomness involved[11].

Example: A chess game is deterministic. A self-driving car operating in real traffic is stochastic (due to unpredictable human behavior)[11].

4. Static vs. Dynamic

- **Static Environment:** The environment does not change while the agent is deliberating or deciding on an action.
- **Dynamic Environment:** The environment can change while the agent is thinking or acting, requiring continuous perception and adaptation[11].

Example: A vacuum cleaner in a static environment (no new dirt appears). A trading agent in a dynamic market (prices constantly change)[11].

5. Discrete vs. Continuous

- **Discrete Environment:** The environment has a finite set of distinct states, percepts, and actions.
- **Continuous Environment:** The environment has infinite or very large number of possible states and actions.

Example: Chess (discrete) vs. robot arm control (continuous)[11].

6. Episodic vs. Sequential

- **Episodic:** The agent's experience can be divided into independent episodes. The action in one episode does not affect future episodes.
- **Sequential:** The current decision can affect future decisions and outcomes. Actions have long-term consequences[8].

Example: Image classification task (episodic) vs. chess game where each move affects future moves (sequential)[8].

7. Known vs. Unknown Environments

- **Known Environment:** The agent knows the rules and dynamics of the environment.
- **Unknown Environment:** The agent does not know how the environment works and must learn its dynamics through interaction[11].

Reference: https://www.youtube.com/watch?v=FiD_xBYGjgE (Task Environment Properties by Mahesh Huddar)

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6. Structure of Agents

Agent Architecture Components

According to GeeksforGeeks, there are four main components in an AI agent's architecture[8]:

1. Profiling Module

- Helps the agent understand its role and purpose
- Gathers information from the environment to form perceptions
- Example: A self-driving car uses sensors and cameras to detect obstacles[8].

2. Memory Module

- Enables the agent to store and retrieve past experiences
- Helps the agent learn from prior actions and improve over time
- Example: A chatbot remembers past conversations to give better responses[8].

3. Planning Module

- Responsible for decision-making
- Evaluates situations, weighs alternatives and selects the most effective course of action
- Example: A chess-playing AI plans its moves based on future possibilities[8].

4. Action Module

- Executes the decisions made by the planning module in the real world
- Translates decisions into real-world actions
- Example: A robot vacuum moves to clean a designated area after detecting dirt[8].

Agent Function and Agent Program

Agent Function (Mahesh Huddar):

An agent function is a mapping of percepts to actions[12].

Agent Program:

The agent program is the implementation of the agent function. According to Mahesh Huddar, agents can be structured in different ways:

1. Simple Reflex Agents

- Act based solely on current perceptions using condition-action rules
- Respond directly to stimuli without considering past experiences
- Operate on basic "if-then" logic
- Key Features: No memory, no model of the world, purely reactive behavior[8]
- Function best in fully observable environments
- Example: Traffic light control systems based on fixed timing[8].

2. Model-Based Reflex Agents

- Maintain an internal representation of the world

- Track aspects of the environment they cannot directly observe
- Allow for more informed decisions by considering how the world evolves
- Key Features: Track world's state over time, infer unobserved aspects, function effectively in partially observable environments[8]
- Example: Robot vacuum cleaners that map rooms and track cleaned areas[8].

3. Goal-Based Agents

- Plan their actions with a specific objective in mind
- Evaluate how different action sequences might lead toward their defined goal
- Select the path that appears most promising
- Key Features: Employ search and planning mechanisms, evaluate actions based on contribution to goal achievement, consider future states[8]
- Example: Logistics routing agents that find optimal delivery routes[8].

4. Utility-Based Agents

- Extend goal-based thinking by evaluating actions based on utility function (measure of "happiness" or "satisfaction")
- Make nuanced trade-offs between competing goals or uncertain outcomes
- Key Features: Balance multiple objectives, handle probabilistic environments, evaluate based on expected utility[8]
- Example: Financial portfolio management agents[8].

5. Learning Agents

- Improve their performance over time based on experience
- Modify behavior by observing consequences of actions
- Adjust internal models and decision-making approaches
- Key Features: Adapt to changing environments, improve with experience, contain performance and learning elements[8]
- Example: Customer service chatbots improving response accuracy over time[8].

Table-Driven Agent (Mahesh Huddar):

A table-driven agent uses a complete look-up table that maps all possible percepts to actions. This table must be fully specified before the agent is put into the environment[12].

Reference: https://www.youtube.com/watch?v=ER9QomwqFmQ (Table-driven Agent by Mahesh Huddar)

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7. Problem Solving Agents

Simple Planning Agent

According to the lectures, a simple planning agent operates as follows[13]:

Components of a Simple Planning Agent:

1. **Sensor:** Senses the present environment
2. **Agent Logic:** Based on the current state perceived, it chooses one particular action
3. **Actuators:** Execute the selected action in the environment
4. **Goal:** Achieve the desired objective.

Process:

1. The agent senses the current environment through sensors
2. Based on the scenarios and current state, it selects an appropriate action
3. The action is executed through actuators
4. The environment responds and a new state is observed
5. The process repeats until the goal is achieved[13]

Reference: https://www.youtube.com/watch?v=Tr3g2NxdybQ (Simple Planning Agent)

Steps to Solve Problems (Mahesh Huddar)

According to Mahesh Huddar[6]:

Step 1: Define the Problem Accurately

The first and foremost step when solving any problem is to define that particular problem accurately. This includes understanding:

- What is the problem?
- What information is available?
- What are the constraints?

Step 2: Problem Formulation

After defining the problem, the next step is to formulate it precisely. This involves determining what constitutes a suitable solution for that problem[6].

Reference: https://www.youtube.com/watch?v=YnFwyHfS67I (Tasks in AI by Mahesh Huddar)

Types of Problem-Solving Approaches

1. Search-Based Problem Solving

Problem-solving agents work by[5]:

- **Perceiving the environment:** Collecting data about their surroundings through sensor inputs or observations
- **Defining the problem:** Understanding the starting point, available actions, and desired goal
- **Exploring different possibilities:** Considering various ways to solve the problem and evaluating which approach is likely to succeed
- **Evaluating and deciding:** Assessing outcomes of different options and picking the best course of action based on time, resources, and success likelihood
- **Learning and adapting:** Many agents can learn from past experiences, improving their decision-making abilities over time[5].

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8. Problem Formulation

What is Problem Formulation?

According to GeeksforGeeks[14]:

Problem formulation is the process by which an agent defines the task it needs to solve. This involves specifying the initial state, goal state, actions, constraints, and the criteria for evaluating solutions. Effective problem formulation is crucial for the success of the agent in finding optimal or satisfactory solutions.

Steps in Problem Formulation

Step 1: Define the Initial State

- The initial state is the starting point of the agent
- It includes all relevant information about the environment that the agent can perceive
- Example: In a navigation problem, the initial state could be the agent's starting location on a map[14].

Step 2: Specify the Goal State

- The goal state defines the desired outcome that the agent aims to achieve
- It represents the condition or set of conditions that signify task completion
- Example: For navigation, the goal state is the destination location[14].

Step 3: Determine the Actions

- Actions are the set of operations or moves that the agent can perform
- Each action should transition from one state to another
- Each action must be well-defined and feasible within the environment
- Example: In robot navigation, actions could include moving forward, turning left, or turning right[14].

Step 4: Establish the Transition Model

- Describes how the environment changes in response to the agent's actions
- Defines the rules that govern state transitions
- Example: In a game, it specifies how the game state changes based on player moves[14].

Step 5: Set Constraints and Conditions

- Constraints are the limitations or restrictions within which the agent must operate
- Can include physical limitations, resource constraints, and safety requirements
- Example: For a delivery drone, constraints include battery life, weight capacity, and no-fly zones[14].

Step 6: Define the Cost Function

- Evaluates the cost associated with different actions or paths
- Helps the agent optimize its strategy by minimizing or maximizing this cost

- Example: In route planning, cost could represent distance traveled, time taken, or energy consumed[14].

Step 7: Criteria for Success

- Determine how the agent evaluates its progress and final solution
- Include metrics for measuring effectiveness and efficiency
- Example: For puzzle-solving, success criteria could be completion within shortest time or fewest moves[14].

Example: Autonomous Drone Package Delivery

According to GeeksforGeeks[14]:

Initial State:

```
class Drone:
def init(self, initial_location, battery):
self.location = initial_location
self.battery = battery
self.goal_location = 'customer_location'
```

Actions and Transition Model:

- takeoff(): Drone takes off (requires battery > 20)
- land(): Drone lands
- move(direction): Drone moves in specified direction

Goal State and Objective Function:

```
def objective_function(self):
if self.location == self.goal_location:
return 100 # High score for reaching goal
return self.battery # Prefer states with more battery
```

Constraints:

- Battery life: must have sufficient charge for all operations
- No-fly zones: must avoid specified restricted areas
- Weight capacity: must not exceed payload limits[14]

Importance of Problem Formulation

Effective problem formulation is essential because[14]:

1. **Clarity:** Provides clear understanding of the problem, making it easier to devise a solution
2. **Efficiency:** Proper formulation can significantly reduce computational resources required
3. **Optimal Solutions:** Helps find optimal or satisfactory solutions by accurately defining goals and constraints
4. **Adaptability:** Structured approach ensures agents can tackle complicated issues methodically and make well-informed decisions[14].

Reference: https://www.geeksforgeeks.org/artificial-intelligence/how-does-an-agent-formulate-a-problem/

Key Learning Resources

YouTube Channels and Lectures

Dr. Mahesh Huddar (HIT, Nidasoshi):

- Channel: https://www.youtube.com/@MaheshHuddar
- Key Videos for Unit-I:
  - Agents and Environments: https://www.youtube.com/watch?v=fCSvGlhl7sA
  - Concept of Rationality: https://www.youtube.com/watch?v=ETd_zGQzoUo
  - Table-driven Agent: https://www.youtube.com/watch?v=ER9QomwqFmQ
  - Task Environment Properties: https://www.youtube.com/watch?v=FiD_xBYGjgE
  - Tasks in AI - Steps to Solve Problem: https://www.youtube.com/watch?v=YnFwyHfS67I
  - State Space Search: https://www.youtube.com/watch?v=0VS62q8U2iA

Sudhakar Atchala:

- Artificial Intelligence Full Course Playlist: https://www.youtube.com/watch?v=xp0uSJ2khZY
- Types of Agents: https://www.youtube.com/watch?v=9qVLFllc38w
- Rational Agent: https://www.youtube.com/watch?v=B99VVFCTzik
- Agents and Environments (Telugu): https://www.youtube.com/watch?v=XdlGE43XQ1M

GeeksforGeeks Articles

Comprehensive AI Resources:

1. Agents in AI: https://www.geeksforgeeks.org/artificial-intelligence/agents-artificial-intelligence/
2. Agent-Environment Interface: https://www.geeksforgeeks.org/artificial-intelligence/agent-environment-interface-in-ai/
3. Problem Formulation: https://www.geeksforgeeks.org/artificial-intelligence/how-does-an-agent-formulate-a-problem/
4. Problem Solving in AI: https://www.geeksforgeeks.org/artificial-intelligence/problem-solving-in-artificial-intelligence/
5. Problems, Problem Spaces, and Search: https://www.geeksforgeeks.org/artificial-intelligence/what-is-problems-problem-spaces-and-search-in-ai/
6. Characteristics of AI Problems: https://www.geeksforgeeks.org/artificial-intelligence/characteristics-of-artificial-intelligence-problems/
7. Intelligent Agents in AI: https://www.geeksforgeeks.org/artificial-intelligence/intelligent-agent-in-ai/

Summary of Unit-I Key Concepts

Concept	Definition	Key Points
Artificial Intelligence	Design of intelligence in artificial devices	Coined in 1956; involves learning, reasoning, problem-solving
Agent	System perceiving environment via sensors and acting via actuators	Autonomous, goal-driven, perceptive, adaptable, collaborative
Environment	Everything external to the agent	Defined by properties like observability, determinism, dynamics
Rationality	Selecting actions to maximize performance measure	Based on percept sequence and built-in knowledge
Problem	Task requiring decision-making or solution-finding	Defined by initial state, goal state, and possible actions
Problem Formulation	Process of defining a problem for agent to solve	Specifies initial state, goal, actions, constraints, transition model
Agent Structure	Architecture components (Profiling, Memory, Planning, Action)	Enables perception, decision-making, action execution
Task Environment	Characteristics of the problem domain	7 properties: observable, agent type, determinism, dynamic, discrete, episodic, knowledge

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