B.S. Abdur Rahman ™ Crescent Institute of Science & Technology

CSD 3102 - ARTIFICIAL INTELLIGENCE TECHNIQUES

III YEAR CSE, CS & IoT

COURSE OBJECTIVES:

COB1: To give appropriate Artificial Intelligence methods to solve a given problem.

COB2: To learn the different search strategies in AI.

COB3: To introduce the facts and concepts of computational model and their applications.

COB4: To provide a planning strategy for real time problems.

COB5: To introduce the concepts of Expert Systems.

COURSE OUTCOMES:

CO1:Solve basic AI based problems.

CO2:Apply AI techniques to real-world problems and develop intelligent systems.

CO3:Implement basic principles of AI in solutions that require problem solving, inference, perception, knowledge representation, and learning.

CO4:Design and implement AI planning systems.

CO5:Develop good evaluation functions and strategies for game playing and expert systems using fuzzy logic

TEXT BOOKS:

1.Stuart Russell and Peter Norvig., “Artificial Intelligence - A Modern Approach”, Prentice Hall Publishers, 4th edition, ISBN-13 : 978- 1292401133, 2021.

REFERENCES:

1.Kevin Night and Elaine Rich, Nair B., “Artificial Intelligence”, Mc Graw Hill Education, 3rd edition, ISBN-13 : 978-0070087705, 2017.

2.Parag Kulkarni, Prachi Joshi, “Artificial Intelligence –Building Intelligent Systems”, PHI learning private Ltd, 1st edition, ISBN-13 : 978-8120350465, 2015.

3.Deepak Khemani “Artificial Intelligence”, Mc Graw Hill Education, ISBN-13 : 978-1259029981, 2017.

MODULE I INTRODUCTION 9

Introduction to Artificial Intelligence(AI) - History of AI- AI Techniques - Problem Solving with AI - AI models - Data Acquisition and Learning Aspects in AI - Problem-Solving Process - Formulating Problems - Problem Types and Characteristics - Problem Analysis and Representation - Performance Measuring - Problem Space and Search - Toy Problems - Real-world problems - Problem Reduction Methods.

COURSE OBJECTIVE- COB1: To give appropriate Artificial Intelligence methods to solve a given problem.

COURSE OUTCOME- CO1:Solve basic AI based problems.

What is AI?

"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models" (Charniak+McDermott, 1985)
"The study of how to make computers do things at which, at the moment, people are better" (Rich+Knight, 1991)	"The branch of computer science that is concerned with the automation of intelligent behavior" (Luger+Stubblefield, 1993)

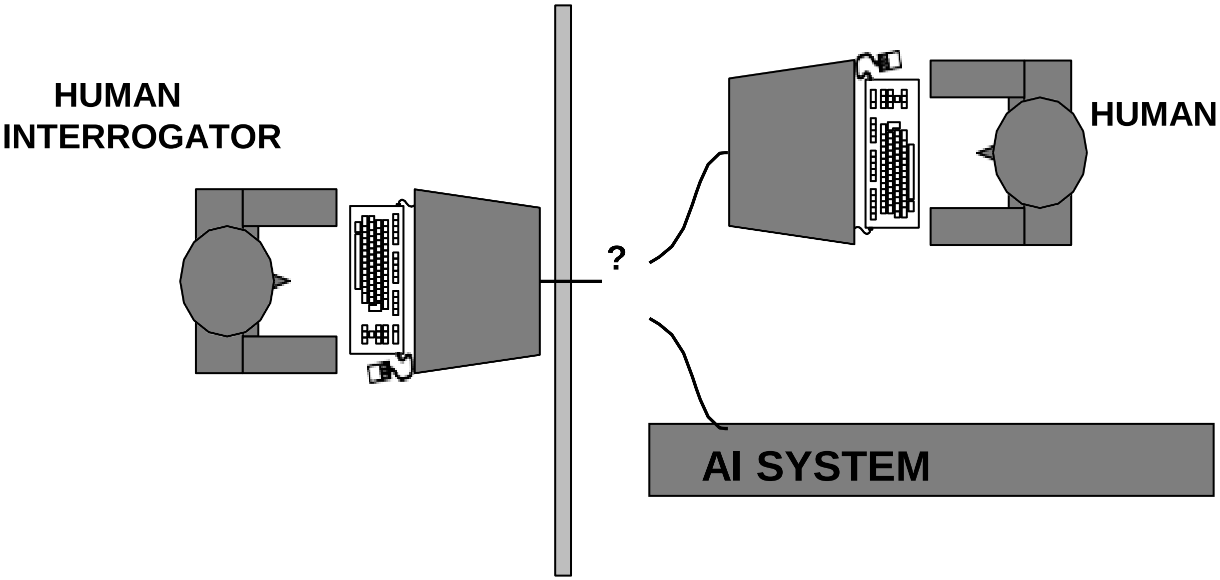
Views/Approaches of AI fall into four categories:

Thinking humanly	Thinking rationally
Acting humanly	Acting rationally

Examining these, we will plump for acting rationally (sort of)

Acting humanly: The Turing test

- The **Turing Test**, proposed by Alan Turing (Turing, 1950), was designed to provide a satisfactory operational definition of intelligence.
- Turing defined intelligent behavior as the ability to achieve human-level performance in all cognitive tasks, sufficient to fool an interrogator.
- Roughly speaking, the test he proposed is that the computer should be interrogated by a human via a teletype, and passes the test if the interrogator cannot tell if there is a computer or a human at the other end. Programming a computer to pass the test provides plenty to work on.



Versions of the Turing test : *Imitation Game*

- The computer would need to possess the following capabilities:
- **Natural language processing** to enable it to communicate successfully in English (or some other human language);
- **Knowledge representation** to store information provided before or during the interrogation;
- **Automated reasoning** to use the stored information to answer questions and to draw new conclusions;
- **Machine learning** to adapt to new circumstances and to detect and extrapolate patterns.

Turing's test deliberately avoided direct physical interaction between the interrogator and the computer, because *physical* simulation of a person is unnecessary for intelligence. However, the so-called **total Turing Test** includes a video signal so that the interrogator can test the subject's perceptual abilities, as well as the opportunity for the interrogator to pass physical objects ``through the hatch." To pass the total Turing Test, the computer will need

- **computer vision** to perceive objects, and
- **robotics** to move them about.

Thinking humanly: Cognitive Science

- Thinking humanly is to make a system or program to think like a human. But to achieve that, we need to know how does a human thinks.
- We can interpret how the human mind thinks in theory, in three ways as follows:
  1. **Introspection method** – Catch our thoughts and see how it flows.
  2. **Psychological Inspections method** – Observe a person on the action.
  3. **Brain Imaging method** (MRI (Magnetic resonance imaging) or fMRI (Functional Magnetic resonance imaging) scanning) – Observe a person's brain in action.
- Allen Newell and Herbert Simon developed the General Problem Solver (GPS) program to model human thinking and check whether it can solve problems like a person by following the same reasoning steps as a human.
- The intent of the program is not just to solve the problem correctly but to go through the same series of steps as that of a human brain to solve it.
- Thinking human goal is to develop modern computational models and intelligent devices to think like a human and those models help humans to solve complex problems.

Thinking rationally: Laws of Thought

Normative (or prescriptive) rather than descriptive

Aristotle (~ 450 B.C.) attempted to codify "right thinking"

What are correct arguments/thought processes?

E.g., "Socrates is a man, all men are mortal; therefore Socrates is mortal"

Another example – All TVs use energy; Energy always generates heat; therefore, all TVs generate heat."

Several Greek schools developed various forms of logic: notation plus rules of derivation for thoughts.

Thinking rationally: Laws of Thought

- The Greek philosopher Aristotle was the one who first codifies “right-thinking” reasoning processes.
- Aristotle’s syllogisms provided patterns for argument structures that always provide correct premises.
- **Laws of thought**, traditionally, the three fundamental laws of logic:

(1) the law of contradiction,

(2) the law of excluded middle(or third), and

(3) the principle of identity.

Thinking Rationally: Laws of Thought

<u>Problems:</u>

1) Uncertainty: Not all facts are certain (e.g., *the flight might be delayed).*

1) Resource limitations:
   - Not enough time to compute/process
   - Insufficient memory/disk/etc
   - Etc.

Acting rationally - Rational Agent Approach

Rational behavior: doing the right thing
The right thing: that which is expected to maximize goal achievement, given the available information

Provides the most general view of AI because it includes:
- Correct inference (“Laws of thought”)
- Uncertainty handling
- Resource limitation considerations (e.g., reflex vs. deliberation)
- Cognitive skills (NLP, AR, knowledge representation, ML, etc.)

Advantages:
1) More general
2) Its goal of rationality is well defined

Rational agents

An agent is an entity that perceives and acts

This course is about designing rational agents

Abstractly, an agent is a function from percept histories to actions:

$f : P^* \rightarrow A$

For any given class of environments and tasks, we seek the agent (or class of agents) with the best performance

AI prehistory

Philosophy logic, methods of reasoning mind as physical system

Mathematics foundations of learning, language, rationality
formal representation and proof algorithms
computation, (un)decidability, (in)tractability
probability
adaptation

Psychology phenomena of perception and motor control
experimental techniques (psychophysics, etc.)

Linguistics knowledge representation grammar

Neuroscience physical substrate for mental activity

Control theory homeostatic systems, stability simple optimal agent designs

AI History

1943	McCulloch & Pitts: Boolean circuit model of brain
1950	Turing's "Computing Machinery and Intelligence"
1952–69	Look, Ma, no hands!
1950s	Early AI programs, including Samuel's checkers program, Newell & Simon's Logic Theorist, Gelernter's Geometry Engine
1956	Dartmouth meeting: "Artificial Intelligence" adopted
1965	Robinson's complete algorithm for logical reasoning
1966–74	AI discovers computational complexity Neural network research almost disappears
1969–79	Early development of knowledge-based systems
1980–88	Expert systems industry booms
1988–93	Expert systems industry busts: "AI Winter"
1985–95	Neural networks return to popularity
1988–	Resurgence of probabilistic and decision-theoretic methods Rapid increase in technical depth of mainstream AI "Nouvelle AI": ALife, GAs, soft computing

Site Link: https://sites.google.com/crescent.education/csd3102-ai-techniques/module-1/history-of-ai

State of the art

Which of the following can be done at present?

- ♦Play a decent game of table tennis
- ♦Drive along a curving mountain road
- ♦Drive in the center of Cairo
- ♦Play a decent game of bridge
- ♦Discover and prove a new mathematical theorem
- ♦Write an intentionally funny story
- ♦Give competent legal advice in a specialized area of law
- ♦Translate spoken English into spoken Swedish in real time

Applications of Artificial Intelligence

Details of following Applications

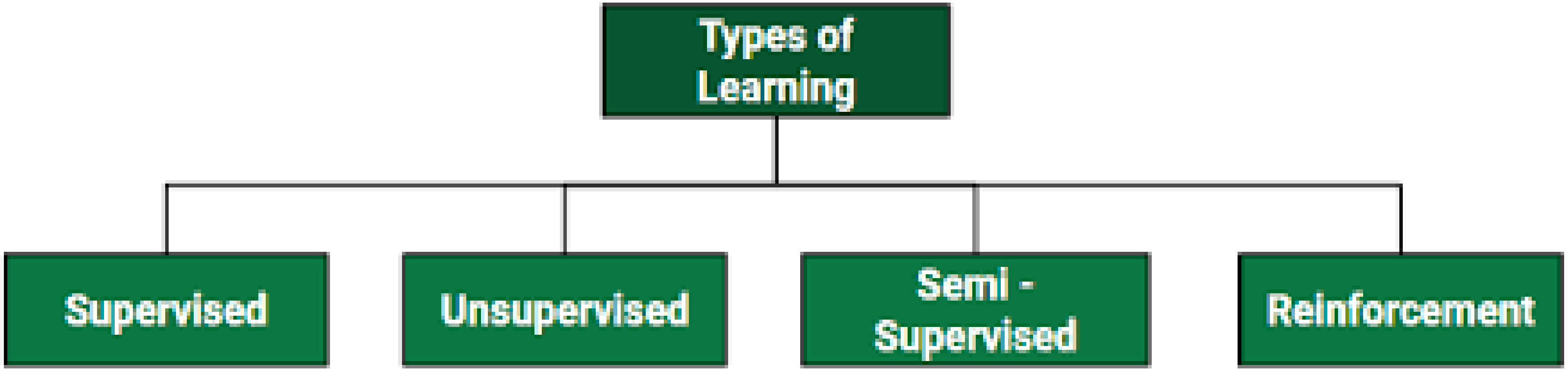
1. Finance
2. Medical
3. Industries
4. Telephone maintenance
5. Telecom
6. Transport
7. Entertainment
8. Pattern Recognition
9. Robotics
10. Data Mining

AI TECHNIQUES

- Artificial Intelligence techniques refer to a set of methods and algorithms used to develop intelligent systems that can perform tasks requiring human-like intelligence. Some of the widely used ones are:

- **Machine Learning**
- **Natural Language Processing**
- **Computer Vision**
- **Deep Learning**
- **Data Mining**
- **Robotics**

MACHINE LEARNING



Machine learning (ML) is defined as a discipline of artificial intelligence (AI) that provides machines the ability to automatically learn from data and past experiences to identify patterns and make predictions with minimal human intervention. This approach involves the building of algorithms to learn patterns in data and make predictions based on it.

1. Unsupervised machine learning -AI systems analyse unlabelled data, where no predefined outcomes are provided. The objective is to uncover inherent structures or patterns within the data without any prior knowledge. For instance, it can group similar customer behaviour data to identify customer segments for targeted marketing strategies.

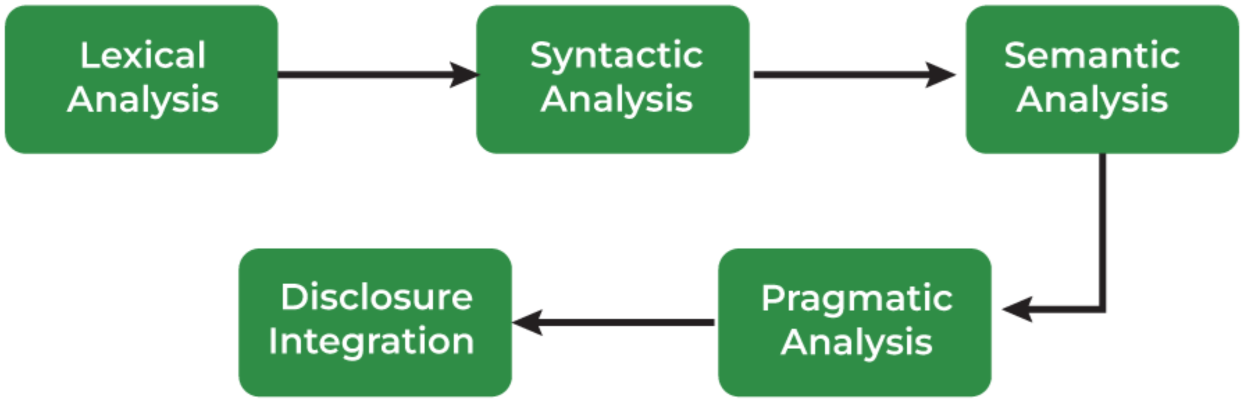
2. Supervised learning – A combination of an input data set and the intended output is inferred from the training data. AI systems learn from a labelled dataset, where each data point is associated with a known outcome. For instance, it enables email spam filters to distinguish between spam and legitimate emails based on learned patterns.

3. Semi-supervised learning – It is a method that uses a small amount of labelled data and a large amount of unlabelled data to train a model. The goal of semi-supervised learning is to learn a function that can accurately predict the output variable based on the input variables, similar to supervised learning. However, unlike supervised learning, the algorithm is trained on a dataset that contains both labelled and unlabelled data.

4. Reinforcement learning – In RL, the data is accumulated from machine learning systems that use a trial-and-error method to learn from outcomes and decide which action to take next. After each action, the algorithm receives feedback that helps it determine whether the choice it made was correct, neutral or incorrect. It performs actions with the aim of maximizing rewards, or in other words, it is learning by doing in order to achieve the best outcomes.

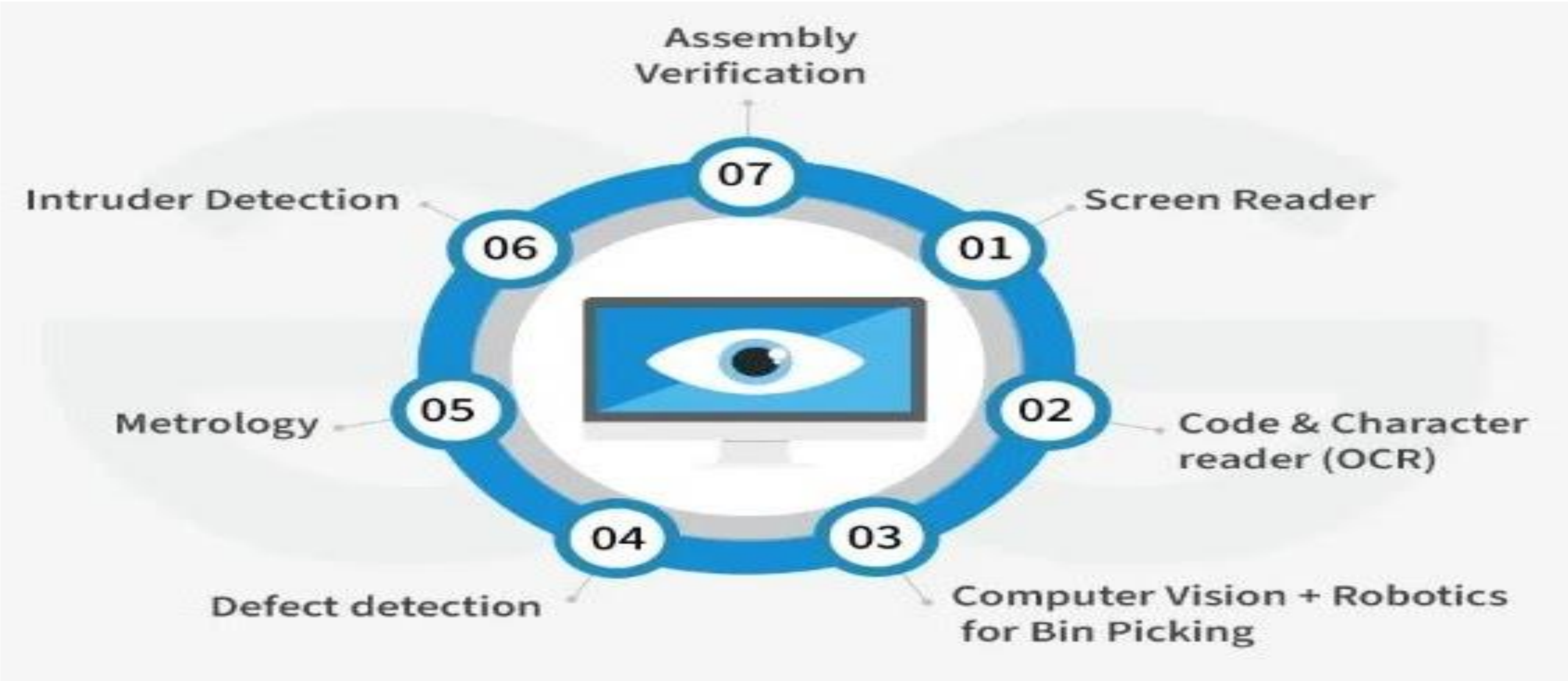
Natural Language Processing

- Natural Language Processing involves programming computers to process human languages to facilitate interactions between humans and computers.
- However, the nature of human languages makes Natural Language Processing difficult because of the rules involved in passing information using natural language.
- NLP leverages algorithms to recognize and abstract the rules of natural languages, converting unstructured human language data into a computer-understandable format.



Computer Vision

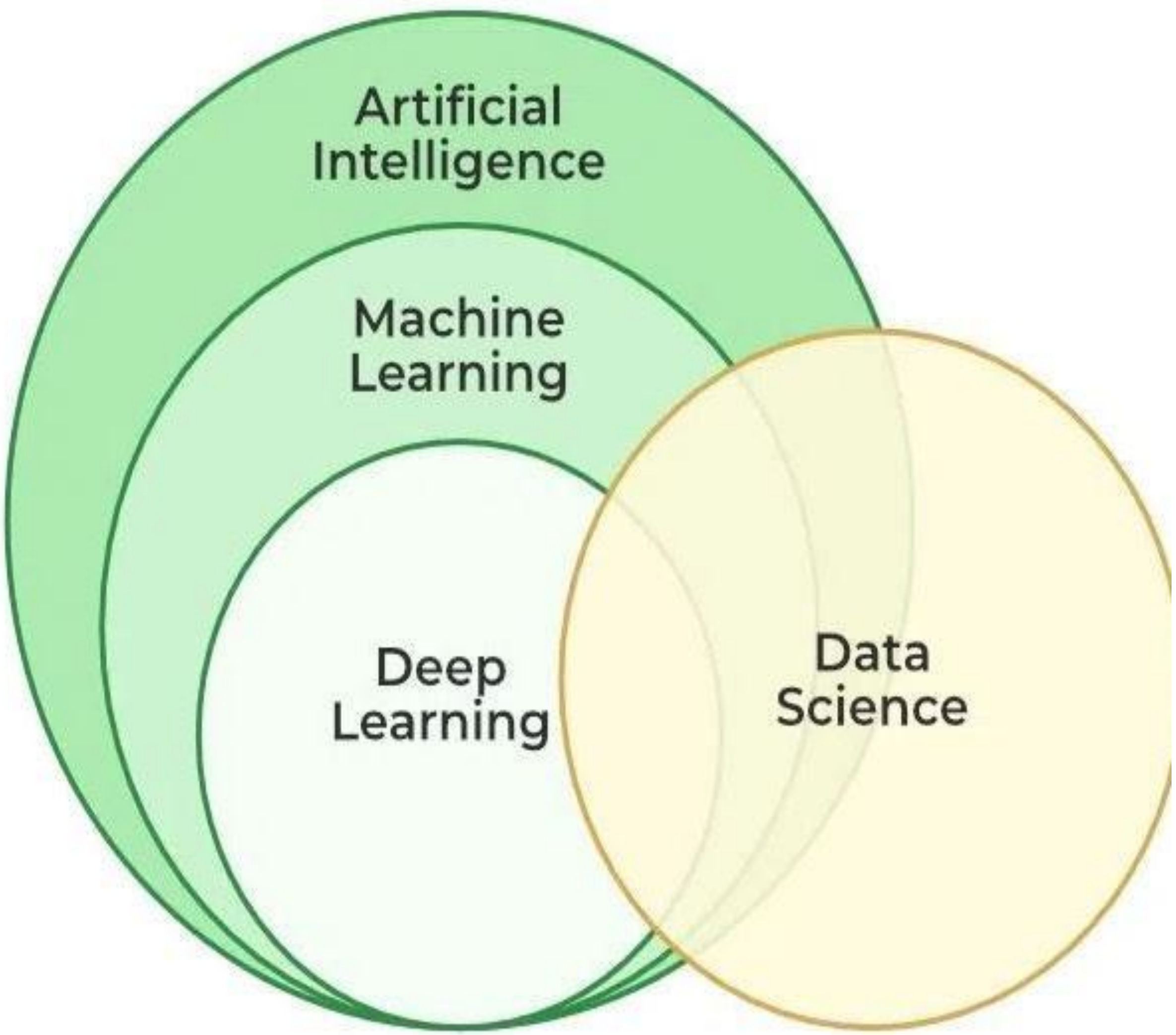
- Computer Vision equips machines with the ability to interpret visual information from the world.
- This technique has revolutionized industries like healthcare, automotive, and robotics, enabling tasks such as facial recognition, object detection, and autonomous driving.
- The extent to which it can discriminate between objects is an essential component of machine vision.



Deep Learning

- Deep learning is the branch of machine learning which is based on artificial neural network architecture. An artificial neural network or ANN uses layers of interconnected nodes called neurons that work together to process and learn from the input data.
- In a fully connected Deep neural network, there is an input layer and one or more hidden layers connected one after the other.
- Each neuron receives input from the previous layer neurons or the input layer.
- The output of one neuron becomes the input to other neurons in the next layer of the network, and this process continues until the final layer produces the output of the network.
- The layers of the neural network transform the input data through a series of nonlinear transformations, allowing the network to learn complex representations of the input data.
- The main applications of deep learning can be divided into computer vision, natural language processing (NLP), and reinforcement learning.

Deep Learning



Data Mining

Data mining is the process of extracting knowledge or insights from large amounts of data using various statistical and computational techniques.

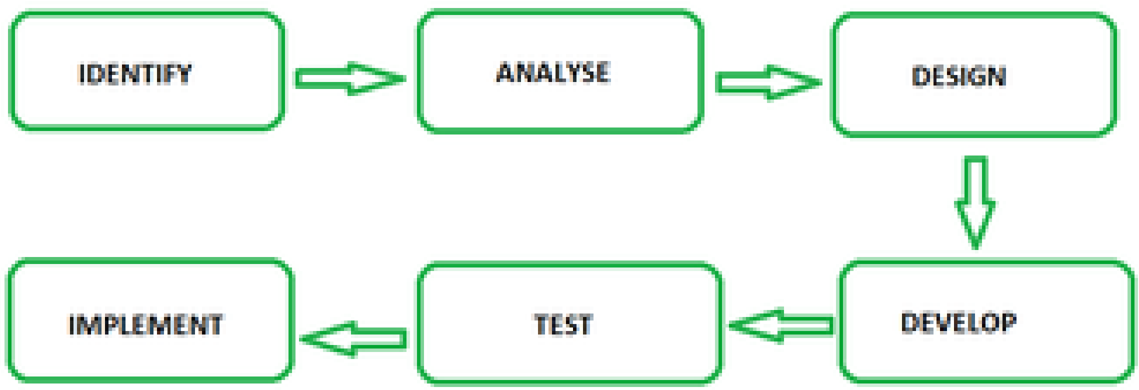
The data can be structured, semi-structured, or unstructured, and can be stored in various forms such as databases, data warehouses, and data lakes.

The primary goal of data mining is to discover hidden patterns and relationships in the data that can be used to make informed decisions or predictions.

This involves exploring the data using various techniques such as clustering, classification, regression analysis, association rule mining, and anomaly detection.

Robotics

- Automation aims to enable machines to perform boring, repetitive jobs, increasing productivity and delivering more effective, efficient, and affordable results.
- To automate processes, many businesses employ machine learning, artificial neural, and graphs.
- By leveraging the CAPTCHA technique, this automation can avoid fraud problems during online payments.
- Robotic process automation is designed to carry out high-volume, repetitive jobs while being capable of adapting to changing conditions.



What is an intelligent agent?

Agent:

- In our daily life, an agent is commonly a person who can do our job usually on some obligation.
- An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors.
- A human agent has eyes, ears, and other organs for sensors, and hands, legs, mouth, and other body parts for effectors.
- A robotic agent substitutes cameras and infrared range finders for the sensors and various motors for the effectors.
- A software agent has encoded bit strings as its percepts and actions; it can produce the square root of any number of any positive number as an example.
- A rational Agent is one which does the things rightly (rationally).

Performance Evaluation of an agent:

- How correctly or efficiently an agent serves to our expectation.
- It could be relative depending on individuals expectations.

Intelligent Agents: Agents which can transform percepts into actions rationally.

Intelligent Agents

- A calculator is also an agent but it provides no intelligence, just a hard core calculation corrected up to maximum possible value. An intelligent agent on the other hand involves capability to take decision not up to perfection like a hard core agent. E.g. diagnosing a patient on the basis of symptoms and predict disease.
- An agent is composed of following two components
- Agent = architecture + program
- An architecture on which an agent resides is a hardware infrastructure like camera, sensors, videos , computer or any machine. A program usually is a software program to control the architecture to initiate agent. An example of a taxi drive agent is below

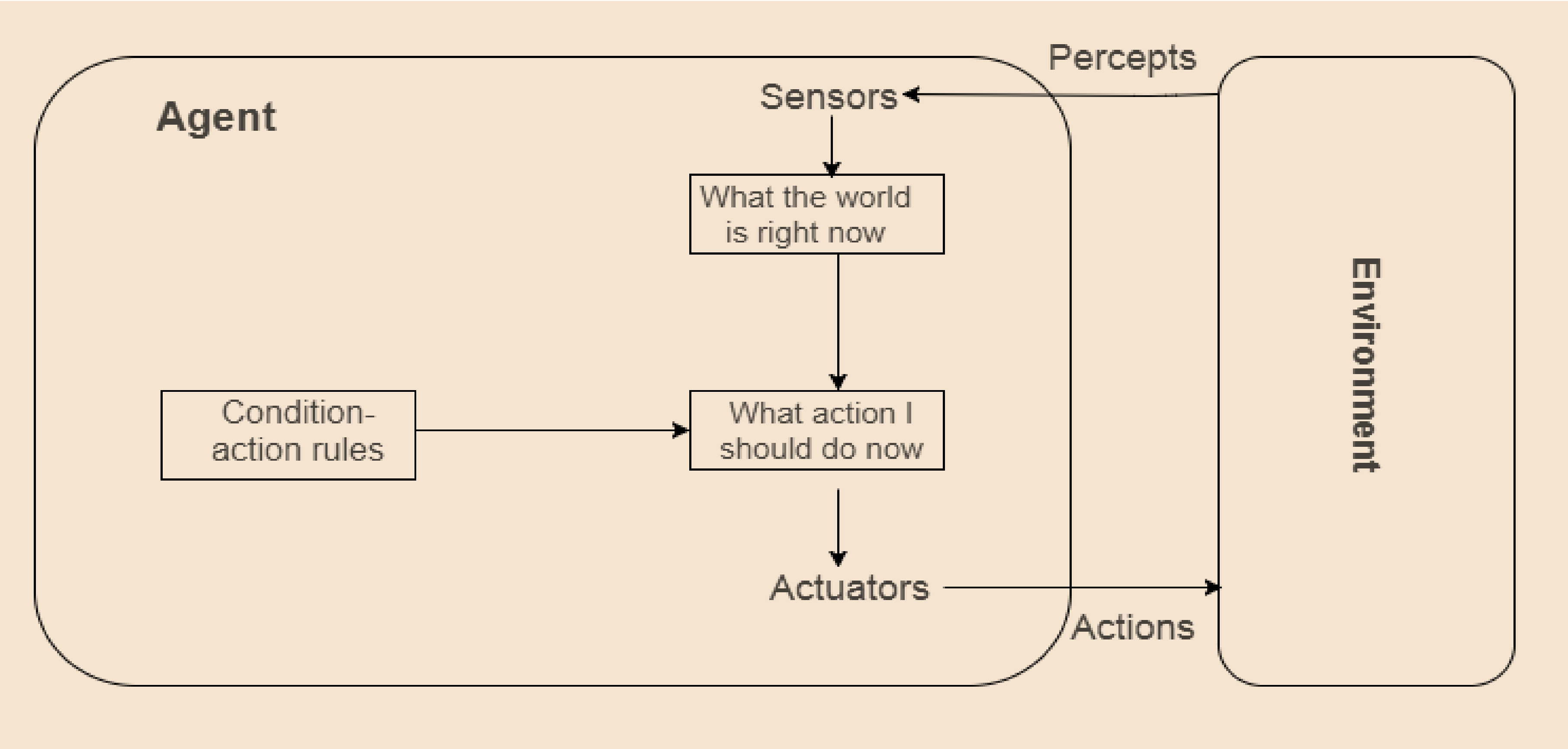
Agent Type	Percepts	Actions	Goals	Environment
Taxi driver	Cameras, speedometer, GPS, sonar, microphone	Steer, accelerate, brake, talk to passenger.	Safe, fast, legal, comfortable trip, maximize profits	Roads, other traffic, pedestrians, customers

Types of agent programs

Simple Reflex Agent: When the actions of nearest object are clearly visible then what response has to be taken.

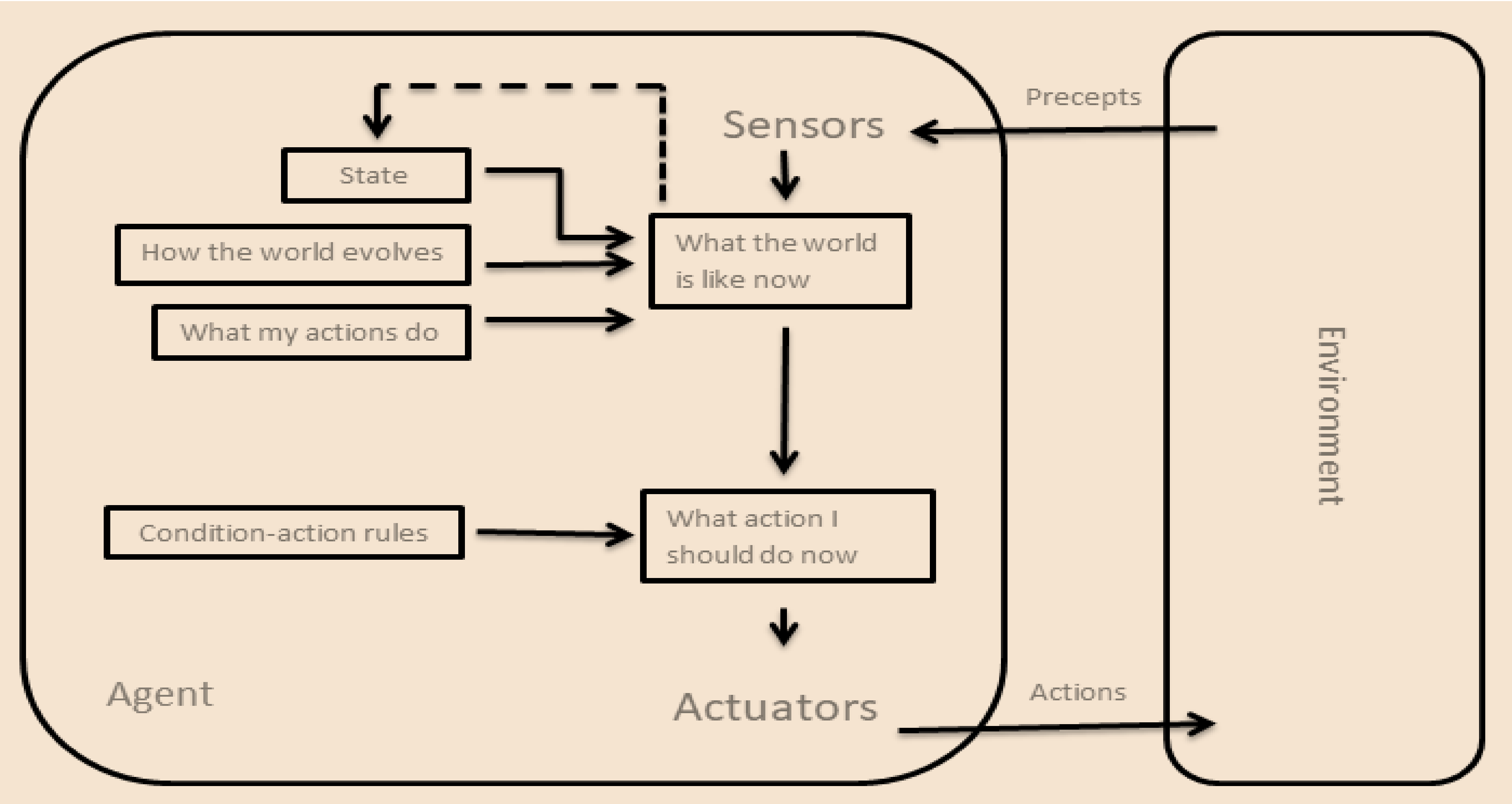
e.g.

If the car going ahead applies brake (as appears from brake lights of the front car), then car following it should also initiate brake. In other words, take a counter action against an action (reaction vs action)



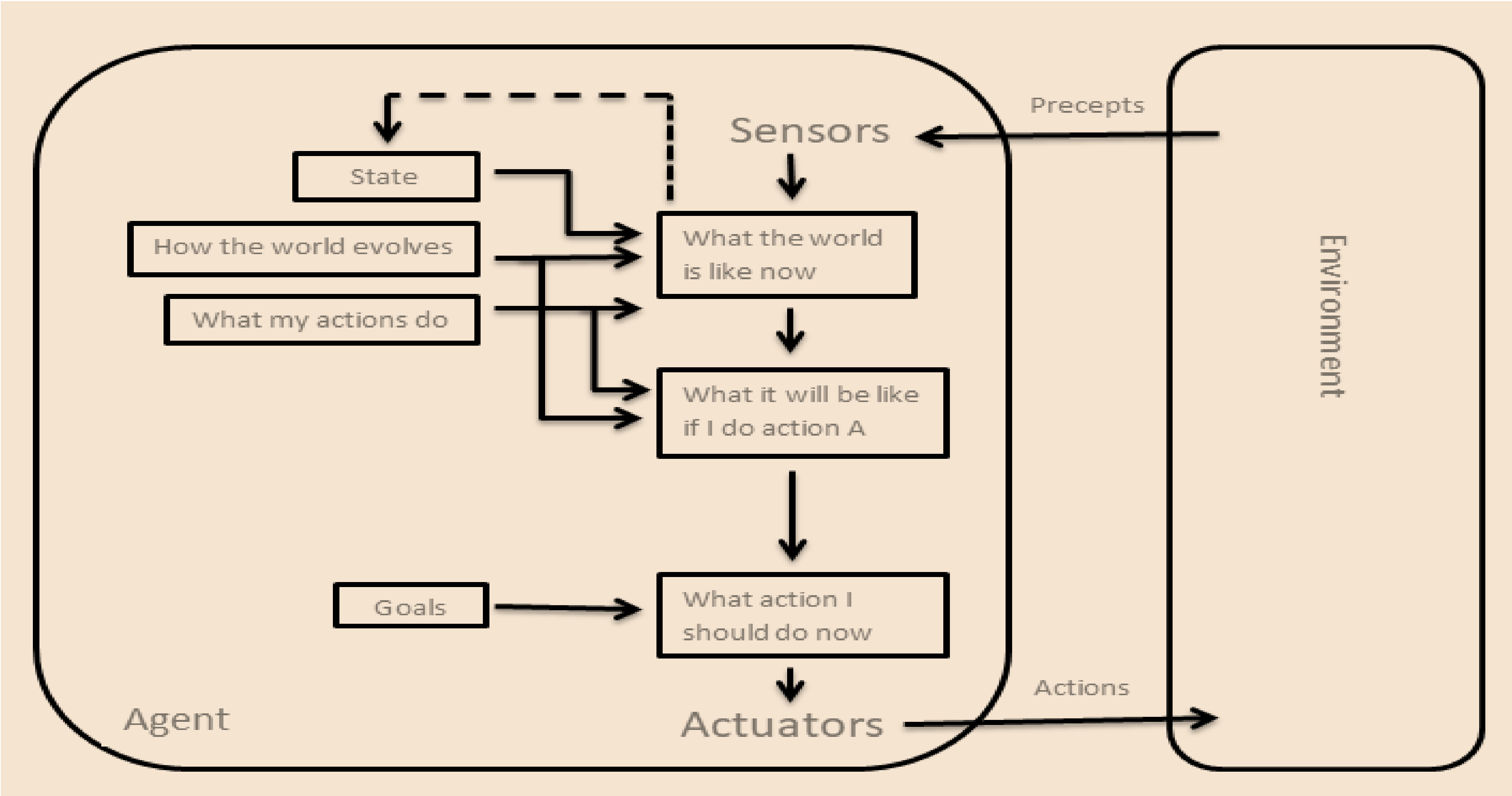
Model-Based Reflex Agents

A model-based agent can handle **partially observable environments** by the use of a model about the world.



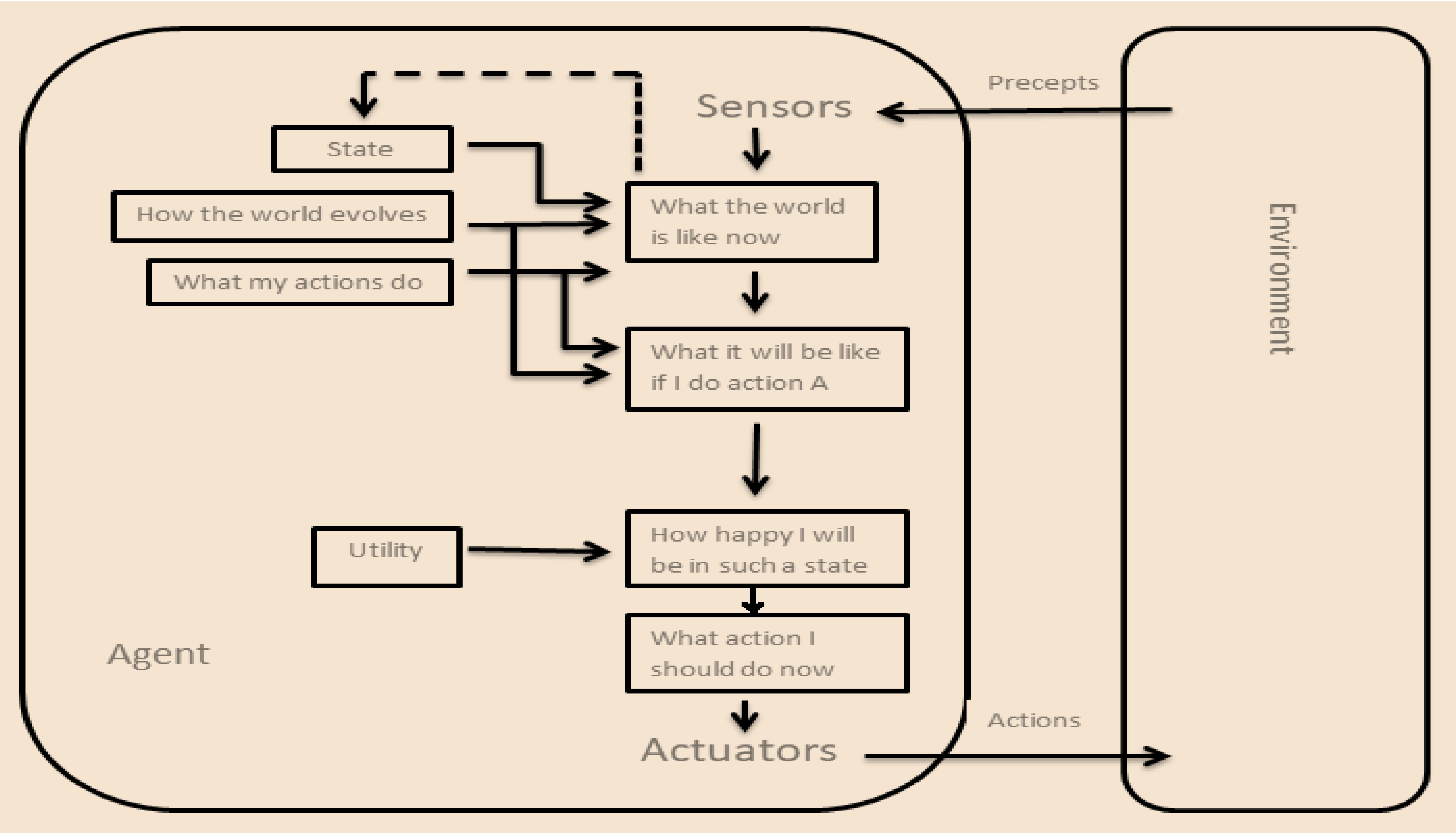
Goal based agents

- The goal should be known to the agent by means of a sequence of actions to follow during operation. E.g. the destination should be known to a taxi driver accordingly paths can be derived.



Utility based agents

- The goal should be achieved with some performance measure set by user. The cost, the degree of comfort, safety could be associated with achieving goals.



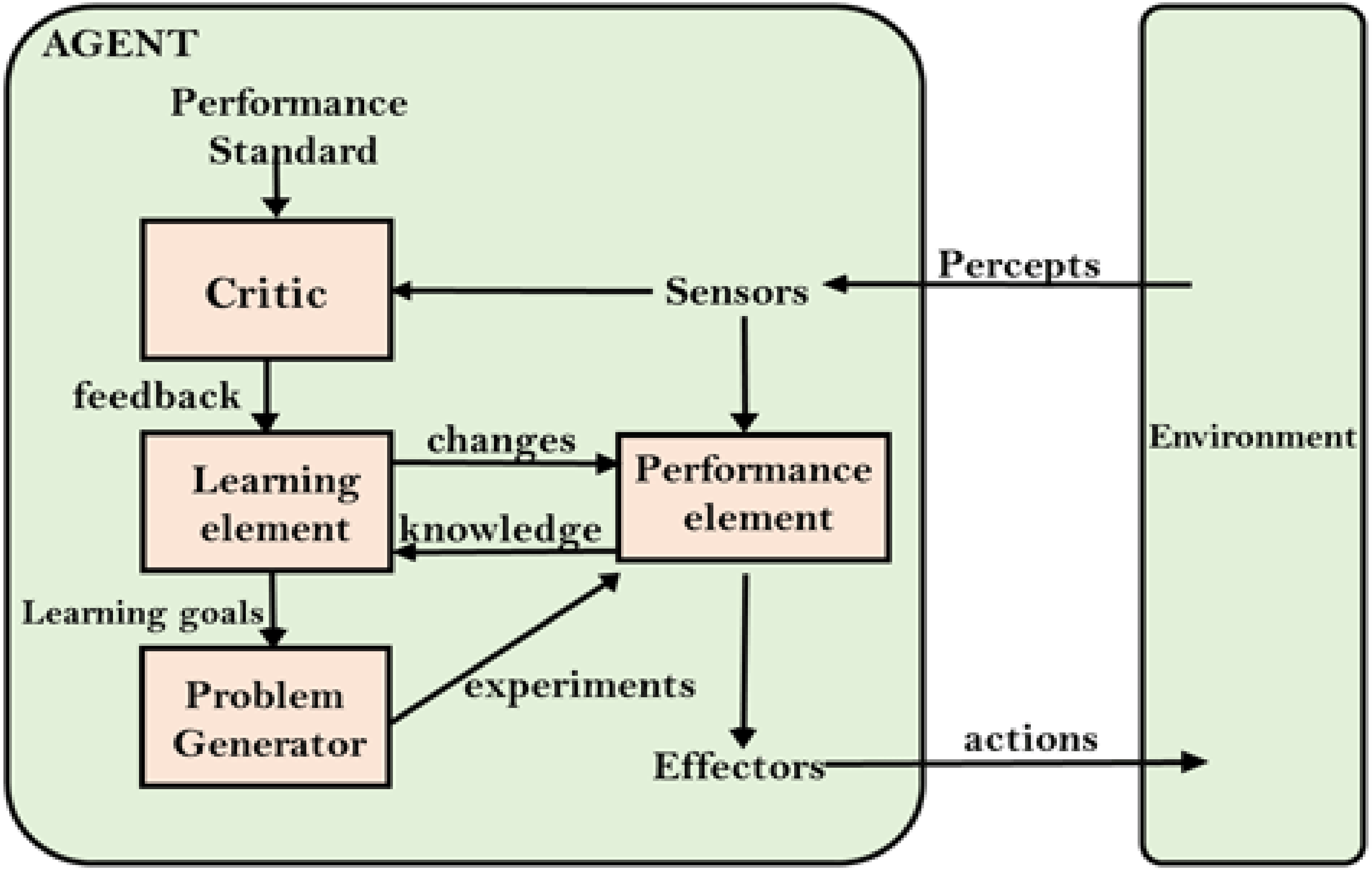
Learning Agent

- The goal should be achieved with some performance measure set by user. The cost, the degree of comfort, safety could be associated with achieving goals.

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

1. **Learning element:** It is responsible for making improvements by learning from the environment.
2. **Critic:** The learning element takes feedback from critics which describes how well the agent is doing with respect to a fixed performance standard.
3. **Performance element:** It is responsible for selecting external action.
4. **Problem Generator:** This component is responsible for suggesting actions that will lead to new and informative experiences.

Learning Agent



Problem Solving with AI

- Artificial intelligence (AI) problem-solving include formulating and ensuring appropriate algorithms, conducting root-cause analysis that identify reasonable solutions, investigating potential solutions to problems through reasoning techniques and achieving objectives or resolve particular situations.
- The reflex agent of AI directly maps states into action.
- Whenever these agents fail to operate in an environment where the state of mapping is too large and not easily performed by the agent, then the stated problem dissolves and sent to a problem-solving domain which breaks the large stored problem into the smaller storage area and resolves one by one.
- The final integrated action will be the desired outcomes.

There are basically three types of problem in artificial intelligence:

1. **Ignorable:** In which solution steps can be ignored.
2. **Recoverable:** In which solution steps can be undone.
3. **Irrecoverable:** Solution steps cannot be undo.

Steps problem-solving in AI: The problem of AI is directly associated with the nature of humans and their activities. So we need a number of finite steps to solve a problem which makes human easy works.

These are the following steps which require to solve a problem :

- **Problem definition:** Detailed specification of inputs as set of rules and acceptable system solutions.
    - a. left side of the rule serves as a pattern.
    - b. Right side of the rule describes the changes to be made.
- **Problem analysis:** Analyze the problem thoroughly.
- **Knowledge Representation:** collect detailed information about the problem and define all possible techniques.
- **Problem-solving:** Selection of best techniques**.**

Problem Formulation

Initial State: This state requires an initial state for the problem which starts the AI agent towards a specified goal. In this state new methods also initialize problem domain solving by a specific class.

Action: Specify the possible actions to transition from one state to another.

Define Constraints: List any limitations or rules.

Transition: This stage of problem formulation integrates the actual action done by the previous action stage and collects the final stage to forward it to their next stage.

Goal test: This stage determines that the specified goal achieved by the integrated transition model or not, whenever the goal achieves stop the action and forward into the next stage to determines the cost to achieve the goal.

Path costing: This component of problem-solving numerical assigned what will be the cost to achieve the goal. It requires all hardware software and human working cost.

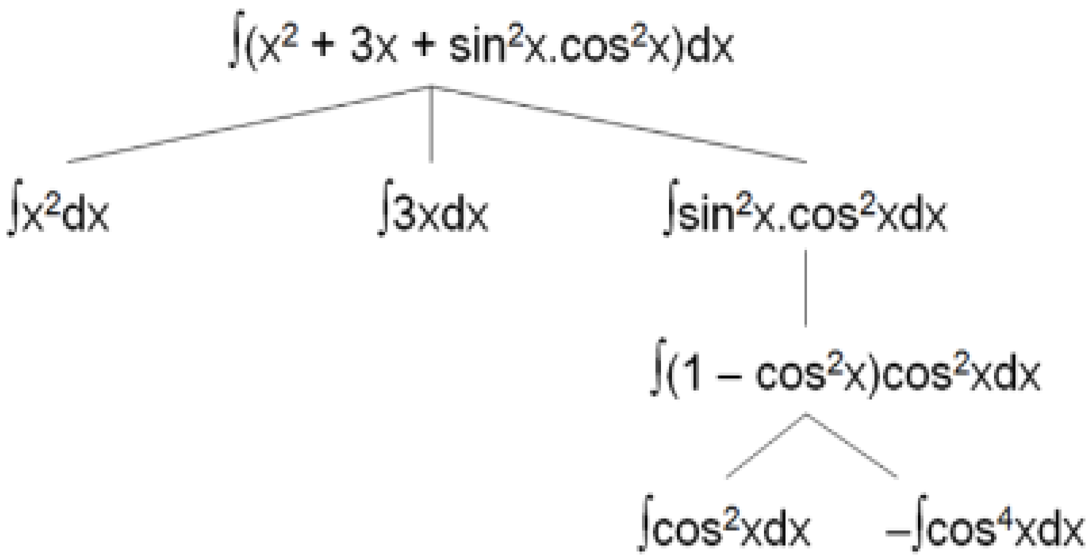
Problem Types and Characteristics

Categorize the problem based on the following characteristics.

- Is the problem decomposable into small sub-problems which are easy to solve?
- Can solution steps be ignored or undone?
- Is the universe of the problem is predictable?
- Is a good solution to the problem is absolute or relative?
- Is the solution to the problem a state or a path?
- What is the role of knowledge in solving a problem using artificial intelligence?
- Does the task of solving a problem require human interaction?

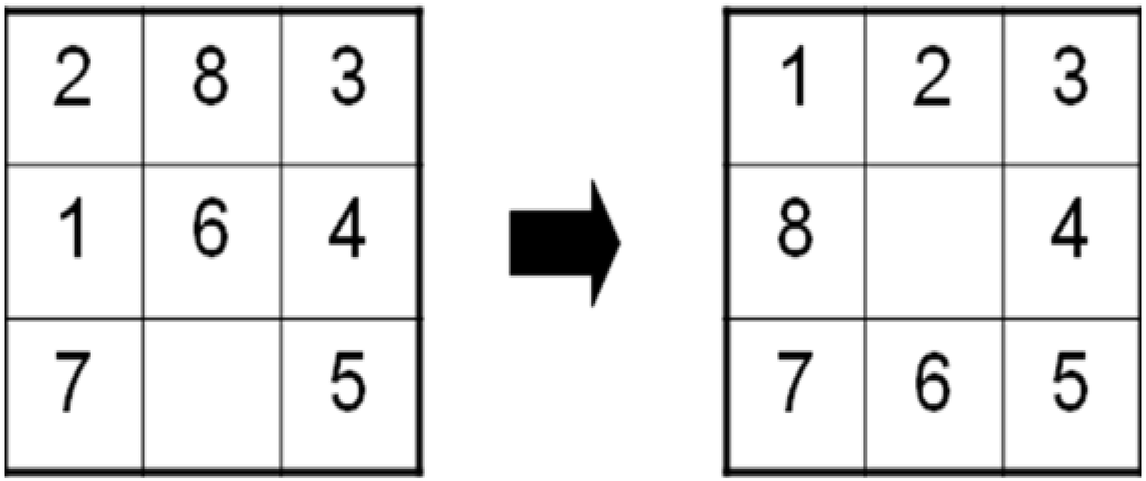
1. Is the problem decomposable into small sub-problems which are easy to solve?

- Can the problem be broken down into smaller problems to be solved independently?
- The decomposable problem can be solved easily.



2. Can solution steps be ignored or undone?

- In the Theorem Proving problem, a lemma that has been proved can be ignored for the next steps.
- Such problems are called Ignorable problems.
- In the 8-Puzzle, Moves can be undone and backtracked.
- Such problems are called Recoverable problems.



- **In Playing Chess, moves can be retracted.**
- **Such problems are called Irrecoverable problems.**
- **Ignorable problems can be solved using a simple control structure that never backtracks. Recoverable problems can be solved using backtracking. Irrecoverable problems can be solved by recoverable style methods via planning.**

3. Is the universe of the problem is predictable?

- In Playing Bridge, We cannot know exactly where all the cards are or what the other players will do on their turns.
- Uncertain outcome!
- For certain-outcome problems, planning can be used to generate a sequence of operators that is guaranteed to lead to a solution.
- For uncertain-outcome problems, a sequence of generated operators can only have a good probability of leading to a solution. Plan revision is made as the plan is carried out and the necessary feedback is provided.

4. Is a good solution to the problem is absolute or relative?

- The Travelling Salesman Problem, we have to try all paths to find the shortest one.
- Any path problem can be solved using heuristics that suggest good paths to explore.
- For best-path problems, a much more exhaustive search will be performed.

5. Is the solution to the problem a state or a path

- The Water Jug Problem, the path that leads to the goal must be reported.
- A path-solution problem can be reformulated as a state-solution problem by describing a state as a partial path to a solution.
- The question is whether that is natural or not.

6. What is the role of knowledge in solving a problem using artificial intelligence?

- Consider again the problem of playing chess. Suppose you had unlimited computing power available.
- How much knowledge would be required by a perfect program?
- The answer to this question is very little—just the rules for determining legal moves and some simple control mechanism that implements an appropriate search procedure.
- Additional knowledge about such things as good strategy and tactics could of course help considerably to constrain the search and speed up the execution of the program. Knowledge is important only to constrain the search for a solution.

7. Does the task of solving a problem require human interaction?

- Sometimes it is useful to program computers to solve problems in ways that the majority of people would not be able to understand.
- This is fine if the level of the interaction between the computer and its human users is problem-in solution-out.
- But increasingly we are building programs that require intermediate interaction with people, both to provide additional input to the program and to provide additional reassurance to the user.
- The solitary problem, in which there is no intermediate communication and no demand for an explanation of the reasoning process.
- The conversational problem, in which intermediate communication is to provide either additional assistance to the computer or additional information to the user.

Problem Analysis and Representation

- **State Space Representation:** Define all possible states and transitions.
- **Graph Representation:** Nodes represent states; edges represent actions.
- **Tree Representation:** Hierarchical structure of states and actions.
- **Constraint Satisfaction Problems (CSPs):** Variables, domains, and constraints.

Performance Measure
An objective criterion (“utility function”) for success of an agent's behavior.
Example:
Performance measures of a vacuum-cleaner agent: amount of dirt cleaned up, amount of time taken, amount of electricity consumed, level of noise generated, etc.

Metrics:
- **Accuracy**: Correctness of the solution.
- **Efficiency**: Time and resources required.
- **Robustness**: Performance under varying conditions.

Evaluation:
- **Benchmarks**: Standardized tests for comparison.
- **Testing**: Simulations or real-world trials.

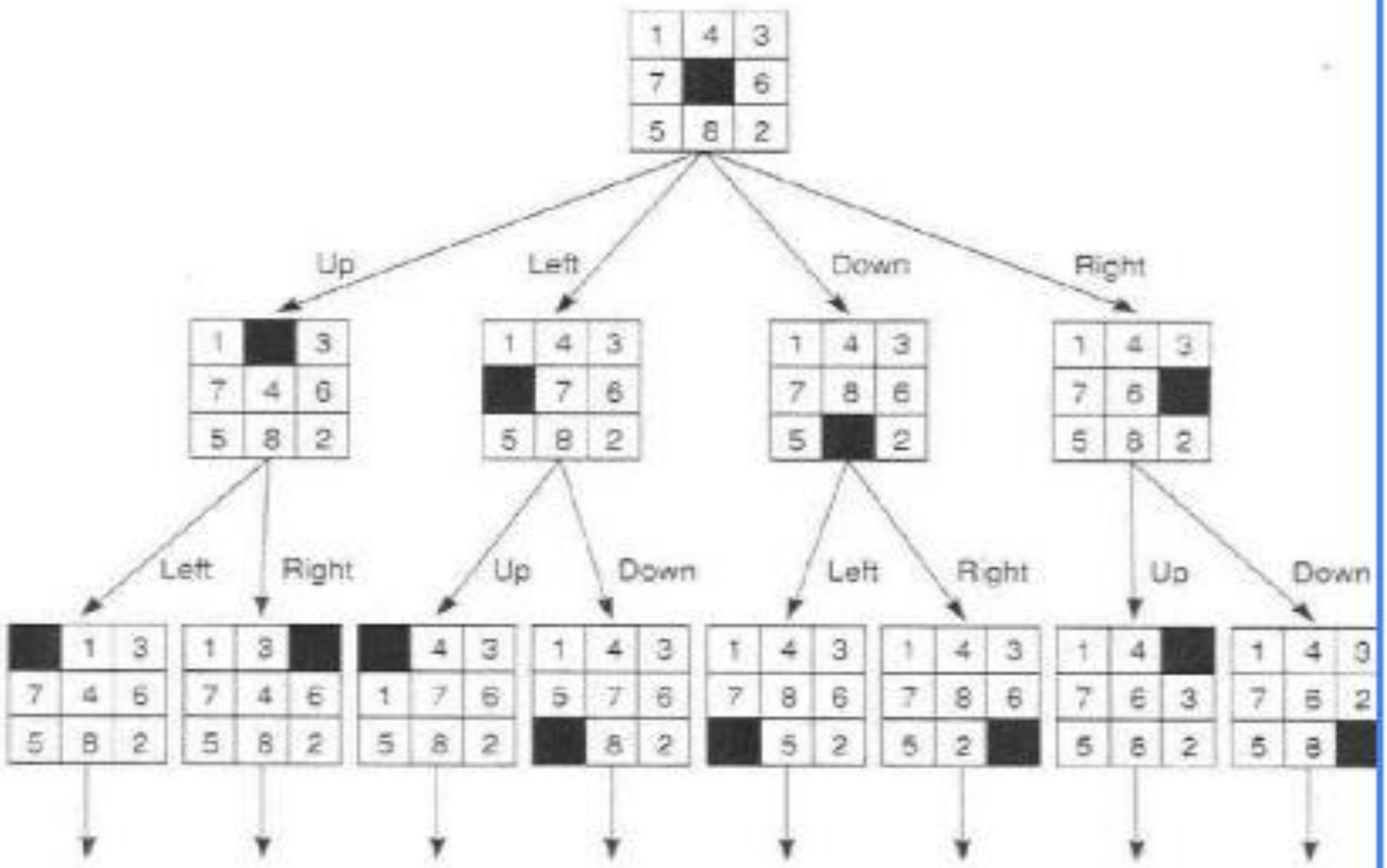
Problem Space and Search

- **Problem Space**: All possible states and actions.

Search Algorithms:

- **Uninformed Search**: No additional information (e.g., Breadth-First Search, Depth-First Search).
- **Informed Search**: Uses heuristics to guide the search (e.g., A* algorithm, Greedy Search).
- **Optimization Search**: Finding the best solution (e.g., Genetic Algorithms, Simulated Annealing).

- **State space search** is a process used in which successive or states of an instance are considered, with the goal of finding a goal state with a desired property.



State space Search tree for 8 puzzle problem

Some of the most common problems resolved by AI are

- Water-Jug Problem
- Travelling Salesman Problem
- Tower of Hanoi Problem
- N-Queen Problem
- Chess
- Sudoku
- Crypt-arithmetic Problems
- Magic Squares
- Logical Puzzles and so on.

Production Systems: Systems that generate (produce) rules (states) to reach a solution

A *production system commonly consists of following four basic components:*

1. A *set of rules of the form* $C_i \rightarrow A_i$ *where* C_i *refers to starting state and* A_i *represents consequent state. Also* C_i *the condition part and* A_i *is the action* part.

1. One or more *knowledge databases that contain whatever information is relevant* for the given problem.

1. A *control strategy that ascertains the order in which the rules must be applied to the available* database

1. A *rule applier which is the computational system that implements the control* strategy and applies the rules to reach to goal (if it is possible).

The water jug problem

- There are two jugs called four and three ; four holds a maximum of four gallons and three a maximum of three gallons.
- There is a pump that can be used to fill the jugs with water. How can you get exactly 2 litres of water into 4-litre jug.
- How can we get 2 gallons in the jug four.
- The state space is a set of ordered pairs giving the number of gallons in the pair of jugs at any time ie (four, three) where four = 0, 1, 2, 3, 4 and three = 0, 1, 2, 3.
- The start state is (0,0) and the goal state is (2,n) where n is a don't care but is limited to three holding from 0 to 3 gallons.

State Space Search

Let x and y be the amounts of water in 4-Lt and 3-Lt Jugs respectively Then (x,y) refers to water available at any time in 4-Lt and 3-Lt jugs.

Also (x,y) (x-d,y+dd) means drop some unknown amount d of water from 4-Lt jug and add dd onto 3-Lt jug.

All possible production rules can be written as follows

1. (x, y) if x < 4 → (4, y) if x<4, fill it to 4; y remains unchanged
2. (x, y) if y < 3 → (x, 3) if y<3, fill it to 3; x remains unchanged
3. (x, y) if x > 0 → (x - d, y) if there is some water in 4 Lt jug, drop some more water from it
4. (x, y) if y > 0 → (x, y - d) if there is some water in 3 Lt jug, drop some more water from it

State Space Search

5. $(x, y) \rightarrow (0, y)$ if there is some water in 4-Lt, empty it, y remains unchanged if $x > 0$

6. $(x, y) \rightarrow (x, 0)$ if there is some water in 3-Lt, empty it, x remains unchanged if $y > 0$

7. (x, y) if $x + y \geq 4, y > 0$ $\rightarrow (4, y - (4 - x))$ if there is some water in 3-Lt, the sum of water of 4-Lt and 3-Lt jug is >=4, then fill water in 4-Lt jug to its capacity from 3-Lt jug

8. (x, y) if $x + y \geq 3, x > 0$ $\rightarrow (x - (3 - y), 3)$ same as 7 with suitable change in x,y

9. (x, y) if $x + y \leq 4, y > 0$ $\rightarrow (x + y, 0)$ if sum of water in both jugs <=4, then drop whole water from 3-Lt into 4-Lt

10. (x, y) if $x + y \leq 3, x > 0$ $\rightarrow (0, x + y)$ if sum of water in both jugs <=3, then drop whole water from 4-Lt into 3-Lt

11. $(0, 2)$ $\rightarrow (2, 0)$ Transfer 2-Lt from 3-Lt jug into empty 4-Lt jug

12. $(2, y)$ $\rightarrow (0, y)$ Empty 2 Lt water onto ground from 4-Lt jug without disturbing 3 Lt jug

State Space Search

Solution of Water Jug Problem

Obviously to solve water jug problem, we can perform following sequence of actions,

$(0,0)\ (0,3) \longrightarrow (3,0) \longrightarrow (3,3) \longrightarrow (4,2) \longrightarrow (0,2) \longrightarrow (2,0) \longrightarrow$

By applying rules 2,9,2,7,5 and 9 with initial empty jugs

Remember: There is NO hard and fast rules to follow this sequence. In any state space search problem, there can be numerous ways to solve, your approach can be different to solve a problem and sequence of actions too.

State Space Search--Other problems

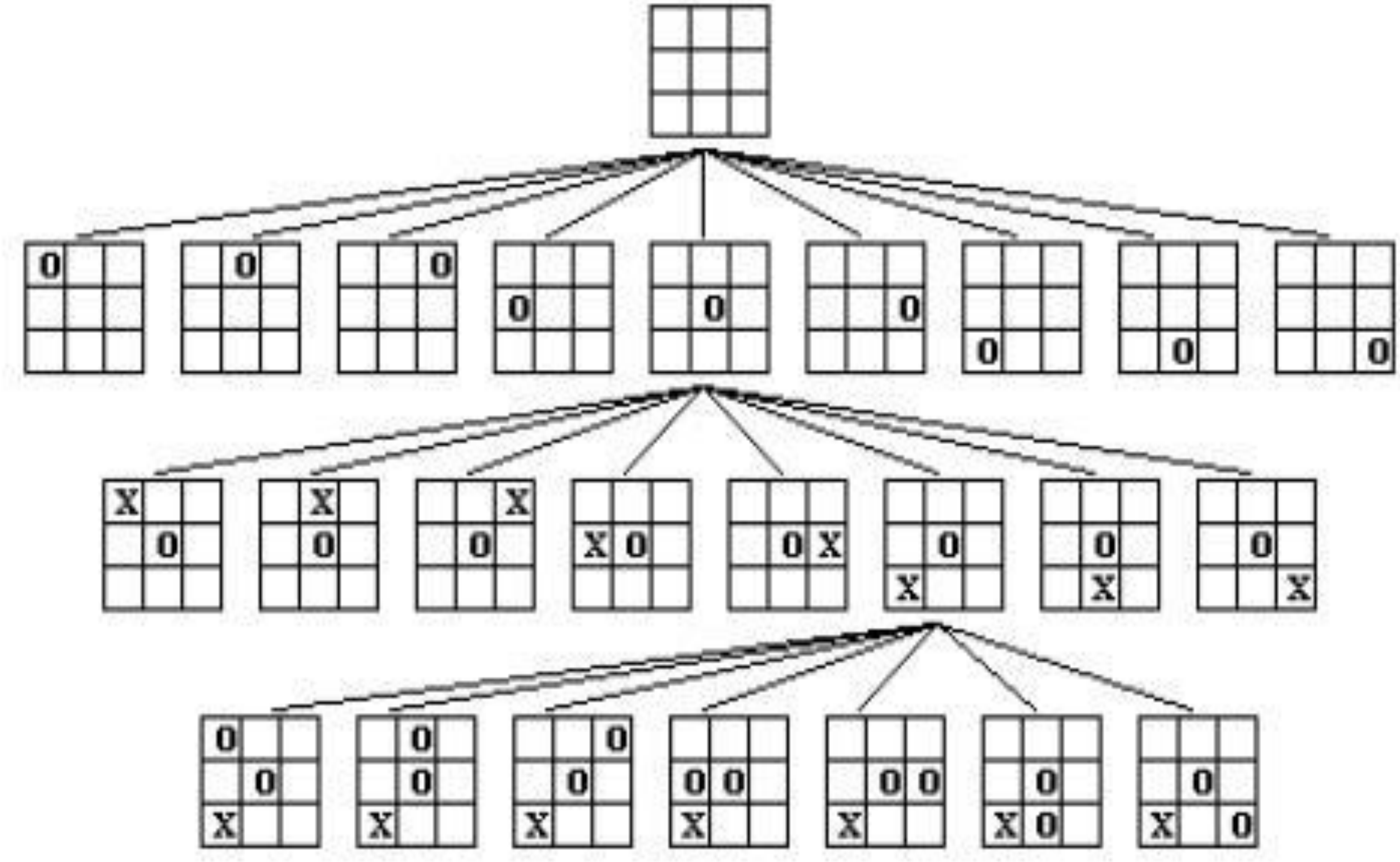
1.Cannibals and missionaries problems: In the missionaries (humans)and cannibal (human eaters) problem, three missionaries and three cannibals must cross a river using boat which can carry at most two people. At any time number of cannibals on either sid should not be greater than number of missionaries otherwise former will eat latter. Also Th boat cannot cross the river by itself with no people on board.

2.Tower of Hanoi Problem: It consists of three pegs, and a number of disks (usually 60) o different sizes which can slide onto any peg. The puzzle starts with the disks in a neat stac in ascending order of size on one rod, the smallest at the top, thus making a conical shape The objective of the puzzle is to move the entire stack to another rod, obeying the followin rules:

- Only one disk must be moved at a time.
- Each move consists of taking the upper disk from one of the rods and sliding it onto another rod, on top of the other disks that may already be present on that rod.
- No disk may be placed on top of a smaller disk.

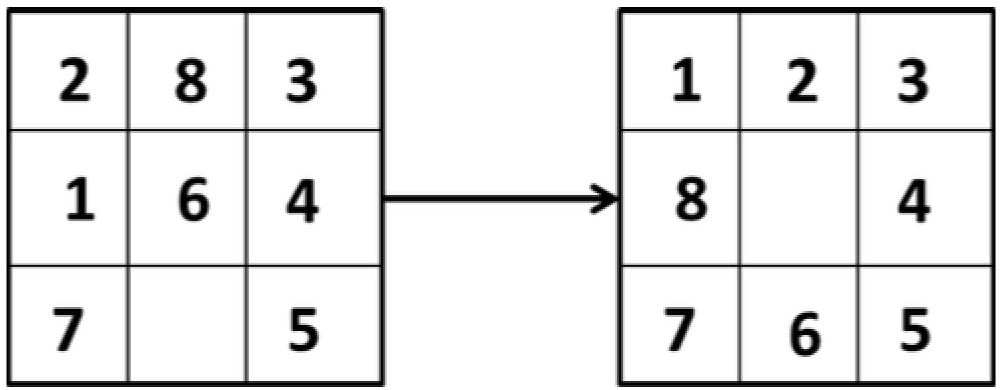
3.Monkey Banana Problem: A monkey is in a room. A bunch of bananas is hanging fron the ceiling and is beyond the monkey's reach. However, in the room there are also a chai and a stick. The ceiling is just the right height so that a monkey standing on a chair coul knock the bananas down with the stick. The monkey knows how to move around, carry othe things around, reach for the bananas, and wave a stick in the air. What is the best sequence o actions for the monkey?

State space for Tic-Tac-Toe game



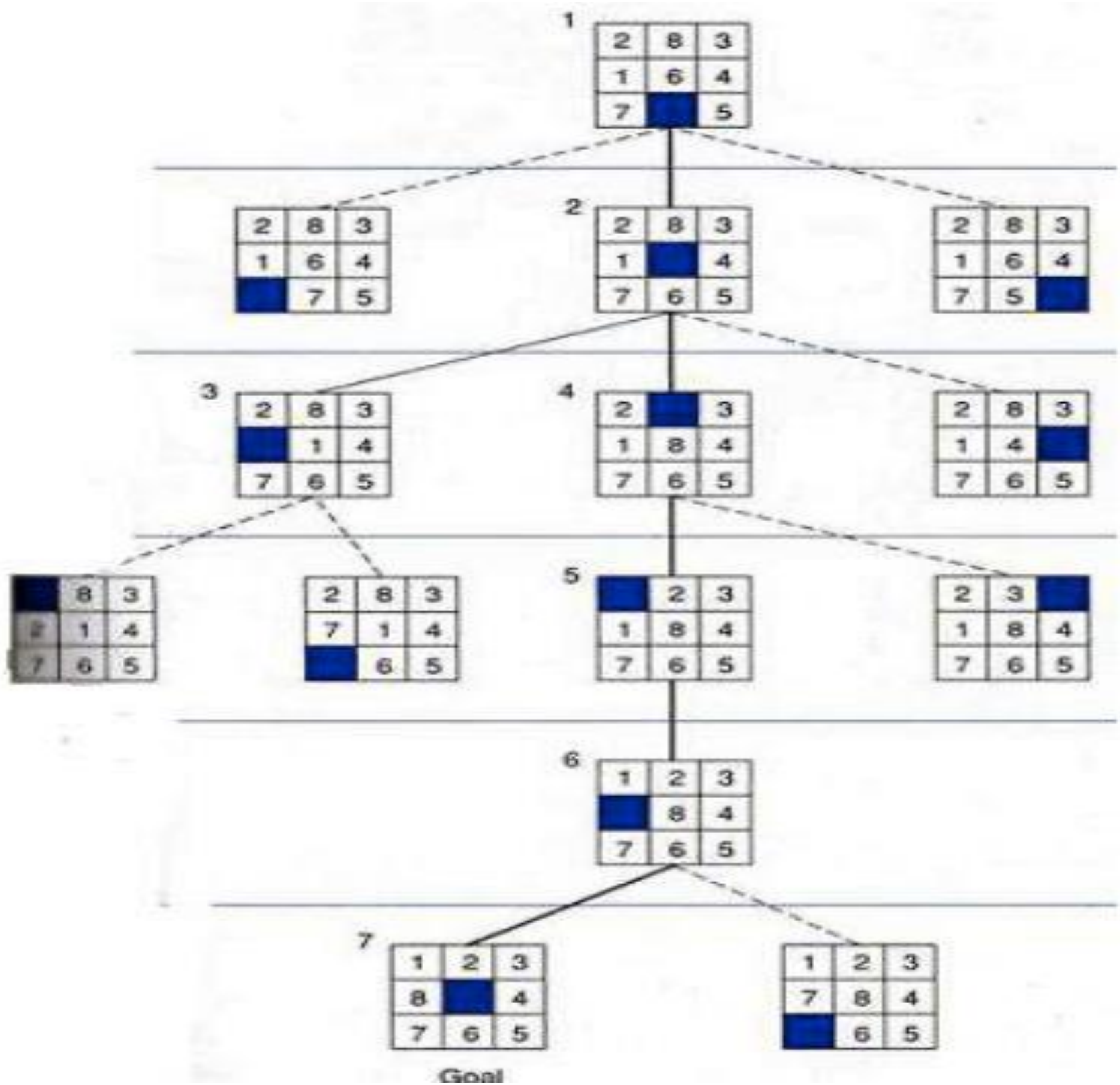
8-puzzle problem

The 8 puzzle consists of eight numbered, movable tiles set in a 3x3 frame. One cell of the frame is always empty thus making it possible to move an adjacent numbered tile into the empty cell. Such a puzzle is illustrated in following diagram.



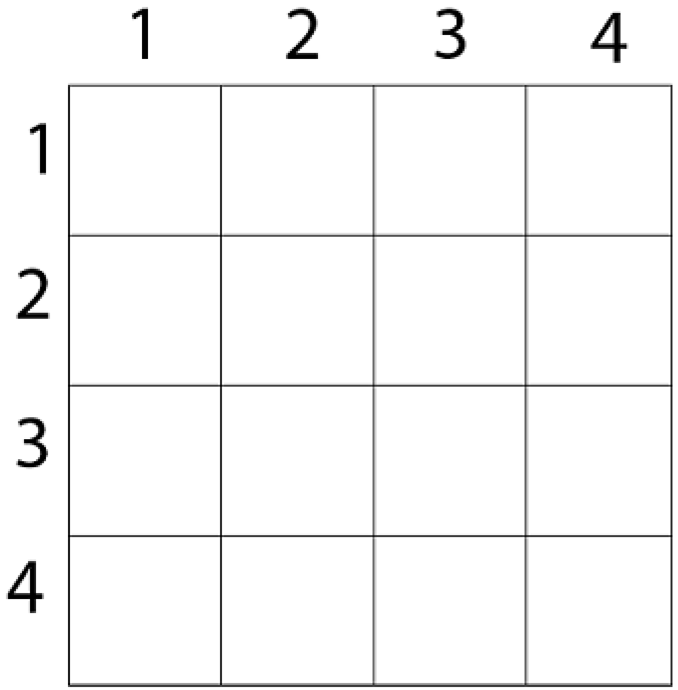
Initial State Goal State

State space for 8-puzzle problem



N-Queens Problem

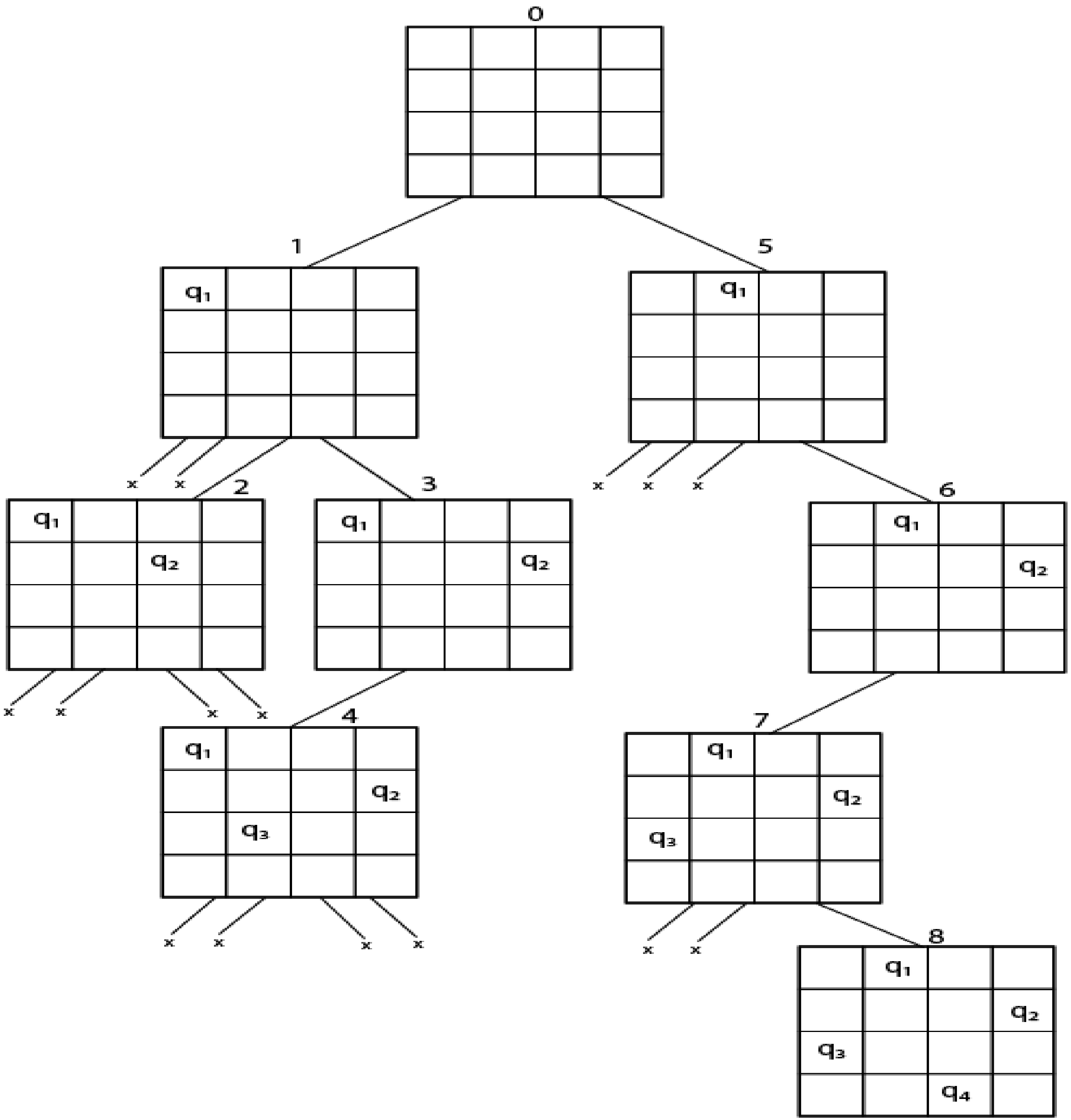
- N - Queens problem is to place n - queens in such a manner on an n x n chessboard that no queens attack each other by being in the same row, column or diagonal.
- It can be seen that for n =1, the problem has a trivial solution, and no solution exists for n =2 and n =3. So first we will consider the 4 queens problem and then generate it to n - queens problem.
- Given a 4 x 4 chessboard and number the rows and column of the chessboard 1 through 4.



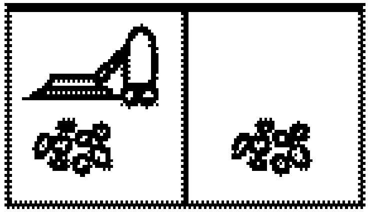
4x4 chessboard

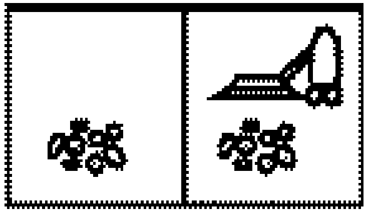
- Since, we have to place 4 queens such as q_1 q_2 q_3 and q_4 on the chessboard, such that no two queens attack each other.
- In such a conditional each queen must be placed on a different row, i.e., we put queen "i" on row "i."

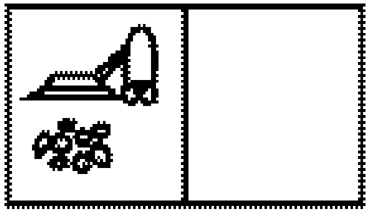
State space for 4-Queens problem

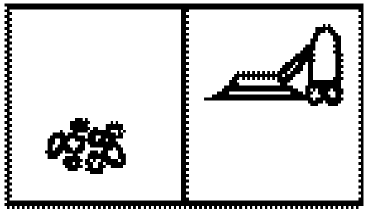


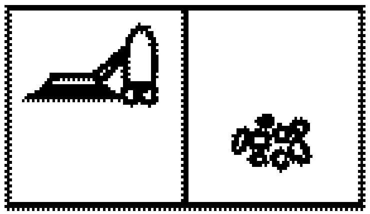
VACUUM CLEANER AGENT PROBLEM

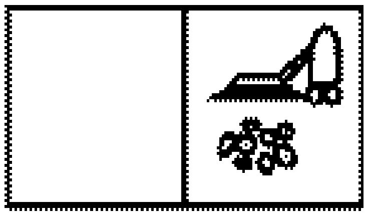
1 

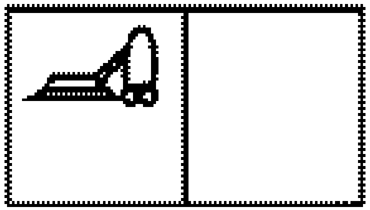
2 

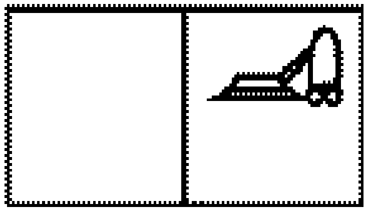
3 

4 

5 

6 

7 

8 

STATE SPACE FOR VACUUM CLEANER AGENT PROBLEM