Module: 02

Intelligent Agents

Motivation:

This module 2: Intelligent Agents will address detailed description for intelligent agents with it's type.

Syllabus:

Lecture no	Content	Duration (Hr)	Self-Study (Hrs)
1	Agents and Environments, The concept of rationality	1	1
2	The nature of environment, The structure of Intelligent Agents	1	1
3	Types of Agents	1	1
4	Learning Agent	1	1

Learning Objective:

Learner should know AI building blocks presented in intelligent agents.

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Theoretical Background:

An AI system can be defined as the study of the rational agent and its environment. The agents sense the environment through sensors and act on their environment through actuators. An AI agent can have mental properties such as knowledge, belief, intention, etc. The world around us is full of agents such as thermostat, cellphone, camera, and even we are also agents.

Key Definitions:

Agent: It can be anything that perceive its environment through sensors and act upon that environment through actuators. An Agent runs in the cycle of perceiving, thinking, and acting.
Human-Agent: A human agent has eyes, ears, and other organs which work for sensors and hand, legs, vocal tract work for actuators.
Robotic Agent: A robotic agent can have cameras, infrared range finder, NLP for sensors and various motors for actuators.
Software Agent: Software agent can have keystrokes, file contents as sensory input and act on those inputs and display output on the screen.

Course Content:

Lecture : 1

Agents and Environments, The concept of rationality

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

Environments in which agents operate can be defined in different ways. It is helpful to view the following definitions as referring to the way the environment appears from the point of view of the agent itself

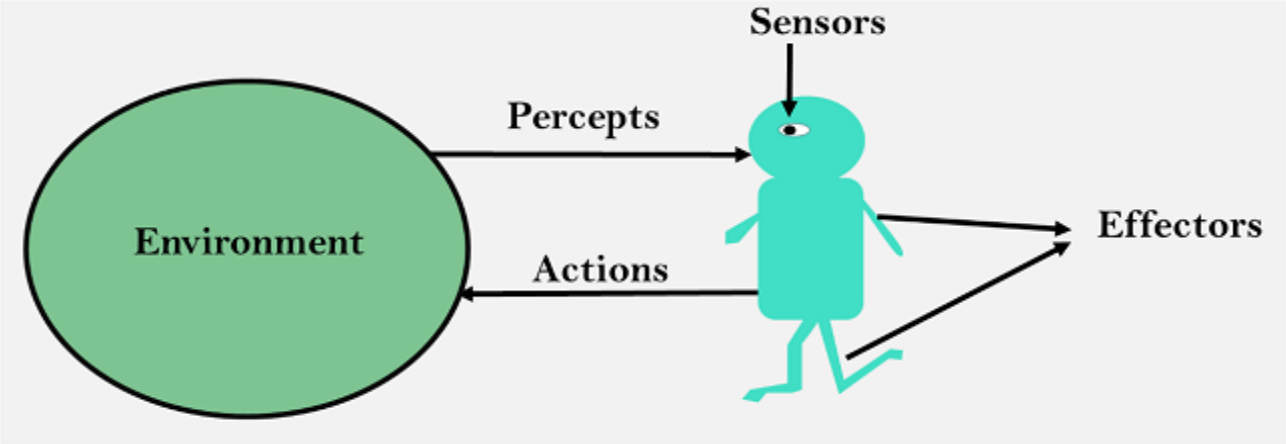
We should first know about sensors, effectors, and actuators.

Sensor: Sensor is a device which detects the change in the environment and sends the information to other electronic devices. An agent observes its environment through sensors.

Actuators: Actuators are the component of machines that converts energy into motion. The actuators are only responsible for moving and controlling a system. An actuator can be an electric motor, gears, rails, etc.

Effectors: Effectors are the devices which affect the environment. Effectors can be legs, wheels, arms, fingers, wings, fins, and display screen.

The **autonomy** of an agent is measured by the extent to which its behavior is determined by its own experience.



Anything that can be viewed as perceiving its environment through sensors and acting upon that environment through its effectors to maximize progress towards its goals.

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. A generic agent is diagrammed in Figure

agent = perceive + act
Thinking
Reasoning
Planning
An agent can be anything that perceive its environment through sensors and act upon that environment through actuators. An Agent runs in the cycle of **perceiving**, **thinking**, and **acting**.

Agent Type	Percepts	Actions	Goals	Environment
Medical diagnosis system	Symptoms, findings, patient's answers	Questions, tests, treatments	Healthy patient, minimize costs	Patient, hospital
Satellite image analysis system	Pixels of varying intensity, color	Print a categorization of scene	Correct categorization	Images from orbiting satellite
Part-picking robot	Pixels of varying intensity	Pick up parts and sort into bins	Place parts in correct bins	Conveyor belt with parts
Refinery controller	Temperature, pressure readings	Open, close valves; adjust temperature	Maximize purity, yield, safety	Refinery
Interactive English tutor	Typed words	Print exercises, suggestions, corrections	Maximize student's score on test	Set of students

A rational agent is an agent which has clear preference, models uncertainty, and acts in a way to maximize its performance measure with all possible actions.

A rational agent is said to perform the right things. AI is about creating rational agents to use for game theory and decision theory for various real-world scenarios.

For an AI agent, the rational action is most important because in AI reinforcement learning algorithm, for each best possible action, agent gets the positive reward and for each wrong action, an agent gets a negative reward.

Note: Rational agents in AI are very similar to intelligent agents.

Rationality:

The rationality of an agent is measured by its performance measure. Rationality can be measured on the basis of following points:

- Performance measure which defines the success criterion.
- Agent prior knowledge of its environment.
- Best possible actions that an agent can perform.

- The sequence of percepts.

How to Evaluate an Agent's Behavior/Performance?

- Rationality => Need a performance measure to say how well a task has been achieved. An ideal rational agent should, for each possible percept sequence, do whatever actions will maximize its performance measure based on (1) the percept sequence, and (2) its built-in and acquired knowledge. Hence includes information gathering, not "rational ignorance."
- Types of objective performance measures: false alarm rate, false dismissal rate, time taken, resources required, effect on environment, etc.
- Examples: Benchmarks and test sets, Turing test
- An AI system can be defined as the study of the rational agent and its environment. The agents sense the environment through sensors and act on their environment through actuators. An AI agent can have mental properties such as knowledge, belief, intention, etc.

Note: Rationality differs from Omniscience because an Omniscient agent knows the actual outcome of its action and act accordingly, which is not possible in reality.

Limited Rationality

Optimal (i.e. best possible) rationality is NOT perfect success: limited sensors, actuators, and computing power may make this impossible

Theory of NP-completeness: some problems are likely impossible to solve quickly on ANY computer

Both natural and artificial intelligence are always limited

Degree of Rationality: the degree to which the agent's internal "thinking" maximizes its performance measure, given

the available sensors

the available actuators

the available computing power

the available built-in knowledge

Structure of an AI Agent

The task of AI is to design 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 we define an AI agent or rational agent, then we can group its properties under PEAS representation model. **It is made up of four words:**

- **P:** Performance measure
- **E:** Environment
- **A:** Actuators
- **S:** Sensors

Here performance measure is the objective for the success of an agent's behavior.

PEAS for self-driving cars:

Let's suppose a self-driving car then PEAS representation will be:

Performance: Safety, time, legal drive, comfort

Environment: Roads, other vehicles, road signs, pedestrian

Actuators: Steering, accelerator, brake, signal, horn

Sensors: Camera, GPS, speedometer, odometer, accelerometer, sonar.

Example of Agents with their PEAS representation

Agent	Performance measure	Environment	Actuators	Sensors
1. Medical Diagnose	Healthy patient Minimized cost	Patient Hospital Staff	Tests Treatments	Keyboard (Entry of symptoms)
2. Vacuum Cleaner	Cleanness Efficiency Battery life Security	Room Table Wood floor Carpet Various obstacles	Wheels Brushes Vacuum Extractor	Camera Dirt detection sensor Cliff sensor Bump Sensor Infrared Wall Sensor
3. Part - picking Robot	Percentage of parts in correct bins.	Conveyor belt with parts, Bins	Jointed Arms Hand	Camera Joint angle sensors.

check the take away from this lecture

Exercise

Q.1 An _____ perceives and acts in an environment.

(a) agent (b) complier

(c) system (d) All of the above

Q.2 Vacuum Cleaner, carpet is _____.

(a) Performance measure **(b) Environment** (c)Actuators (d) Sensors

Q.3 Agent = Architecture + _____

(a) Agent Software

(b)Agent Program

(c) Agent Instructions

(d) None of above

Q.4 In PEAS model E stands for_____

(a) Environment

(b) Effectors

(c) Energy

(d) All of above

Learning from this lecture: Learners will be able to understand Agents and Environments, The concept of rationality.

Lecture : 2

The nature of environment, The structure of Intelligent Agents

Environments in which agents operate can be defined in different ways. It is helpful to view the following definitions as referring to the way the environment appears from the point of view of the agent itself.

We have seen that intelligent agents should take into account certain information when choosing a rational action, including information from its sensors, information from the world, information from previous states of the world, information from its goal and information from its utility function(s). We also need to take into account some specifics about the environment it works in. On the surface, this consideration would appear to apply more to robotic agents moving around the real world. However, the considerations also apply to software agents who are receiving data and making decisions which affect the data they receive - in this case we can think of the environment as the flow of information in the data stream. For example, an AI agent may be employed to dynamically update web pages based on the requests from internet users.

An environment is everything in the world which surrounds the agent, but it is not a part of an agent itself. An environment can be described as a situation in which an agent is present.

The environment is where agent lives, operate and provide the agent with something to sense and act upon it. An environment is mostly said to be non-feministic.

Features of Environment

As per Russell and Norvig, an environment can have various features from the point of view of an agent:

1. Fully observable vs Partially Observable
2. Static vs Dynamic
3. Discrete vs Continuous

4. Deterministic vs Stochastic
5. Single-agent vs Multi-agent
6. Episodic vs sequential
7. Known vs Unknown
8. Accessible vs Inaccessible

1. Fully observable vs Partially Observable:

- If an agent sensor can sense or access the complete state of an environment at each point of time then it is **a fully observable** environment, else it is **partially observable**.
- A fully observable environment is easy as there is no need to maintain the internal state to keep track history of the world.
- An agent with no sensors in all environments then such an environment is called as **unobservable**.

2. Deterministic vs Stochastic:

- If an agent's current state and selected action can completely determine the next state of the environment, then such environment is called a deterministic environment.
- A stochastic environment is random in nature and cannot be determined completely by an agent.
- In a deterministic, fully observable environment, agent does not need to worry about uncertainty.

3. Episodic vs Sequential:

- In an episodic environment, there is a series of one-shot actions, and only the current percept is required for the action.
- However, in Sequential environment, an agent requires memory of past actions to determine the next best actions.

4. Single-agent vs Multi-agent

- If only one agent is involved in an environment, and operating by itself then such an environment is called single agent environment.
- However, if multiple agents are operating in an environment, then such an environment is called a multi-agent environment.
- The agent design problems in the multi-agent environment are different from single agent environment.

5. Static vs Dynamic:

- If the environment can change itself while an agent is deliberating then such environment is called a dynamic environment else it is called a static environment.

- Static environments are easy to deal because an agent does not need to continue looking at the world while deciding for an action.
- However for dynamic environment, agents need to keep looking at the world at each action.
- Taxi driving is an example of a dynamic environment whereas Crossword puzzles are an example of a static environment.

6. Discrete vs Continuous:

- If in an environment there are a finite number of percepts and actions that can be performed within it, then such an environment is called a discrete environment else it is called continuous environment.
- A chess gamecomes under discrete environment as there is a finite number of moves that can be performed.
- A self-driving car is an example of a continuous environment.

7. Known vs Unknown

- Known and unknown are not actually a feature of an environment, but it is an agent's state of knowledge to perform an action.
- In a known environment, the results for all actions are known to the agent. While in unknown environment, agent needs to learn how it works in order to perform an action.
- It is quite possible that a known environment to be partially observable and an Unknown environment to be fully observable.

8. Accessible vs Inaccessible

- If an agent can obtain complete and accurate information about the state's environment, then such an environment is called an Accessible environment else it is called inaccessible.
- An empty room whose state can be defined by its temperature is an example of an accessible environment.
- Information about an event on earth is an example of Inaccessible environment.

Task environment	Car driving	Part – Picking Robot	Cross word puzzle	Soccer game	Checkers with clock
Observable	Partially	Partially	fully	Partially	Fully
Agents	Multi agent (cooperative)	Single agent	single	Multi agent (competitive)	Multi agent (competitive)
Deterministic	Stochastic	Stochastic	Deterministic	Strategic	Strategic

Episodic	Sequential	Episodic	Sequential	Sequential	Sequential
Static	Dynamic	Dynamic	Static	Dynamic	Semi
Discrete	Continuous	Discrete	Discrete	Continuous	Discrete
Known and Unknown	Unknown	Known	Known	Known	Known

Environment	Accessible	Deterministic	Episodic	Static	Discrete
Chess with a clock	Yes	Yes	No	Semi	Yes
Chess without a clock	Yes	Yes	No	Yes	Yes
Poker	No	No	No	Yes	Yes
Backgammon	Yes	No	No	Yes	Yes
Taxi driving	No	No	No	No	No
Medical diagnosis system	No	No	No	No	No
Image-analysis system	Yes	Yes	Yes	Semi	No
Part-picking robot	No	No	Yes	No	No
Refinery controller	No	No	No	No	No
Interactive English tutor	No	No	No	No	Yes

l acts rationally at a time, and

aracteristics are situatedness, autonomy, adaptivity, and sociability.

- An intelligent agent is one that is capable of taking flexible self governed actions.

Agent Characteristics

- **Situatedness**
  The agent receives some form of sensory input from its environment, and it performs some action that changes its environment in some way. Examples of environments: the physical world and the Internet.
- **Autonomy**
  The agent can act without direct intervention by humans or other agents and that it has control over its own actions and internal state.
- **Adaptivity**
  The agent is capable of (1) reacting flexibly to changes in its environment; (2) taking goal-directed initiative (i.e., is pro-active), when appropriate; and (3) learning from its own experience, its environment, and interactions with others.
- **Sociability**
  The agent is capable of interacting in a peer-to-peer manner with other agents or humans.

Intelligent agent architecture is a model of an intelligent information-processing system defining its major subsystems, their functional roles, and the flow of information and control among them. An intelligent agent is a device that interacts with its environment in flexible, goal-directed ways, recognizing important states of the environment and acting to achieve desired results. Clearly, when designing a particular agent, many domain-specific features of the environment must be reflected in the detailed design of the agent. Still, the general form of the subsystems underlying intelligent interaction with the environment may carry over from domain to domain. Intelligent agent architectures attempt to capture these general forms and to enforce basic system properties such as soundness of reasoning, efficiency of response, or interpretability. Much architecture has been proposed that emphasize one or another of these properties, and these architectures can be usefully grouped into three broad categories: the deliberative, the reactive, or the distributed.

Every time environment changes the agent first observes the environment through its sensors and get the input then scans the database of input and actions for the corresponding action for given input and lastly sets the internal state to the appropriate action.

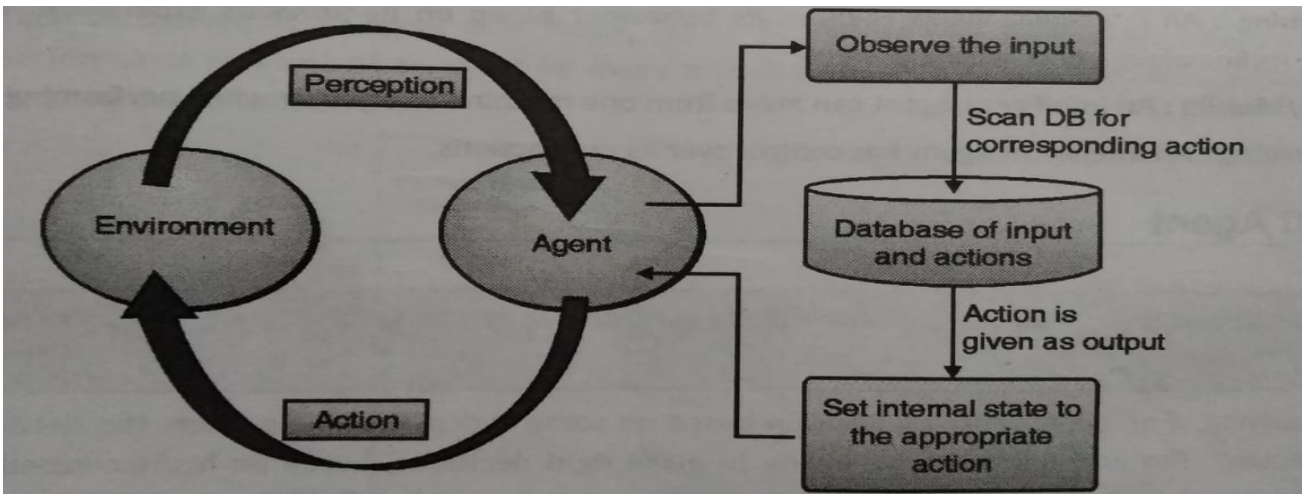
An intelligent agent is an autonomous entity which acts upon an environment using sensors and actuators for achieving goals. An intelligent agent may learn from the environment to achieve their goals. A thermostat is an example of an intelligent agent.

A simple example of an agent in a physical environment is a thermostat for a heater. The thermostat receives input from a sensor, which is embedded in the environment, to detect the temperature. Two states: (1) temperature too cold and (2) temperature OK are possible. Each state has an associated action: (1) too cold turn the heating on and (2) temperature OK turn the heating off. The first action has the effect of raising the room temperature, but this is not guaranteed. If cold air continuously comes into the room, the added heat may not have the desired effect of raising the room temperature.

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.

Architecture of Intelligent Agent



Real time example:
Cooking in kitchen and by mistakenly touch a hot pan. Your touch sensors take inputs from environment then it ask your brain what action should be taken when you go near hot elements? Now the brain will inform your hands (actuators) that you should immediately take it away from hot element otherwise it will burn. Once this signal reaches your hand you will take your hand away from the hot pan.
The idea of intelligent software agents has captured the popular imagination. Tell the agent what you want done, set it free, and wait for it to return results sounds too good to be true. But we'll come back to that later. In the meantime, let's address the question of what makes an agent intelligent. Wooldridge and Jennings (1995) define an intelligent agent as one that is capable of flexible autonomous action to meet its design objectives. Flexible means It is with following three things:

Reactivity: intelligent agents perceive and respond in a timely fashion to changes that occur in their environment in order to satisfy their design objectives. The agent's goals and/or assumptions that form the basis for a procedure that is currently executing may be affected by a changed environment and a different set of actions may be need to be performed. E.g In above example if an agent takes more time to take hand away from the hot pan then agents hand will be burnt.

Pro-activeness: reacting to an environment by mapping a stimulus into a set of responses is not enough. As we want intelligent agents to do things for us, goal directed behavior is needed. In a changed environment, intelligent agents have to recognize opportunities and take the initiative if they are to produce meaningful results. The challenge to the agent designer is to integrate effectively goal-directed and reactive behavior. E.g Chess game killing and loosing 16 pieces is not important, to checkmate your opponent is important.

Social ability: intelligent agents are capable of interacting with other agents (and possibly humans).e.g Automatic driving car where agent might have to interact with other agent and human being while driving the car.

Other properties sometimes mentioned in the context of intelligent agents include:

- **mobility**: the ability to move around an electronic environment
- **veracity**: an agent will not knowingly communicate false information
- **benevolence**: agents do not have conflicting goals and every agent will therefore always try to do what is asked of it
- **rationality**: an agent will act in order to achieve its goals insofar as its beliefs permit
- **learning/adaptation**: agents improve performance over time
- **self governing:** It has control over its own actions

Let's check the take away from this lecture

Exercise

Q.1 An environment is everything in the world which _____the agent.

(a)related

(b)above

(c)behinds

(d)surrounds

Q.2 Taxi driving is example of _____environment.

(a) Dynamic

(b) Static

(c) Mixed

(d) neutral

(3) The agent can act without direct intervention by humans or other agents is_____feature.

(a) Reactive

(b) Proactive

(c) Autonomy

(d) Social ability

(4) agents improve performance over time is _____

(a) Learning

(b) Reactive

(b) Proactive

(d) Autonomy

(5)_____ is/are rule of AI Agent.

(a)An AI agent must have the ability to perceive the environment.
(b)The observation must be used to make decisions.
(c)Decision should result in an action.
(d) **All of above**

Learning from this lecture: Learners will be able to understand the nature of environment and the structure of Agents

Lecture : 3

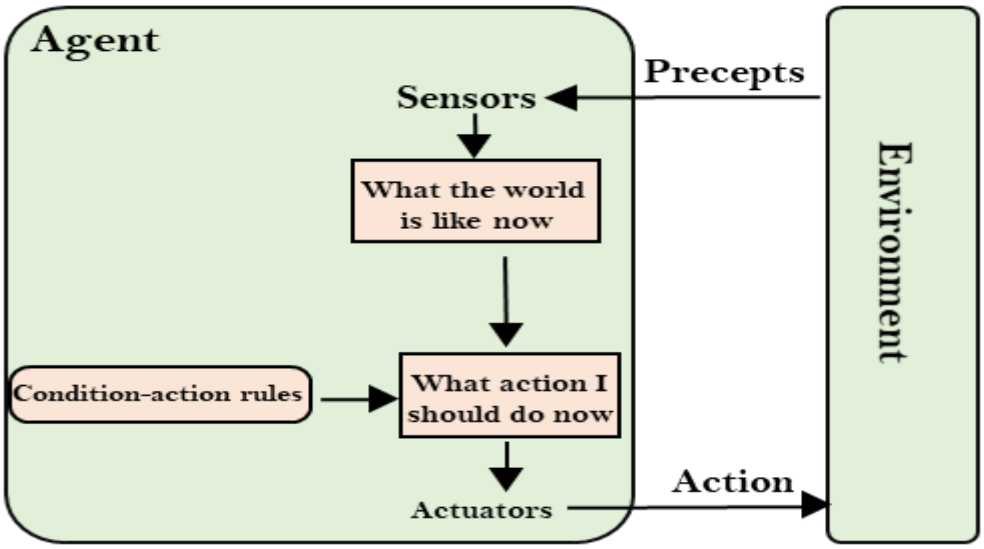
Types of Agents

Agents can be grouped into five classes based on their degree of perceived intelligence and capability. All these agents can improve their performance and generate better action over the time. These are given below:

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

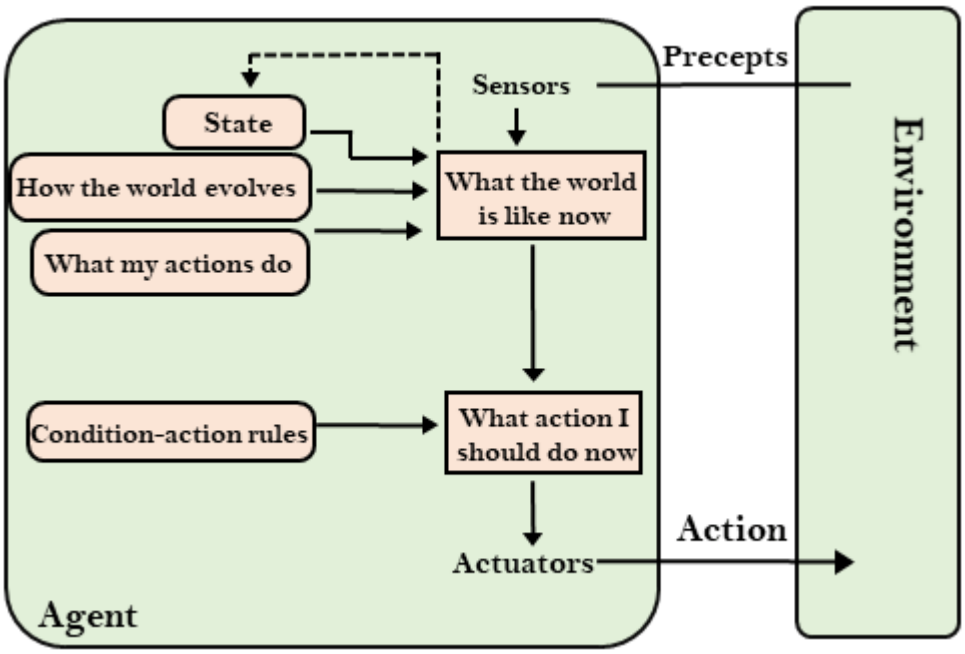
1. Simple Reflex agent:

- The Simple reflex agents are the simplest agents. These agents take decisions on the basis of the current percepts and ignore the rest of the percept history.
- These agents only succeed in the fully observable environment.
- The Simple reflex agent does not consider any part of percepts history during their decision and action process.
- The Simple reflex agent works on Condition-action rule, which means it maps the current state to action. Such as a Room Cleaner agent, it works only if there is dirt in the room.
- Problems for the simple reflex agent design approach:
  - They have very limited intelligence
  - They do not have knowledge of non-perceptual parts of the current state
  - Mostly too big to generate and to store.
  - Not adaptive to changes in the environment.



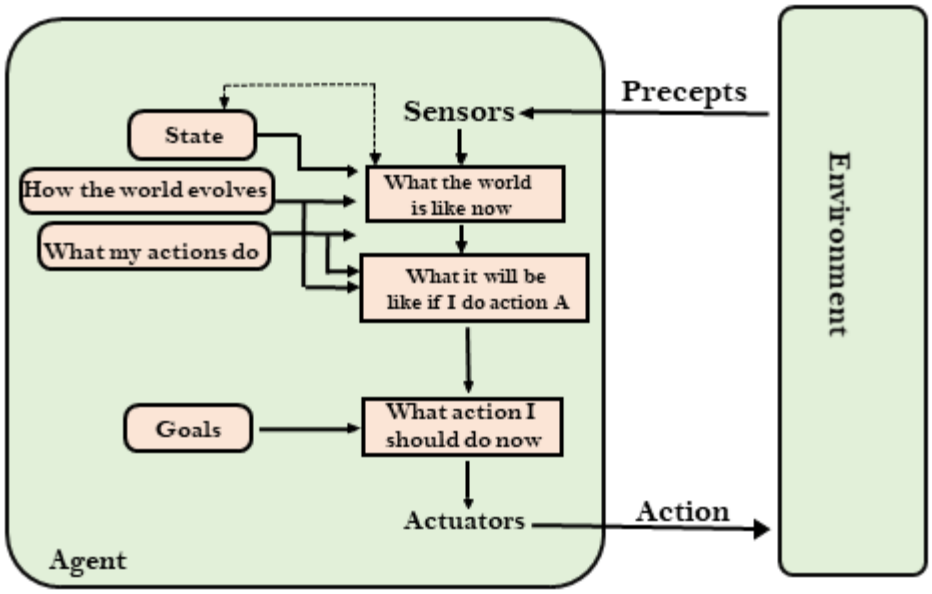
2. Model-based reflex agent

- The Model-based agent can work in a partially observable environment, and track the situation.
- A model-based agent has two important factors:
  - **Model:** It is knowledge about "how things happen in the world," so it is called a Model-based agent.
  - **Internal State:** It is a representation of the current state based on percept history.
- These agents have the model, "which is knowledge of the world" and based on the model they perform actions.
- Updating the agent state requires information about:
  - How the world evolves
  - How the agent's action affects the world.



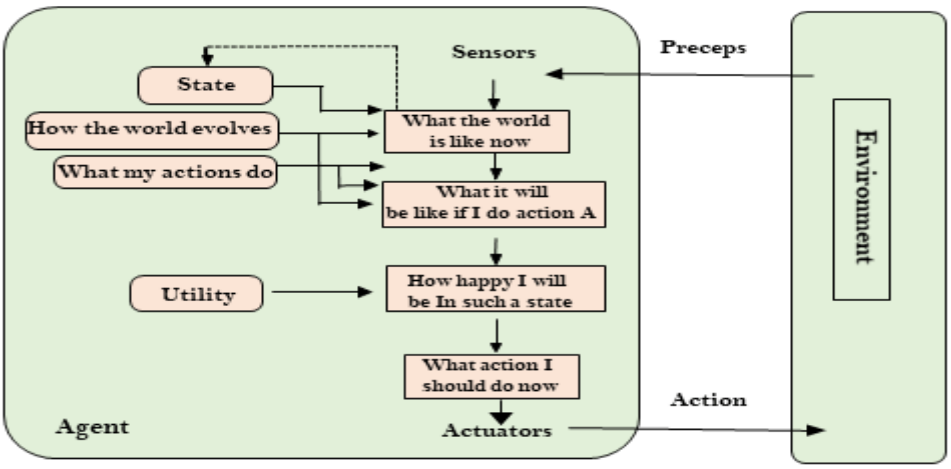
3. Goal-based agents

- The knowledge of the current state environment is not always sufficient to decide for an agent to what to do.
- The agent needs to know its goal which describes desirable situations.
- Goal-based agents expand the capabilities of the model-based agent by having the "goal" information.
- They choose an action, so that they can achieve the goal.
- These agents may have to consider a long sequence of possible actions before deciding whether the goal is achieved or not. Such considerations of different scenario are called searching and planning, which makes an agent proactive.



4. Utility-based agents

- These agents are similar to the goal-based agent but provide an extra component of utility measurement which makes them different by providing a measure of success at a given state.
- Utility-based agent act based not only goals but also the best way to achieve the goal.
- The Utility-based agent is useful when there are multiple possible alternatives, and an agent has to choose in order to perform the best action.
- The utility function maps each state to a real number to check how efficiently each action achieves the goals.



Let's check the take away from this lecture

Exercise

Q.1 _____ agents act only on the basis of the current percept.

(A) Goal based agent (B) Utility based agent

(C) Simple reflex agent (D) None of above

Q.2 _____can work in a partially observable environment, and track the situation.

(A) Goal based agent (B) Utility based agent

(C) Simple reflex agent **(D) Model based agents**

Q.3 The knowledge of the current state environment is not always sufficient to decide for an agent to what to do for_____.

(A) Goal based agent (B) Utility based agent

(C) Simple reflex agent (D) Model based agents

Q.4 _____is useful when there are multiple possible alternatives, and an agent has to choose in order to perform the best action.

(A) Goal based agent **(B) Utility based agent**

(C) Simple reflex agent (D) Model based agents

Learning from this lecture: Learners will be able to understand **Types of Agents**

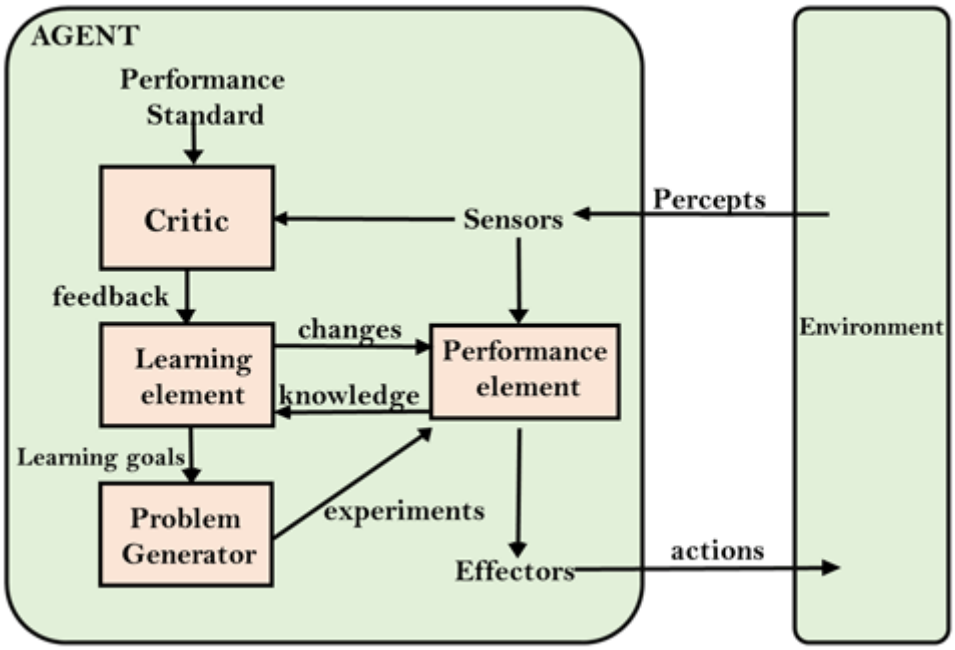
Lecture : 4

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:

    1. **Learning element:** It is responsible for making improvements by learning from environment
    2. **Critic:** Learning element takes feedback from critic which describes that 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.

- Hence, learning agents are able to learn, analyze performance, and look for new ways to improve the performance.



Let’s check the take away from this lecture

Exercise

Q.1 _____is responsible for making improvements by learning from environment.

(a) Learning element (b) Critic (c) Performance element (d) Problem generator

Q.2 _____is responsible for selecting external action

(a) Learning element (b) Critic **(c) Performance element** (d) Problem generator

Learning from this lecture: Learners will be able to understand learning agents and their components.

Conclusion

This Module is all about agents and rationality, nature of environments, types of agents and learning agent

Short Answer Questions:

1. Define the following: Agent, Intelligent Agent, Agent function, Agent program, Rationality and reflex agent.(R)
2. Discuss correspondence between intelligent agents and human agents. (U)
3. Can there be more than one agent program that implements a given agent function. Explain with example. (AN)
4. Are there agent's functions which cannot be implemented by any agent program? [AN]
5. Explain various types of intelligent agents with suitable diagram. [U]

Long Answer Questions:

1. Describe an Agents, the Concept of Rationality and Intelligent agents in detail.[U]
2. Explain the intelligent agent with architecture diagram and characteristics. [U]
3. Discuss the properties of task environments with one example of each. [U]
4. Tabulate PEAS description for E-commerce System, An automated face recogniser, ATM System, Interactive English Tutor and Part Picking robot. [A]
5. Distinguish between various types of agents. [AN]

References:

Books:

	Title	Authors	Publisher	Edition	Year
1	Artificial Intelligence a Modern Approach	Stuart J. Russell and Peter Norvig	McGraw Hill	3rd Edition	2009
2	A First Course in Artificial	Deepak Khemani	McGraw Hill	1st Edition	

	Intelligence		Education (India)		2013

Online Resources:

- https://onlinecourses.nptel.ac.in/noc20_cs81/preview
- https://nptel.ac.in/courses/106/102/106102220/
- https://www.coursera.org/learn/introduction-to-ai/
- https://www.coursera.org/learn/ai-for-everyone?#syllabus
- https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligent_systems.htm
- https://www.javatpoint.com/history-of-artificial-intelligence
- https://people.eecs.berkeley.edu/~russell/
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- http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.89.5278&rep=rep1&type=pdf