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UNIVERSITY INSTITUTE OF ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE AND ENGG.

Bachelor of Engineering (Computer Science & Engineering)

Principles of Artificial Intelligence (20CST-258)

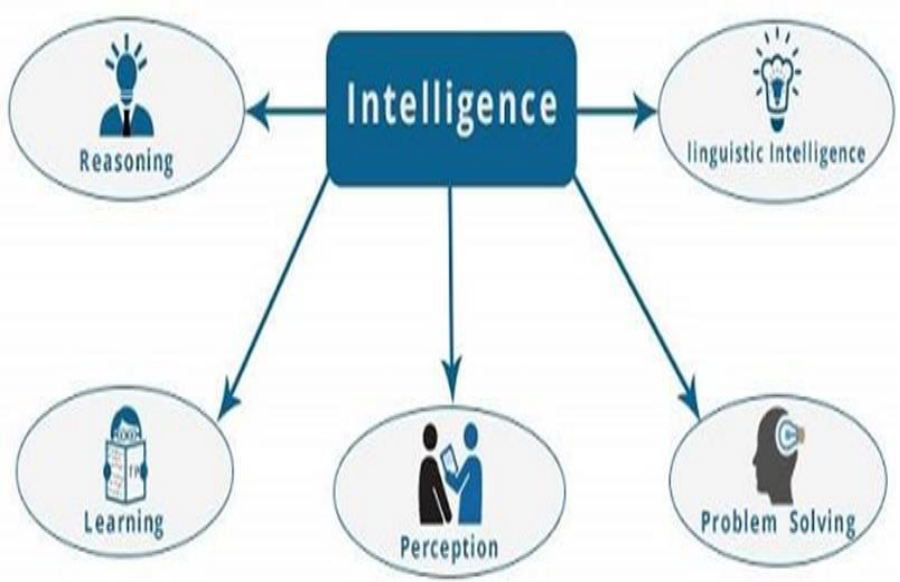
Problem state spaces

Outline

- Intelligent Agents
- Structure of Agents
- Types of Agents
- Problem state spaces
- Problem Solving
- Measuring problem-solving performance

Intelligence

- Ability of a system to:
  - calculate,
  - reason,
  - perceive relationships and analogies,
  - learn from experience,
  - solve problems, comprehend complex ideas,
  - classify, generalize,
  - adapt new situations.

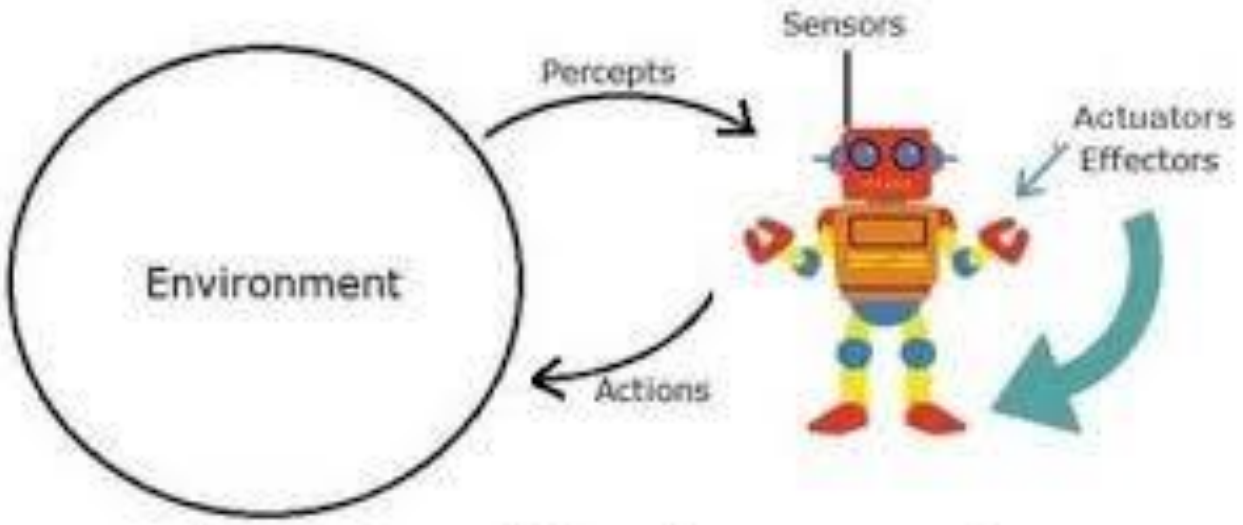


Agents

- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators

  - Operates in an environment
  - Perceive its environment through sensors
  - Acts upon its environment through actuators/ effectors
  - Has Goals

Agents



Agent and Environment

Intelligent Agents

- An intelligent agent is an autonomous entity which act upon an environment using sensors and actuators for achieving goals.
- An intelligent agent may learn from the environment to achieve their goals.
- Following are the main four rules for an AI agent:
  - Rule 1: An AI agent must have the ability to perceive the environment.
  - Rule 2: The observation must be used to make decisions.
  - Rule 3: Decision should result in an action.
  - Rule 4: The action taken by an AI agent must be a rational action.
- A thermostat is an example of an intelligent agent.

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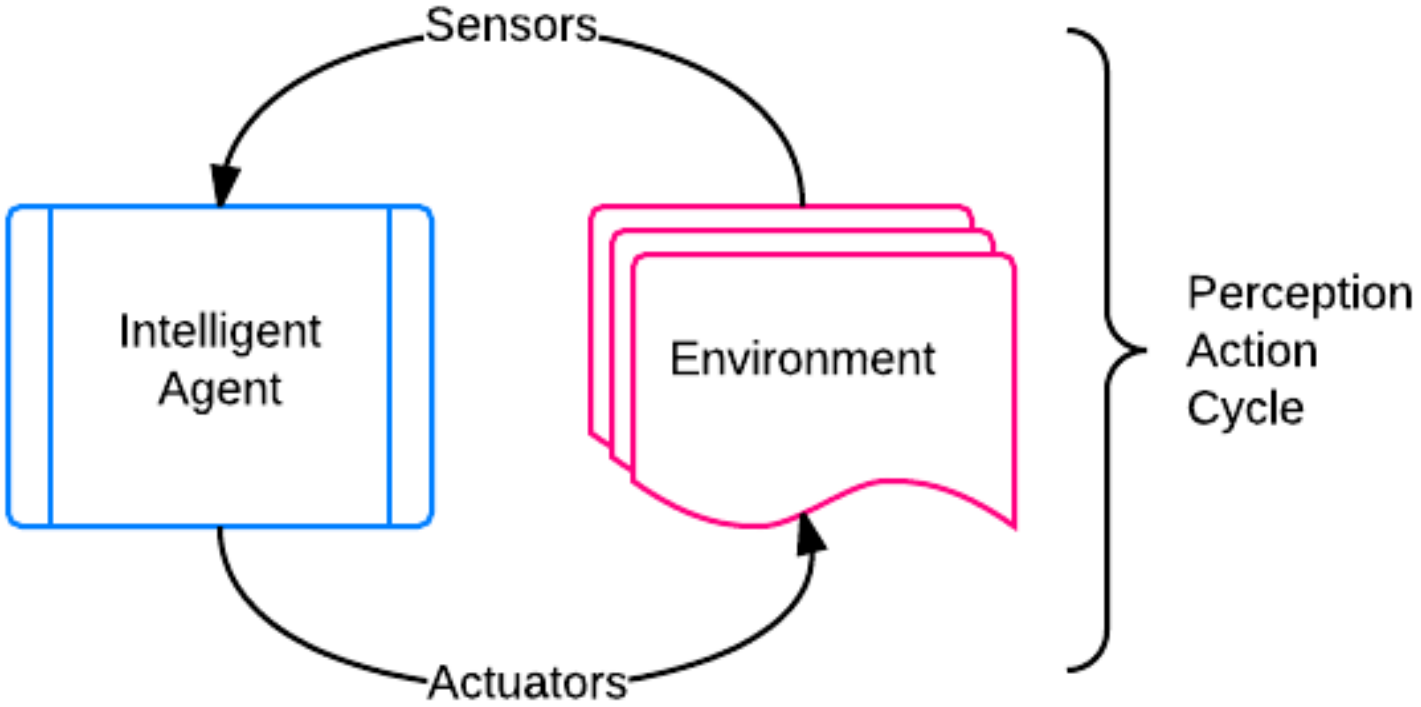
Intelligent Agent



Sensor and actuators

- An agent perceives its environment through sensors
  - The complete set of inputs at a given time is called a percept
  - The current percept or Sequence of percepts can influence the action of an agent
- It can change the environment through actuators/ effectors
  - An operation involving an actuator is called an action
  - Action can be grouped into action sequences

Structure of an AI Agent

- An agent program which implements the agent function. The structure of an intelligent agent is a combination of architecture and agent program. It can be viewed as:

  Agent = Architecture + Agent program

- Following are the main three terms involved in the structure of an AI agent:

  - **Architecture:** Architecture is machinery that an AI agent executes on.
  - **Agent Function:** Agent function is used to map a percept to an action.

    $f: P^* \rightarrow A$

  - **Agent program:** Agent program is an implementation of agent function. An agent program executes on the physical architecture to produce function f.

PEAS Representation

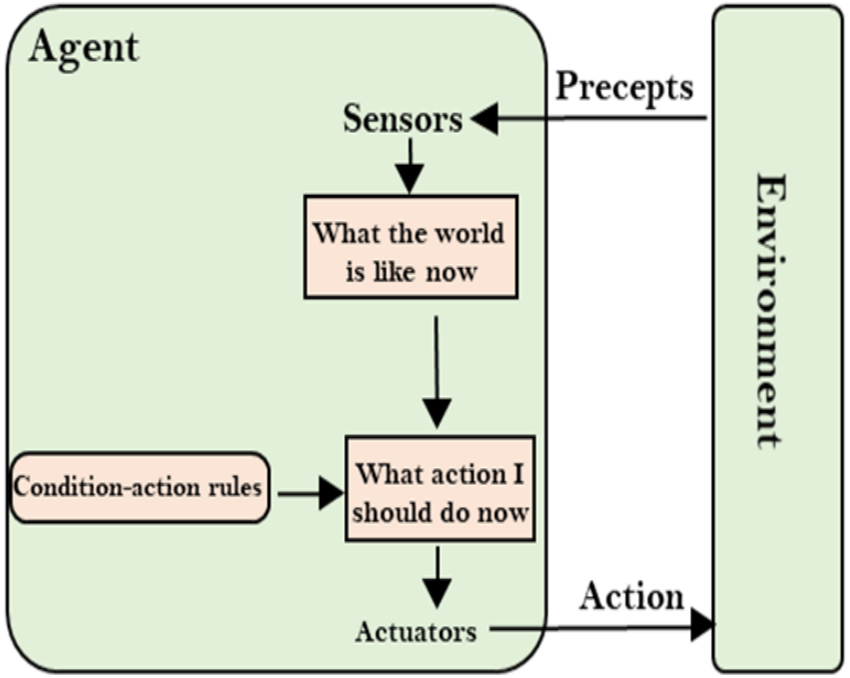
- PEAS is a type of model on which an AI agent works upon.
- When an AI agent or rational agent is defined, then its properties can be under PEAS representation model.
- It is made up of four words:
  - **P:** Performance measure
  - **E:** Environment
  - **A:** Actuators
  - **S:** Sensors
- Performance measure is the objective for the success of an agent's behaviour.

Types of AI Agents

- Simple Reflex Agent
- Model-based reflex agent
- Goal-based agents
- Utility-based agent
- Learning agent

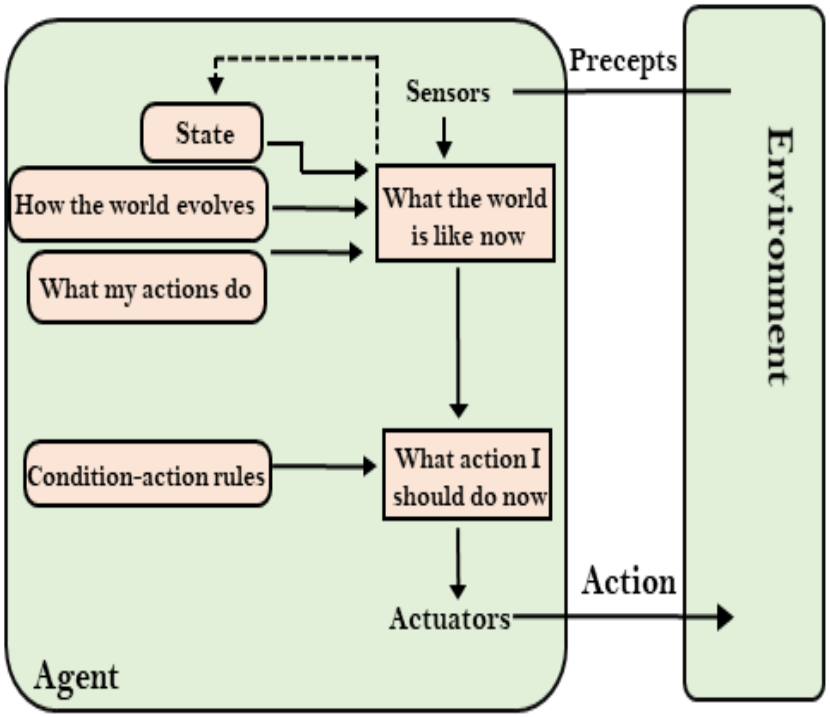
Simple Reflex Agent

- Choose actions only based on the current percept.
- Rational only if a correct decision is made only on the basis of current precept.
- Their environment is completely observable.
- Condition-Action Rule – It is a rule that maps a state (condition) to an action.



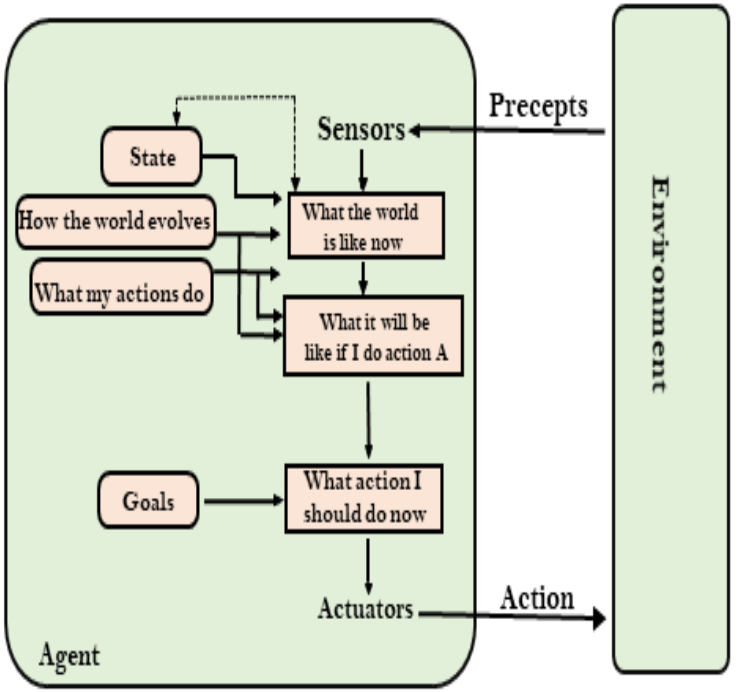
Model-based reflex agent

- A model of the world to choose their actions. They maintain an internal state.
- Model − knowledge about "how the things happen in the world".
- Internal State − It is a representation of unobserved aspects of current state depending on percept history.
- Updating the state requires the information about −
  - How the world evolves.
  - How the agent's actions affect the world.



Goal-based agents

- Choose their actions in order to achieve goals.
- Goal-based approach is more flexible than reflex agent since the knowledge supporting a decision is explicitly modelled, thereby allowing for modifications.
- Goal – It is the description of desirable situations.

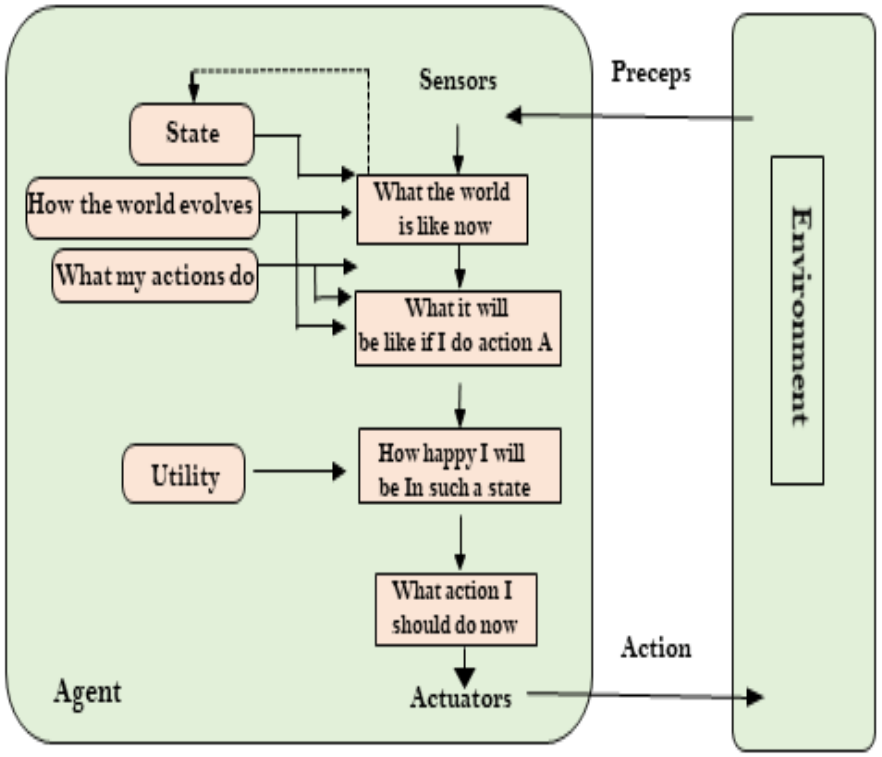


Utility-based agent

- Choose actions based on a preference (utility) for each state.

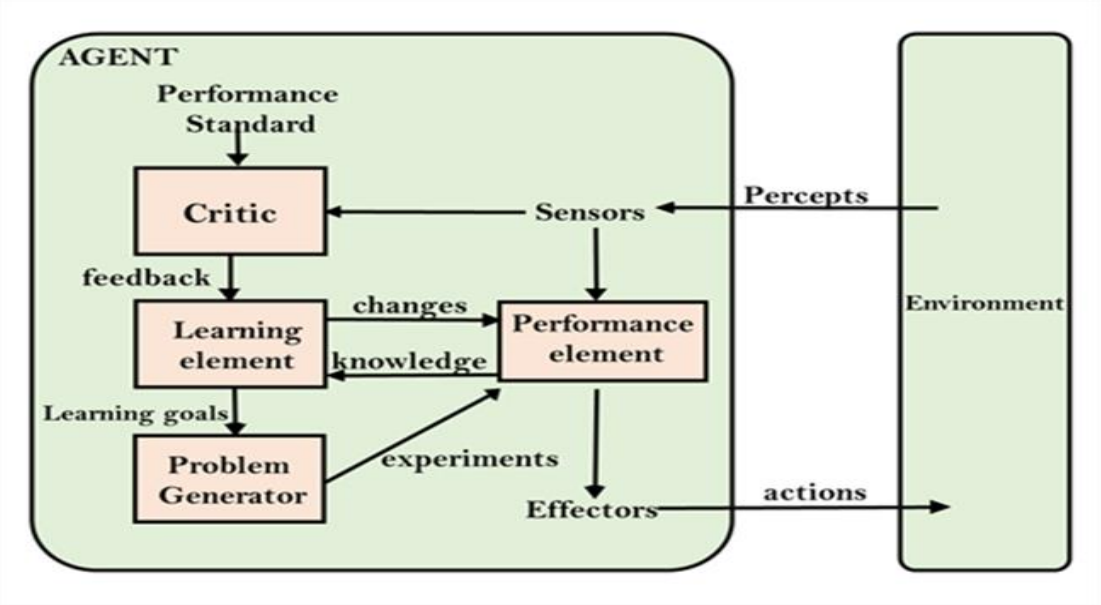
- Goals are inadequate when –
- There are conflicting goals, out of which only few can be achieved.

- Goals have some uncertainty of being achieved and you need to weigh likelihood of success against the importance of a goal.



Learning agent

- A learning agent in AI is the type of agent which can learn from its past experiences, or it has learning capabilities.
- It starts to act with basic knowledge and then able to act and adapt automatically through learning.



- A learning agent has mainly four conceptual components, which are:
  - **Learning element:** It is responsible for making improvements by learning from environment
  - **Critic:** Learning element takes feedback from critic which describes that how well the agent is doing with respect to a fixed performance standard.
  - **Performance element:** It is responsible for selecting external action.
  - **Problem generator:** This component is responsible for suggesting actions that will lead to new and informative experiences.

Related Terminology

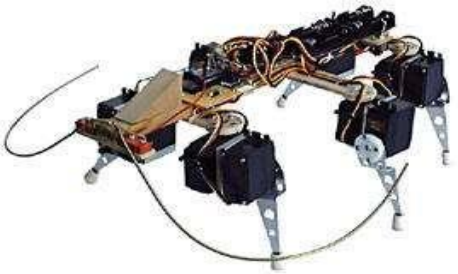
- **Performance Measure of Agent** – It is the criteria, which determines how successful an agent is.
- **Behavior of Agent** – It is the action that agent performs after any given sequence of percepts.
- **Percept** – It is agent's perceptual inputs at a given instance.
- **Percept Sequence** – It is the history of all that an agent has perceived till date.
- **Agent Function** – It is a map from the precept sequence to an action.

Characteristics of an Intelligence Agent

- Must sense
- Must act
- Must autonomous (to some extend)
- Must rational

Examples of Agents

```
Else
    If (Len(Trim$(str
        blnFileNext =
    Else
        ' Process data
        intColon = InSt
        If (intColon
            strName =
            strValue =
            strName = S
            Call xnNod
        End If
    End If
End If
```



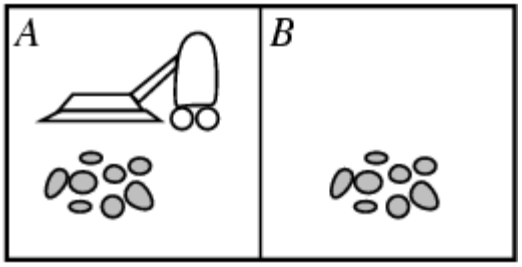
Examples of Agents

- Human agent: eyes, ears, and other organs for sensors;
  - hands, legs, mouth, and other body parts for actuators

- Robotic agent: cameras and infrared range finders for sensors;
  - various motors, wheels, and speakers for actuators

- A software agent: function (Input) as sensors
  - function as actuators (output-Screening)

Homework
Vacuum-Cleaner World



- **Percepts:** location and contents, e.g., [A,Dirty]
- **Actions:** *Left*, *Right*, *Suck*, *NoOp*

A vacuum-cleaner agent

A vacuum-cleaner agent

Percept sequence	Action
$[A, Clean]$	$Right$
$[A, Dirty]$	$Suck$
$[B, Clean]$	$Left$
$[B, Dirty]$	$Suck$
$[A, Clean], [A, Clean]$	$Right$
$[A, Clean], [A, Dirty]$	$Suck$
⋮	⋮

```
function REFLEX-VACUUM-AGENT([location,status]) returns an action
    if status = Dirty then return Suck
    else if location = A then return Right
    else if location = B then return Left
```

What is the **right** function?
Can it be implemented in a small agent program?

Problem state spaces

- A Problem is the issue which comes across any system. A solution is needed to solve that particular problem.

- Technically, a **problem** is defined by its '*elements*' and their '*relations*'.
- To provide a formal description of a problem, we need to understand the following terms:

  a. Define a ***state space*** that contains all the possible configurations of the relevant objects, including some impossible ones.

  b. Specify one or more states that describe possible situations, from which the problem solving process may start. These states are called ***initial states***.

  c. Specify one or more states that would be acceptable solution to the problem. These states are called ***goal states***.

Examples of Problems in Artificial Intelligence

- The most prevalent problems that artificial intelligence has resolved are the following:
  - Chess
  - N-Queen problem
  - Tower of Hanoi Problem
  - Travelling Salesman Problem
  - Water-Jug Problem

Some Real World Problems

- The real world problems that artificial intelligence has resolved are the following:
  - Route-finding problems
  - Touring problems
  - VLSI layout problem
  - Robot navigation
  - Automatic assembly sequencing
  - Internet searching
  - Speech Recognition System etc.

An Example

- Scenario:

  You want to go on holiday to city ‘A’ but currently you live in city ‘B’ And the flight for ‘A’ leaves from another city ‘C’.

- Goal:
  - To reach city ‘C’ from ‘B’ to catch the flight for ‘A’.

An Example:

- Scenario:
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- Formulate Problem:
  - States: various cities
  - Action: movement between the cities

An Example

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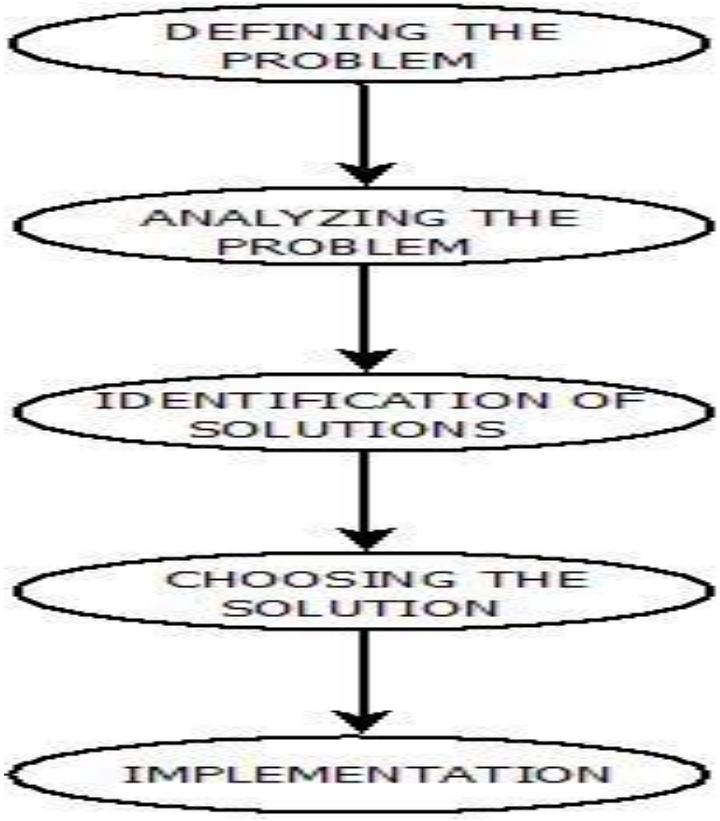
- Goal:
  - To reach city ‘C’ from ‘B’ to catch the flight for ‘A’.
- Formulate Problem
  - States: various cities
  - Action: movement between the cities
- Solution
  - Appropriate sequence of the cities.
  - Say, B->X->Y->Z->C

Problem Solving

- Problem-solving is commonly known as the method to reach the desired goal or finding a solution to a given situation.
- In computer science, problem-solving refers to artificial intelligence techniques, including various techniques such as:
  - forming efficient algorithms,
  - heuristics, and
  - performing root cause analysis to find desirable solutions.

Steps in Problem Solving in AI



Steps in Problem Solving in AI

- **Goal Formulation:** It is the first and simplest step in problem-solving. It organizes the steps/sequence required to formulate one goal out of multiple goals as well as actions to achieve that goal. Goal formulation is based on the current situation and the agent's performance measure (discussed below).

- **Problem Formulation:** It is the most important step of problem-solving which decides what actions should be taken to achieve the formulated goal.

- There are following five components involved in problem formulation:
  - **Initial State:** It is the starting state or initial step of the agent towards its goal.
  - **Actions:** It is the description of the possible actions available to the agent.
  - **Transition Model:** It describes what each action does.
  - **Goal Test:** It determines if the given state is a goal state.
  - **Path cost:** It assigns a numeric cost to each path that follows the goal. The problem-solving agent selects a cost function, which reflects its performance measure. Remember, **an optimal solution has the lowest path cost among all the solutions.**

Problem space

- A ***'problem space'*** is an abstract space.
- A problem space encompasses all *valid states* that can be generated by the application of any combination of *operators* on any combination of *objects*.
- The problem space may contain one or more *solutions*. A solution is a combination of *operations/actions* and *objects* that achieve the *goals*.

State Space Search

A state space consists of:

- A representation of the *states* the system can be in.
- A set of *operators* that can change one state into another state. In a board game, the operators are the legal moves from any given state. Often the operators are represented as programs that change a state representation to represent the new state.
- An *initial state*.
- A set of *final states*; some of these may be desirable, others undesirable.
- This set is often represented implicitly by a program that detects terminal states.

State Space Search

- A *state space* represents a problem in terms of *states* and *operators* that change states.

  S:{S ,A, Action(S),Result(S,A),Cost(S,A)}

- Where
  - S- start, goal state.
  - A-set of possible actions.
  - Action(S)- the action performed from the set of states.
  - Result(S,A)- Final sate
  - Cost(S,A) – A constant value either in terms of time or distance.

Measuring problem-solving performance

- Measures of Performance:
  - Completeness: Is a solution found if one exists?
  - Optimality: Does the strategy find the optimal solution?
  - Time Complexity: How long does it take to find a solution?
  - Space Complexity: How much memory is needed to perform the search?
- Time and space complexity are measured in terms of problem difficulty defined by:
  - b - branching factor of the search tree.
  - d - depth of the shallowest goal node.
  - m - maximum length of any path in the state space.

Water jug Problem in AI

- In this problem, we use two jugs called **four** and **three;** four holds a maximum of four gallons of water and **three** a maximum of three gallons of water. How can we get two gallons of water in the **four** jug?

Water jug Problem in AI

- The start state is (0, 0) and the goal state is (2, n) where n may be any but it is limited to **three** holding from 0 to 3 gallons of water or empty. Three and four shows the name and numerical number shows the amount of water in jugs for solving the water jug problem. The major production rules for solving this problem are shown below:

Water jug Problem in AI

- Production Rules:

1.(x,y)=(4,y)

2.(x,y)=(x,3)

3.(x,y)=(x-d,y) if x>0

4.(x,y)=(x,y-d) if y>0

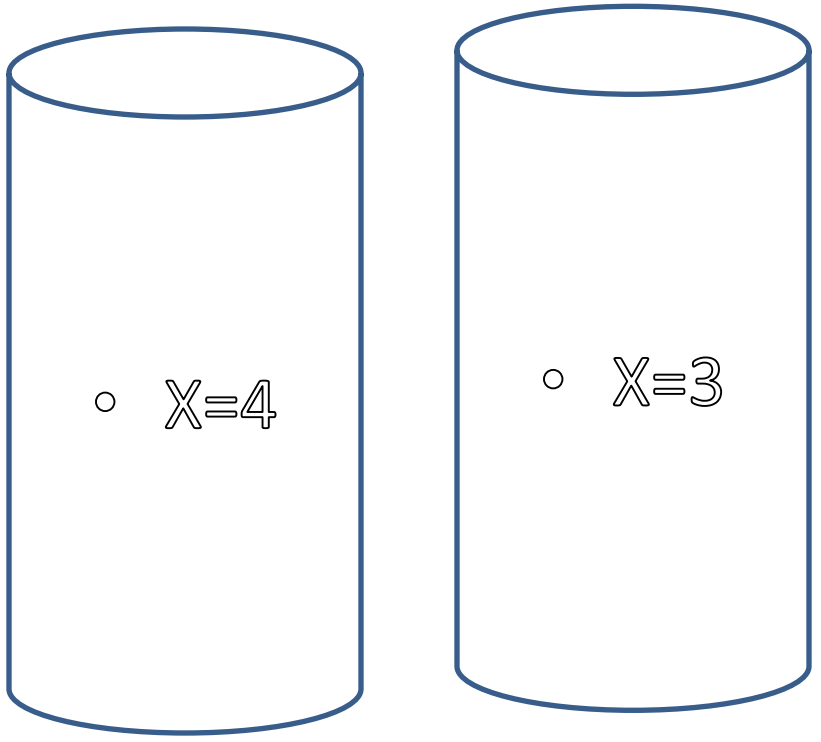
5.(x,y)=(0,y) if x>0

6.(x,y)=(x,0) if y>0

7.(x,y)= (4,y-(4-x)) if y>0

8.(x,y)=(x-(3-y),3) if x>0

9.(x,y)=(x+y,0) , if x+y<=4,y>0



Solution of Water jug Problem in AI

x	y	Rule
0	0	-
0	3	2
3	0	8
3	3	2
4	2	6
0	2	5
2	0	9

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Practice Question

Eight puzzle (8-Puzzle) problem

Eight puzzle (8-Puzzle) problem

- The 8-puzzle is a 3 × 3 array containing eight square pieces, numbered 1 through 8, and one empty space. A piece can be moved horizontally or vertically into the empty space, in effect exchanging the positions of the piece and the empty space. There are four possible moves, UP (move the blank space up), DOWN, LEFT and RIGHT. The aim of the game is to make a sequence of moves that will convert the board from the start state into the goal state:

Eight puzzle (8-Puzzle) problem

1	2	3
4	8	---
7	6	5

Initial state

1	2	3
4	5	6
7	8	---

Goal state

THANK YOU