Subject: ARTIFICIAL INTELLIGENCE Code:BCACsT6.11

Chapter-1

Introduction to Artificial Intelligence

Introduction:

Artificial Intelligence (AI) is the study and creation of computer systems that can perceive, reason and act. The primary aim of AI is to produce intelligent machines. The intelligence should be exhibited by thinking, making decisions, solving problems more importantly by learning. AI is an interdisciplinary field that requires knowledge in computer science, linguistics, psychology, biology and so on for serious research.

AI draws heavily on following domains of study

- Computer science
- Cognitive science
- Engineering
- Ethics
- Linguistics
- Logic
- Mathematics
- Natural Sciences
- Philosophy
- Physiology

What is Artificial Intelligence?

According to the father of Artificial Intelligence John McCarthy, it is "***The science and engineering of making intelligent machines, especially intelligent computer programs***".

AI is accomplished by studying how human brain thinks, and how humans learn, decide, and work while trying to solve a problem, and then using the outcomes of this study as a basis of developing intelligent software and systems.

Definition1: **AI is a branch of computer science dealing with the simulation of intelligent behavior in computers. The capability of a machine to imitate human intelligent behavior.**

Definition 2: **Artificial Intelligence is the development of computer systems that are able to perform tasks that would require human intelligence.**

Definition 3: **Artificial Intelligence is a way of making a computer, a computer-controlled robot, or a software think intelligently, in the similar manner the intelligent humans think.**

Other definitions of AI

"The exciting new effort to make computers think . . . *machines with minds*, in the full and literal sense" (Haugeland, 1985) "[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning . . ." (Bellman, 1978)	"The study of mental faculties through the use of computational models" (Charniak and McDermott, 1985) "The study of the computations that make it possible to perceive, reason, and act" (Winston, 1992)
"The art of creating machines that perform functions that require intelligence when performed by people" (Kurzweil, 1990) "The study of how to make computers do things at which, at the moment, people are better" (Rich and Knight, 1991)	"A field of study that seeks to explain and emulate intelligent behavior in terms of computational processes" (Schalkoff, 1990) "The branch of computer science that is concerned with the automation of intelligent behavior" (Luger and Stubblefield, 1993)

Some definitions of AI. They are organized into four categories:

Systems that think like humans.	Systems that think rationally.
Systems that act like humans.	Systems that act rationally.

Philosophy of AI

While exploiting the power of the computer systems, the curiosity of human, lead him to wonder, **"Can a machine think and behave like humans do?"** Thus, the development of AI started with the intention of creating similar intelligence in machines that we find and regard high in humans.

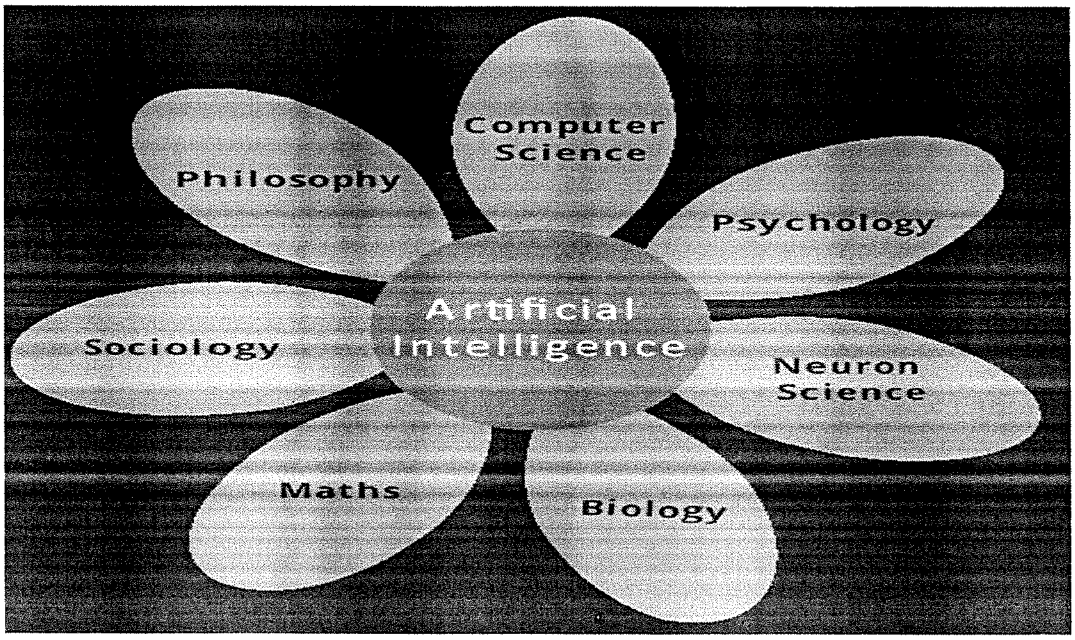
Goals of AI

- **To Create Expert Systems:** The systems which exhibit intelligent behavior, learn, demonstrate, explain, and advice its users.
- **To Implement Human Intelligence in Machines:** Creating systems that understand, think, learn, and behave like humans.

What Contributes to AI? Major contributions to AI

Artificial intelligence is a science and technology based on disciplines such as Computer Science, Biology, Psychology, Linguistics, Mathematics, and Engineering. A major thrust of AI is in the development of computer functions associated with human intelligence, such as reasoning, learning, and problem solving.

Out of the following areas, one or multiple areas can contribute to build an intelligent system.



History of Artificial Intelligence:

Artificial Intelligence was first proposed by John McCarthy in 1956 in his first academic conference on the subject. The idea of machines operating like human beings began to be the center of scientist's mind and whether if it is possible to make machines have the same ability to think and learn by itself was introduced by the mathematician Alan Turing. Alan Turing was able to put his hypotheses and questions into actions by testing whether "*machines can think*"? After series of testing (later was called as Turing Test) it turns out that it is possible to enable machines to think and learn just like humans. Turing Test uses the pragmatic approach to be able to identify if machines can respond as humans. ("Smith", (n.d.)).

- **1923:** Karel Capek first introduced the robot concept in the theater play of Rossum's Universal Robots (RUR -Rossum's Universal Robots).
- **1931:** Kurt Gödel introduced the theory of deficiency, which is called by his own name.
- **1936:** Konrad Zuse developed a programmable computer named Z1 named 64K memory.
- **1946:** ENIAC (Electronic Numerical Integrator and Computer), the first computer in a room size of 30 tons, started to work.
- **1948:** John von Neumann introduced the idea of self replicating program.
- **1950:** Alan Turing, founder of computer science, introduced the concept of the Turing Test.

1951: The first artificial intelligence programs for the Mark 1 device were written.

1956: The logic theorist (Logic Theory-LT) program for solving mathematical problems is introduced by Neweell, Shaw and Simon. *The system is regarded as the first artificial intelligence system.*

The end of the 1950s - the beginning of the 1960s: A schematic network for machine translation was developed by Margaret Master man et al.

1956; John McCarthy coined the term *Artificial Intelligence.* Demonstration of the first *Intelligence.* Demonstration of the first running AI program at Carnegie Mellon University

1958: John McCarty of MIT created the LISP (list Processing language) language.

1960: JCR Lickliter described the human-machine relationship in his work.

1962: Unimation was established as the first company to produce robots for the industrial field.

1965: An artificial intelligence program ELIZA is written.

1966: The first animated robot "Shakey" was produced at Stanford University.

1973: DARPA begins development for protocols called TCP / IP.

1974: The Internet has begun to be used for the firs time.

1978: Herbert Simon earned a Nobel Prize for his limited Rationality Theory, which is an important workon Artificial Intelligence.

1981: IBM produced the first personal computer.

1993: Production of Cog, a human-looking robot at MIT, began.

1997: Deep Blue named supercomputer defeated world famous chess player Kasparov.

1998: Furby, the first artificial intelligence player, was driven to the market.

2000: Kismet named robot which can use gesture and mimic movements in communication is introduced.

2005: Asimo, the closest robot to artificial intelligence and human ability and skill, is introduced.

2010: Asimo is made to act using mind power

What is AI Technique? Or Technique of AI

In the real world, Data is rich but information poor and the knowledge has some unwelcomed properties:

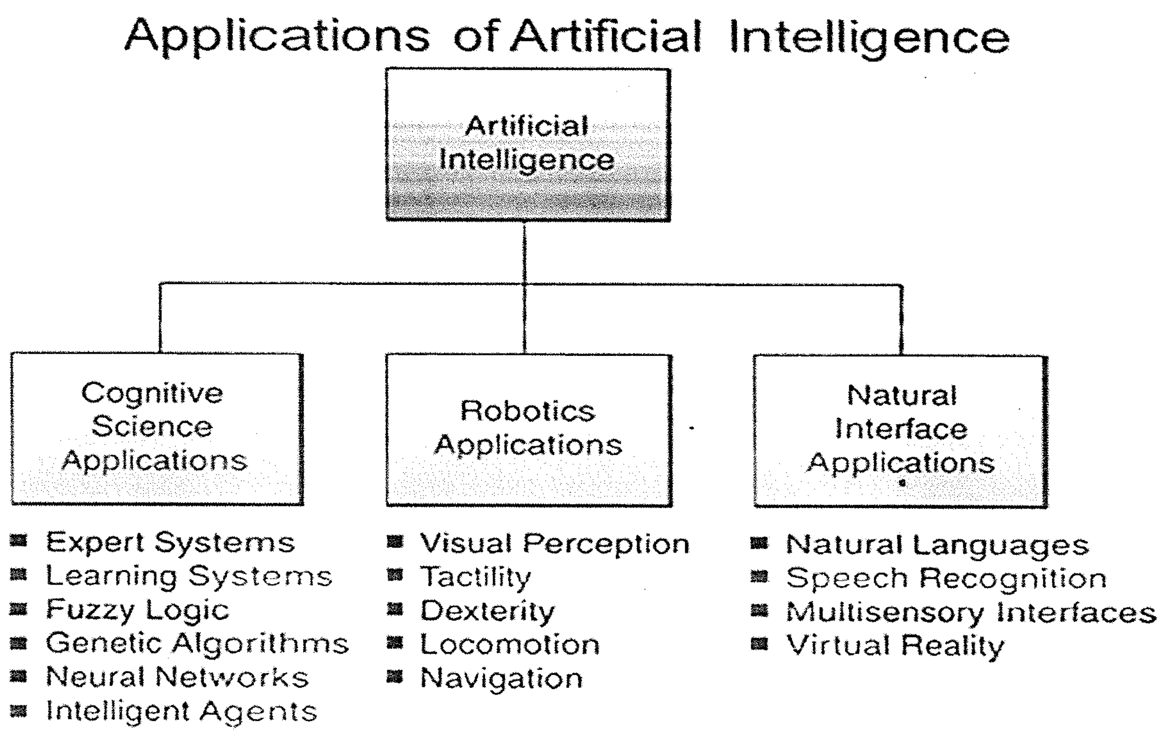
- Its volume is huge, next to unimaginable.
- It is not well-organized or well-formatted.
- It keeps changing constantly.

AI Technique is a manner to organize and to use the knowledge efficiently in such a way that:

- It should be perceivable by the people who provide it.
- It should be easily modifiable to correct errors.
- It should be useful in many situations though it is incomplete or inaccurate.

AI techniques elevate the speed of execution of the complex program it is equipped with by reaching the primary goals of AI.

Applications of AI :
The applications of AI can be mainly classified into:



AI has been dominant in various fields such as:

- **Gaming**

AI plays crucial role in strategic games such as chess, poker, tic-tac-toe, etc., where machine can think of large number of possible positions based on heuristic knowledge.

- **Natural Language Processing**

It is possible to interact with the computer that understands natural language spoken by humans.

- **Expert Systems**

There are some applications which integrate machine, software, and special information to impart reasoning and advising. They provide explanation and advice to the users.

Vision Systems

These systems understand, interpret, and comprehend visual input on the computer. For example,
o A spying Aero plane takes photographs which are used to figure out spatial information or map of the areas.

o Doctors use clinical expert system to diagnose the patient.

o Police use computer software that can recognize the face of criminal with the stored portrait made by forensic artist.

Speech Recognition

Some intelligent systems are capable of hearing and comprehending the language in terms of sentences and their meanings while a human talk to it. It can handle different accents, slang words, noise in the background, change in human's noise due to cold, etc.

Handwriting Recognition

The handwriting recognition software reads the text written on paper by a pen or on screen by a stylus. It can recognize the shapes of the letters and convert it into editable text.

Intelligent Robots

Robots are able to perform the tasks given by a human. They have sensors to detect physical data from the real world such as light, heat, temperature, movement, sound, bump, and pressure. They have efficient processors, multiple sensors and huge memory, to exhibit intelligence. In addition, they are capable of learning from their mistakes and they can adapt to the new environment.

Programming Without and With AI

The programming without and with AI is: different in following ways

Programming Without AI	Programming With AI
A computer program without AI can answer the **specific** questions it is meant to solve.	A computer program with AI can answer the **generic** questions it is meant to solve.
Modification in the program leads to change in its structure.	AI programs can absorb new modifications by putting highly independent pieces of information together. Hence you can modify even a minute piece of information of program without affecting its structure.
Modification is not quick and easy. It may lead to affecting the program adversely.	Quick and Easy program modification.
Input: In regular programming, input is a sequence of alphanumeric symbols presented and stored as per some given set of previously stipulated rules and that uses a limited set of communication media such as keyboard, mouse, disc, etc	In Artificial Intelligence programming the input may be a sight, sound, touch, smell or taste. Sight means one dimensional symbols such as typed text, two dimensional objects or three dimensional scenes. Sound input include spoken language, music, noise made by objects
Processing: in regular programming, processing means manipulation of the stored alpha numeric symbols by a set of previously defined algorithms.	In AI programming, processing includes knowledge representation and pattern matching, search, logic, problem solving and learning.
Output: output is a sequence of alphanumeric symbols, may be in a given set of colors, that represents the result of the processing and that is placed on such a medium as a CRT screen, paper, or magnetic disk.	In AI programming, output can be in the form of printed language and synthesized speech, manipulation of physical objects or locomotion i.e., movement in space.

Intelligence and Types

Intelligence: The ability to acquire and apply knowledge and skills.

Machine Intelligence:

The ability of a system to calculate, reason, perceive relationships and analogies, learn from experience, store and retrieve information from memory, solve problems, comprehend complex ideas, use natural language fluently, classify, generalize, and adapt new situations.

Types of intelligence

Intelligence	Description	Example
Linguistic intelligence	The ability to speak, recognize, and use mechanisms of phonology (speech sounds), syntax (grammar), and semantics (meaning).	Narrators, Orators
Musical intelligence	The ability to create, communicate with, and understand meanings made of sound, understanding of pitch, rhythm.	Musicians, Singers, Composers
Logical-mathematical intelligence	The ability of use and understand relationships in the absence of action or objects. Understanding complex and abstract ideas.	Mathematicians, Scientists
Spatial intelligence	The ability to perceive visual or spatial information, change it, and re-create visual images without reference to the objects, construct 3D images, and to move and rotate them.	Map readers, Astronauts, Physicists
Bodily-Kinesthetic intelligence	The ability to use complete or part of the body to solve problems or fashion products, control over fine and coarse motor skills, and manipulate the objects.	Players, Dancers
Intra-personal intelligence	The ability to distinguish among one's own feelings, intentions, and motivations.	Gautam Buddha
Interpersonal intelligence	The ability to recognize and make distinctions among other people's feelings, beliefs, and intentions.	Mass Communicators, Interviewers

Knowledge Representation of AI

- **Artificial intelligence** is a system that is concerned with the study of understanding, designing and implementing the ways, associated with knowledge representation to computers.
- In any intelligent system, representing the knowledge is supposed to be an important technique to encode the knowledge.
- The main objective of AI system is to design the programs that provide information to the computer, which can be helpful to interact with humans and solve problems in various fields which require human intelligence.

What to Represent in AI?

We need to consider what kinds of knowledge might need to be represented in AI systems:

Objects

-- Facts about objects in our world domain.

Events

-- Actions that occur in our world.

Performance

-- A behavior which involves knowledge about how to do things.

Meta-knowledge

-- knowledge about what we know.

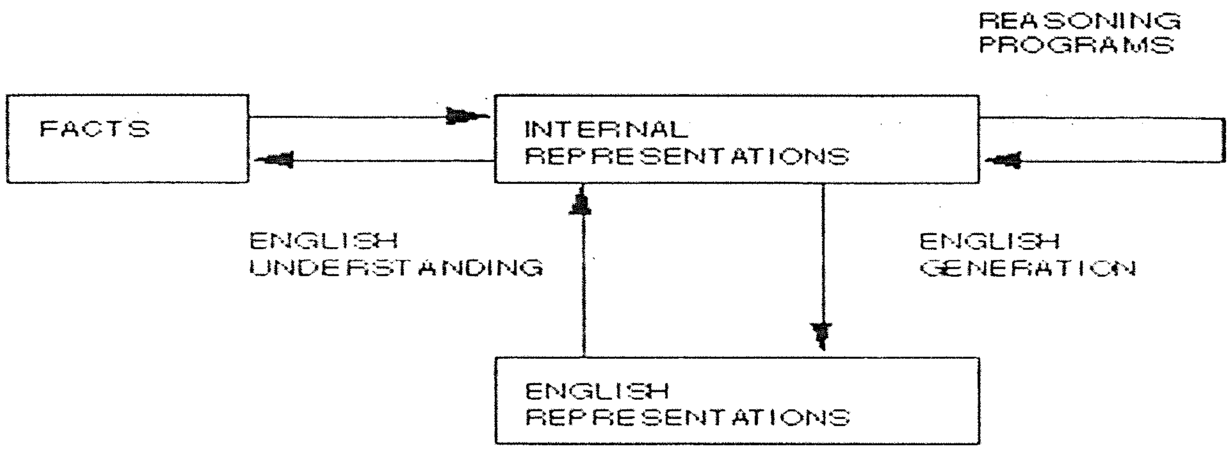
Thus in solving problems in AI we must represent knowledge and there are two entities to deal with:

1. **Facts**-- truths about the real world and what we represent. This can be regarded as the *knowledge level*
2. **Representation of the facts** which we manipulate. This can be regarded as the *symbol level* since we usually define the representation in terms of symbols that can be manipulated by programs.

We can structure these entities at two levels

the knowledge level-- at which facts are described

the symbol level-- at which representations of objects are defined in terms of symbols that can be manipulated in programs.



Internal Representation of AI

Internal representation of AI

It is necessary to represent the computer's knowledge of the world by some kind of data structures in the machine's memory. Traditional computer programs deal with large amounts of data that are structured in simple and uniform ways. A.I. programs need to deal with complex relationships, reflecting the complexity of the real world.

What is Knowledge?

Knowledge is an useful information or the terms used to judge the understanding of an individual on a given subject. In intelligent systems, domain is the main focused subject area. So, the system specifically focuses on acquiring the domain knowledge.

Types of knowledge in AI

Depending on the type of functionality, the knowledge in AI is categorized as:

1. Declarative knowledge

The knowledge which is based on concepts, facts and objects, is termed as 'Declarative Knowledge'. It provides all the necessary information about the problem in terms of simple statements, either true or false.

2. Procedural knowledge

Procedural knowledge derives the information on the basis of rules, strategies, agendas and procedure. It describes how a problem can be solved. Procedural knowledge directs the steps on how to perform something. **For example:** Computer program.

3. Heuristic knowledge or Shallow knowledge

In this type, the knowledge representation is based on the strategies to solve the problems through the experience of past problems, compiled by an expert. Hence, it is also known as **Shallow knowledge.**

4. Meta-knowledge

This type gives an idea about the other types of knowledge that are suitable for solving problem. Meta-knowledge is helpful in enhancing the efficiency of problem solving through proper reasoning process.

5. Structural knowledge

Structural knowledge is associated with the information based on rules, sets, concepts and relationships .It provides the information necessary for developing the knowledge structures and overall **mental model** of the problem.

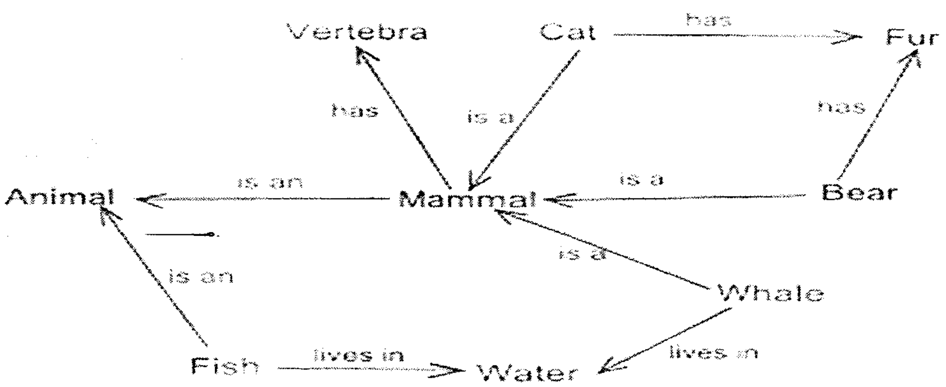
Types of Knowledge representation:

the best ways of representing knowledge for particular techniques are

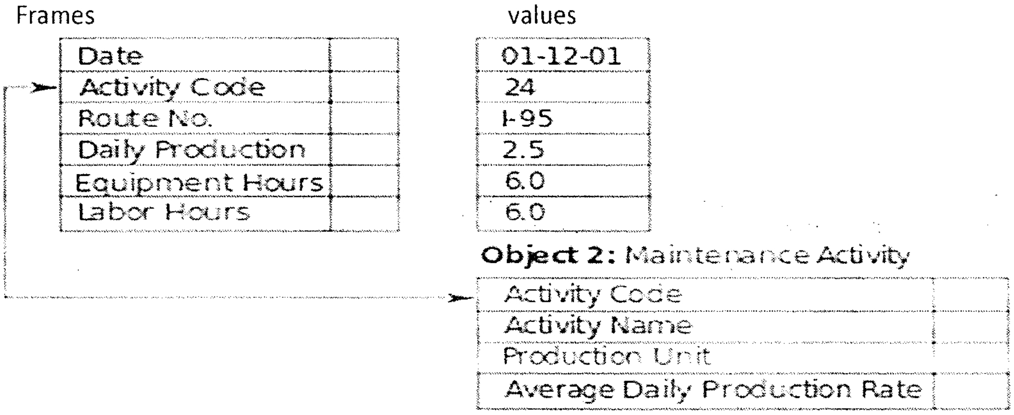
1. **Logical representation**
   Certain logics are very popular for the representation of information, and range in terms of their expressiveness. More expressive logics allow us to translate more sentences from our natural language. we use some Boolean expressions with some symbols to represent knowledge

2. **Production rule:**
   Another way to represent knowledge is as a set of production rules. These are condition-action pairs which are associated to make final decisions in order to represent some knowledge.

3. **Semantic networks(Inheritable & Hierarchical knowledge)**
   This type is used to store and manipulate knowledge in terms of associations and hierarchies, rather than in terms of lists of statements in some logic. This gives us the starting point for ways of representing knowledge in graphical networks. Graph kind of structures are very easy to store inside programs because they can be easily represented with nodes and edges.



4. **Frame representation(Simple relational knowledge)**
   These are frameworks consisting of slots, with each slot containing facts, information in various representations, including logical sentences and production rules in tables. A slot can also contain another frame, which gives us a hierarchy.



Properties for Knowledge Representation Systems

The following properties should be possessed by a knowledge representation system.

Representational Adequacy

-- the ability to represent the required knowledge completely;

Inferential Adequacy

- the ability to manipulate the knowledge represented to produce new knowledge .

Inferential Efficiency

- the ability to handle inferential mechanisms into the most productive directions by storing appropriate knowledge;

Acquisitional Efficiency

- the ability to acquire new knowledge using automatic methods wherever possible rather than human intervention.

Task Classification of AI

The domain of AI is classified into **Formal tasks, Mundane tasks,** and **Expert tasks.**

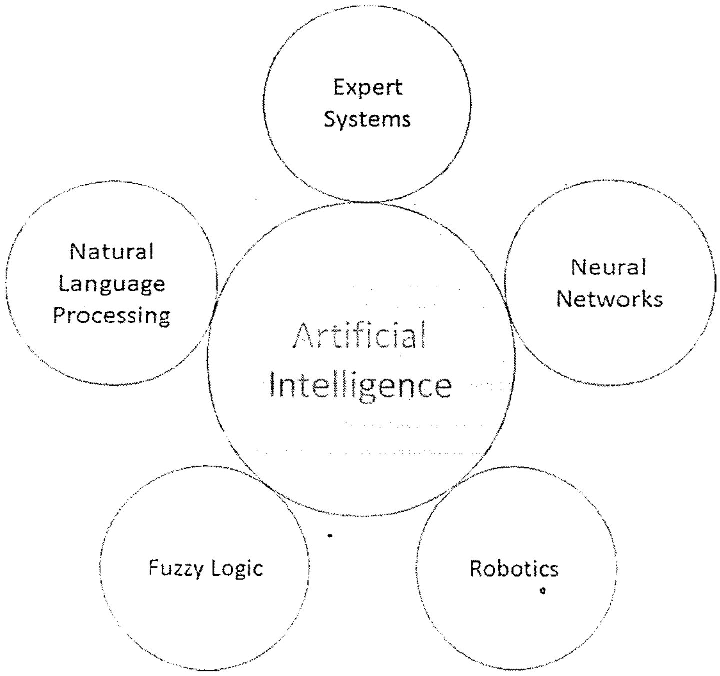
It is mainly classified based on intelligence level.

Task Domains of Artificial Intelligence

Mundane (Ordinary) Tasks	**Formal Tasks**	**Expert Tasks**
No or very less AI	**Weak AI**	**Strong AI**
• Computer Vision • Speech, Voice	• Mathematics • Geometry • Logic • Integration and Differentiation	• Engineering • Fault Finding • Manufacturing • Monitoring
Natural Language Processing	Games	Scientific Analysis
• Understanding • Language Generation • Language Translation	• Go • Chess (Deep Blue) • Checkers	
Common Sense	Verification	Financial Analysis
Robotics	Theorem Proving	Medical Diagnosis
Locomotive		
Planning		Creativity

Artificial Intelligence - Research Areas

The domain of artificial intelligence is huge in breadth and width. While proceeding, we consider the broadly common and prospering research areas in the domain of AI –



1.Expert Systems

The expert systems are the computer applications developed to solve complex problems in a particular domain, at the level of extra-ordinary human intelligence and expertise.

Expert systems (ES) are one of the prominent research domains of AI. It is introduced by the researchers at Stanford University, Computer Science Department.

Capabilities of Expert Systems

The expert systems are capable of –

- Advising
- Instructing and assisting human in decision making
- Demonstrating

- Deriving a solution
- Diagnosing
- Explaining
- Interpreting input
- Predicting results
- Justifying the conclusion
- Suggesting alternative options to a problem

2.Natural Language Processing

Natural Language Processing (NLP) refers to AI method of communicating with an intelligent system using a natural language such as English.

Processing of Natural Language is required when you want an intelligent system like robot to perform as per your instructions, when you want to hear decision from a dialogue based clinical expert system, etc.

The field of NLP involves making computers to perform useful tasks with the natural languages humans use. The input and output of an NLP system can be –

- Speech
- Written Text

Components of NLP

There are two components of NLP

Speech recognition

- Mapping the given input in natural language into useful representations.

Voice recognition

- Analyzing different aspects of the language.

Speech and Voice Recognition

These both terms are common in robotics, expert systems and natural language processing. Though these terms are used interchangeably, their objectives are different.

Speech Recognition	**Voice Recognition**
The speech recognition aims at understanding and comprehending **WHAT** was spoken.	The objective of voice recognition is to recognize **WHO** is speaking.
It is used in hand-free computing, map, or menu navigation.	It is used to identify a person by analysing its tone, voice pitch, and accent, etc.
Machine does not need training for Speech Recognition as it is not speaker dependent.	This recognition system needs training as it is person oriented.
Speaker independent Speech Recognition systems are difficult to develop.	Speaker dependent Speech Recognition systems are comparatively easy to develop.

3. Fuzzy logic

Fuzzy Logic (FL) is a method of reasoning that resembles human reasoning. The approach of FL imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO.

Fuzzy Logic Systems (FLS) produce acceptable but definite output in response to incomplete, ambiguous, distorted, or inaccurate (fuzzy) input.

Fuzzy logic is useful for commercial and practical purposes.

- It can control machines and consumer products.
- It may not give accurate reasoning, but acceptable reasoning.
- Fuzzy logic helps to deal with the uncertainty in engineering.

4 . Robotics

Robotics is a branch of AI, which is composed of Electrical Engineering, Mechanical Engineering, and Computer Science for designing, construction, and application of robots.

Robot: **Robots are the artificial agents acting in real world environment.**

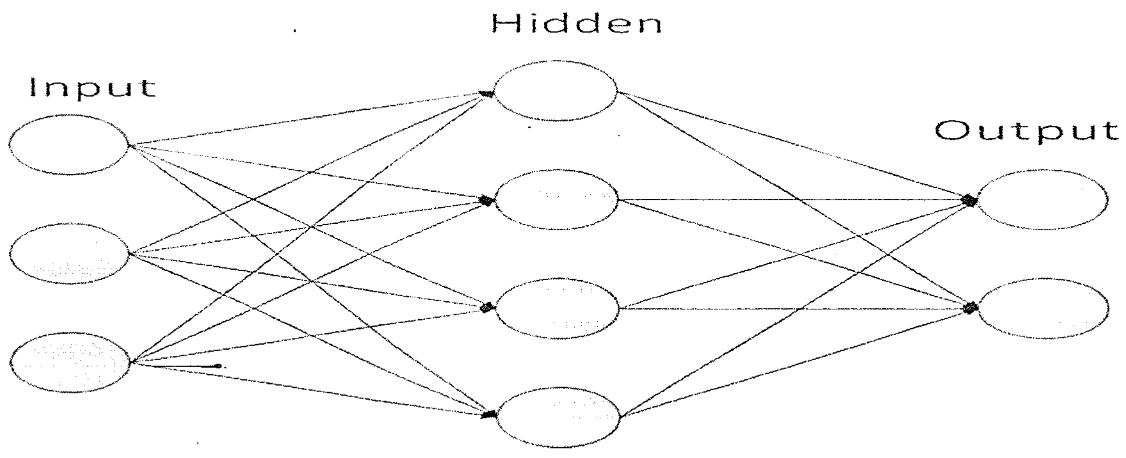
Aspects of Robotics

- The robots have **mechanical construction**, form, or shape designed to accomplish a particular task.
- They have **electrical components** which power and control the machinery.
- They contain some level of **computer program** that determines what, when and how a robot does something.

5 . Neural Networks

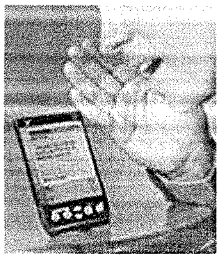
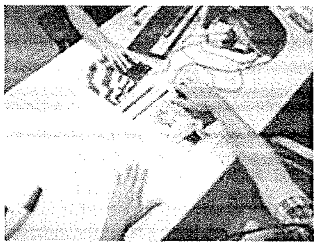
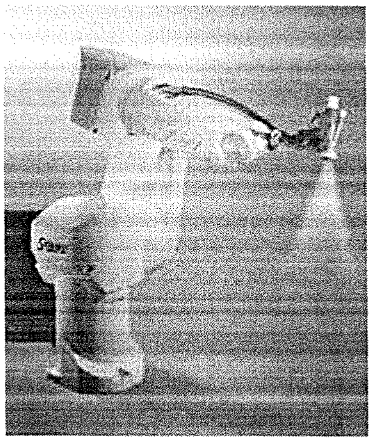
Is a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs.

It is another research area in AI which is inspired from the natural neural network of human nervous system.



Real Life Applications of Research Areas

There is a large array of applications where AI is serving common people in their day-to-day lives –

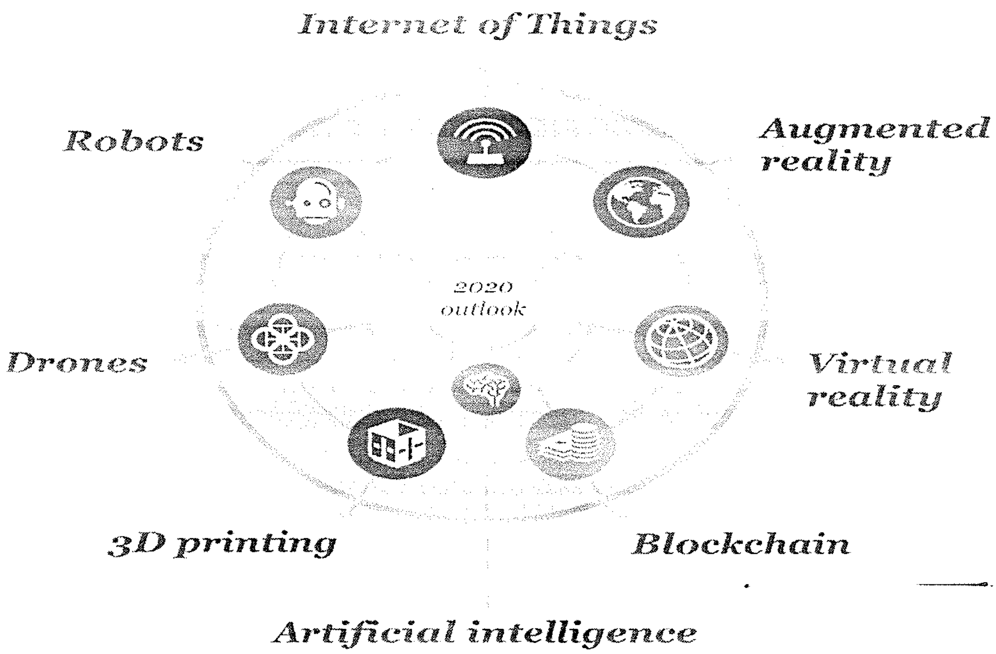
Sr.No.	Research Areas	Real Life Application
1	**Expert Systems** Examples – Flight-tracking systems, Clinical systems for medical diagonisis.	
2	**Natural Language Processing** Examples: Google assistant with the features, speech recognition, Automatic voice output.	
3	**Neural Networks** Examples – Pattern recognition systems such as face recognition, character recognition, handwriting recognition etc.	
4	**Robotics** Examples – Industrial robots for moving, spraying, painting, precision checking, drilling, cleaning, coating, carving, etc.	

5 **Fuzzy Logic Systems**

Examples – Consumer electronics such as smart microwave, automobiles, etc.

The Future or Emerging technologies of AI.

- Military Bots
- The perfect lawyer
- Music
- Business
- Healthcare
- Automated Transport



Benefits of A.I.

The most important purpose of A.I. is to reduce human casualties in
→ Wars
→ Dangerous Workspaces
→ Car Accidents
→ Natural Disasters

Or to just make everyday life easier by helping with tasks such as:
→ Cleaning
→ Shopping
→ Transportation

AI Issues

AI is developing with such an incredible speed, sometimes it seems magical. There is an opinion among researchers and developers that AI could grow so immensely strong that it would be difficult for humans to control.

Humans developed AI systems by introducing into them every possible intelligence they could, for which the humans themselves now seem to be threatened.

1.Threat to Privacy

An AI program that recognizes speech and understands natural language is theoretically capable of understanding each conversation on e-mails and telephones.

2.Threat to Human Dignity

AI systems have already started replacing the human beings in few industries. It should not replace people in the sectors where they are holding dignified positions which are pertaining to ethics such as nursing, surgeon, judge, police officer, etc.

3.Threat to Safety

The self-improving AI systems can become so mighty than humans that could be very difficult to stop from achieving their goals, which may lead to unintended consequences.

Subject: ARTIFICIAL INTELLIGENCE **code:BCACsT6.11**

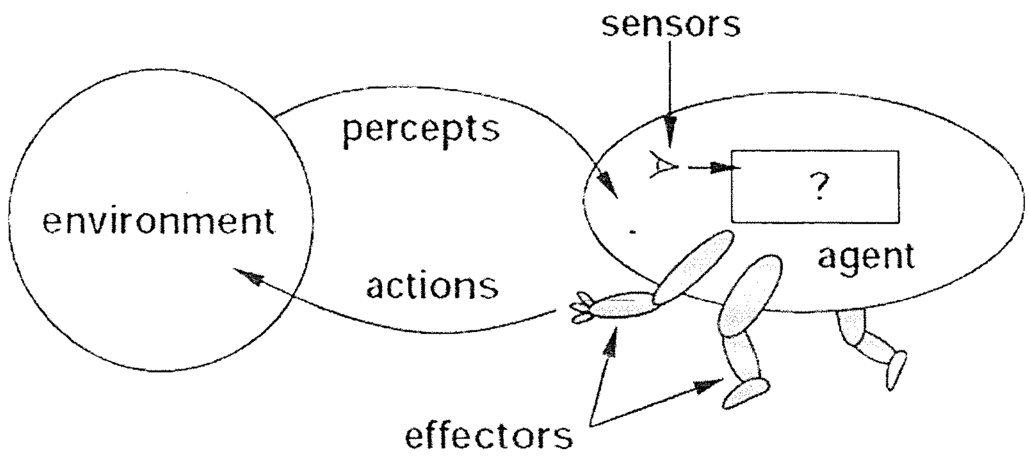
Chapter-2

Agent and Environment

Definition

> **"An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors"**
> **- *(Artificial Intelligence: A Modern Approach by Stuart Russell and Peter Novig)***

A human agent has sensory organs to get information (percepts) from the world (environment) and has muscles (effectors) to take actions in response to the percepts. Robots, the physical instantiation of agents, have got sensors like infrared range finders and cameras to gather information. In this case the effectors are the motors.



On this site we shall consider some properties of Intelligent Agents namely Rationality, Autonomy, Reactivity (Knowledge-based agents) The notion of a rational agents will be introduced and explained and we shall also consider different types of environments and agents.

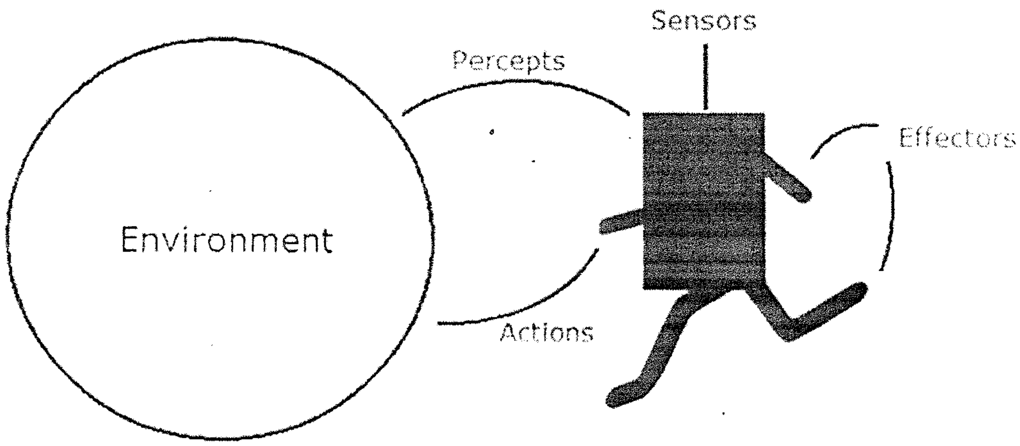
An AI system is composed of an agent and its environment. The agents act in their environment. The environment may contain other agents.

What are Agent and Environment?

An **agent** is anything that can perceive its environment through **sensors** and acts upon that environment through **effectors.**

Environment: Is some thing or Everything surrounded to Agent

- A **human agent** has sensory organs such as eyes, ears, nose, tongue and skin parallel to the sensors, and other organs such as hands, legs, mouth, for effectors.
- A **robotic agent** replaces cameras and infrared range finders for the sensors, and various motors and actuators for effectors.
- A **software agent** has encoded bit strings as its programs and actions.



Agent Terminology

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

Rationality

Rationality is nothing but status of being reasonable, sensible, and having good sense of judgment.

Rationality is concerned with expected actions and results depending upon what the agent has perceived. Performing actions with the aim of obtaining useful information is an important part of rationality.

What is Ideal Rational Agent?

An ideal rational agent is the one, which is capable of doing expected actions to maximize its performance measure, on the basis of –

- Its percept sequence
- Its built-in knowledge base

Rationality of an agent depends on the following –

- The **performance measures**, which determine the degree of success.
- Agent's **Percept Sequence** till now.
- The agent's **prior knowledge about the environment.**
- The **actions** that the agent can carry out.

A rational agent always performs right action, where the right action means the action that causes the agent to be most successful in the given percept sequence. The problem the agent solves is characterized by Performance Measure, Environment, Actuators, and Sensors (PEAS).

The Structure of Intelligent Agents

Agent's structure can be viewed as –

- Agent = Architecture + Agent Program
- Architecture = the machinery that an agent executes on.
- Agent Program = an implementation of an agent function.

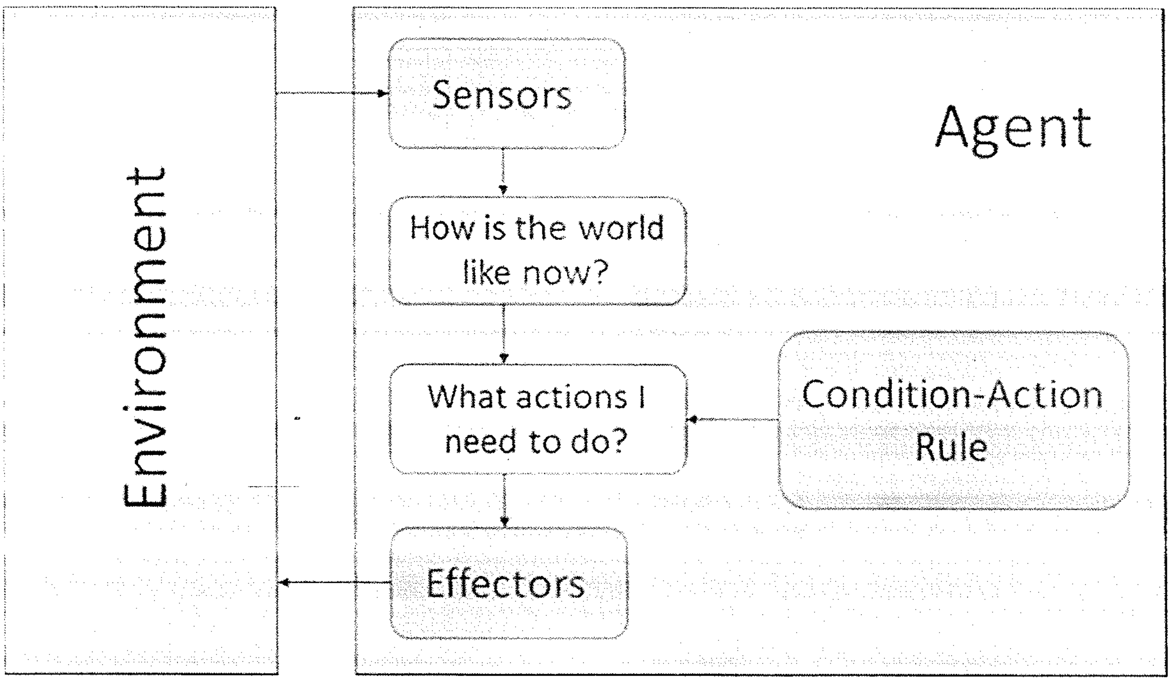
Types of Intelligent Agents

1. Simple Reflex Agents
2. Model Based Reflex agents
3. Goal based Agents
4. Utility based agent
5. Learning Agents

Simple Reflex Agents

- They choose actions only based on the current percept.
- They are rational only if a correct decision is made only on the basis of current precept.
- Their environment is completely observable.

Condition-Action Rule – It is a rule that maps a state (condition) to an action.



Example of this class is a robotic vacuum cleaner that deliberate in an infinite loop, each percept contains a state of a current location [clean] or [dirty] and accordingly it decides whether to [suck] or [continue-moving].

Model Based Reflex Agents

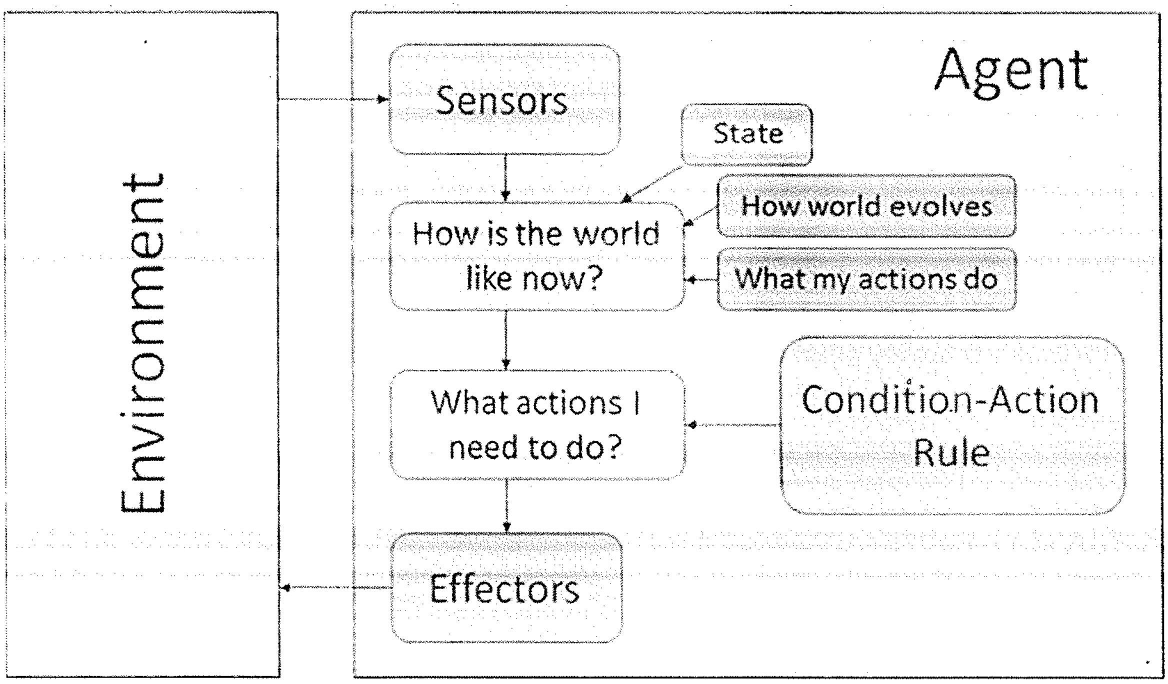
They use a model of the world to choose their actions. They maintain an internal state.

Model – knowledge about "how the things happen in the world".

Internal State – It is a representation of unobserved aspects of current state depending on percept history.

Updating the state requires the information about –

- How the world evolves.
- How the agent's actions affect the world.

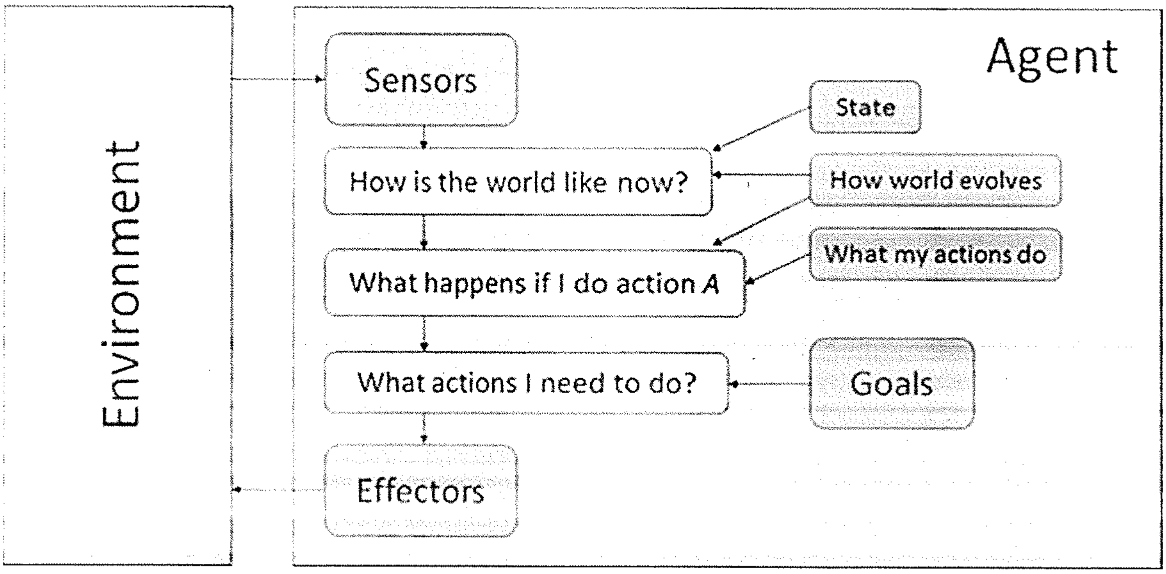


example of this IA class is the self-steering mobile vision where it's necessary to check the percept history to fully understand how the world is evolving.

Goal Based Agents

They choose their actions in order to achieve goals. Goal-based approach is more flexible than reflex agent since the knowledge supporting a decision is explicitly modeled, thereby allowing for modifications.

Goal – It is the description of desirable situations.



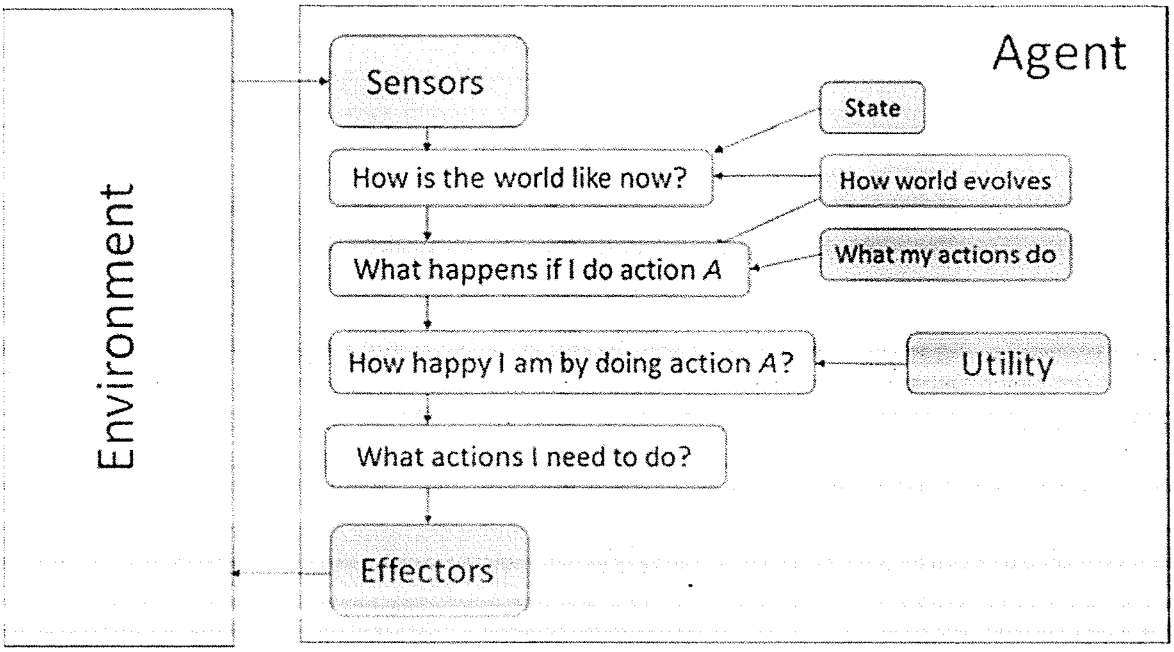
Example of this IA class is any searching robots that has initial location and want to reach a destination.

Utility Based Agents

They choose actions based on a preference (utility) for each state.

Goals are inadequate when –

- There are conflicting goals, out of which only few can be achieved.
- Goals have some uncertainty of being achieved and you need to weigh likelihood of success against the importance of a goal.



example is the route recommendation system which solves for the 'best' route to reach a destination.

Learning agents: The essential component of autonomy, this agent is capable of learning from experience, it has the capability of automatic information acquisition and integration into the system, any agent designed and expected to be successful in an uncertain environment is considered to be learning agent.

The Nature of Environments

Some programs operate in the **entirely artificial environment** confined to keyboard input, database, computer file systems and character output on a screen.

In contrast, some software agents (software robots or softbots) exist in rich, unlimited softbots domains. The simulator has a **very detailed, complex environment**. The software agent needs to choose from a long array of actions in real time. A softbot designed to scan the online preferences of the customer and show interesting items to the customer works in the **real** as well as an **artificial** environment.

The most famous **artificial environment** is the **Turing Test environment**, in which one real and other artificial agents are tested on equal ground. This is a very challenging environment as it is highly difficult for a software agent to perform as well as a human.

Turing Test

The success of an intelligent behavior of a system can be measured with Turing Test.

Two persons and a machine to be evaluated participate in the test. Out of the two persons, one plays the role of the tester. Each of them sits in different rooms. The tester is unaware of who is machine and who is a human. He interrogates the questions by typing and sending them to both intelligences, to which he receives typed responses.

This test aims at fooling the tester. If the tester fails to determine machine's response from the human response, then the machine is said to be intelligent. **Ex: Captcha**

Properties of Environment

The environment has multifold properties –

- **Discrete / Continuous** – If there are a limited number of distinct, clearly defined, states of the environment, the environment is discrete (For example, chess); otherwise it is continuous (For example, driving).
- **Observable / Partially Observable** – If it is possible to determine the complete state of the environment at each time point from the percepts it is observable; otherwise it is only partially observable.
- **Static / Dynamic** – If the environment does not change while an agent is acting, then it is static; otherwise it is dynamic.
- **Single agent / Multiple agents** – The environment may contain other agents which may be of the same or different kind as that of the agent.
- **Accessible / Inaccessible** – If the agent's sensory apparatus can have access to the complete state of the environment, then the environment is accessible to that agent.
- **Deterministic / Non-deterministic** – If the next state of the environment is completely determined by the current state and the actions of the agent, then the environment is deterministic; otherwise it is non-deterministic.
- **Episodic / Non-episodic** – In an episodic environment, each episode consists of the agent perceiving and then acting. The quality of its action depends just on the episode itself. Subsequent episodes do not depend on the actions in the previous episodes. Episodic environments are much simpler because the agent does not need to think ahead.

Subject: ARTIFICIAL INTELLIGENCE code:BCACsT6.11

Chapter-3

Popular Search Algorithms

Searching is the universal technique of problem solving in AI. There are some single-player games such as tile games, Sudoku, crossword, etc. The search algorithms help you to search for a particular position in such games.

1	2	5
3	4	
6	7	8

Single Agent Pathfinding Problems

The games such as 3X3 eight-tile, 4X4 fifteen-tile, and 5X5 twenty four tile puzzles are single-agent-path-finding challenges. They consist of a matrix of tiles with a blank tile. The player is required to arrange the tiles by sliding a tile either vertically or horizontally into a blank space with the aim of accomplishing some objective.

The other examples of single agent pathfinding problems are Travelling Salesman Problem, Rubik's Cube, and Theorem Proving.

Search Terminology

- **Problem Space** – It is the environment in which the search takes place. (A set of states and set of operators to change those states)
- **Problem Instance** – It is Initial state + Goal state.
- **Problem Space Graph** – It represents problem state. States are shown by nodes and operators are shown by edges.
- **Depth of a problem** – Length of a shortest path or shortest sequence of operators from Initial State to goal state.

- **Space Complexity** – The maximum number of nodes that are stored in memory.
- **Time Complexity** – The maximum number of nodes that are created.
- **Admissibility** – A property of an algorithm to always find an optimal solution.
- **Branching Factor** – The average number of child nodes in the problem space graph.
- **Depth** – Length of the shortest path from initial state to goal state.

Brute-Force Search Strategies

They are most simple, as they do not need any domain-specific knowledge. They work fine with small number of possible states.

Requirements –

- State description
- A set of valid operators
- Initial state
- Goal state description

Breadth-First Search

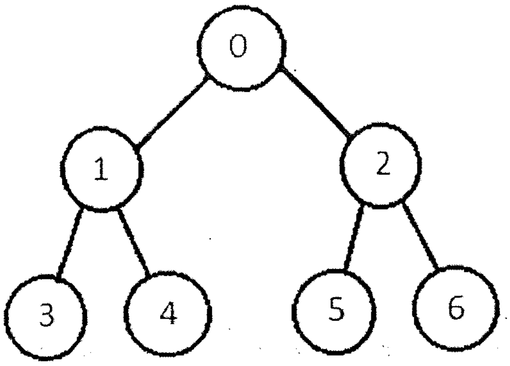
It starts from the root node, explores the neighboring nodes first and moves towards the next level neighbors. It generates one tree at a time until the solution is found. It can be implemented using FIFO queue data structure. This method provides shortest path to the solution.

If **branching factor** (average number of child nodes for a given node) = b and depth = d, then number of nodes at level d = b^d.

The total no of nodes created in worst case is $b + b^2 + b^3 + \dots + b^d$.

Disadvantage – Since each level of nodes is saved for creating next one, it consumes a lot of memory space. Space requirement to store nodes is exponential.

Its complexity depends on the number of nodes. It can check duplicate nodes.



BFS Traversal for above graph is: 0 1 2 3 4 5 6

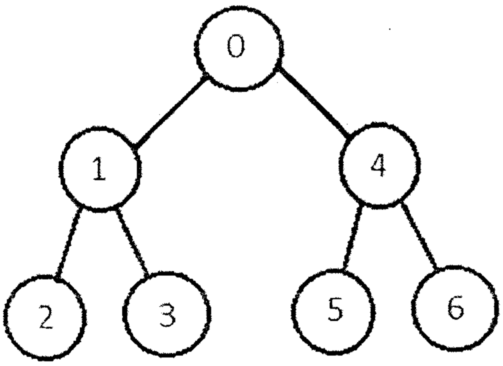
Depth-First Search

It is implemented in recursion with LIFO stack data structure. It creates the same set of nodes as Breadth-First method, only in the different order.

As the nodes on the single path are stored in each iteration from root to leaf node, the space requirement to store nodes is linear. With branching factor *b*and depth as *m*, the storage space is *bm*.

Disadvantage – This algorithm may not terminate and go on infinitely on one path. The solution to this issue is to choose a cut-off depth. If the ideal cut-off is *d*, and if chosen cut-off is lesser than *d*, then this algorithm may fail. If chosen cut-off is more than *d*, then execution time increases.

Its complexity depends on the number of paths. It cannot check duplicate nodes.

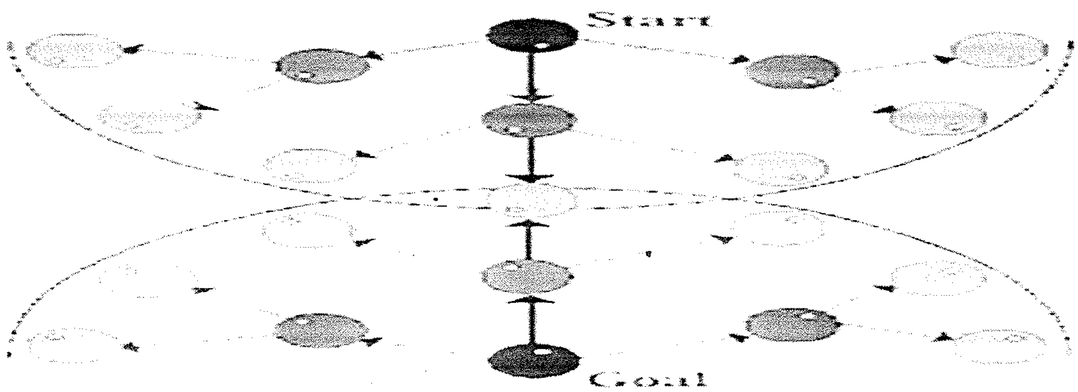


DFS Traversal for above graph is: 0 1 2 3 4 5 6

Bidirectional Search

It searches forward from initial state and backward from goal state till both meet to identify a common state.

The path from initial state is concatenated with the inverse path from the goal state. Each search is done only up to half of the total path.



Comparison of Various Algorithms Complexities

Let us see the performance of algorithms based on various criteria –

Criterion	Breadth First	Depth First	Bidirectional
Time	b^d	b^m	$b^{d/2}$
Space	b^d	b^m	$b^{d/2}$
Optimality	Yes	No	Yes

Completeness	Yes	No	Yes

Informed (Heuristic) Search Strategies

To solve large problems with large number of possible states, problem-specific knowledge needs to be added to increase the efficiency of search algorithms.

Heuristics:

- Rules for choosing the branches in a state space that are most likely to lead to an acceptable problem solution.
- Rules that provide guidance in decision making
- Often improves the decision making:
  - Shopping: *Choosing the shortest queue in a supermarket does not necessarily means that you will out of the market earlier*

Used when:

- Information has inherent ambiguity
- computational costs are high

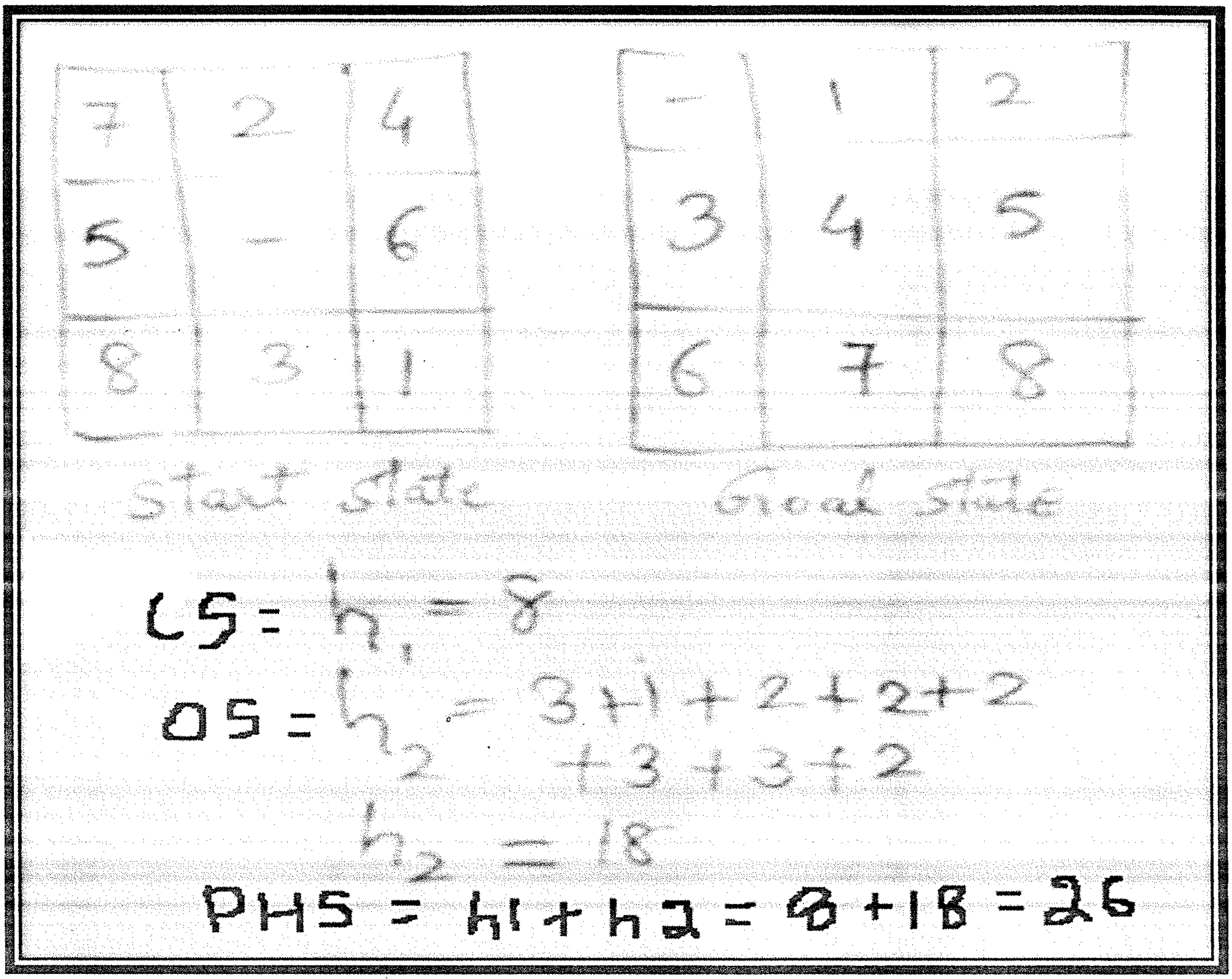
Heuristic Evaluation Functions

They calculate the cost of optimal path between two states. A heuristic function for sliding-tiles games is computed by counting number of moves that each tile makes from its goal state and adding these number of moves for all tiles.

Pure Heuristic Search

It expands nodes in the order of their heuristic values. It creates two lists, a closed list for the already expanded nodes and an open list for the created but unexpanded nodes.

In each iteration, a node with a minimum heuristic value is expanded, all its child nodes are created and placed in the closed list. Then, the heuristic function is applied to the child nodes and they are placed in the open list according to their heuristic value. The shorter paths are saved and the longer ones are disposed.

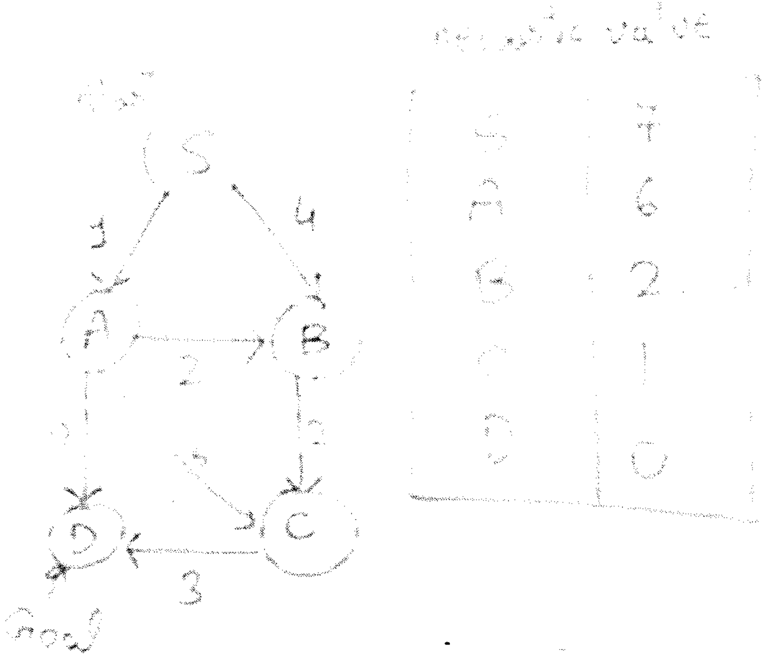


A * Search

It is best-known form of Best First search. It avoids expanding paths that are already expensive, but expands most promising paths first.

f(n) = g(n) + h(n), where

- g(n) the cost (so far) to reach the node
- h(n) estimated cost of the reaching node(priority).
- **Disadvantage** – It can get stuck in loops. It is not optimal.



F(N)=G(N) + H(N)

S=0+7=7
S->A=1+6=7
S->B=4+2=6
S->A=1+6=7
(S->A)->B=3+2=5
(S->A)->C=6+1=7
(S->A)->D=13+0=13
(S->B)->C=6+1=7
(S->A->B)->C=5+1=6
(S->A->C)->D=9+0=9
(S->B->C)->D=9+0=9

(S->A->B->C)->D=8+0=8

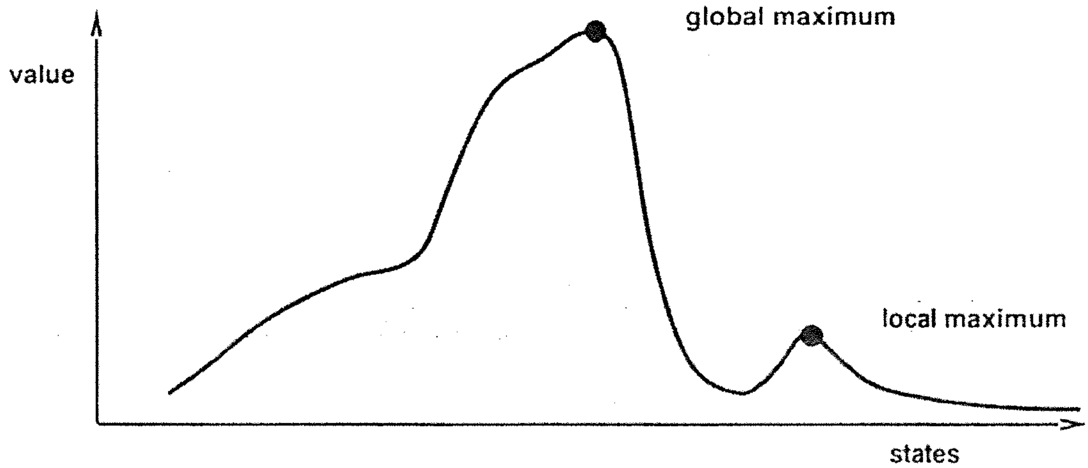
OPTIMAL SOLUTION= (S->A->B->C)->D=8+0=8

Local Search Algorithms

They start from a prospective solution and then move to a neighboring solution. They can return a valid solution even if it is interrupted at any time before they end.

Hill-Climbing Search

It is an iterative algorithm that starts with an arbitrary solution to a problem and attempts to find a better solution by changing a single element of the solution incrementally. If the change produces a better solution, an incremental change is taken as a new solution. This process is repeated until there are no further improvements.



function Hill-Climbing (problem), returns a state that is a local maximum.

inputs: problem, a problem
local variables: current, a node
neighbor, a node
current <-Make_Node(Initial-State[problem])
loop
do neighbor <- a highest_valued successor of *current*
if Value[neighbor] ≤ Value[current] then
return State[current]
current <- neighbor

end

Disadvantage – This algorithm is neither complete, nor optimal.

Local Beam Search

In this algorithm, it holds k number of states at any given time. At the start, these states are generated randomly. The successors of these k states are computed with the help of objective function. If any of these successors is the maximum value of the objective function, then the algorithm stops.

Otherwise the (initial k states and k number of successors of the states = 2k) states are placed in a pool. The pool is then sorted numerically. The highest k states are selected as new initial states. This process continues until a maximum value is reached.

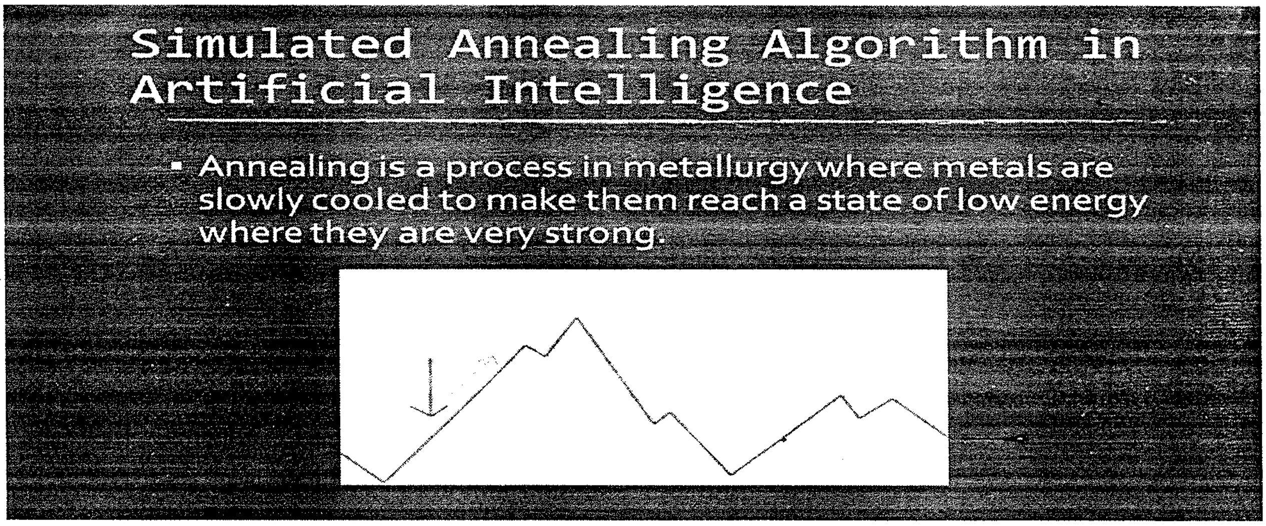
function BeamSearch(*problem, k*), returns a solution state.

```
start with k randomly generated states
loop
   generate all successors of all k states
   if any of the states = solution, then return the state
   else select the k best successors
end
```

Simulated Annealing

Annealing is the process of heating and cooling a metal to change its internal structure for modifying its physical properties. When the metal cools, its new structure is seized, and the metal retains its newly obtained properties. In simulated annealing process, the temperature is kept variable.

We initially set the temperature high and then allow it to 'cool' slowly as the algorithm proceeds. When the temperature is high, the algorithm is allowed to accept worse solutions with high frequency.



Start

- Initialize k = 0; L = integer number of variables;

- From i → j, search the performance difference Δ.
- If Δ <= 0 then accept else if exp(-Δ/T(k)) > random(0,1) then accept;
- Repeat steps 1 and 2 for L(k) steps.
- k = k + 1;

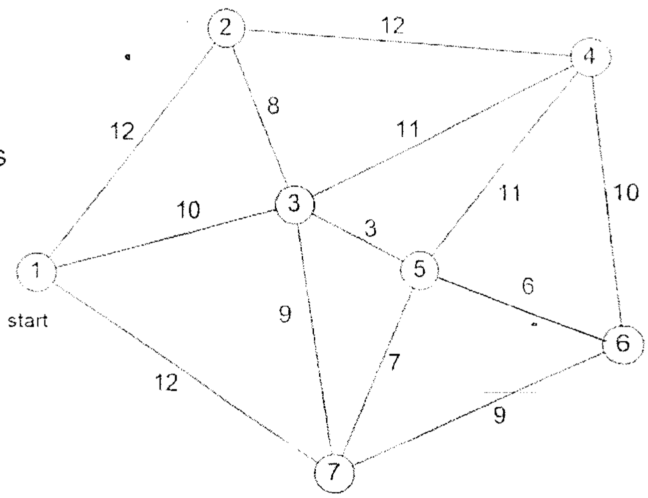
Repeat steps 1 through 4 till the criteria is met.

End

Travelling Salesman Problem

The Traveling Salesman Problem

- Starting from city 1, the salesman must travel to all cities once before returning home
- The distance between each city is given, and is assumed to be the same in both directions
- Only the links shown are to be used
- Objective - Minimize the total distance to be travelled



In this algorithm, the objective is to find a low-cost tour that starts from a city, visits all cities en-route exactly once and ends at the same starting city.

Start
Find out all (n -1)! Possible solutions, where n is the total number of cities.
Determine the minimum cost by finding out the cost of each of these (n -1)! solutions.
Finally, keep the one with the minimum cost.
end

Subject: ARTIFICIAL INTELLIGENCE code:BCACsT6.11

Chapter-4

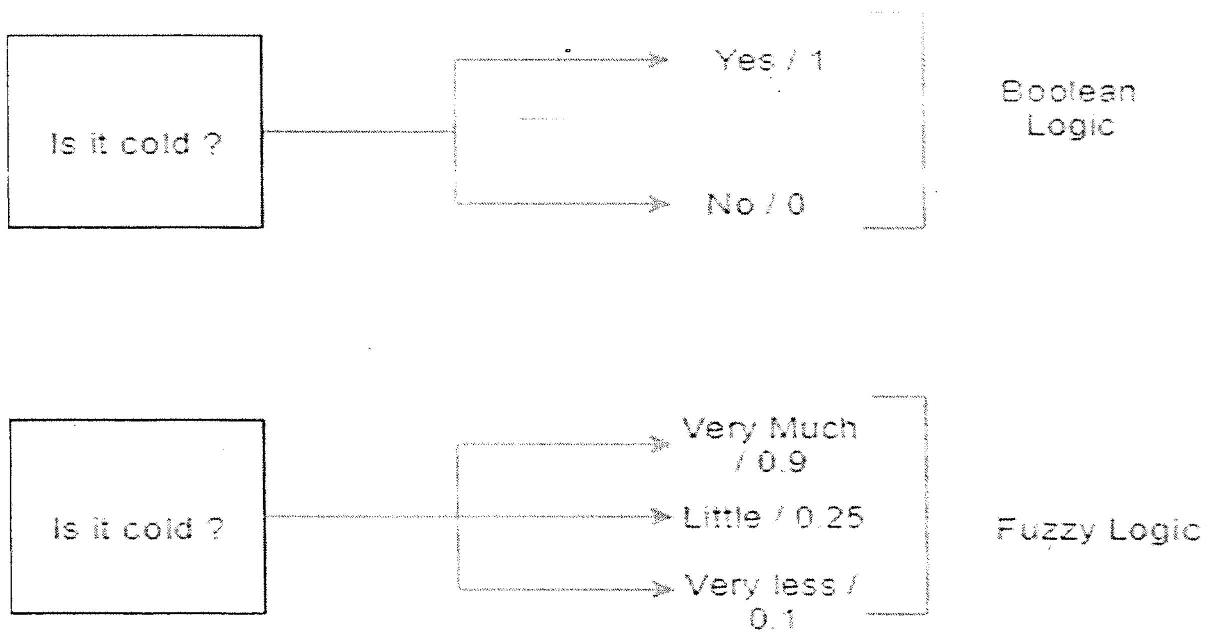
Fuzzy Logic Systems

Fuzzy Logic Systems (FLS) produce acceptable but definite output in response to incomplete, ambiguous, distorted, or inaccurate (fuzzy) input.

Fuzzy Logic | Introduction

The term **fuzzy** refers to things which are not clear or are vague. In the real world many times we encounter a situation when we can't determine whether the state is true or false, their fuzzy logic provides a very valuable flexibility for reasoning. In this way, we can consider the inaccuracies and uncertainties of any situation.

In boolean system truth value, 1.0 represents absolute truth value and 0.0 represents absolute false value. But in the fuzzy system, there is no logic for absolute truth and absolute false value. But in fuzzy logic, there is intermediate value too present which is partially true and partially false.



What is Fuzzy Logic?

Fuzzy Logic (FL) is a method of reasoning that resembles human reasoning. The approach of FL imitates the way of decision making in humans that involves all intermediate possibilities between digital values YES and NO.

The conventional logic block that a computer can understand takes precise input and produces a definite output as TRUE or FALSE, which is equivalent to human's YES or NO.

The inventor of fuzzy logic, **Lotfi Zadeh**, observed that unlike computers, the human decision making includes a range of possibilities between YES and NO, such as –

CERTAINLY YES
POSSIBLY YES
CANNOT SAY
POSSIBLY NO
CERTAINLY NO

The fuzzy logic works on the levels of possibilities of input to achieve the definite output.

Implementation

- It can be implemented in systems with various sizes and capabilities ranging from small micro-controllers to large, networked, workstation-based control systems.
- It can be implemented in hardware, software, or a combination of both.

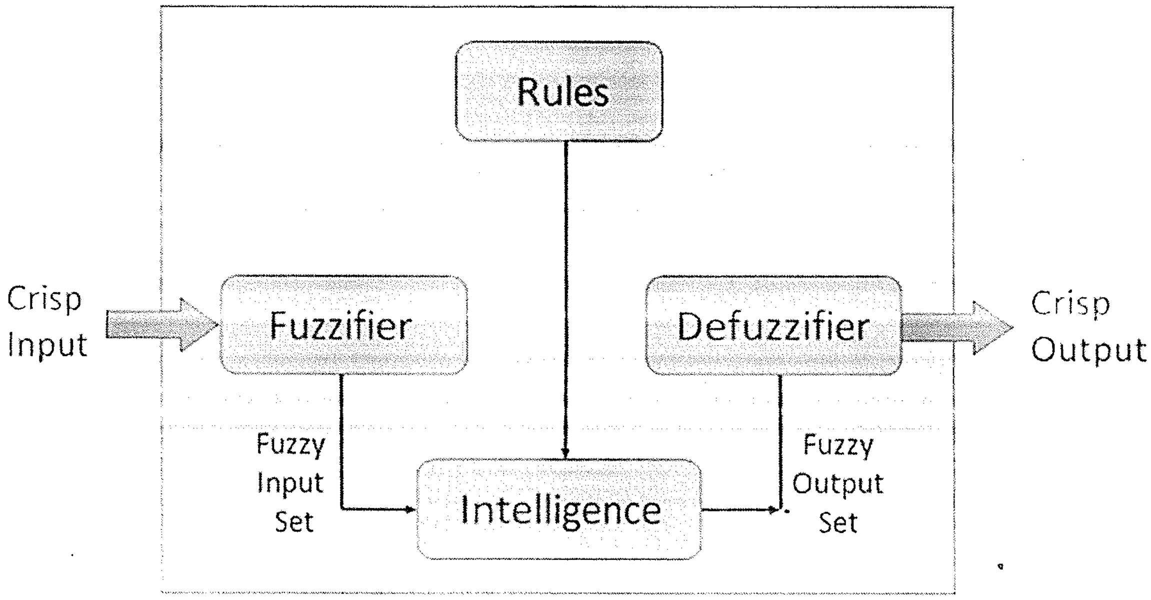
Why Fuzzy Logic?

Fuzzy logic is useful for commercial and practical purposes.

- It can control machines and consumer products.
- It may not give accurate reasoning, but acceptable reasoning.
- Fuzzy logic helps to deal with the uncertainty in engineering.

Fuzzy Logic Systems Architecture

It has four main parts as shown –



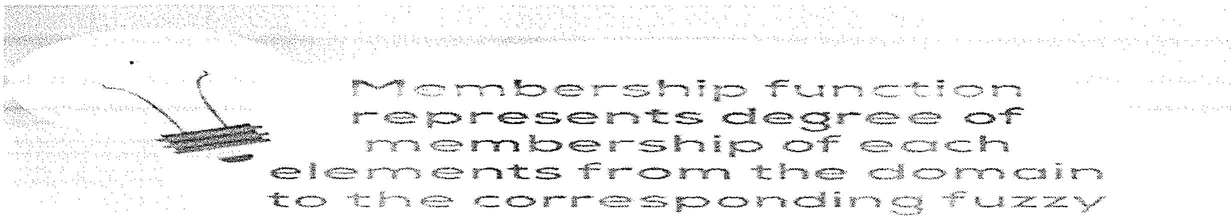
- **Fuzzification Module** – It transforms the system inputs, which are crisp numbers, into fuzzy sets. It splits the input signal into five steps such as –

LP	x is Large Positive
MP	x is Medium Positive
S	x is Small
MN	x is Medium Negative
LN	x is Large Negative

The **membership functions work on** fuzzy sets of variables.

- **Knowledge Base** – It stores IF-THEN rules provided by experts.
- **Inference Engine** – It simulates the human reasoning process by making fuzzy inference on the inputs and by using IF-THEN rules.
- **Defuzzification Module** – It transforms the fuzzy set obtained by the inference engine into a crisp value.

Membership Function



Membership function

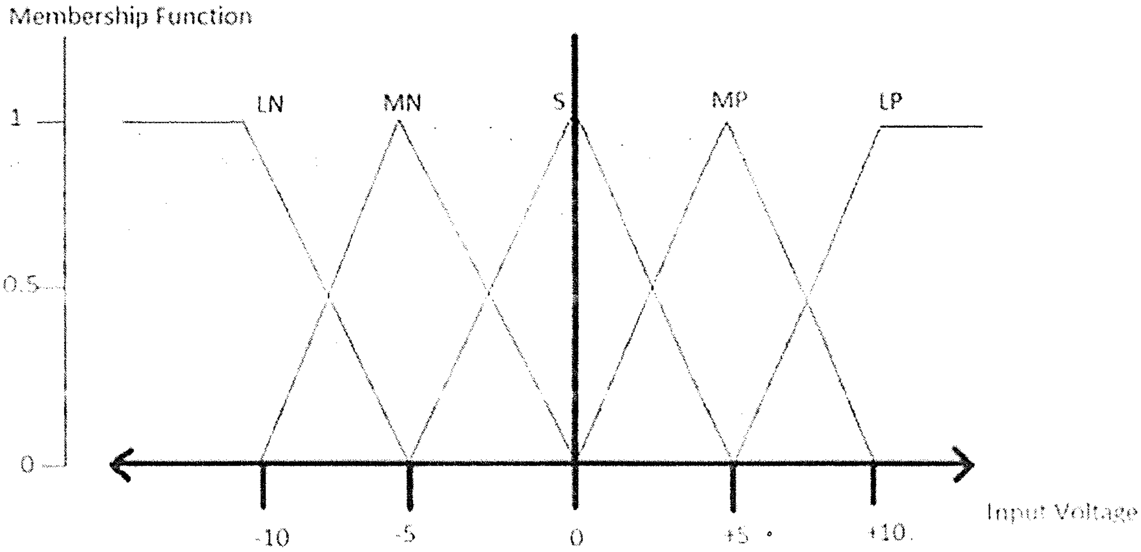
Definition: A graph that defines how each point in the input space is mapped to membership value between 0 and 1. Input space is often referred as the universe of discourse or universal set (u), which contain all the possible elements of concern in each particular application.

There are largely three types of fuzzifiers:

1. **singleton fuzzifier,**
2. **Gaussian fuzzifier, and**
3. **trapezoidal or triangular fuzzifier**

Membership functions allow you to quantify linguistic term and represent a fuzzy set graphically. A **membership function** for a fuzzy *set A* on the universe of discourse X is defined as $\mu_A: X \rightarrow [0,1]$.

Here, each element of X is mapped to a value between 0 and 1. It is called **membership value** or **degree of membership**. It quantifies the degree of membership of the element in X to the fuzzy set A.



- x axis represents the universe of discourse.
- y axis represents the degrees of membership in the [0, 1] interval.

There can be multiple membership functions applicable to fuzzify a numerical value. Simple membership functions are used as use of complex functions does not add more precision in the output.

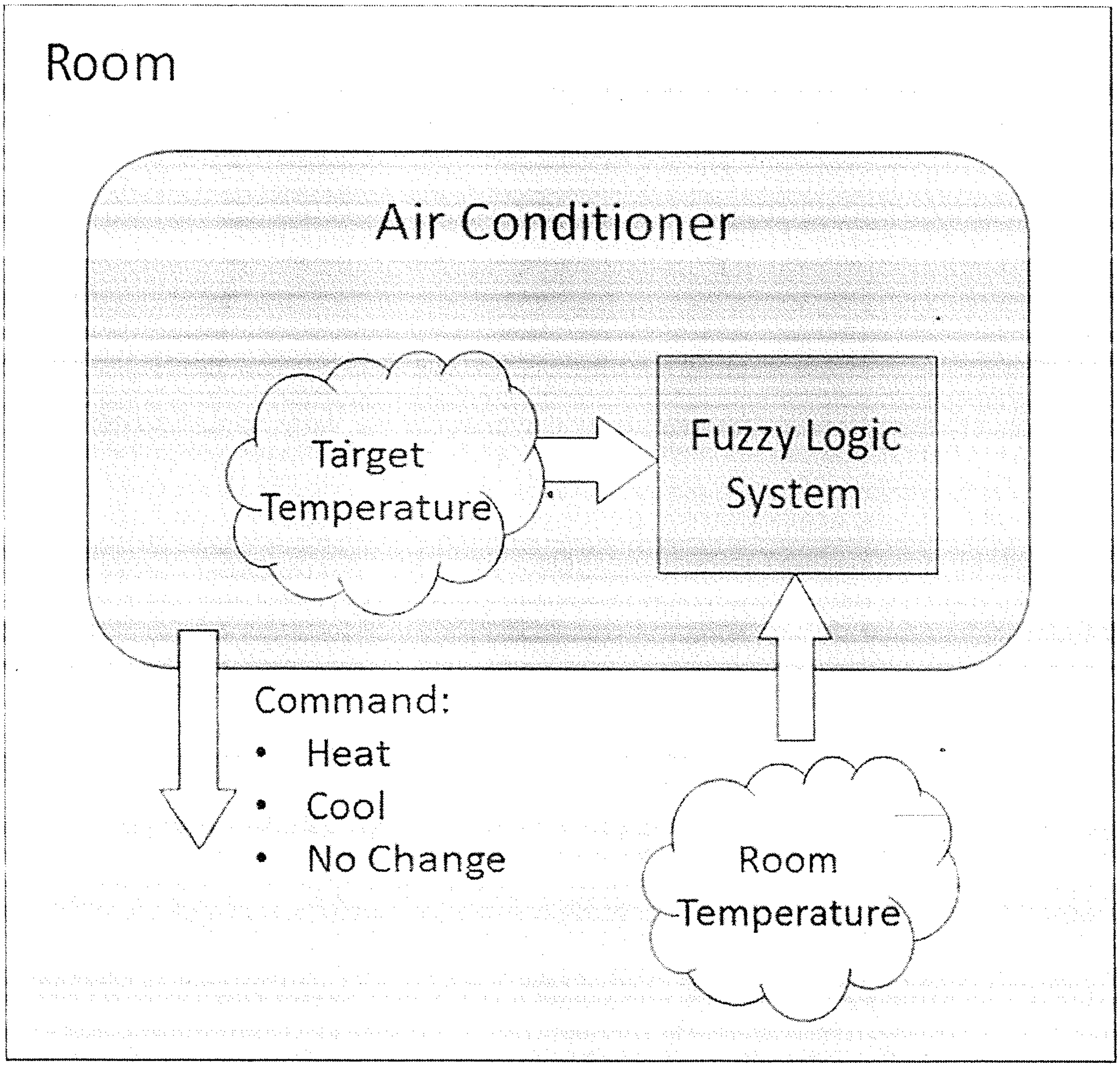
All membership functions for **LP, MP, S, MN,** and **LN** are shown as above –

The triangular membership function shapes are most common among various other membership function shapes such as trapezoidal, singleton, and Gaussian.

Here, the input to 5-level fuzzifier varies from -10 volts to +10 volts. Hence the corresponding output also changes.

Example of a Fuzzy Logic System

Let us consider an air conditioning system with 5-level fuzzy logic system. This system adjusts the temperature of air conditioner by comparing the room temperature and the target temperature value.



Algorithm

- Define linguistic Variables and terms (start)
- Construct membership functions for them. (start)
- Construct knowledge base of rules (start)

- Convert crisp data into fuzzy data sets using membership functions. (fuzzification)
- Evaluate rules in the rule base. (Inference Engine)
- Combine results from each rule. (Inference Engine)
- Convert output data into non-fuzzy values. (defuzzification)

Development

Step 1 – Define linguistic variables and terms

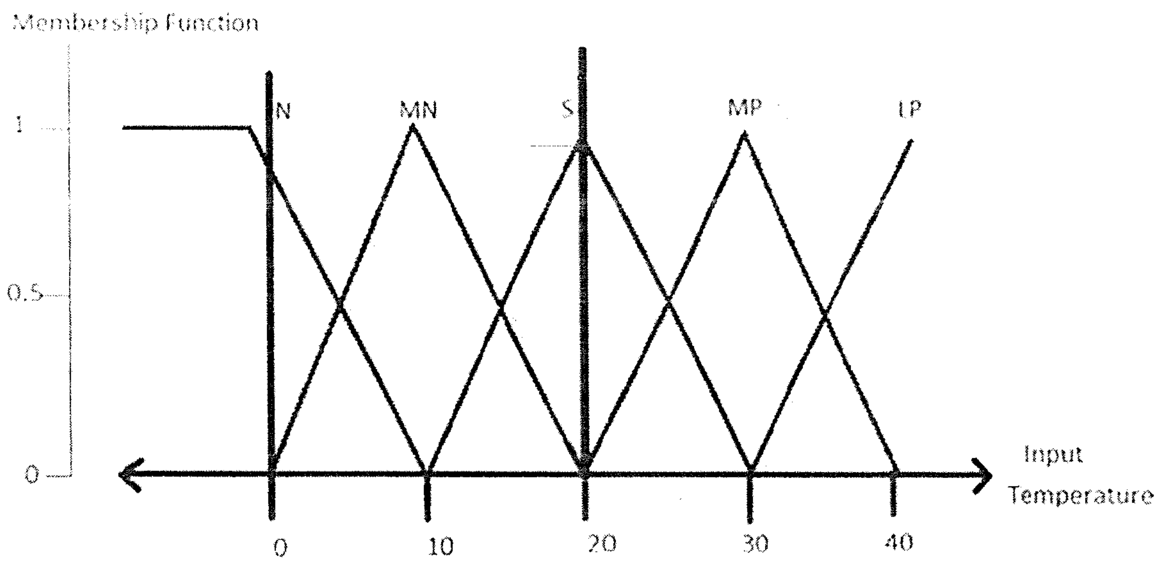
Linguistic variables are input and output variables in the form of simple words or sentences. For room temperature, cold, warm, hot, etc., are linguistic terms.

Temperature (t) = {very-cold, cold, warm, very-warm, hot}

Every member of this set is a linguistic term and it can cover some portion of overall temperature values.

Step 2 – Construct membership functions for them

The membership functions of temperature variable are as shown –



Step3 – Construct knowledge base rules

Create a matrix of room temperature values versus target temperature values that an air conditioning system is expected to provide.

RoomTemp. /Target	Very_Cold	Cold	Warm	Hot	Very_Hot
Very_Cold	No_Change	Heat	Heat	Heat	Heat
Cold	Cool	No_Change	Heat	Heat	Heat
Warm	Cool	Cool	No_Change	Heat	Heat
Hot	Cool	Cool	Cool	No_Change	Heat
Very_Hot	Cool	Cool	Cool	Cool	No_Change

Build a set of rules into the knowledge base in the form of IF-THEN-ELSE structures.

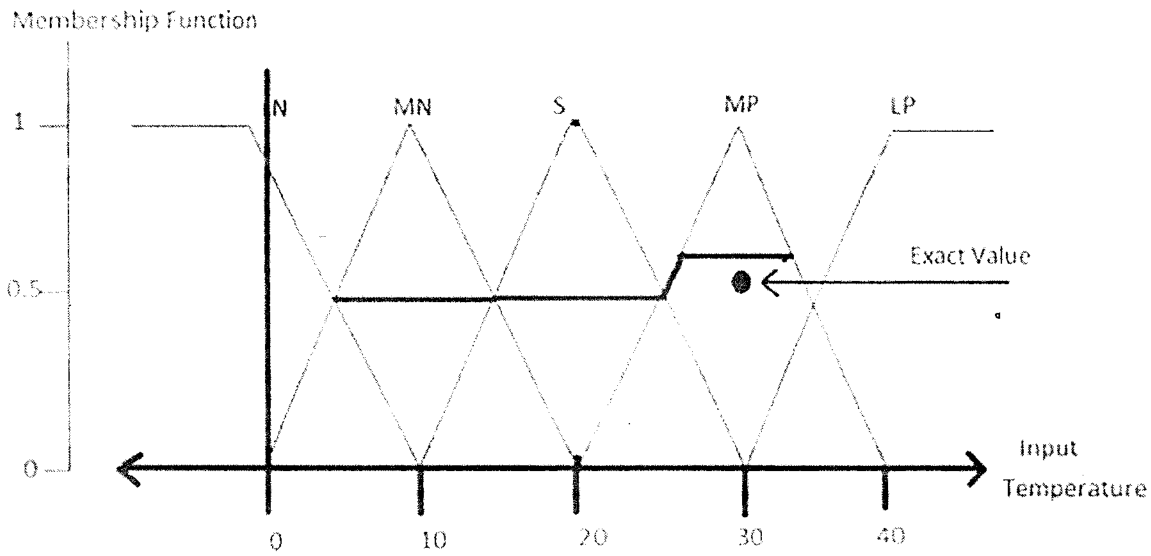
Sr. No.	Condition	Action
1	IF temperature=(Cold OR Very_Cold) AND target=Warm THEN	Heat
2	IF temperature=(Hot OR Very_Hot) AND target=Warm THEN	Cool
3	IF (temperature=Warm) AND (target=Warm) THEN	No_Change

Step 4 – Obtain fuzzy value

Fuzzy set operations perform evaluation of rules. The operations used for OR and AND are Max and Min respectively. Combine all results of evaluation to form a final result. This result is a fuzzy value.

Step 5 – Perform defuzzification

Defuzzification is then performed according to membership function for output variable.



Application Areas of Fuzzy Logic

The key application areas of fuzzy logic are as given –

Automotive Systems

- Automatic Gearboxes
- Four-Wheel Steering
- Vehicle environment control

Consumer Electronic Goods

- Hi-Fi Systems
- Photocopiers
- Still and Video Cameras
- Television

Domestic Goods

- Microwave Ovens
- Refrigerators
- Toasters
- Vacuum Cleaners
- Washing Machines

Environment Control

- Air Conditioners/Dryers/Heaters
- Humidifiers

Advantages of FLSs

- Mathematical concepts within fuzzy reasoning are very simple.
- You can modify a FLS by just adding or deleting rules due to flexibility of fuzzy logic.
- Fuzzy logic Systems can take imprecise, distorted, noisy input information.
- FLSs are easy to construct and understand.
- Fuzzy logic is a solution to complex problems in all fields of life, including medicine, as it resembles human reasoning and decision making.

Disadvantages of FLSs

- There is no systematic approach to fuzzy system designing.
- They are understandable only when simple.
- They are suitable for the problems which do not need high accuracy.

Subject: ARTIFICIAL INTELLIGENCE **code:BCACsT6.11**

Chapter-5

Natural Language Processing

Natural Language Processing (NLP) refers to AI method of communicating with an intelligent system using a natural language such as English.

Processing of Natural Language is required when you want an intelligent system like robot to perform as per your instructions, when you want to hear decision from a dialogue based clinical expert system, etc.

The field of NLP involves making computers to perform useful tasks with the natural language's humans use. **The input and output of an NLP system can be –**

- **Speech**
- **Written Text**

<u>Components of NLP</u>

There are two components of NLP as given –

1.Natural Language Understanding (NLU)

Understanding involves the following tasks –

- Mapping the given input in natural language into useful representations.
- Analyzing different aspects of the language.

2.Natural Language Generation (NLG).

It is the process of producing meaningful phrases and sentences in the form of natural language from some internal representation.

It involves –

- **Text planning** – It includes retrieving the relevant content from knowledge base.
- **Sentence planning** – It includes choosing required words, forming meaningful phrases, setting tone of the sentence.

- **Text Realization** – It is mapping sentence plan into sentence structure.

The NLU is harder than NLG.

Difficulties in NLU

NL has an extremely rich form and structure.

It is very ambiguous. There can be different levels of ambiguity –

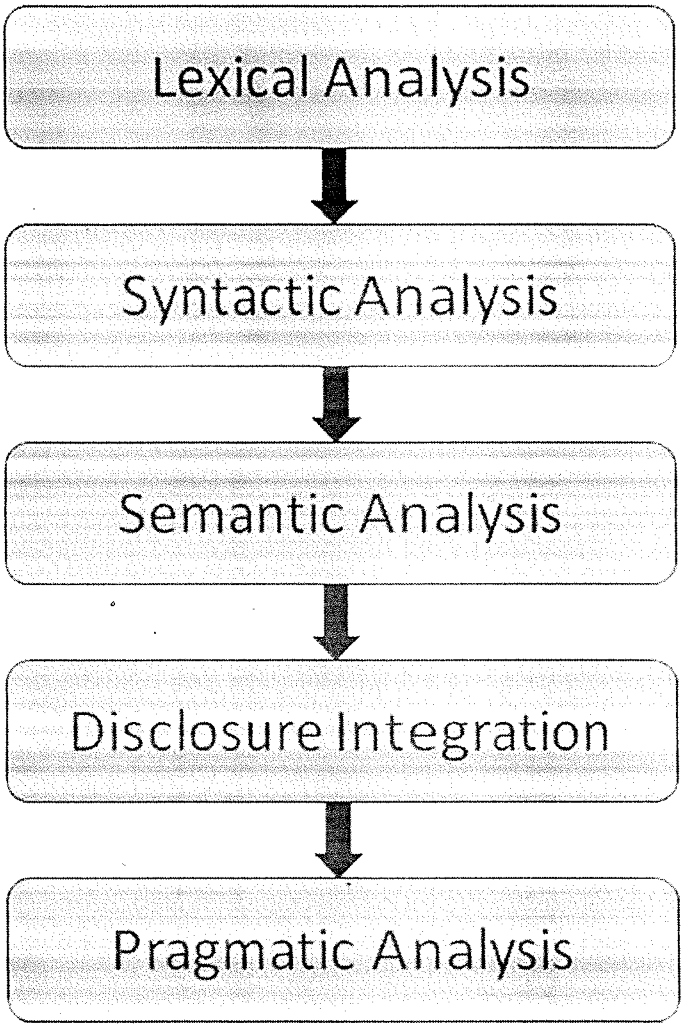
- **Lexical ambiguity** – It is at very primitive level such as word-level.
- For example, treating the word "board" as noun or verb?
- **Syntax Level ambiguity** – A sentence can be parsed in different ways.
- For example, "He lifted the beetle with red cap." – Did he use cap to lift the beetle or he lifted a beetle that had red cap?
- **Referential ambiguity** – Referring to something using pronouns. For example, Rima went to Gauri. She said, "I am tired." – Exactly who is tired?
- One input can have different meanings.
- Many inputs can have the same meaning.

NLP Terminology

- **Phonology** – It is study of organizing sound systematically.
- **Morphology** – It is a study of construction of words from primitive meaningful units.
- **Morpheme** – It is primitive unit of meaning in a language.
- **Syntax** – It refers to arranging words to make a sentence. It also involves determining the structural role of words in the sentence and in phrases.
- **Semantics** – It is concerned with the meaning of words and how to combine words into meaningful phrases and sentences.
- **Pragmatics** – It deals with using and understanding sentences in different situations and how the interpretation of the sentence is affected.
- **Discourse** – It deals with how the immediately preceding sentence can affect the interpretation of the next sentence.
- **World Knowledge** – It includes the general knowledge about the world.

Logical Steps in NLP

There are general five steps –



- **Lexical Analysis** – It involves identifying and analyzing the structure of words. Lexicon of a language means the collection of words and phrases in a language. Lexical analysis is dividing the whole chunk of txt into paragraphs, sentences, and words.
- **Syntactic Analysis (Parsing)** – It involves analysis of words in the sentence for grammar and arranging words in a manner that shows the relationship among the words. The sentence such as "The school goes to boy" is rejected by English syntactic analyzer.
- **Semantic Analysis** – It draws the exact meaning or the dictionary meaning from the text. The text is checked for meaningfulness. It is done by mapping syntactic structures

and objects in the task domain. The semantic analyzer disregards sentence such as "hot ice-cream".

- **Discourse Integration** – The meaning of any sentence depends upon the meaning of the sentence just before it. In addition, it also brings about the meaning of immediately succeeding sentence.
- **Pragmatic Analysis** – During this, what was said is re-interpreted on what it actually meant. It involves deriving those aspects of language which require real world knowledge.

Implementation Aspects of Syntactic Analysis

There are a number of algorithms researchers have developed for syntactic analysis, but we consider only the following simple methods –

- Context-Free Grammar
- Top-Down Parser

Let us see them in detail –

Context-Free Grammar

A *context-free grammar (CFG)* is a list of rules that define the set of all well-formed sentences in a language. Each rule has a left-hand side, which identifies a syntactic category, and a right-hand side, which defines its alternative component parts, reading from left to right.

It is the grammar that consists rules with a single symbol on the left-hand side of the rewrite rules.

Grammars and parsing

A *sentence* in the language defined by a CFG is a series of words that can be derived by systematically applying the rules, beginning with a rule that has s on its left-hand side. A *parse* of the sentence is a series of rule applications in which a syntactic category is replaced by the right-hand side of a rule that has that category on its left-hand side, and the final rule application yields the sentence itself.

Syntactic categories (common denotations) in NLP

- np - noun phrase
- vp - verb phrase
- tv - transitive verb (takes an object)

- iv - intransitive verb
- s - sentence
- det - determiner (article)
- n - noun
- prep - preposition
- pp - prepositional phrase

adj - adjective

The rule s --> np vp means that "a sentence is defined as a noun phrase followed by a verb phrase."

Let us create grammar to parse a sentence –

"The bird pecks the grains"

S -> NP VP

Noun Phrase (NP) – Article + Noun | Article + Adjective + Noun

= DET N | DET ADJ N

Verb Phrase (VP) – NP V | V NP

Articles (DET) – a | an | the

Nouns – bird | birds | grain | grains

Verbs – pecks | pecking | pecked

CFG

Merit – The simplest style of grammar, therefore widely used one.

Demerits –

- They are not highly precise. For example, "The grains peck the bird", is a syntactically correct according to parser, but even if it makes no sense, parser takes it as a correct sentence.
- To bring out high precision, multiple sets of grammar need to be prepared. It may require a completely different sets of rules for parsing singular and plural variations, passive sentences, etc., which can lead to creation of huge set of rules that are unmanageable.

Parse Down Tree

The parse tree breaks down the sentence into structured parts so that the computer can easily understand and process it. In order for the parsing algorithm to construct this parse tree, a set of rewrite rules, which describe what tree structures are legal, need to be constructed.

Here, the parser starts with the S symbol and attempts to rewrite it into a sequence of *terminal symbols* that matches the classes of the words in the input sentence until it consists entirely of terminal symbols.

These rules say that a certain symbol may be expanded in the tree by a sequence of other symbols. According to first order logic rule, if there are two strings Noun Phrase (NP) and Verb Phrase (VP), then the string combined by NP followed by VP is a sentence. The rewrite rules for the sentence are as follows –

These are then checked with the input sentence to see if it matched. If not, the process is started over again with a different set of rules. This is repeated until a specific rule is found which describes the structure of the sentence.

S → **NP VP**

NP → DET N | DET ADJ N

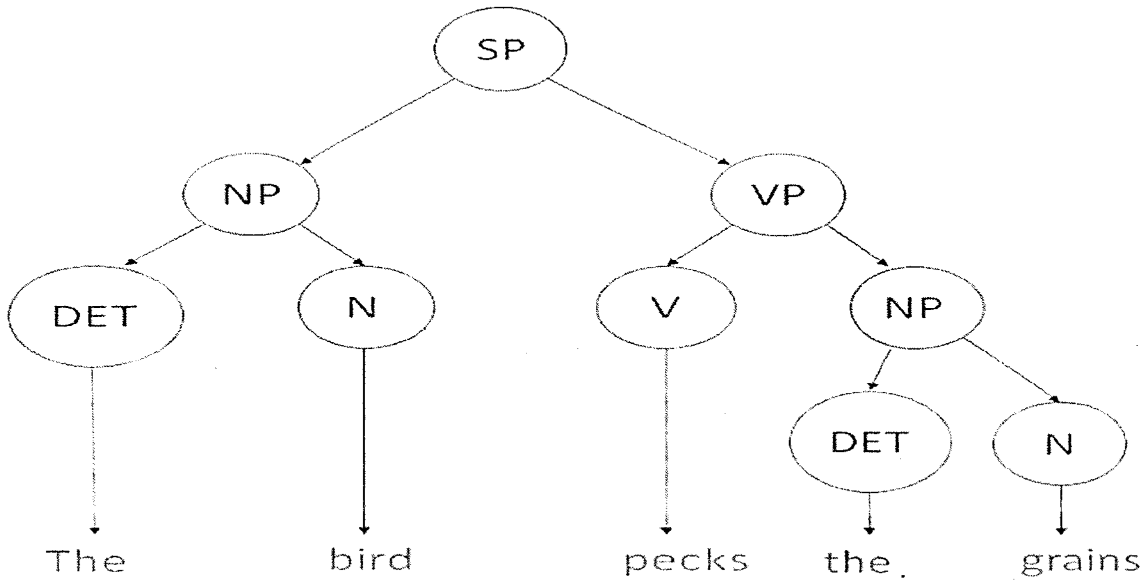
VP → V NP

DET → a | the

N → bird | birds | grain | grains

V → peck | pecks | pecking

The parse tree can be created as shown –



Top-Down Parser

Merit – It is simple to implement.

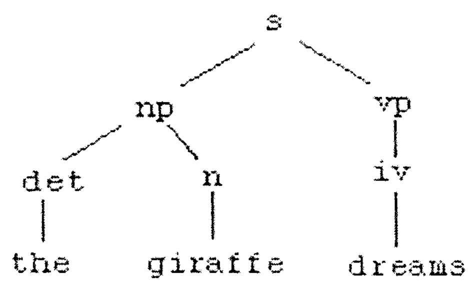
Demerits –

- It is inefficient, as the search process has to be repeated if an error occurs.
- Slow speed of working.

Ex-2 CFG and Parse tree

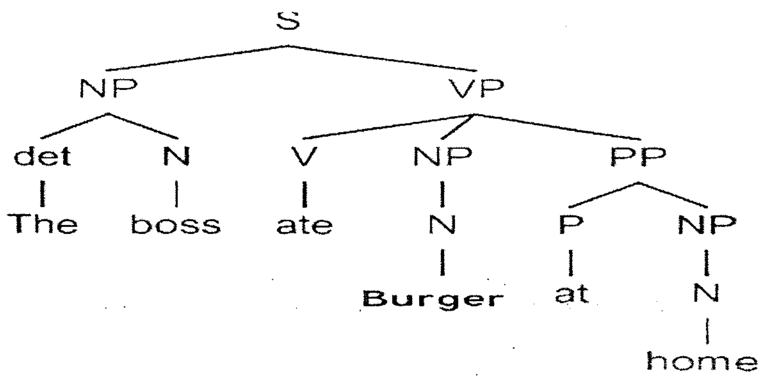
Figure 1. A grammar and a parse tree for "the giraffe dreams".

```
s    --> np vp

np   --> det n
vp   --> tv np
     --> iv

det  --> the
     --> a
     --> an

n    --> giraffe
     --> apple

iv   --> dreams
tv   --> eats
     --> dreams
```



Ex-3: CFG and parse tree for Sentence : " The Boss Ate Burger at Home"

S-> NP VP
NP -> Art Noun
VP -> V NP PP
NP -> Noun
PP-> Prep Noun
Noun -> Boss| Burger| Home
Verb -> ate| eat
Art -> a|an|the
Prep -> at|in



Overview of NLP: Issues and Strategies

Natural Language Processing (NLP) is the capacity of a computer to "understand" natural language text at a level that allows meaningful interaction between the computer and a person working in a particular application domain.

Application Domains of NLP:

- text processing - word processing, e-mail, spelling and grammar checkers
- interfaces to data bases - query languages, information retrieval, data mining, text summarization
- expert systems - explanations, disease diagnosis
- linguistics - machine translation, content analysis, writers' assistants, language generation

Tools for NLP:

- Programming languages and software - Prolog , ALE , Lisp/Scheme, C/C++
- Statistical Methods - Markov models, probabilistic grammars, text-based analysis
- Abstract Models - Context-free grammars (BNF), Attribute grammars, Predicate calculus and other semantic models, Knowledge-based and ontological methods

Subject: ARTIFICIAL INTELLIGENCE code:BCACsT6.11

Chapter-6

Expert Systems

Expert systems (ES) are one of the prominent research domains of AI. It is introduced by the researchers at Stanford University, Computer Science Department.

What are Expert Systems?

The expert systems are the computer applications developed to solve complex problems in a particular domain, at the level of extra-ordinary human intelligence and expertise.

Characteristics of Expert Systems

- High performance
- Understandable
- Reliable
- Highly responsive

Capabilities of Expert Systems

The expert systems are capable of –

- Advising
- Instructing and assisting human in decision making
- Demonstrating
- Deriving a solution
- Diagnosing
- Explaining
- Interpreting input
- Predicting results
- Justifying the conclusion
- Suggesting alternative options to a problem

They are incapable of –

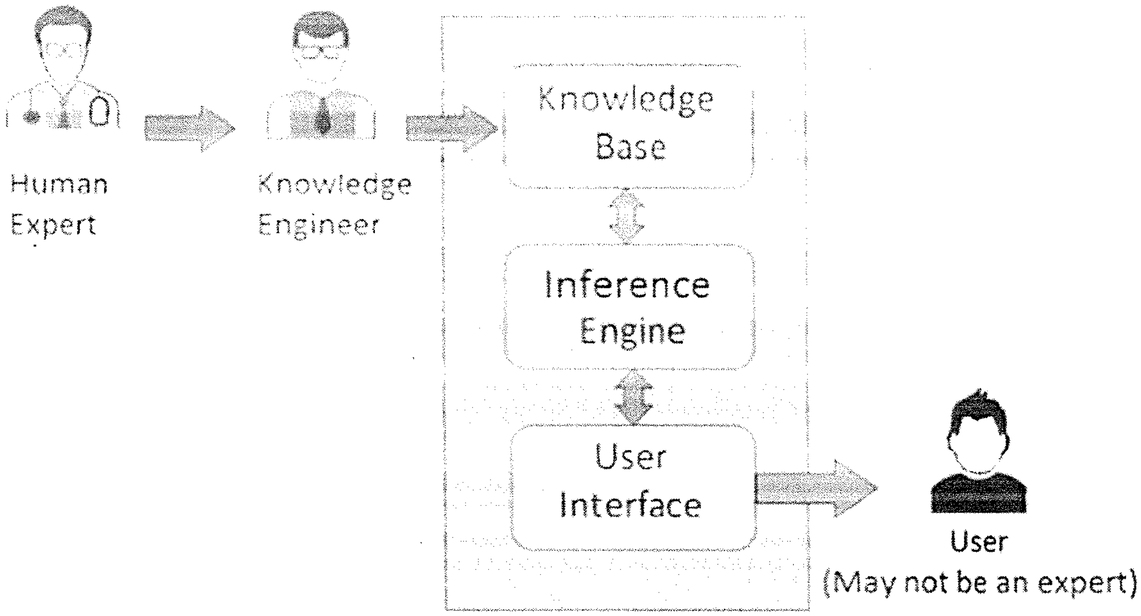
- Substituting human decision makers
- Possessing human capabilities
- Producing accurate output for inadequate knowledge base
- Refining their own knowledge

Components of Expert Systems

The components of ES include –

- Knowledge Base
- Inference Engine
- User Interface

Let us see them one by one briefly –



Knowledge Base

It contains domain-specific and high-quality knowledge.

Knowledge is required to exhibit intelligence. The success of any ES majorly depends upon the collection of highly accurate and precise knowledge.

What is Knowledge?

The data is collection of facts. The information is organized as data and facts about the task domain. **Data, information,** and **past experience** combined together are termed as knowledge.

Components of Knowledge Base

The knowledge base of an ES is a store of both, factual and heuristic knowledge.

- **Factual Knowledge** – It is the information widely accepted by the Knowledge Engineers and scholars in the task domain.
- **Heuristic Knowledge** – It is about practice, accurate judgement, one's ability of evaluation, and guessing.

Knowledge representation

It is the method used to organize and formalize the knowledge in the knowledge base. It is in the form of IF-THEN-ELSE rules.

Knowledge Acquisition

The success of any expert system majorly depends on the quality, completeness, and accuracy of the information stored in the knowledge base.

The knowledge base is formed by readings from various experts, scholars, and the **Knowledge Engineers**. The knowledge engineer is a person with the qualities of empathy, quick learning, and case analyzing skills.

He acquires information from subject expert by recording, interviewing, and observing him at work, etc. He then categorizes and organizes the information in a meaningful way, in the form of IF-THEN-ELSE rules, to be used by interference machine. The knowledge engineer also monitors the development of the ES.

Inference Engine

Use of efficient procedures and rules by the Inference Engine is essential in deducting a correct, flawless solution.

In case of knowledge-based ES, the Inference Engine acquires and manipulates the knowledge from the knowledge base to arrive at a particular solution.

In case of rule based ES, it –

- Applies rules repeatedly to the facts, which are obtained from earlier rule application.
- Adds new knowledge into the knowledge base if required.
- Resolves rules conflict when multiple rules are applicable to a particular case.

To recommend a solution, the Inference Engine uses the following strategies –

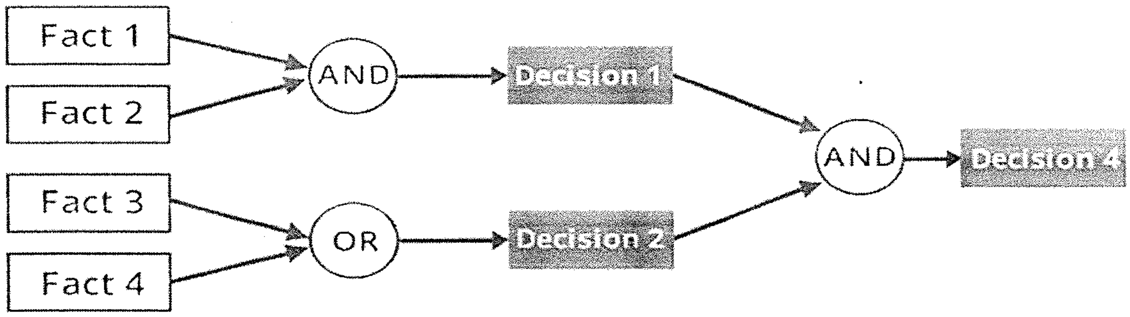
- Forward Chaining
- Backward Chaining

Forward Chaining

It is a strategy of an expert system to answer the question, **"What can happen next?"**

Here, the Inference Engine follows the chain of conditions and derivations and finally deduces the outcome. It considers all the facts and rules, and sorts them before concluding to a solution.

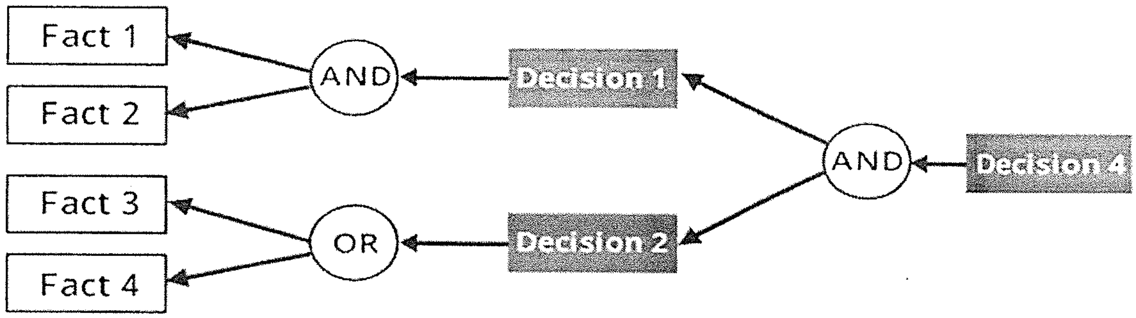
This strategy is followed for working on conclusion, result, or effect. For example, prediction of share market status as an effect of changes in interest rates.



Backward Chaining

With this strategy, an expert system finds out the answer to the question, **"Why this happened?"**

On the basis of what has already happened, the Inference Engine tries to find out which conditions could have happened in the past for this result. This strategy is followed for finding out cause or reason. For example, diagnosis of blood cancer in humans.



User Interface

User interface provides interaction between user of the ES and the ES itself. It is generally Natural Language Processing so as to be used by the user who is well-versed in the task domain. The user of the ES need not be necessarily an expert in Artificial Intelligence.

It explains how the ES has arrived at a particular recommendation. The explanation may appear in the following forms –

- Natural language displayed on screen.
- Verbal narrations in natural language.
- Listing of rule numbers displayed on the screen.

The user interface makes it easy to trace the credibility of the deductions.

Requirements of Efficient ES User Interface

- It should help users to accomplish their goals in shortest possible way.
- It should be designed to work for user's existing or desired work practices.
- Its technology should be adaptable to user's requirements; not the other way round.
- It should make efficient use of user input.

Expert Systems Limitations

No technology can offer easy and complete solution. Large systems are costly, require significant development time, and computer resources. ESs have their limitations which include –

- Limitations of the technology
- Difficult knowledge acquisition
- ES are difficult to maintain
- High development costs

Applications of Expert System

The following table shows where ES can be applied.

Application	Description
Design Domain	Camera lens design, automobile design.
Medical Domain	Diagnosis Systems to deduce cause of disease from observed data, conduction medical operations on humans.
Monitoring Systems	Comparing data continuously with observed system or with prescribed behavior such as leakage monitoring in long petroleum pipeline.
Process Control Systems	Controlling a physical process based on monitoring.
Knowledge Domain	Finding out faults in vehicles, computers.
Finance/Commerce	Detection of possible fraud, suspicious transactions, stock market trading, Airline scheduling, cargo scheduling.

Expert System Technology

There are several levels of ES technologies available. Expert systems technologies include –

- **Expert System Development Environment** – The ES development environment includes hardware and tools. They are –
    - Workstations, minicomputers, mainframes.

- High level Symbolic Programming Languages such as **LISt P**rogramming (LISP) and **PRO**grammation en **LOG**ique (PROLOG).
- Large databases.

- **Tools** – They reduce the effort and cost involved in developing an expert system to large extent.
  - Powerful editors and debugging tools with multi-windows.
  - They provide rapid prototyping
  - Have Inbuilt definitions of model, knowledge representation, and inference design.
- **Shells** – A shell is nothing but an expert system without knowledge base. A shell provides the developers with knowledge acquisition, inference engine, user interface, and explanation facility. For example, few shells are given below –
  - Java Expert System Shell (JESS) that provides fully developed Java API for creating an expert system.
  - *Vidwan*, a shell developed at the National Centre for Software Technology, Mumbai in 1993. It enables knowledge encoding in the form of IF-THEN rules.

Development of Expert Systems: General Steps

The process of ES development is iterative. Steps in developing the ES include –

Identify Problem Domain

- The problem must be suitable for an expert system to solve it.
- Find the experts in task domain for the ES project.
- Establish cost-effectiveness of the system.

Design the System

- Identify the ES Technology
- Know and establish the degree of integration with the other systems and databases.
- Realize how the concepts can represent the domain knowledge best.

Develop the Prototype

From Knowledge Base: The knowledge engineer works to –

- Acquire domain knowledge from the expert.
- Represent it in the form of If-THEN-ELSE rules.

Test and Refine the Prototype

- The knowledge engineer uses sample cases to test the prototype for any deficiencies in performance.
- End users test the prototypes of the ES.

Develop and Complete the ES

- Test and ensure the interaction of the ES with all elements of its environment, including end users, databases, and other information systems.
- Document the ES project well.
- Train the user to use ES.

Maintain the System

- Keep the knowledge base up-to-date by regular review and update.
- Cater for new interfaces with other information systems, as those systems evolve.

Benefits of Expert Systems

- **Availability** – They are easily available due to mass production of software.
- **Less Production Cost** – Production cost is reasonable. This makes them affordable.
- **Speed** – They offer great speed. They reduce the amount of work an individual puts in.
- **Less Error Rate** – Error rate is low as compared to human errors.
- **Reducing Risk** – They can work in the environment dangerous to humans.
- **Steady response** – They work steadily without getting motional, tensed or fatigued.

Subject: ARTIFICIAL INTELLIGENCE code:BCACsT6.11

Chapter-7

Robotics

Robotics is a domain in artificial intelligence that deals with the study of creating intelligent and efficient robots.

What are Robots?

Robots are the artificial agents acting in real world environment.

Objective

Robots are aimed at manipulating the objects by perceiving, picking, moving, modifying the physical properties of object, destroying it, or to have an effect thereby freeing manpower from doing repetitive functions without getting bored, distracted, or exhausted.

What is Robotics?

Robotics is a branch of AI, which is composed of Electrical Engineering, Mechanical Engineering, and Computer Science for designing, construction, and application of robots.

Aspects of Robotics

- The robots have **mechanical construction**, form, or shape designed to accomplish a particular task.
- They have **electrical components** which power and control the machinery.
- They contain some level of **computer program** that determines what, when and how a robot does something.

Difference in Robot System and Other AI Program

Here is the difference between the two –

AI Programs	Robots
They usually operate in computer-stimulated worlds.	They operate in real physical world
The input to an AI program is in symbols and rules.	Inputs to robots is analog signal in the form of speech waveform or images
They need general purpose computers to operate on.	They need special hardware with sensors and effectors.

Robot Locomotion

Locomotion is the mechanism that makes a robot capable of moving in its environment. There are various types of locomotions –

- **Legged**
- **Wheeled**
- **Combination of Legged and Wheeled Locomotion**
- **Tracked slip/skid**

Legged Locomotion

- This type of locomotion consumes more ~~power~~ while demonstrating walk, jump, trot, hop, climb up or down, etc.
- It requires more number of motors to accomplish a movement. It is suited for rough as well as smooth terrain where irregular or too smooth surface makes it consume more power for a wheeled locomotion.. It is little difficult to implement because of stability issues.

- It comes with the variety of one, two, four, and six legs. If a robot has multiple legs then leg coordination is necessary for locomotion.

The total number of possible **gaits** (a periodic sequence of lift and release events for each of the total legs) a robot can travel depends upon the number of its legs.

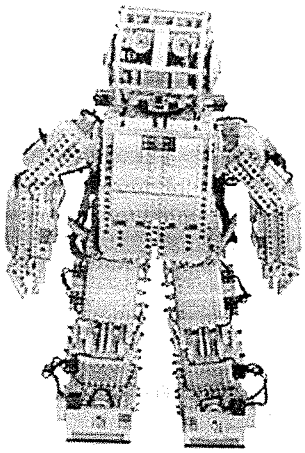
If a robot has k legs, then the number of possible events N = (2k-1)!.

In case of a two-legged robot (k=2), the number of possible events is N = (2k-1)! = (2*2-1)! = 3! = 6.

Hence there are six possible different events –

- Lifting the Left leg
- Releasing the Left leg
- Lifting the Right leg
- Releasing the Right leg
- Lifting both the legs together
- Releasing both the legs together

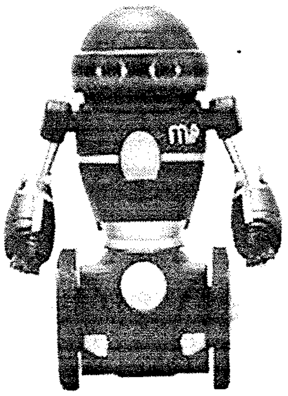
In case of k=6 legs, there are 39916800 possible events. Hence the complexity of robots is directly proportional to the number of legs.



Wheeled Locomotion

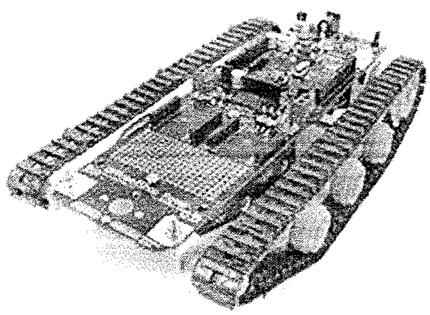
It requires fewer number of motors to accomplish a movement. It is little easy to implement as there are less stability issues in case of more number of wheels. It is power efficient as compared to legged locomotion.

- **Standard wheel** – Rotates around the wheel axle and around the contact
- **Castor wheel** – Rotates around the wheel axle and the offset steering joint.
- **Swedish 45^0 and Swedish 90^0 wheels** – Omni-wheel, rotates around the contact point, around the wheel axle, and around the rollers.
- **Ball or spherical wheel** – Omnidirectional wheel, technically difficult to implement.



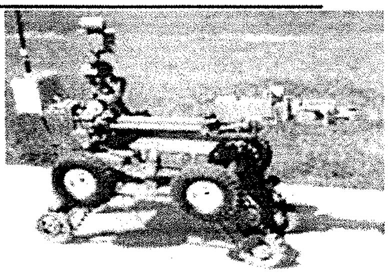
Slip/Skid Locomotion

In this type, the vehicles use tracks as in a tank. The robot is steered by moving the tracks with different speeds in the same or opposite direction. It offers stability because of large contact area of track and ground.

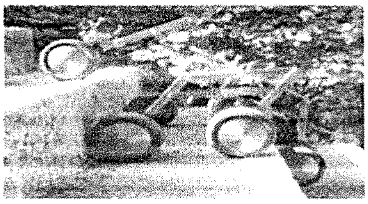


LEG-WHEEL HYBRID ROBOTS

- • The *Mini-Andros* is used
- by bomb squads across
- the country to locate and
- dispose of bombs. About
- three feet long, the *Mini-*
- *Andros* looks something
- like a small armoured
- tank with eight wheels on
- four "legs" that extend
- for climbing stairs.



- *Mini-Andros*



Shrimp (EPFL)

What is a Robot Architecture?

- There are many different ways in which a robot control program can be put together. In order to program a robot in a structured and principled fashion, we use an appropriate robot control architecture.

- System developers have typically relied upon robotic architectures **to guide the construction of robotic devices** and for providing computational services (e.g., communications, processing, etc.) **to subsystems and components.**

- A **control architecture** provides a set of principles for **organizing a control system**.
  - It provides structure and constraints which aid the designer in producing a well-behaved controller.
- To be successful a system designer has to decide how (in what order? with what priority?) does he put together multiple feedback controllers in a principled fashion and how to ***scale up*** control to more complex robots, which generally have to deal with many behaviors at once.
  - *How would you put multiple feedback controllers together?*
  - *How would you decide which one to use when and for how long and in what priority relative to the others?*

Robot Architecture Major Classes/Categories

Intuitively, this means that there are infinitely many ways to structure a robot program, but they all fall into one of **major classes/categories of control:**

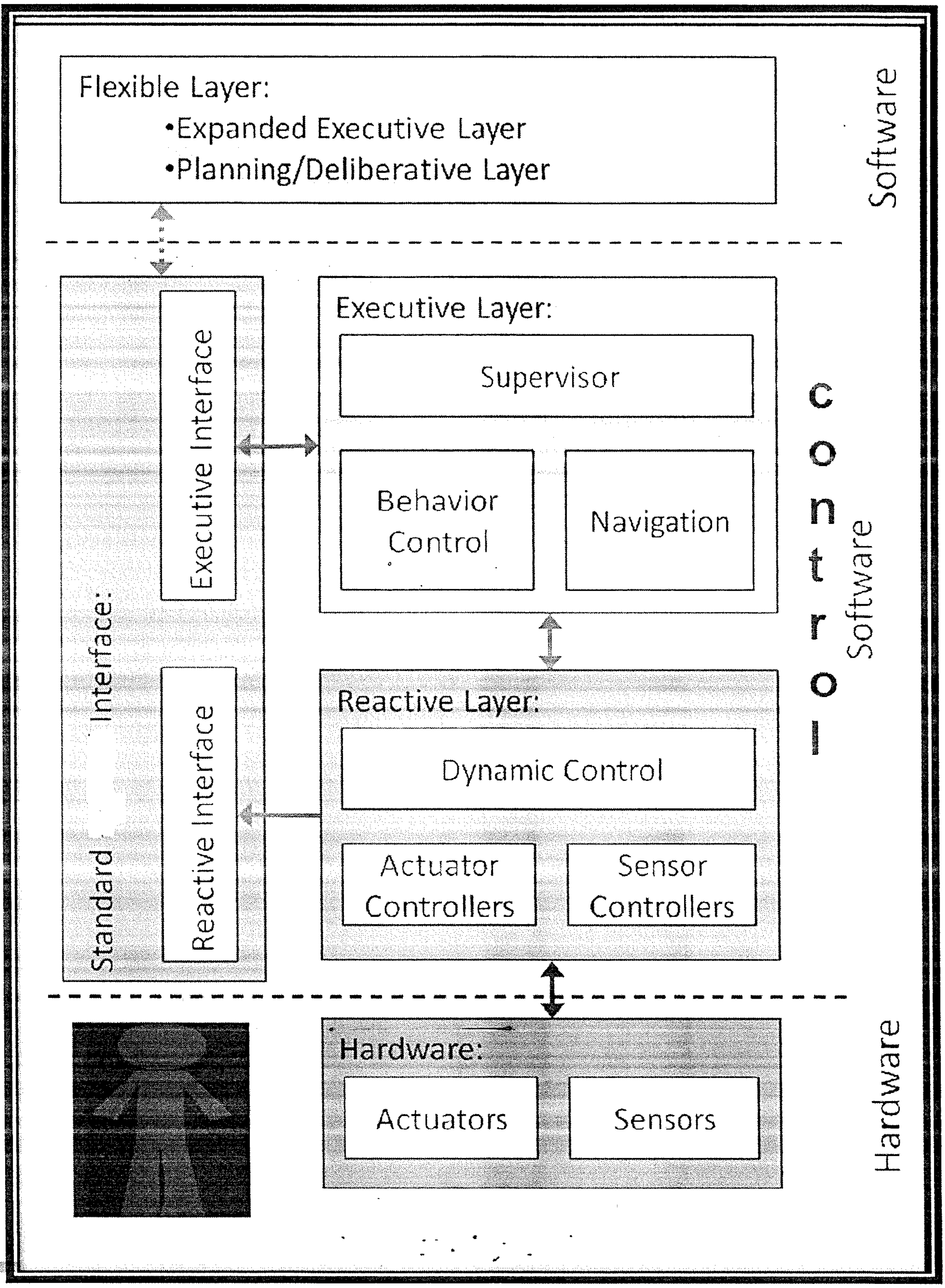
- **Deliberative Control** : Think hard, act later.
  - SPA, serial, complete each step first – then proceed
- **Reactive Control** : Don't think, (re)act.
  - Direct connection between perception to action, no memory, no planning.
- **Hybrid Control** : Think and act independently, in parallel.
  - Deliberative and Reactive modules run independently at different time scales
- **Behavior-Based Control** : Think the way you act.
  - Distributed by behavioral task decomposition
  - Each behavior has its restricted planning and execution capabilities

The Choice of the Control Architecture

- In many cases, it is impossible to tell, just by observing a robot's behavior, what control architecture it is using. Only for simple robots, it is often the case.
- However, **when it comes to more complex robots**, i.e., robots that have to deal with complex environments and complex tasks, the control architecture becomes very important.
- The different properties of an environment that will impact the robot's controller (and therefore the choice of control **architecture**):
  - noisy,
  - speed/response time of sensors and effectors
  - total/partial hidden state/ observable
  - discrete v. continuous state : static v. dynamic ...
- Similarly, the properties of the robot's task impact the choice of the control architecture. The task requirements can constrain the architecture choice.

Architecture of Robot

- Most popular hybrid architecture
  - Reactive layer (low-level control, milliseconds)
  - Executive layer:
    - Selects which reactive control to invoke
    - Following points proposed by deliberative ctrl
  - Deliberative layer (planning, minutes/cycle)
- Other possible layers
  - User Interface Layer
  - Inter-robot interface


Flexible Layer:
•Expanded Executive Layer
•Planning/Deliberative Layer
Software
Standard Interface:
Executive Interface
Reactive Interface
Executive Layer:
Supervisor
Behavior Control
Navigation
Reactive Layer:
Dynamic Control
Actuator Controllers
Sensor Controllers
control
Software
Hardware:
Actuators
Sensors
Hardware

most popular hybrid architecture of robot is mainly divided into three layers

- Hardware
- Control Architecture
- Software

and other possible layers are

- User Inter face layer
- Inter Robot Interface

Hardware: It mainly consists of physical componentsto percieve inputs and perform actions with ie ,Sensors , Actuators effectors.

Control Architecture: It has 2 sub layers

Reactive layer

The lower level control of the robot which controls and monitors the Sensor and Actuator signals.

Executive layer

It supervises all the control mechanisms, selects which reactive control to invoke following the points proposed by deliberative control.

Software:

it is also called as flexible layer, does complete planning scheduling with predefined programs .

interface

User Inter face layer(interaction between user and a robot)

Inter Robot Interface(interaction between the different layers of robot)

Components of a Robot

- **1. Manipulator or Rover: Main Body of robot** (Links, Joints, other structural element of the robot)
- **2. End Effecter:** The part that is connected to the last joint hand) of a manipulator.
- **3. Actuators:** Muscles of the manipulators (servomotor, stepper motor, pneumatic and hydraulic cylinder).
- **4. Sensors:** To collect information about the internal state of the robot or To communicate with the outside environment.

Robots are constructed with the following –

- **Power Supply** – The robots are powered by batteries, solar power, hydraulic, or pneumatic power sources.
- **Actuators** – They convert energy into movement.
- **Electric motors (AC/DC)** – They are required for rotational movement.
- **Pneumatic Air Muscles** – They contract almost 40% when air is sucked in them.
- **Muscle Wires** – They contract by 5% when electric current is passed through them.
- **Piezo Motors and Ultrasonic Motors** – Best for industrial robots.
- **Sensors** – They provide knowledge of real time information on the task environment. Robots are equipped with vision sensors to be to compute the depth in the environment. A tactile sensor imitates the mechanical properties of touch receptors of human fingertips.

Computer Vision

This is a technology of AI with which the robots can see. The computer vision plays vital role in the domains of safety, security, health, access, and entertainment.

Computer vision automatically extracts, analyzes, and comprehends useful information from a single image or an array of images. This process involves development of algorithms to accomplish automatic visual comprehension.

Hardware of Computer Vision System

This involves –

- Power supply
- Image acquisition device such as camera
- A processor
- A software
- A display device for monitoring the system
- Accessories such as camera stands, cables, and connectors

Tasks of Computer Vision

- **OCR** – In the domain of computers, Optical Character Reader, a software to convert scanned documents into editable text, which accompanies a scanner.
- **Face Detection** – Many state-of-the-art cameras come with this feature, which enables to read the face and take the picture of that perfect expression. It is used to let a user access the software on correct match.
- **Object Recognition** – They are installed in supermarkets, cameras, high-end cars such as BMW, GM, and Volvo.
- **Estimating Position** – It is estimating position of an object with respect to camera as in position of tumor in human's body.

Application Domains of Computer Vision

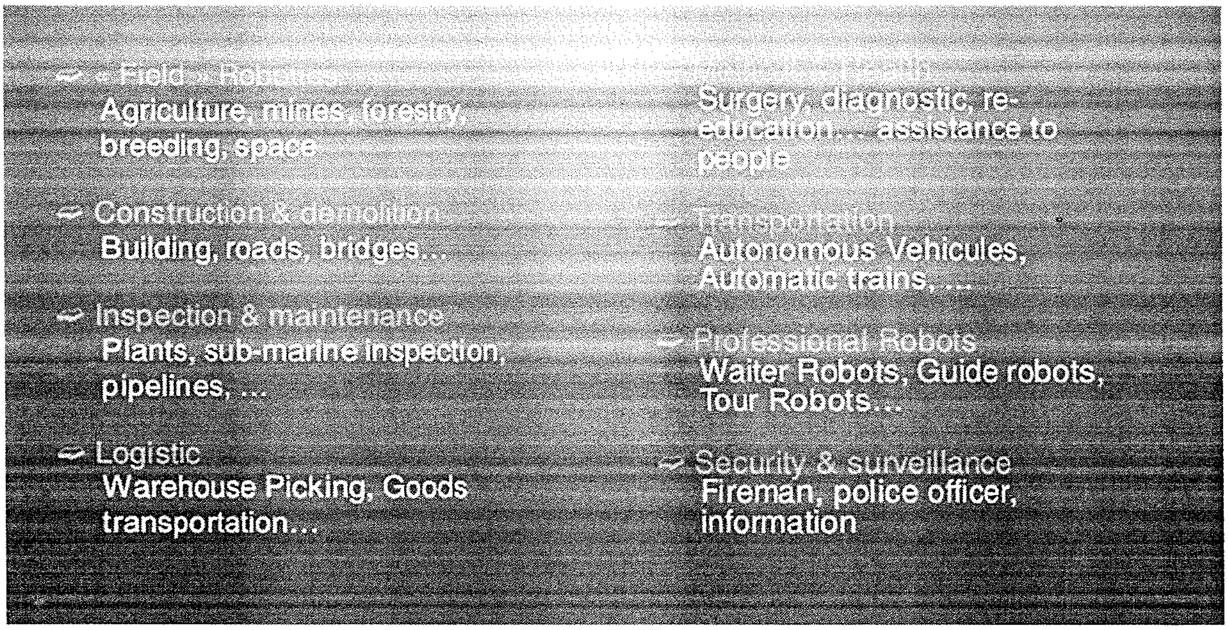
- Agriculture
- Autonomous vehicles
- Biometrics
- Character recognition
- Forensics, security, and surveillance
- Industrial quality inspection
- Face recognition.
- Gesture analysis
- Geoscience
- Medical imagery
- Pollution monitoring
- Process control
- Remote sensing
- Robotics
- Transport

Applications of Robotics

The robotics has been instrumental in the various domains such as –

- **Industries** – Robots are used for handling material, cutting, welding, color coating, drilling, polishing, etc.
- **Military** – Autonomous robots can reach inaccessible and hazardous zones during war. A robot named *Daksh*, developed by Defense Research and Development Organization (DRDO), is in function to destroy life-threatening objects safely.
- **Medicine** – The robots are capable of carrying out hundreds of clinical tests simultaneously, rehabilitating permanently disabled people, and performing complex surgeries such as brain tumors.
- **Exploration** – The robot rock climbers used for space exploration, underwater drones used for ocean exploration are to name a few.
- **Entertainment** – Disney's engineers have created hundreds of robots for movie making.

Professional Service Robots



Subject: ARTIFICIAL INTELLIGENCE code:BCACsT6.11

Chapter-8

Neural Networks

Yet another research area in AI, neural networks, is inspired from the natural neural network of human nervous system.

What are Artificial Neural Networks (ANNs)?

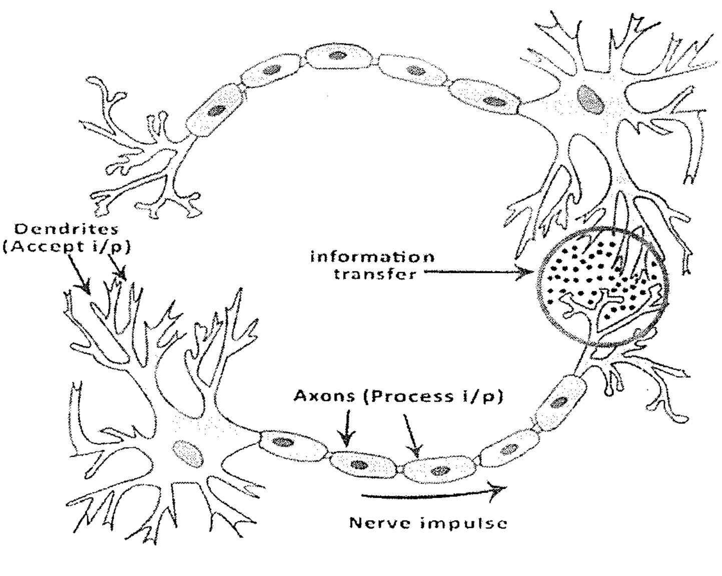
The inventor of the first neuro computer, **Dr. Robert Hecht-Nielsen,** defines a neural network as –

"...a computing system made up of a number of simple, highly interconnected processing elements, which process information by their dynamic state response to external inputs."

Basic Structure of Neural Networks

The idea of ANNs is based on the belief that working of human brain by making the right connections, can be imitated using silicon and wires as living **neurons** and **dendrites**.

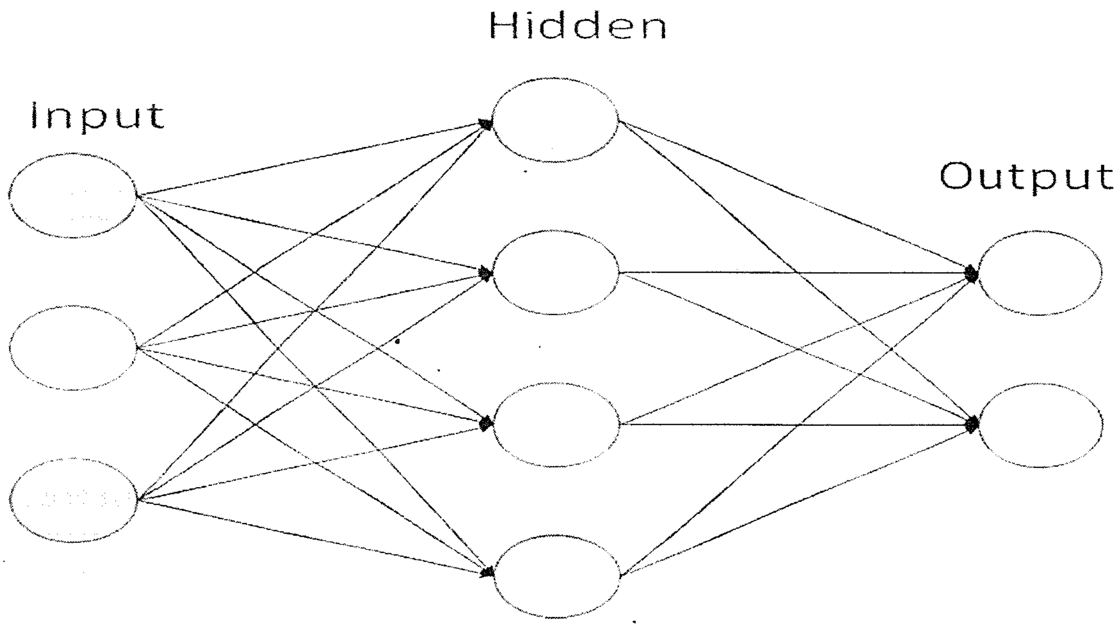
The human brain is composed of 86 billion nerve cells called **neurons.** They are connected to other thousand cells by **Axons.** Stimuli from external environment or inputs from sensory organs are accepted by dendrites. These inputs create electric impulses, which quickly travel through the neural network. A neuron can then send the message to other neuron to handle the issue or does not send it forward.

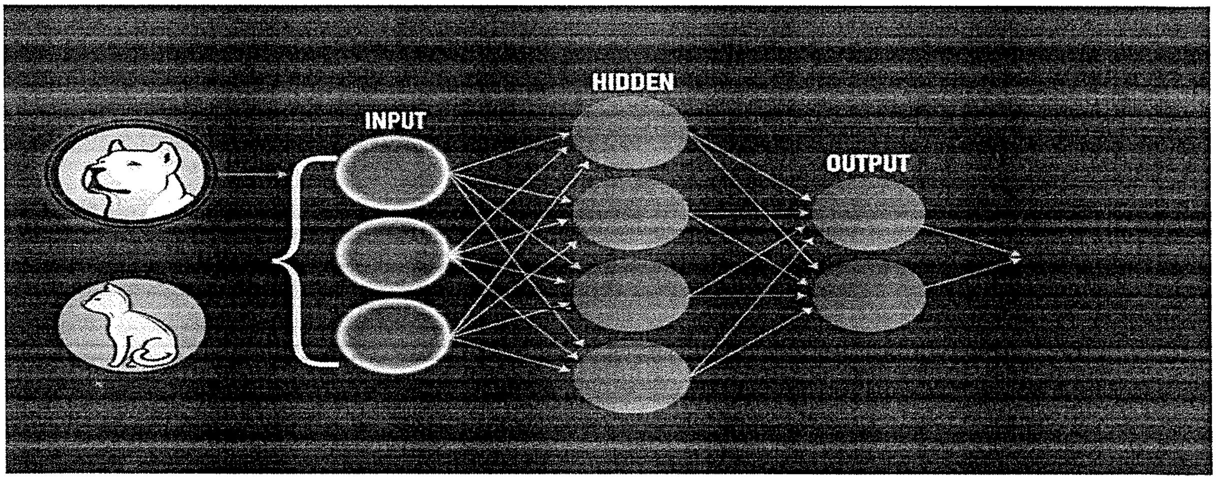


Artificial Neural Network

ANNs are composed of multiple **nodes**, which imitate biological **neurons** of human brain. The neurons are connected by links and they interact with each other. The nodes can take input data and perform simple operations on the data. The result of these operations is passed to other neurons. The output at each node is called its **activation** or **node value.**

Each link is associated with **weight.** ANNs are capable of learning, which takes place by altering weight values. The following illustration shows a simple ANN –



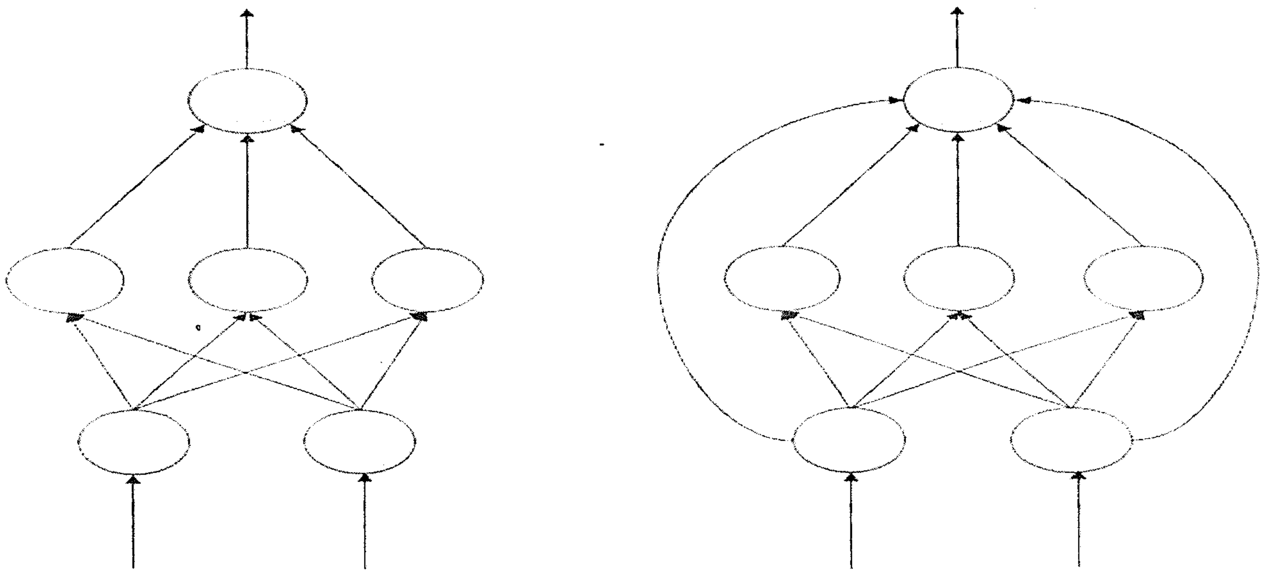


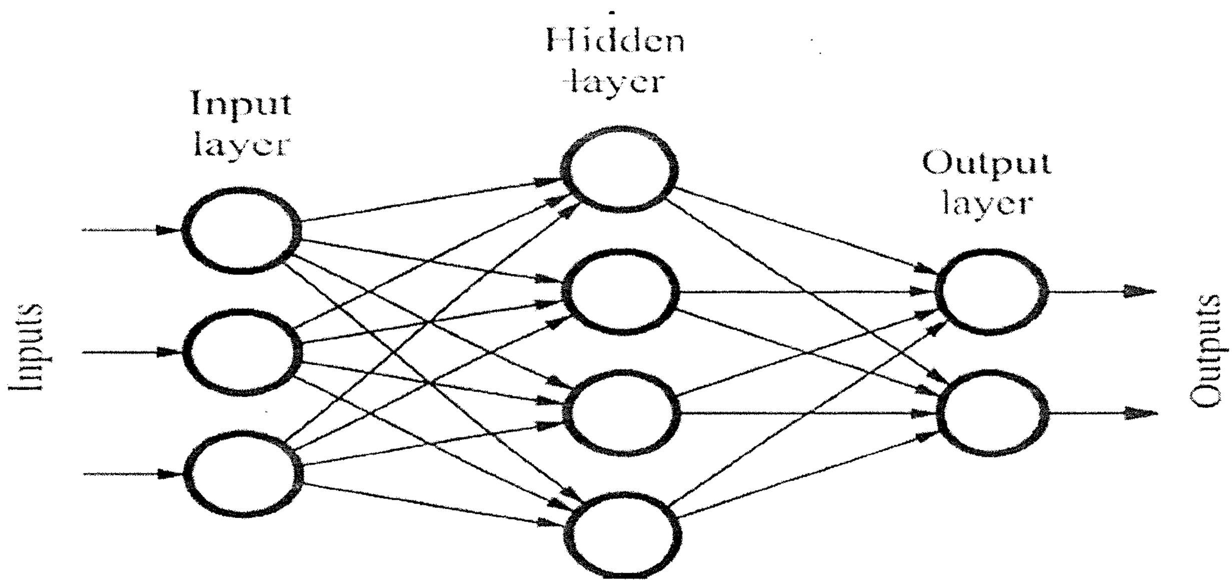
Types of Artificial Neural Networks

There are two Artificial Neural Network topologies – **FeedForward** and **Feedback.**

FeedForward ANN

In this ANN, the information flow is unidirectional. A unit sends information to other unit from which it does not receive any information. There are no feedback loops. They are used in pattern generation/recognition/classification. They have fixed inputs and outputs. In feed forward networks, inputs are fed to the network and transformed into an output. That is when we feed examples, then labels are output.

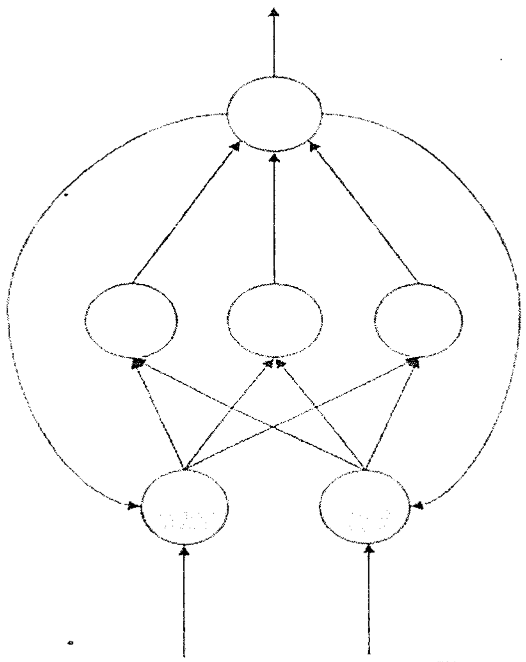


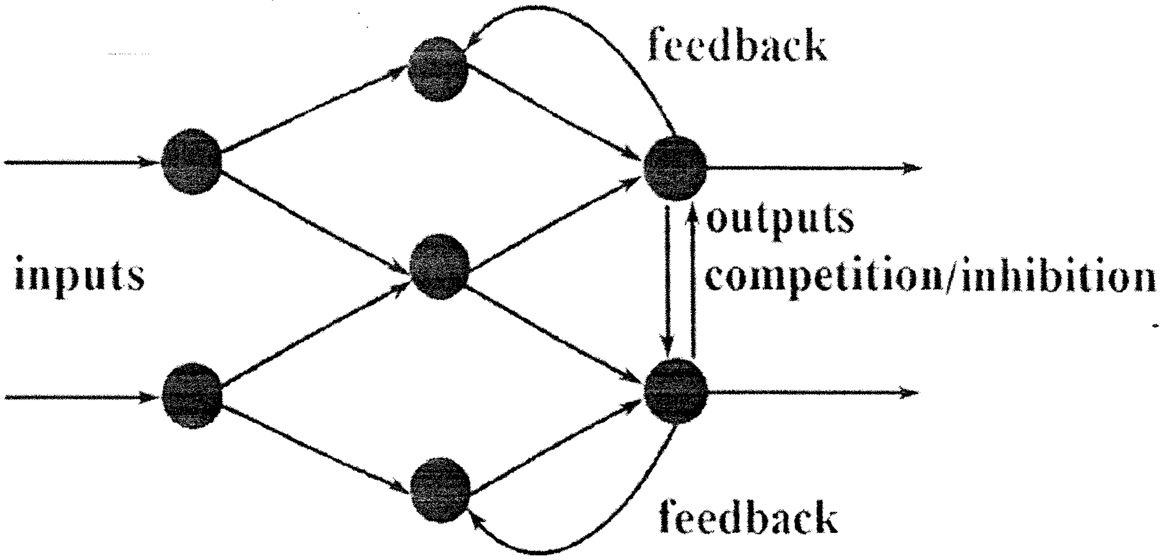


FeedBack ANN

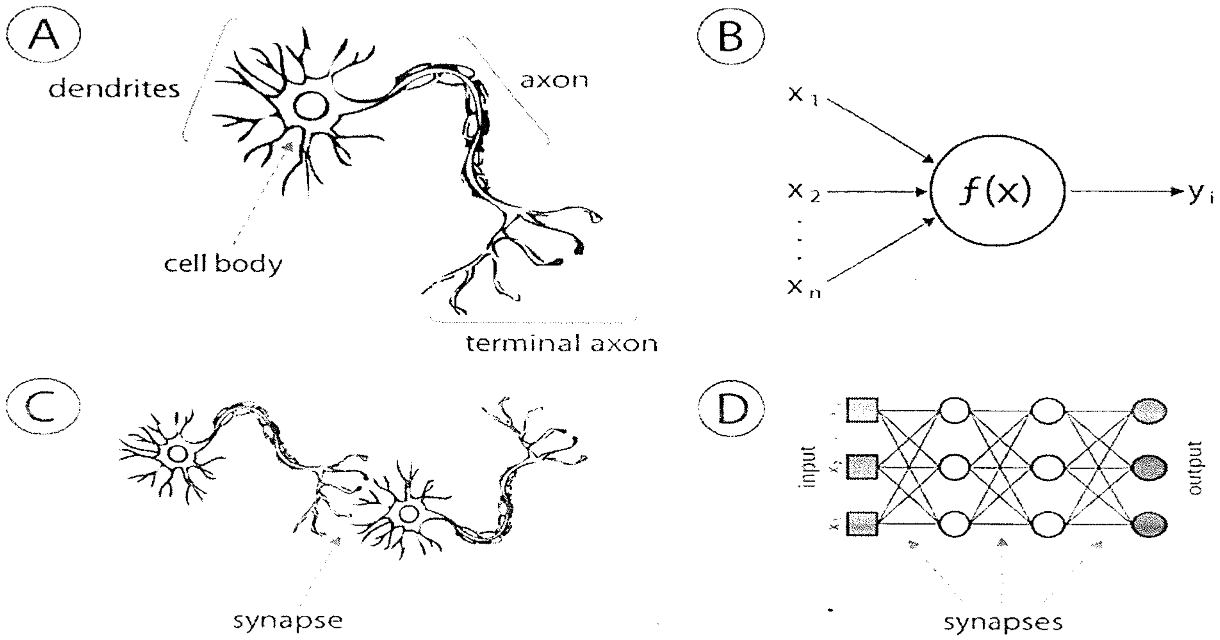
feedback neural networks, or recurrent neural networks, do contain cycles. The feedback cycles can represent an internal state for the network that can cause the network's behavior to change over time based on its input.

Here, feedback loops are allowed. They are used in content addressable memories.





Working of ANNs



In the topology diagrams shown, each arrow represents a connection between two neurons and indicates the pathway for the flow of information. Each connection has a weight, an integer number that controls the signal between the two neurons.

If the network generates a "good or desired" output, there is no need to adjust the weights. However, if the network generates a "poor or undesired" output or an error, then the system alters the weights in order to improve subsequent results.

Difference between Biological neural network and Artificial Neural Network

Biological Neural Networks	Artificial Neural Networks
Stimulus	Input
Receptors	Input Layer
Neural Net	Processing Layer(s)
Neuron	Processing Element
Effectors	Output Layer
Response	Output and an entry

Machine Learning in ANNs

ANNs are capable of learning and they need to be trained. There are several learning strategies –

Supervised Learning – It involves a teacher that is scholar than the ANN itself. For example, the teacher feeds some example data about which the teacher already knows the answers.

- **The majority of practical machine learning uses supervised learning. Supervised learning is where you have input variables (x) and an output variable (Y) and you use an algorithm to learn the mapping function from the input to the output. Y = f(X)The goal is to approximate the mapping function so well that when you have new input data (x) that you can predict the output variables (Y) for that data.**
- It is called supervised learning because the process of an algorithm learning from the training dataset can be thought of as a teacher supervising the learning process.
- Supervised learning problems can be further grouped into **classification** and **outlier analysis.**
- Supervised learning is more commonly used in applications where historical data predict future events, such as fraudulent credit card transactions, diagnosing diseases etc

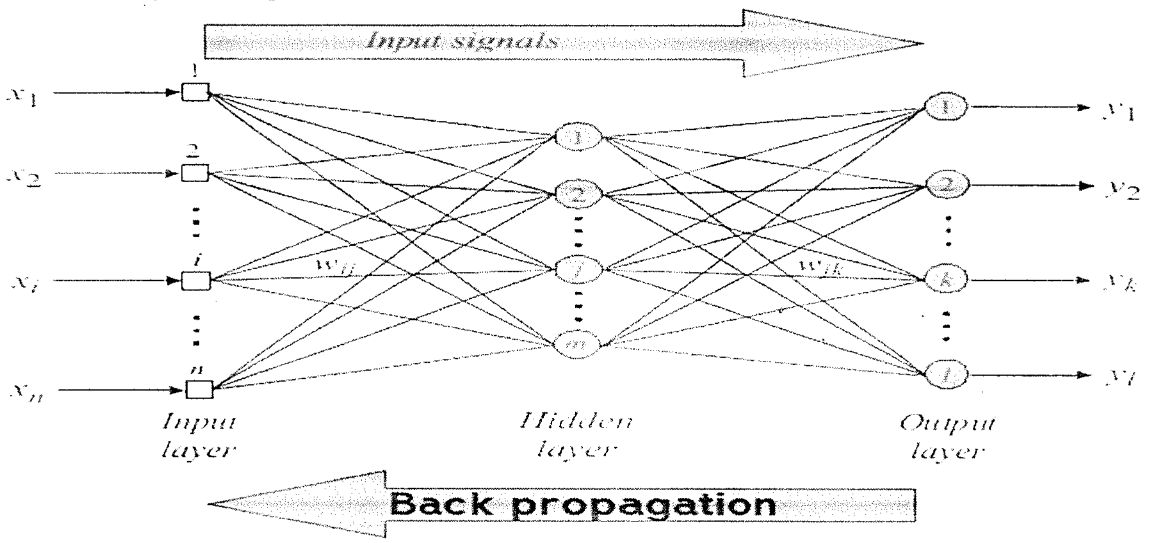
Unsupervised Learning – It is required when there is no example data set with known answers. For example, searching for a hidden pattern. In this case, clustering i.e. dividing a set of elements into groups according to some unknown pattern is carried out based on the existing data sets present.

- **Unsupervised learning is where you only have input data (X) and no corresponding output variables. The goal for unsupervised learning is to model the underlying structure or distribution in the data in order to learn more about the data.**
- These are called unsupervised learning because unlike supervised learning above there is no correct answers and there is no teacher. Algorithms are left to their own devises to discover and present the interesting structure in the data.
- Unsupervised learning problems can be further grouped **into clustering** and **association** problems.

- Unsupervised learning is more commonly used in applications Basically to associate products, online recommendations, identification of data outliers, and segments, topics etc.

Reinforcement Learning – This strategy built on observation. The ANN makes a decision by observing its environment. If the observation is negative, the network adjusts its weights to be able to make a different required decision the next time.

Back Propagation Algorithm



It is the training or learning algorithm. It learns by example. If you submit to the algorithm the example of what you want the network to do, it changes the network's weights so that it can produce desired output for a particular input on finishing the training.

- **During learning phase, the network learns by adjusting weights so as to able to predict the correct class label of the input tuples. During classification** desired outputs are compared to achieve system outputs, and then ~~the systems~~ are tuned by adjusting connection ie, **for the expected class label the weights are updated with the connections backwards from output to input, hence the name back propagation.**
- Back Propagation networks are ideal for simple Pattern Recognition and Mapping Tasks.

- Neural networks have been used in many business applications for pattern recognition (radar systems, face identification, object recognition and more), forecasting, prediction, and classification.

Bayesian Networks (BN)

These are the graphical structures used to represent the probabilistic relationship among a set of random variables. Bayesian networks are also called **Belief Networks** or **Bayes Nets.** BNs reason about uncertain domain.

In these networks, each node represents a random variable with specific propositions. For example, in a medical diagnosis domain, the node Cancer represents the proposition that a patient has cancer.

The edges connecting the nodes represent probabilistic dependencies among those random variables. If out of two nodes, one is affecting the other then they must be directly connected in the directions of the effect. The strength of the relationship between variables is quantified by the probability associated with each node.

There is an only constraint on the arcs in a BN that you cannot return to a node simply by following directed arcs. Hence the BNs are called Directed Acyclic Graphs (DAGs).

BNs are capable of handling multivalued variables simultaneously. The BN variables are composed of two dimensions –

- Range of prepositions
- Probability assigned to each of the prepositions.

Consider a finite set $X = \{X_1, X_2, \ldots, X_n\}$ of discrete random variables, where each variable X_i may take values from a finite set, denoted by $Val(X_i)$. If there is a directed link from variable X_i to variable, X_j, then variable X_i will be a parent of variable X_j showing direct dependencies between the variables.

The structure of BN is ideal for combining prior knowledge and observed data. BN can be used to learn the causal relationships and understand various problem domains and to predict future events, even in case of missing data.

Building a Bayesian Network

A knowledge engineer can build a Bayesian network. There are a number of steps the knowledge engineer needs to take while building it.

Steps in building a Bayesian network

- **Gather Relevant Information of Problem**
- **Identify Interesting Variables**
- The knowledge engineer tries to answer the questions –

Which nodes to represent?

What values can they take? In which state can they be?

- **Common types of discrete nodes are** –
- **Boolean nodes** – They represent propositions, taking binary values TRUE (T) and FALSE (F).
- **Ordered values** – A node *Pollution* might represent and take values from {low, medium, high} describing degree of a patient's exposure to pollution.
- **Integral values** – A node called *Age* might represent patient's age with possible values from 1 to 120. Even at this early stage, modeling choices are being made.
- **Create arcs between nodes**
- **Conditional Probabilities**
- **Joint probability**

Example problem – *Lung cancer.* A patient has been suffering from breathlessness. He visits the doctor, suspecting he has lung cancer. The doctor knows that barring lung cancer, there are various other possible diseases the patient might have such as tuberculosis and bronchitis.

Gather Relevant Information of Problem

- Is the patient a smoker? If yes, then high chances of cancer and bronchitis.
- Is the patient exposed to air pollution? If yes, what sort of air pollution?
- Take an X-Ray positive X-ray would indicate either TB or lung cancer.

Identify Interesting Variables

The knowledge engineer tries to answer the questions –

- Which nodes to represent?
- What values can they take? In which state can they be?

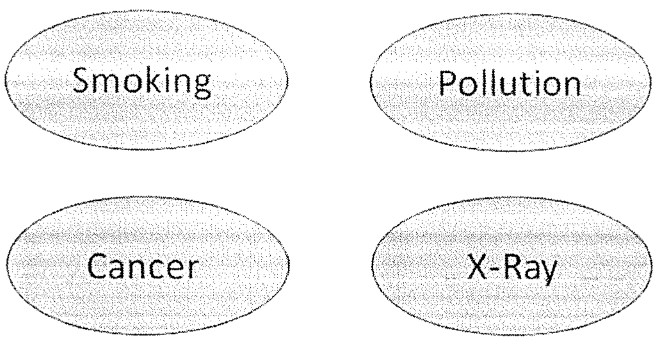
For now let us consider nodes, with only discrete values. The variable must take on exactly one of these values at a time.

Common types of discrete nodes are –

- **Boolean nodes** – They represent propositions, taking binary values TRUE (T) and FALSE (F).
- **Ordered values** – A node *Pollution* might represent and take values from {low, medium, high} describing degree of a patient's exposure to pollution.
- **Integral values** – A node called *Age* might represent patient's age with possible values from 1 to 120. Even at this early stage, modeling choices are being made.

Possible nodes and values for the lung cancer example –

Node Name	Type	Value	Nodes Creation
Polution	Binary	{LOW, HIGH, MEDIUM}	
Smoker	Boolean	{TRUE, FASLE}	
Lung-Cancer	Boolean	{TRUE, FASLE}	
X-Ray	Binary	{Positive, Negative}	

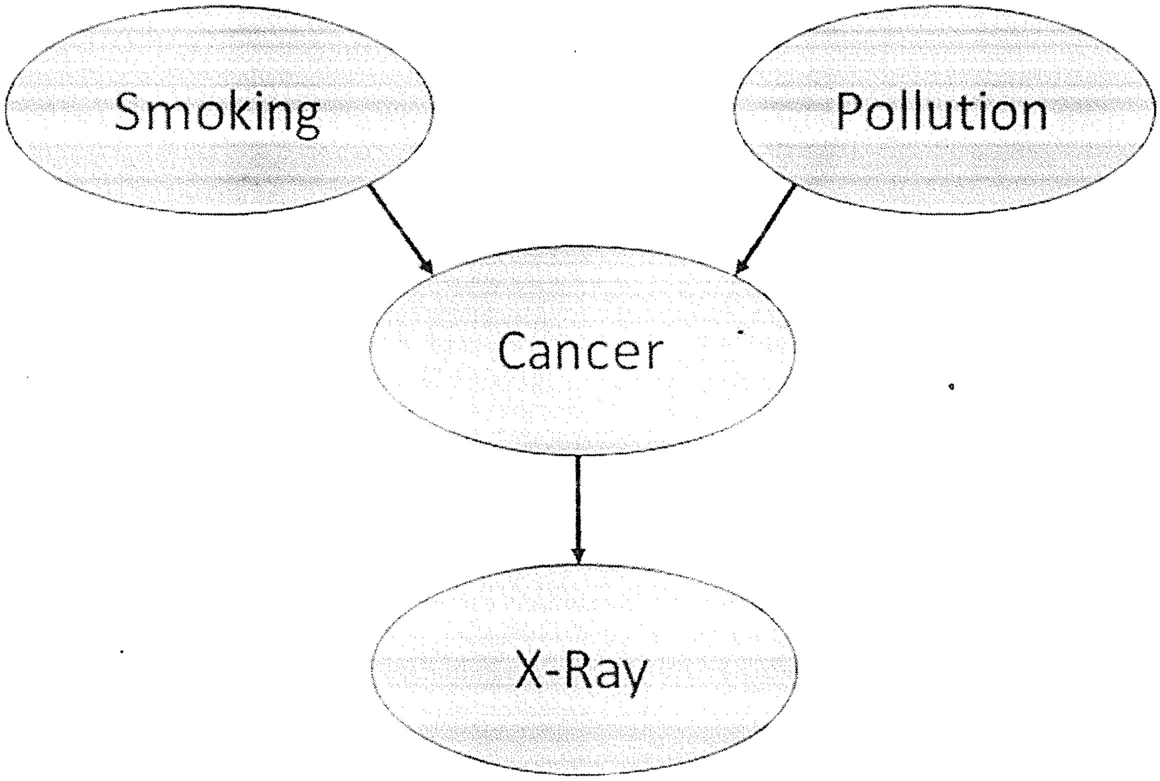


Create Arcs between Nodes

Topology of the network should capture qualitative relationships between variables.

For example, what causes a patient to have lung cancer? - Pollution and smoking. Then add arcs from node *Pollution* and node *Smoker* to node *Lung-Cancer*.

Similarly if patient has lung cancer, then X-ray result will be positive. Then add arcs from node *Lung-Cancer* to node *X-Ray*.



Specify Topology

Conventionally, BNs are laid out so that the arcs point from top to bottom. The set of parent nodes of a node X is given by Parents(X).

The *Lung-Cancer* node has two parents (reasons or causes): *Pollution* and *Smoker*, while node *Smoker* is an **ancestor** of node *X-Ray*. Similarly, *X-Ray* is a child (consequence or effects) of node *Lung-Cancer* and **successor** of nodes *Smoker* and *Pollution*.

Conditional Probabilities

Now quantify the relationships between connected nodes: this is done by specifying a conditional probability distribution for each node. As only discrete variables are considered here, this takes the form of a **Conditional Probability Table (CPT).**

First, for each node we need to look at all the possible combinations of values of those parent nodes. Each such combination is called an **instantiation** of the parent set. For each distinct instantiation of parent node values, we need to specify the probability that the child will take.

For example, the *Lung-Cancer* node's parents are *Pollution* and *Smoking*. They take the possible values = { (H,T), (H,F), (L,T), (L,F)}. The CPT specifies the probability of cancer for each of these cases as <0.05, 0.02, 0.03, 0.001> respectively.

Each node will have conditional probability associated as follows –

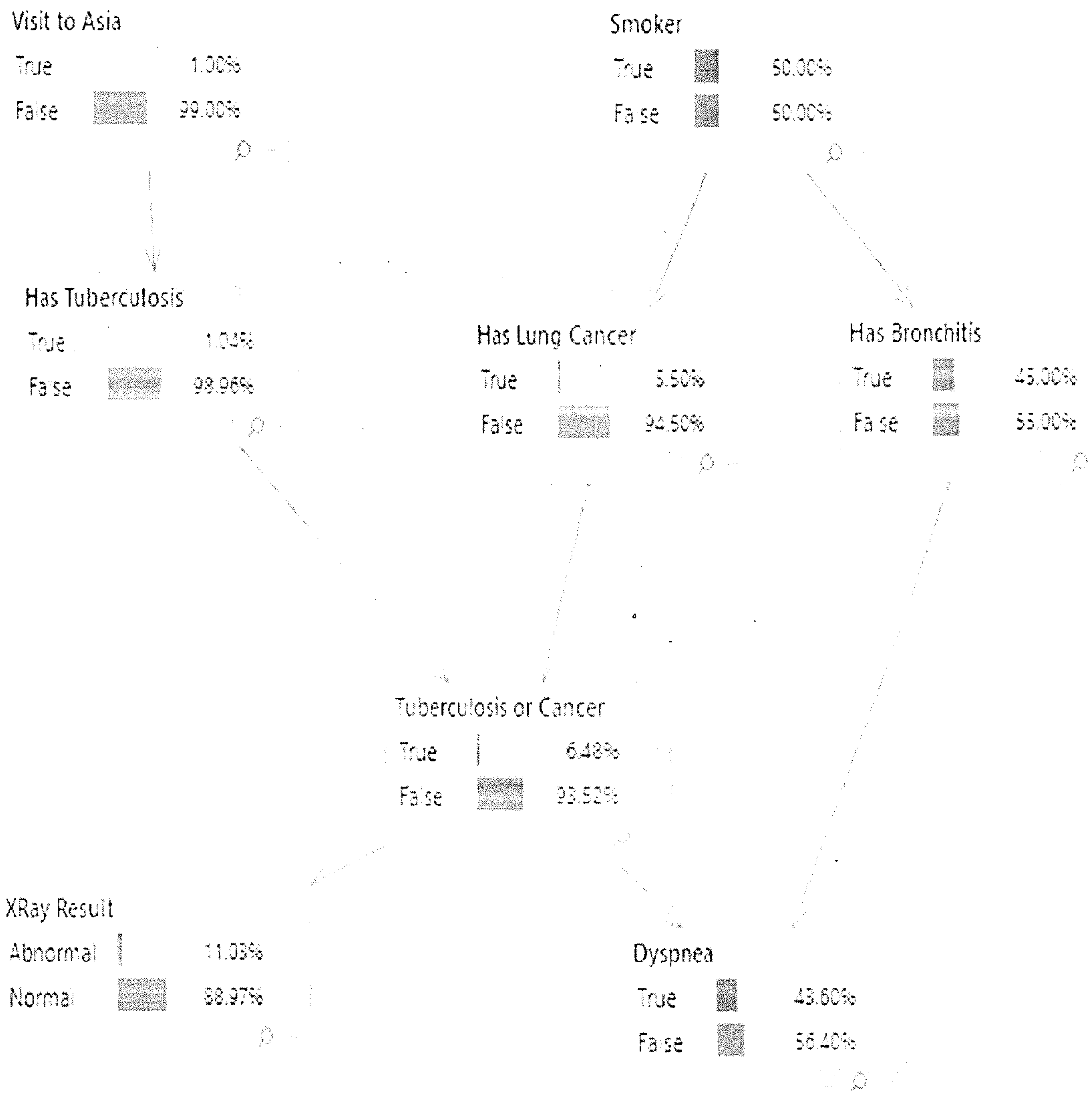
Smoking
P(S = T)
0.30

Pollution
P(P = L)
0.90

Lung-Cancer		
P	S	P (C = T | P, S)
H	T	0.05
H	F	0.02
L	T	0.03
L	F	0.001

X-Ray	
C	X = (Pos | C)
T	0.90
F	0.20

Visualization of Bayesian network


Visit to Asia
True 1.00%
False 99.00%
Smoker
True 50.00%
False 50.00%
Has Tuberculosis
True 1.04%
False 98.96%
Has Lung Cancer
True 5.50%
False 94.50%
Has Bronchitis
True 45.00%
False 55.00%
Tuberculosis or Cancer
True 6.48%
False 93.52%
XRay Result
Abnormal 11.03%
Normal 88.97%
Dyspnea
True 43.60%
False 56.40%

Applications of Neural Networks

They can perform tasks that are easy for a human but difficult for a machine –

- **Aerospace** – Autopilot aircrafts, aircraft fault detection.
- **Automotive** – Automobile guidance systems.
- **Military** – Weapon orientation and steering, target tracking, object discrimination, facial recognition, signal/image identification.
- **Electronics** – Code sequence prediction, IC chip layout, chip failure analysis, machine vision, voice synthesis.
- **Financial** – Real estate appraisal, loan advisor, mortgage screening, corporate bond rating, portfolio trading program, corporate financial analysis, currency value prediction, document readers, credit application evaluators.
- **Industrial** – Manufacturing process control, product design and analysis, quality inspection systems, welding quality analysis, paper quality prediction, chemical product design analysis, dynamic modeling of chemical process systems, machine maintenance analysis, project bidding, planning, and management.
- **Medical** – Cancer cell analysis, EEG and ECG analysis, prosthetic design, transplant time optimizer.
- **Speech** – Speech recognition, speech classification, text to speech conversion.
- **Telecommunications** – Image and data compression, automated information services, real-time spoken language translation.
- **Transportation** – Truck Brake system diagnosis, vehicle scheduling, routing systems.
- **Software** – Pattern Recognition in facial recognition, optical character recognition, etc.
- **Time Series Prediction** – ANNs are used to make predictions on stocks and natural calamities.
- **Signal Processing** – Neural networks can be trained to process an audio signal and filter it appropriately in the hearing aids.
- **Control** – ANNs are often used to make steering decisions of physical vehicles.
- **Anomaly Detection** – As ANNs are expert at recognizing patterns, they can also be trained to generate an output when something unusual occurs that misfits the pattern.