AKSHAYA INSTITUTE OF TECHNOLOGY, TUMKURU

Department of Electronics & Communication Engineering

Module 1 notes for

Intelligent Systems and Machine Learning Algorithms

[BEC515A]

Prepared by:

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VISION

To produce competent engineering professionals in the field of Electronics and Communication Engineering by imparting value based quality technical education to meet the societal needs and to develop socially responsible citizens.

MISSION

M1: To provide strong fundamentals and technical skills in the field of Electronics and Communication Engineering through effective teaching learning process.

M2: Enhancing employability of the students by providing skills in the fields of VLSI, Embedded systems, Signal processing, etc., through Centre of Excellence.

M3: Encourage the students to participate in co-curricular and extra-curricular activities that creates a spirit of social responsibility and leadership qualities.

Program Specific Outcomes (PSOs)

After Successful Completion of Electronics and Communication Engineering Program Students will be able to

1. Apply fundamental knowledge of core. Electronics and Communication Engineering in the analysis, design and development of Electronics Systems as well as to interpret and synthesize experimental data leading to valid conclusions.
2. Exhibit the skills gathered to analyze, design, develop software applications and hardware products in the field of embedded systems and allied areas.

Program Educational Objectives (PEOs)

PEO1: Graduates exhibit their innovative ideas and management skills to meet the day to day technical challenges.

PEO2: Graduates utilize their knowledge and skills for the development of optimal solutions to the problems in the field of Electronics and Communication Engineering..

PEO3: Graduates exhibit good interpersonal skills, leadership qualities and adapt themselves for life-long Learning

Intelligent Systems and Machine Learning Algorithms		Semester	5
Course Code	**BEC515A**	CIE Marks	50
Teaching Hours/Week (L: T:P: S)	3:0:0	SEE Marks	50
Total Hours of Pedagogy	40	Total Marks	100
Credits	03	Exam Hours	03
Examination type (SEE)	THEORY		

Course objectives:

This course will enable students to:

- Gain a historical perspective of AI and its foundations.
- Become familiar with basic principles of AI toward Problem-Solving
- Get to know approaches of inference, perception, knowledge representation, and learning
- Define Machine Learning and understand the basic theory underlying machine learning.
- Differentiate supervised, unsupervised, and reinforcement learning

Teaching-Learning Process (General Instructions)

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These are sample Strategies teachers can use to accelerate the attainment of the various course outcomes.

1. Lecture method (L) does not mean only traditional lecture method; different teaching methods may be adopted to develop the outcomes.
2. Encourage collaborative (Group) Learning in the class.
3. Ask at least three HOTS (Higher Order Thinking) questions in the class, which promotes criticalthinking.
4. Adopt Problem-Based Learning (PBL), which fosters students' Analytical skills, and develops thinking skillssuch as evaluating, generalizing, and analyzing information rather than simply recalling it.
5. Topics will be introduced in a multiple representation.
6. Show the different ways to solve the same problem and encourage the students to come up withcreative ways to solve them.
7. Discuss how every concept can be applied to the real world and when that's possible, it helps improve the student's understanding.
8. Adopt the Flipped class technique by sharing the materials/Sample Videos before the class and having discussions on the topic in the succeeding classes.

Module-1

Introduction: What is AI? Foundations and History of AI Intelligent Agents: Agents and environment, Concept of Rationality, The nature of environment, The structure of agents.

Text book 1: Chapter 1- 1.1, 1.2, 1.3 Chapter 2- 2.1, 2.2, 2.3, 2.4

Module-2

Problem-solving: Problem-solving agents, Example problems, Searching for Solutions Uninformed Search Strategies: Breadth First search, Depth First Search, Iterative deepening depth first search;

Text book 1: Chapter 3- 3.1, 3.2, 3.3, 3.4

Module-3

Informed Search Strategies: Heuristic functions, Greedy best first search, A*search. Heuristic Functions Logical Agents: Knowledge–based agents, The Wumpus world, Logic, Propositional logic, Reasoning patterns in Propositional Logic

Text book 1: Chapter 3-3.5,3.6 Chapter 4 – 4.1, 4.2 Chapter 7- 7.1, 7.2, 7.3, 7.4, 7.5

Module-4
Introduction: Machine learning Landscape: what is ML?, Why, Types of ML, main challenges of ML Concept learning and Learning Problems – Designing Learning systems, Perspectives and Issues – Concept Learning – Find S-Version Spaces and Candidate Elimination Algorithm – Remarks on VS- Inductive bias. Text book 3: Chapter 1, Textbook 4:Chapter 1 and 2
Module-5
End-to-end Machine learning Project: Working with real data, Look at the big picture, Get the data, Discover and visualize the data, Prepare the data, select and train the model, Fine tune your model. Classification: MNIST, training a Binary classifier, performance measure, multiclass classification, error analysis, multi-label classification, multi-output classification Textbook 4: Chapter 2, Chapter 3
Course outcome (Course Skill Set) At the end of the course, the student will be able to: CO1. Apply knowledge of agent architecture, searching, and reasoning techniques for different Applications. CO 2. Compare various Searching and Inferencing Techniques. CO 3. Develop knowledge base sentences using propositional logic and first-order logic CO 4. Understand the concept of Machine Learning and Concept Learning. CO 5. Apply the concept of ML and various classification methods in a project

Module-1

Introduction: What is AI? Foundations and History of AI; Intelligent Agents: Agents and environment. Concept of Rationality, The nature of environment, The structure of agents.

* What is AI?

Def:- AI is the technology, where by machines try to mimic the activities of human. Specially, the cognitive activities of human like thinking, problem solving, decision making use of logic, there by creating a kind of a system, where human activities which does not require logical reasoning to a very greatest extent can be replaced by AI.

→ AI is a field of science concerned with building computers and machines, that can reason, learn and act in such a way, that would normally require human intelligence or that involves data, whose scale exceeds what humans can analyze.

* Foundations of AI :-

The foundation provides the disciplines that contributed ideas, viewpoints and techniques to AI.

i) Philosophy
ii) Mathematics and Statistics
iii) Economics
iv) Neuroscience
v) Psychology
vi) Computer Science and Engineering
vii) Control theory and Cybernetics
viii) Linguistics

i) Philosophy :- (Asking the Big questions)

→ It is the very basic foundation of AI.
→ The study of fundamental nature of knowledge, reality and existence are considered for solving a specific problem is a basic thing in AI.
→ It defines that how can the formal rules be used to draw valid conclusions.
→ Without Philosophy, it is difficult to answer the following questions:
- How does the mind arise from a physical brain?
- Where does the knowledge come from?
- How does the knowledge lead to action?

ii) Mathematics and Statistics :- (Crunching numbers & patterns)

→ AI required formal logic and Probability for planning and learning.

→ Computation required for analyzing relation and implementation.

→ Knowledge & Formal representation are most required for writing actions for agents.

→ In AI, the Mathematics and Statistics are most important for:

- providing theorems
- writing algorithms
- computation
- decidability
- Tractability
- modeling ~~and~~ uncertainty
- Learning from data

→ So, mathematics and Statistics, is important for, answering:-

- What are the formal rules to draw valid conclusions?
- What can be computed?
- How do we reason with uncertain information?

iv) Economics: (making smart choices)

→ Deals with investing the amount of money and maximization of utility with minimal investment.

→ While developing an AI product, we should make decisions for:
- When to invest?
- How to invest?
- How much to invest?
- Where to invest?

→ To answer these questions, one should

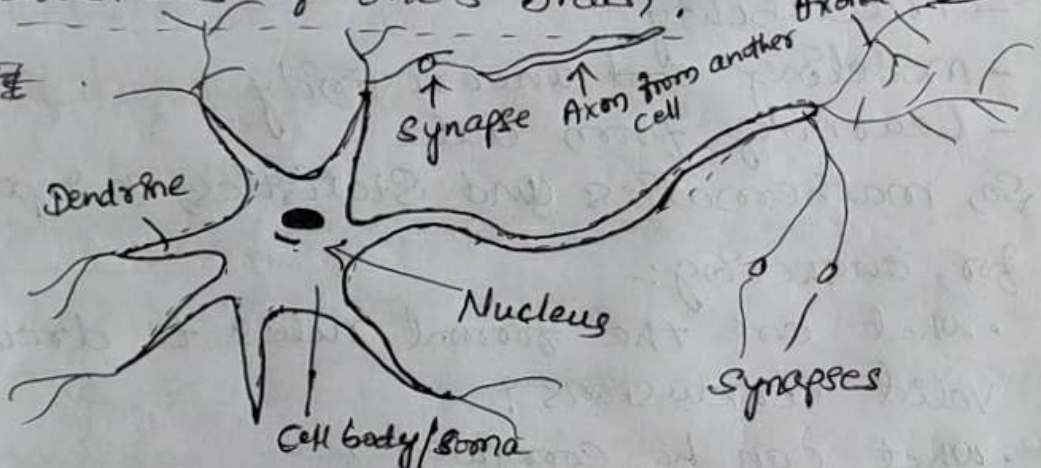
have knowledge about Decision Theory, Game Theory, Operation Research, ..etc.

N) Neuroscience :- (Exploring the Brain's Secrets)

→ It is the study of the Nervous system, particularly the human brain.

→ Human brains are somehow different, when compared to other creatures, man has the largest brain in proportion to his size.

→ The brain consisted largely of nerve cells, or neurons and the observation of individual neurons can lead to thought, action and conciousness of one's brain.



→ It is important to understand, How do brains process information?

V) Psychology :- (Cognitive Science) (Understanding our minds)

→ The scientific method to the study of human vision.

→ Cognitive psychology → views the brain as an information-processing device.

→ Psychology is like a map, guiding us through our thoughts and actions.

→ Imagine trying to understand, why someone feels happy or scared.

→ Psychology helps us explore :-

. How humans and ~~humans~~ animals think and behave in different situations.

vi) Computer Science and Engineering :- ~~(Building smarter Machines)~~

→ Logic and Inference theory, algorithms, programming languages and system building are important parts of computer science.

→ Computer hardware gradually changed for AI applications, such as the Graphics Processing Unit (GPU), Tesor Processing Unit (TPU), and Wafer Scale engine (WSE).

→ The amount of computing power used to train ~~top~~ top machine learning applications and the utilization doubled every 100 days.

→ The super computers and quantum computers can solve very complicated AI problems.

→ The software side of computer science, supplied the Operating System, programming languages, and tools needed to write modern programs.

→ AI has founded many ideas to modern and mainstream computer science, including: Time sharing, interactive interpreters, personal computers with windows and mice, rapid development environments and key concepts of symbolic, functional, declarative and object-oriented programming.

→ So, it leads to ask: How can we build fast and efficient computer?

vii) Control theory :- (Keeping Things in Check)

→ Control theory helps the system to analyze, define, debug and fix errors by itself.

→ Developing: Self Controlling machine, self-regulating feedback control systems and the submarine are some examples of control theory.

→ Calculus and matrix algebra, and the tools of control theory, provide themselves to systems, that are describable by fixed sets of continuous variables, are foundation of AI.

→ Knowledge representation, grammers, computational linguistics or natural language processing (NLP) are significant to developing AI applications.

→ The tools of logical inference and computation provide the language, vision and symbolic planning of agent programming.

→ It leads to ask: How can artifacts operate

under their own control?

viii) Linguistics :- (The power of words)

→ Speech recognition is a technology, which enables a machine to understand the spoken language and translate it into a machine readable format.

→ It is a way to talk with a computer, and on the basis of that command, a computer can perform a specific task.

→ It includes Speech to Text, Text to speech conversion.

→ It asks: How does language relate to thought?

* History of AI :-(Evolution of AI)

⇒ 1) Early Foundations (Before 1950s):-

→ The idea of intelligent machines dates back to ancient myths and automata.

→ Mathematical logic (e.g. works of Aristotle, Boole) laid the foundation for reasoning.

→ Alan Turing (1936) proposed the Turing machine, and later (1950) introduced the Turing Test to define machine intelligence.

2) Birth of AI (1950s-1960s):-

→ 1956 - Dartmouth conference - considered the birth of AI; John McCarthy coined the term 'Artificial Intelligence'.

→ Early AI programs:- . Logic Theorist (1955) by Newell & Simon - 1st AI program to prove mathematical theorems.

. General Problem Solver (1957) - Aimed at solving any problem, but had limitations.

→ Development of Perceptron (1958) by Frank Rosenblatt, an early neural network model.

3) The Rise and Fall of AI: (1960s-1970s)

→ AI research flourished with early expert systems and symbolic reasoning.

→ However, lack of computing power and limited understanding of learning led to the first AI Winter (1970s) where funding and interest declined.

4) Expert Systems and Knowledge-Based AI (1980s):-

→ AI regained momentum with Expert Systems like MYCIN (medical diagnosis) and XCON (business applications).

→ Machine learning concepts began to develop, but AI was still rule-based.

→ Another AI slowdown occured due to high costs and limitations of rule-based systems.

5) The Rise of Machine Learning and AI Boom :- (1990s-2000s)

→ AI shifted from rule-based systems to probabi-

listic reasoning and data-driven approaches.
→ Breakthroughs in Machine Learning, Natural Language Processing (NLP) and Robotics occured.
→ IBM's Deep Blue (1997) defeated world chess champion Garry Kasparov.

6) Modern AI and Deep Learning Era (2010s - present):
→ AI exploded with advancements in Big Data, Deep Learning and Computing Power.
→ Key breakthroughs:
- 2011 :- IBM Watson won Jeopardy.
- 2012 :- AlexNet revolutionized deep learning for image recognition.
- 2016 :- AlphaGo defeated world champion Go player.
- 2018 - present : GPT, BERT and other AI models transformed NLP.

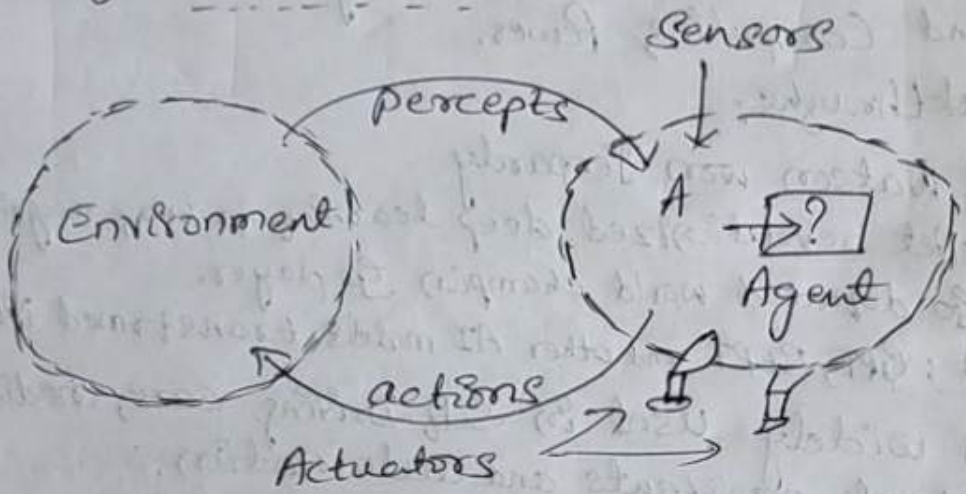
→ AI is now widely used in Self-Driving cars, medical diagnosis, virtual assistants and automation.

7) The Future of AI :-
→ AI research focuses on explainability, ethics and Artificial General Intelligence (AGI).
→ Challenges include bias, security and ensuring AI benefits humanity.

i.e.,
AI approaches are categorized into :-
i) Thinking humanly (cognitive modeling)
ii) Thinking rationally (Logic-based AI)
iii) Acting humanly (Turing Test approach)
iv) Acting rationally (Rational agent approach)

* Intelligent Agents :- (Structure of Intelligent Agents)
(Agents and Environment)

Agent : It is anything that can be viewed as perceiving its environment through Sensors and acting upon that environment through Actuators.



• Human agent :-
→ Eyes, ears and other organs for Sensors.
→ Hands, legs, mouth and other body parts for Actuators.

• Robotic Agent :-
→ Cameras and IR range finders for Sensors.
→ Various motors for Actuators.

• The Agent function :-
→ The Agent function maps from percept histories to actions:

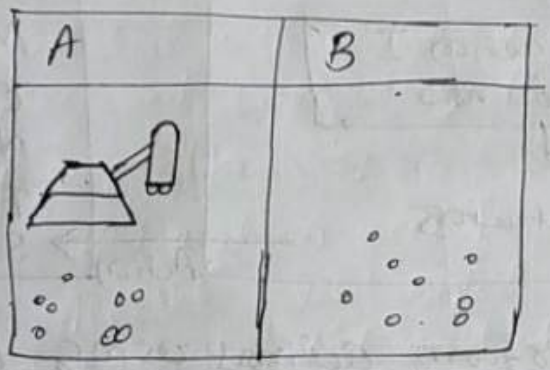
$$f : P^* \rightarrow A$$

→ The Agent program runs on the physical architecture to produce 'f'
→ IA structure consists of 3 main parts :- Agent function, Architecture of Agent program.
i.e., Agent = Architecture + Program ;

Eg:- Vaccum Cleaner World;

- Percepts: location and contents;
  eg, [A, Dirty]
- Actions : Left, Right, Suck, NoOp;

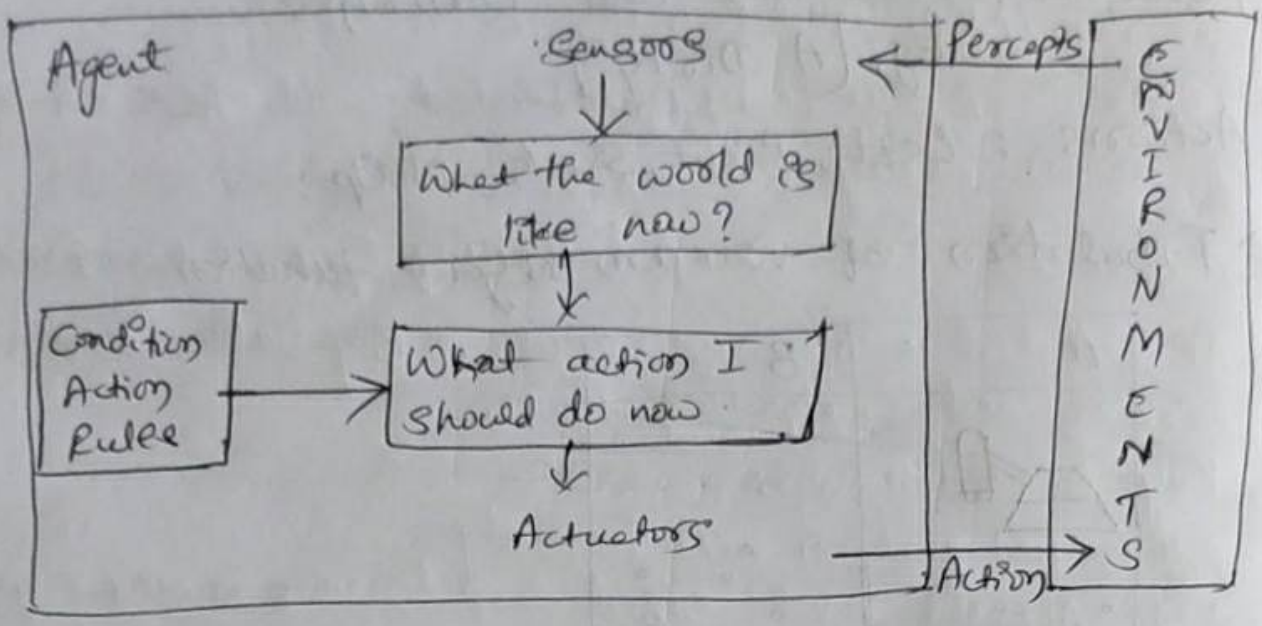
→ Tabulation of vaccum agent function.



Percept sequence	Action
[A, Clean]	→ Right
[A, Dirty]	→ Suck
[B, Clean]	→ Left
[B, Dirty]	→ Suck
All Clean	→ NoOp

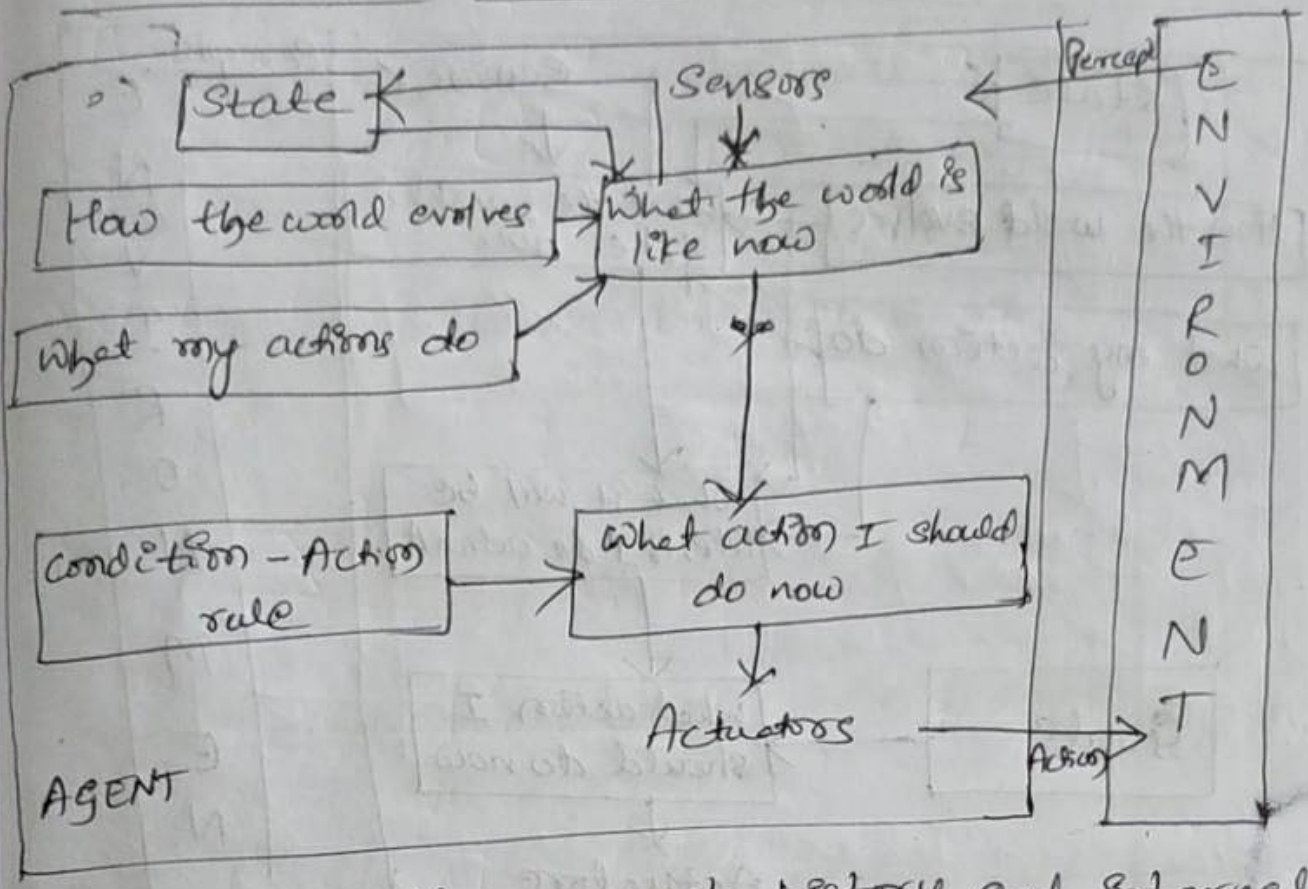
* Types of Agents: (Different forms of IA)
  i) Simple Reflex Agent
  ii) Model Based Reflex Agent
  iii) Goal Based Agent
  iv) Utility Based Agent
  v) Learning Agent

① Simple Reflex Agent :-



→ These agents perform actions using the current percept, ignoring the rest of percept history.
→ Works only if the environment is fully observable.
→ Perform actions only on simple situation.
→ Agent function is based on the condition - action rule; 'if condition, then action'.
→ This can only be done, based on the pre-determined rules, that are present in the knowledge base.
Eg:- If Red colour in traffic signal, car should stop.

② Model based reflex agent :-



→ It uses the percept history and internal memory.

→ Agent can work in a partially observable environment.

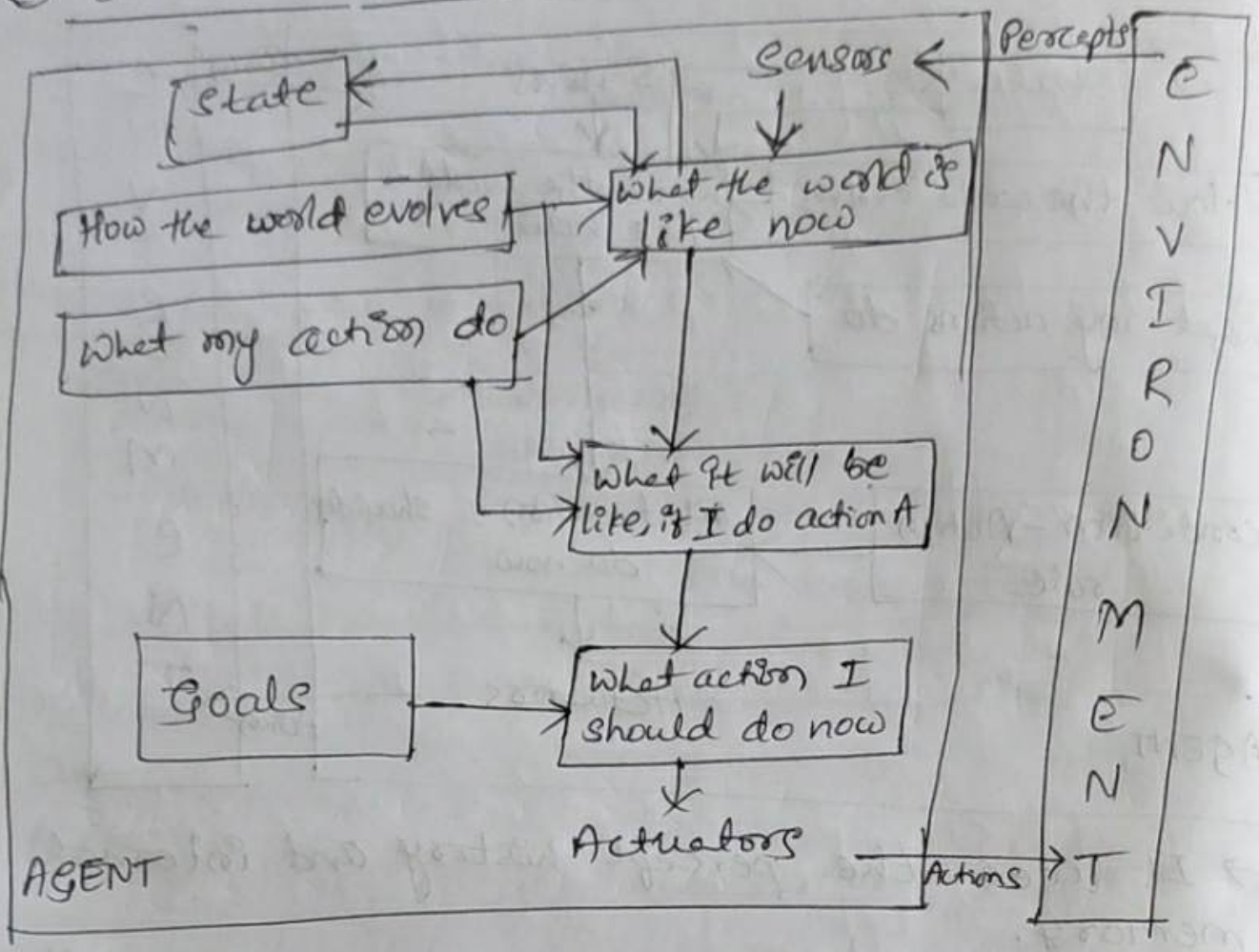
→ a) Model - knowledge about 'how the things happens in the world'.

b) Internal State - Unobserved aspects of state can get from percept history.

→ Updating the state requires the information about : ⇒ How the world evolves

⇒ How agents actions affect the world.

③ Goal-Based Agent :-



→ They choose their actions in order to achieve goals.

→ This allows the agent a way to choose among multiple possibilities, selecting the one which reaches a goal state.

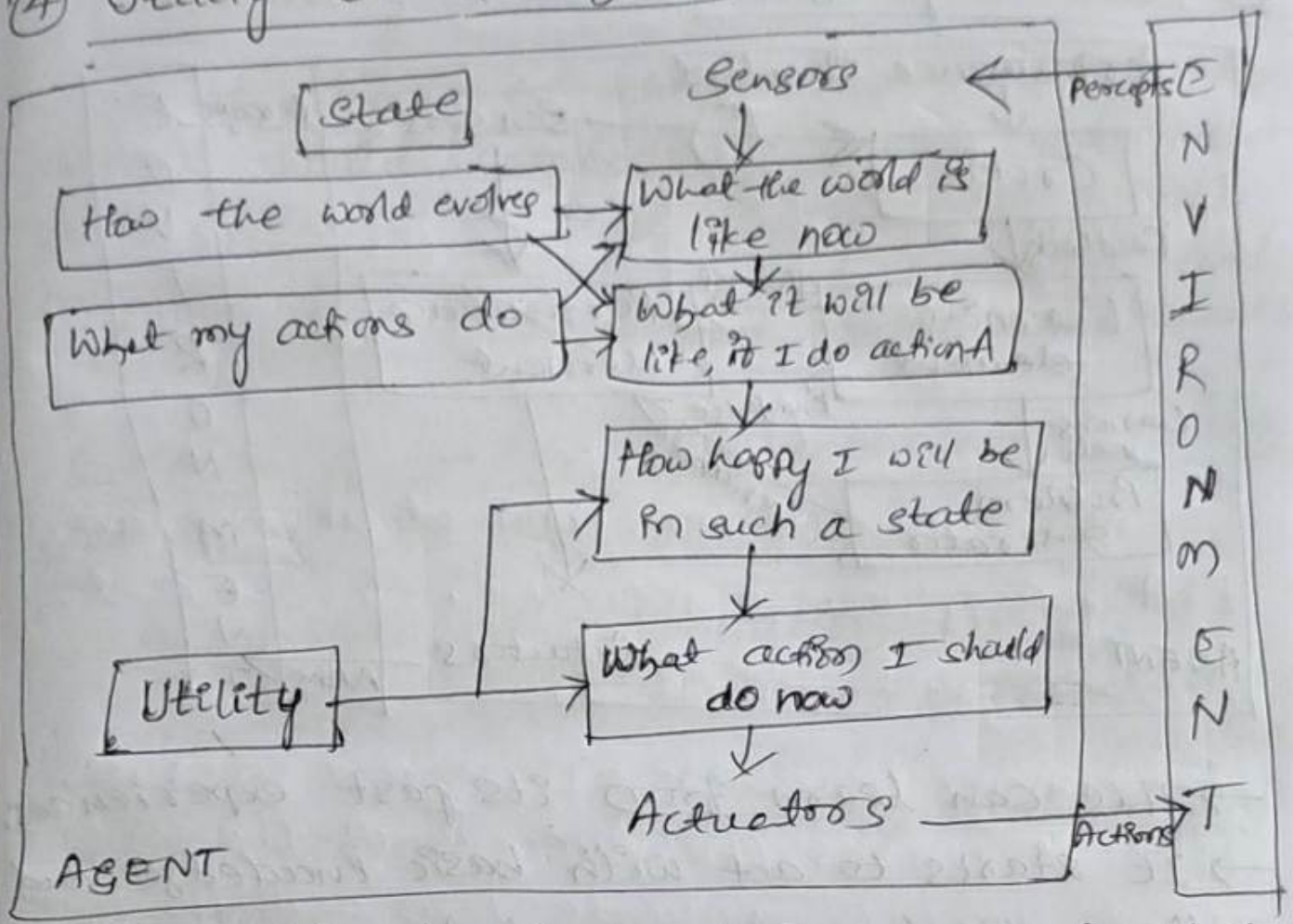
→ Usually requires 'search and Planning'.

Eg:- GPS

→ Current state information only is not enough.

→ Goal information will be provided to the Agent.

④ Utility based agent :-



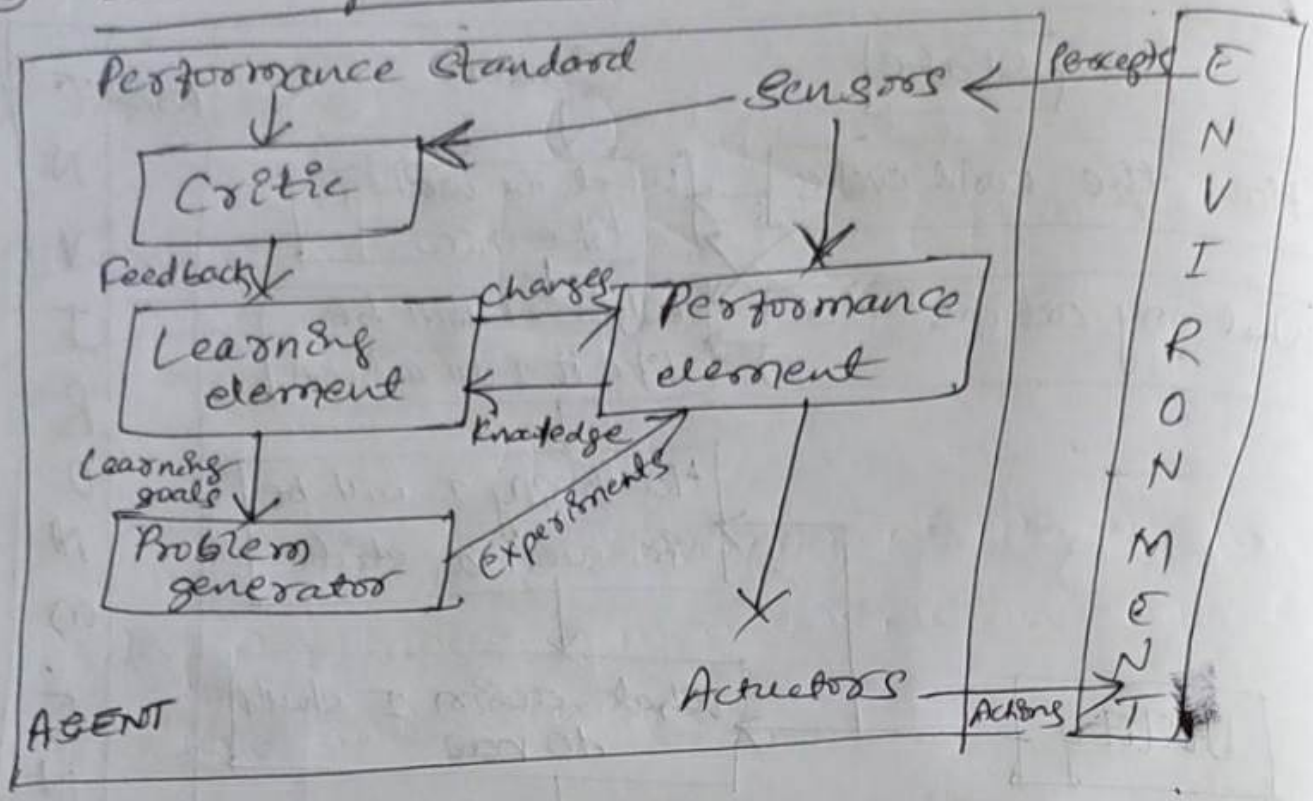
→ A utility based agent is an agent, that acts based not only on what the goal is, but the best way to reach a goal.

→ They choose actions based on preference, for each state.

→ Some are better, more desirable than other methods, there is a 'utility function', which captures this notion of better.

→ Utility function maps a state or sequence of states onto a metric.

(5) Learning agent :-



→ This can learn from its past experiences.
→ It starts to act with basic knowledge and then able to act and adapt automatically through learning.
→ 4 main components are :- i) Performance element ii) Learning element iii) Critic [Feedback] N) Problem generator

- Performance element : the previously described actions and changes in states.
- Learning element : makes changes to actions.
- Critic : Evaluates actions, gives feedback to learning element.
- Problem generator : Suggests actions.

* Rationality in AI :-

It refers to the principle that, such agents should consistently choose actions that are expected to lead to the best possible outcomes, given their current knowledge and the uncertainties present in the environment.

. Rationality guides the behaviour of Intelligent Agents in the following :-

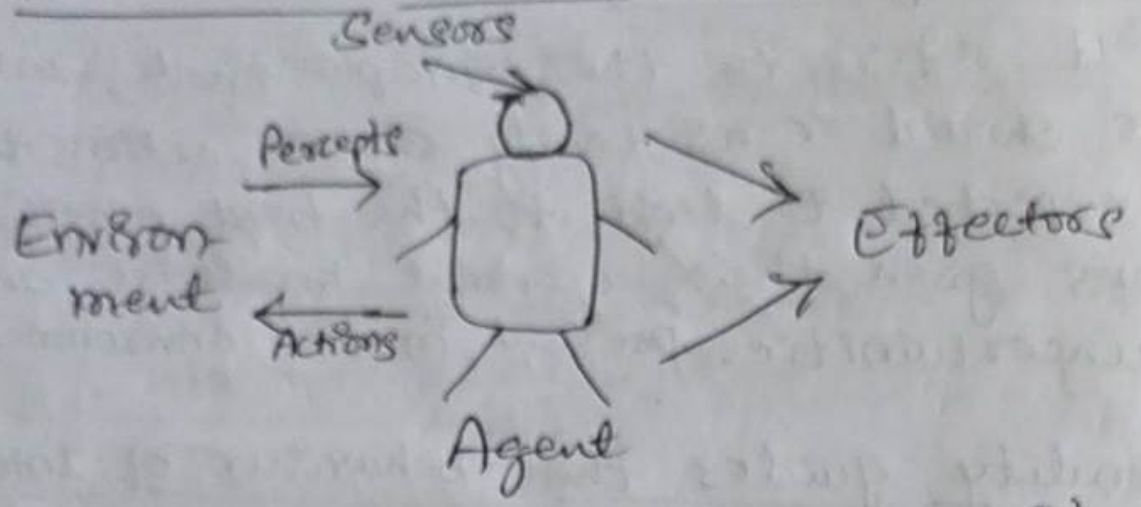
→ Perception and Information Processing :- Rational agents strive to perceive and process information efficiently to gain the most accurate understanding of their environment.

→ Reasoning and Inference : They employ logical reasoning and probabilistic inference to make informed decisions based on available evidence and prior knowledge.

→ Decision-making under Uncertainty :- When faced with uncertainty, rational agents weigh the probabilities of different outcomes and choose actions that maximize their expected utility or achieve the best possible outcome given the available information.

→ Adaptation and Learning :- Rational agents adapt their behavior over time, based on feedback and experience, continuously refining their decision-making strategies to improve performance and achieve their goals more effectively.

* Nature of Environment :-



→ The Nature of environment mainly involves PEAS [Performance measure, Environment, Actuators and Sensors].

- Performance measure: It is a criteria, that measures the success of the agent. It is used to evaluate how well the agent is achieving its goal.
- Environment: It represents the domain context, in which the agent operates and interacts. This can range from physical spaces like rooms to virtual environments such as game worlds or online platforms like the Internet.
- Actuators :- Actuators are the mechanisms through which the AI agent performs actions or interacts with its environment to achieve its goals. These can include physical actuators like motors and robotic hands, as well as digital actuators like computer screens and Text-to-Speech converters.

- **Sensors**: Sensors enable the AI agent to gather information from its environment, providing data that form its decision-making process and actions.

→ These sensors can capture various environmental parameters, such as temperature, sound, movement or visual input. Examples of sensors include Cameras, Microphones, temperature sensors and motion sensors.

* Features (Properties) of Task Environment :-

① Fully observable v/s Partially Observable:

- **Fully observable**: When the agent has complete data about the environment.
- **Partially Observable**: When the agent makes decisions with limited information.

Eg:- Chess game: Fully observable (The entire board is visible)

- Taxi Driving: Partially observable (The taxi driver can't see inside other cars)

② Single Agent v/s Multi Agent:

- **Single Agent**: If only one Intelligent system is working
- **Multi Agent**: When multiple agents are competing or coordinating.

Eg:- • Robot Vaccum Cleaner – Single Agent
• Chess – Multi Agent (there are 2 players)

③ Deterministic v/s Stochastic :-

- Deterministic : Every action has a fixed result
- Stochastic : The environment is unpredictable.

Eg:- • Crossword puzzle - Deterministic (A fixed answer from each word)

• Self-Driving car - Stochastic (Anything can change suddenly)

④ Episodic v/s Sequential :-

- Episodic : Actions are independent of each other
- Sequential : Previous decisions affect future actions

Eg: Quality Inspection Robot :- Episodic (each item's decision is independent - part picking robot)

• Taxi driving - Sequential (a wrong turn can ruin the whole route)

⑤ Static v/s Dynamic :

- Static : When the environment is fixed.
- Dynamic : When the environment is continuously changing

Eg:- • Chess :- static (The board doesnot change)

• Taxi Driving :- Dynamic (Traffic and pedestrians are always changing).

⑥ Discrete v/s Continuous :

- Discrete : When the environment has fixed values
- Continuous : When the environment changes

smoothly.

Eg:- • Chess → Discrete (moves are fixed)
• Self-Driving Car → Continuous (speed and location change smoothly).

⑦ Known V/s Unknown :-

• Known: When the agent already knows the rules of the environment.

• Unknown: When the agent needs to learn the rules.

Eg:- • Chess → Known (Rules are fixed)
• Real world robot (or) A new video game → Unknown (Needs to learn new rules).

* Applications of IAs :-

→ Autonomous (self govern) Systems :- IAs power autonomous vehicles, drones and robots, enabling them to perceive their surroundings, Navigate complex environments and make decisions in real-time.

→ Personal Assistants : Virtual personal assistants like Siri, Alexa and Google assistant employ intelligent agents to understand user queries, retrieve relevant information and perform tasks, such as Scheduling appointments, Setting reminders and Controlling Smart home devices.

→ Recommendation Systems :- E-commerce platforms, streaming services and social media platforms utilize IAs to analyze user preferences and behavior, providing personalized recommendations for products, movies, music and content.

→ Financial Trading :- IAs are employed in algorithmic trading systems to analyze market data, identify trading opportunities and execute trades autonomously, maximizing returns and minimizing risks.

* Challenges for IAs :-

→ Ethical and Legal Implications :- IAs raise ethical concerns regarding privacy, bias, transparency and accountability. Developers must ensure that agents behave ethically and comply with legal regulations and societal norms.

→ Robustness and Reliability :- Agents must be robust and reliable in dynamic and uncertain environments. They should be capable of handling unexpected situations, adversarial attacks, and noisy or incomplete data.

→ Interpretability :- Understanding and interpreting the decisions made by IAs is crucial for building trust and transparency. Explainable AI techniques are

essential for providing insights into the reasoning process and decision-making of agents.

→ Scalability and Efficiency :- As AI systems become increasingly complex and data-intensive, scalability and efficiency become critical considerations. Designing agents that can scale to large-scale deployments and operate efficiency with limited computational resource is essential.

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