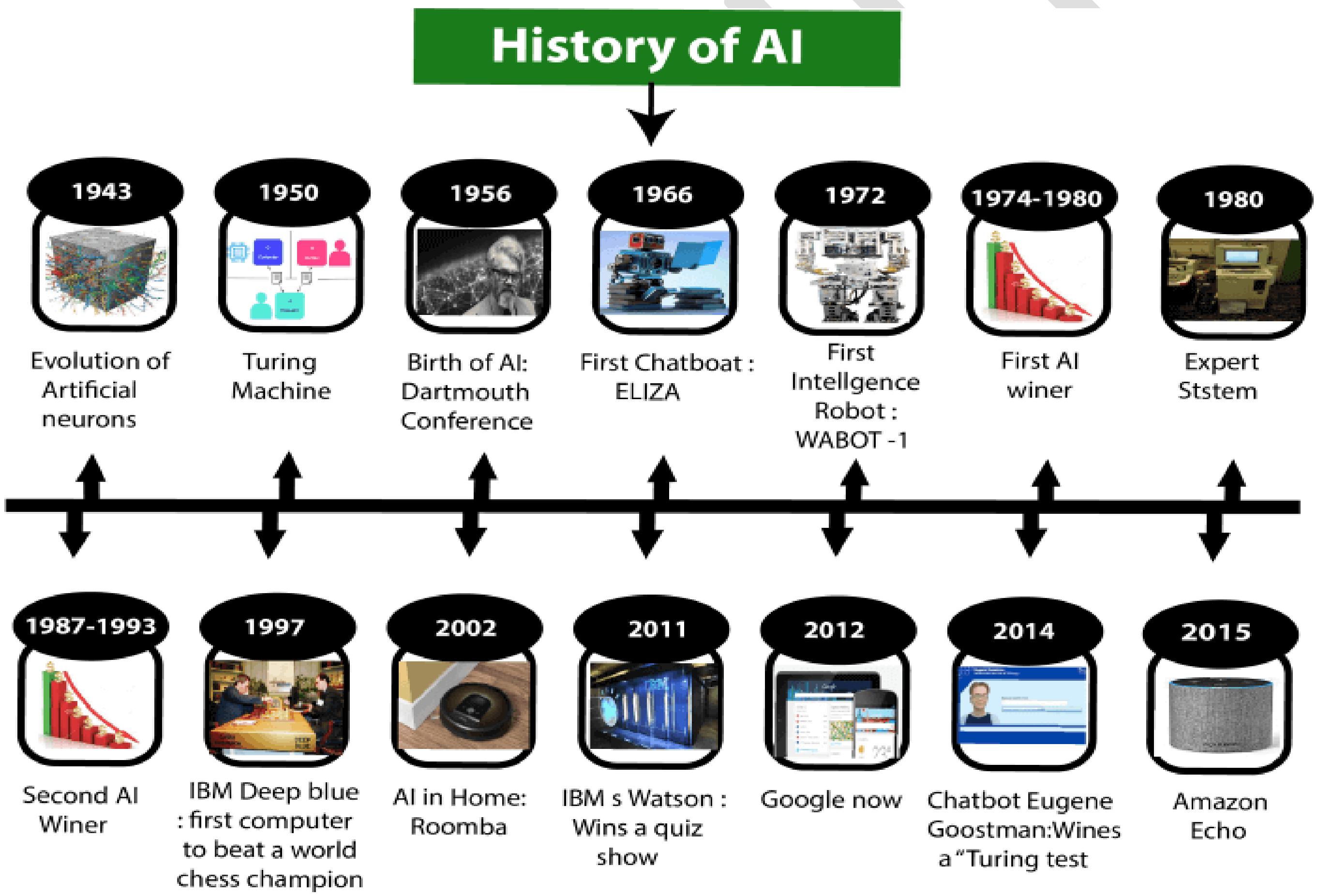
EAL5003-ARTIFICIAL INTELLIGNCE

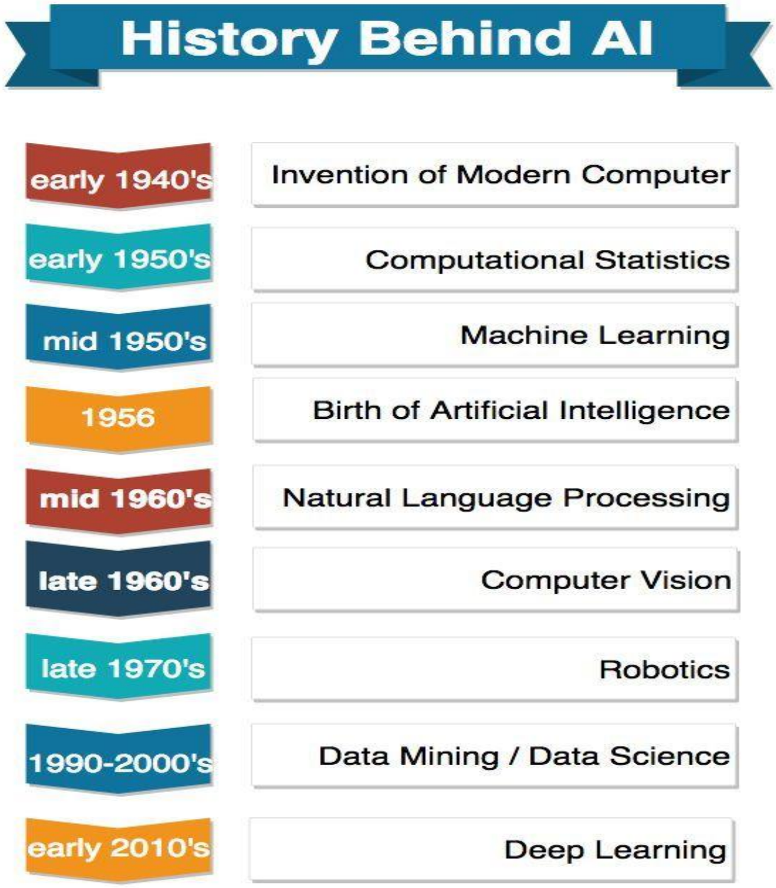
UNIT-1

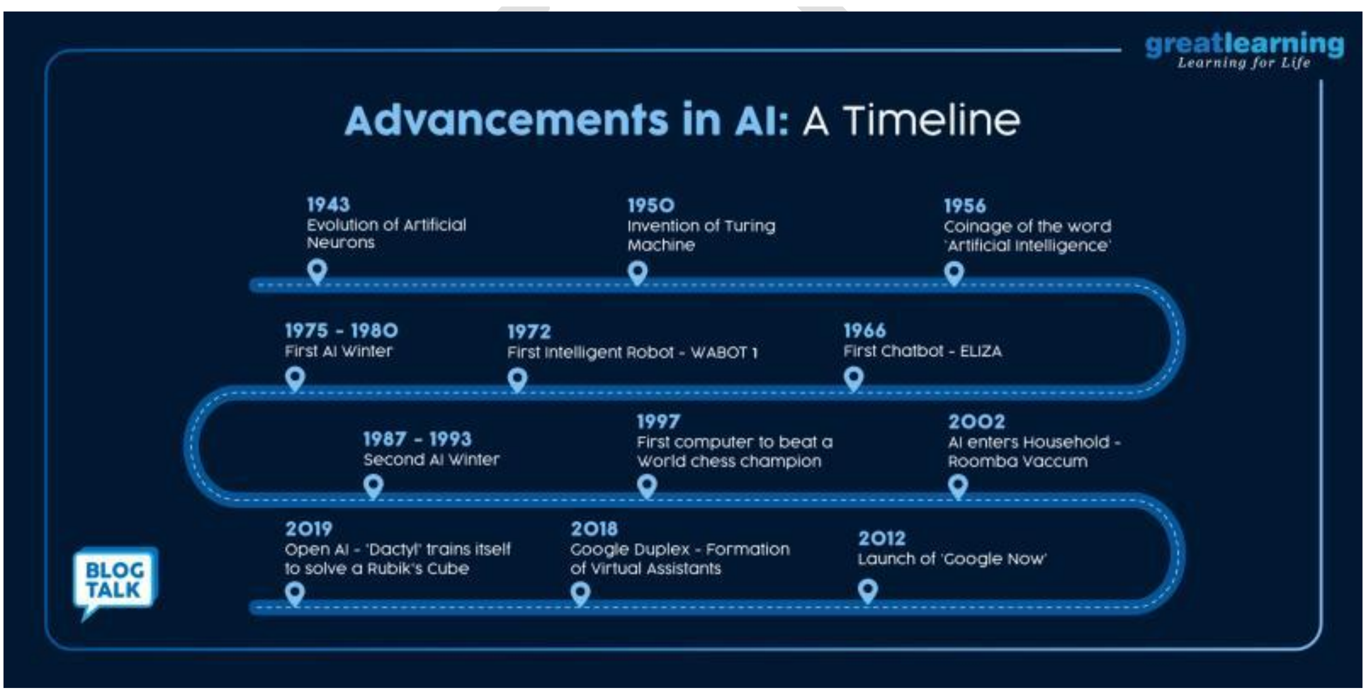
INTRODUCTION TO ARTIFICIAL INTELLIGENCE & LOGICAL APPROACH TO AL AND KNOWLEDGE-BASED SYSTEM

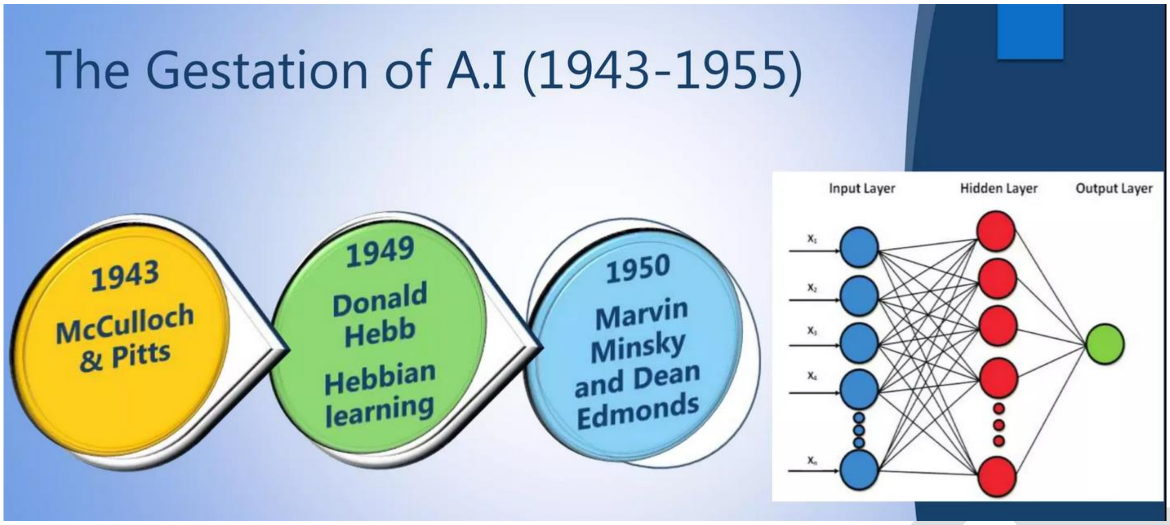
History of artificial intelligence, Todays' AI, Historical milestones in the development of AI, Differences between strong AI and weak AI, Technological advances, Machine Learning, Deep Learning, Functions of AI, Characteristics of artificial intelligence, Applications of AI, Cognitive science and AI, Cognition and process of Cognition, Linguistics, Artificial intelligence as Cognitive science, Methods in Cognitive science, Introduction to knowledge representation systems, Knowledge representation using logic, Propositional logic, Semantics of propositional logic, Properties of propositional logic statements, Tautologies and logical implication, Resolution, Conjunctive normal form, Resolution is valid, Resolution algorithm, Knowledgebase systems, Structure of a knowledge based system, Components of expert systems, Semantic networks.

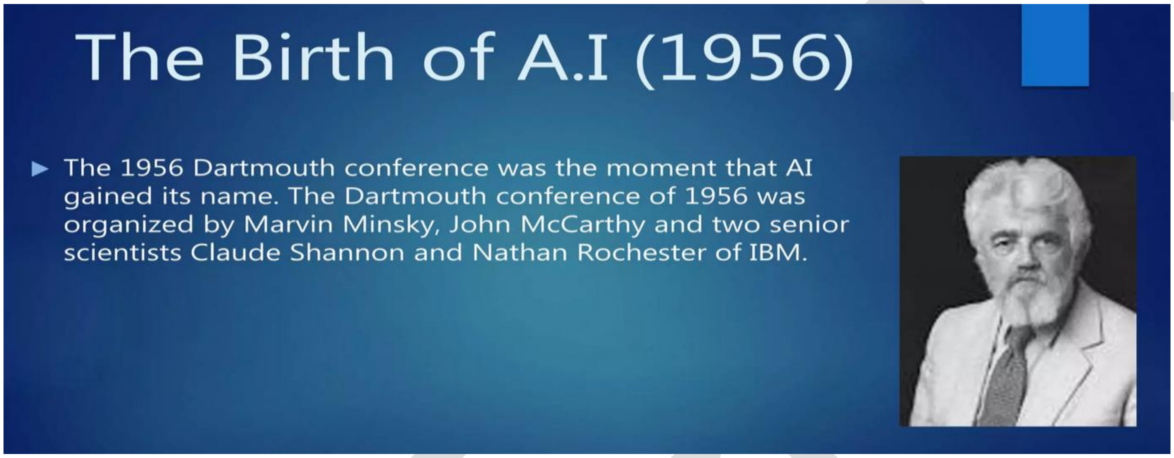
1. HISTORY OF ARTIFICIAL INTELLIGENCE




History Behind AI
early 1940's
Invention of Modern Computer
early 1950's
Computational Statistics
mid 1950's
Machine Learning
1956
Birth of Artificial Intelligence
mid 1960's
Natural Language Processing
late 1960's
Computer Vision
late 1970's
Robotics
1990-2000's
Data Mining / Data Science
early 2010's
Deep Learning


greatlearning
Learning for Life
Advancements in AI: A Timeline
1943
Evolution of Artificial Neurons
1950
Invention of Turing Machine
1956
Coinage of the word 'Artificial Intelligence'
1975 - 1980
First AI Winter
1972
First Intelligent Robot - WABOT 1
1966
First Chatbot - ELIZA
1987 - 1993
Second AI Winter
1997
First computer to beat a World chess champion
2002
AI enters Household - Roomba Vaccum
2019
Open AI - 'Dactyl' trains itself to solve a Rubik's Cube
2018
Google Duplex - Formation of Virtual Assistants
2012
Launch of 'Google Now'
BLOG TALK





Maturation of Artificial Intelligence (1943-1952)

- **Year 1943:** The first work which is now recognized as AI was done by Warren McCulloch and Walter pits in 1943. They proposed a model of **artificial neurons**.
- **Year 1949:** Donald Hebb demonstrated an updating rule for modifying the connection strength between neurons. His rule is now called **Hebbian learning**.
- **Year 1950:** The Alan Turing who was an English mathematician and pioneered Machine learning in 1950. Alan Turing publishes **"Computing Machinery and Intelligence"** in which he proposed a test. The test can check the machine's ability to exhibit intelligent behavior equivalent to human intelligence, called a **Turing test**.

The birth of Artificial Intelligence (1952-1956)

- **Year 1955:** An Allen Newell and Herbert A. Simon created the "first artificial intelligence program"Which was named as **"Logic Theorist"**. This program had proved 38 of 52 Mathematics theorems, and find new and more elegant proofs for some theorems.
- **Year 1956:** The word "Artificial Intelligence" first adopted by American Computer scientist John McCarthy at the Dartmouth Conference. For the first time, AI coined as an academic field.

At that time high-level computer languages such as FORTRAN, LISP, or COBOL were invented. And the enthusiasm for AI was very high at that time.

The golden years-Early enthusiasm (1956-1974)

- **Year 1966:** The researchers emphasized developing algorithms which can solve mathematical problems. Joseph Weizenbaum created the first chatbot in 1966, which was named as ELIZA.
- **Year 1972:** The first intelligent humanoid robot was built in Japan which was named as WABOT-1.

The first AI winter (1974-1980)

- The duration between years 1974 to 1980 was the first AI winter duration. AI winter refers to the time period where computer scientist dealt with a severe shortage of funding from government for AI researches.
- During AI winters, an interest of publicity on artificial intelligence was decreased.

A boom of AI (1980-1987)

- **Year 1980:** After AI winter duration, AI came back with "Expert System". Expert systems were programmed that emulate the decision-making ability of a human expert.
- In the Year 1980, the first national conference of the American Association of Artificial Intelligence **was held at Stanford University**.

The second AI winter (1987-1993)

- The duration between the years 1987 to 1993 was the second AI Winter duration.
- Again Investors and government stopped in funding for AI research as due to high cost but not efficient result. The expert system such as XCON was very cost effective.

The emergence of intelligent agents (1993-2011)

- **Year 1997:** In the year 1997, IBM Deep Blue beats world chess champion, Gary Kasparov, and became the first computer to beat a world chess champion.
- **Year 2002:** for the first time, AI entered the home in the form of Roomba, a vacuum cleaner.
- **Year 2006:** AI came in the Business world till the year 2006. Companies like Facebook, Twitter, and Netflix also started using AI.

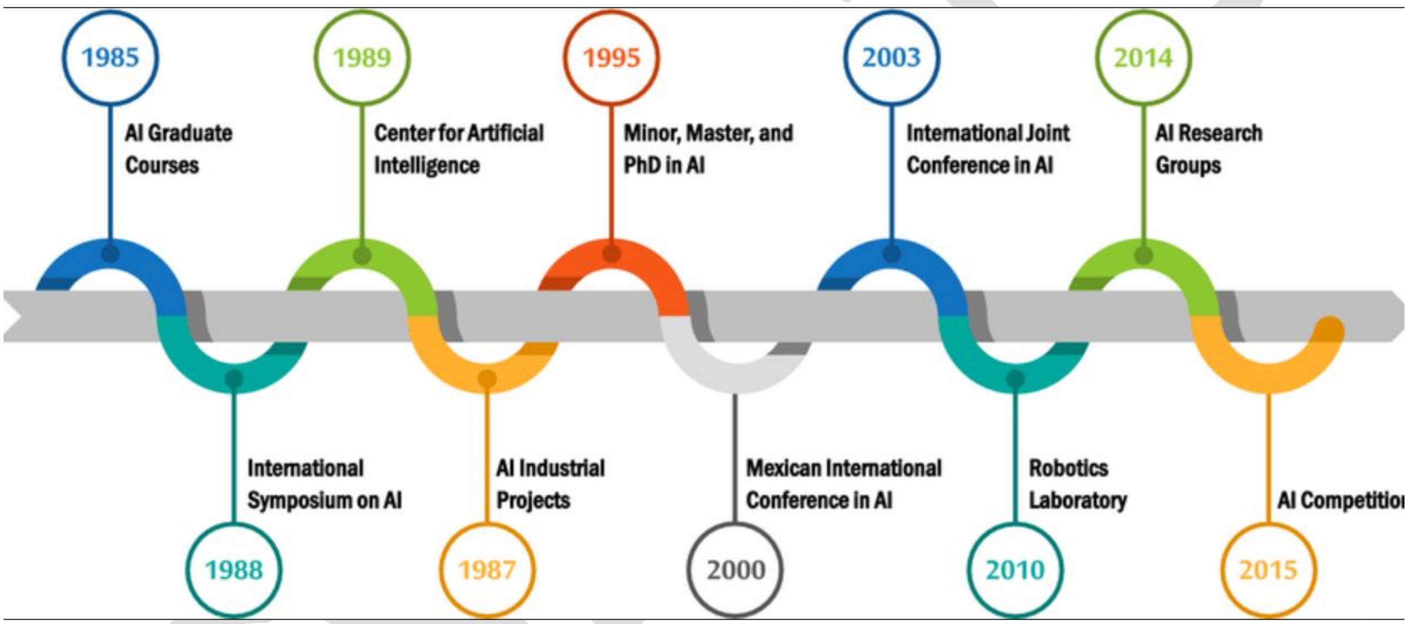
Deep learning, big data and artificial general intelligence (2011-present)

- **Year 2011:** In the year 2011, IBM's Watson won jeopardy, a quiz show, where it had to solve the complex questions as well as riddles. Watson had proved that it could understand natural language and can solve tricky questions quickly.
- **Year 2012:** Google has launched an Android app feature "Google now", which was able to provide information to the user as a prediction.

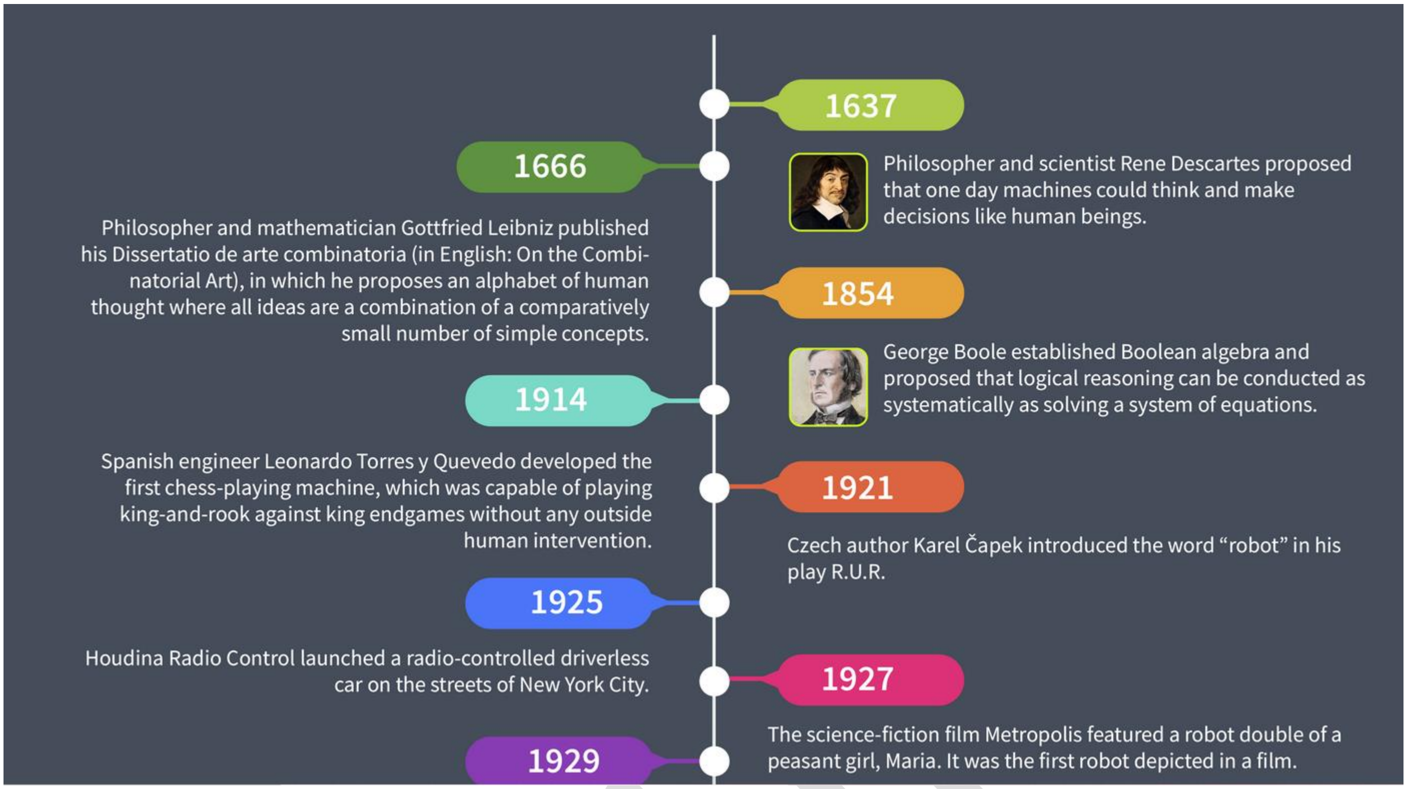
- **Year 2014:** In the year 2014, Chatbot "Eugene Goostman" won a competition in the infamous "Turing test."
- **Year 2018:** The "Project Debater" from IBM debated on complex topics with two master debaters and also performed extremely well.
- Google has demonstrated an AI program "Duplex" which was a virtual assistant and which had taken hairdresser appointment on call, and lady on other side didn't notice that she was talking with the machine.

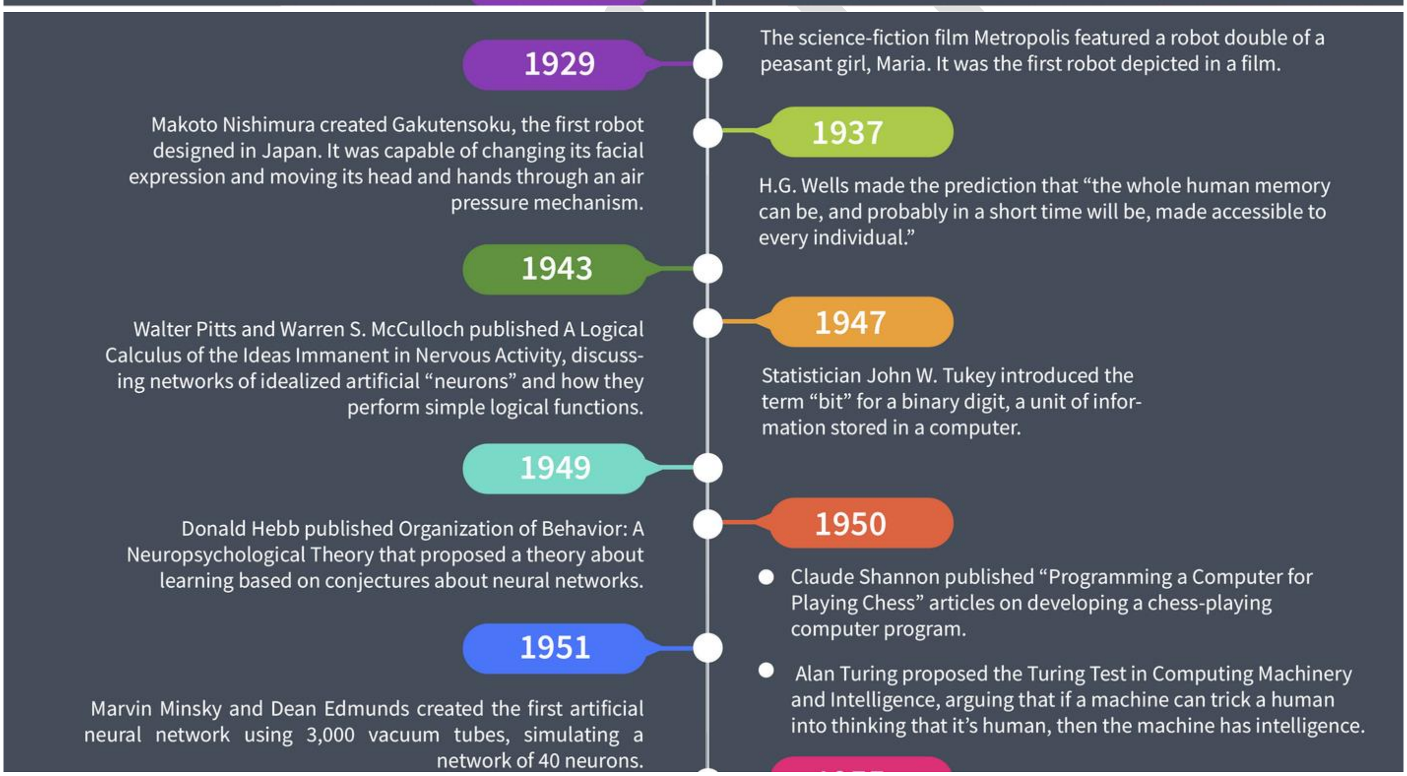
Now AI has developed to a remarkable level. The concept of Deep learning, big data, and data science are now trending like a boom. Nowadays companies like Google, Facebook, IBM, and Amazon are working with AI and creating amazing devices. The future of Artificial Intelligence is inspiring and will come with high intelligence.

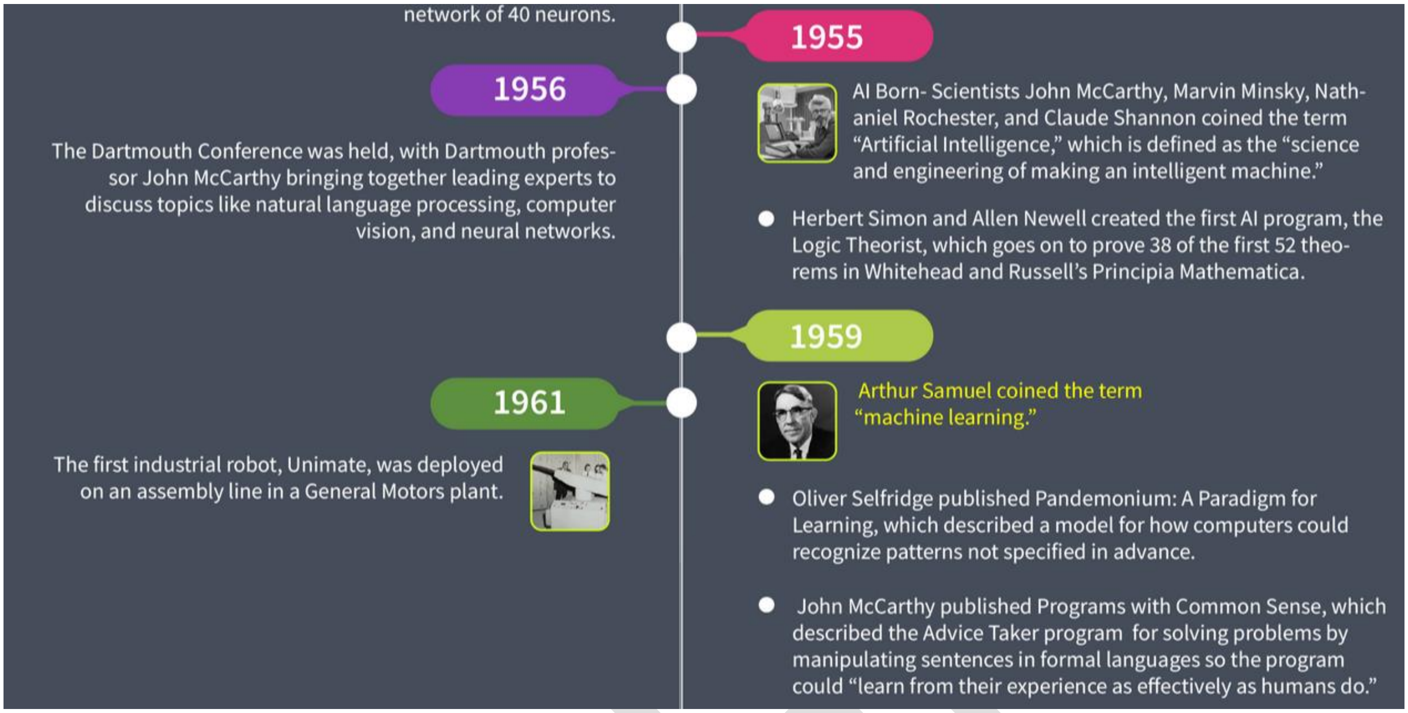
2. TODAYS AI

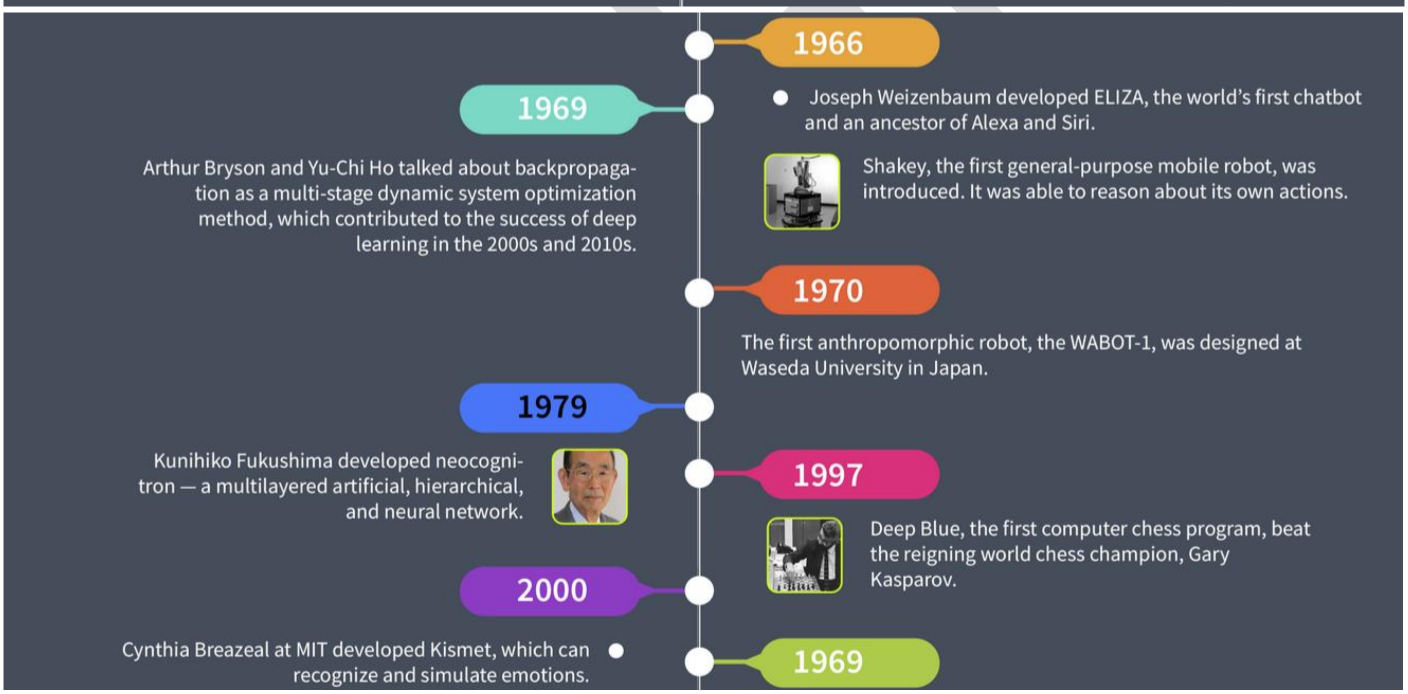


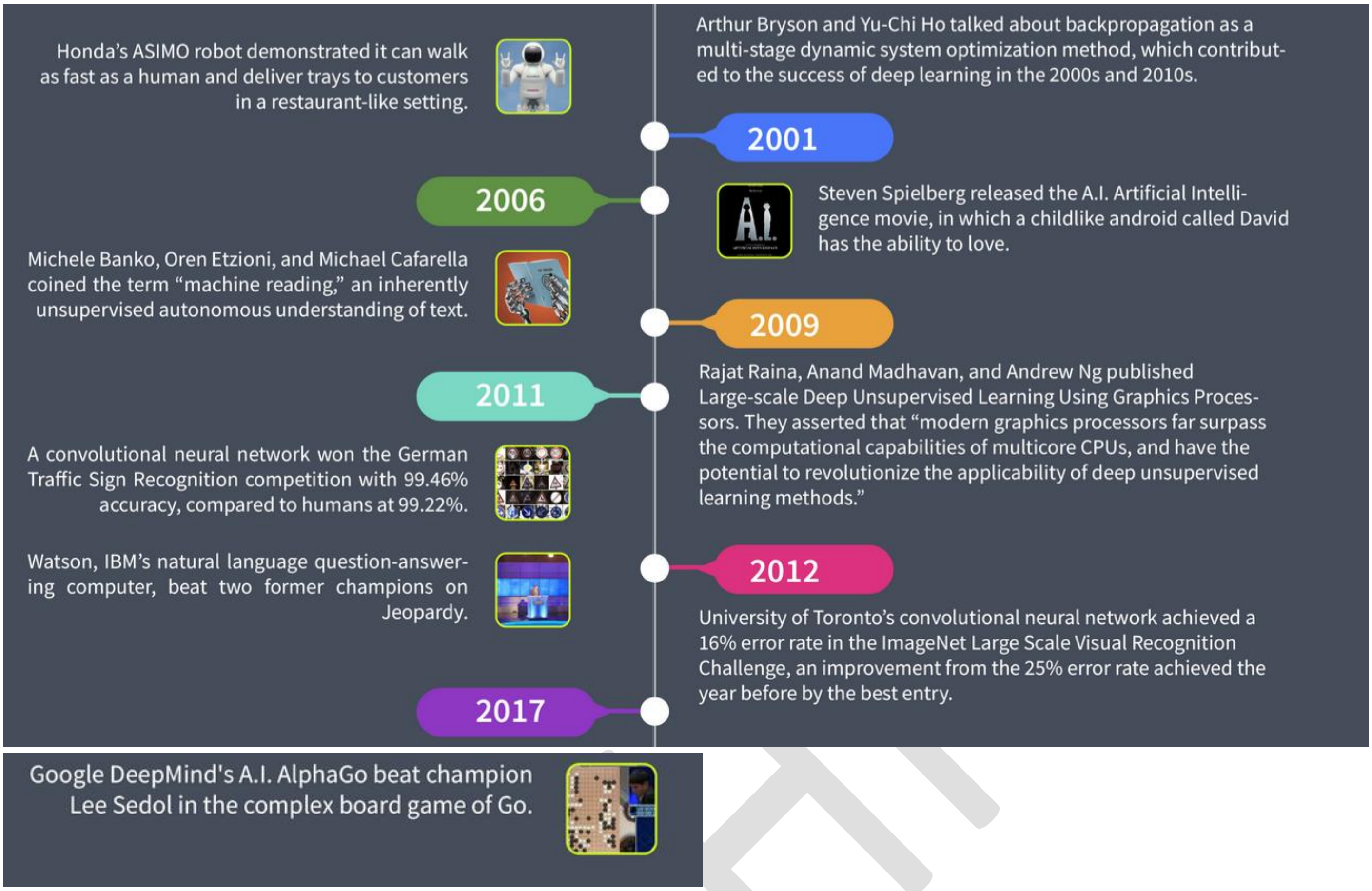
3. HISTORICAL MILESTONES IN THE DEVELOPMENT OF AI


1637
Philosopher and scientist Rene Descartes proposed that one day machines could think and make decisions like human beings.
1666
Philosopher and mathematician Gottfried Leibniz published his Dissertatio de arte combinatoria (in English: On the Combinatorial Art), in which he proposes an alphabet of human thought where all ideas are a combination of a comparatively small number of simple concepts.
1854
George Boole established Boolean algebra and proposed that logical reasoning can be conducted as systematically as solving a system of equations.
1914
Spanish engineer Leonardo Torres y Quevedo developed the first chess-playing machine, which was capable of playing king-and-rook against king endgames without any outside human intervention.
1921
Czech author Karel Čapek introduced the word "robot" in his play R.U.R.
1925
Houdina Radio Control launched a radio-controlled driverless car on the streets of New York City.
1927
The science-fiction film Metropolis featured a robot double of a peasant girl, Maria. It was the first robot depicted in a film.
1929


The science-fiction film Metropolis featured a robot double of a peasant girl, Maria. It was the first robot depicted in a film.
1929
Makoto Nishimura created Gakutensoku, the first robot designed in Japan. It was capable of changing its facial expression and moving its head and hands through an air pressure mechanism.
1937
H.G. Wells made the prediction that "the whole human memory can be, and probably in a short time will be, made accessible to every individual."
1943
Walter Pitts and Warren S. McCulloch published A Logical Calculus of the Ideas Immanent in Nervous Activity, discussing networks of idealized artificial "neurons" and how they perform simple logical functions.
1947
Statistician John W. Tukey introduced the term "bit" for a binary digit, a unit of information stored in a computer.
1949
Donald Hebb published Organization of Behavior: A Neuropsychological Theory that proposed a theory about learning based on conjectures about neural networks.
1950
Claude Shannon published "Programming a Computer for Playing Chess" articles on developing a chess-playing computer program.
Alan Turing proposed the Turing Test in Computing Machinery and Intelligence, arguing that if a machine can trick a human into thinking that it's human, then the machine has intelligence.
1951
Marvin Minsky and Dean Edmunds created the first artificial neural network using 3,000 vacuum tubes, simulating a network of 40 neurons.


network of 40 neurons.
1955
1956
The Dartmouth Conference was held, with Dartmouth professor John McCarthy bringing together leading experts to discuss topics like natural language processing, computer vision, and neural networks.
AI Born- Scientists John McCarthy, Marvin Minsky, Nathaniel Rochester, and Claude Shannon coined the term "Artificial Intelligence," which is defined as the "science and engineering of making an intelligent machine."
Herbert Simon and Allen Newell created the first AI program, the Logic Theorist, which goes on to prove 38 of the first 52 theorems in Whitehead and Russell's Principia Mathematica.
1959
1961
Arthur Samuel coined the term "machine learning."
The first industrial robot, Unimate, was deployed on an assembly line in a General Motors plant.
Oliver Selfridge published Pandemonium: A Paradigm for Learning, which described a model for how computers could recognize patterns not specified in advance.
John McCarthy published Programs with Common Sense, which described the Advice Taker program for solving problems by manipulating sentences in formal languages so the program could "learn from their experience as effectively as humans do."


1966
1969
Joseph Weizenbaum developed ELIZA, the world's first chatbot and an ancestor of Alexa and Siri.
Arthur Bryson and Yu-Chi Ho talked about backpropagation as a multi-stage dynamic system optimization method, which contributed to the success of deep learning in the 2000s and 2010s.
Shakey, the first general-purpose mobile robot, was introduced. It was able to reason about its own actions.
1970
The first anthropomorphic robot, the WABOT-1, was designed at Waseda University in Japan.
1979
Kunihiko Fukushima developed neocognitron — a multilayered artificial, hierarchical, and neural network.
1997
Deep Blue, the first computer chess program, beat the reigning world chess champion, Gary Kasparov.
2000
Cynthia Breazeal at MIT developed Kismet, which can recognize and simulate emotions.
1969

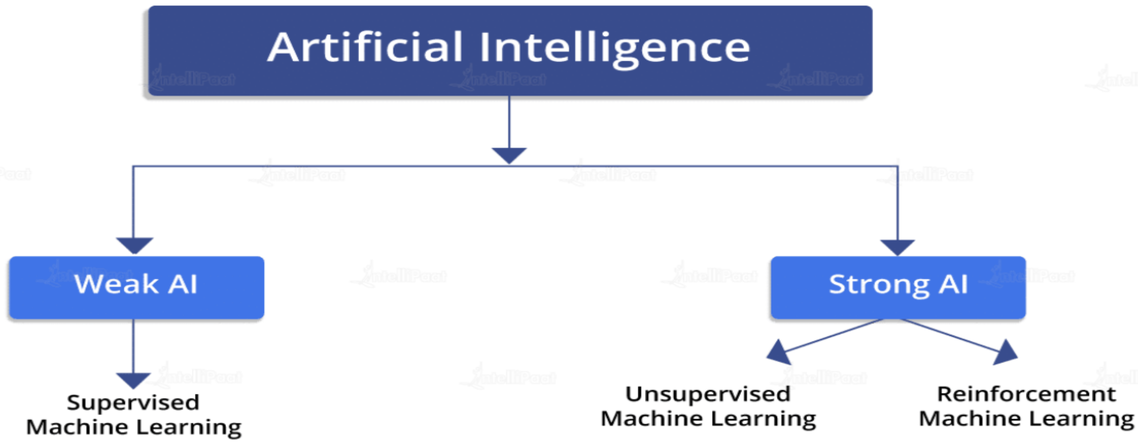


4. DIFFERENCES BETWEEN STRONG AI AND WEAK AI

Strong vs Weak AI

Comparison Chart

Weak AI	Strong AI
Weak AI is simply the view that intelligent behavior can be modeled and used by computers to solve complex problems.	Strong AI refers to a hypothetical machine that exhibits human cognitive abilities.
Weak AI refers to systems that are programmed to accomplish a wide range problems but operate within a pre-defined range of functions.	Strong AI refers to machines with the mind of their own and which can think and accomplish complex tasks on their own.
Weak AI-powered machines do not have mind of their own.	Strong AI-powered machines can exhibit strong human cognitive abilities.
Alexa and Siri are the best examples of weak AI programs.	Strong AI is a hypothetical concept which does not exist yet in its true form.



Categories of Artificial Intelligence

Weak Artificial Intelligence: In weak AI, the reaction of a machine to a specific input is well-defined. Here, we create a set of rules for the machine. It is then bound to give responses according to those confined rules. The supervised Machine Learning technique comes under Weak Artificial Intelligence.

Example: If we instruct a coffee machine to provide a Cappuccino, then it will perform well-defined sequences of actions. It will not respond beyond the set of rules that we have pre-defined.

Strong Artificial Intelligence: In strong AI, the algorithms and instructions for a machine are designed such that they give the machine the ability to learn by itself from the given inputs and iteratively enhance accuracy by experience.

Examples: Google Translate, Google Maps, **AI Chatbots**, recommendation engines, etc. are real-life examples of strong Artificial Intelligence.

Artificial intelligence (AI) as computational intelligence that emulates the human mind. However, this characterization does not hold true for all AI systems, as various types of AI have distinct characteristics. Two major categories within AI are "strong AI" and "weak AI," representing different approaches to machine intelligence.

What Is Weak AI?

Weak AI, also known as narrow AI, refers to AI applications that are specifically designed to automate tasks requiring a particular cognitive skill. This category of AI utilizes machine learning models tailored for specific tasks such as object recognition, chatbot interactions, personal voice assistants, autocorrect systems, and Google search algorithms, among others.

Let's explore seven common applications of weak AI:

1. **Email spam filters:** Features designed to detect and divert spam emails to the spam folder.
2. **Chatbots:** Tools that utilize Natural Language Processing (NLP) to interact with humans are another instance of weak AI.

3. **AI artists:** Computer-generated art using AI can transform natural language instructions into images and also falls under the umbrella of narrow AI.
4. **Smart voice assistants:** Siri, Cortana, Alexa, and others can perform numerous tasks on your behalf by responding to voice commands.
5. **Social media algorithms:** The recommendations on platforms like Twitter, Instagram, Facebook, or even Spotify are all powered by weak AI algorithms.
6. **Autonomous driving:** The self-driving feature in vehicles is yet another application of weak AI.
7. **Healthcare:** AI applications in healthcare, such as medical diagnostic systems capable of identifying diseases with minimal human intervention, serve as additional examples of weak AI in action.

Let's explore some of the limitations and drawbacks of weak AI:

- Limited capabilities due to task-specific models.
- Narrow AI applications depend highly on data, requiring large datasets to learn and perform certain tasks.
- By extension, the use of large datasets can create privacy and data processing issues.,
- Weak AI often relies on human intervention to execute tasks, which can introduce human biases into the process.
- These applications may be susceptible to cyber threats and vulnerabilities.

What Is Strong AI or AGI?

We often perceive artificial intelligence (AI) as computational intelligence that emulates the human mind. However, this characterization does not hold true for all AI systems, as various types of AI have distinct characteristics. Two major categories within AI are "strong AI" and "weak AI," representing different approaches to machine intelligence.

Now, let's look into the fundamental differences between strong AI and weak AI and explore the current state of AI technology.

What Is Weak AI?

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The term "weak" may mistakenly imply that these AI applications are lacking in some way. However, it is important to recognize that the rapid advancements in AI and their pervasive impact across various industries are largely due to narrow machine intelligence. The label "weak" indicates that these applications focus on a specific or narrow cognitive function.

Applications of Weak AI

ChatGPT, Midjourney, Stable Diffusion, DALL-E, and Bard are just a few examples of the AI tools that took the world by storm in 2022 and 2023. It is remarkable that so many professions are utilizing their widespread application, even sparking debates about the potential for AI to replace humans and leaving many of us with the question, "Can ChatGPT replace me?"

However, it's important to note that these amazing tools are still classified as examples of "weak AI" in action.

Let's explore seven common applications of weak AI:

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2. **Chatbots:** Tools that utilize Natural Language Processing (NLP) to interact with humans are another instance of weak AI.
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6. **Autonomous driving:** The self-driving feature in vehicles is yet another application of weak AI.
7. **Healthcare:** AI applications in healthcare, such as medical diagnostic systems capable of identifying diseases with minimal human intervention, serve as additional examples of weak AI in action.

Despite the term "weak AI," it's clear that it has numerous real-world applications that we're already using.

Limitations of Weak AI

The primary reason for the limitations of AI today is its focus on automating specific tasks for humans. For example, ChatGPT and Google Bard are designed as large language models (LLMs). They are specifically programmed for generating text-based content. Similarly, Midjourney and Stable Diffusion are text-to-image generators limited to this particular function.

Let's explore some of the limitations and drawbacks of weak AI:

- Limited capabilities due to task-specific models.
- Narrow AI applications depend highly on data, requiring large datasets to learn and perform certain tasks.
- By extension, the use of large datasets can create privacy and data processing issues.,
- Weak AI often relies on human intervention to execute tasks, which can introduce human biases into the process.
- These applications may be susceptible to cyber threats and vulnerabilities.

However, despite these limitations, tools like ChatGPT have become effectively indispensable within a short period of public release.

What Is Strong AI or AGI?

Applications of Strong AI

1. **Emotional intelligence and thought processing:** The understanding of human emotions and thought processes can be incorporated into AGI systems, benefiting industries such as healthcare, education, and customer services.
2. **Decision-making:** Machines equipped with strong AI can possess the ability to make autonomous decisions based on rationality.
3. **Evolution:** Strong AI systems could enable machines to adapt and modify themselves to better fit their surroundings.

4. **Consciousness:** Self-awareness and conscious decision-making capabilities could be achieved through strong AI systems.
5. **Artificial creativity:** Strong AI may unlock the potential for artificial creativity, allowing machines to generate innovative ideas without human instructions.

Limitations of Strong AI

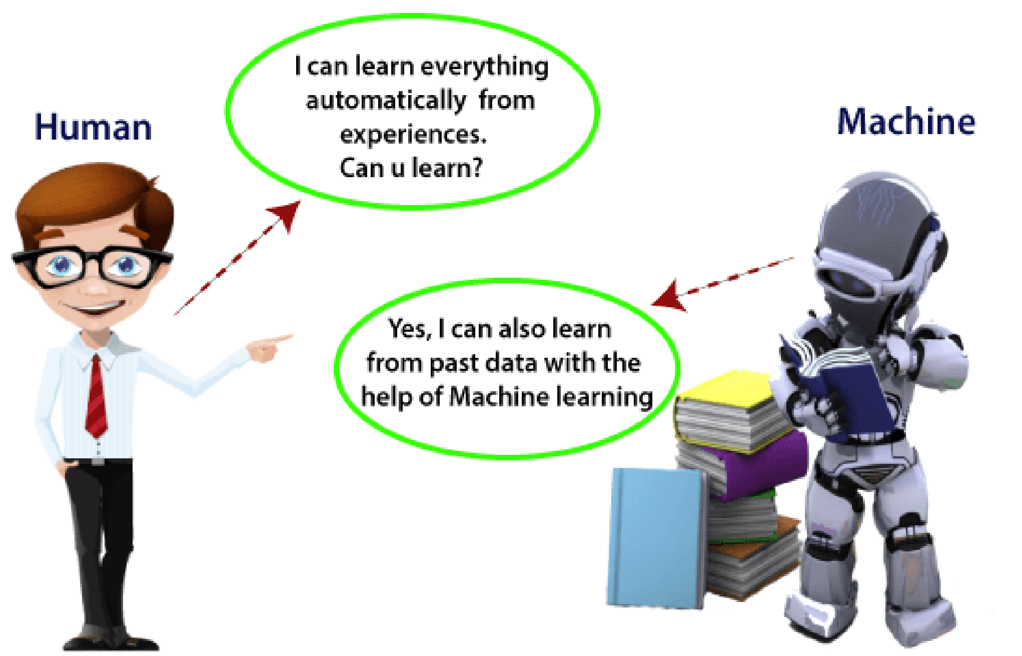
Strong AI or AGI has the potential to be transformative for our society. However, several considerations and challenges must be addressed when implementing such systems.

- Complexity, as strong AI requires vast amounts of data and high computational power for training.
- Ethical considerations that arise from the uncertainty surrounding the behavior of strong AI in real-world scenarios (e.g., AGI systems may make harmful decisions for humans).
- AGI systems will rely heavily on human data, which may lead to human-borne biases.
- Security and responsibility for the actions of strong AI (e.g., determining who should be held accountable when things go wrong).

5. TECHNOLOGICAL ADVANCES,MACHINE LEARNING

Machine learning is a growing technology which enables computers to learn automatically from past data. Machine learning uses various algorithms for **building mathematical models and making predictions using historical data or information**. Currently, it is being used for various tasks such as **image recognition**, **speech recognition**, **email filtering**, **Facebook auto-tagging**, **recommender system**, and many more.

What is Machine Learning

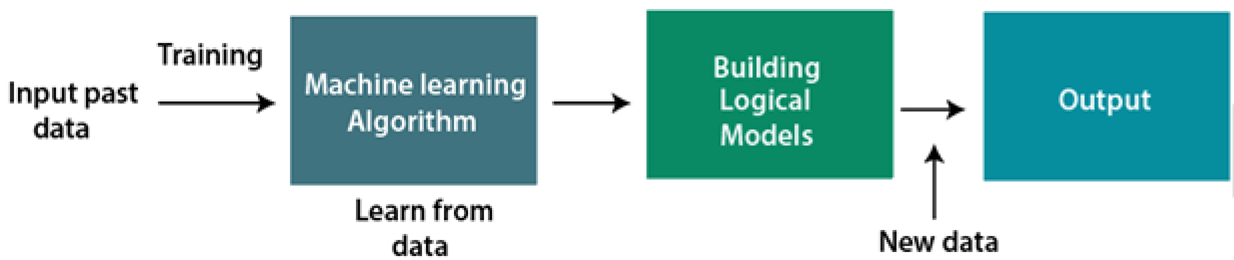


Machine Learning is said as a subset of **artificial intelligence** that is mainly concerned with the development of algorithms which allow a computer to learn from the data and past experiences on their own

How does Machine Learning work

A Machine Learning system **learns from historical data, builds the prediction models, and whenever it receives new data, predicts the output for it**. The accuracy of predicted output depends upon the amount of data, as the huge amount of data helps to build a better model which predicts the output more accurately.

Suppose we have a complex problem, where we need to perform some predictions, so instead of writing a code for it, we just need to feed the data to generic algorithms, and with the help of these algorithms, machine builds the logic as per the data and predict the output. Machine learning has changed our way of thinking about the problem. The below block diagram explains the working of Machine Learning algorithm:



Features of Machine Learning:

- Machine learning uses data to detect various patterns in a given dataset.
- It can learn from past data and improve automatically.
- It is a data-driven technology.
- Machine learning is much similar to data mining as it also deals with the huge amount of the data.

Need for Machine Learning

We can train machine learning algorithms by providing them the huge amount of data and let them explore the data, construct the models, and predict the required output automatically. The performance of the machine learning algorithm depends on the amount of data, and it can be determined by the cost function. With the help of machine learning, we can save both time and money.

The importance of machine learning can be easily understood by its uses cases, Currently, machine learning is used in **self-driving cars**, **cyber fraud detection**, **face recognition**, and **friend suggestion by Facebook**, etc. Various top companies such as Netflix and Amazon have build machine learning models that are using a vast amount of data to analyze the user interest and recommend product accordingly.

Following are some key points which show the importance of Machine Learning:

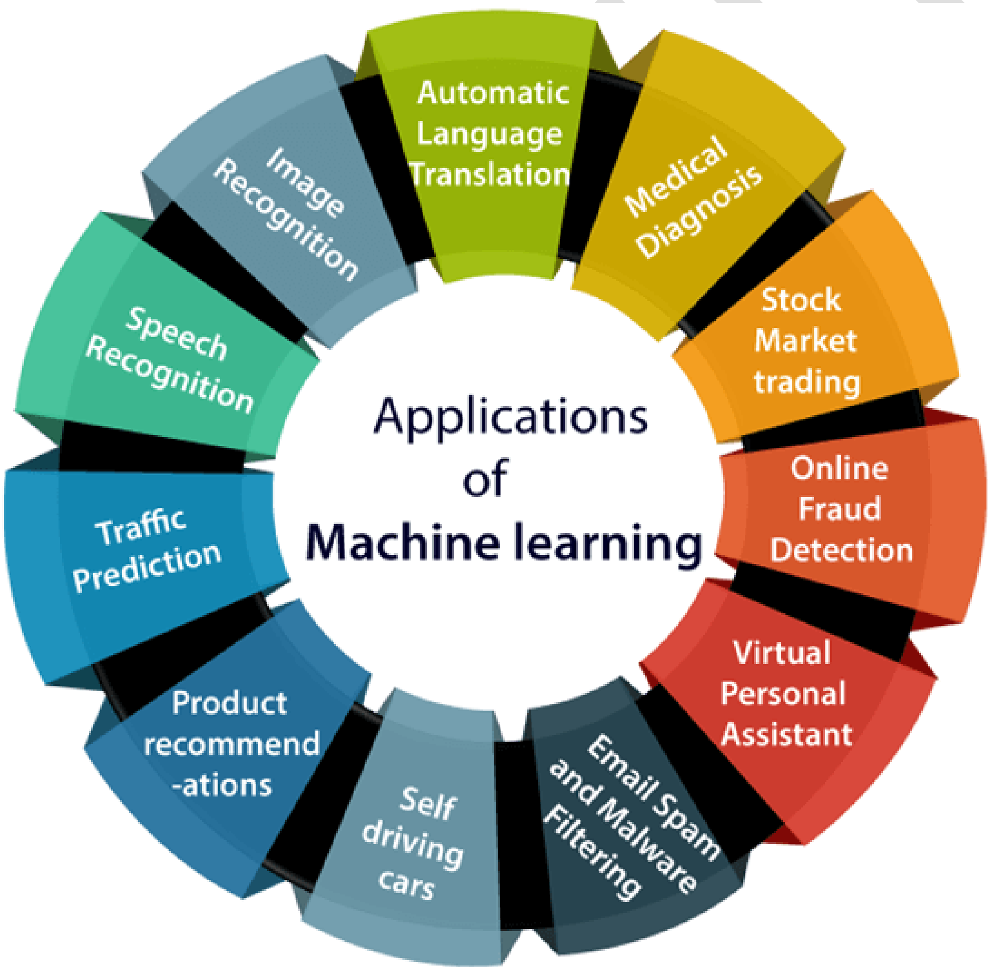
- Rapid increment in the production of data
- Solving complex problems, which are difficult for a human
- Decision making in various sector including finance
- Finding hidden patterns and extracting useful information from data.

Classification of Machine Learning

At a broad level, machine learning can be classified into three types:

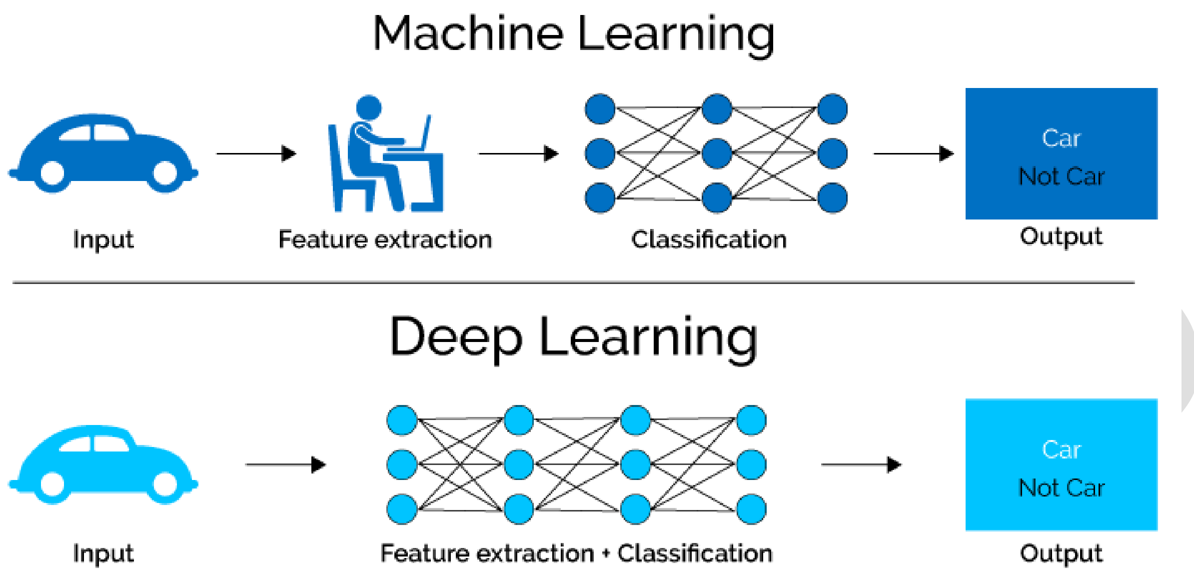
1. **Supervised learning**
2. **Unsupervised learning**
3. **Reinforcement learning**
4. Machine Learning at present:
5. Now machine learning has got a great advancement in its research, and it is present everywhere around us, such as **self-driving cars**, **Amazon Alexa**, **Catboats**, **recommender system**, and many more. It includes **Supervised**, **unsupervised**, and **reinforcement learning with clustering**, **classification**, **decision tree**, **SVM algorithms**, etc.
6. Modern machine learning models can be used for making various predictions, including **weather prediction**, **disease prediction**, **stock market analysis**, etc.

Applications of Machine learning



6.DEEP LEARNING

Deep learning is **a machine learning technique that teaches computers to do what comes naturally to humans**: learn by example. Deep learning is a key technology behind driverless cars, enabling them to recognize a stop sign, or to distinguish a pedestrian from a lamppost.



The deep learning revolution started around 2010.

Since then, Deep Learning has solved many "unsolvable" problems.

The deep learning revolution was not started by a single discovery. It more or less happened when several needed factors were ready:

- Computers were fast enough
- Computer storage was big enough
- Better training methods were invented
- Better tuning methods were invented

Neurons

Scientists agree that our brain has between 80 and 100 billion neurons.

These neurons have hundreds of billions connections between them.

Image credit: University of Basel, Biozentrum.

Neurons (aka Nerve Cells) are the fundamental units of our brain and nervous system.

The neurons are responsible for receiving input from the external world, for sending output (commands to our muscles), and for transforming the electrical signals in between.

Neural Networks

Artificial Neural Networks are normally called Neural Networks (NN).

Neural networks are in fact multi-layer **Perceptrons**.

The perceptron defines the first step into multi-layered neural networks.

Neural Networks is the essence of **Deep Learning**.

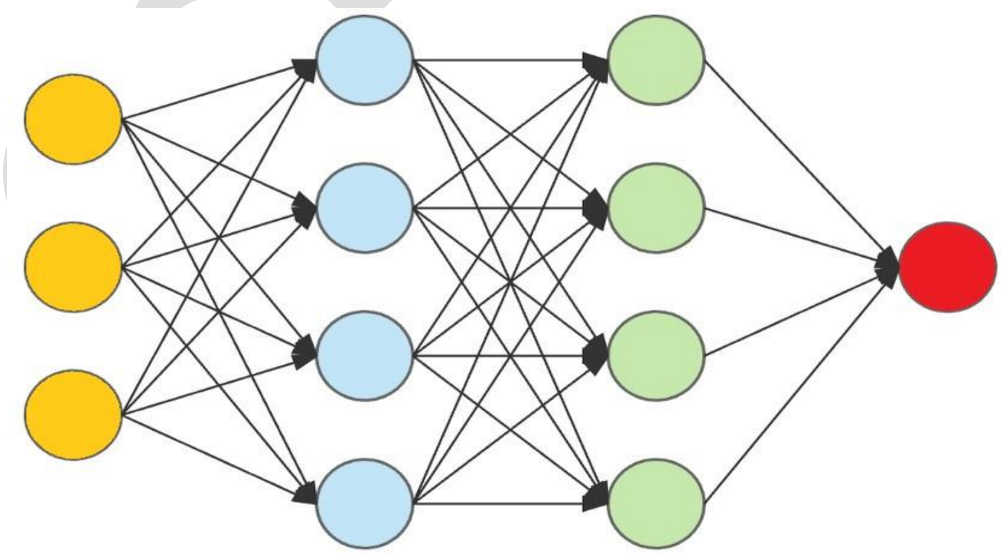
Neural Networks is one of the most significant discoveries in history.

Neural Networks can solve problems that can NOT be solved by algorithms:

- Medical Diagnosis
- Face Detection
- Voice Recognition

The Neural Network Model

Input data (Yellow) are processed against a hidden layer (Blue) and modified against another hidden layer (Green) to produce the final output (Red).



"A computer program is said to learn from experience E with respect to some class of tasks T and performance measure P, if its performance at tasks in T, as measured by P, improves with experience E."

Tom Mitchell (1999)

Deep Learning

Classical programming uses programs (algorithms) to create results:

Traditional Computing

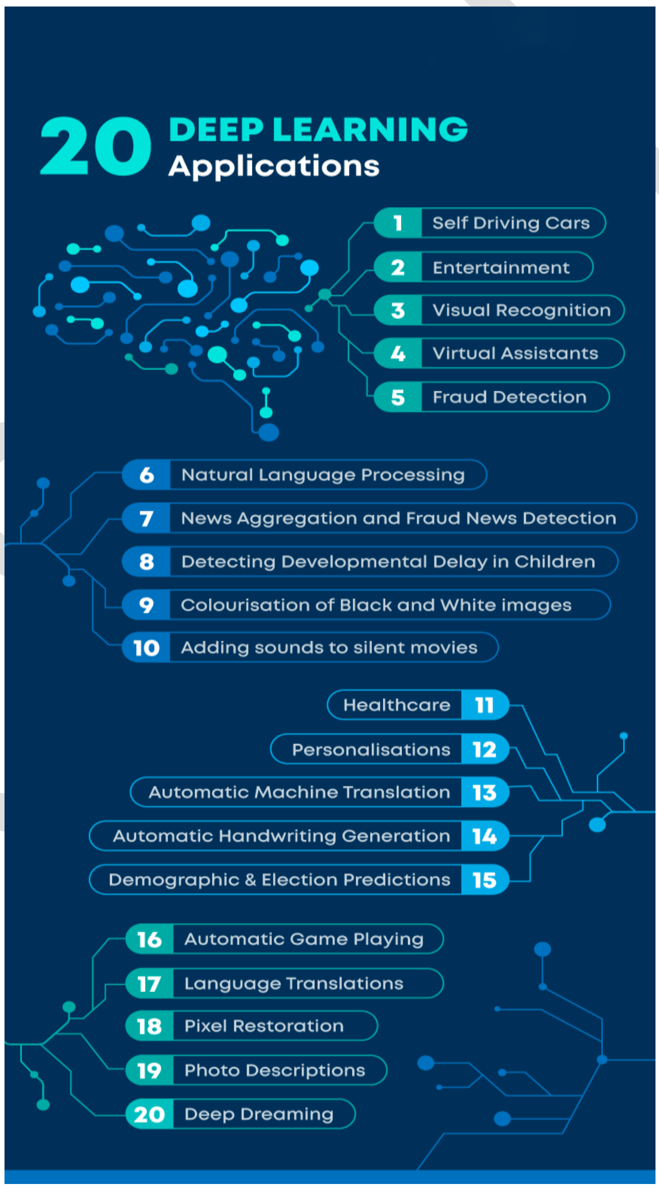
Data + Computer Algorithm = **Result**

Machine Learning uses results to create programs (algorithms):

Machine Learning

Data + Result = **Computer Algorithm**

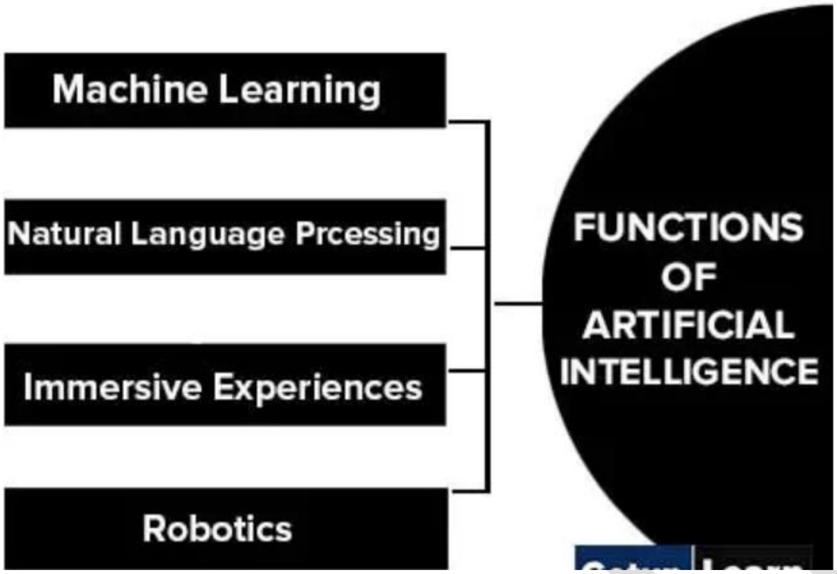
Top Applications of Deep Learning Across Industries



7. **FUNCTIONS OF AI**

These are functions of artificial intelligence which given below:

1. Machine Learning
2. Natural Language Processing (NLP)
3. Immersive Experiences
4. Robotics



Machine Learning

Machine Learning is a subsystem of Artificial Intelligence, wherein computers have the ability to learn from data using statistical techniques, without being explicitly programmed by a human being. It comprises algorithms that use data to learn on their own and make predictions.

These algorithms called models are first trained and tested using training data and testing data, respectively. After successive training, once these models are able to give results to an acceptable level of accuracy, they are used to make predictions about new and unknown data.

Natural Language Processing (NLP)

The predictive typing feature of the search engine helps us by suggesting the next word in the sentence while typing keywords and the spell checking features are examples of Natural Language Processing (NLP). It deals with the interaction between humans and computers using human spoken languages, such as Hindi, English, etc.

In fact, it is possible to search the web or operate or control our devices using our voice. All this has been possible by NLP. An NLP system can perform text-to-speech and speech-to-text conversion.

Machine translation is a rapidly emerging field where machines are already able to translate texts from one language to another with a fair amount of correctness. Another emerging application area is automated customer service where computer software can interact with customers to serve their queries or complaints.

Immersive Experiences

With the three-dimensional (3D) videography, the joy of watching movies in theatres has reached to a new level. Video games are also being developed to provide immersive experiences to the player. Immersive experiences allow us to visualize, feel and react by stimulating our senses.

It enhances our interaction and involvement, making them more realistic and engaging. Immersive experiences have been used in the field of training, such as driving simulators, flight simulators, and so on.

Immersive experience can be achieved using virtual reality and augmented reality:

1. Virtual Reality
2. Augmented Reality

Virtual Reality

Everything that we experience in our reality is perceived through our senses. From this came the idea that if we can present our senses with made-up or nonreal information, our perception of reality would also alter in response to that.

Virtual Reality (VR) is a three-dimensional, computer-generated situation that simulates the real world. The user can interact with and explore that environment by getting immersed in it while interacting with the objects and other actions of the user. At present, it is achieved with the help of VR Headsets.

In order to make the experience of VR more realistic, it promotes other sensory information like sound, smell, motion, temperature, etc.

It is a comparatively new field and has found its applications in gaming, military training, medical procedures, entertainment, social science and psychology, engineering, and other areas where simulation is needed for a better understanding and learning.

Augmented Reality

The superimposition of computer-generated perceptual information over the existing physical surroundings is called Augmented Reality (AR). It adds components of the digital world to the physical world, along with the associated tactile and other sensory requirements, thereby making the environment interactive and digitally manipulable.

Users can access information about the nearest places with reference to their current location. They can get information about places and choose on the basis of user reviews.

With help of location-based AR App, travelers can access real-time information of historical places just by pointing their camera viewfinder to subjects as depicted in Location-based AR apps are major forms of AR apps.

Robotics

A robot is basically a machine capable of carrying out one or more tasks automatically with accuracy and precision. Unlike other machines, a robot is programmable by a computer, which means it can follow the instructions given through computer programs.

Robots were initially conceptualized for doing repetitive industrial tasks that are boring or stressful for humans or were labor-intensive. Sensors are one of the prime components of a robot.

Robot can be of many types, such as wheeled robots, legged robots, manipulators, and humanoids. Robots that resemble humans are known as humanoids. Robots are being used in industries, medical science, bionics, scientific research, the military, etc.

Some examples are:

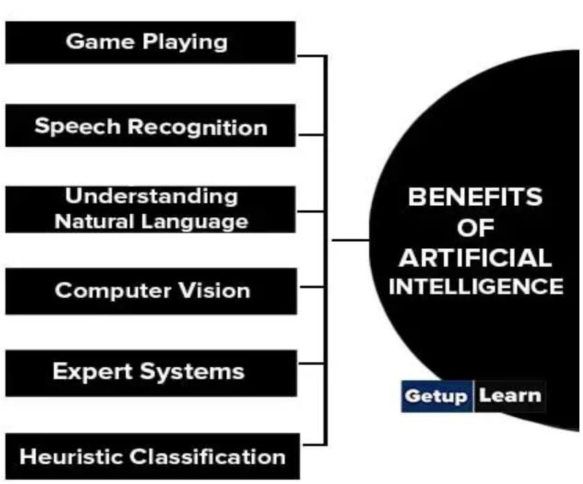
- NASA's Mars Exploration Rover (MER) mission is a robotic space mission to study about the planet Mars.
- Sophia is a humanoid that uses artificial intelligence, visual data processing, facial recognition and also imitates human gestures and facial expressions.
- A drone is an unmanned aircraft which can be remotely controlled or can fly autonomously through software-controlled flight plans in their embedded systems, working in conjunction with onboard sensors and GPS .

  They are being used in many fields, such as journalism, filming and aerial photography, shipping or delivery at short distances, disaster management, search and rescue operations, healthcare, geographic mapping and structural safety inspections, agriculture, wildlife monitoring or pooching, besides law-enforcement and border patrolling.

Benefits of Artificial Intelligence

These are some benefits of artificial intelligence (AI) discussed below:

1. Game Playing
2. Speech Recognition
3. Understanding Natural Language
4. Computer Vision
5. Expert Systems
6. Heuristic Classification



8.CHARACTERISTICS OF ARTIFICIAL INTELLIGENCE

Characteristics of artificial intelligence

1. **Elimination of monotonous tasks**

It implies that an artificial intelligence system continues to do the task as instructed, no matter how many times it has to do it. This also leads to minimizing human errors and costs.

2. **Handling a large amount of data**

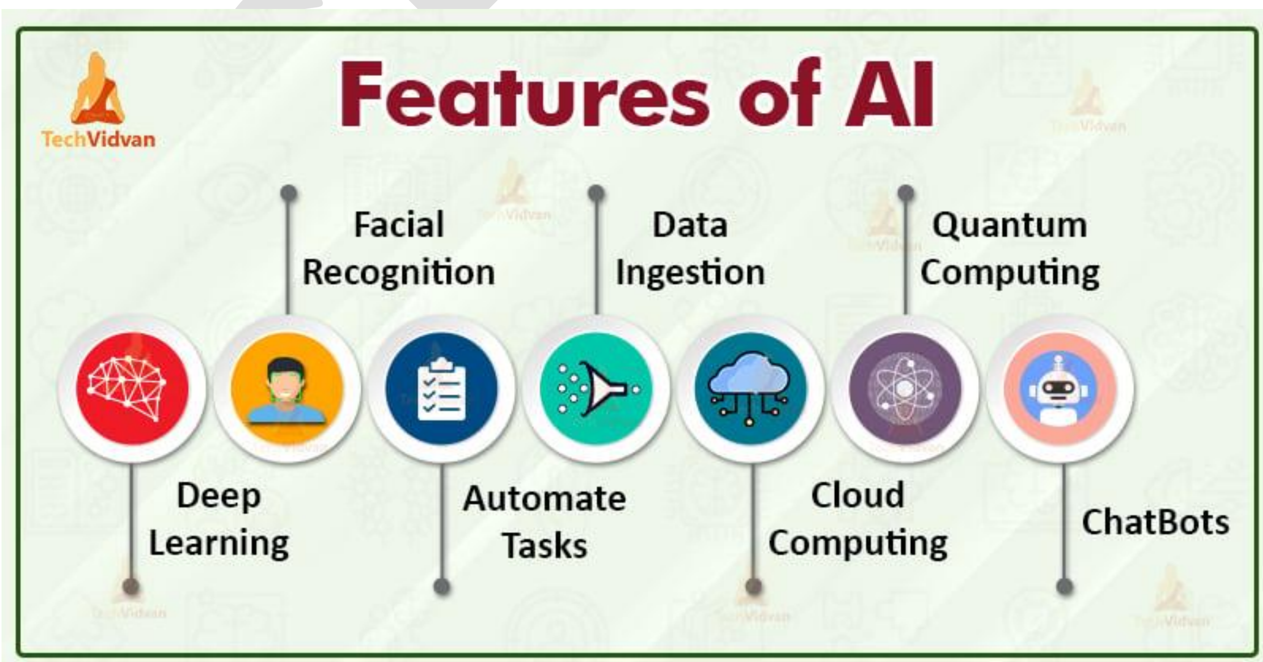
It represents one of the most relevant aspects of **the characteristics of artificial intelligence**. Artificially intelligent systems manage large amounts of data. Even a small company of about fifty employees has enormous amounts of data to analyze, which can be managed thanks to these systems. In addition, information is stored from multiple sources.

3. **Imitation of human cognition**

This is one of the most outstanding **characteristics of artificial intelligence**. Why? Well, these systems mimic the way the human mind thinks and solves problems. So inferences are made, the environment is interpreted and decisions are made (Mazurek, 2019). It is possible that not everything can be identical; however, developers and scientists are working hard to fully achieve this particularity.

4. **They are futuristic**

Businesses that employ artificial intelligence can rely on environmental sensing to find opportunities. For example, an autonomous vehicle records the speed of nearby cars and attempts to execute patterns similar to those found in traffic. Using technologies such as machine learning, data can be fed into algorithms and a certain target can be obtained in various scenarios.



Artificial Intelligence Characteristics

1. Deep Learning

Deep learning is a machine learning technique that teaches computers to do what comes naturally to humans, to learn by example. Innumerable developers are leveraging the latest deep learning innovative technologies to take their business to the new high.

There are large numbers of fields of Artificial Intelligence technology like autonomous vehicles, computer vision, automatic text generation, and the like, where the scope and use of deep learning are increasing.

Take an example of **Self Driving feature in cars like Tesla(Autopilot)**, where Deep learning is a key technology behind enabling them to recognize a stop sign or to distinguish a pedestrian from a lamppost.

2. Facial Recognition

Artificial Intelligence has made it possible to recognize individual faces using biometric mapping. This has lead to pathbreaking advancements in surveillance technologies. It compares the knowledge with a database of known faces to seek out a match.

However, this has also faced a lot of criticism for breach of privacy.

For example, Clearview AI, an American technology company, offers surveillance technology for law agencies to monitor entire cities with a network of CCTV Cameras exactly assigning each and every citizen with their Social Credit Score in real-time.

3. Automate Simple and Repetitive Tasks

AI has the ability to execute the same kind of work over and over again without breaking a sweat. To understand this feature better, let's take the example of **Siri**, a voice-enabled assistant created by Apple Inc. It can handle so many commands in a single day!

From asking to take up notes for a brief, to rescheduling the calendar for a meeting, to guiding us through the streets with navigation, the assistant has it all covered.

Earlier, all of these activities had to be done manually which used to take up a lot of time and effort.

The automation would not only lead to increased efficiencies but also result in lower overhead costs and in some cases a safer work environment.

4. Data Ingestion

With every passing day, the data that we are all producing is growing exponentially, which is where AI steps in. Instead of manually feeding this data, **AI-enabled** not just gathers this data but also analyzes it with the help of its previous experiences.

Data ingestion is that the transportation of knowledge from assorted sources to a data-storage medium where it are often accessed, used, and analyzed by a corporation.

AI, with the help of neural networks, analyzes a large amount of such data and helps in providing a logical inference out of it.

5. Chatbots

Chatbots are software to provide a window for solving customer problems' through either audio or textual input. Earlier the bots used to respond only to specific commands. If you say the wrong thing, it didn't know what you meant.

The bot was only as smart as it was programmed to be. The real change came when these chatbots were enabled by artificial intelligence.

Now, you don't have to be ridiculously specific when you are talking to the chatbot. It understands language, not just commands.

For example, **Watson Assistant, an AI-powered assistant, developed by IBM** which can run across various channels like websites, messengers, and apps and requires zero human intervention once programmed.

There are a lot of companies that have moved on from voice process executives to chatbots to help customers solve their problems.

The chatbots not only offer services revolving around issues that the customers face but also provides product suggestions to the users. All this, just because of AI.

6. Quantum Computing

AI is helping solve complex quantum physics problems with the accuracy of supercomputers with the help of quantum neural networks. This can lead to path-breaking developments in the near future.

It is an interdisciplinary field that focuses on building quantum algorithms for improving computational tasks within AI, including sub-fields like machine learning.

The whole concept of quantum-enhanced AI algorithms remains in the conceptual research domain

For example, A pioneer in this field is **Google AI Quantum** whose objective is to develop superconducting qubit processors and quantum-assisted optimization for varied applications.

7. Cloud Computing

Next Artificial Intelligence characteristics is Cloud Computing. With such a huge amount of data being churned out every day, data storage in a physical form would have been a major problem.

AI capabilities are working within the business cloud computing environment to make organizations more efficient, strategic, and insight-driven.

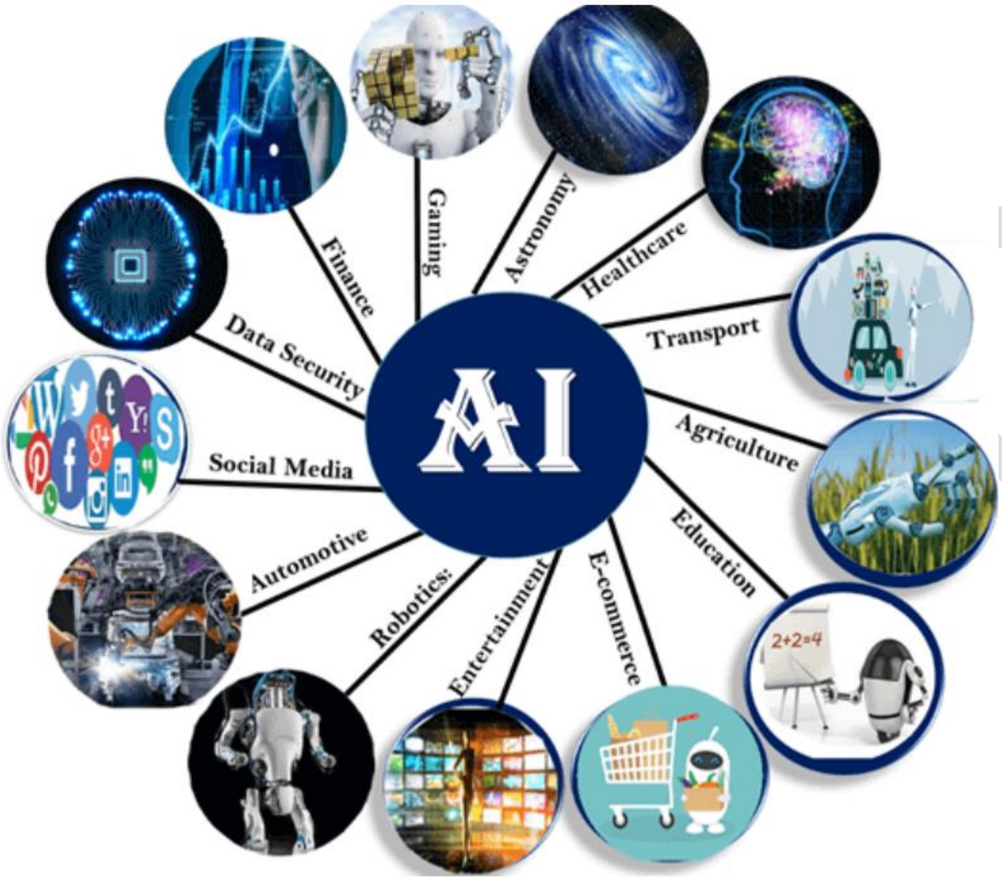
However, the advent of Cloud Computing has saved us from such worries.

Microsoft Azure is one of the prominent players in the cloud computing industry. It offers to deploy your own machine learning models to your data stored in cloud servers without any lock-in.

9.APPLICATIONS OF AI

It is becoming essential for today's time because it can solve complex problems with an efficient way in multiple industries, such as Healthcare, entertainment, finance, education, etc. AI is making our daily life more comfortable and fast.

Following are some sectors which have the application of Artificial Intelligence:



1. AI in Astronomy

- Artificial Intelligence can be very useful to solve complex universe problems. AI technology can be helpful for understanding the universe such as how it works, origin, etc.

2. AI in Healthcare

- In the last, five to ten years, AI becoming more advantageous for the healthcare industry and going to have a significant impact on this industry.
- Healthcare Industries are applying AI to make a better and faster diagnosis than humans. AI can help doctors with diagnoses and can inform when patients are worsening so that medical help can reach to the patient before hospitalization.

3. AI in Gaming

- AI can be used for gaming purpose. The AI machines can play strategic games like chess, where the machine needs to think of a large number of possible places.

4. AI in Finance

- AI and finance industries are the best matches for each other. The finance industry is implementing automation, chatbot, adaptive intelligence, algorithm trading, and machine learning into financial processes.

5. AI in Data Security

- The security of data is crucial for every company and cyber-attacks are growing very rapidly in the digital world. AI can be used to make your data more safe and secure. Some examples such as AEG bot, AI2 Platform,are used to determine software bug and cyber-attacks in a better way.

6. AI in Social Media

- Social Media sites such as Facebook, Twitter, and Snapchat contain billions of user profiles, which need to be stored and managed in a very efficient way. AI can organize and manage massive amounts of data. AI can analyze lots of data to identify the latest trends, hashtag, and requirement of different users.

7. AI in Travel & Transport

- AI is becoming highly demanding for travel industries. AI is capable of doing various travel related works such as from making travel arrangement to suggesting the hotels, flights, and best routes to the customers. Travel industries are using AI-powered chatbots which can make human-like interaction with customers for better and fast response.

8. AI in Automotive Industry

- Some Automotive industries are using AI to provide virtual assistant to their user for better performance. Such as Tesla has introduced TeslaBot, an intelligent virtual assistant.
- Various Industries are currently working for developing self-driven cars which can make your journey more safe and secure.

9. AI in Robotics:

- Artificial Intelligence has a remarkable role in Robotics. Usually, general robots are programmed such that they can perform some repetitive task, but with the help of AI, we can create intelligent robots which can perform tasks with their own experiences without pre-programmed.
- Humanoid Robots are best examples for AI in robotics, recently the intelligent Humanoid robot named as Erica and Sophia has been developed which can talk and behave like humans.

10. AI in Entertainment

- We are currently using some AI based applications in our daily life with some entertainment services such as Netflix or Amazon. With the help of ML/AI algorithms, these services show the recommendations for programs or shows.

11. AI in Agriculture

- Agriculture is an area which requires various resources, labor, money, and time for best result. Now a day's agriculture is becoming digital, and AI is emerging in this field. Agriculture is applying AI as agriculture robotics, solid and crop monitoring, predictive analysis. AI in agriculture can be very helpful for farmers.

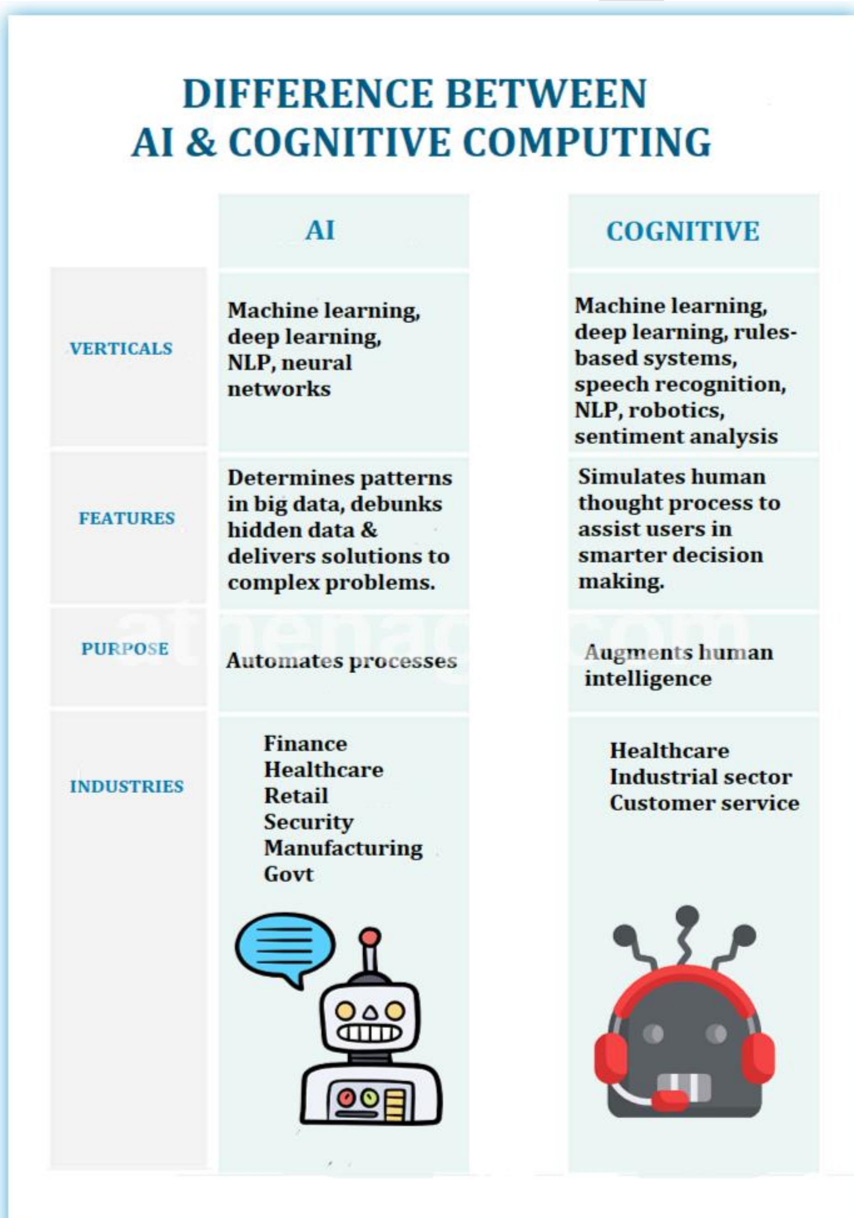
12. AI in E-commerce

- AI is providing a competitive edge to the e-commerce industry, and it is becoming more demanding in the e-commerce business. AI is helping shoppers to discover associated products with recommended size, color, or even brand.

13. AI in education:

- AI can automate grading so that the tutor can have more time to teach. AI chatbot can communicate with students as a teaching assistant.
- AI in the future can be work as a personal virtual tutor for students, which will be accessible easily at any time and any place.

10.COGNITIVE SCIENCE AND AI



DIFFERENCE BETWEEN AI & COGNITIVE COMPUTING

	AI	COGNITIVE
VERTICALS	Machine learning, deep learning, NLP, neural networks	Machine learning, deep learning, rules-based systems, speech recognition, NLP, robotics, sentiment analysis
FEATURES	Determines patterns in big data, debunks hidden data & delivers solutions to complex problems.	Simulates human thought process to assist users in smarter decision making.
PURPOSE	Automates processes	Augments human intelligence
INDUSTRIES	Finance Healthcare Retail Security Manufacturing Govt	Healthcare Industrial sector Customer service

Cognitive systems are designed to solve problems the way humans solve problems, by thinking, reasoning, and remembering.

Cognitive computing, on the other hand, is a sub-field of artificial intelligence. This synthetic technology is majorly based on reasoning and understanding at a much higher level. Cognitive technology, in a way, tries to match the level of the human apprehension, as it is designed to make human-like decisions in complex situations.

Based on the reasoning capability, cognitive systems are able to learn quickly and adapt as new data arrives. They explore and understand things that earlier machines had failed and humans ignored.

Artificial intelligence, sometimes called machine intelligence, is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and other animals. In computer science, AI research is defined as the study of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. Colloquially, the term "artificial intelligence" is applied when a machine mimics "cognitive" functions that humans associate with other human minds, such as "learning" and "problem-solving".

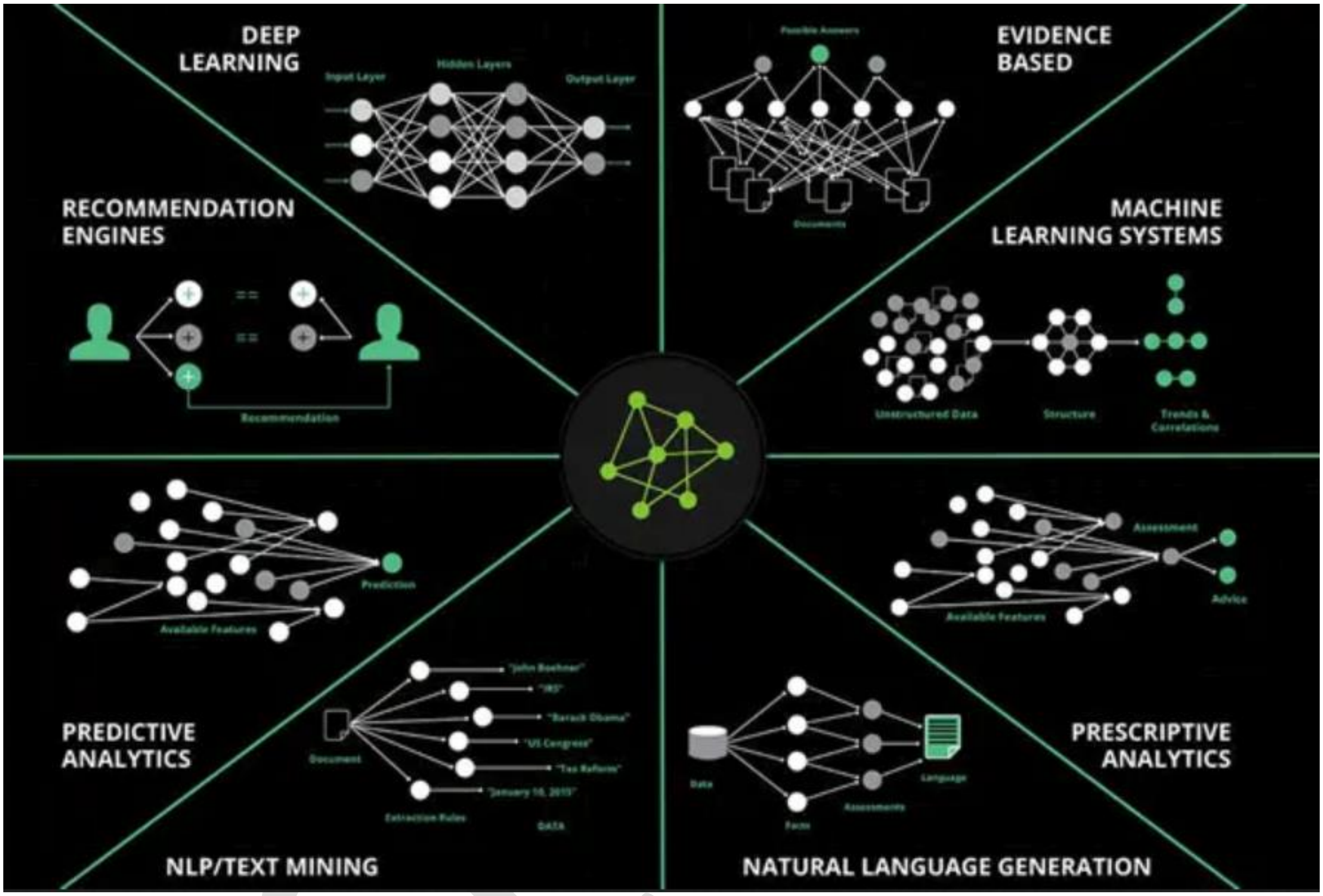
AI enables computers to execute tasks that were performed by human intelligence until now. Implying that machine learning, robotics, NLP, synthetic intelligence and text mining are all a part of artificial intelligence and are correlated in some way or the other.

Artificial intelligence (AI) is already present in plenty of applications, from search algorithms and tools you use every day to bionic limbs for the disabled. Cognitive computing is a term used by IBM. Computers aren't really cognitive, however.

Fast growing AI technologies for consumer facing industries include chat bots and Virtual Personal Assistants *(VPA)* and smart advisors.

Artificial intelligence is being used faster in many technological and societal areas although there is quite some hype about what "it" can do from vendors. Still, the increasing attention and adoption of forms of AI in specific areas triggers debates about how far we want it to go in the future.

AI in context: how it interacts with other transformational technologies



11.COGNITION AND PROCESS OF COGNITION

What is cognitive computing?

Cognitive computing is the use of computerized models to simulate the human thought process in complex situations where the answers might be ambiguous and uncertain. The phrase is closely associated with IBM's cognitive computer system, Watson.

Computers are faster than humans at processing and calculating, but they've yet to master some tasks, such as understanding natural language and recognizing objects in an image. Cognitive computing is an attempt to have computers mimic the way the human brain works.

To accomplish this, cognitive computing uses artificial intelligence (AI) and other underlying technologies, including the following:

- Expert systems.
- Neural networks.
- Machine learning.
- Deep learning.

- Natural language processing (NLP).
- Speech recognition.
- Object recognition.
- Robotics.

Cognitive computing uses these processes in conjunction with self-learning algorithms, data analysis and pattern recognition to teach computing systems. The learning technology can be used for sentiment analysis, risk assessments and face detection. In addition, cognitive computing is particularly useful in fields such as healthcare, banking, finance and retail.

How cognitive computing works

Systems used in the cognitive sciences combine data from various sources while weighing context and conflicting evidence to suggest the best possible answers. To achieve this, cognitive systems include self-learning technologies that use data mining, pattern recognition and NLP to mimic human intelligence.

Using computer systems to solve the types of problems that humans are typically tasked with requires vast amounts of structured and unstructured data fed to machine learning algorithms. Over time, cognitive systems can refine the way they identify patterns and process data. They become capable of anticipating new problems and modeling possible solutions.

For example, by storing thousands of pictures of dogs in a database, an AI system can be taught how to identify pictures of dogs. The more data a system is exposed to, the more it's able to learn and the more accurate it becomes over time.

To achieve those capabilities, cognitive computing systems must have the following attributes:

- **Adaptive.** Systems must be flexible enough to learn as information changes and goals evolve. They must digest dynamic data in real time and adjust as the data and environments change.
- **Interactive.** Human-computer interaction is a critical component in cognitive systems. Users must be able to interact with cognitive machines and define their needs as they change. The technologies must also be able to interact with other processors, devices and cloud platforms.
- **Iterative and stateful.** Cognitive computing technologies can ask questions and pull in additional data to identify or clarify a problem. They must be stateful in that they keep information about similar situations that have occurred previously.

Contextual. Understanding context is critical in thought processes. Cognitive systems must understand, identify and mine contextual data, such as syntax, time, location, domain, user requirements, user profiles, tasks and goals. The systems can draw on multiple sources of information, including structured and unstructured data and visual, auditory and sensor data.

<u>Examples and applications of cognitive computing</u>

Cognitive computing systems are typically used to accomplish tasks that require parsing large amounts of data. For example, in computer science, cognitive computing aids in big data analytics, identifying trends and patterns, understanding human language and interacting with customers.

The following examples show how cognitive computing is used in various industries:

- **Healthcare.** Cognitive computing can manage and analyze large amounts of unstructured healthcare data such as patient histories, diagnoses, conditions and journal research articles to make recommendations to medical professionals. The goal is to help doctors make better treatment decisions, as cognitive technology expands their capabilities and assists with decision-making.
- **Retail.** In retail environments, cognitive technologies analyze basic information about the customer, along with details about the product the customer is considering and can provide the customer with personalized suggestions.
- **Banking and finance.** Cognitive computing in the banking and finance industry analyzes unstructured data from different sources to gain more knowledge about customers. NLP is used to create chatbots that communicate with customers to help improve operational efficiency and customer engagement.
- **Logistics.** Cognitive computing aids in areas such as warehouse management, warehouse automation, networking, and internet of things and other edge computing devices.
- **Human cognitive augmentation.** This interdisciplinary field integrates cognitive computing, psychology, neuroscience, engineering and other disciplines to collaboratively create innovative apps and tools for cognitive enhancement. Cognitive technologies are used to surpass the average level of mental capabilities. Examples include memory recall assistance and cognitive-enhancing brain implants, which can be particularly beneficial for individuals with conditions such as attention-deficit/hyperactive disorder or amnesia.
- **Customer service.** By employing intelligent chatbots and virtual assistants, cognitive computing can augment the customer service experience. These advanced systems can decipher natural language inquiries, enabling tailored interactions and faster resolution of customer queries.

Advantages of cognitive computing

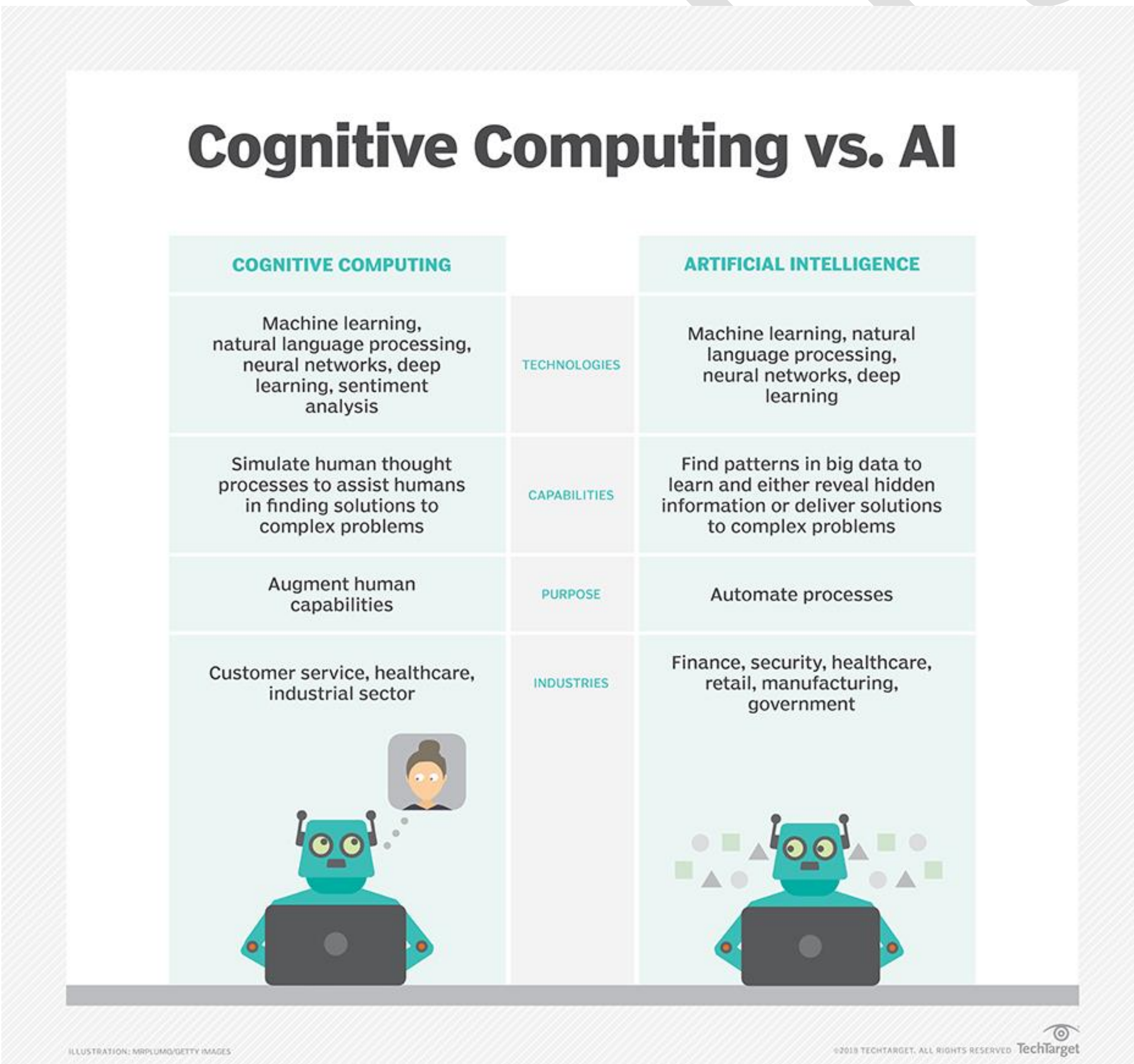
Advantages of cognitive computing include positive outcomes for the following:

- **Analytical accuracy.** Cognitive computing is proficient at juxtaposing and cross-referencing structured and unstructured data from a variety of sources, such as images, videos and text.
- **Business process efficiency.** Cognitive technology can recognize patterns when analyzing large data sets.
- **Customer interaction and experience.** The contextual and relevant information that cognitive computing provides to customers through tools like chatbots improves customer interactions. A combination of cognitive assistants, personalized recommendations and behavioral predictions enhances the customer experience.
- **Employee productivity and service quality.** Cognitive systems help employees analyze structured and unstructured data to identify data patterns and trends.
- **Troubleshooting and error detection.** With the ability to conduct pattern analysis and tracking, cognitive computing models are highly effective at detecting errors in software code and encryption algorithms for security systems. In sophisticated technical frameworks, cognitive computing promotes faster and more precise problem-solving by enabling error detection in business processes.

Disadvantages of cognitive systems

Cognitive technology also has downsides, including the following:

- **Security challenges.** Cognitive systems need large amounts of data to learn from, which can make them more vulnerable to cybersecurity breaches. Organizations using the systems must properly protect the data, especially if it's health, customer or any type of personally identifiable information.
- **Long development cycle length.** These systems require skilled development teams and a considerable amount of time to develop software that makes them useful. The systems themselves need extensive and detailed training with large data sets to understand given tasks and processes. That process might hinder companies with smaller development teams from integrating cognitive computing processes into their applications due to the complexity and level of expertise required.
- **Slow adoption.** The development lifecycle is one reason for slow adoption rates. Smaller organizations might anticipate the difficulty of implementing cognitive systems and therefore avoid them.
- **Negative environmental impact.** The process of training cognitive systems and neural networks consumes a lot of power, resulting in a sizable carbon footprint.



12. LINGUISTICS, ARTIFICIAL INTELLIGENCE AS COGNITIVE SCIENCE

Artificial intelligence (AI) and cognitive computing are two stellar technologies crafted to:

- Reduce human intervention
- Improve business processes across industries.

Differences between artificial intelligence and cognitive computing

Artificial intelligence	Cognitive computing
1. It's very likely you have seen a need for Natural Language Processing (NLP), speech recognition, document or image processing, and chatbots. That's where AI plays a tremendous role.	1. When it comes to sentiment analysis, facial recognition, and fraud detection, cognitive computing lends a hand in all of these.
2. Artificial intelligence helps machines make everyday decisions instead of humans.	2. Cognitive technology blends computer science and cognitive science to take human intelligence to the next level!
3. AI utilizes human senses, human processing, and human responses thanks to fascinating tools and technologies such as deep learning and machine learning.	3. Cognitive computing utilizes cognitive technologies to imitate human behavior and logic, making decision-making abilities much better.

Use cases of cognitive computing

Here are certain instances where cognitive computing plays a key role:

- In the realm of medicine, cognitive computing is contributing towards more accurate diagnoses and more prudent treatment decisions. These days doctors have easier access to therapies and diagnoses since cognitive computing has the capacity to access datasets, location notwithstanding.
- Cognitive computing makes a mark in the retail realm to give customers a personalized e-shopping experience that is supremely convenient.
- Companies offering financial services also leverage the analytic capabilities of cognitive computing. Chances are that you have been wondering how to find a good tool in order to gauge investment risk. Cognitive computing helps financial organizations in assessing investment risk.
- The technology of cognitive computing comes in very useful for manufacturers as well. They leverage it for the upkeep of their equipment and machinery.

13. METHODS IN COGNITIVE SCIENCE –PPT

14. INTRODUCTION TO KNOWLEDGE REPRESENTATION SYSTEMS,

Humans are best at understanding, reasoning, and interpreting knowledge. Human knows things, which is knowledge and as per their knowledge they perform various actions in the real world. **But how machines do all these things comes under knowledge representation and reasoning**. Hence we can describe Knowledge representation as following:

- Knowledge representation and reasoning (KR, KRR) is the part of Artificial intelligence which concerned with AI agents thinking and how thinking contributes to intelligent behavior of agents.
- It is responsible for representing information about the real world so that a computer can understand and can utilize this knowledge to solve the complex real world problems such as diagnosis a medical condition or communicating with humans in natural language.
- It is also a way which describes how we can represent knowledge in artificial intelligence. Knowledge representation is not just storing data into some database, but it also enables an intelligent machine to learn from that knowledge and experiences so that it can behave intelligently like a human.

What to Represent:

Following are the kind of knowledge which needs to be represented in AI systems:

- **Object:** All the facts about objects in our world domain. E.g., Guitars contains strings, trumpets are brass instruments.
- **Events:** Events are the actions which occur in our world.
- **Performance:** It describe behavior which involves knowledge about how to do things.
- **Meta-knowledge:** It is knowledge about what we know.
- **Facts:** Facts are the truths about the real world and what we represent.
- **Knowledge-Base:** The central component of the knowledge-based agents is the knowledge base. It is represented as KB. The Knowledgebase is a group of the Sentences (Here, sentences are used as a technical term and not identical with the English language).

Knowledge: Knowledge is awareness or familiarity gained by experiences of facts, data, and situations. Following are the types of knowledge in artificial intelligence:

Types of knowledge

1. Declarative Knowledge:

- Declarative knowledge is to know about something.
- It includes concepts, facts, and objects.
- It is also called descriptive knowledge and expressed in declarativesentences.
- It is simpler than procedural language.

2. Procedural Knowledge

- It is also known as imperative knowledge.
- Procedural knowledge is a type of knowledge which is responsible for knowing how to do something.
- It can be directly applied to any task.
- It includes rules, strategies, procedures, agendas, etc.
- Procedural knowledge depends on the task on which it can be applied.

3. Meta-knowledge:

- Knowledge about the other types of knowledge is called Meta-knowledge.

4. Heuristic knowledge:

- Heuristic knowledge is representing knowledge of some experts in a filed or subject.
- Heuristic knowledge is rules of thumb based on previous experiences, awareness of approaches, and which are good to work but not guaranteed.

5. Structural knowledge:

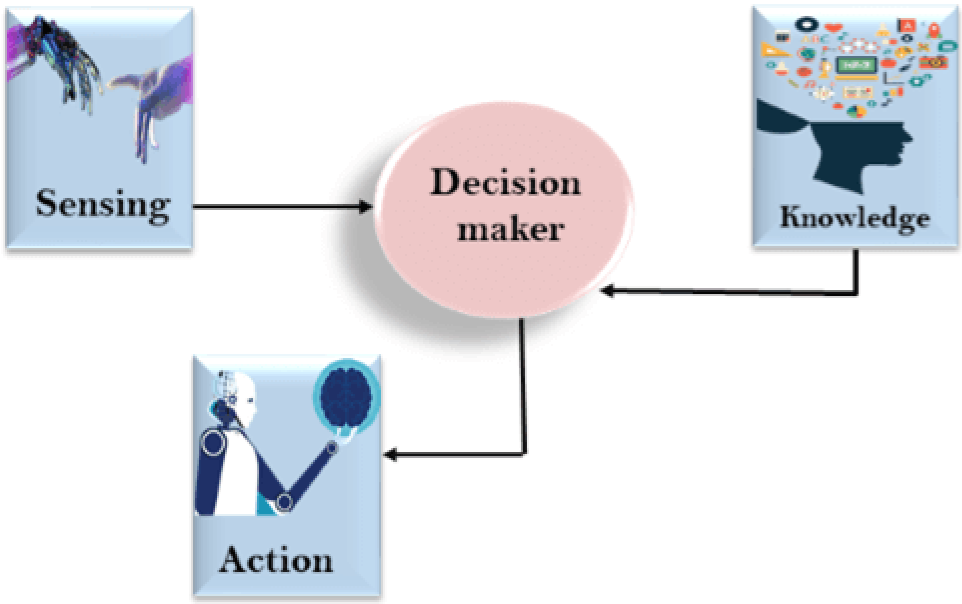
- Structural knowledge is basic knowledge to problem-solving.
- It describes relationships between various concepts such as kind of, part of, and grouping of something.
- It describes the relationship that exists between concepts or objects.

The relation between knowledge and intelligence:

Knowledge of real-worlds plays a vital role in intelligence and same for creating artificial intelligence. Knowledge plays an important role in demonstrating intelligent behavior in AI agents. An agent is only able to accurately act on some input when he has some knowledge or experience about that input.

Let's suppose if you met some person who is speaking in a language which you don't know, then how you will able to act on that. The same thing applies to the intelligent behavior of the agents.

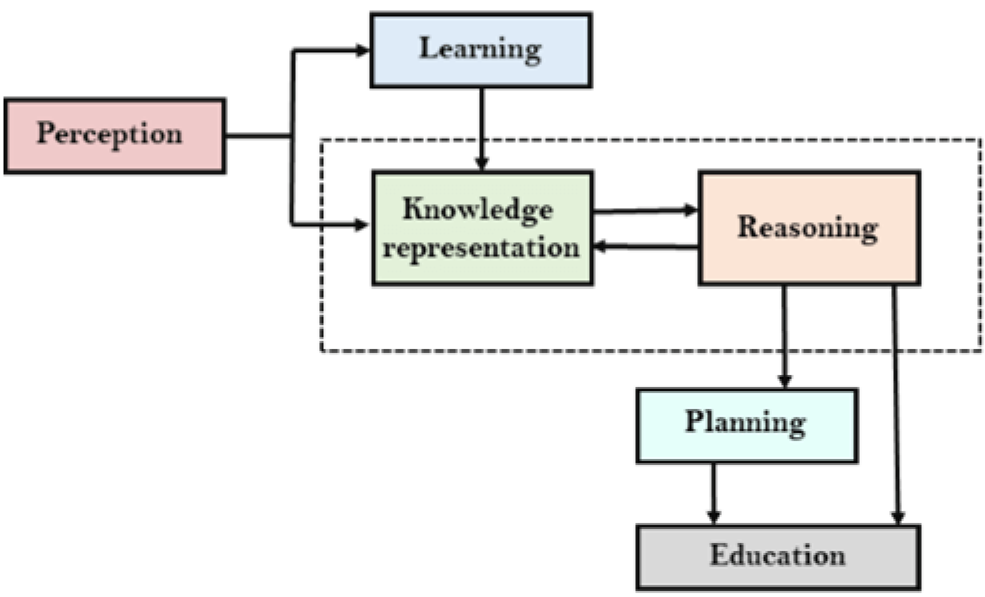
As we can see in below diagram, there is one decision maker which act by sensing the environment and using knowledge. But if the knowledge part will not present then, it cannot display intelligent behavior.



AI knowledge cycle:

An Artificial intelligence system has the following components for displaying intelligent behavior:

- Perception
- Learning
- Knowledge Representation and Reasoning
- Planning
- Execution



The above diagram is showing how an AI system can interact with the real world and what components help it to show intelligence. AI system has Perception component by which it retrieves information from its environment. It can be visual, audio or another form of sensory input. The learning component is responsible for learning from data captured by Perception comportment.

In the complete cycle, the main components are knowledge representation and Reasoning. These two components are involved in showing the intelligence in machine-like humans. These two components are independent with each other but also coupled together. The planning and execution depend on analysis of Knowledge representation and reasoning.

Approaches to knowledge representation:

There are mainly four approaches to knowledge representation, which are givenbelow:

1. Simple relational knowledge:

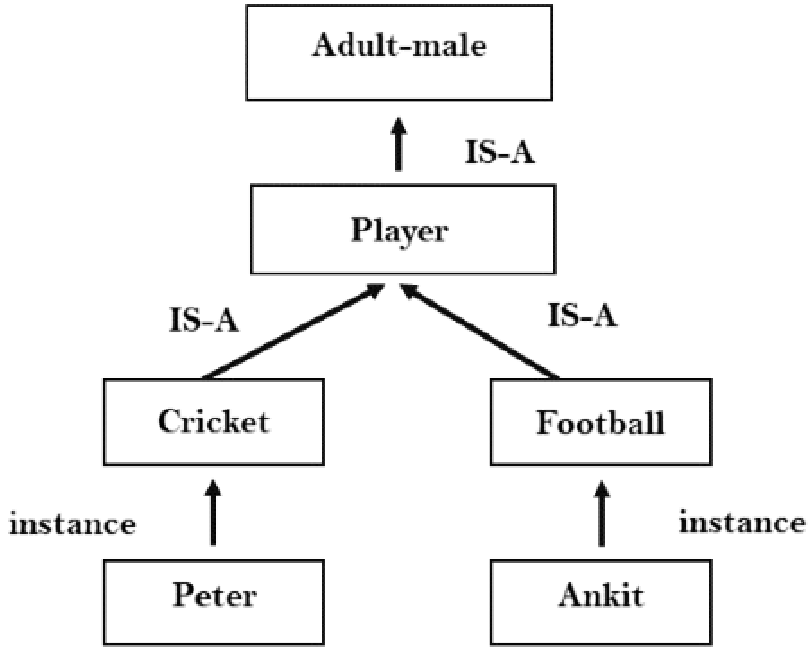
- It is the simplest way of storing facts which uses the relational method, and each fact about a set of the object is set out systematically in columns.
- This approach of knowledge representation is famous in database systems where the relationship between different entities is represented.
- This approach has little opportunity for inference.

Example: The following is the simple relational knowledge representation.

Player	Weight	Age
Player1	65	23
Player2	58	18
Player3	75	24

2. Inheritable knowledge:

- In the inheritable knowledge approach, all data must be stored into a hierarchy of classes.
- All classes should be arranged in a generalized form or a hierarchal manner.
- In this approach, we apply inheritance property.
- Elements inherit values from other members of a class.
- This approach contains inheritable knowledge which shows a relation between instance and class, and it is called instance relation.
- Every individual frame can represent the collection of attributes and its value.
- In this approach, objects and values are represented in Boxed nodes.
- We use Arrows which point from objects to their values.
- **Example:**



3. Inferential knowledge:

- Inferential knowledge approach represents knowledge in the form of formal logics.
- This approach can be used to derive more facts.
- It guaranteed correctness.
- **Example:** Let's suppose there are two statements:
    1. Marcus is a man
    2. All men are mortal
       Then it can represent as;

       man(Marcus)
       ∀x = man (x) ----------> mortal (x)s

4. Procedural knowledge:

- Procedural knowledge approach uses small programs and codes which describes how to do specific things, and how to proceed.
- In this approach, one important rule is used which is **If-Then rule**.
- In this knowledge, we can use various coding languages such as **LISP language** and **Prolog language**.
- We can easily represent heuristic or domain-specific knowledge using this approach.
- But it is not necessary that we can represent all cases in this approach.

Requirements for knowledge Representation system:

A good knowledge representation system must possess the following properties.

1. Representational Accuracy:
KR system should have the ability to represent all kind of required knowledge.

2. Inferential Adequacy:
KR system should have ability to manipulate the representational structures to produce new knowledge corresponding to existing structure.

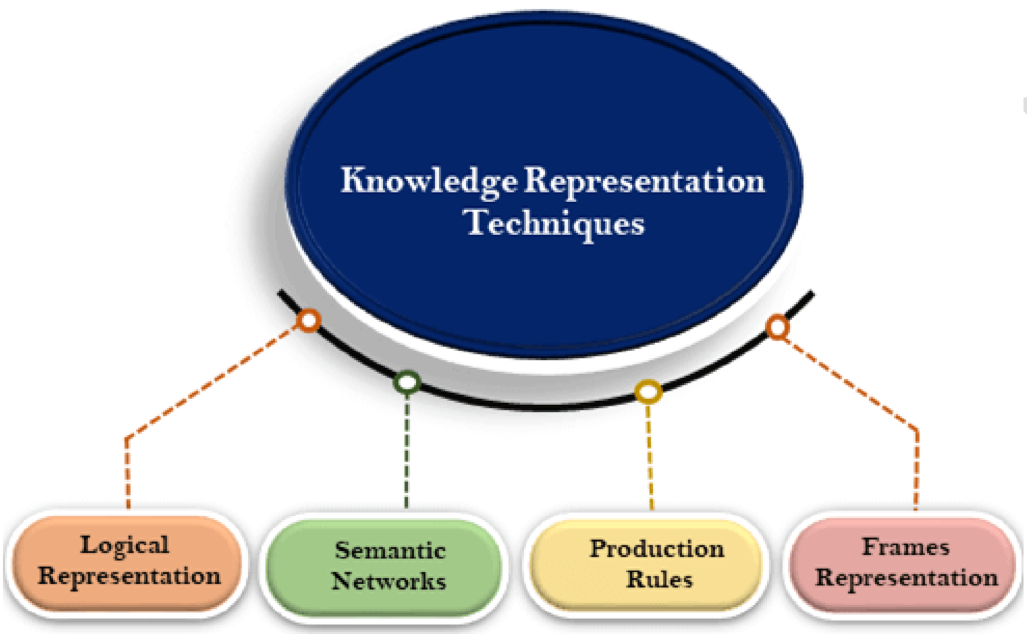
3. Inferential Efficiency:
The ability to direct the inferential knowledge mechanism into the most productive directions by storing appropriate guides.

4. Acquisitional efficiency- The ability to acquire the new knowledge easily using automatic methods.

15. KNOWLEDGE REPRESENTATION USING LOGIC

There are mainly four ways of knowledge representation which are given as follows:

1. Logical Representation
2. Semantic Network Representation
3. Frame Representation
4. Production Rules



1. Logical Representation

Logical representation is a language with some concrete rules which deals with propositions and has no ambiguity in representation. Logical representation means drawing a conclusion based on various conditions. This representation lays down some important communication rules. It consists of precisely defined syntax and semantics which supports the sound inference. Each sentence can be translated into logics using syntax and semantics.

Syntax:

- Syntaxes are the rules which decide how we can construct legal sentences in the logic.
- It determines which symbol we can use in knowledge representation.
- How to write those symbols.

Semantics:

- Semantics are the rules by which we can interpret the sentence in the logic.
- Semantic also involves assigning a meaning to each sentence.

Logical representation can be categorised into mainly two logics:

1. Propositional Logics
2. Predicate logics

Advantages of logical representation:

1. Logical representation enables us to do logical reasoning.
2. Logical representation is the basis for the programming languages.

Disadvantages of logical Representation:

1. Logical representations have some restrictions and are challenging to work with.
2. Logical representation technique may not be very natural, and inference may not be so efficient.

2. Semantic Network Representation

Semantic networks are alternative of predicate logic for knowledge representation. In Semantic networks, we can represent our knowledge in the form of graphical networks. This network consists of nodes representing objects and arcs which describe the relationship between those objects. Semantic networks can categorize the object in different forms and can also link those objects. Semantic networks are easy to understand and can be easily extended.

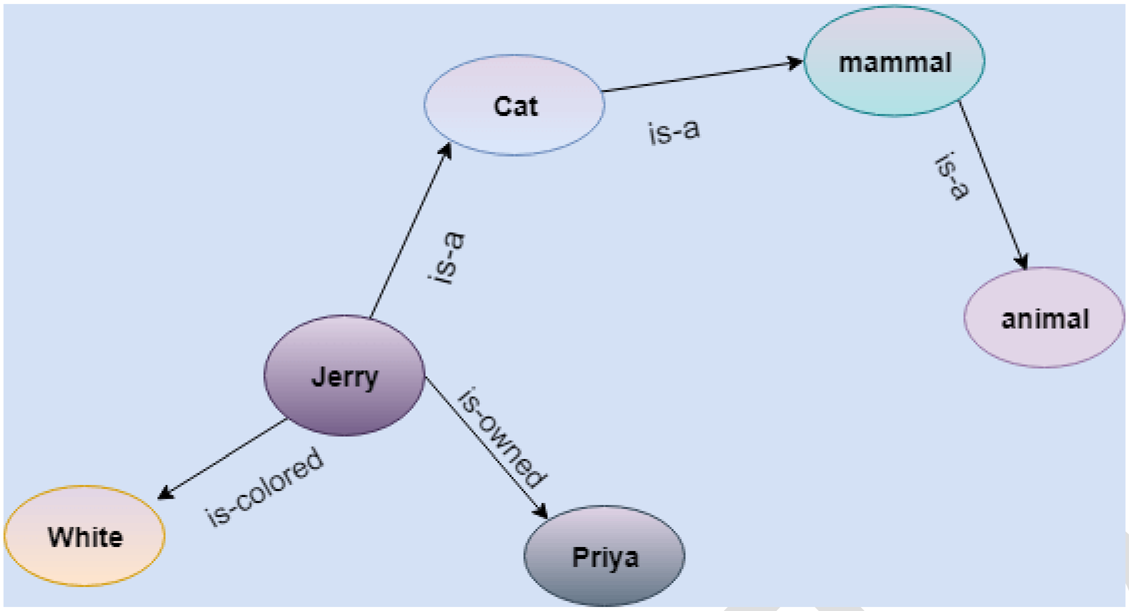
This representation consist of mainly two types of relations:

1. IS-A relation (Inheritance)
2. Kind-of-relation

Example: Following are some statements which we need to represent in the form of nodes and arcs.

Statements:

1. Jerry is a cat.
2. Jerry is a mammal
3. Jerry is owned by Priya.
4. Jerry is brown colored.
5. All Mammals are animal.



In the above diagram, we have represented the different type of knowledge in the form of nodes and arcs. Each object is connected with another object by some relation.

Drawbacks in Semantic representation:

1. Semantic networks take more computational time at runtime as we need to traverse the complete network tree to answer some questions. It might be possible in the worst case scenario that after traversing the entire tree, we find that the solution does not exist in this network.
2. Semantic networks try to model human-like memory (Which has 1015 neurons and links) to store the information, but in practice, it is not possible to build such a vast semantic network.
3. These types of representations are inadequate as they do not have any equivalent quantifier, e.g., for all, for some, none, etc.
4. Semantic networks do not have any standard definition for the link names.
5. These networks are not intelligent and depend on the creator of the system.

Advantages of Semantic network:

1. Semantic networks are a natural representation of knowledge.
2. Semantic networks convey meaning in a transparent manner.
3. These networks are simple and easily understandable.

3. Frame Representation

A frame is a record like structure which consists of a collection of attributes and its values to describe an entity in the world. Frames are the AI data structure which divides knowledge into substructures by representing stereotypes situations. It consists of a collection of slots and slot values. These slots may be of any type and sizes. Slots have names and values which are called facets.

Facets: The various aspects of a slot is known as **Facets**. Facets are features of frames which enable us to put constraints on the frames. Example: IF-NEEDED facts are called when data of any particular slot is needed. A frame may consist of any number of slots, and a slot may include any number of facets and facets may have any number of values. A frame is also known as **slot-filter knowledge representation** in artificial intelligence.

Frames are derived from semantic networks and later evolved into our modern-day classes and objects. A single frame is not much useful. Frames system consist of a collection of frames which are connected. In the frame, knowledge about an object or event can be stored together in the knowledge base. The frame is a type of technology which is widely used in various applications including Natural language processing and machine visions.

Example: 1

Let's take an example of a frame for a book

Slots	Filters
Title	Artificial Intelligence
Genre	Computer Science
Author	Peter Norvig
Edition	Third Edition
Year	1996
Page	1152

Example 2:

Let's suppose we are taking an entity, Peter. Peter is an engineer as a profession, and his age is 25, he lives in city London, and the country is England. So following is the frame representation for this:

Slots	Filter
Name	Peter
Profession	Doctor
Age	25
Marital status	Single
Weight	78

Advantages of frame representation:

1. The frame knowledge representation makes the programming easier by grouping the related data.
2. The frame representation is comparably flexible and used by many applications in AI.
3. It is very easy to add slots for new attribute and relations.
4. It is easy to include default data and to search for missing values.
5. Frame representation is easy to understand and visualize.

Disadvantages of frame representation:

1. In frame system inference mechanism is not be easily processed.
2. Inference mechanism cannot be smoothly proceeded by frame representation.
3. Frame representation has a much generalized approach.

4. Production Rules

Production rules system consist of (**condition, action**) pairs which mean, "If condition then action". It has mainly three parts:

- The set of production rules
- Working Memory
- The recognize-act-cycle

In production rules agent checks for the condition and if the condition exists then production rule fires and corresponding action is carried out. The condition part of the rule determines which rule may be applied to a problem. And the action part carries out the associated problem-solving steps. This complete process is called a recognize-act cycle.

The working memory contains the description of the current state of problems-solving and rule can write knowledge to the working memory. This knowledge match and may fire other rules.

If there is a new situation (state) generates, then multiple production rules will be fired together, this is called conflict set. In this situation, the agent needs to select a rule from these sets, and it is called a conflict resolution.

Example:

- **IF (at bus stop AND bus arrives) THEN action (get into the bus)**
- **IF (on the bus AND paid AND empty seat) THEN action (sit down).**
- **IF (on bus AND unpaid) THEN action (pay charges).**
- **IF (bus arrives at destination) THEN action (get down from the bus).**

Advantages of Production rule:

1. The production rules are expressed in natural language.
2. The production rules are highly modular, so we can easily remove, add or modify an individual rule.

Disadvantages of Production rule:

1. Production rule system does not exhibit any learning capabilities, as it does not store the result of the problem for the future uses.
2. During the execution of the program, many rules may be active hence rule-based production systems are inefficient.

16. PROPOSITIONAL LOGIC

Propositional logic (PL) is the simplest form of logic where all the statements are made by propositions. A proposition is a declarative statement which is either true or false. It is a technique of knowledge representation in logical and mathematical form.

Example:

a) It is Sunday.
b) The Sun rises from West (False proposition)
c) 3+3= 7(False proposition)
d) 5 is a prime number.

Following are some basic facts about propositional logic:

- Propositional logic is also called Boolean logic as it works on 0 and 1.
- In propositional logic, we use symbolic variables to represent the logic, and we can use any symbol for a representing a proposition, such A, B, C, P, Q, R, etc.
- Propositions can be either true or false, but it cannot be both.
- Propositional logic consists of an object, relations or function, and **logical connectives**.
- These connectives are also called logical operators.
- The propositions and connectives are the basic elements of the propositional logic.
- Connectives can be said as a logical operator which connects two sentences.
- A proposition formula which is always true is called **tautology**, and it is also called a valid sentence.
- A proposition formula which is always false is called **Contradiction**.
- A proposition formula which has both true and false values is called
- Statements which are questions, commands, or opinions are not propositions such as "**Where is Rohini**", "**How are you**", "**What is your name**", are not propositions.

Syntax of propositional logic:

The syntax of propositional logic defines the allowable sentences for the knowledge representation. There are two types of Propositions:

1. **Atomic Propositions**
2. **Compound propositions**

- **Atomic Proposition:** Atomic propositions are the simple propositions. It consists of a single proposition symbol. These are the sentences which must be either true or false.

Example:

1. a) 2+2 is 4, it is an atomic proposition as it is a true fact.
2. b) "The Sun is cold" is also a proposition as it is a false fact.

- **Compound proposition:** Compound propositions are constructed by combining simpler or atomic propositions, using parenthesis and logical connectives.

Example:

1. a) "It is raining today, and street is wet."
2. b) "Ankit is a doctor, and his clinic is in Mumbai."

Logical Connectives:

Logical connectives are used to connect two simpler propositions or representing a sentence logically. We can create compound propositions with the help of logical connectives. There are mainly five connectives, which are given as follows:

1. **Negation:** A sentence such as ¬ P is called negation of P. A literal can be either Positive literal or negative literal.
2. **Conjunction:** A sentence which has ∧ connective such as, **P ∧ Q** is called a conjunction.
   Example: Rohan is intelligent and hardworking. It can be written as,
   P= Rohan is intelligent,
   Q= Rohan is hardworking. → P∧ Q.
3. **Disjunction:** A sentence which has ∨ connective, such as **P ∨ Q**. is called disjunction, where P and Q are the propositions.
   Example: "Ritika is a doctor or Engineer",
   Here P= Ritika is Doctor. Q= Ritika is Doctor, so we can write it as **P ∨ Q**.
4. **Implication:** A sentence such as P → Q, is called an implication. Implications are also known as if-then rules. It can be represented as
   If it is raining, then the street is wet.
   Let P= It is raining, and Q= Street is wet, so it is represented as P → Q
5. **Biconditional:** A sentence such as **P⇔ Q is a Biconditional sentence, example If I am breathing, then I am alive**
   P= I am breathing, Q= I am alive, it can be represented as P ⇔ Q.

Following is the summarized table for Propositional Logic Connectives:

Connective symbols	Word	Technical term	Example
∧	AND	Conjunction	A ∧ B
∨	OR	Disjunction	A ∨ B
→	Implies	Implication	A → B
⇔	If and only if	Biconditional	A⇔ B
¬ or ~	Not	Negation	¬ A or ¬ B

Truth Table:

In propositional logic, we need to know the truth values of propositions in all possible scenarios. We can combine all the possible combination with logical connectives, and the representation of these combinations in a tabular format is called **Truth table**. Following are the truth table for all logical connectives:

For Negation:

P	¬ P
True	**False**
False	**True**

For Conjunction:

P	Q	P∧ Q
True	True	**True**
True	False	**False**
False	True	**False**
False	False	**False**

For disjunction:

P	Q	P V Q.
True	True	**True**
False	True	**True**
True	False	**True**
False	False	**False**

For Implication:

P	Q	P→ Q
True	True	**True**
True	False	**False**
False	True	**True**
False	False	**True**

For Biconditional:

P	Q	P⇔ Q
True	True	**True**
True	False	**False**
False	True	**False**
False	False	**True**

Truth table with three propositions:

We can build a proposition composing three propositions P, Q, and R. This truth table is made-up of 8n Tuples as we have taken three proposition symbols.

P	Q	R	¬R	Pv Q	PvQ→¬R
True	True	True	False	True	False
True	True	False	True	True	True
True	False	True	False	True	False
True	False	False	True	True	True
False	True	True	False	True	False
False	True	False	True	True	True
False	False	True	False	False	True
False	False	False	True	False	True

Precedence of connectives:

Just like arithmetic operators, there is a precedence order for propositional connectors or logical operators. This order should be followed while evaluating a propositional problem. Following is the list of the precedence order for operators:

Precedence	Operators
First Precedence	Parenthesis
Second Precedence	Negation
Third Precedence	Conjunction(AND)
Fourth Precedence	Disjunction(OR)
Fifth Precedence	Implication
Six Precedence	Biconditional

Logical equivalence:

Logical equivalence is one of the features of propositional logic. Two propositions are said to be logically equivalent if and only if the columns in the truth table are identical to each other.

Let's take two propositions A and B, so for logical equivalence, we can write it as A⇔B. In below truth table we can see that column for ¬AV B and A→B, are identical hence A is Equivalent to B

A	B	¬A	¬AV B	A→B
T	T	F	**T**	**T**
T	F	F	**F**	**F**
F	T	T	**T**	**T**
F	F	T	**T**	**T**

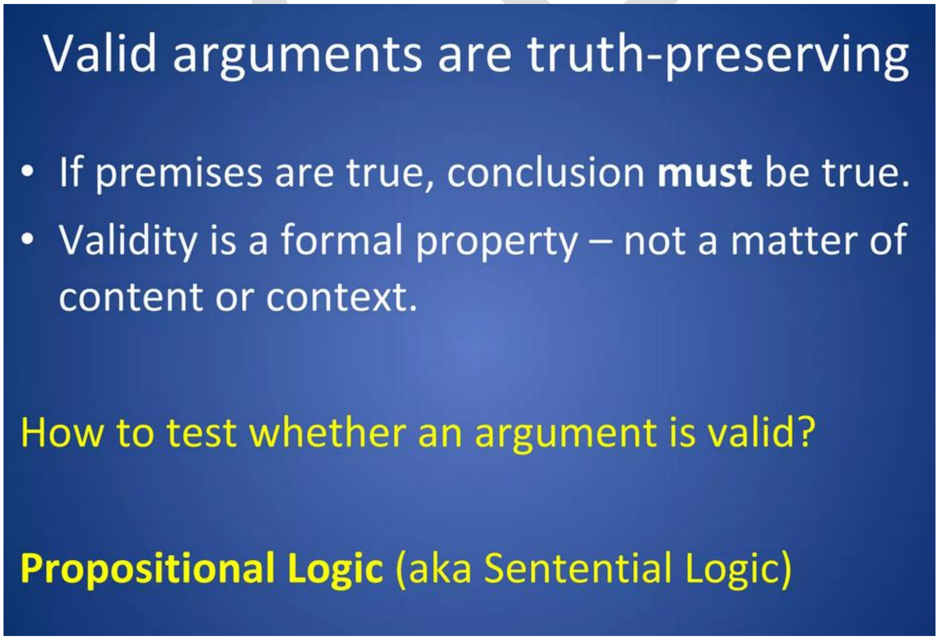
Properties of Operators:

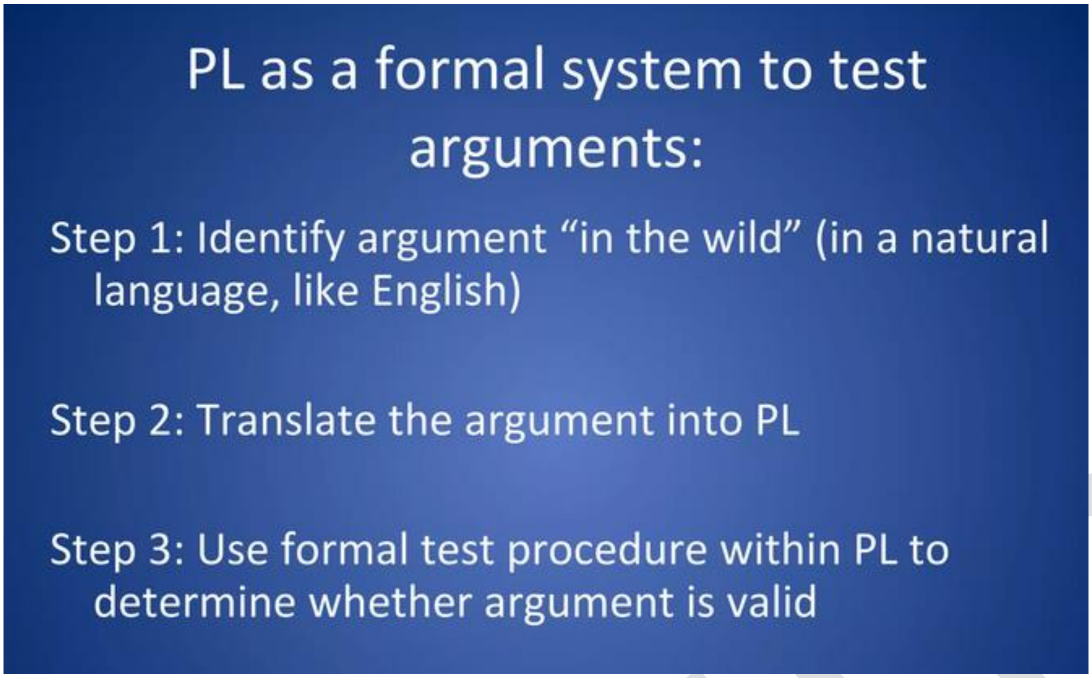
- **Commutativity:**
  - $P \wedge Q = Q \wedge P$, or
  - $P \vee Q = Q \vee P$.
- **Associativity:**
  - $(P \wedge Q) \wedge R = P \wedge (Q \wedge R)$,
  - $(P \vee Q) \vee R = P \vee (Q \vee R)$
- **Identity element:**
  - $P \wedge True = P$,
  - $P \vee True = True$.
- **Distributive:**
  - $P \wedge (Q \vee R) = (P \wedge Q) \vee (P \wedge R)$.
  - $P \vee (Q \wedge R) = (P \vee Q) \wedge (P \vee R)$.
- **DE Morgan's Law:**
  - $\neg (P \wedge Q) = (\neg P) \vee (\neg Q)$
  - $\neg (P \vee Q) = (\neg P) \wedge (\neg Q)$.
- **Double-negation elimination:**
  - $\neg (\neg P) = P$.

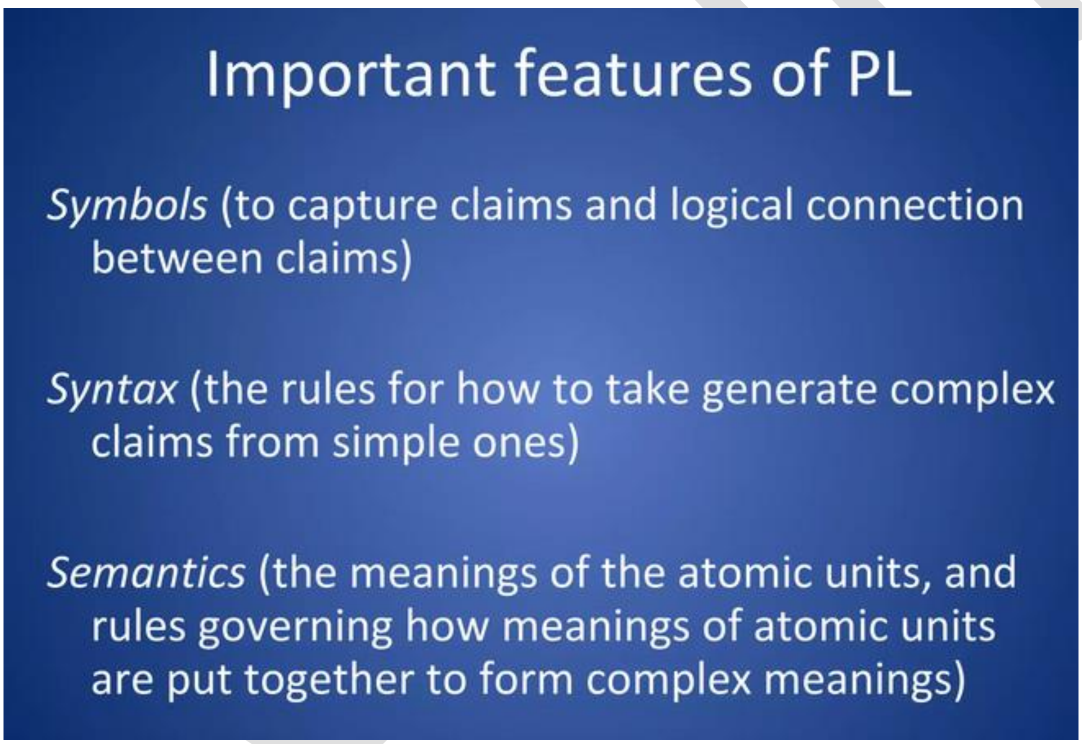
Limitations of Propositional logic:

- We cannot represent relations like ALL, some, or none with propositional logic. Example:
  1. **All the girls are intelligent.**
  2. **Some apples are sweet.**
- Propositional logic has limited expressive power.
- In propositional logic, we cannot describe statements in terms of their properties or logical relationships.

17. SEMANTICS OF PROPOSITIONAL LOGIC




PL as a formal system to test arguments:
Step 1: Identify argument "in the wild" (in a natural language, like English)
Step 2: Translate the argument into PL
Step 3: Use formal test procedure within PL to determine whether argument is valid


Important features of PL
Symbols (to capture claims and logical connection between claims)
Syntax (the rules for how to take generate complex claims from simple ones)
Semantics (the meanings of the atomic units, and rules governing how meanings of atomic units are put together to form complex meanings)

Syntax of PL

Using logical connectives and operators (which connect or operate on propositions)

Symbols:

Use letters (P, Q, R, … X, Y, Z) to stand for specific statements

Unary propositional operator: ~

Binary propositional connectives: → , ↔ , • , ∨

Grouping symbols: ( ), [ ]

Syntax of PL

Negation; *not*: ~	~P
Conjunction; *and*: •	P•Q
Disjunction; *or*: ∨	P∨Q
Material conditional; *if … then* ..: →	P→Q
Biconditional: … *if and only if* …: ↔	P↔Q

"Good grammar" in PL: well-formed formula (wff)

(1) Every statement letter P, … Z is a well-formed formula (wff)

(2) If p and q are wffs, then so are:

- (i) ~p
- (ii) (p•q)
- (iii) (p∨q)
- (iv) (p→q)
- (v) (p↔q)

(3) Nothing is a wff unless rules (1) and (2) imply that it is.

Syntax of PL

Strings that are not wffs:

(P~Q)

(•QP)

(→R)

Strings that are wffs:

((P•Q)↔R)

~(X∨(Y→Z))

Syntax of PL

In PL, every compound formula is one of the following:

- negation
- conjunction
- disjunction
- conditional
- biconditional

To determine which one, isolate main connective or operator.

Syntax of PL

(P•Q) conjunction

((P•Q)↔R) biconditional

(Y→Z) conditional

(X∨(Y→Z)) disjunction

~(X∨(Y→Z)) negation

Syntax of PL

By convention, we can drop the outermost set of parentheses if the main connective is not unary (~)

$$(P \bullet Q) \leftrightarrow R$$

$$Y \rightarrow Z$$

$$X \vee (Y \rightarrow Z)$$

$$\sim(X \vee (Y \rightarrow Z))$$

Syntax of PL

Important note:

$$\sim(P \bullet Q)$$

is not equivalent to

$$\sim P \bullet Q$$

Semantics of PL

Semantic rules of PL tell us how the meaning of its constituent parts, and their mode of combination, determine the meaning of a compound statement.

Logical operators in PL determine what the truth-values of compound statements are depending on the truth-values of the formulae in the compound.

Semantics of PL

Logical operators defined by **truth-tables**.

(T= true, F=false)

Negation:

P	**~P**
T	F
F	T

Semantics of PL

Conjunction:

P	Q	P• Q
T	T	T
T	F	F
F	T	F
F	F	F

Semantics of PL

Disjunction:

P	Q	P∨ Q
T	T	T
T	F	T
F	T	T
F	F	F

Semantics of PL

Material conditional:

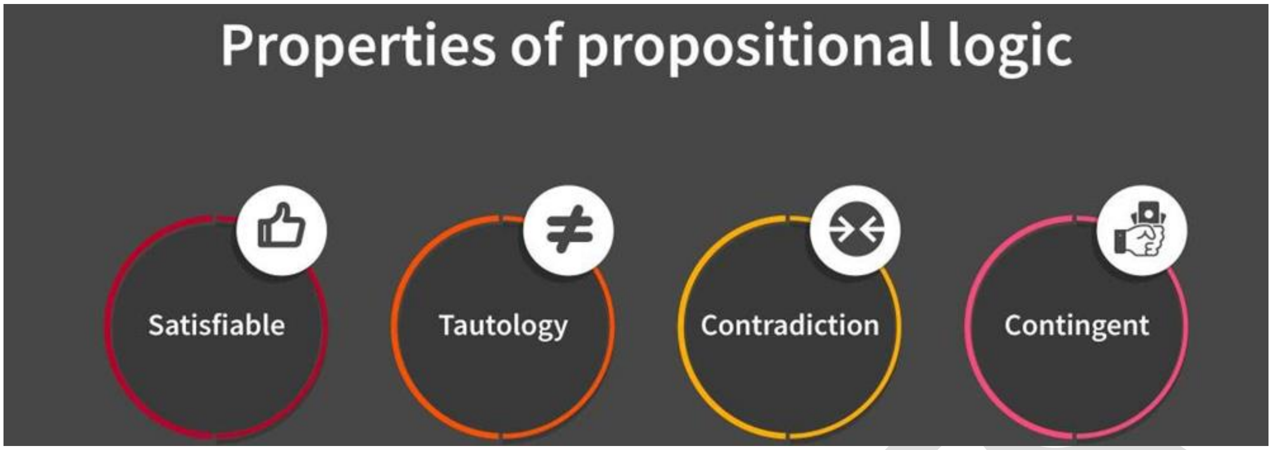
P	Q	P→ Q
T	T	T
T	F	F
F	T	T
F	F	T

Semantics of PL

Biconditional:

P	Q	P↔ Q
T	T	T
T	F	F
F	T	F
F	F	T

18. PROPERTIES OF PROPOSITIONAL LOGIC STATEMENTS



Satisfiable

An atomic propositional formula can be considered satisfiable if an interpretation exists for which it is true.

Tautology

A propositional formula is valid or a tautology only if it holds true for every possible interpretation.

Contradiction

A propositional formula is considered to be contradictory or unsatisfiable if there no interpretation exists for which it is true.

Contingent

It is possible for a propositional logic to be contingent. This basically means that it can be neither a tautology nor a contradiction.

Why is propositional logic important?

Propositional logic is rather important because it is used for the purpose of developing rather powerful search algorithms including implementation methods.

It is also important because of its wide usage in artificial intelligence for planning, problem-solving, intelligent control and for decision-making.

PROPERTIES OF PROPOSITIONAL LOGIC

Soundness theorem (*syntactic validity* implies *semantic validity*):

If $\vdash U$ **then** $\models U$ (A theorem is a tautology).

Completeness theorem (*semantic validity* implies *syntactic validity*):

If $\models U$ **then** $\vdash U$ (A tautology is a theorem).

Theorem of soundness and completeness for propositional logic:

$\vdash U$ **if and only if** $\models U$.

Consequences of this theorem are the following **properties**:

- **Propositional logic is *non-contradictory***: we can't have simultaneously $\vdash U$ and $\vdash \neg U$.
- **Propositional logic is *coherent***: not every propositional formula is a theorem.
- **Propositional logic is *decidable***: we can always decide whether a propositional formula is a theorem or not. The truth table method is a decision method.

19. TAUTOLOGIES AND LOGICAL IMPLICATION

Tautologies

A *truth assignment* is an assignment of T or F to every proposition.

- How hard is it to check if a formula is true under a given truth assignment?
- Easy: just plug it in and evaluate.
  - Time linear in the length of the formula

A *tautology* (or *theorem*) is a formula that evaluates to T for *every* truth assignment.

Examples:

- $(P \vee Q) \Leftrightarrow \neg(\neg P \wedge \neg Q)$
- $P \vee Q \vee (\neg P \wedge \neg Q)$
- $(P \Rightarrow Q) \vee (Q \Rightarrow P)$
  - It's necessarily true that if elephants are pink then the moon is made of green cheese or if the moon is made of green cheese, then elephants are pink.

How hard is it to check if a formula is a tautology?

- How many truth assignments do we have to try?

Arguments

Definition: An argument has the form

$$\begin{array}{l} A_1 \\ A_2 \\ \vdots \\ A_n \\ \hline B \end{array}$$

$A_1, \ldots, A_n$ are called the *premises* of the argument; B is called the *conclusion*. An argument is *valid* if, whenever the premises are true, then the conclusion is true.

Logical Implication

A formula A *logically implies* B if $A \Rightarrow B$ is a tautology.

Theorem: An argument is valid iff the conjunction of its premises logically implies the conclusion.

Proof: Suppose the argument is valid. We want to show $(A_1 \wedge \ldots \wedge A_n) \Rightarrow B$ is a tautology.

- Do we have to try all 2^k truth assignments (where $k = \#$primitive propositions in $A_1, \ldots, A_n, B$).

It's not that bad.

- Because of the way we defined $\Rightarrow$, $A_1 \wedge \ldots \wedge A_n \Rightarrow B$ is guaranteed to be true if $A_1 \wedge \ldots \wedge A_n$ is false.
- But if $A_1 \wedge \ldots \wedge A_n$ is true, B is true, since the argument is valid.
- Thus, $(A_1 \wedge \ldots \wedge A_n) \Rightarrow B$ is a tautology.

For the converse, suppose $(A_1 \wedge \ldots \wedge A_n) \Rightarrow B$ is a tautology. If $A_1, \ldots, A_n$ are true, then B must be true. Hence the argument is valid.

Remember:

Borogroves are mimsy whenever it is brillig.
It is now brillig and this thing is a borogrove.
Hence this thing is mimsy.

Suppose

- P: It is now brillig
- Q: This thing is a borogrove
- R: This thing is mimsy

This becomes:

$P \Rightarrow (Q \Rightarrow R)$
$P \wedge Q$

R

This argument is valid if

$$[(P \Rightarrow (Q \Rightarrow R)) \wedge (P \wedge Q)] \Rightarrow R$$

is a tautology.

Tautologies

A proposition P is a tautology if it is true under all circumstances. It means it contains the only T in the final column of its truth table.

Example: Prove that the statement (p⟶q) ↔(~q⟶~p) is a tautology.

Solution: Make the truth table of the above statement:

p	q	p→q	~q	~p	~q⟶~p	(p→q)⟷(~q⟶~p)
T	T	T	F	F	T	T
T	F	F	T	F	F	T
F	T	T	F	T	T	T
F	F	T	T	T	T	T

As the final column contains all T's, so it is a tautology.

Tautologies

- Remember, Tautologies are always true.
- Thus, if we can use different propositions and logical equivalences to show two statements are tautologies, we can do proofs.
- Proofs are conditional and biconditional statements that are tautologies
- Notation: p and q are atomic statements, while A and B are statements of all types, including atomic and compound.
- We are looking for tautological implications, which are tautologies of the form $A \rightarrow B$.

Direct Reasoning, also called *Modus Ponens*

- In an implication and its premise are both true, then so is its conclusion: In symbols $[(p \rightarrow q) \wedge p] \rightarrow q$
- Example: p: I work hard

  q: I will do good research

then we have the following:

If working hard implies I will do good research, then if I do work hard, I will do good research.

Symbolic and argument form

We write proofs by putting what is ***given*** above a line, and the ***tautological implication*** below a line:

If I work hard I will do good research

I will work hard

Therefore, I will do good research

$$\begin{array}{l} p \rightarrow q \\ p \\ \hline \therefore\ q \end{array}$$

Essentially have an affirming hypothesis

- Given information
  - $p \rightarrow q$
  - p is true
  - conclude that q is true as well

- Is this an affirming hypothesis? Why not – discuss in symbolic logic
  - If I were an Olympic athlete then I would drink beer.
  - I drink beer, therefore I am an Olympic athlete.

Indirect Reasoning or *Modus Tollens*

- If an implication is true but its conclusion is false, then its premise is false. In symbols $[(p \rightarrow q) \wedge \sim q] \rightarrow \sim p$.
- Example: p: I work hard

  q: I will do good research

then we have the following:

If working hard implies I will do good research, then if I don't do good research, I did not work hard.

If I work hard I will do good research $(p \rightarrow q)$

<u>I did not do good research (~q)</u>

Therefore, I did not work hard $(\therefore \sim p)$

$$\begin{array}{l} p \rightarrow q \\ \sim q \\ \hline \therefore \ \sim p \end{array}$$

Essentially have an denying hypothesis

- Given information
  - $p \rightarrow q$
  - q is false
  - conclude that p is falseas well

- Is this an denying hypothesis? Why not – discuss in symbolic logic
  - If I were an Olympic athlete then I would drink beer.
  - I am not Olympic athlete, therefore I don't drink beer.

Useful tautologies: Let's give examples of each

- Simplification: If both p and q are true, then p is true.

  $$(p \wedge q) \rightarrow p$$

- Addition: If p is true, then we know that either p or q is true.

  $$p \rightarrow (p \vee q)$$

- Disjuntive Syllogism (One-or-the-Other): If either p or q is true, and one is know to be false, then the other must be true

  $$[(p \vee q) \wedge (\sim p) \rightarrow q$$

- Transitivity: If p implies q and q implies r then p implies r.

  $$[(p \rightarrow q) \wedge (q \rightarrow r)] \rightarrow (p \rightarrow r)$$

Tautological equivalences are tautologies of compound statements, A ↔ B, so that A and B are equivalent statements.

- To say that A≡B is the same as saying A ↔ B is a tautology.
- So every logical equivalence is a tautological equivalence.
- The simplest tautological equivalence is the double negative:

$$\frac{p}{\therefore\ \sim(\sim p)} \quad \text{and} \quad \frac{\sim(\sim p)}{\therefore\ p}$$

Useful tautological equivalences (examples?)

Symbolic Form	Argument Forms		Name
$p\leftrightarrow\sim(\sim p)$	$\frac{p}{\therefore\ \sim(\sim p)}$	$\frac{\sim(\sim p)}{\therefore\ p}$	Double Negative
$p\wedge q\leftrightarrow q\wedge p$ $p\vee q\leftrightarrow q\vee p$	$\frac{p\wedge q}{\therefore\ q\wedge p}$	$\frac{p\vee q}{\therefore\ q\vee p}$	Commutative Laws
$(p\wedge q)\wedge r\leftrightarrow p\wedge(q\wedge r)$	$\frac{(p\wedge q)\wedge r}{\therefore\ p\wedge(q\wedge r)}$	$\frac{p\wedge(q\wedge r)}{\therefore\ (p\wedge q)\wedge r}$	Associative Laws
$(p\vee q)\vee r\leftrightarrow p\vee(q\vee r)$	$\frac{(p\vee q)\vee r}{\therefore\ p\vee(q\vee r)}$	$\frac{p\vee(q\vee r)}{\therefore\ (p\vee q)\vee r}$	
$\sim(p\vee q)\leftrightarrow(\sim p)\wedge(\sim q)$	$\frac{\sim(p\vee q)}{\therefore\ (\sim p)\wedge(\sim q)}$	$\frac{(\sim p)\wedge(\sim q)}{\therefore\ \sim(p\vee q)}$	DeMorgan's Laws
$\sim(p\wedge q)\leftrightarrow(\sim p)\vee(\sim q)$	$\frac{\sim(p\wedge q)}{\therefore\ (\sim p)\vee(\sim q)}$	$\frac{(\sim p)\vee(\sim q)}{\therefore\ \sim(p\wedge q)}$	

Inference

- Inference is just using logical sequences to arrive at a conclusion. We had direct Reasoning, or Modus Ponens, as

$$\begin{array}{l} p \rightarrow q \\ p \\ \hline \therefore\ q \end{array}$$

- Statements above the line are premises, and statements below the line are conclusions.
- Any tautology from the lists in previous slides may be used as premises in a proof.

Take the following statements

- p: roses are red
- q: violets are blue
- r: sugar is sweet
- s: so are you

And the poem:

If roses are red and violets are blue, then sugar is sweet and so are you.

Roses are red and violets are blue

Therefore, sugars is sweet and so are you.

$$\begin{array}{l} (p \wedge q) \rightarrow (r \wedge s) \\ p \wedge q \\ \hline \therefore\ r \wedge s \end{array} \quad \text{or} \quad \begin{array}{l} A \rightarrow B \\ A \\ \hline \therefore\ B \end{array}$$

15

Proofs use rules of inference to assemble a list of true statements. The statements can be atomic or compound.

Example:

1. $(p \vee q) \rightarrow (r \wedge \sim s)$	Premise
2. $\sim r \rightarrow s$	Premise
3. $p \vee q$	Premise
4. $r \wedge \sim s$	1, 3 Modus Ponens

We write the statement and the role is plays or its justification. Do we need statement 2? Why or why not?

Example : The following statements are premises (assumed to be true – we call them assumptions)

1. A→B
2. ~B
3. A→C

What are the conclusions from this list? ~A .

Taking 1. and 2. as true, since we don't have B we can't have A, because of Indirect Reasoning. If A implies B, then if B isn't true, A can't be either.

But also from 3., so we get ~C? Why or why not? Give an example.

Tools of inference

- Premises are taken as true.
- Tautologies are rules of inference that can be used in proofs.
- We can replace any part of a compound statements with a tautologically equivalent statements. That is, we can substitute likes for each other.
- If A and B are two lines in a proof, then we can add a line $A \wedge B$ to the proof.

20. RESOLUTION, CONJUNCTIVE NORMAL FORM, RESOLUTION IS VALID, RESOLUTION ALGORITHM

Resolution

Resolution is a theorem proving technique that proceeds by building refutation proofs, i.e., proofs by contradictions. It was invented by a Mathematician John Alan Robinson in the year 1965.

Resolution is used, if there are various statements are given, and we need to prove a conclusion of those statements. Unification is a key concept in proofs by resolutions. Resolution is a single inference rule which can efficiently operate on the **conjunctive normal form or clausal form**.

Clause: Disjunction of literals (an atomic sentence) is called a **clause**. It is also known as a unit clause.

Conjunctive Normal Form: A sentence represented as a conjunction of clauses is said to be **conjunctive normal form** or **CNF**.

The resolution inference rule:

The resolution rule for first-order logic is simply a lifted version of the propositional rule. Resolution can resolve two clauses if they contain complementary literals, which are assumed to be standardized apart so that they share no variables.

$$\frac{l_1 \vee \dots \dots \vee l_k, \qquad m_1 \vee \dots \dots \vee m_n}{SUBST(\theta, l_1 \vee \dots \dots \vee l_{i-1} \vee l_{i+1} \vee \dots \vee l_k \vee m_1 \vee \dots \dots \vee m_{j-1} \vee m_{j+1} \vee \dots \dots \vee m_n)}$$

Where $\mathbf{l_i}$ and $\mathbf{m_j}$ are complementary literals.

This rule is also called the **binary resolution rule** because it only resolves exactly two literals.

Example:

We can resolve two clauses which are given below:

[Animal (g(x) V Loves (f(x), x)]   and   [¬ Loves(a, b) V ¬Kills(a, b)]

Where two complimentary literals are: **Loves (f(x), x) and ¬ Loves (a, b)**

These literals can be unified with unifier **θ= [a/f(x), and b/x]** , and it will generate a resolvent clause:

[Animal (g(x) V ¬ Kills(f(x), x)].

Steps for Resolution:

1. Conversion of facts into first-order logic.
2. Convert FOL statements into CNF
3. Negate the statement which needs to prove (proof by contradiction)
4. Draw resolution graph (unification).

To better understand all the above steps, we will take an example in which we will apply resolution.

Example:

a. **John likes all kind of food.**

b. **Apple and vegetable are food**

c. **Anything anyone eats and not killed is food.**

d. **Anil eats peanuts and still alive**

e. **Harry eats everything that Anil eats.**
Prove by resolution that:

f. **John likes peanuts.**

Step-1: Conversion of Facts into FOL

In the first step we will convert all the given statements into its first order logic.

a. $\forall x$: food(x) → likes(John, x)
b. food(Apple) Λ food(vegetables)
c. $\forall x \forall y$: eats(x, y) Λ ¬ killed(x) → food(y)
d. eats (Anil, Peanuts) Λ alive(Anil).
e. $\forall x$: eats(Anil, x) → eats(Harry, x)
f. $\forall x$: ¬ killed(x) → alive(x)
g. $\forall x$: alive(x) →¬ killed(x)

added predicates.

h. likes(John, Peanuts)

Step-2: Conversion of FOL into CNF

In First order logic resolution, it is required to convert the FOL into CNF as CNF form makes easier for resolution proofs.

- **Eliminate all implication (→) and rewrite**
    a. ∀x ¬ food(x) V likes(John, x)
    b. food(Apple) Λ food(vegetables)
    c. ∀x ∀y ¬ [eats(x, y) Λ ¬ killed(x)] V food(y)
    d. eats (Anil, Peanuts) Λ alive(Anil)
    e. ∀x ¬ eats(Anil, x) V eats(Harry, x)
    f. ∀x¬ [¬ killed(x)] V alive(x)
    g. ∀x ¬ alive(x) V ¬ killed(x)
    h. likes(John, Peanuts).

- **Move negation (¬)inwards and rewrite**
    a. ∀x ¬ food(x) V likes(John, x)
    b. food(Apple) Λ food(vegetables)
    c. ∀x ∀y ¬ eats(x, y) V killed(x) V food(y)
    d. eats (Anil, Peanuts) Λ alive(Anil)
    e. ∀x ¬ eats(Anil, x) V eats(Harry, x)
    f. ∀x ¬killed(x)] V alive(x)
    g. ∀x ¬ alive(x) V ¬ killed(x)
    h. likes(John, Peanuts).

- **Rename variables or standardize variables**

    a. ∀x ¬ food(x) V likes(John, x)

    b. food(Apple) Λ food(vegetables)

    c. ∀y ∀z ¬ eats(y, z) V killed(y) V food(z)

    d. eats (Anil, Peanuts) Λ alive(Anil)

    e. ∀w¬ eats(Anil, w) V eats(Harry, w)

    f. ∀g ¬killed(g)] V alive(g)

    g. ∀k ¬ alive(k) V ¬ killed(k)

    h. likes(John, Peanuts).

- **Eliminate existential instantiation quantifier by elimination.**
  In this step, we will eliminate existential quantifier ∃, and this process is known as **Skolemization**. But in this example problem since there is no existential quantifier so all the statements will remain same in this step.

- **Drop Universal quantifiers.**
  In this step we will drop all universal quantifier since all the statements are not implicitly quantified so we don't need it.

    a. ¬ food(x) V likes(John, x)

    b. food(Apple)

    c. food(vegetables)

    d. ¬ eats(y, z) V killed(y) V food(z)

    e. eats (Anil, Peanuts)

    f. alive(Anil)

    g. ¬ eats(Anil, w) V eats(Harry, w)

    h. killed(g) V alive(g)

    i. ¬ alive(k) V ¬ killed(k)

    j. likes(John, Peanuts).

- **Distribute conjunction ∧ over disjunction ¬.**

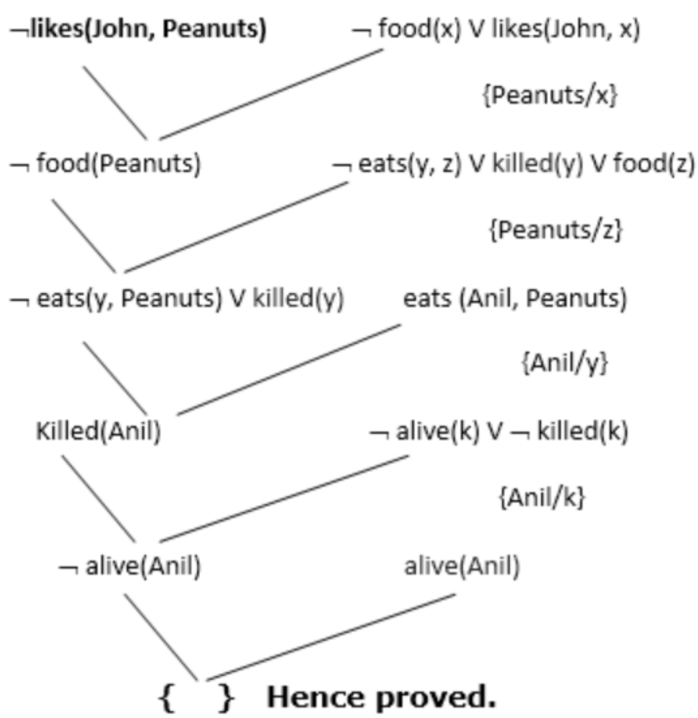
  This step will not make any change in this problem.

Step-3: Negate the statement to be proved

In this statement, we will apply negation to the conclusion statements, which will be written as ¬likes(John, Peanuts)

Step-4: Draw Resolution graph:

Now in this step, we will solve the problem by resolution tree using substitution. For the above problem, it will be given as follows:



Hence the negation of the conclusion has been proved as a complete contradiction with the given set of statements.

Explanation of Resolution graph:

- In the first step of resolution graph, **¬likes(John, Peanuts)** , and **likes(John, x)** get resolved(canceled) by substitution of **{Peanuts/x}**, and we are left with **¬ food(Peanuts)**
- In the second step of the resolution graph, **¬ food(Peanuts)** , and **food(z)** get resolved (canceled) by substitution of **{ Peanuts/z}**, and we are left with **¬ eats(y, Peanuts) V killed(y)** .
- In the third step of the resolution graph, **¬ eats(y, Peanuts)** and **eats (Anil, Peanuts)** get resolved by substitution **{Anil/y}**, and we are left with **Killed(Anil)** .
- In the fourth step of the resolution graph, **Killed(Anil)** and **¬ killed(k)** get resolve by substitution **{Anil/k}**, and we are left with **¬ alive(Anil)** .
- In the last step of the resolution graph **¬ alive(Anil)** and **alive(Anil)** get resolved.

RESOLUTION ALGORITHM

Inference algorithms based on resolution work utilize the proof-by-contradiction. To establish that is $KB \models \alpha$ unsatisfiable, we show that $(KB \wedge \neg\alpha)$ is unsatisfiable. We do this by demonstrating a contradiction.

function PL-RESOLUTION (KB, α) returns t rue or false

inputs: KB, the knowledge base, a sentence in propositional logic

α, the query, a sentence in propositional logic

clauses $\leftarrow$ the set of clauses in the CNF representation of $KB \wedge \neg\alpha$

new $\leftarrow \{\}$

loop do

for each pair of clauses C_i, C_j in clauses do

resolvents $\leftarrow$ PL-RESOLVE (C_i, C_j)

if resolvents contains the empty clause then return t rue

new $\leftarrow$ new $\cup$ resolvents

if new $\subseteq$ clauses then return false

clauses $\leftarrow$ clauses $\cup$ new

The equations above show a resolution algorithm. To begin, $(KB \wedge \neg\alpha)$ is transformed to CNF. The resolution rule is then applied to the clauses that result. Each pair of complementary literals is resolved into a new clause, which is added to the set if it does not exist before. The procedure continues until either

- no more clauses can be added, in which case, KB does not entail
- two clauses resolve to produce the empty clause, in which case KB entails.

Because a disjunction is true only if at least one of its disjunctions is true, the empty clause—a disjunction with no disjunctions—is identical to False. Another approach to recognize that an empty sentence is a contradiction is to notice that it only appears when two complementary unit clauses, such as P and $\neg P$, are resolved.

21. KNOWLEDGEBASE SYSTEMS, STRUCTURE OF A KNOWLEDGE BASED SYSTEM

A knowledge-based system (KBS) is a type of computer system that analyzes knowledge, data and other information from sources to generate new knowledge. It uses AI concepts to solve problems, which may be useful for assisting with human learning and making decisions. These systems often have built-in problem-solving capabilities that allow them to understand the context of the data that they review and process and make informed decisions based on the knowledge that they store.

Knowledge-based systems typically have three components, which include:

- Knowledge base: A knowledge base is an established collection of information and resources. The system uses this as its repository for the knowledge it uses to make decisions.
- Interface engine: An interface engine processes data throughout the system. It acts similarly to a search engine within the system by locating relevant information based on the requests.
- User interface: The user interface is how the knowledge-based system appears to users on the computer. This allows users to interact with the system and submit requests.

Types of knowledge-based systems

Some example types of knowledge-based systems include the following:

- **Blackboard systems.** These systems enable multiple sources to input new information into a system to help create solutions to potential problems. Blackboard systems rely heavily on updates from human experts.
- **Case-based systems.** These systems use case-based reasoning to create solutions to a problem. This system works by reviewing past data of similar situations.
- **Classification systems.** These systems analyze different data to understand its classification status.

- **Eligibility analysis systems.** These systems are used to determine a user's eligibility for a specific service. A system asks a user guided questions until it receives a disqualifying answer.
- **Expert systems.** These are a common type of KBS that simulate human expert decision-making in a particular field. Expert systems provide solutions for problems as well as the explanations behind them. For example, they could be used for calculations and predictions.
- **Intelligent tutoring systems.** These systems are designed to support human learning and education. Intelligent tutoring systems provide users with instructions and give feedback based on performance or questions.
- **Medical diagnosis systems.** These systems help diagnose patients by inputting data or having a patient answer a series of questions. Based on the responses, the KBS identifies a diagnosis and makes recommendations medical professionals can use to determine a patient's treatment.
- **Rule-based systems.** These systems rely on human-specified rules to analyze or change data to reach a desired outcome. For example, rule-based systems might use if-then rules.

Uses of knowledge-based systems

Knowledge-based systems are useful for providing expertise to people who require it, especially when they're attempting to make decisions quickly. They can be helpful for providing recommendations for various industries, and their potential may continue to grow as technology evolves. Some examples of current uses for knowledge-based systems include:

Blackboard systems

A blackboard knowledge-based system allows users to collaborate to achieve a solution. Human experts can continuously input new information into the system, helping to create partial solutions as they investigate the final outcome. The system uses partial solutions to determine the appropriate answer to a problem.

Classification systems

Classification systems analyze data and assign it to appropriate groups. This type of knowledge-based system allows you to determine what the classification status is for a section of data. It may be particularly useful for scientists, such as analyzing chemical components to determine the classification of particular chemical compounds.

Eligibility analysis systems

Eligibility analysis systems may include guided questions for a user. These are often rule-based systems because they typically allow users to continue to answer questions until one of their responses indicates they're not eligible for the service. This type of system may be useful for those looking to make their screening processes more efficient, such as government organizations or hiring professionals.

Medical diagnosis systems

Medical diagnosis systems help diagnose patients based on their symptoms in medical history. They may answer a series of questions or a medical professional may enter the information for them, and, based on their responses, the knowledge-based system identifies what condition they may be experiencing, Many of these systems also recommend treatment methods the patient may consider based on their responses and potential diagnosis. It's important to note the system alone is not an appropriate replacement for professional medical care.

Benefits of knowledge-based systems

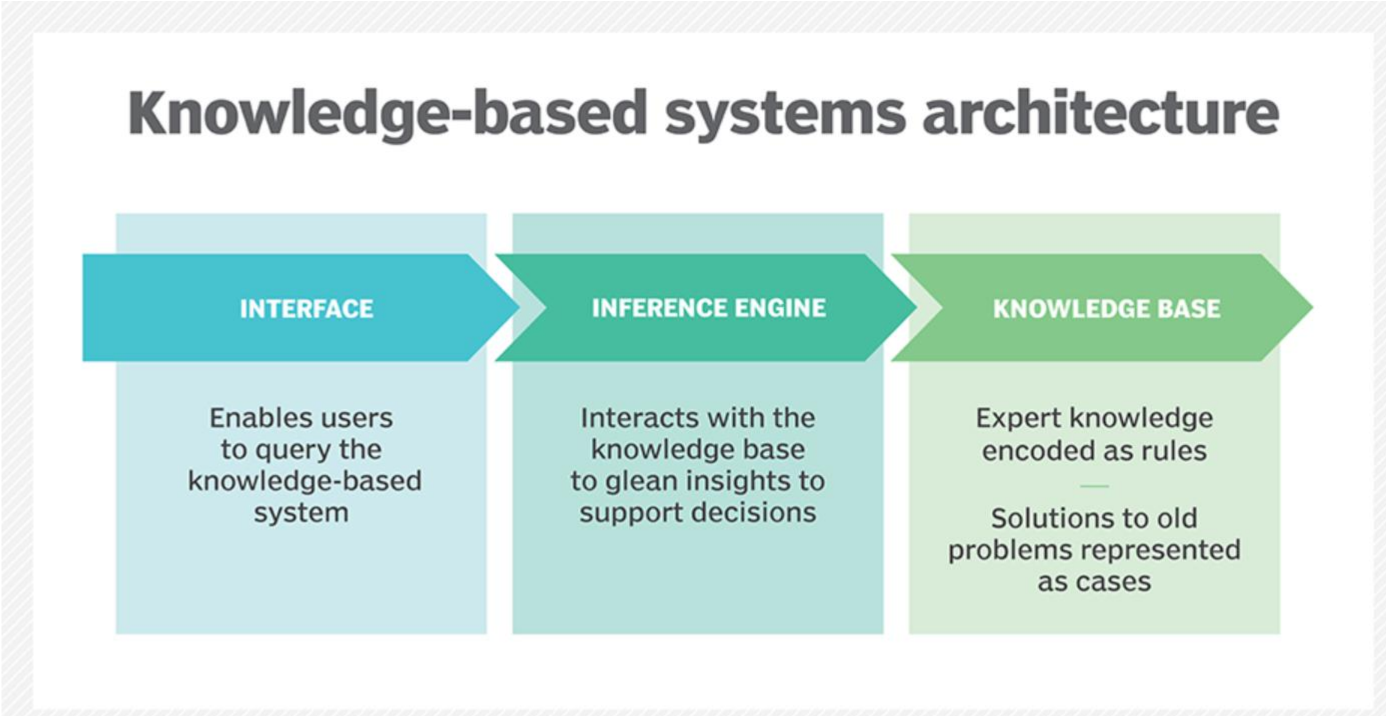
Some benefits of using knowledge-based systems include:

- Accelerating delivery processes of goods and services for B2C organizations
- Assisting users in making expert decisions
- Creating new knowledge by reviewing existing data and stored knowledge
- Grouping data across different areas of expertise
- Handling significant amounts of structured and unstructured data intelligently and efficiently
- Improving productivity and consistency with decision-making processes
- Integrating knowledge on a large scale to create a common platform for accessing knowledge
- Providing efficient documentation of important data for users to access easily
- Serving as an expert resource with human experts are unavailable
- Storing data conveniently for future use

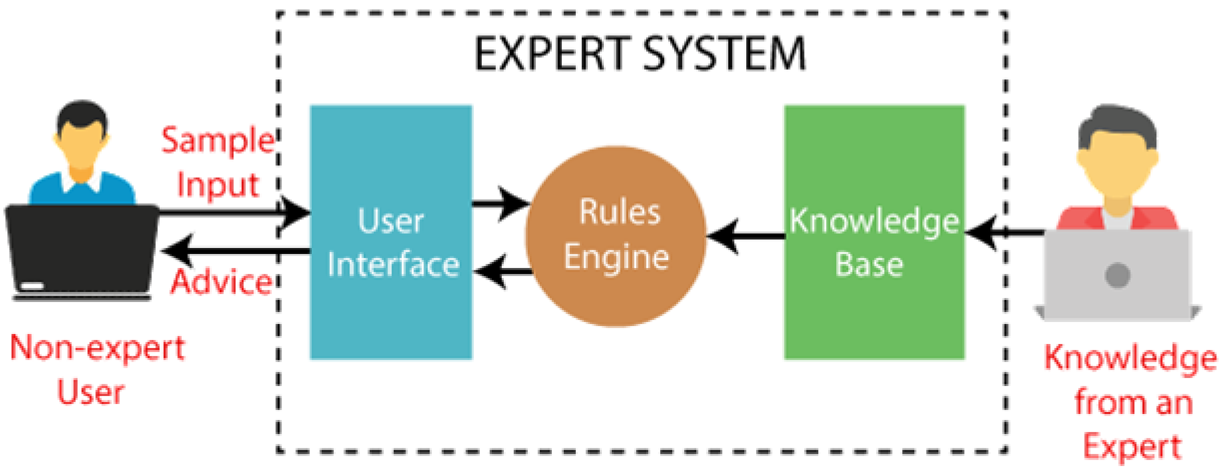
Challenges of knowledge-based systems

Some challenges of using knowledge-based systems include:

- Acquiring, organizing and manipulating large volumes of data and information
- Experiencing potential anomalies in the systems, such as redundant rules and circular dependencies
- Handling the limitations of scientific and cognitive techniques
- Navigating the generally abstract nature of knowledge
- Providing a system that is only as high quality as the data and information it contains
- Requiring accurate and extensive data to perform correctly



22. Components of expert systems, Semantic networks.



An expert system is a computer program that is designed to solve complex problems and to provide decision-making ability like a human expert. It performs this by extracting knowledge from its knowledge base using the reasoning and inference rules according to the user queries.
The performance of an expert system is based on the expert's knowledge stored in its knowledge base. The more knowledge stored in the KB, the more that system improves its performance. One of the common examples of an ES is a suggestion of spelling errors while typing in the Google search box.

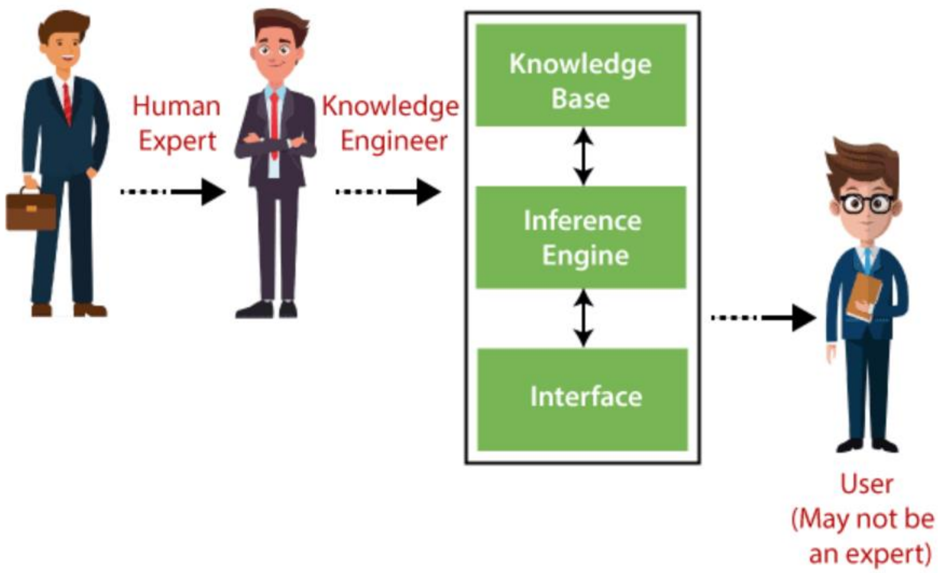
Characteristics of Expert System

- **High Performance:** The expert system provides high performance for solving any type of complex problem of a specific domain with high efficiency and accuracy.
- **Understandable:** It responds in a way that can be easily understandable by the user. It can take input in human language and provides the output in the same way.
- **Reliable:** It is much reliable for generating an efficient and accurate output.
- **Highly responsive:** ES provides the result for any complex query within a very short period of time.

Components of Expert System

An expert system mainly consists of three components:

- **User Interface**
- **Inference Engine**
- **Knowledge Base**



1. User Interface

With the help of a user interface, the expert system interacts with the user, takes queries as an input in a readable format, and passes it to the inference engine. After getting the response from the inference engine, it displays the output to the user. In other words, **it is an interface that helps a non-expert user to communicate with the expert system to find a solution**.

2. Inference Engine(Rules of Engine)

- The inference engine is known as the brain of the expert system as it is the main processing unit of the system. It applies inference rules to the knowledge base to derive a conclusion or deduce new information. It helps in deriving an error-free solution of queries asked by the user.
- With the help of an inference engine, the system extracts the knowledge from the knowledge base.
- There are two types of inference engine:
- **Deterministic Inference engine:** The conclusions drawn from this type of inference engine are assumed to be true. It is based on **facts** and **rules**.
- **Probabilistic Inference engine:** This type of inference engine contains uncertainty in conclusions, and based on the probability.

Inference engine uses the below modes to derive the solutions:

- **Forward Chaining:** It starts from the known facts and rules, and applies the inference rules to add their conclusion to the known facts.
- **Backward Chaining:** It is a backward reasoning method that starts from the goal and works backward to prove the known facts.

3. Knowledge Base

- The knowledgebase is a type of storage that stores knowledge acquired from the different experts of the particular domain. It is considered as big storage of knowledge. The more the knowledge base, the more precise will be the Expert System.
- It is similar to a database that contains information and rules of a particular domain or subject.
- One can also view the knowledge base as collections of objects and their attributes. Such as a Lion is an object and its attributes are it is a mammal, it is not a domestic animal, etc.

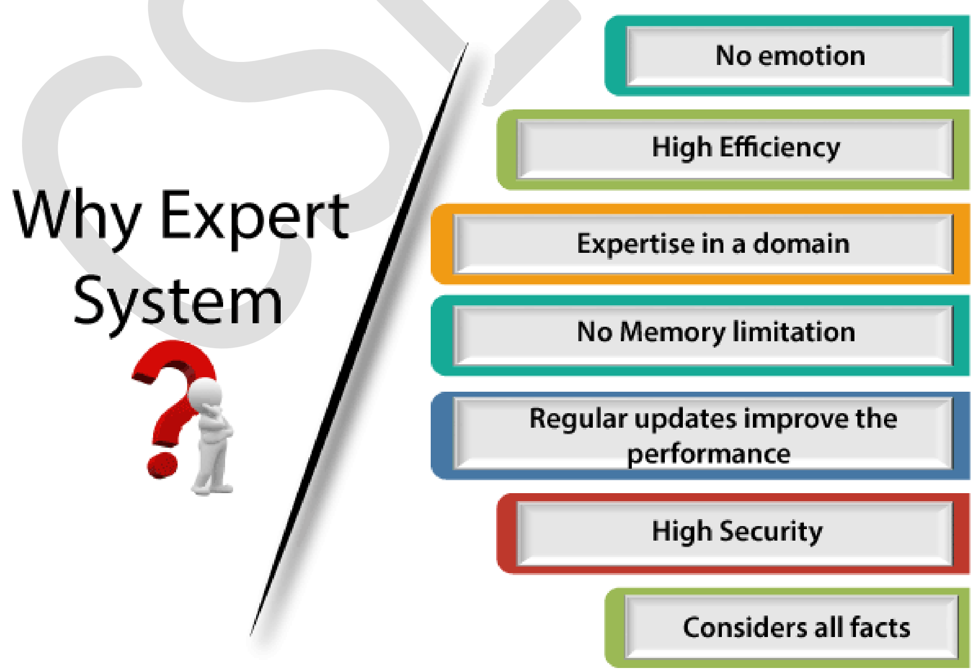
Components of Knowledge Base

- **Factual Knowledge:** The knowledge which is based on facts and accepted by knowledge engineers comes under factual knowledge.
- **Heuristic Knowledge:** This knowledge is based on practice, the ability to guess, evaluation, and experiences.

Knowledge Representation: It is used to formalize the knowledge stored in the knowledge base using the If-else rules.

Knowledge Acquisitions: It is the process of extracting, organizing, and structuring the domain knowledge, specifying the rules to acquire the knowledge from various experts, and store that knowledge into the knowledge base.

Why Expert System?



Before using any technology, we must have an idea about why to use that technology and hence the same for the ES. Although we have human experts in every field, then what is the need to develop a computer-based system. So below are the points that are describing the need of the ES:

1. **No memory Limitations:** It can store as much data as required and can memorize it at the time of its application. But for human experts, there are some limitations to memorize all things at every time.
2. **High Efficiency:** If the knowledge base is updated with the correct knowledge, then it provides a highly efficient output, which may not be possible for a human.
3. **Expertise in a domain:** There are lots of human experts in each domain, and they all have different skills, different experiences, and different skills, so it is not easy to get a final output for the query. But if we put the knowledge gained from human experts into the expert system, then it provides an efficient output by mixing all the facts and knowledge
4. **Not affected by emotions:** These systems are not affected by human emotions such as fatigue, anger, depression, anxiety, etc.. Hence the performance remains constant.
5. **High security:** These systems provide high security to resolve any query.
6. **Considers all the facts:** To respond to any query, it checks and considers all the available facts and provides the result accordingly. But it is possible that a human expert may not consider some facts due to any reason.
7. **Regular updates improve the performance:** If there is an issue in the result provided by the expert systems, we can improve the performance of the system by updating the knowledge base.

Applications of Expert System

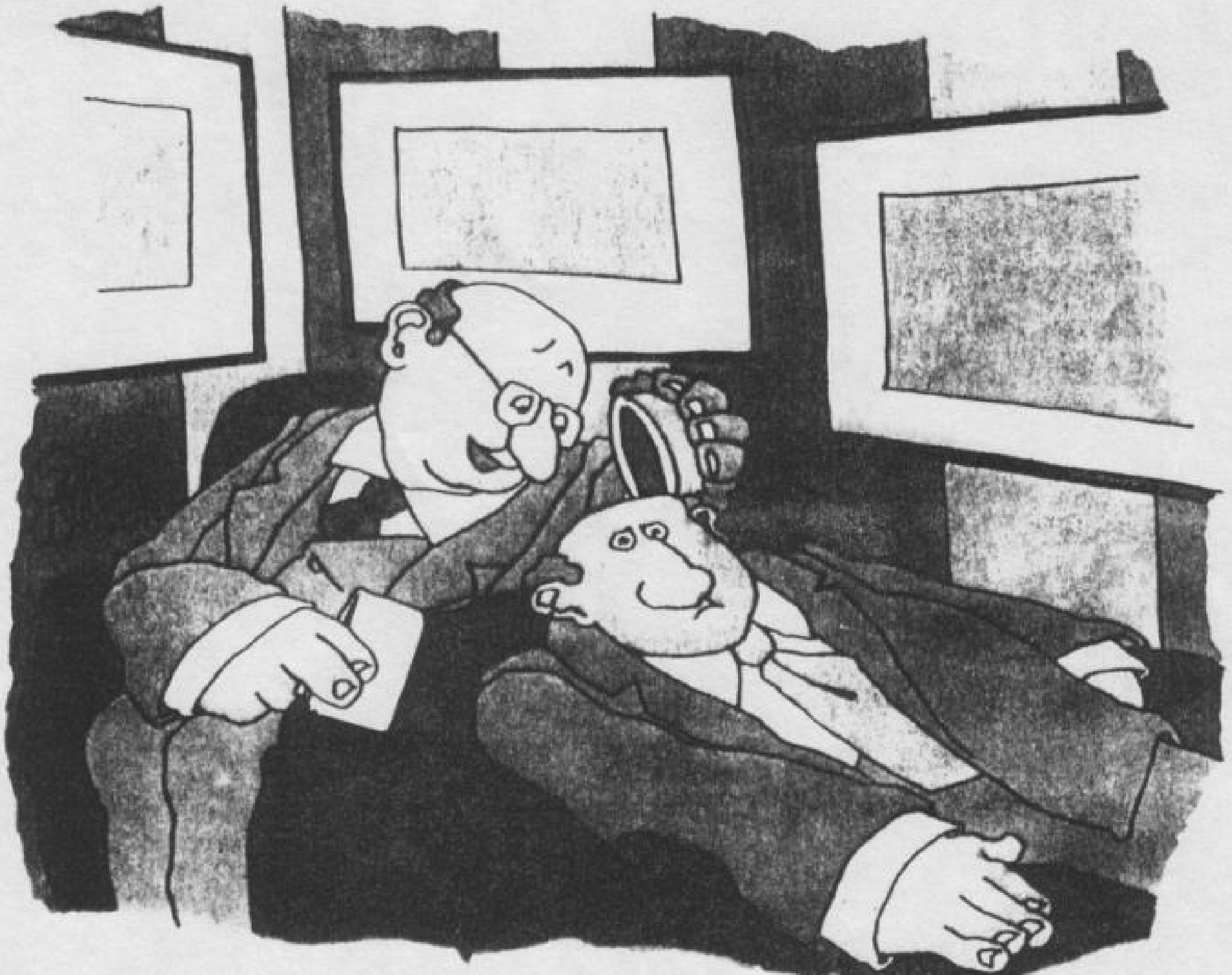
- **In designing and manufacturing domain**
  It can be broadly used for designing and manufacturing physical devices such as camera lenses and automobiles.
- **In the knowledge domain**
  These systems are primarily used for publishing the relevant knowledge to the users. The two popular ES used for this domain is an advisor and a tax advisor.
- **In the finance domain**
  In the finance industries, it is used to detect any type of possible fraud, suspicious activity, and advise bankers that if they should provide loans for business or not.
- **In the diagnosis and troubleshooting of devices**
  In medical diagnosis, the ES system is used, and it was the first area where these systems were used.
- **Planning and Scheduling**
  The expert systems can also be used for planning and scheduling some particular tasks for achieving the goal of that task.

Outline

- Definition and Scope of Cognitive Science
- A Brief History and Overview of Major Concepts
- Multidisciplinarity
- Introducing Contributing Disciplines
- Concluding Remarks- How to Become a Cognitive Scientist?

What IS Cognitive Science?

- The interdisciplinary study of mind and intelligence.
- Study of cognitive processes involved in the acquisition, representation and use of human knowledge.
- Scientific study of the mind, the brain, and intelligent behaviour, whether in humans, animals, machines or the abstract.
- *A discipline in the process of construction*.



"Looking good!"

Intelligence vs. Cognition

- The goal of cognitive science: develop a theory of Intelligent Systems?
- The goal of artificial intelligence: passing Turing Test?

History of Cognitive Science

- Linguistics:
  - Saussure- late 19th century, on structure of language
  - Bloomfield, Sapir: behaviourist
  - Zellig Harris and Chomsky: language as a generative system- innateness

Behaviourism and Cognitive Science

Definition 1

- "the study of intelligence and intelligent systems, with particular reference to intelligent behavior as computation" (Simon & Kaplan, 1989)
- Simon, H. A. & C. A. Kaplan, "Foundations of cognitive science", in Posner, M.I. (ed.) 1989, Foundations of Cognitive Science, MIT Press, Cambridge MA.

History of Cognitive Science

- 1950s – problem-solving (Newell & Simon)
- 1960s/70s – computational models
  - Planning
  - Attention
  - Reading
  - Reasoning
  - Consciousness

Evaluating cognitive theories

- Psychological plausibility
- Neurological plausibility
- Representational-computational power
- Practical applicability (education, design, intelligent systems)

Neuroscience

- Neurocognition, cognitive neuroscience, cognitive neuropsychology: Study of neurological basis of cognitive processing
- Computational neuroscience: Detailed simulation of neuronal mechanisms

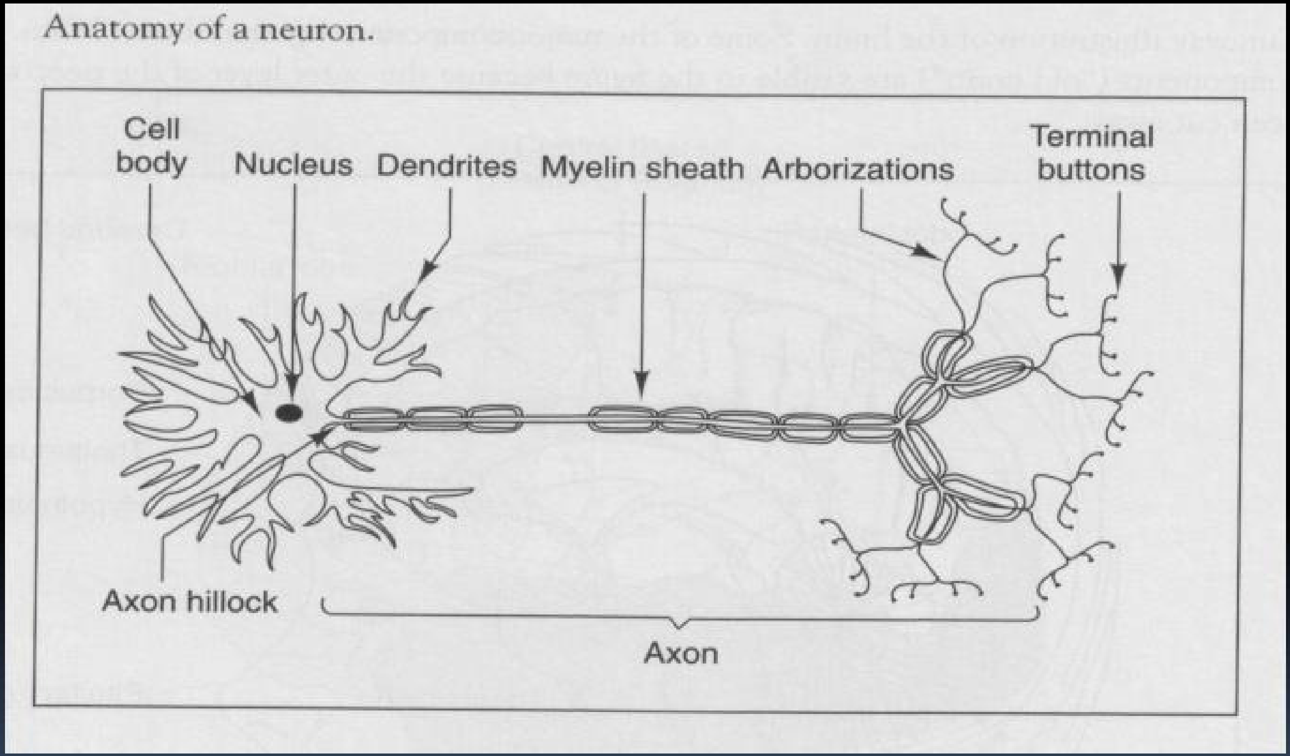
Neurons

- Major cell type in the nervous system (other: glial cells)
- About 50- 100 billion neurons (10^{11}) connectedness (typical fanout 10^3)
- Different types of neurons
- Different types of synapses

Major Components of Analysis

- Phonology
- Morphology
- Syntax
- Semantics
- Discourse
- Pragmatics

Structure of a Neuron



Cognitive Psychology

- Perception, Pattern Recognition
- Attention
- Skill Acquisition, Learning
- Memory
- Language
- Reasoning and Problem Solving

Experimental Methods, Simulation

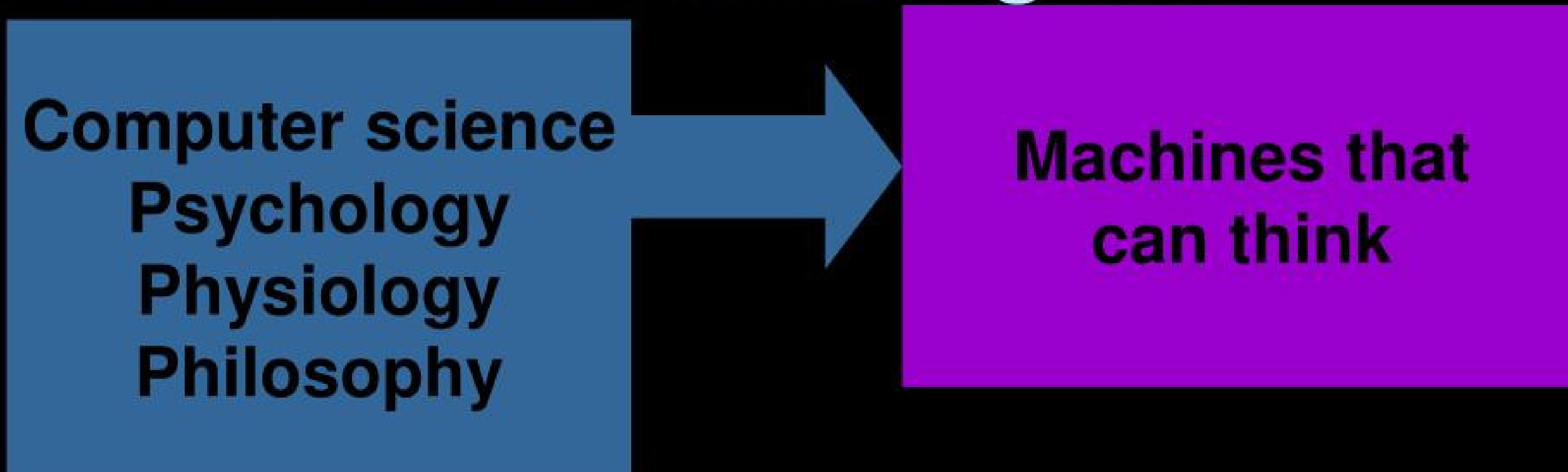
Cognitively Important Subdisciplines of Linguistics

- Psycholinguistics
  - Language Acquisition
  - Discourse Comprehension and Memory
- Neurolinguistics
- Computational Linguistics

What do these disciplines add?

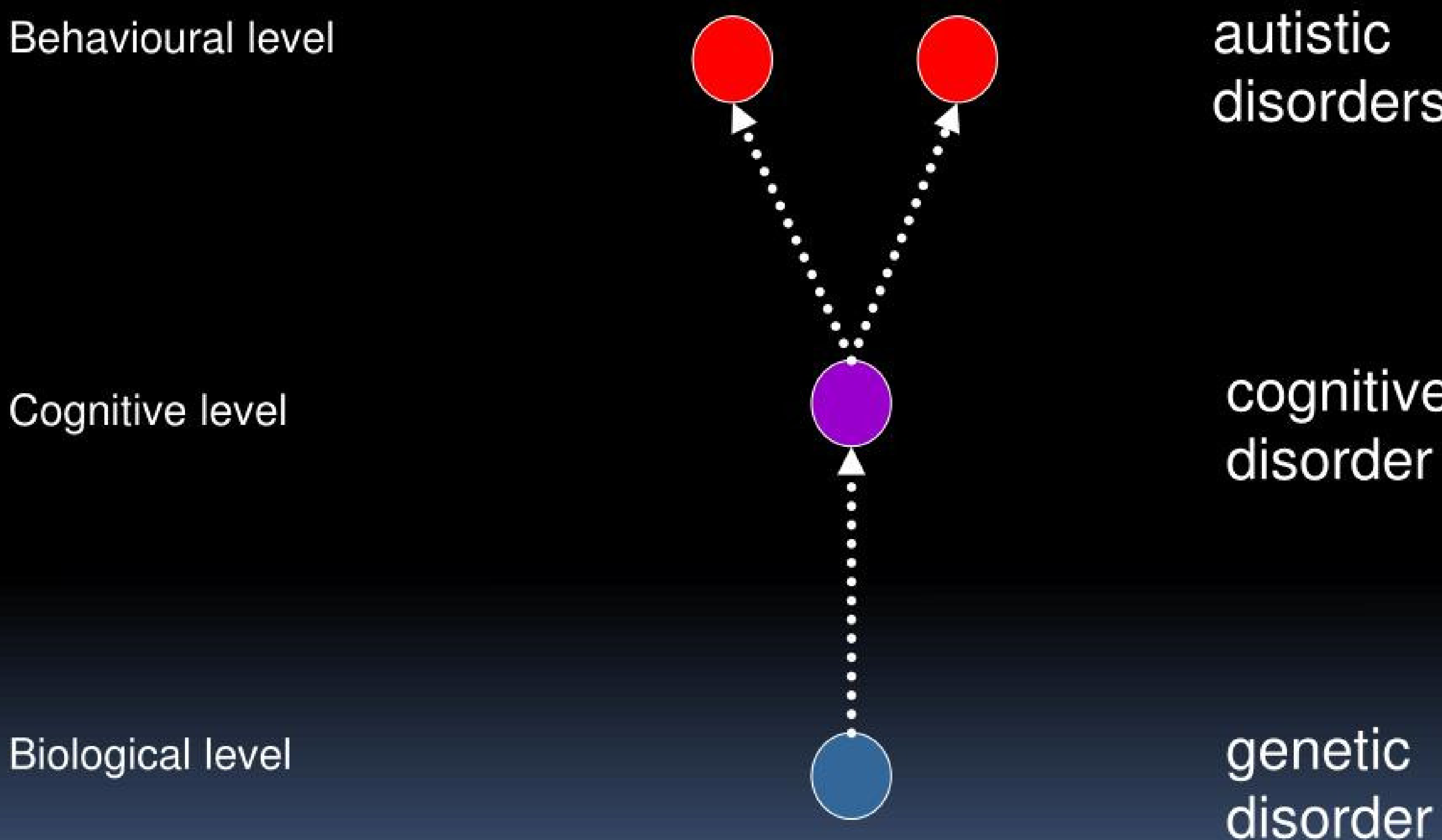
- Language
  - Intelligent behaviour associated with language
- Neuroscience
  - Brain
  - Nervous system
- Philosophy
  - Can computers think?
  - Mind-body problem

Artificial Intelligence



- Need to define “intelligence”
  - Problem-solving
  - Generalising
  - Perception

3 levels of description



Definition in wiki

- **Cognitive science** may be broadly defined as the multidisciplinary study of mind and behavior. It draws on multiple empirical disciplines, including psychology, philosophy, neuroscience, linguistics, anthropology, computer science, sociology and biology.

Definition in Plato encyclopedia

- Cognitive science is the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology.

Disciplines in Cognitive Science

- **Philosophy**
- **Neuroscience**
- **Computer Science- Artificial Intelligence**
- **Psychology – Cognitive Psychology**
- **Linguistics**
- Anthropology (the study of humankind, including the comparative study of societies and cultures and the science of human zoology and evolution.), Education

Cognition

- Cognition – from Latin base cognitio – “know together”
- The collection of mental processes and activities used in perceiving, learning, remembering, thinking, and understanding, and the act of using those processes

Embodied Embedded Cognition

- The theory states that intelligent behaviour emerges out of the interplay between brain, body and world. The world is not just the 'play-ground' on which the brain is acting. Rather, brain, body and world are equally important factors in the explanation of how particular intelligent behaviors come about in practice.

Cognitive Processes

- Learning and Memory
- Thinking and Reasoning (Planning, Decision Making, Problem Solving …)
- Language
- Vision-Perception
- Social Cognition (The study of how people process social information)
- Metacognition (It is traditionally defined as the knowledge and experiences we have about our own cognitive processes)
- Emotions
- Dreaming and Consciousness

Relatively Recent Challenges

- Not only Connectionist but dynamic and statistical models of cognition: e.g. versions of Optimality Theory in Linguistics
- Increasing role of neuroscience
  - On philosophy of mind
  - Emergence of new subdisciplines: cognitive neuroscience, computational neuroscience
- Embedded, situated cognition
  - Cognitive anthropology, cognitive informatics
- Tackling *hard* subjects
  - Consciousness

History of Cognitive Science

- Against Behaviourism: Watson, Skinner "psychology as a science of behaviour"
- The Cognitive Revolution – Chomsky, Miller, Bruner, Putnam, Newell, Simon, McCarthy- 1950s
- Contributing research paradigms: Cybernetics, Gestalt Psychology

History of Cognitive Science

- Cognitive Psychology (a branch of psychology that investigates internal mental processes such as problem solving, memory, and language.)
  - First textbook by Neisser in 1967
  - Advances in memory models (60s)
- Artificial Intelligence
  - Newell and Simon – Logic Theorist, GPS
  - McCarthy – frame problem
  - Minsky

History of Cognitive Science

Neuroscience:

- Brain structure and function (Gall, Spurzheim)
- Phrenology-late 19th century(analysis of personal traits according to the shape of the skull)
- Localization of function: Wernicke, Broca
- Neural impulse: Helmholtz
- Complexity of the human cortex: Lashley, Penfield
- The Man who Mistook his Wife for a Hat-a case for prosopagnosia
- Neural Network Modeling in 1950s: Pitts and McCulloch, Hebb, Rosenblatt

Definition 2 (con.)

- Cognitive science was a synthesis concerned with the kinds of knowledge that underlie human cognition, the details of human cognitive processing, and the computational modeling of those processes.
- There are five major topic areas in cognitive science: knowledge representation, language, learning, thinking, and perception.
- Eysenck, M.W. ed. (1990). **The Blackwell Dictionary of Cognitive Psychology.** Cambridge, Massachusetts: Basil Blackwell Ltd.

Definition 2

- Cognitive science refers to the interdisciplinary study of the acquisition and use of knowledge. It includes as contributing disciplines: artificial intelligence, psychology, linguistics, philosophy, anthropology, neuroscience, and education.
- Cognitive science grew out of three developments: the invention of computers and the attempts to design programs that could do the kinds of tasks that humans do; the development of information processing psychology where the goal was to specify the internal processing involved in perception, language, memory, and thought; and the development of the theory of generative grammar and related offshoots in linguistics

History of Cognitive Science

- Birth date: Symposium on Information Theory at MIT in 1956-Participants: Chomsky, Newell, Simon, Miller…
- Cognitive Science journal in 1977
- Cognitive Science society in 1980
- Around 200 Cognitive Science programs worldwide in 1995.

Paradigms of Cognitive Science

- Computational Representational Understanding of Mind
  - Computational Theory of Mind
  - Cognitivism, Functionalism
- Symbolicism – Connectionism- Dynamicism - Hybrid approaches

Is cognition information processing?

- Church-Turing Thesis
- Universal Turing Machine
- The information-processing metaphor: data+ algorithms
- Searle's Chinese Room Argument (attempts to show that a symbol-processing machine like a computer can never be properly described as having a "mind" or "understanding", regardless of how intelligently it may behave.)

Localist or Holist View of Multidisiplinarity

- (Von Eckardt, 2001) A field is multidisciplinary if individual research efforts are multidisciplinary- localist view
- A field is multidisciplinary if multiple disciplines contribute to the execution

to its research program (elaborate layered set of goals directed at the main goal)-holist view

Multidisciplinarity in Cognitive Science

- (Schunn et al, 1998) study on Journal Cognitive Science and Cognitive Science Society Meetings : computer science and cognitive psychology dominates.
- Multidisciplinarity esp. impact of neuroscience on the growth
- Still only 30-50% of the work are multidisciplinary
- Nature of multidisciplinary collaborations differ

References

- COGS 590- Slides from Ashcraft, Sobel, Stillings and Thagard
- Slides from http://psychology.derby.ac.uk/~steve/cogsci/

- Alberta's Dictionary of Cognitive Science
- Wikipedia
- Plato Stanford encyclopedia
- Oxford dictionary

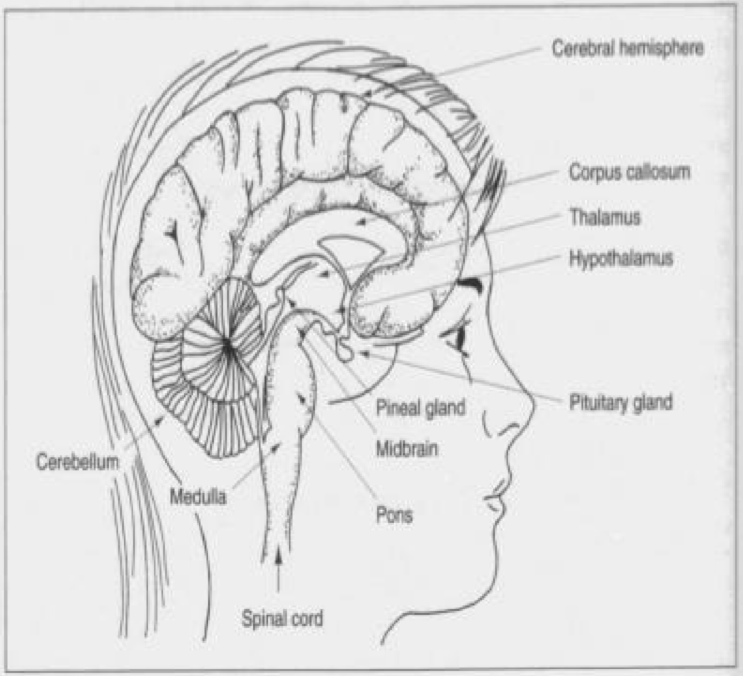
The End

Nervous System

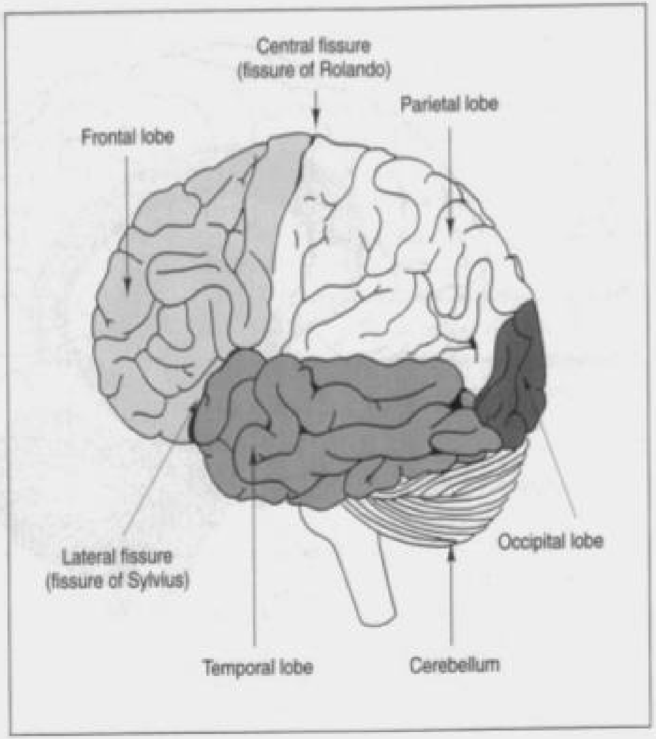
- Peripheral (nerve fibers, glands) vs. Central nervous system (brain, spinal cord)
- Brain: Cerebral cortex vs. Subcortical areas, such as the limbic system
- Two hemispheres (left-right); four lobes (frontal, parietal, occipital, temporal)

Human Brain

Cutaway illustration of the brain. Some of the major components of the human brain. The lower components ("old brain") are visible in the figure because the outer layer of the neocortex has been cut away.



The four lobes of the neocortex.



Neurons (cont).

- Resting membrane potential vs. Action potential (fire!) : concentration of ions
- Electrical synapses vs. Chemical synapses
- Excitatory vs inhibitory
- Neurotransmitters and neuromodulators
- Acetylocholine, dopamine, serotonin-around 30 known

Linguistics

- Linguistic Universals
- Grammar as a Descriptive System
  - Explaining productivity, e.g. This is the cheese that lay in the house Jack built
- I-language & E-language
- Universal Grammar
- Major theories of Grammar (such as Minimalist Program, Construction Grammars etc) have different cognitive claims

Artificial Intelligence

- Study of intelligent behaviour
- Automation of intelligent behaviour
- Machines acting and reacting adaptively
- How to make computers do things, which humans do better
- Study and construction of rational (goal and belief-directed) agents

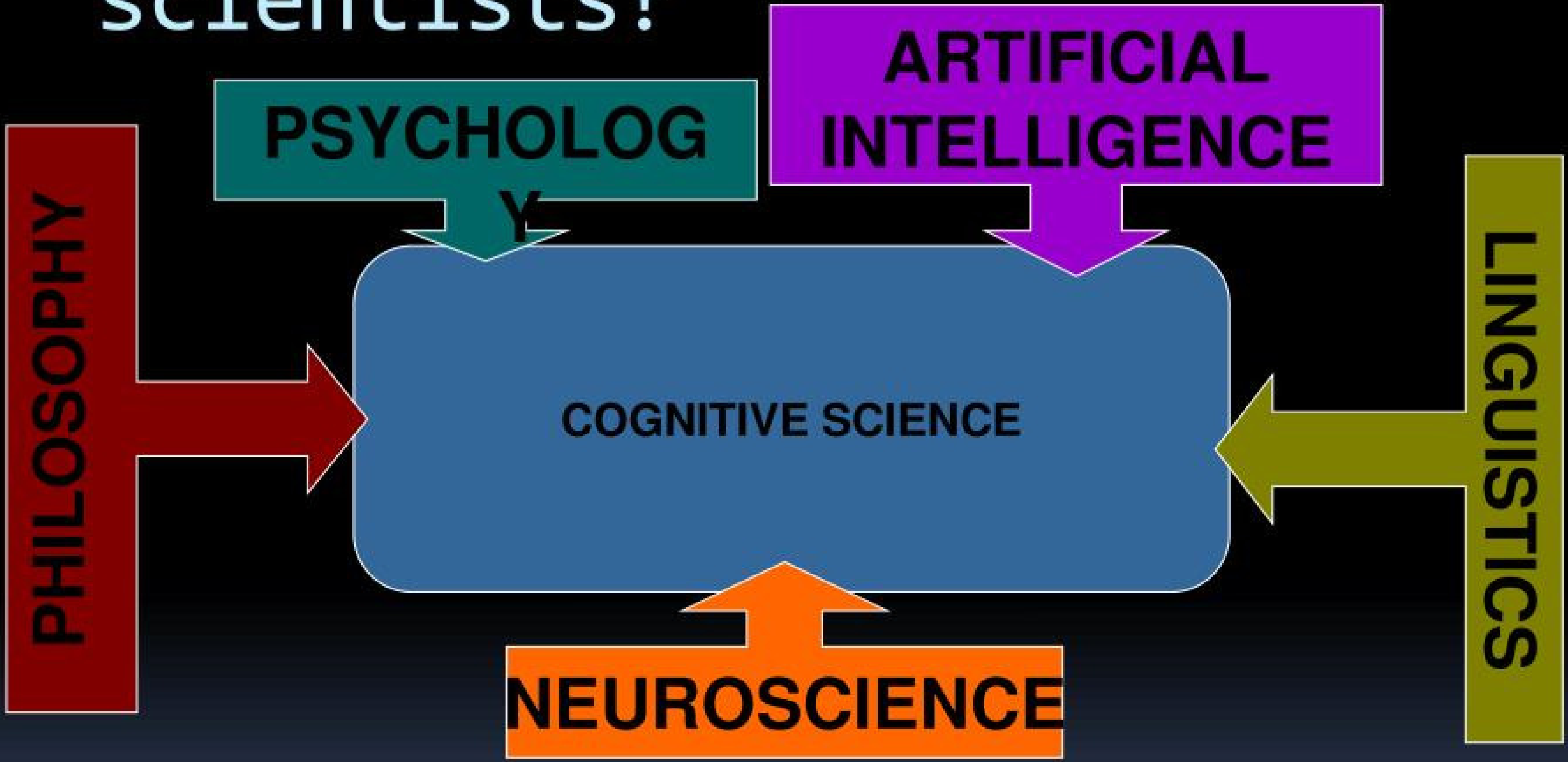
Concluding Remarks

- All these will take time; be patient; do not get discouraged.
- Take relief in that you are getting into a very, very interesting discipline.
- Pay attention, not only to the but to the processes of becoming a Cognitive Scientist.

Philosophy in Cognitive Science

- Philosophy of Mind
- Philosophical Logic
- Philosophy of Language
- Representations (Ontology)
- Knowledge and belief (Epistemology)
- Defining the scientific enterprise of cognitive science (Philosophy of science)
- Metaphysics, Phenomenology

Who are cognitive scientists?



Modeling for Study of Cognition

- Strong AI (duplicating a mind by implementing the right program) vs Weak AI (machines that act as if they are intelligent)
- aI (the study of human intelligence using computer as a tool) vs Ai (the study of machine intelligence as artificial intelligence) (Yeap)
- Artificial Intelligence and Cognitive Science: a history of interaction

Definition 3

- Generally stated, this is the study of intelligence and intelligence systems.
- It is a relatively new science that combines knowledge gained from a number of disciplines. These include: computer science, neuroscience, cognitive psychology, philosophy, and linguistics.
- As a result of the collaborative effort between these disciplines, there have been, and will continue to be, huge advancements in our understanding of human cognition.

History of Cognitive Science

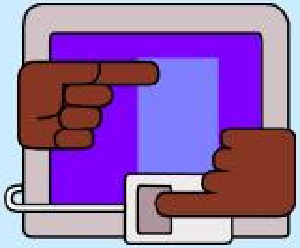
- Cognitive Science has a very long past but a relatively short history (Gardner, 1985)
- Philosophy: rationalism - that reason rather than experience is the foundation of certainty in knowledge - (Plato, Descartes, Kant, …) vs empiricism -doctrine that all knowledge is based on observation and experience - (Aristotle, Locke, Hume, Mill, …)
- Cartesian Dualism (relationship between mind and matter)
- Putnam – functionalism (60s); Fodor (70s) Language of Thought hypothesis

Methods of Cognitive Science

- Experimentation (psychology, linguistics, neuroscience)
- Computational Modeling (artificial intelligence, computational neuroscience)
- Introspection (the examination of one's own thoughts or feelings), Argumentation(the action of reasoning systematically in support of something), Formal Logic and Mathematical Modeling (philosophy, linguistics)
- Ethnography (cognitive anthropology)

Methods of Cognitive Science

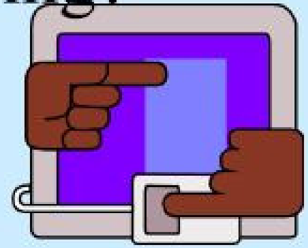
- Psychological measures
  - Self-reports
  - Speed of responses
  - Analysis of errors
- Neurological methods
  - Brain damage studies
  - Brain imaging techniques



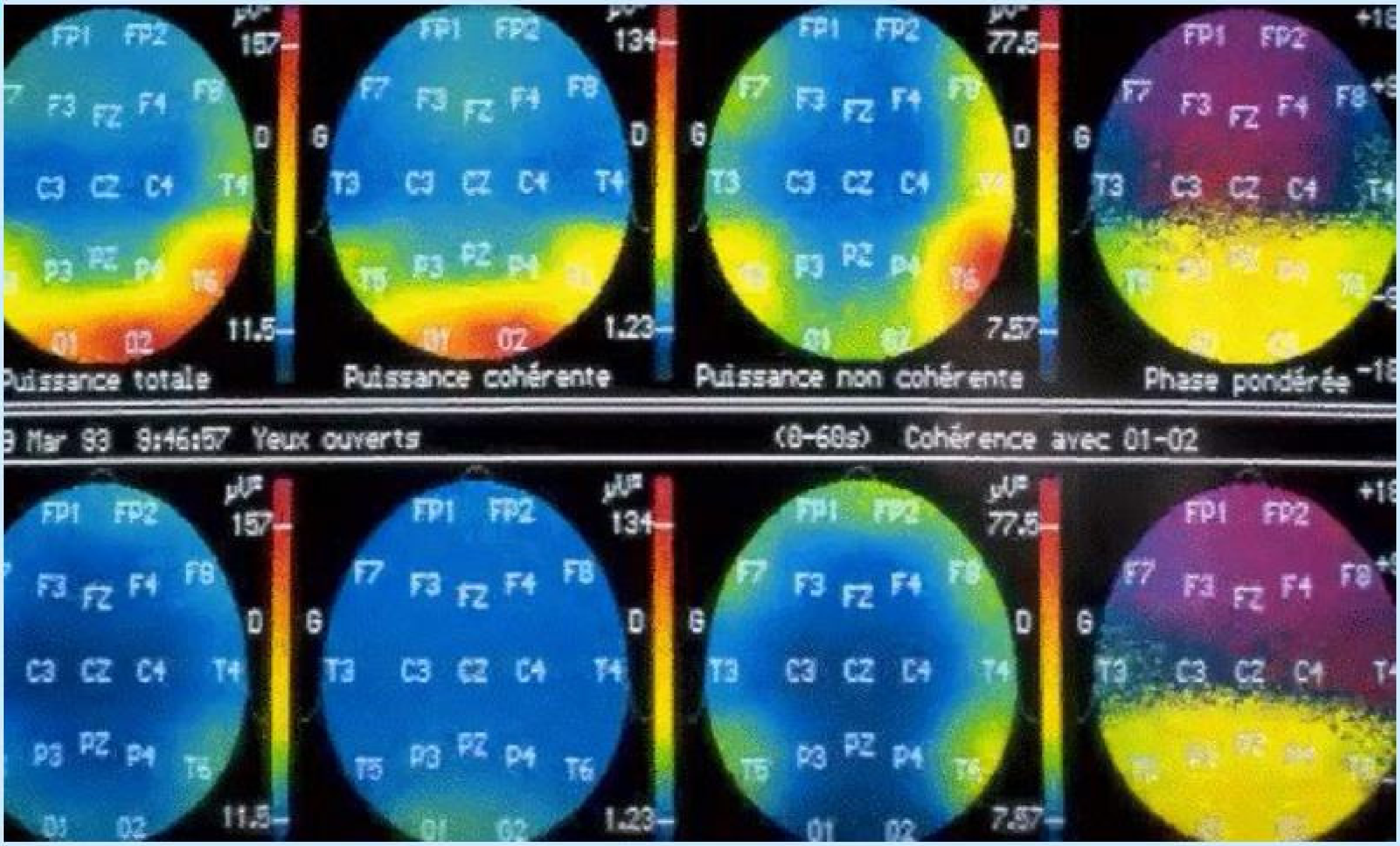
Magnetic resonance imaging (MRI)

Example: Child adds 4 + 3 = 7

- Possible models:
  - Child has memorized answer and “looks it up”
  - Child is using a counting algorithm
- Which model is correct?
  - Ask child to think aloud
  - Time responses to “4 + 1” and “4 + 3”
  - Examine nature of errors
  - What parts of brain are active while counting? While searching memory?

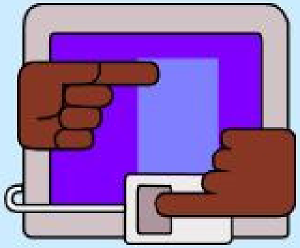


Electroencephalograph



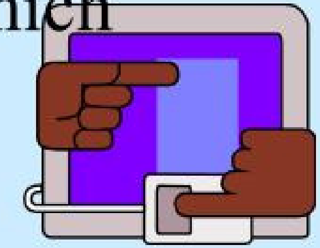
- Computer science
  - Programming; computational models
  - Turing test

- Philosophy: method of analogy



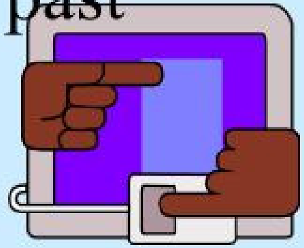
Levels of description

- Behavioral (knowledge) level
  - Addresses competence, not underlying algorithms
- Cognitive (formal) level
  - Analyzes the algorithm that information processor is using
- Biological (physical) level
  - Tells us about physical structures from which cognition arises

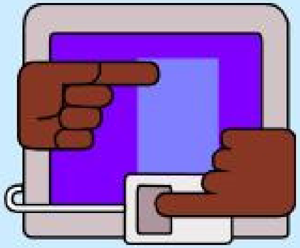


Example: Language development

- Behavioral level:
  - Very young child says “Mommy went to work”
  - Months later, “Mommy goed to work”
  - Still later, “Mommy went to work” again
- Formal level:
  - Very young child: simple imitation
  - Months later, algorithm of “add -ed” for past
  - Still later, algorithm plus idea of irregular past tenses (exceptions to the rule)

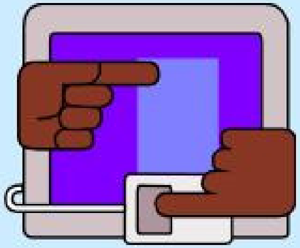


- Physical level:
  - What parts of the brain are active as child learns language?
  - What nerve connections are forming as child's skill develops?



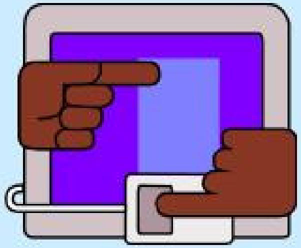
Cognitive Architecture

- Building's architecture: formal structure or plan of a building
- Computer architecture: fixed processing structure underlying the design of the machine
- **Cognitive architecture**: fixed structure that allows intelligent behavior



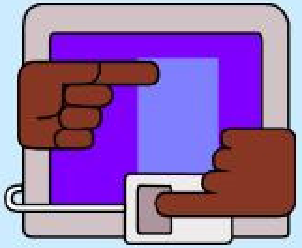
Characteristics of a cognitive architecture

- Should be **cognitively impenetrable**
  - Cannot be caused to change function simply by changing its goals or knowledge
  - Like a reflex: fast, automatic, innate
- Opposite of *cognitively penetrable*:
  - Changes in goals/knowledge lead to changes in function
  - Cannot reflect underlying architecture of mind



Characteristics of a cognitive architecture

- Should be cognitively impenetrable
- Need for independent **mental modules**

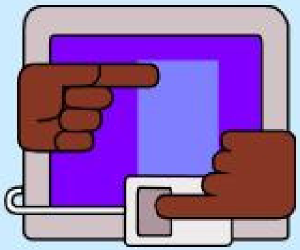


But *are* there cognitive reflexes?

- Müller-Lyer illusion

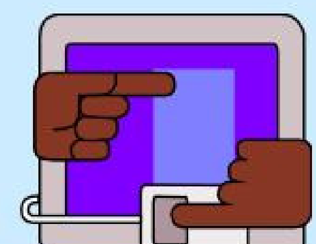
But *are* there cognitive reflexes?

- Müller-Lyer illusion
  - Knowledge of the facts does not alter perception
  - Occurs immediately
  - Innate? (Some dispute over this)
- Illusion of self-motion
- Phonemic restoration effects
- Perceptual constancies



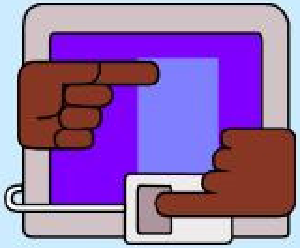
Properties of mental modules

- Domain specific
- Informationally encapsulated
- Mandatory - we cannot escape them
- Speedy
- MAY involve localization in the brain



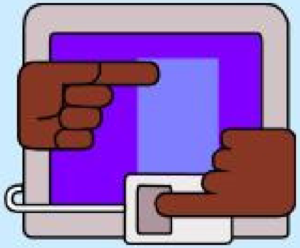
Properties of mental modules

- Domain-specific
  - Takes limited set of stimuli as input
  - Performs a particular set of operations
  - Limited range of output
- Informationally encapsulated
  - Restricted to its own knowledge base
  - Does not draw upon full range of goals, knowledge, beliefs of overall system



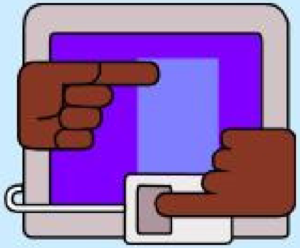
The Language Module

- Language processing = fast, automatic, probably innate
  - McGurk effect



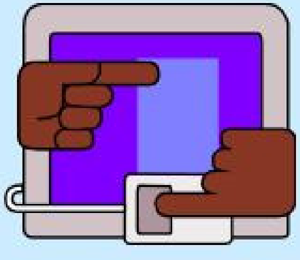
The McGurk Effect

- See video of person pronouncing “ga ga”
- Hear audio of person pronouncing “ba ba”
- What do we perceive? Something in between - “da da” or “bag ba” or “gab ga”



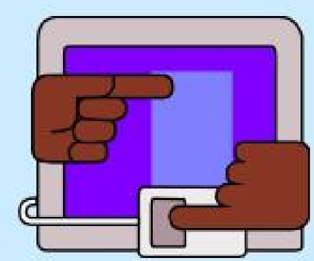
The Language Module

- Language processing = fast, automatic, probably innate
- **Double dissociations** between language and other cognitive abilities
- Evidence for fixed neurological structures involved in language
- Basics of grammatical parsing are informationally encapsulated



The Language Module

- Language processing = fast, automatic, probably innate
  - McGurk effect
  - Development of language in deaf children
- **Double dissociations** between language and other cognitive abilities
  - Aphasias
  - Linguistic savants



Example:

a. **John likes all kind of food.**

b. **Apple and vegetable are food**

c. **Anything anyone eats and not killed is food.**

d. **Anil eats peanuts and still alive**

e. **Harry eats everything that Anil eats.**

Prove by resolution that:

f. **John likes peanuts.**

Step-1: Conversion of Facts into FOL

In the first step we will convert all the given statements into its first order logic.

a. $\forall x$: food(x) → likes(John, x)

b. food(Apple) Λ food(vegetables)

c. $\forall x \forall y$: eats(x, y) Λ ¬ killed(x) → food(y)

d. eats (Anil, Peanuts) Λ alive(Anil).

e. $\forall x$: eats(Anil, x) → eats(Harry, x)

f. $\forall x$: ¬ killed(x) → alive(x) **added predicates.**

g. $\forall x$: alive(x) →¬ killed(x)

h. likes(John, Peanuts)

Step-2: Conversion of FOL into CNF

In First order logic resolution, it is required to convert the FOL into CNF as CNF form makes easier for resolution proofs.

- **Eliminate all implication (→) and rewrite**
  a. ∀x ¬ food(x) V likes(John, x)
  b. food(Apple) Λ food(vegetables)
  c. ∀x ∀y ¬ [eats(x, y) Λ ¬ killed(x)] V food(y)
  d. eats (Anil, Peanuts) Λ alive(Anil)
  e. ∀x ¬ eats(Anil, x) V eats(Harry, x)
  f. ∀x¬ [¬ killed(x)] V alive(x)
  g. ∀x ¬ alive(x) V ¬ killed(x)
  h. likes(John, Peanuts).

- **Move negation (¬)inwards and rewrite**
  a. $\forall x \neg$ food(x) V likes(John, x)
  b. food(Apple) Λ food(vegetables)
  c. $\forall x \forall y \neg$ eats(x, y) V killed(x) V food(y)
  d. eats (Anil, Peanuts) Λ alive(Anil)
  e. $\forall x \neg$ eats(Anil, x) V eats(Harry, x)
  f. $\forall x \neg$killed(x)] V alive(x)
  g. $\forall x \neg$ alive(x) V $\neg$ killed(x)
  h. likes(John, Peanuts).

- **Rename variables or standardize variables**

   a. ∀x ¬ food(x) V likes(John, x)

   b. food(Apple) Λ food(vegetables)

   c. ∀y ∀z ¬ eats(y, z) V killed(y) V food(z)

   d. eats (Anil, Peanuts) Λ alive(Anil)

   e. ∀w¬ eats(Anil, w) V eats(Harry, w)

   f. ∀g ¬killed(g)] V alive(g)

   g. ∀k ¬ alive(k) V ¬ killed(k)

   h. likes(John, Peanuts).

- **Eliminate existential instantiation quantifier by elimination.**

  In this step, we will eliminate existential quantifier ∃, and this process is known as **Skolemization**. But in this example problem since there is no existential quantifier so all the statements will remain same in this step.

- **Drop Universal quantifiers.**

  In this step we will drop all universal quantifier since all the statements are not implicitly quantified so we don't need it.

  a. ¬ food(x) V likes(John, x)
  b. food(Apple)
  c. food(vegetables)
  d. ¬ eats(y, z) V killed(y) V food(z)
  e. eats (Anil, Peanuts)
  f. alive(Anil)
  g. ¬ eats(Anil, w) V eats(Harry, w)
  h. killed(g) V alive(g)
  i. ¬ alive(k) V ¬ killed(k)
  j. likes(John, Peanuts).

- **Distribute conjunction ∧ over disjunction ¬.**
  This step will not make any change in this problem.

Step-3: Negate the statement to be proved

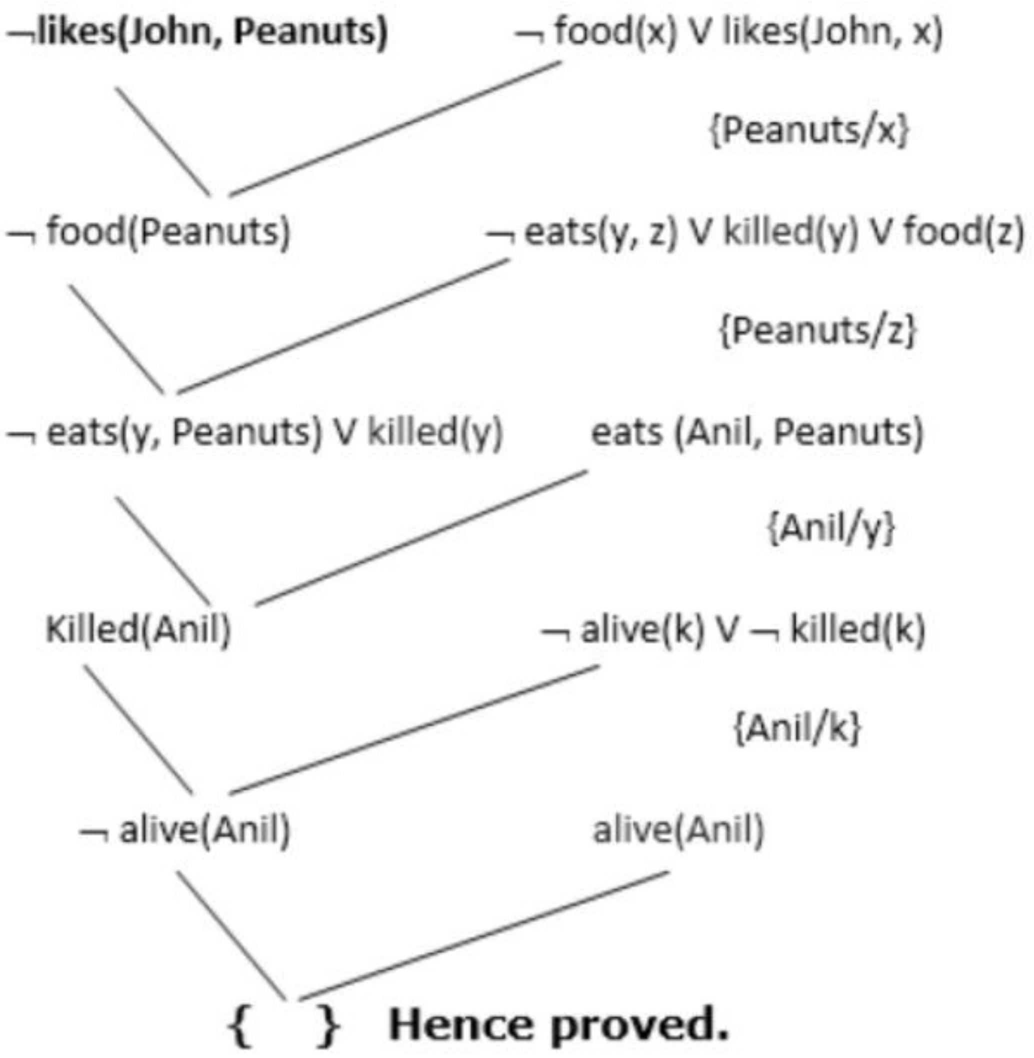
In this statement, we will apply negation to the conclusion statements, which will be written as ¬likes(John, Peanuts)

Step-4: Draw Resolution graph:

Now in this step, we will solve the problem by resolution tree using substitution. For the above problem, it will be given as follows:

Step-4: Draw Resolution graph:

Now in this step, we will solve the problem by resolution tree using substitution. For the above problem, it will be given as follows:



STEP 1: Express all statements in First-Order Logic (FOL)

Let's define predicates:

Predicate	Meaning
`Likes(x, y)`	Person `x` likes thing `y`
`Food(y)`	`y` is food
`Eats(x, y)`	Person `x` eats `y`
`Killed(x)`	Person `x` is killed

a. John likes all kinds of food

$\rightarrow \forall x(Food(x) \rightarrow Likes(John, x))$

b. Apple and vegetable are food

$\rightarrow Food(Apple)$

$\rightarrow Food(Vegetable)$

c. Anything anyone eats and is not killed is food

$\rightarrow \forall x, y\,(Eats(x, y) \land \neg Killed(x) \rightarrow Food(y))$

d. Anil eats peanuts and is alive

$\rightarrow Eats(Anil, Peanuts)$

$\rightarrow \neg Killed(Anil)$

e. Harry eats everything Anil eats

$\rightarrow \forall y(Eats(Anil, y) \rightarrow Eats(Harry, y))$

STEP 2: Convert everything to CNF

We'll break down each formula, eliminate implications, skolemize, and write in CNF form.

a. $\forall x(Food(x) \rightarrow Likes(John, x))$

Eliminate →:

$\forall x(\neg Food(x) \vee Likes(John, x))$

CNF:

→ $\neg Food(x) \vee Likes(John, x)$ [Clause 1]

---

b. $Food(Apple)$ **and** $Food(Vegetable)$

CNF:

→ $Food(Apple)$ [Clause 2]

→ $Food(Vegetable)$ [Clause 3]

c. $\forall x, y(Eats(x, y) \land \neg Killed(x) \rightarrow Food(y))$

Eliminate →:

$\forall x, y(\neg(Eats(x, y) \land \neg Killed(x)) \lor Food(y))$

Apply De Morgan's:

$\forall x, y((\neg Eats(x, y) \lor Killed(x)) \lor Food(y))$

$\rightarrow \neg Eats(x, y) \lor Killed(x) \lor Food(y)$ [Clause 4]

---

d. $Eats(Anil, Peanuts)$**,** $\neg Killed(Anil)$

$\rightarrow Eats(Anil, Peanuts)$ [Clause 5]

$\rightarrow \neg Killed(Anil)$ [Clause 6]

e. $\forall y(Eats(Anil, y) \rightarrow Eats(Harry, y))$

Eliminate →:

$\forall y(\neg Eats(Anil, y) \vee Eats(Harry, y))$

→ $\neg Eats(Anil, y) \vee Eats(Harry, y)$ [Clause 7]

¬Goal (Negate the statement to prove by refutation):

We want to prove: $Likes(John, Peanuts)$

So negate it: $\neg Likes(John, Peanuts)$ [Clause 8]

STEP 3: All CNF Clauses Together

#	Clause
1	$\neg Food(x) \vee Likes(John, x)$
2	$Food(Apple)$
3	$Food(Vegetable)$
4	$\neg Eats(x, y) \vee Killed(x) \vee Food(y)$
5	$Eats(Anil, Peanuts)$
6	$\neg Killed(Anil)$
7	$\neg Eats(Anil, y) \vee Eats(Harry, y)$
8	$\neg Likes(John, Peanuts)$ ← Negated goal

STEP 4: Apply Resolution

We want to derive a contradiction.

← Step A:

From Clause 5: $Eats(Anil, Peanuts)$

Clause 6: $\neg Killed(Anil)$

Use Clause 4:

$\neg Eats(x, y) \vee Killed(x) \vee Food(y)$

Substitute $x = Anil, y = Peanuts$:

Clause 4 becomes:

→ $\neg Eats(Anil, Peanuts) \vee Killed(Anil) \vee Food(Peanuts)$

Resolve with Clause 5: $Eats(Anil, Peanuts)$

→ Resolvent: $Killed(Anil) \vee Food(Peanuts)$ [Clause 9]

Now resolve with Clause 6: $\neg Killed(Anil)$

→ Resolvent: $Food(Peanuts)$ [Clause 10]

⟵ Step B:

From Clause 10: $Food(Peanuts)$

Use Clause 1: $\neg Food(x) \vee Likes(John, x)$

Substitute $x = Peanuts$:

→ $\neg Food(Peanuts) \vee Likes(John, Peanuts)$

Resolve with Clause 10: $Food(Peanuts)$

→ Resolvent: $Likes(John, Peanuts)$ [Clause 11]

⬅ Step C:

Now, resolve Clause 11: $Likes(John, Peanuts)$

With Clause 8: $\neg Likes(John, Peanuts)$

→ Resolvent: **Empty Clause (contradiction)**

Step-4: Draw Resolution graph:

Now in this step, we will solve the problem by resolution tree using substitution. For the above problem, it will be given as follows: