CHAPTER 1

Unit I

Introduction to Artificial Intelligence(AI) and Soft Computing

Syllabus

1.1 Introduction and Definition of Artificial Intelligence.

1.2 Intelligent Agents : Agents and Environments ,Rationality, Nature of Environment, Structure of Agent, types of Agent

1.3 Soft Computing: Introduction of soft computing, soft computing vs. hard computing, various types of soft computing techniques.

1.1 Introduction to Artificial Intelligence

- John McCarthy who has coined the word "Artificial Intelligence" in 1956, has defined AI as "the science and engineering of making intelligent machines", especially intelligent computer programs.
- **Artificial Intelligence (AI)** is relevant to any intellectual task where the machine needs to take some decision or choose the next action based on the current state of the system, in short act intelligently or rationally. As it has a very wide range of applications, it is truly a universal field.
- In simple words, Artificial Intelligent System works like a Human Brain, where a machine or software shows intelligence while performing given tasks; such systems are called **intelligent systems** or **expert systems**. You can say that these systems can "think" while generating output!!!
- AI is one of the newest fields in science and engineering and has a wide variety of application fields. AI applications range from the general fields like learning, perception and prediction to the specific field, such as writing stories, proving mathematical theorems, driving a bus on a crowded street, diagnosing diseases, and playing chess.
- AI is the study of how to make machines do thing which at the moment people do better. Following are the four approaches to define AI.

1.2 Foundations and Mathematical Treatments

- In general, artificial intelligence is the study of how to make machines do things which at the moment human do better. Following are the four approaches to define AI.
- Historically, all four approaches have been followed by different group of people with different methods.

1.2.1 Acting Humanly : The Turing Test Approach

MU - May 16

Q. Explain turing test designed for satisfactory operational definition of AI. **(May 16, 5 Marks)**

- **Definition 1 :** "The art of creating machines that perform functions that requires intelligence when performed by people." (Kurzweil, 1990)
- **Definition 2 :** "The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)

- To judge whether the system can act like a human, Sir Alan Turing had designed a test known as **Turing test.**
- As shown in Fig. 1.2.1, in Turing test, a computer needs to interact with a human interrogator by answering his questions in written format. Computer passes the test if a human interrogator, cannot identify whether the written responses are from a person or a computer. Turing test is valid even after 60 year of research.

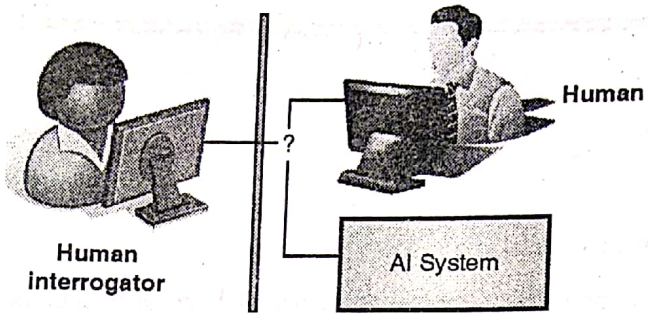


Fig.1.2.1 : Turing Test Environment

- For this test, the computer would need to possess the following capabilities:
  1. **Natural Language Processing (NLP) :** This unit enables computer to interpret the English language and communicate successfully.
  2. **Knowledge Representation :** This unit is used to store knowledge gathered by the system through input devices.
  3. **Automated Reasoning:** This unit enables to analyze the knowledge stored in the system and makes new inferences to answer questions.
  4. **Machine Learning:** This unit learns new knowledge by taking current input from the environment and adapts to new circumstances, thereby enhancing the knowledgebase of the system.
- To pass total Turing test, the computer will also need to have **computer vision,** which is required to perceive objects from the environment and **Robotics,** to manipulate those objects.

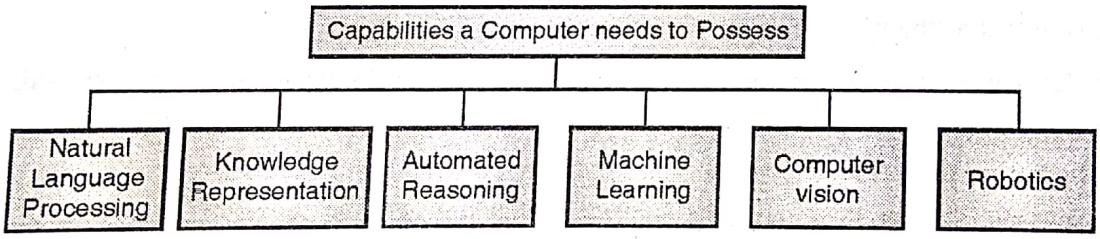


Fig. 1.2.2 : Capabilities a Computer needs to possess

- Fig. 1.2.2 lists all the capabilities a computer needs to have in order to exhibit artificial intelligence. Mentioned above are the six disciplines which implement most of the artificial intelligence.

1.2.2 Thinking Humanly : The Cognitive Modelling Approach

- **Definition1 :** "The exciting new effort to make computers think ... machines with minds, in the full and literal sense". (Haugeland, 1985)
- **Definition 2 :** "The automation of activities that we associate with human thinking, activities such as decision making, problem solving, learning ..." (Hellman, 1978)
- **Cognitive science :**It is interdisciplinary field which combines computer models from Artificial Intelligence with the techniques from psychology in order to construct precise and testable theories for working of human mind.

- In order to make machines think like human, we need to first understand how human think. Research showed that there are three ways using which human's thinking pattern can be caught.
  1. **Introspection** through which human can catch their own thoughts as they go by.
  2. **Psychological experiments** can be carried out by observing a person in action.
  3. **Brain imaging** can be done by observing the brain in action.
- By catching the human thinking pattern, it can be implemented in computer system as a program and if the program's input output matches with that of human, then it can be claimed that the system can operate like humans.

1.2.3 Thinking Rationally : The "Laws of Thought" Approach

- **Definition1 :** "The study of mental faculties through the use of computational models". (Charniak and McDermott, 1985)
- **Definition2 :** "The study of the computations that make it possible to perceive, reason, and act".
- The laws of thought are supposed to implement the operation of the mind and their study initiated the field called logic. It provides precise notations to express facts of the real world.
- It also includes reasoning and "right thinking" that is irrefutable thinking process. Also computer programs based on those logic notations were developed to create intelligent systems.

There are two problems in this approach :

1. This approach is not suitable to use when 100% knowledge is not available for any problem.
2. As vast number of computations was required even to implement a simple human reasoning process; practically, all problems were not solvable because even problems with just a few hundred facts can exhaust the computational resources of any computer.

1.2.4 Acting Rationally : The Rational Agent Approach

- **Definition 1 :**"Computational Intelligence is the study of the design of intelligent agents". (Poole et at, 1998)
- **Definition 2:**"AI ... is concerned with intelligent behaviour in artifacts". (Nilsson, 1998)

Rational Agent

- Agents perceive their environment through sensors over a prolonged time period and adapt to change to create and pursue goals and take actions through actuators to achieve those goals. A rational agent is the one that does "right" things and acts rationally so as to achieve the best outcome even when there is uncertainty in knowledge.
- **The rational-agent approach has two advantages over the other approaches**
  1. As compared to other approaches this is the more general approach as, rationality can be achieved by selecting the correct inference from the several available.
  2. Rationality has specific standards and is mathematically well defined and completely general and can be used to develop agent designs that achieve it. Human behavior, on the other hand, is very subjective and cannot be proved mathematically.

- The two approaches namely, thinking humanly and thinking rationally are based on the reasoning expected from intelligent systems while; the other two acting humanly and acting rationally are based on the intelligent behaviour expected from them.
- In our syllabus we are going to study acting rationally approach.

1.3 Categorization of Intelligent Systems

As AI is a very broad concept, there are different types or forms of AI. The critical categories of AI can be based on the capacity of intelligent program or what the program is able to do. Under this consideration there are three main categories:

1. Artificial Narrow Intelligence/ Weak AI

Weak AI is AI that specializes in one area. It is not a general purpose intelligence. An intelligent agent is built to solve a particular problem or to perform a specific task is termed as narrow intelligence or weak AI. For example, it took years of AI development to be able to beat the chess grandmaster, and since then we have not been able to beat the machines at chess. But that is all it can do, which is does extremely well.

2. Artificial General Intelligence / Strong AI

Strong AI or general AI refers to intelligence demonstrated by machines in performing any intellectual task that human can perform. Developing strong AI is much harder than developing weak AI. Using artificial general intelligence machines can demonstrate human abilities like reasoning, planning, problem solving, comprehending complex ideas, learning from self experiences, etc. Many companies, corporations' are working on developing a general intelligence but they are yet to complete it.

3. Artificial Super Intelligence

As defined by a leading AI thinker Nick Bostrom, "Super intelligence is an intellect that is much smarter than the best human brains in practically every field, including scientific creativity, general wisdom and social skills." Super intelligence ranges from a machine which is just a little smarter than a human to a machine that is trillion times smarter. Artificial super intelligence is the ultimate power of AI.

1.4 Components of AI

AI is a vast field for research and it has got applications in almost all possible domains. By keeping this in mind, components of AI can be identified as follows: (Refer Fig.1.4.1)

1. Perception
2. Knowledge representation
3. Learning
4. Reasoning
5. Problem solving
6. Natural language processing (Language-understanding)

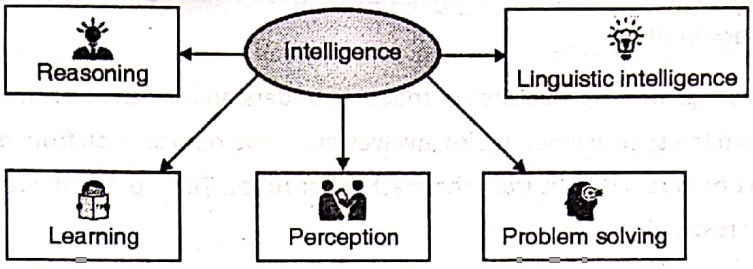


Fig. 1.4.1 : Components of AI

1. Perception

In order to work in the environment, intelligent agents need to scan the environment and the various objects in it. Agent scans the environment using various sense organs like camera, temperature sensor, etc. This is called as perception. After capturing various scenes, perceiver analyses the different objects in it and extracts their features and relationships among them.

2. Knowledge representation

The information obtained from environment through sensors may not be in the format required by the system. Hence, it need to be represented in standard formats for further processing like learning various patterns, deducing inference, comparing with past objects, etc. There are various knowledge representation techniques like Prepositional logic and first order logic.

3. Learning

Learning is a very essential part of AI and it happens in various forms. The simplest form of learning is by trial and error. In this form the program remembers the action that has given desired output and discards the other trial actions and learns by itself. It is also called as unsupervised learning. In case of rote learning, the program simply remembers the problem solution pairs or individual items. In other case, solution to few of the problems is given as input to the system, basis on which the system or program needs to generate solutions for new problems. This is known as supervised learning.

4. Reasoning

Reasoning is also called as logic or generating inferences form the given set of facts. Reasoning is carried out based on strict rule of validity to perform a specified task. Reasoning can be of two types, deductive or inductive. The deductive reasoning is in which the truth of the premises guarantees the truth of the conclusion while, in case of inductive reasoning, the truth of the premises supports the conclusion, but it cannot be fully dependent on the premises. In programming logic generally deductive inferences are used. Reasoning involves drawing inferences that are relevant to the given problem or situation.

5. Problem-solving

AI addresses huge variety of problems. For example, finding out winning moves on the board games, planning actions in order to achieve the defined task, identifying various objects from given images, etc. As per the types of problem, there is variety of problem solving strategies in AI. Problem solving methods are mainly divided into general purpose methods and special purpose methods. General purpose methods are applicable to wide range of problems while, special purpose methods are customized to solve particular type of problems.

6. Natural language processing

Natural Language Processing, involves machines or robots to understand and process the language that human speak, and infer knowledge from the speech input. It also involves the active participation from machine in the form of dialog i.e. NLP aims at the text or verbal output from the machine or robot. The input and output of an NLP system can be speech and written text respectively.

1.4.1 Computational Intelligence vs. Artificial Intelligence

Computational Intelligence (CI)	Artificial Intelligence (AI)
Computational Intelligence is the study of the design of intelligent agents	Artificial Intelligence is study of making machines which can do things which at presents human do better.
CI involves numbers and computations.	AI involves designs and symbolic knowledge representations.
CI constructs the system starting from the bottom level computations, hence follows bottom-up approach.	AI analyses the overall structure of an intelligent system by following top down approach.
CI concentrates on low level cognitive function implementation.	AI concentrates of high level cognitive structure design.

1.5 History of Artificial Intelligence

- The term **Artificial Intelligence (AI)** was introduced by John McCarthy, in 1955. He defined artificial intelligence as "The science and engineering of making intelligent machines".
- Mathematician Alan Turing and others presented a study based on logic driven computational theories which showed that any computer program can work by simply shuffling "0" and "1" (i.e. electricity off and electricity *on*). Also, during that time period, research was going on in the areas like Automations, Neurology, Control theory, Information theory, etc.
- This inspired a group of researchers to think about the possibility of creating an electronic brain. In the year 1956 a conference was conducted at the campus of Dartmouth College where the field of artificial intelligence research was founded.
- This conference was attended by John McCarthy, Marvin Minsky, Allen Newell and Herbert Simon, etc., who are supposed to be the pioneers of artificial intelligence research for a very long time. During that time period, Artificial Intelligence systems were developed by these researchers and their students.
- Let's see few examples of such artificial intelligent systems :
  1. **Game : Checkers :** Computer played as an opponent,
  2. **Education : Algebra :** For solving word problems,
  3. **Education : Math :**Proving logical theorems,
  4. **Education : Language :** Speaking English, etc.
- During that time period these founders predicted that in few years machines can do any work that a man can do, but they failed to recognize the difficulties which can be faced.

- Meanwhile we will see the ideas, viewpoints and techniques which Artificial Intelligence has inherited from other disciplines. They can be given as follows :

1. **Philosophy :** Theories of reasoning and learning have emerged, along with the viewport that the mind is constituted by the operation of a physical system.
2. **Mathematical :** Formal theories of logic, probability, decision making and computation have emerged.
3. **Psychology :** Psychology has emerged tools to investigate the human mind and a scientific language which are used to express the resulting theories.
4. **Linguistic :** Theories of the structure and meaning of language have emerged.
5. **Computer science :** The tools which can make artificial intelligence a reality has emerged.

1.6 Applications of Artificial Intelligence

- You must have seen use of Artificial Intelligence in many SCI-FI movies. To name a few we have I Robot, Wall-E, The Matrix Trilogy, Star Wars, etc. movies. Many a times these movies show positive potential of using AI and sometimes also emphasize the dangers of using AI. Also there are games based on such movies, which show us many probable applications of AI.
- Artificial Intelligence is commonly used for problem solving by analyzing or/and predicting output for a system. AI can provide solutions for constraint satisfaction problems. It is used in wide range of fields for example in diagnosing diseases, in business, in education, in controlling a robots, in entertainment field, etc.

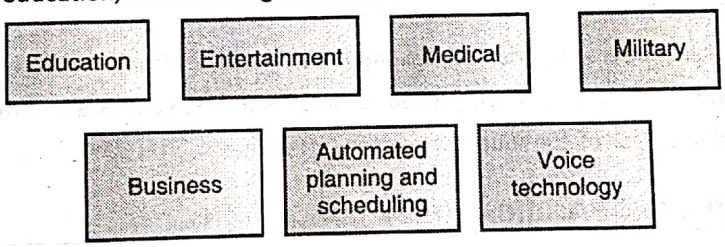


Fig. 1.6.1 : Fields of AI Application

- Fig. 1.6.1 shows few fields in which we have applications of artificial intelligence. There can be many fields in which Artificially Intelligent Systems can be used.

1. **Education**

Training simulators can be built using artificial intelligence techniques. Software for pre-school children are developed to enable learning with fun games. Automated grading, Interactive tutoring, instructional theory are the current areas of application.

2. **Entertainment**

Many movies, games, robots are designed to play as a character. In games they can play as an opponent when human player is not available or not desirable.

3. **Medical**

AI has applications in the field of cardiology (CRG), Neurology (MRI), Embryology (Sonography), complex operations of internal organs, etc. It can be also used in organizing bed schedules, managing staff rotations, store and retrieve information of patient. Many expert systems are enabled to predict the decease and can provide with medical prescriptions.

4. **Military**

Training simulators can be used in military applications. Also areas where human cannot reach or in life stacking conditions, robots can be very well used to do the required jobs. When decisions have to be made quickly taking into account an enormous amount of information, and when lives are at stake, artificial intelligence can provide crucial assistance. From developing intricate flight plans to implementing complex supply systems or creating training simulation exercises, AI is a natural partner in the modern military.

5. **Business and Manufacturing**

Latest generation of robots are equipped well with the performance advances, growing integration of vision and an enlarging capability to transform manufacturing.

6. **Automated planning and scheduling**

Intelligent planners are available with AI systems, which can process large datasets and can consider all the constraints to design plans satisfying all of them.

7. **Voice technology**

Voice recognition is improved a lot with AI. Systems are designed to take voice inputs which are very much applicable in case of handicaps. Also scientists are developing an intelligent machine to emulate activities of a skillful musician. Composition, performance, sound processing, music theory are some of the major areas of research.

8. **Heavy industry**

Huge machines involve risk in operating and maintaining them. Human robots are better replacing human operators. These robots are safe and efficient. Robot are proven to be effective as compare to human in the jobs of repetitive nature, human may fail due to lack of continuous attention or laziness.

1.7 Sub Areas/ Domains of Artificial Intelligence

AI Applications can be roughly classified based on the type of tools/approaches used for inoculating intelligence in the system, forming sub areas of AI. Various sub domains/ areas in intelligent systems can be given as follows; Natural Language Processing, Robotics, Neural Networks and Fuzzy Logic. Fig. 1.7.1 shows these areas in Intelligent Systems.

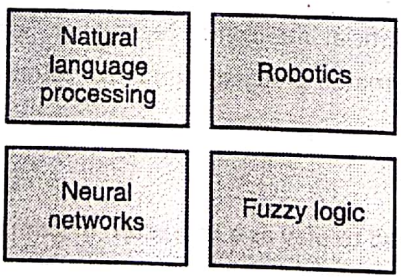


Fig. 1.7.1 : Sub-areas in Intelligent Systems

1. **Natural language processing :** One of the application of AI is in field of Natural Language Processing (NLP). NLP enables interaction between computers and human (natural) language. Practical applications of NLP are in machine translation (e.g. Lunar System), information retrieval, text categorization, etc. Few more applications are extracting 3D information using vision, speech recognition, perception, image formation.

2. **Robotics :** One more major application of AI is in Robotics. Robot is an active agent whose environment is the physical world. Robots can be used in manufacturing and handling material, in medical field, in military, etc. for automating the manual work.

3. **Neural networks :** Another application of AI is using Neural Networks. Neural Network is a system that works like a human brain/nervous system. It can be useful for stock market analysis, in character recognition, in image compression, in security, face recognition, handwriting recognition, Optical Character Recognition (OCR), etc.

4. **Fuzzy logic :** Apart from these AI systems are developed with the help of Fuzzy Logic. Fuzzy Logic can be useful in making approximations rather than having a fixed and exact reasoning for a problem. You must have seen systems like AC, fridge, washing machines which are based on fuzzy logic (they call it "6th sense technology!").

1.8 Current Trends in Artificial Intelligence

Artificial Intelligence has touched each and every aspect of our life. From washing machine, Air conditioners, to smart phones everywhere AI is serving to ease our life. In industry, AI is doing marvellous work as well. Robots are doing the sound work in factories. Driverless cars have become a reality. WiFi-enabled Barbie uses speech-recognition to talk and listen to children. Companies are using AI to improve their product and increase sales. AI saw significant advances in machine learning. Following are the areas in which AI is showing significant advancements.

1. **Deep learning**

Convolutional Neural Networks enabling the concept of deep learning is the top most area of focus in Artificial intelligence in todays' era. Many problems and applications areas of AI like, natural language and text processing, speech recognition, computer vision, information retrieval, and multimodal information processing empowered by multi-task deep learning.

2. **Machine learning**

The goal of machine learning is to program computers to use example data or past experience to solve a given problem. Many successful applications of machine learning include systems that analyze past sales data to predict customer behaviour, optimize robot behaviour so that a task can be completed using minimum resources, and extract knowledge from bioinformatics data.

3. **AI replacing workers**

In industry where there are safety hazards, robots are doing a good job. Human resources are getting replaced by robots rapidly. People are worries to see that the white color jobs of data processing are being done exceedingly well by intelligent programs. A study from The National Academy of Sciences brought together technologists and economists and social scientists to figure out what's going to happen.

4. **Internet of Things (IoT)**

The concepts of smarter homes, smarter cars and smarter world is evolving rapidly with the invention of internet of things. The future is no far when each and every object will be wirelessly connected to something in order to perform soma smart actions without any human instructions or interference. The worry is how the mined data can potentially be exploited.

5. **Emotional AI**

Emotional AI, where AI can detect human emotions, is another upcoming and important area of research. Computers ability to understand speech will lead to an almost seamless interaction between human and computer. With increasingly accurate cameras, voice and facial recognition, computers are better able to detect our emotional state. Researchers are exploring how this new knowledge can be used in education, to treat depression, to accurately predict medical diagnoses, and to improve customer service and shopping online.

6. **AI in shopping and customer service**

Using AI, customers' buying patterns, behavioral patterns can be studied and systems that can predict the purchase or can help customer to figure out the perfect item. AI cab be used to find out what will make the customer happy or unhappy. For example, if a customer is shopping online, like a dress pattern but needs dark shades and thick material, computer understand the need and brings out new set of perfectly matching clothing for him.

7. **Ethical AI**

With all the evolution happening in technology in every walk of life, ethics must be considered at the forefront of research. For example, in case of driverless car, while driving, if the decision has to be made between weather to dash a cat or a lady having both in an uncontrollable distance in front of the car, is an ethical decision. In such cases how the programming should decide who is more valuable, is a question. These are not the problems to be solved by computer engineers or research scientists but someone has to come up with an answer.

1.9 Intelligent Agents

1.9.1 What is an Agent?

- **Agent** is something that perceives its environment through sensors and acts upon that environment through effectors or actuators. Fig. 1.9.1 shows agent and environment.
- Take a simple example of a human agent. It has five senses : Eyes, ears, nose, skin, tongue. These senses sense the environment are called as **sensors**. Sensors collect percepts or inputs from environment and passes it to the processing unit.
- Actuators or effectors are the organs or tools using which the agent acts upon the environment. Once the sensor senses the environment, it gives this information to nervous system which takes appropriate action with the help of actuators.
- In case of human agents we have hands, legs as actuators or effectors.

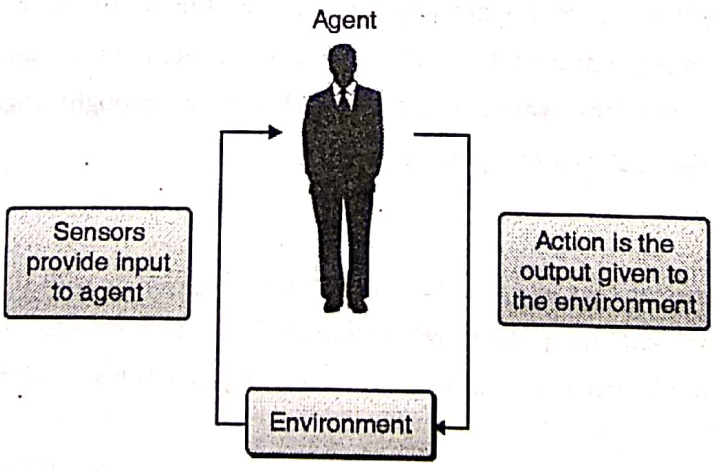


Fig. 1.9.1 : Agent and Environment

- Fig. 1.9.2 shows generic robotic agent structure.

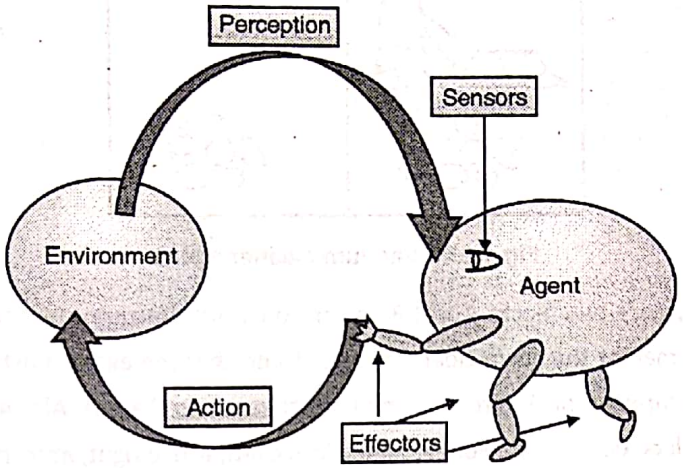


Fig.1.9.2 : Generic robotic agent architecture

- After understanding what an agent is, let's try to figure out sensor and actuator for a robotic agent, can you think of sensors and actuators in case of a robotic agent?
- The robotic agent has cameras, infrared range finders, scanners, etc. used as **sensors**, while various types of motors, screen, printing devices, etc. used as **actuators** to perform action on given input.

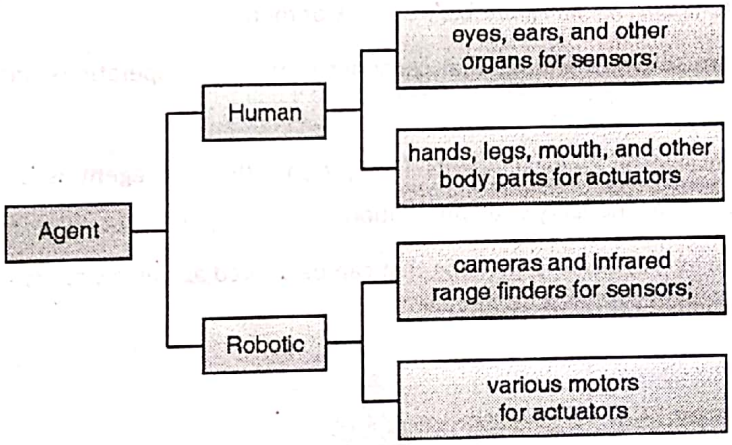


Fig.1.9.3 : Sensors and actuators in human and robotic agent

- The **agent function** is the **description of what all functionalities** the agent is supposed to do. The agent function provides mapping between percept sequences to the desired actions. It can be represented as [f: P* ⇒ A]
- **Agent program is a computer program that** implements agent function in an architecture suitable language. Agent programs needs to be installed on a device in order to run the device accordingly. That device must have some form of sensors to sense the environment and actuators to act upon it. Hence agent is a combination of the architecture hardware and program software.

Agent = Architecture + Program

- Take a simple example of vacuum cleaner agent. You might have seen vacuum cleaner agent in "WALL-E"(animated movie). Let's understand how to represent the percept's (input) and actions (outputs) used in case of a vacuum cleaner agent.

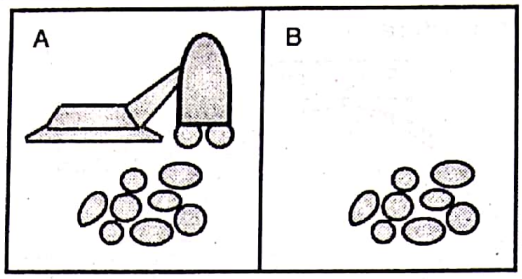


Fig.1.9.4 : Vacuum cleaner agent

- As shown in Fig. 1.9.4, there are two blocks A and B having some dirt. Vacuum cleaner agent supposed to sense the dirt and collect it, thereby making the room clean. In order to do that the agent must have a camera to see the dirt and a mechanism to move forward, backward, left and right to reach to the dirt. Also it should absorb the dirt. Based on the percepts, actions will be performed. For example : Move left, Move right, absorb, No Operation.
- Hence the sensor for vacuum cleaner agent can be camera, dirt sensor and the actuator can be motor to make it move, absorption mechanism. And it can be represented as :

  [A, Dirty], [B, Clean], [A, absorb],[B, Nop], etc.

1.9.2 Definitions of Agent

There are various definitions exist for an agent. Let's see few of them.

- IBM states that **agents** are software entities that carry out some set of operations on behalf of a user or another program.
- **FIPA :** Foundation for Intelligent Physical Agents (FIPA) terms that, an **agent** is a computational process that implements the autonomous functionality of an application.
- Another definition is given as "An agent is anything that can be viewed as perceiving its environment through sensors and acting upon the environment through effectors".

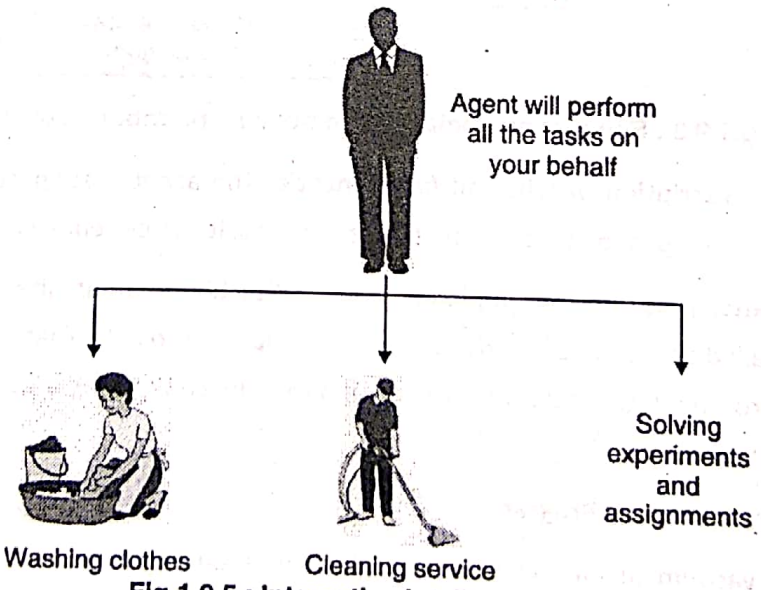


Fig.1.9.5 : Interactive Intelligent Agent

- By Russell and Norvig, F. Mills and R. Stuffle beam's definition says that "**An agent** is anything that is capable of acting upon information it perceives. An intelligent agent is an agent capable of making decisions about how it acts based on experience".

- From above definitions we can understand that an agent is: (As per Terziyan, 1993)
  - Goal-oriented
  - Adaptive
  - Social
  - Creative
  - Mobile
  - Self-configurable

1.9.3 Intelligent Agent

- In the human agent example, we read that there is something called as **"Nervous System"** which helps in deciding an action with the assistance of effectors, based on the input given by sensors. In robotic agent, we have software's which demonstrates the functionality of nervous system.
- **Intelligent agent** is the one which can take input from the environment through its sensors and act upon the environment through its actuators. Its actions are always directed to achieve a goal.
- The basic abilities of an intelligent agent are to exist to be self-governed, responsive, goal-oriented, etc.
- In case of intelligent agents, the software modules are responsible for exhibiting intelligence. Generally observed capabilities of an intelligent agent can be given as follows:
  - Ability to remain autonomous (Self-directed)
  - Responsive
  - Goal-Oriented
- Intelligent agent is the one which can take input from the environment through its sensors and act upon the environment through its actuators. Its actions are always directed to achieve a goal.

1.9.3(A) Structure of Intelligent Agents

- Fig.1.9.6 shows the general structure of an intelligent agent.

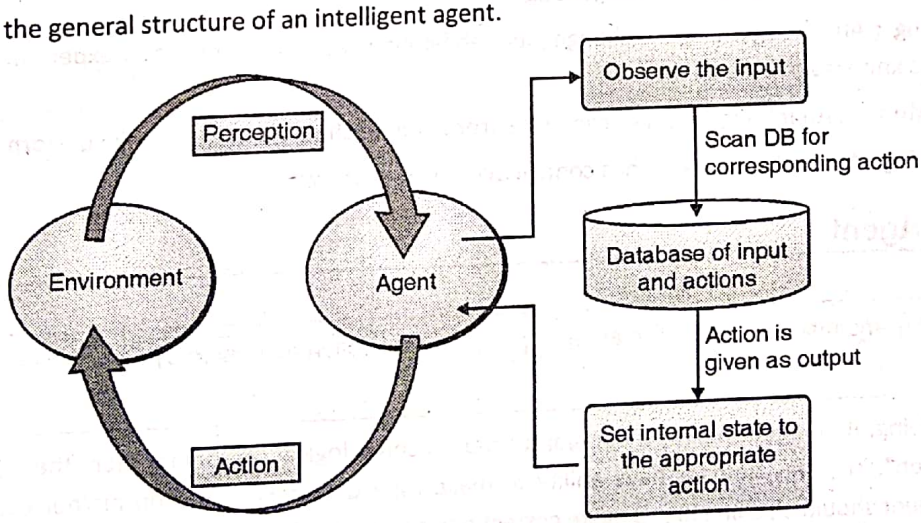


Fig.1.9.6: General structure of intelligent agent

- From Fig. 1.9.6, it can be observed how agent and environment interact with each other. 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.
- Let's understand this working with a real life example. Consider you are an agent and your surroundings is an environment. Now, take a situation where you are cooking in kitchen and by mistake you touch a hot pan. We will see what happens in this situation step by step. Your touch sensors take input from environment (i.e. you have touched

some hot element), then it asks your brain if it knows "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 the hot element otherwise it will burn. Once this signal reaches your hand you will take your hand away from the hot pan.

- The agent keeps taking input from the environment and goes through these states every time. In above example, if your action takes more time then in that case your hand will be burnt.
- So the new task will be to find solution if the hand is burnt. Now, you think about the states which will be followed in this situation. As per Wooldridge and Jennings, "An intelligent agent is one that is capable of taking flexible self-governed actions".
- They say for an intelligent agent to meet design objectives, flexible means three things:

1.	Reactiveness	2.	Pro-activeness
3.	Social ability		

1. **Reactiveness :** It means giving reaction to a situation in a stipulated time frame. An agent can perceive the environment and respond to the situation in a particular time frame. In case of reactiveness, reaction within situation time frame is more important. You can understand this with above example, where, if an agent takes more time to take his hand away from the hot pan then agents hand will be burnt.
2. **Pro-activeness :** It is controlling a situation rather than just responding to it. Intelligent agent show goal-directed behavior by taking the initiative. For example : If you are playing chess then winning the game is the main objective. So here we try to control a situation rather than just responding to one-one action which means that killing or losing any of the 16 pieces is not important, whether that action can be helpful to checkmate your opponent is more important.
3. **Social ability :** Intelligent agents can interact with other agents (also humans). Take automatic car driver example, where agent might have to interact with other agent or a human being while driving the car.

- Following are few more features of an intelligent agent.
  - **Self-Learning :** An intelligent agent changes its behaviour based on its previous experience. This agent keeps updating its knowledge base all the time.
  - **Movable/Mobile :** An Intelligent agent can move from one machine to another while performing actions.
  - **Self-governing :** An Intelligent agent has control over its own actions.

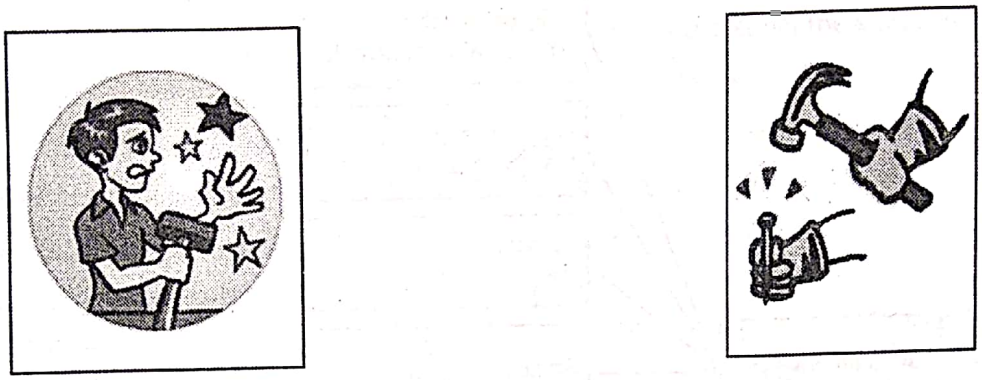
1.10 Rational Agent

MU - Dec. 15

Q. Define rationality and rational agent. Give an example of rational action performed by any intelligent agent. **(Dec. 15, 5 Marks)**

- For problem solving, if an agent makes a decision based on some logical reasoning, then, the decision is called as a "Rational Decision". The way humans have ability to make right decisions, based on his/her experience and logical reasoning; an agent should also be able to make correct decisions, based on what it knows from the percept sequence and actions which are carried out by that agent from its knowledge.
- Agents perceive their environment through sensors over a prolonged time period and adapt to change to create and pursue goals and take actions through actuators to achieve those goals. **A rational agent** is the one that does "right" things and acts rationally so as to achieve the best outcome even when there is uncertainty in knowledge.
- A rational agent is an agent that has clear preferences, can model uncertainty via expected values of variables or functions of variables, and always chooses to perform the action with the optimal expected outcome for itself from among all feasible actions. A rational agent can be anything that makes decisions, typically a person, a machine, or software program.

- **Rationality** depends on four main criteria: First is the performance measure which defines the criterion of success for an agent, second is the agent's prior knowledge of the environment, and third is the action performed by the agent and the last one is agent's percept sequence to date.
- Performance measure is one of the major criteria for measuring success of an agent's performance. Take a vacuum-cleaner agent's example. The performance measure of a vacuum-cleaner agent can depend upon various factors like it's dirt cleaning ability, time taken to clean that dirt, consumption of electricity, etc.
- For every percept sequence a built-in knowledge base is updated, which is very useful for decision making, because it stores the consequences of performing some particular action. If the consequences direct to achieve desired goal then we get a good performance measure factor, else, if the consequences do not lead to desired goal state, then we get a poor performance measure factor.



(a) Agent's finger is hurt while using nail and hammer **(b) Agent is using nail and hammer efficiently**

Fig. 1.10.1

- For example, see Fig.1.10.1. If agent hurts his finger while using nail and hammer, then, while using it for the next time agent will be more careful and the probability of not getting hurt will increase. In short agent will be able to use the hammer and nail more efficiently.
- Rational agent can be defined as an agent who makes use of its percept sequence, experience and knowledge to maximize the performance measure of an agent for every probable action. It selects the most feasible action which will lead to the expected results optimally.

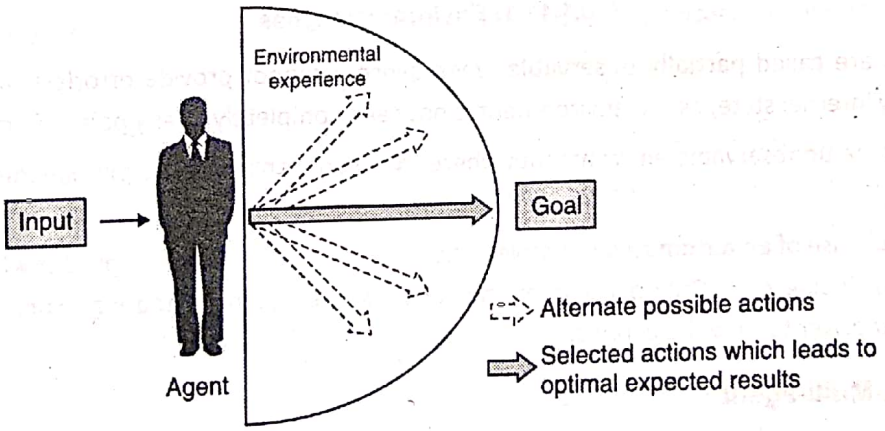


Fig.1.10.2 : Rational Agent

1.11 Nature of Environment and PEAS Properties of Agent

1.11.1 Environments Types / Nature of Environment / Task Environment Properties

MU -Dec. 13, May 15

Q. Describe different types of environments applicable to AI agents. **(Dec. 13, May 15, 10 Marks)**

1. Fully observable vs. Partially observable

- The first type of environment is based on the observability. Whether the agent sensors can have access to complete state of environment at any given time or not, decides if it is a fully observable or partially observable environment.
- In **Fully observable** environments agents are able to gather all the necessary information required to take actions. Also in case of fully observable environments agents don't have to keep records of internal states. For example, Word-block problem, 8-puzzle problem, Sudoku puzzle, etc. in all these problem worlds, the state is completely visible at any point of time.

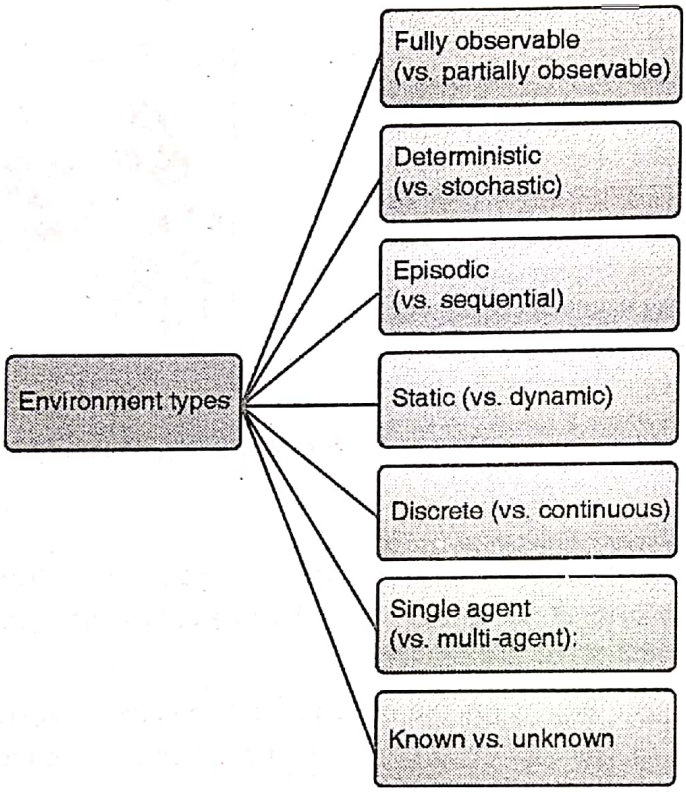


Fig.1.11.1: Environment types

- Environments are called **partially observable** when sensors cannot provide errorless information at any given time for every internal state, as the environment is not seen completely at any point of time.
- Also there can be unobservable environments where the agent sensors fail to provide information about internal states.
- For example, In case of an **automated car driver system**, automated car cannot predict what the other drivers are thinking while driving cars. Only because of the sensor's information gathering expertise it is possible for an automated car driver to take the actions.

2. Single agent vs. Multi-agent

- The second type of an environment is based on the number of agents acting in the environment. Whether the agent is operating on its own or in collaboration with other agents decides if it is a **Single agent** or a multi-agent environment.
- For example : An agent playing Tetris by itself can be a single agent environment, whereas we can have an agent playing checkers in a two-agent environment. Or in case of vacuum cleaner world, only one machine is working, so it's a single agent while in case of car driving agent, there are multiple agents driving on the road, hence it's a **multi-agent environment.**

- Multi-agent environment is further classified as Co-operative multi-agent and Competitive multi-agent. Now, you might be thinking in case of an automated car driver system which type of agent environment do we have?
- Let's understand it with the help of an automated car driving example. For a car driving system 'X', other car say 'Y' is considered as an Agent. When 'Y' tries to maximize its performance measure and the input taken by car 'Y' depends on the car 'X'. Thus it can be said that for an automated car driving system we have a cooperative multi-agent environment.
- Whereas in case of "chess game" when two agents are operating as opponents, and trying to maximize their own performance, they are acting in competitive multi agent environment.

3. Deterministic vs. Stochastic

- An environment is called **deterministic environment**, when the next state of the environment can be completely determined by the previous state and the action executed by the agent.
- For example, in case of vacuum cleaner world, 8-puzzle problem, chess game the next state of the environment solely depends on the current state and the action performed by agent.
- **Stochastic environment** generally means that the indecision about the actions is enumerated in terms of probabilities. That means environment changes while agent is taking action, hence the next state of the world does not merely depends on the current state and agent's action. And there are few changes happening in the environment irrespective of the agent's action. An automated car driving system has a stochastic environment as the agent cannot control the traffic conditions on the road.
- In case of checkers we have a multi-agent environment where an agent might be unable to predict the action of the other player. In such cases if we have partially observable environment then the environment is considered to be stochastic.
- If the environment is deterministic except for the actions of other agents, then the environment is **strategic.** That is, in case of game like chess, the next state of environment does not only depend upon the current action of agent but it is also influenced by the strategy developed by both the opponents for future moves.
- We have one more type of environment in this category. That is when the environment types are not fully observable or non-deterministic; such type of environment is called as **uncertain environment.**

4. Episodic vs. Sequential

- An **episodic task environment** is the one where each of the agent's action is divided into an atomic incidents or episodes. The current incident is different than the previous incident and there is no dependency between the current and the previous incident. In each incident the agent receives an input from environment and then performs a corresponding action.
- Generally, classification tasks are considered as episodic. Consider an example of pick and place robot agent, which is used to detect defective parts from the conveyor belt of an assembly line. Here, every time agent will make the decision based on current part, there will not be any dependency between the current and previous decision.
- In **sequential environments**, as per the name suggests, the previous decision can affect all future decisions. The next action of the agent depends on what action he has taken previously and what action he is supposed to take in future.

- For example, in checkers where previous move can affect all the following moves. Also sequential environment can be understood with the help of an automatic car driving example where, current decision can affect the next decisions. If agent is initiating breaks, then he has to press clutch and lower down the gear as next consequent actions.

5. Static vs. Dynamic

- You have learnt about static and dynamic terms in previous semesters with respect to web pages. Same way we have **static (vs. dynamic) environments.** If an environment remains unchanged while the agent is performing given tasks then it is called as a static environment. For example, Sudoku puzzle or vacuum cleaner environment are static in nature.
- If environment is not changing over the time but, an agent's performance is changing then, it is called as **a semi-dynamic** environment. That means, there is a timer exist in the environment who is affecting the performance of the agent.
- For example, In chess game or any puzzle like block word problem or 8-puzzle if we introduce timer, and if agent's performance is calculated by time taken to play the move or to solve the puzzle, then it is called as semi-dynamic environment.
- Lastly, if the environment changes while an agent is performing some task, then it is called **dynamic environment.**
- In this type of environment agent's sensors have to continuously keep sending signals to agent about the current state of the environment so that appropriate action can be taken with immediate effect.
- Automatic car driver example comes under dynamic environment as the environment keeps changing all the time.

6. Discrete vs. Continuous

- You have seen discrete and continuous signals in old semesters. When you have distinct, quantized, clearly defined values of a signal it is considered as discrete signal.
- Same way, when there are distinct and clearly defined inputs and outputs or precepts and actions, then it is called a **discrete environment.** For example : chess environment has a finite number of distinct inputs and actions.
- When a continuous input signal is received by an agent, all the precepts and actions cannot be defined beforehand then it is called **continuous environment.** For example : An automatic car driving system.

7. Known vs. Unknown

- In a **known environment**, the output for all probable actions is given. Obviously, in case of **unknown environment,** for an agent to make a decision, it has to gain knowledge about - how the environment works.
- Table 1.11.1 summarizes few task environment and their characteristics.

Table 1.11.1 : Task environments

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

Task environment	Car driving	Part – Picking Robot	Cross word puzzle	Soccer game	Checkers with clock
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

1.11.2 PEAS Properties of Agent

MU - May 13, Dec. 14, May 16

Q. Give PEAS description for a robot soccer player. Characterize its environment. **(May 16, 5 Marks)**

Q. What are PEAS descriptor ? Give PEAS descriptors for Part – picking Robot. **(May 13, Dec. 14, 3 Marks)**

- **PEAS :** PEAS stands for **Performance Measure, Environment, Actuators, and Sensors**. It is the short form used for performance issues grouped under Task Environment.
- You might have seen driverless/ self driving car videos of Audi/ Volvo/ Mercedes, etc. To develop such driverless cars we need to first define PEAS parameters.
- **Performance Measure :** It the objective function to judge the performance of the agent. For example, in case of pick and place robot, number of correct parts in a bin can be the performance measure.
- **Environment :** It the real environment where the agent need to deliberate actions.
- **Actuators :** These are the tools, equipment or organs using which agent performs actions in the environment. This works as the output of the agent.
- **Sensors :** These are the tools, equipment or organs using which agent captures the state of the environment. This works as the input to the agent.
- To understand the concept of PEAS, consider following examples.

(A) Automated car driving agent

1. Performance measures which should be satisfied by the automated car driver:

   (i) Safety : Automated system should be able to drive the car safely without dashing anywhere.

   (ii) Optimum speed : Automated system should be able to maintain the optimal speed depending upon the surroundings.

   (iii) Comfortable journey : Automated system should be able to give a comfortable journey to the end user, i.e. depending upon the road it should ensure the comfort of the end user.

   (iv) Maximize profits : Automated system should provide good mileage on various roads, the amount of energy consumed to automate the system should not be very high, etc. such features ensure that the user is benefited with the automated features of the system and it can be useful for maximizing the profits.

2. **Environment**

   (i) Roads : Automated car driver should be able to drive on any kind of a road ranging from city roads to highway.

(ii) **Traffic conditions :** You will find different set of traffic conditions for different type of roads. Automated system should be able to drive efficiently in all types of traffic conditions. Sometimes traffic conditions are formed because of pedestrians, animals, etc.

(iii) **Clients :** Automated cars are created depending on the client's environment. For example, in some countries you will see left hand drive and in some countries there is a right hand drive. Every country/state can have different weather conditions. Depending upon such constraints automated car driver should be designed.

3. **Actuators** are responsible for performing actions/providing output to an environment.

In case of car driving agent following are the actuators :

(i) **Steering wheel** which can be used to direct car in desired direction (i.e. right/left)

(ii) **Aaccelerator, gear**, etc. can be useful to increase or decrease the speed of the car.

(iii) **Brake** is used to stop the car.

(iv) **Light signal, horn** can be very useful as indicators for an automated car.

4. **Sensors:** To take input from environment in car driving example cameras, sonar system, speedometer, GPS, engine sensors, etc. are used as sensors.

(B) Part-picking ARM robot

(i) **Performance measures** : Number of parts in correct container.

(ii) **Environment :** Conveyor belt used for handling parts, containers used to keep parts, and Parts.

(iii) **Actuators** : Arm with tooltips, to pick and drop parts from one place to another.

(iv) **Sensors** : Camera to scan the position from where part should be picked and joint angle sensors which are used to sense the obstacles and move in appropriate place.

(C) Medical diagnosis system

(i) **Performance measures**

a. **Healthy patient:** system should make use of sterilized instruments to ensure the safety (healthiness) of the patient.

b. **Minimize costs :** The automated system results should not be very costly otherwise overall expenses of the patient may increase, Lawsuits. Medical diagnosis system should be legal.

(ii) **Environment :** Patient, Doctors, Hospital Environment

(iii) **Sensors :** Screen, printer

(iv) **Actuators :** Keyboard and mouse which is useful to make entry of symptoms, findings, patient's answers to given questions. Scanner to scan the reports, camera to click pictures of patients.

(D) Soccer player robot

(i) **Performance measures :** Number of goals, speed, legal game.

(ii) **Environment:** Team players, opponent team players, playing ground, goal net.

(iii) **Sensors:** Camera, proximity sensors, infrared sensors.

(iv) **Actuators :** Joint angles, motors.

1.12 Structure of Agents / Types of Agents

- Depending upon the degree of intelligence and ability to achieve the goal, agents are categorized into five basic types. These five types of agents are depicted in the Fig. 1.12.1.

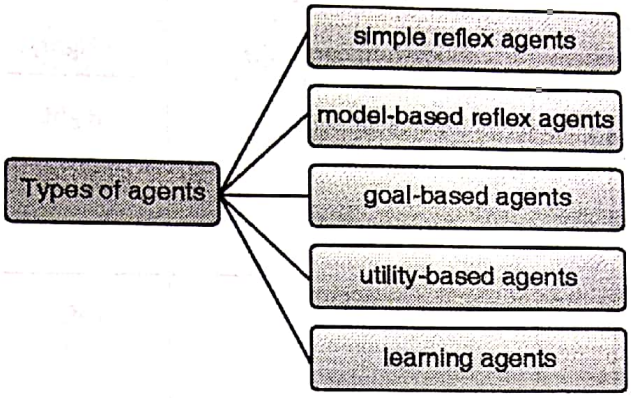


Fig.1.12.1 : Types of agents

- Let us understand these agent types one by one.

1.12.1 Simple Reflex Agents

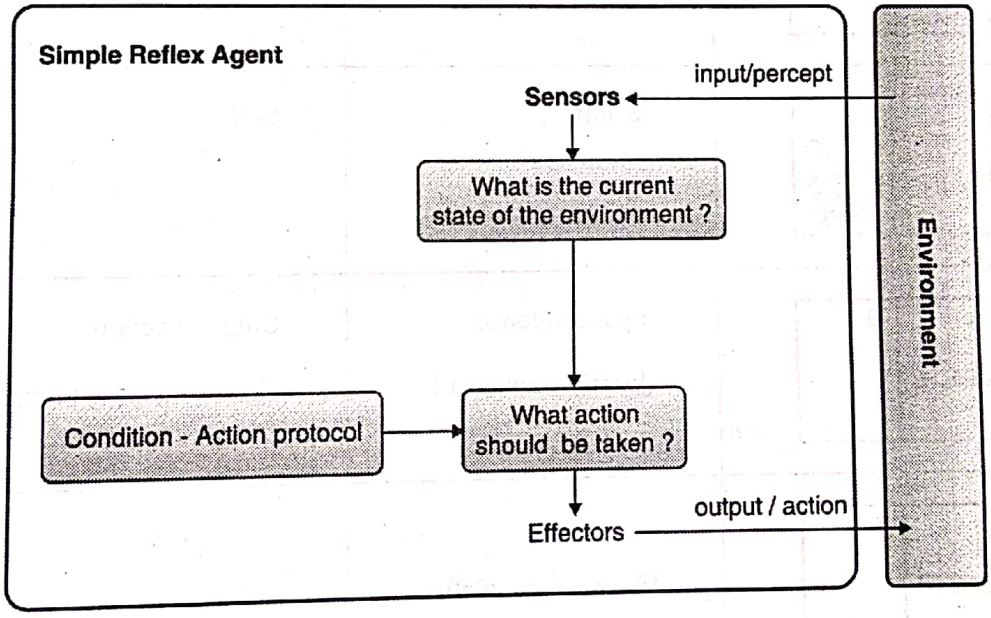
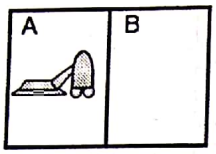
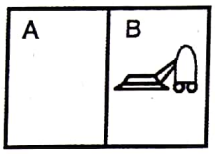
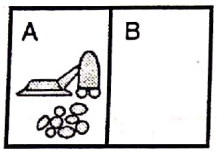
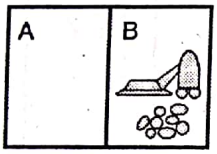
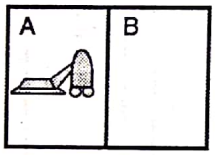
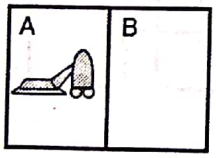
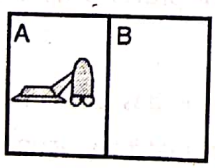
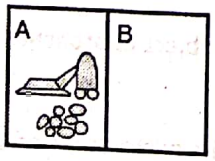


Fig.1.12.2 : Simple reflex agents

- An agent which performs actions based on the current input only, by ignoring all the previous inputs is called as **simple reflex agent.**
- It is a totally uncomplicated type of agent. The simple reflex agent's function is based on the situation and its corresponding action (condition-action protocol). If the condition is true, then matching action is taken without considering the percept history.
- You can understand simple reflexes with the help of a real life example, say some object approaches eye then, you will blink your eye. This type of simple reflex is called natural/innate reflex.
- Consider the example of the vacuum cleaner agent. It is a simple reflex agent, as its decision is based only on whether the current location contains dirt. The agent function is tabulated in Table 1.12.1.

– Few possible input sequences and outputs for vacuum cleaner world with 2 locations are considered for simplicity.

Table 1.12.1

Figure	Input sequence {location, content }	Output / action Right, left, suck, no-op
	{A, clean}	Right
	{B, clean}	Left
	{A, dirt}	Suck
	{B, dirt}	Suck
	Input sequence {location, content }	Output / action Right, left, suck, no-op
	{A, clean}{A, clean}	Right
	{A, clean}{A, dirt}	Suck
	: : :	: :

- In case of above mentioned vacuum agent only one sensor is used and that is a dirt sensor. This dirt sensor can detect if there is dirt or not. So the possible inputs are 'dirt' and 'clean'.
- Also the agent will have to maintain a database of actions, which will help to decide what output should be given by an agent. Database will contain conditions like : If there is dirt on the floor to left or right then find out if there is dirt in the next location and repeat these actions till the entire assigned area is cleaned then, vacuum cleaner should suck that dirt. Else, dirt should move. Once the assigned area is fully covered, no other action should be taken until further instruction.
- If the vacuum cleaner agent keeps searching for dirt and clean area, then, it will surely get trapped in an infinite loop. Infinite loops are unavoidable for simple reflex agents operating in partially observable environments. By randomizing its actions the simple reflex agent can avoid these infinite loops. For example, on receiving {clean} as input, the vacuum cleaner agent should either go to left or right direction.
- If the performance of an agent is of the right kind then randomized behaviour can be considered as rational in few multi-agent environments.

1.12.2 Model-Based Reflex Agents

- Partially observable environment cannot be handled well by simple reflex agents because it does not keep track on the previous state. So, one more type of agent was created that is model based reflex agent.
- An agent which performs actions based on the current input and one previous input is called as model-based agent. Partially observable environment can be handled well by model-based agent.
- From Fig. 1.12.3, it can be seen that once the sensor takes input from the environment, agent checks for the current state of the environment. After that, it checks for the previous state which shows how the world is developing and how the environment is affected by the action which was taken by the agent at earlier stage. This is termed as model of the world.

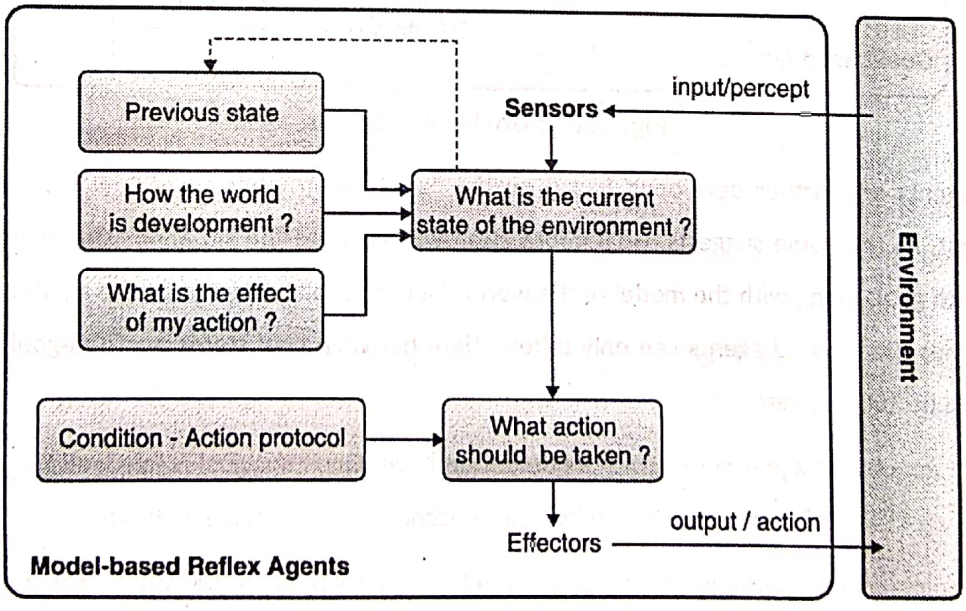


Fig.1.12.3 : Model-based reflex agents

- Once this is verified, based on the condition-action protocol an action is decided. This decision is given to effectors and the effectors give this output to the environment.

- The knowledge about "how the world is changing" is called as a model of the world. Agent which uses such model while working is called as the **"model-based agent".**
- Consider a simple example of automated car driver system. Here, the world keeps changing all the time. You must have taken a wrong turn while driving on some or the other day of your life. Same thing applies for an agent. Suppose if some car "X" is overtaking our automated driver agent "A", then speed and direction in which "X" and "A" are moving their steering wheels is important. Take a scenario where agent missed a sign board as it was overtaking other car. The world around that agent will be different in that case.
- Internal model based on the input history should be maintained by model-based reflex agent, which can reflect at least some of the unobserved aspects of the current state. Once this is done it chooses an action in the same way as the simple reflex agent.

1.12.3 Goal-Based Agents

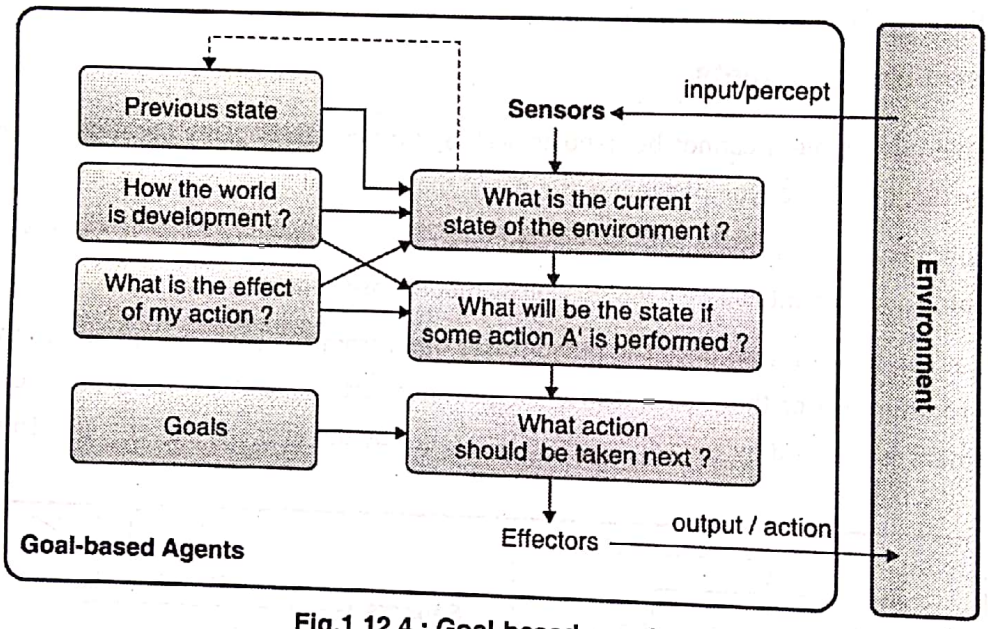


Fig.1.12.4 : Goal-based agents

- Model-based agents are further developed based on the "goal" information. This new type of agent is called as goal-based agent. As the name suggests, Goal information will illustrate the situations that is desired. These agents are provided with goals along with the model of the world. All the actions selected by the agent are with reference of the specified goals. Goal based agents can only differentiate between goal states and non-goal states. Hence, their performance can be 100% or zero.
- The limitation of goal based agent comes with its definition itself. Once the goal is fixed, all the actions are taken to fulfill it. And the agent loses flexibility to change its actions according to the current situation.
- You can take example of a vacuum cleaning robot agent whose goal is to keep the house clean all the time. This agent will keep searching for dirt in house and will keep the house clean all the time. Remember M-O the cleaning robot from Wall-E movie which keeps cleaning all the time no matter what is the environment or the Healthcare companion robot Baymax from Big Hero 6 which does not deactivate until user says that he/she is satisfied with care.

1.12.4 Utility-Based Agents

MU -May 13

Q. Explain utility-based agents with the help of neat diagram. (May 13, 10 Marks)

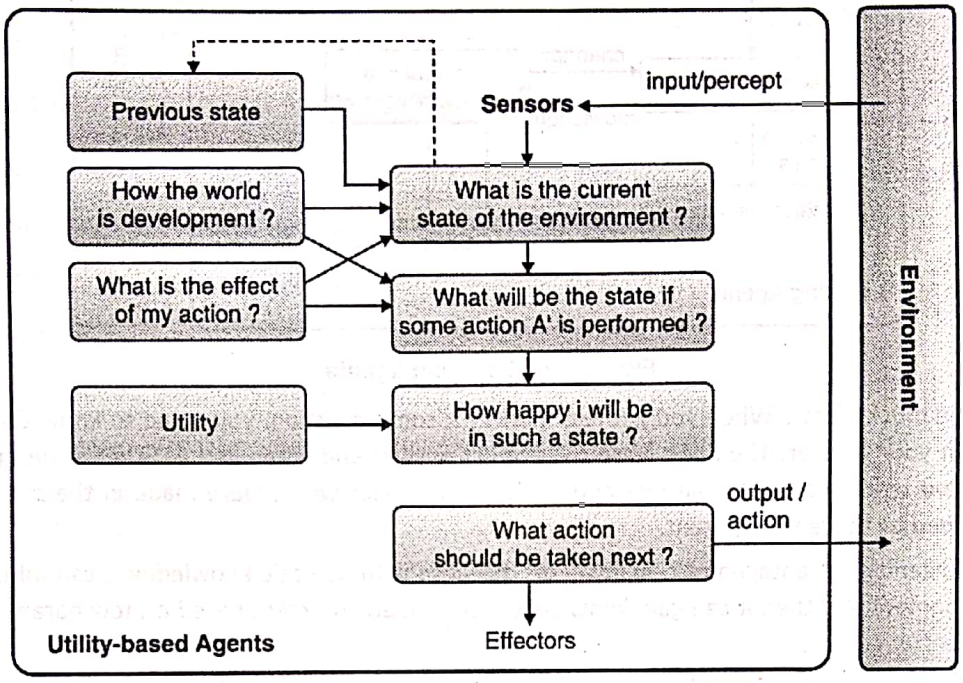


Fig.1.12.5:Utility-based agents

- Utility function is used to map a state to a measure of utility of that state. We can define a measure for determining how advantageous a particular state is for an agent. To obtain this measure utility function can be used.
- The term utility is used to depict how "happy" the agent is to find out a generalized performance measure, various world states according to exactly how happy they would make an agent is compared.
- Take one example; you might have used Google maps to find out a route which can take you from source location to your destination location in least possible time. Same logic is followed by utility based automatic car driving agent.
- Goals utility based automatic car driving agent can be used to reach given location safely within least possible time and save fuel. So this car driving agent will check the possible routes and the traffic conditions on these routes and will select the route which can take the car at destination in least possible time safely and without consuming much fuel.

1.12.5 Learning Agents

MU -May 13, Dec. 13, May 14, May 15, Dec. 15, May 16

Q. Explain the learning agent with the help of suitable diagram. (May 13, 10 Marks)

Q. Explain the structure of learning agent architecture. What is role of critic in learning ? (Dec. 13, May 15, 10 Marks)

Q. Discuss structure of learning agent. (May 14, 5 Marks)

Q. What are the basic building blocks of learning agent ? Explain each of them with a neat block diagram. (Dec. 15, May 16, 8/10 Marks)

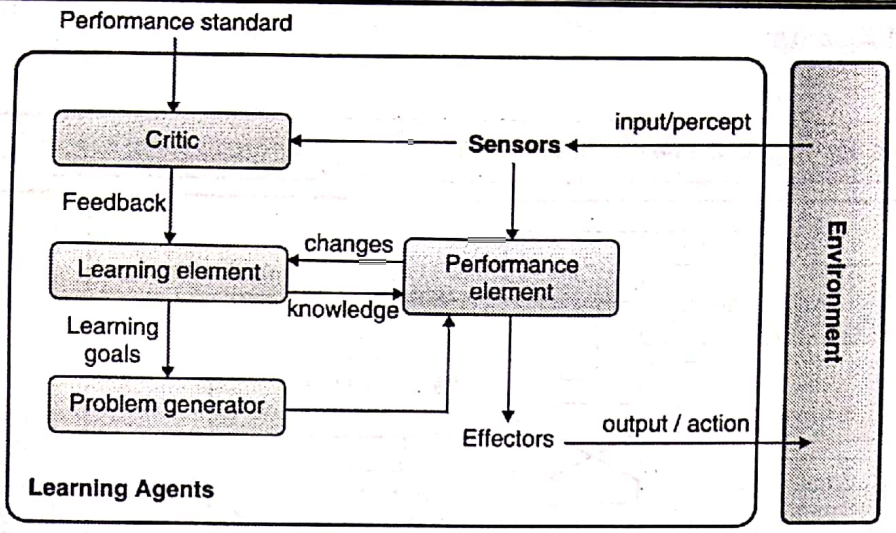


Fig. 1.12.6 : Learning agents

- Why do you give mock tests ? When you get less marks for some question, you come to know that you have made some mistake in your answer. Then you learn the correct answer and when you get that same question in further examinations, you write the correct answer and avoid the mistakes which were made in the mock test. This same concept is followed by the learning agent.
- Learning based agent is advantageous in many cases, because with its basic knowledge it can initially operate in an unknown environment and then it can gain knowledge from the environment based on few parameters and perform actions to give better results.
- Following are the components of learning agent :

1. Critic
2. Learning element
3. Performance element
4. Problem generator

1. **Critic :** It is the one who compares sensor's input specifying effect of agent's action on the environment with the performance standards and generate feedback for leaning element.
2. **Learning element :** This component is responsible to learn from the difference between performance standards and the feedback from critic. According to the current percept it is supposed to understand the expected behavior and enhance its standards
3. **Performance element :** Based on the current percept received from sensors and the input obtained by the learning element, performance element is responsible to choose the action to act upon the external environment.
4. **Problem generator :** Based on the new goals learnt by learning agent, problem generator suggests new or alternate actions which will lead to new and instructive understanding.

1.13 Introduction to Soft Computing

- Soft computing is a collection of all the techniques that help us to construct computationally intelligent systems. It has been now realized that, real world problems are complex, pervasively imprecise and uncertain. To solve such problems, we require computationally intelligent systems that combine knowledge, techniques and methodologies from various sources.

- There are three main requirements of any intelligent system.
  1. They must possess **human like expertise** within a specific domain.
  2. They should be able to **adapt and learn** to do better in changing environment.
  3. Should be capable of **making decisions** and taking actions accordingly.

1.14 Soft Computing vs. Hard Computing

- Hard computing involves the traditional methods of computing that require precisely stated analytical models. They often require more computational time. Examples of hard computing are:
  - Solving numerical problems (e.g. roots of polynomial, integration etc.)
  - Searching and sorting techniques
  - Solving Computational geometry problem etc.
- Unlike hard computing, soft computing techniques are tolerant of imprecision, uncertainty, partial truth and approximation that are present in the real world problems. Examples of soft computing techniques are Neural networks, Fuzzy logic, genetic algorithms etc.
- Following are differences between hard computing and soft computing.

Sr. No.	Hard computing	Soft computing
1.	Hard computing is a conventional type of computing that requires a precisely stated analytic model.	Soft computing techniques are imprecision, approximation and uncertainty tolerant.
2.	Hard computing requires programs to be written.	Soft computing techniques are model free. They can evolve their own models and programs.
3.	Hard computing is deterministic and uses two-valued logic.	Soft computing is stochastic and uses multi-valued logic such as fuzzy logic.
4.	Hard computing needs exact data to solve a particular problem.	Soft computing can deal with incomplete, uncertain and noisy data.
5.	Hard computing techniques perform sequential computation.	Soft computing allows parallel computations. E.g. Neural networks.
6.	The solution or output of hard computing is precise.	Soft computing can generate approximate output or solution.
7.	Hard computing is based on crisp logic, binary logic and numerical analysis.	Soft computing is based on neural networks, fuzzy logic, and evolutionary computations etc.
8.	Hard computing techniques are not fault tolerant. The reason is conventional programs and algorithms are built in such a way that errors have serious consequences, unless enough redundancy is added into the system.	Soft computing techniques are fault tolerant due to their redundancy, adaptability and reduced precision characteristics.

1.15 Various Types of Soft Computing Techniques

- Soft Computing is the fusion of different techniques that were designed to model and enable solutions to complex real world problems.
- These real world problems are the problems that are too difficult to model, mathematically.
- These problems result from the fact that our world seems to be imprecise, uncertain and difficult to categorize.
- The soft computing techniques are capable of handling such uncertainty, impreciseness and vagueness present in the real world data.
- Most of the Soft computing techniques are based on some biological inspired methodologies such as human nervous systems, genetics, evolution, ant's behaviors etc.
- Soft Computing is the fusion of different techniques that were designed to model and enable solutions to complex real world problems, which are not modeled or too difficult to model, mathematically.
- Soft computing consist several computing paradigms mainly are:
  - Neural Network
  - Fuzzy Logic
  - Evolutionary Algorithms such as Genetic algorithm
- Every paradigm of soft computing mentioned above has its own strength. In order to build a computationally intelligent system, we may integrate multiple techniques or methodologies to take advantage of the strengths of each of them. Such systems are called **Hybrid soft computing** systems.
- Table 1.15.1 summarizes the soft computing methodologies and their strengths.

Table 1.15.1 : Soft computing constituents and their strengths

Sr. No.	Methodology	Strengths
1.	Neural networks	Has capability of learning and adaptation.
2.	Fuzzy set theory	Handles uncertainty and incorporates human-like reasoning into the system.
3.	Evolutionary algorithms	Has capability of finding optimum solution to a problem.

- The seamless integration of these methodologies forms the base of soft computing.
- **Neural networks** have the capability of recognizing patterns and adapting themselves to cope with changing environments.
- The **evolutionary algorithms** such as Genetic Algorithms are search and optimization techniques based on biological evolution that help us to optimize certain parameters in a given problem.
- **Fuzzy logic** incorporates human knowledge and performs inference and decision making.

1.15.1 Introduction to Neural Networks

- An Artificial Neural Network (ANN), inspired by the biological nervous system basically tries to mimic the working of a human brain.
- An ANN is composed of a large number of highly interconnected processing elements called neurons. All these neurons work in parallel to solve a specific problem.

- An ANN learns by examples the way humans learn by their experiences.
- ANN can be designed and configured for a specific application such as data classification, pattern reorganization, data clustering etc.

Advantages of Neural Networks

1. Neural networks provide human like artificial intelligence.
2. A neural network learns and does not need to be reprogrammed.
3. A neural network can do a task that a linear program cannot do.
4. Parallel organization of neural networks permits solutions to problems where multiple constraints must be satisfied simultaneously.
5. Because of its parallel nature, when an element of the neural network fails, it can continue without any problem.

Applications of Neural Networks

Neural networks have been successfully applied to a broad spectrum of data-intensive applications. Few of them are listed below.

(a) Forecasting

Neural network can be used very effectively in forecasting exchange rates, predicting stock values, inflation and cash forecasting, forecasting weather conditions etc. Researchers have proved that the forecasting accuracy of NN systems tend to excel over that of the linear regression model.

(b) Image compression

- Digital images require a large amount of memory for storage. As a result, the transmission of image from one computer to another can be very expensive in terms of time and bandwidth required.
- With the explosion of Internet, more sites are using images. Image compression is a technique that removes some of the redundant information present in the image without affecting its perceptibility, thus, reducing the storage size required to store the image.
- NN can be effectively used to compress the image. Several NN techniques such as Kohonen's self organizing maps, Back propagation algorithm, Cellular neural network etc. can be used for image compression.

(c) Industrial process control

- Neural networks have been applied successfully in industrial process control of dynamic systems.
- Neural networks (especially multi layer perceptrons) have been proved to be the best choice for modelling non-linear systems and implementing general – purpose non-linear controllers, due to their universal approximation capabilities. For example control and management of agriculture machinery.

(d) Optical character recognition

- Well known application using image recognition is the Optical Character Recognition (OCR) tools that are available with the standard scanning software for the home computer.
- **Scansoft** has had great success in combining NN with a rule based system for correctly recognizing both characters and words, to get a high level of accuracy.

(e) Customer relationship management

- Another popular application for NN is Customer Relationship Management (CRM).
- Customer Relationship Management requires key information to be derived from raw data collected for each individual customer. This can be achieved by building models using historical data information.
- Many companies are now using neural technology to help in their day to day business
- processes. They are doing this to achieve better performance, greater insight, faster development and increased productivity.
- By using Neural Networks for data mining in the databases, patterns, however complex, can be identified for the different types of customers, thus giving valuable customer information to the company.
- Also, NN could be useful for important tasks related to CRM, such as forecasting call centre loading, demand and sales levels, monitoring and analyzing the market, validating, completing and enhancing databases, clustering and profiling client base etc.
- One example is the airline reservation system AMT, which could predict sales of tickets in relation to destination, time of year and ticket price.

(f) Medical science

- Medicine is the field that has always taken benefits from the latest and advanced technologies.
- Artificial Neural Networks (ANN) is currently the next promising area of interest in medical science.
- It is believed that neural networks will have extensive application to biomedical problems in the next few years.
- ANN has already been successfully applied in medical applications such as diagnostic systems, bio chemical analysis, disease detection, image analysis and drug development.

1.15.2 Introduction to Fuzzy Logic

- **Fuzzy logic** is an approach to computing based on "**degrees of truth**" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based.
- The idea of **fuzzy logic** was first proposed by Dr.Lotfi Zadeh of the University of California at Berkeley in the 1960s.
- The human brain can interpret imprecise, vague and incomplete information provided by sensory organs.
- Fuzzy logic is a powerful mathematical tool that can deal with such imprecise, incomplete and uncertain information present in complex real world problems.
- Using fuzzy logic, it is now possible to include vague human assessment in computing problems.
- Also, it provides an effective means for conflict resolution of multiple criteria and better assessment of options.
- Fuzzy logic can be used in the development of various applications such as pattern recognition, optimization, control applications, identification and any intelligent system for decision making.

A. Advantages of Fuzzy Logic Controllers

- simplicity and flexibility
- can handle problems with imprecise and incomplete data

- can model nonlinear functions of arbitrary complexity
- cheaper to develop,
- cover a wider range of operating conditions, more readily customizable in natural language terms.

B. Applications of Fuzzy Logic

- Fuzzy logic can be used in applications where human like decision making with an ability to generate precise solutions from certain or approximate information is required.
- Fuzzy logic has been extensively used in design of controllers for home appliances such as washing machine, vacuum cleaner, air conditioner etc.
- Fuzzy logic can also be used for other applications such as facial pattern recognition, anti-skid braking systems, transmission systems, control of subway systems and unmanned helicopters.
- Another application area of fuzzy logic is development of knowledge-based systems for multi objective optimization of power systems, weather forecasting systems, models for new product pricing or project risk assessment, medical diagnosis and treatment plans, and stock trading.
- Fuzzy logic has been successfully used in numerous fields such as control systems engineering, image processing, power engineering, industrial automation, robotics, consumer electronics and optimization.

1.15.3 Introduction to Genetic Algorithms

- Genetic Algorithms are ***adaptive heuristic search*** algorithms based on the evolutionary ideas of natural selection and genetics.
- GAs are often used to find optimal or near-optimal solutions to difficult problems which otherwise would take a lifetime to solve.
- GA can efficiently explore a large space of candidate designs and find optimum solutions.
- GAs are a subset of an Evolutionary Computation.
- GAs were developed by John Holland and his students and colleagues at the University of Michigan,
- In GAs, we select the initial pool or a population of possible solutions to the given problem.
- These solutions then undergo various GA operations like recombination and mutation which in turn produce new children.
- The process is repeated over various generations.
- Each individual or candidate solution is assigned a fitness value and the fitter individuals are given a higher chance to mate and yield more "fitter" individuals. This is in line with the Darwinian Theory of "Survival of the Fittest".
- Thus GA keeps "evolving" better individuals or solutions over generations, till it reaches a stopping criterion.
- Genetic Algorithms are sufficiently randomized in nature, but they perform much better than random local search.

A. Advantages of Genetic Algorithms

- GAs are easy to understand since they do not demand the knowledge of complex mathematics.
- Does not require any derivative information

- Good for noisy environment.
- Easy to discover global optimum.
- They can solve multimodal, non differentiable, non continuous or even NP-complete problems.
- GAs are inherently parallel and distributed.
- Provides a list of "good" solutions and not just a single solution.
- Flexible in forming building blocks for hybrid applications.
- Have substantial history and range of use.
- Useful when the search space is very large and there are a large number of parameters involved.

B. Applications of Genetic Algorithms

1. **Automotive design :** Genetic algorithms can be used to design composite materials and aerodynamic shapes for race cars to provide faster, lighter, more fuel efficient and safer vehicles for all the things we use vehicles for.
2. **Engineering design :** GA are most commonly used to optimize the structural and operational design of buildings, factories, machines, etc. GA s are used for optimizing the design of robot gripping arms, satellite booms, building trusses turbines, , flywheels or any other computer-aided engineering design application. 3.
3. **Robotics :** GAs have found applications that span the range of architectures for intelligent robotics. GAs can be used to design the entirely new types of robots that can perform multiple tasks and have more general application.

Review Questions

Q. 1 Define artificial intelligence.

Q. 2 Write a short note on: Applications of artificial intelligence.

Q. 3 Explain the various artificial intelligence problems and artificial intelligence techniques.

Q. 4 What is artificial intelligence ?

Q. 5 What are the components of AI?

Q. 6 What are the various AI techniques ?

Q. 7 Explain various applications of Artificial Intelligence.

Q. 8 Explain PEAS representation with example.

Q. 9 Define agent and give classification of agents.

Q. 10 What is intelligent agent ?

Q. 11 Write a short note on: Rational agent.

Q. 12 Write a short note on : Structure of intelligent agents.

Q. 13 Give types of agents.

Q. 14 What are various agent environments ? Give PEAS representation for an agent.

Q. 15 Define in your own words, the following terms :

1. Agent
2. Agent function
3. Agent program
4. Autonomy

Q. 16 Explain various types of intelligent agents, state limitations of each and how it is overcome in other type of agent.

Q. 17 What do you mean by PEAS? Explain properties of task environment.

Q. 18 Explain detail architecture of goal based agent.

Q. 19 Explain Simple reflex agent architecture.

Q. 20 Explain learning agent architecture.

Q. 21 What are the constituents of Soft Computing ? Explain each in brief.

Q. 22 Differentiate between hard computing and soft computing.

Q. 23 Explain the basics of genetic algorithm along with its applications.

Q. 24 What are the applications of neural networks ?

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