CHAPTER 4: ARTIFICIAL INTELLIGENCE

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”.

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.

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.

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.

Benefits and Challenges of Artificial Intelligence

People fear artificial intelligence, but balancing AI pros and cons suggests it's a necessary evil – and even vital in places.

Pros of Artificial Intelligence:

The pros of artificial intelligence are numerous.

1) Mundane tasks: humans get bored, machines don't. Let them do the humdrum jobs. "A.I. allows for more intricate process automation, which increases productivity of resources and takes repetitive, boring labor off the shoulders of humans. They can focus on creative tasks instead," said Felicia Schneiderhan, CEO of 30SecondToFly, an AI virtual travel assistant.
2) Faster actions and decisions: A.I. and cognitive technologies help in making faster actions and decisions. "Areas like automated fraud detection, planning and scheduling further demonstrate this benefit," said Kalyan Kumar, executive vice president at HCL Technologies, an IT services provider in India.
3) Machine Learning: Big Data means datasets in the petabytes, far too much for a human to sift through. AI can chew through that data as fast as the Xeon processors in the servers can go and derive insights from the data much faster than any human could.

   CloudPassage co-founder and CTO Carson Sweet argues this isn‘t actual AI. "A lot of the big data processing and analysis being attributed to AI is really just the work of machine learning. True AI would need to take things so much further; toward genuine self-learning using artificial neural networks that emulate the structure and functions of neural networks in human brains," he said.

4) Error-Free Processing: To error is human. Computers don't. The only mistakes they make is when you don't program them properly. AI processing will insure error-free processing of data, no matter how large the dataset. Judgement calls, however, are a different matter.

   "Computers are 'stupid,' but that is their brilliance - they demand such a high level of rigor and AI adds quantitative rigor on top of that, that to use AI at all you first have to ask yourself the very challenging but stimulating question of what you're trying to do, with a new level of acuity," said Dr. Nathan Wilson, CTO and co-founder of Nara Logics, synaptic intelligence company.

5) Taking the Risk: AI-powered machines are doing jobs humans either can't do or would have to do very carefully. Space exploration is one of them. The Mars rover Curiosity is an example. It is freely roaming Mars because it examines the landscape as it explores and determines the best path to take. The result is that Curiosity is learning to think for itself.
6) Better research outcomes: "AI-based technologies like computer vision help in achieving better outcomes through improved prediction, which can include medical diagnosis, oil exploration and demand forecasting," said Kumar.

The Cons of Artificial Intelligence

The Cons of Artificial Intelligence provoke a gut-level response.

1) Job losses: There is no way around it, AI will cost lesser-skilled people their jobs. Robots have already taken many jobs on assembly lines and as AI gets better at doing complex tasks, even more low-skill jobs will be taken.

   "AI will create much more wealth than it destroys, but it will not be equitably distributed, especially at first," said Wilson. Driverless cars is one obvious singular tech that will displace millions of human drivers fairly quickly, although the recent fatality involving a Tesla car on auto-drive may have set the whole effort back a bit.

   The changes will be subliminally felt and not overt, said Wilson. "A tax accountant won't one day receive a pink slip and meet the robot that is now going to sit at her desk. Rather, the next time the tax accountant applies for a job, it will be a bit harder to find a job."

2) A concentration of power: AI could mean a lot of power will be in the hands of a few who are controlling it. "AI de-humanizes warfare as the nations in possession of advanced AI technology can kill humans without involving an actual human to pull the trigger," said Schneiderhan.
3) Bad calls: AI does not have the ability to make a judgement call and may never get that ability. A really good example happened in Sydney, Australia in 2014, when there was a shooting and hostage drama downtown. People began ringing up Uber to get out of the affected area, and because of the surge in demand in a concentrated area, Uber's algorithms fell back on the trusted economics of supply-and-demand and ride rates skyrocketed.

   The Uber algorithms didn't take into account the violent crisis impacting downtown, and affected riders didn't care. They were livid that they had been gouged at a time of crisis. It forced Uber to reevaluate how it handles such emergencies. Perhaps in the future it will handle them better, but for a few Aussies, it left a bad taste in their mouths.

"There is nothing artificial about intelligence," said Kartik Iyengar, senior vice president of IoT & Skylab at VirtusaPolaris, a global IT consulting and technology services company. "Intelligence is a fine balance of emotions and skill that is constantly developing. Today, shades of gray exist when we make judgements. Our behavior is an outcome of the world around us – the more artificial it becomes, the more our definitions are subject to deciding on simply right or wrong, rather than the quick mid-course corrections that make us human. Replacing adaptive human behavior with rigid, artificial intelligence could cause irrational behavior within ecosystems of people and things."

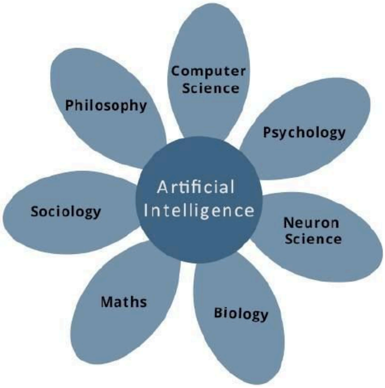
4) Judgement calls, part 2: The Uber situation highlights the fact that unless all such solutions are anticipated and specifically programmed to be out of bounds, an AI can arrive at a situation and implement it to the detriment of people or the environment. Dr. Tim Lynch, who has a doctorate in the psychology of computers and intelligent machines, calls this "Perverse Instantiation."

   What that means is an AI can be programmed with a benign goal but implement it in a perverse manner just because the solution is logical and expeditious. "So if there is a problem with the food supply, an AI's solution may be to reduce the population by any means available rather than find ways to increase food production or decrease food waste," he said.

   In short, an ultimate pro and con of artificial intelligence: AI still isn't all that smart.

What Contributes 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.



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.

Applications of AI

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,

- A spying aeroplane takes photographs, which are used to figure out spatial information or map of the areas.
- Doctors use clinical expert system to diagnose the patient.
- 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 talks 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.

History of AI

Here is the history of AI during 20th century −

Year	Milestone / Innovation
1923	Karel Čapek play named ―Rossum's Universal Robots‖ (RUR) opens in London, first use of the word "robot" in English.
1943	Foundations for neural networks laid.
1945	Isaac Asimov, a Columbia University alumni, coined the term Robotics.
1950	Alan Turing introduced Turing Test for evaluation of intelligence and published Computing Machinery and Intelligence. Claude Shannon published Detailed Analysis of Chess Playing as a search.
1956	John McCarthy coined the term Artificial Intelligence. Demonstration of the first running AI program at Carnegie Mellon University.
1958	John McCarthy invents LISP programming language for AI.
1964	Danny Bobrow's dissertation at MIT showed that computers can understand natural language well enough to solve algebra word problems correctly.
1965	Joseph Weizenbaum at MIT built ELIZA, an interactive problem that carries on a dialogue in English.
1969	Scientists at Stanford Research Institute Developed Shakey, a robot, equipped with locomotion, perception, and problem solving.
1973	The Assembly Robotics group at Edinburgh University built Freddy, the Famous Scottish Robot, capable of using vision to locate and assemble models.
1979	The first computer-controlled autonomous vehicle, Stanford Cart, was built.
1985	Harold Cohen created and demonstrated the drawing program, Aaron.
1990	Major advances in all areas of AI − Significant demonstrations in machine learning

	- Case-based reasoning - Multi-agent planning - Scheduling - Data mining, Web Crawler - natural language understanding and translation - Vision, Virtual Reality - Games
1997	The Deep Blue Chess Program beats the then world chess champion, Garry Kasparov.
2000	Interactive robot pets become commercially available. MIT displays Kismet, a robot with a face that expresses emotions. The robot Nomad explores remote regions of Antarctica and locates meteorites.

AI - Intelligent Systems

While studying artificially intelligence, you need to know what intelligence is. This chapter covers Idea of intelligence, types, and components of intelligence.

Meaning of 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

As described by Howard Gardner, an American developmental psychologist, the Intelligence comes in multifold −

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 Buddhha
Interpersonal	The ability to recognize and make distinctions	Mass

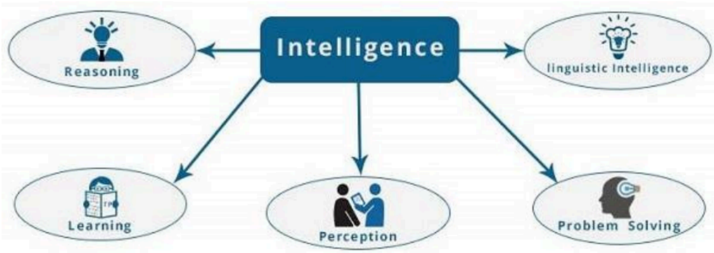
intelligence	among other people's feelings, beliefs, and intentions.	Communicators, Interviewers

You can say a machine or a system is artificially intelligent when it is equipped with at least one and at most all intelligences in it.

Composition of Intelligence

The intelligence is intangible. It is composed of −

- Reasoning
- Learning
- Problem Solving
- Perception
- Linguistic Intelligence



Let us go through all the components briefly −

- Reasoning − It is the set of processes that enables us to provide basis for judgement, making decisions, and prediction. There are broadly two types −

Inductive Reasoning	Deductive Reasoning
It conducts specific observations to makes broad general statements.	It starts with a general statement and examines the possibilities to reach a specific, logical conclusion.
Even if all of the premises are true in a statement, inductive reasoning allows for the conclusion to be false.	If something is true of a class of things in general, it is also true for all members of that class.
Example − "Nita is a teacher. All teachers are studious. Therefore, Nita is studious."	Example − "All women of age above 60 years are grandmothers. Shalini is 65 years. Therefore, Shalini is a grandmother."

- Learning − It is the activity of gaining knowledge or skill by studying, practising, being taught, or experiencing something. Learning enhances the awareness of the subjects of the study.

  The ability of learning is possessed by humans, some animals, and AI-enabled systems. Learning is categorized as −

  - Auditory Learning − It is learning by listening and hearing. For example, students listening to recorded audio lectures.
  - Episodic Learning − To learn by remembering sequences of events that one has witnessed or experienced. This is linear and orderly.
  - Motor Learning − It is learning by precise movement of muscles. For example, picking objects, Writing, etc.
  - Observational Learning − To learn by watching and imitating others. For example, child tries to learn by mimicking her parent.
  - Perceptual Learning − It is learning to recognize stimuli that one has seen before. For example, identifying and classifying objects and situations.
  - Relational Learning − It involves learning to differentiate among various stimuli on the basis of relational properties, rather than absolute properties. For Example, Adding ‗little less' salt at the time of cooking potatoes that came up salty last time, when cooked with adding say a tablespoon of salt.
  - Spatial Learning − It is learning through visual stimuli such as images, colors, maps, etc. For Example, A person can create roadmap in mind before actually following the road.
  - Stimulus-Response Learning − It is learning to perform a particular behavior when a certain stimulus is present. For example, a dog raises its ear on hearing doorbell.
- Problem Solving − It is the process in which one perceives and tries to arrive at a desired solution from a present situation by taking some path, which is blocked by known or unknown hurdles.

  Problem solving also includes decision making, which is the process of selecting the best suitable alternative out of multiple alternatives to reach the desired goal are available.

- Perception − It is the process of acquiring, interpreting, selecting, and organizing sensory information.

  Perception presumes sensing. In humans, perception is aided by sensory organs. In the domain of AI, perception mechanism puts the data acquired by the sensors together in a meaningful manner.

- Linguistic Intelligence − It is one's ability to use, comprehend, speak, and write the verbal and written language. It is important in interpersonal communication.

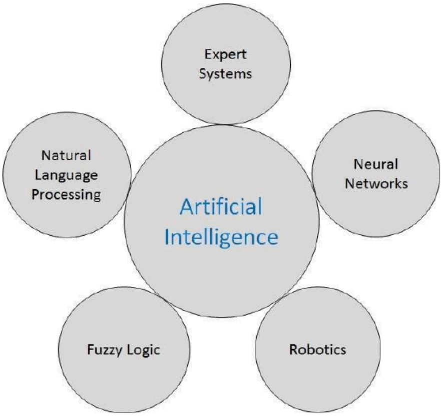
Difference between Human and Machine Intelligence

- Humans perceive by patterns whereas the machines perceive by set of rules and data.

- Humans store and recall information by patterns, machines do it by searching algorithms. For example, the number 40404040 is easy to remember, store, and recall as its pattern is simple.
- Humans can figure out the complete object even if some part of it is missing or distorted; whereas the machines cannot do it correctly.

AI – Category 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 −



Neural Networks

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

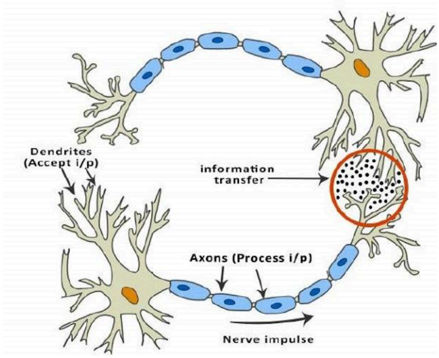
What are Artificial Neural Networks (ANNs)?

The inventor of the first neurocomputer, 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 ANNs

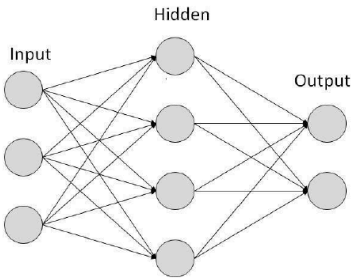
The idea of ANNs is based on the belief that working of human brain by making the right connections can be imitated using silicon and wires as living neurons and dendrites.

The human brain is composed of 100 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.



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 −

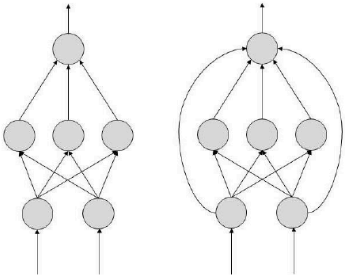


Types of Artificial Neural Networks

There are two Artificial Neural Network topologies − FeedForward and Feedback.

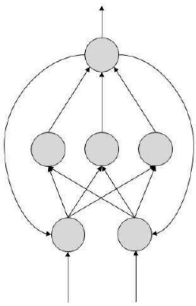
FeedForward ANN

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.



FeedBack ANN

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



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

Fuzzy Logic Systems

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

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 Y
POSSIBLY YE
CANNOT SAY
POSSIBLY NO
CERTAINLY N

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.

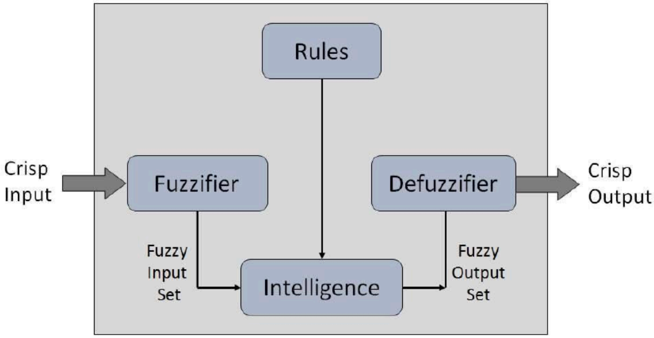
- It can control machines and consumer products.
- It may not give accurate reasoning, but acceptable reasoning.
- Fuzzy logic helps to deal with the uncertainty in engineering.

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

- 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 IF-THEN rules.
- Defuzzification Module − It transforms the fuzzy set obtained by the inference engine into a crisp value.



The membership functions work on fuzzy sets of variables.

Membership Function

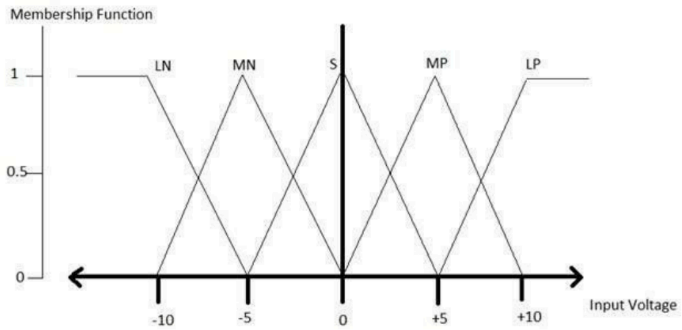
Membership functions allow you to quantify linguistic term and represent a fuzzy set graphically. A membership function for a fuzzy set A on the universe of discourse X is defined as $\mu_A:X \rightarrow [0,1]$.

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 below −

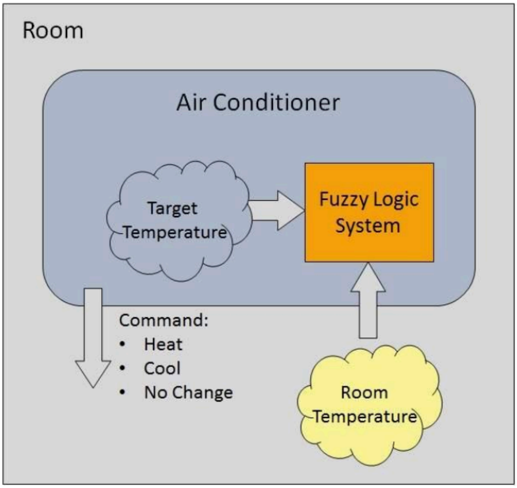


The triangular membership function shapes are most common among various other membership function shapes such as trapezoidal, singleton, and Gaussian.

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.



AI - Natural Language Processing

Natural Language Processing (NLP) refers to AI method of communicating with an intelligent systems 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 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 mean different meanings.
- Many inputs can mean the same thing.

NLP Terminology

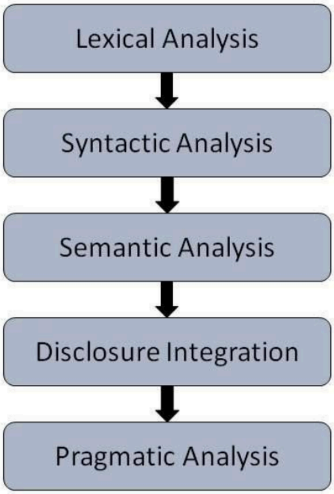
- Phonology − It is study of organizing sound systematically.
- Morphology − It is a study of construction of words from primitive meaningful units.
- Morpheme − It is primitive unit of meaning in a language.
- Syntax − It refers to arranging words to make a sentence. It also involves determining the 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.

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 - It is the grammar that consists rules with a single symbol on the left-hand side of the rewrite rules. Let us create grammar to parse a sentence − “The bird pecks the grains”

Top-Down Parser - 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 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.

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 −

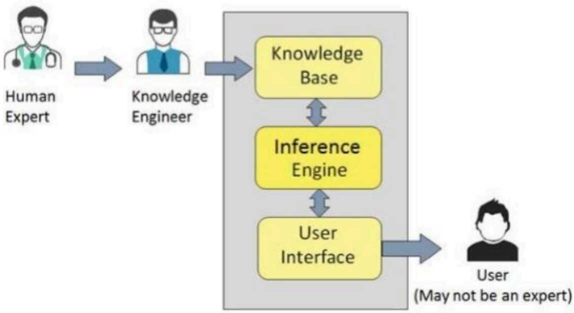
- Substituting human decision makers
- Possessing human capabilities
- Producing accurate output for inadequate knowledge base
- Refining their own knowledge

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 −

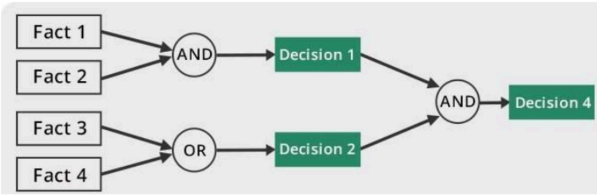
- Forward Chaining
- Backward Chaining

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.

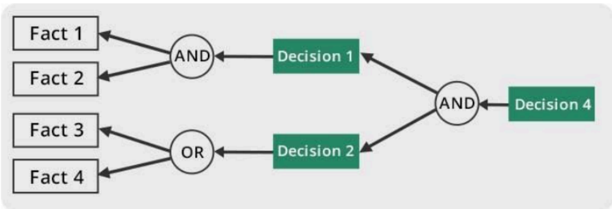
This strategy is followed for working on conclusion, result, or effect. For example, prediction of share market status as an effect of changes in interest rates.



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 Programming (LISP) and PROgrammation en LOGique (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 ES

- 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.

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.

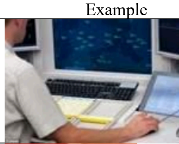
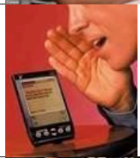
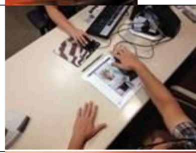
Working of Speech and Voice Recognition Systems

The user input spoken at a microphone goes to sound card of the system. The converter turns the analog signal into equivalent digital signal for the speech processing. The database is used to compare the sound patterns to recognize the words. Finally, a reverse feedback is given to the database.

This source-language text becomes input to the Translation Engine, which converts it to the target language text. They are supported with interactive GUI, large database of vocabulary, etc.

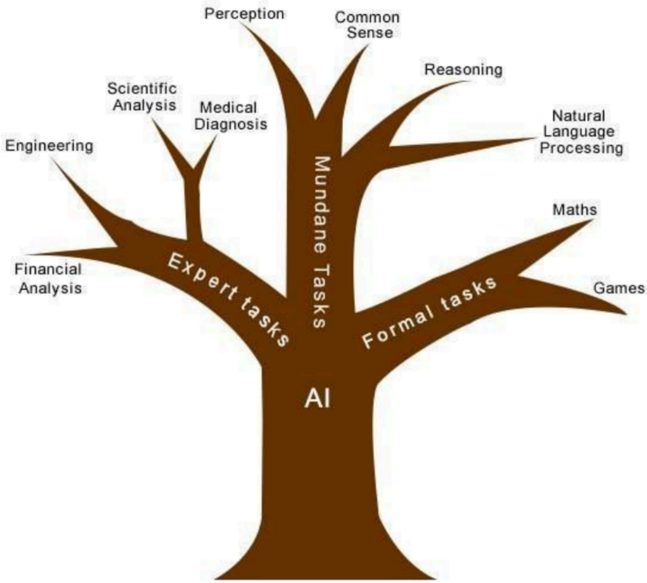
Real Life Applications of AI Research Areas

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

Sr.No.	Research Areas	Example
1	Expert Systems Examples − Flight-tracking systems, Clinical systems.	
2	Natural Language Processing Examples: Google Now feature, speech recognition, Automatic voice output.	
3	Neural Networks Examples − Pattern recognition systems such as face recognition, character recognition, handwriting recognition.	
4	Robotics Examples − Industrial robots for moving, spraying, painting, precision checking, drilling, cleaning, coating, carving, etc.	
5	Fuzzy Logic Systems Examples − Consumer electronics, automobiles, etc.	

Task Classification of AI

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



Task Domains of Artificial Intelligence		
Mundane (Ordinary) Tasks	Formal Tasks	Expert Tasks
Perception • Computer Vision • Speech, Voice	• Mathematics • Geometry • Logic • Integration and Differentiation	• Engineering • Fault Finding • Manufacturing • Monitoring
Natural Language Processing • Understanding • Language Generation • Language Translation	Games • Go • Chess (Deep Blue) • Ckeckers	Scientific Analysis
Common Sense	Verification	Financial Analysis
Reasoning	Theorem Proving	Medical Diagnosis
Planing		Creativity
Robotics		

Locomotive		

Humans learn mundane (ordinary) tasks since their birth. They learn by perception, speaking, using language, and locomotives. They learn Formal Tasks and Expert Tasks later, in that order.

For humans, the mundane tasks are easiest to learn. The same was considered true before trying to implement mundane tasks in machines. Earlier, all work of AI was concentrated in the mundane task domain.

Later, it turned out that the machine requires more knowledge, complex knowledge representation, and complicated algorithms for handling mundane tasks. This is the reason why AI work is more prospering in the Expert Tasks domain now, as the expert task domain needs expert knowledge without common sense, which can be easier to represent and handle.

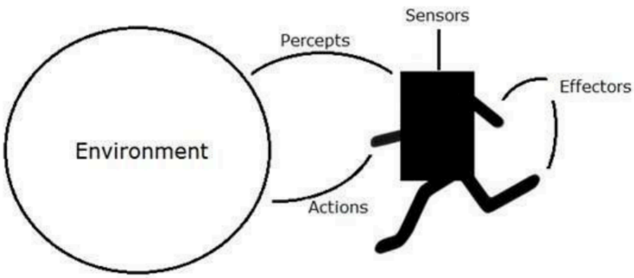
AI - Agents & Environments

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.

- 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 four factors −

- 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 −

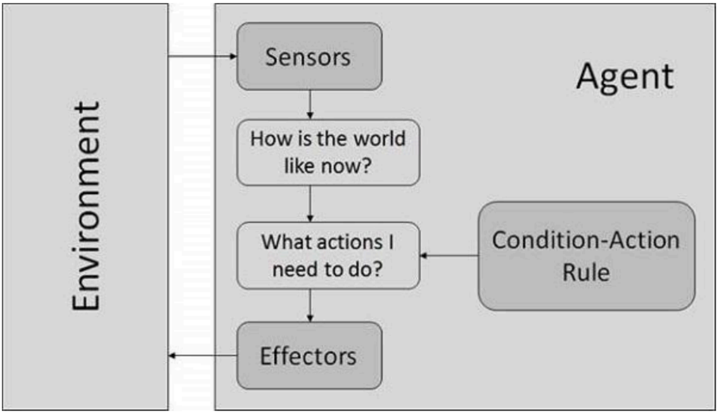
- Agent = Architecture + Agent Program
- Architecture = the machinery that an agent executes on.
- Agent Program = an implementation of an agent function.

<u>Simple Reflex Agents</u>

- 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.



Model Based Reflex Agents

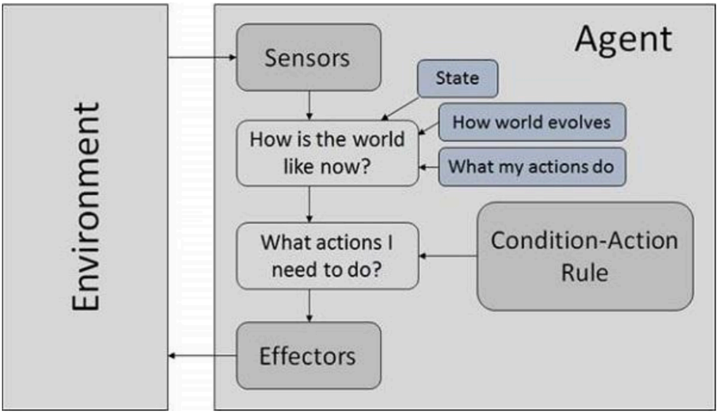
They use a model of the world to choose their actions. They maintain an internal state.

Model − The 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 −

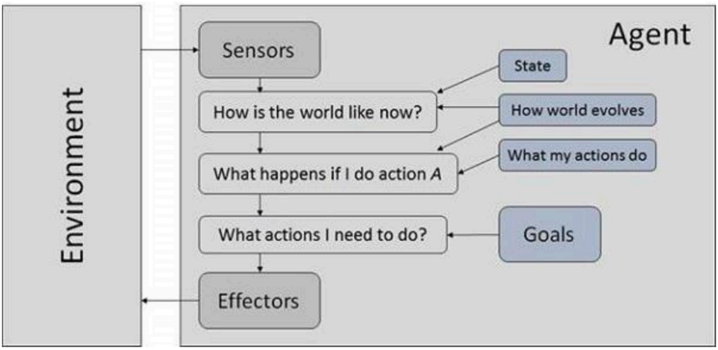
- How the world evolves.
- How the agent's actions affect the world.



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.

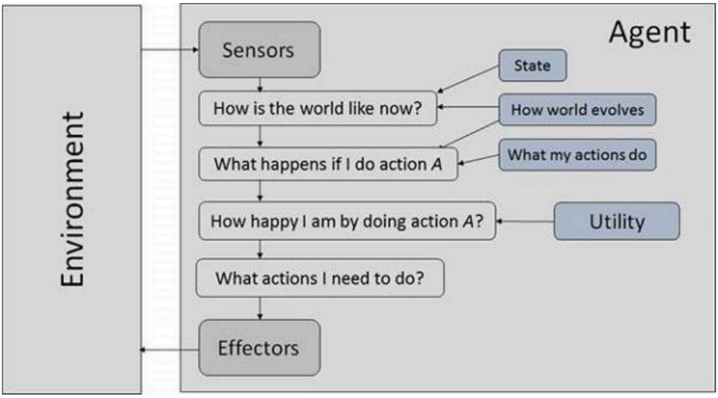
Goal − It is the description of desirable situations.



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.



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.

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.

Breakthroughs Unleashing AI on the World

AI researchers have predicted that AI is right around the corner, yet until a few years ago it seemed as stuck in the future as ever. There was even a term coined to describe this era of meager results and even more meager research funding: the AI winter. Has anything really changed?

Yes. Three recent breakthroughs have unleashed the long-awaited arrival of artificial intelligence:

1. Cheap parallel computation

Thinking is an inherently parallel process, billions of neurons firing simultaneously to create synchronous waves of cortical computation. To build a neural network—the primary architecture of AI software—also requires many different processes to take place simultaneously. Each node of a neural network loosely imitates a neuron in the brain—mutually interacting with its neighbors to make sense of the signals it receives. To recognize a spoken word, a program must be able to hear all the phonemes in relation to one another; to identify an image, it needs to see every pixel in the context of the pixels around it—both deeply parallel tasks. But until recently, the typical computer processor could only ping one thing at a time.

That began to change more than a decade ago, when a new kind of chip, called a graphics processing unit, or GPU, was devised for the intensely visual—and parallel—demands of videogames, in which millions of pixels had to be recalculated many times a second. That required a specialized parallel computing chip, which was added as a supplement to the PC motherboard. The parallel graphical chips worked, and gaming soared. By 2005, GPUs were being produced in such quantities that they became much cheaper. In 2009, Andrew Ng and a team at Stanford realized that GPU chips could run neural networks in parallel.

That discovery unlocked new possibilities for neural networks, which can include hundreds of millions of connections between their nodes. Traditional processors required several weeks to calculate all the cascading possibilities in a 100 million-parameter neural net. Ng found that a cluster of GPUs could accomplish the same thing in a day. Today neural nets running on GPUs are routinely used by cloud-enabled companies such as Facebook to identify your friends in photos or, in the case of Netflix, to make reliable recommendations for its more than 50 million subscribers.

2. Big Data
Every intelligence has to be taught. A human brain, which is genetically primed to categorize things, still needs to see a dozen examples before it can distinguish between cats and dogs. That's even more true for artificial minds. Even the best-programmed computer has to play at least a thousand games of chess before it gets good. Part of the AI breakthrough lies in the incredible avalanche of collected data about our world, which provides the schooling that AIs need. Massive databases, self-tracking, web cookies, online footprints, terabytes of storage, decades of search results, Wikipedia, and the entire digital universe became the teachers making AI smart.
3. Better algorithms
Digital neural nets were invented in the 1950s, but it took decades for computer scientists to learn how to tame the astronomically huge combinatorial relationships between a million—or 100 million—neurons. The key was to organize neural nets into stacked layers. Take the relatively simple task of recognizing that a face is a face. When a group of bits in a neural net are found to trigger a pattern—the image of an eye, for instance—that result is moved up to another level in the neural net for further parsing. The next level might group two eyes together and pass that meaningful chunk onto another level of hierarchical structure that associates it with the pattern of a nose. It can take many millions of these nodes (each one producing a calculation feeding others around it), stacked up to 15 levels high, to recognize a human face. In 2006, Geoff Hinton, then at the University of Toronto, made a key tweak to this method, which he dubbed ―deep learning.‖ He was able to mathematically optimize results from each layer so that the learning accumulated faster as it proceeded up the stack of layers. Deep-learning algorithms accelerated enormously a few years later when they were ported to GPUs. The code of deep learning alone is insufficient to generate complex logical thinking, but it is an essential component of all current AIs, including IBM's Watson, Google's search engine, and Facebook's algorithms.

This perfect storm of parallel computation, bigger data, and deeper algorithms generated the 60-years-in-the-making overnight success of AI. And this convergence suggests that as long as these technological trends continue—and there's no reason to think they won't—AI will keep improving.

As it does, this cloud-based AI will become an increasingly ingrained part of our everyday life. But it will come at a price. Cloud computing obeys the law of increasing returns, sometimes called the network effect, which holds that the value of a network increases much faster as it grows bigger. The bigger the network, the more attractive it is to new users, which makes it even bigger, and thus more attractive, and so on. A cloud that serves AI will obey the same law. The more people who use an AI, the smarter it gets. The smarter it gets, the more people use it. The more people that use it, the smarter it gets. Once a company enters this virtuous cycle, it tends to grow so big, so fast, that it overwhelms any upstart competitors. As a result, our AI future is likely to be ruled by an oligarchy of two or three large, general-purpose cloud-based commercial intelligences.