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Introduction to Intelligent Systems (IIS)

Topic : Introduction to Intelligent Systems

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COURSE OBJECTIVES :

- **Upon successful completion of this course, students will be able to:**
- **Evolutions of intelligent systems.**
- **How to build an Intelligent Systems to solve problems by computational reasoning using captured domain knowledge and data.**
- **Intelligent Systems that will help to control the advanced robotic systems.**
- **The skills and techniques required to build Intelligent Sensing Systems that are able to make decisions based on real world data.**
- **To develop the ability to implement a particularly intelligent system of choice.**

Topic / Unit 1 :

Introduction

- What are Intelligent systems?
- Modern Computational Intelligence
- History of Artificial Intelligence
- Artificial Intelligence - Intelligent Systems
- Modern Artificial Intelligence
- Applications of Intelligence systems
- Parallel Computing
- Research areas in Artificial Intelligence
- Smart Materials
- Neuromorphic Computing
 - Difference between Von Neumann and Neuromorphic Computing

INTRODUCTION:

Intelligent systems are technological platforms that use various components such as Big Data, the Internet of Things (IoT), artificial intelligence, robotics, and more to solve complex problems automatically and efficiently within specific environments. They can be applied in various sectors, including manufacturing, healthcare, and education.

- These systems can reduce errors by analyzing data and identifying patterns, optimize performance by adjusting processes based on insights, and learn from their own identification, among other capabilities.
- **Intelligent systems can be classified into three main types: Cognitive, Social, and Emotional Intelligent Systems.**
 - Cognitive intelligent systems can think, reason, learn, and remember;
 - Social intelligent systems can understand and manage social relationships; and
 - Emotional intelligent systems can recognize, understand, and manage emotions.
- The development of intelligent systems involves various technologies, such as machine learning, deep learning, and natural language processing, which enable these systems to perform complex tasks and adapt to new situations.

What are Intelligent Systems ?

- Intelligent systems are formed by the collaboration of people and technologies to collect, analyze, and respond to data from their surrounding environment. They can be used in various applications, including factory automation, field and service robotics, assistive robotics, military applications, medical care, education, entertainment, visual inspection, and character recognition.
- These systems can reduce errors by analyzing data and identifying patterns, optimize performance by adjusting processes based on insights, and learn from their own identification, among other capabilities.
- Intelligent systems can be classified into three main types: cognitive, social, and emotional intelligent systems. Cognitive intelligent systems can think, reason, learn, and remember; social intelligent systems can understand and manage social relationships; and emotional intelligent systems can recognize, understand, and manage emotions.

Link for reference :

https://www.algotive.ai/blog/intelligent-systems-what-are-they-how-do-they-work-and-why-are-they-so-important#ancla_1

Modern Computational Intelligence:

- While there isn't a specific link for modern computational intelligence, it generally refers to the current state of AI and computational intelligence, which involves the use of various techniques and methods to create intelligent systems.
- Modern computational intelligence includes techniques such as machine learning, deep learning, and natural language processing, which enable intelligent systems to perform complex tasks and adapt to new situations.
- Modern computational intelligence also involves the use of parallel computing, which allows multiple processing units to work together to solve complex problems more efficiently than a single processing unit.
- Modern computational intelligence also includes the use of neuromorphic computing, which is an approach to designing computer systems that mimic the structure and function of the human brain, allowing for more efficient and energy-efficient processing of information.

Link for reference :

https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligent_systems.htm

History of Artificial Intelligence:

The history of artificial intelligence (AI) spans several decades and is marked by significant milestones, breakthroughs, and shifts in focus. Here is a brief overview of the key developments in the history of AI:

- **1950s: Birth of AI and Dartmouth Conference:** The term "artificial intelligence" was coined in the 1950s, and the Dartmouth Conference in 1956 marked the official establishment of the AI field.
- **1960s-1970s:** Early AI Programs and AI Winter: Early AI programs focused on symbolic reasoning, but the field experienced a downturn with limited progress during the AI winter.
- **1980s-1990s:** Expert Systems and Neural Networks: AI research shifted to expert systems and neural networks, with backpropagation as a key breakthrough in the late 1980s.
- **2000s-2010s:** Rise of Machine Learning and Deep Learning: Machine learning gained prominence, and deep learning, with its application of neural networks with many layers, became a dominant approach.
- **2010s-Present:** AI in Everyday Life and Ethical Considerations: AI applications became integral to daily life, raising ethical concerns regarding bias, transparency, accountability, and societal impact.

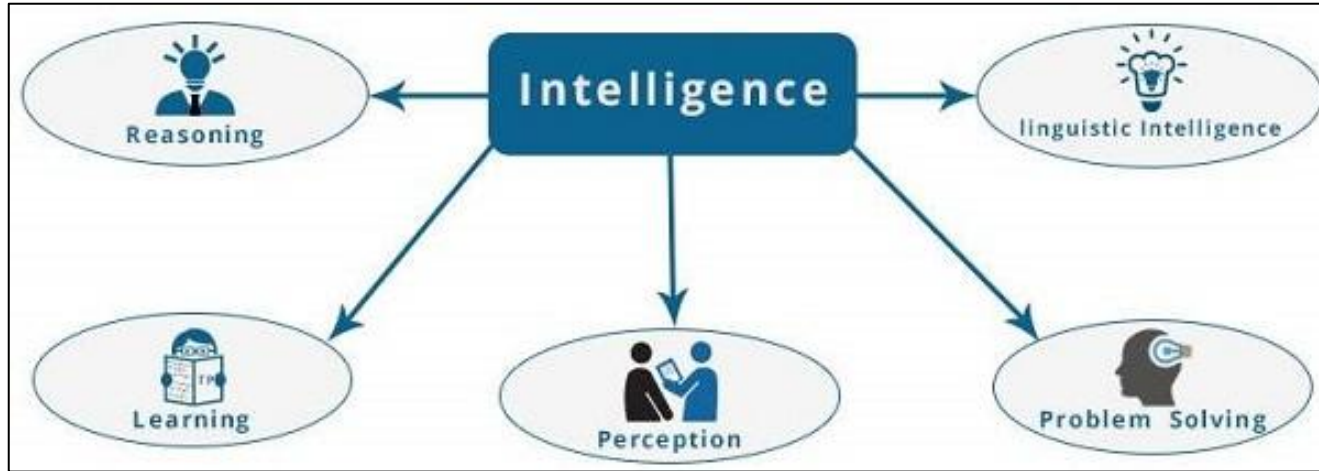
Artificial Intelligence - Intelligent Systems :

“While studying artificial intelligence, you need to know what intelligence is.”

What is Intelligence?

- The ability of a system to calculate, reason, perceive relationships and analogies, learn from experience, store and retrieve information from memory, solve problems, comprehend complex ideas, use natural language fluently, classify, generalize, and adapt new situations.
- The roots of artificial intelligence can be traced back to the study of how computers can understand and interpret visual information from static images, and it has evolved into a powerful technology central to various sectors.

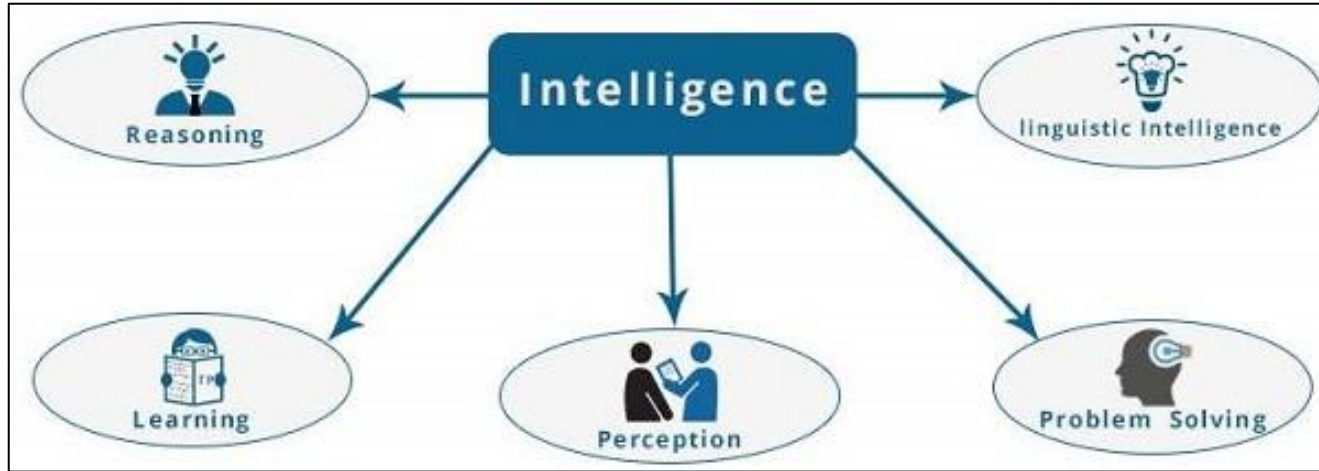
What is Intelligence Composed of ?



- **Reasoning :**

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

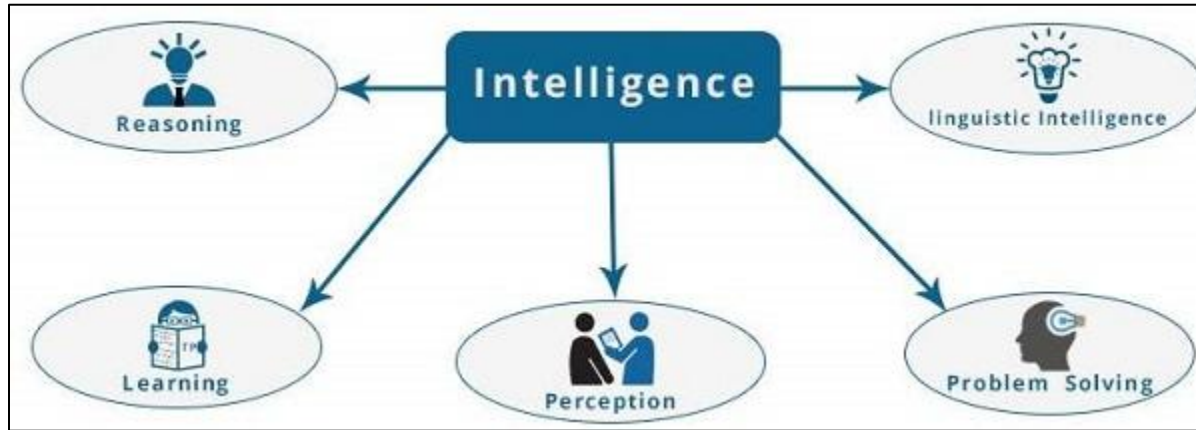
What is Intelligence Composed of ?



- **Learning :**

- It is the activity of gaining knowledge or skill by studying, practising, being taught, or experiencing something.
Learning enhances the awareness of the subjects of the study.
- The ability of learning is possessed by humans, some animals, and AI-enabled systems.

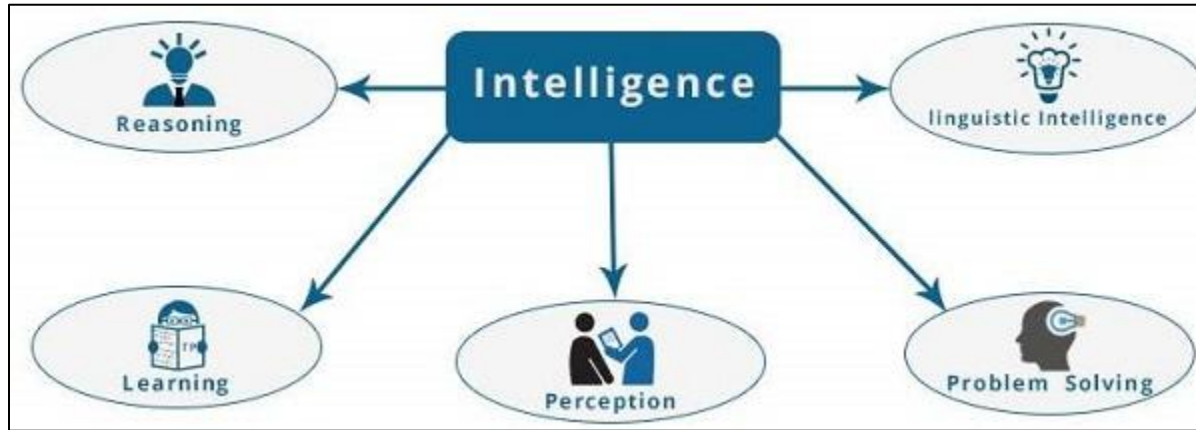
What is Intelligence Composed of ?



- **Problem Solving :**

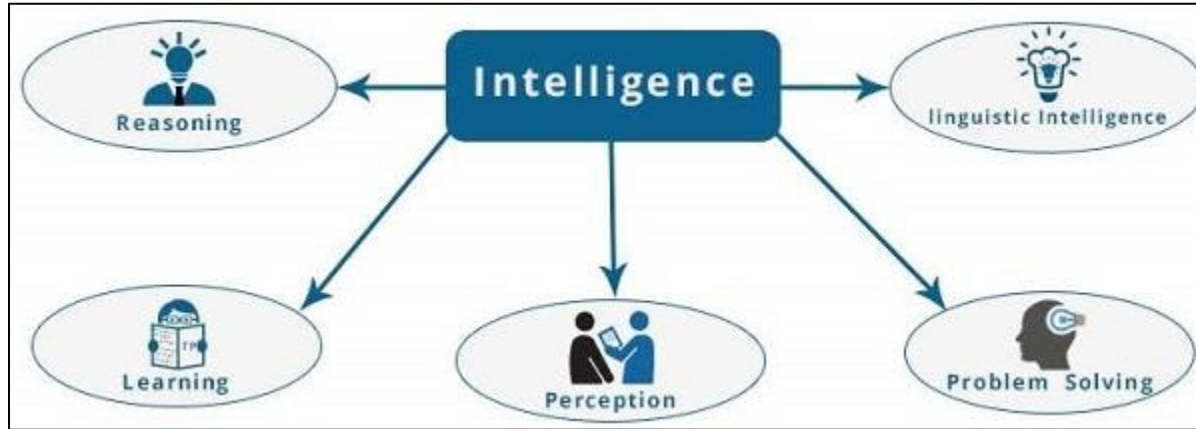
- It is the process in which one perceives and tries to arrive at a desired solution from a present situation by taking some path, which is blocked by known or unknown hurdles.
- Problem solving also includes decision making, which is the process of selecting the best suitable alternative out of multiple alternatives to reach the desired goal are available.

What is Intelligence Composed of ?



- **Perception :**
 - It is the process of acquiring, interpreting, selecting, and organizing sensory information.
 - Perception presumes sensing. In humans, perception is aided by sensory organs. In the domain of AI, perception mechanism puts the data acquired by the sensors together in a meaningful manner.

What is Intelligence Composed of ?



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

Modern Artificial Intelligence:

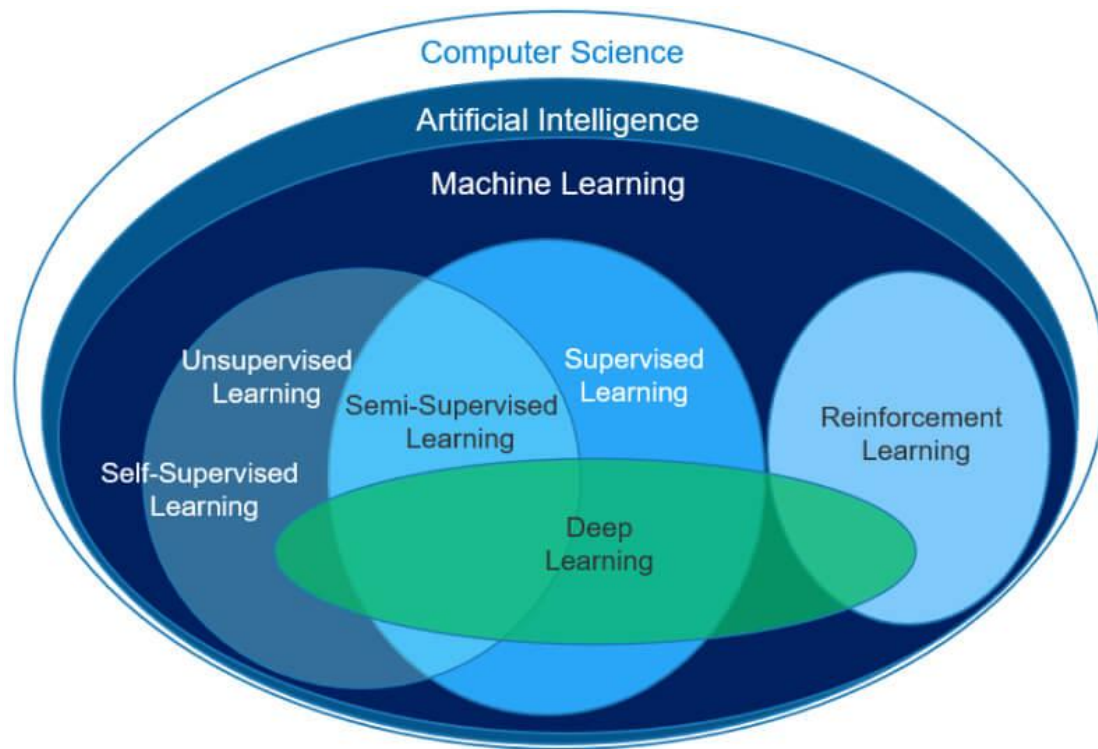
- Modern AI encompasses various techniques and methods, such as

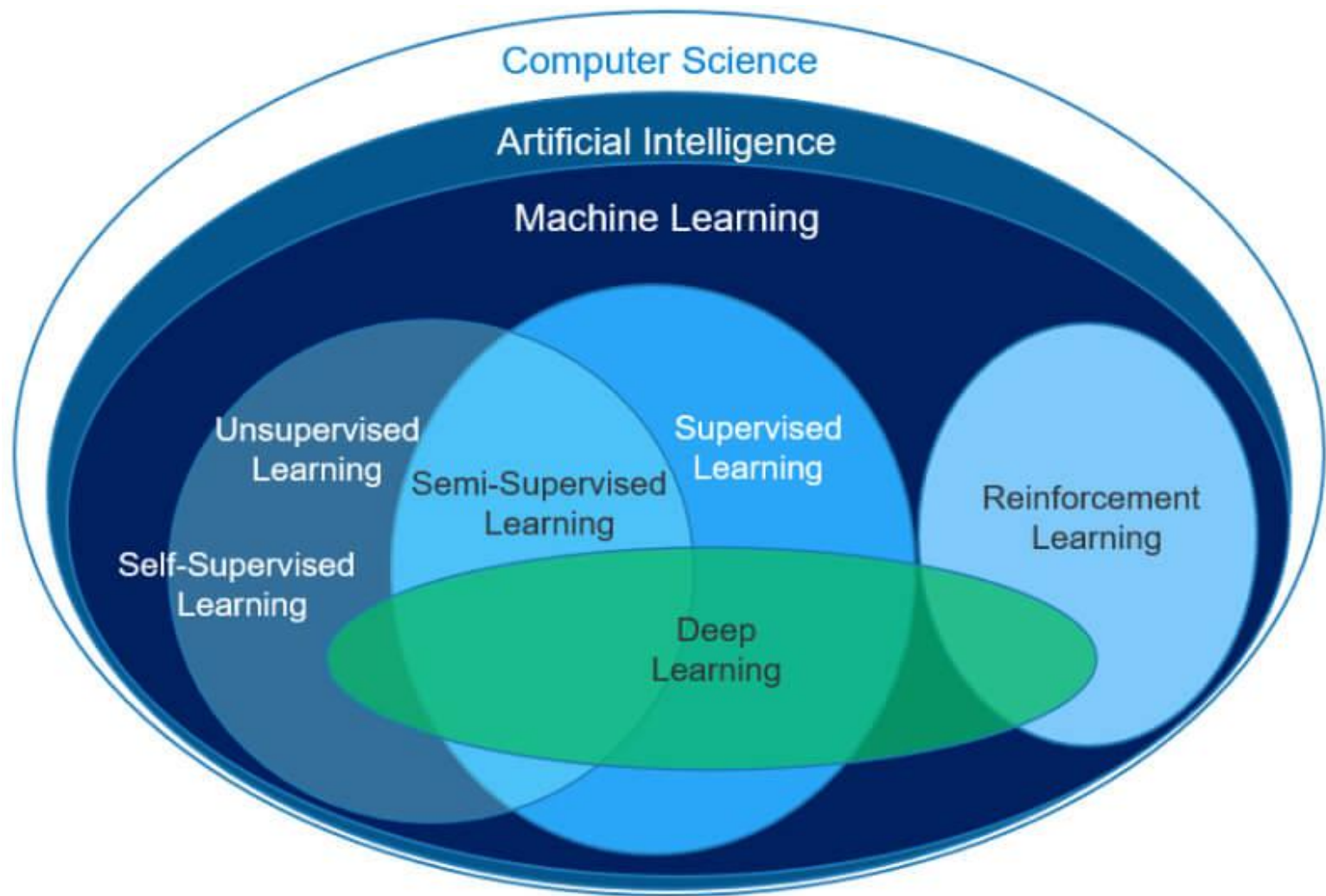
Modern Artificial Intelligence:

- Modern AI encompasses various techniques and methods, such as
 - **Machine learning,**
 - **Deep learning, and**
 - **Natural language processing,**to create intelligent systems that can perform complex tasks and adapt to new situations.

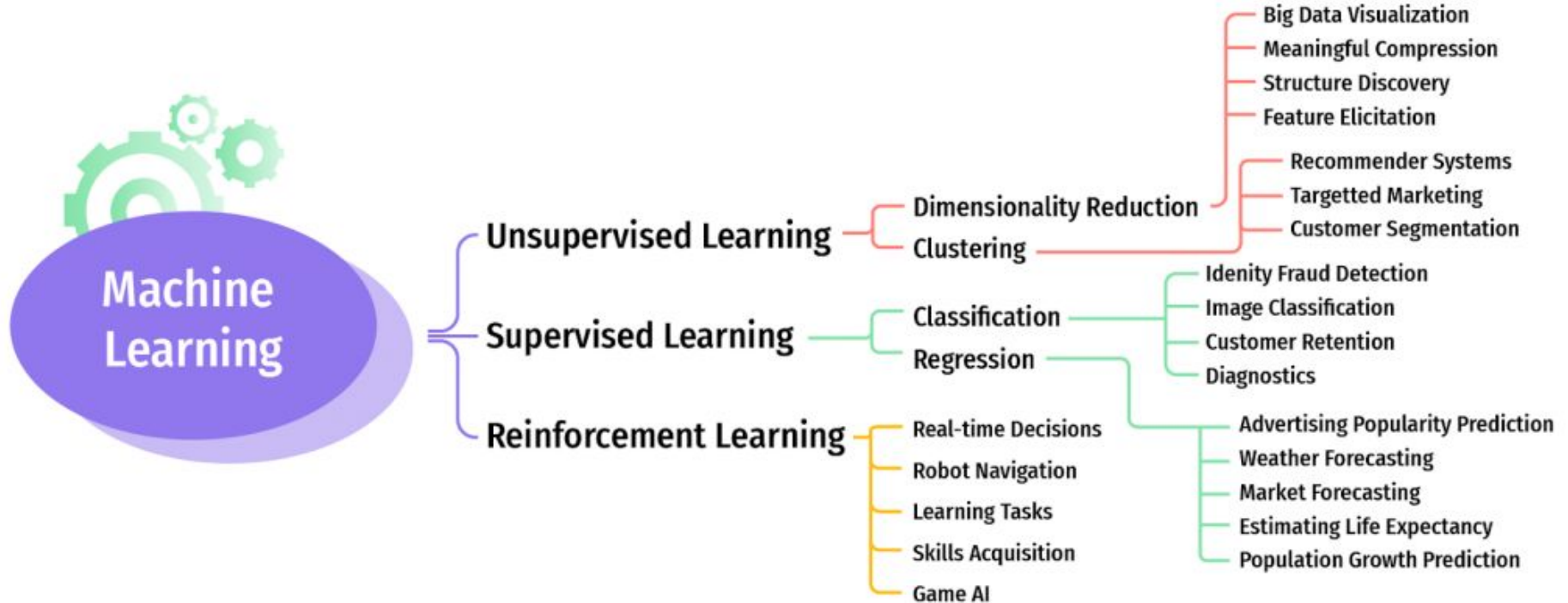
Modern Artificial Intelligence:

- Machine learning is a subfield of AI that focuses on developing algorithms that can learn from data without being explicitly programmed.





Machine learning and its types :



Machine learning and its types :

- **Supervised Learning:**

- Supervised learning uses labeled datasets to train algorithms that classify data or predict outcomes. It is widely used in real-world applications such as spam classification and image recognition

- **Unsupervised Learning:**

- Unsupervised learning involves training algorithms on unlabeled data to discover hidden patterns or intrinsic structures. It is commonly used in clustering and dimensionality reduction tasks

- **Reinforcement Learning:**

- Reinforcement learning is a type of machine learning where an agent learns to make decisions by interacting with its environment.
- It receives feedback in the form of rewards or penalties for its actions, allowing it to learn the best behavior through trial and error.

Modern Artificial Intelligence:

- **Definition of NLP:**

- Natural Language Processing (NLP) is a field of artificial intelligence that focuses on the interaction between computers and humans through natural language. It enables computers to understand, interpret, and generate human language in a valuable way

- **Key NLP Tasks:**

- Text Processing, Language Modeling, Spelling Correction, Text Classification, Sentiment Analysis, Information Extraction, Named Entity Recognition, Relation Extraction, Question Answering, Summarization.

- **Importance of NLP:**

- NLP plays a crucial role in various applications such as chatbots, language translation, voice assistants, and sentiment analysis, revolutionizing the way humans interact with machines

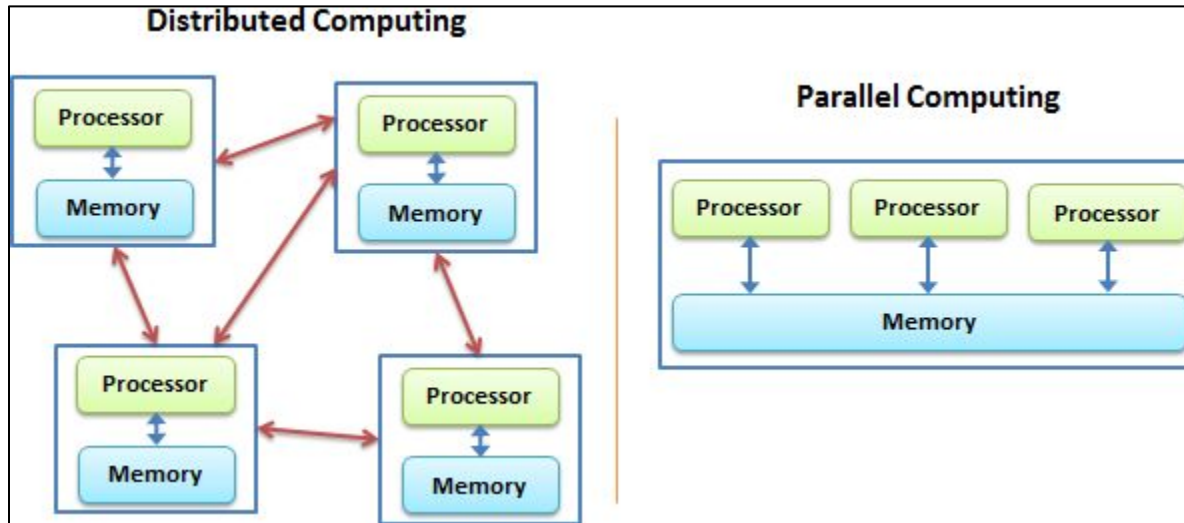
Applications of Intelligent Systems:

- **Healthcare:** "Intelligent systems are used in healthcare for tasks such as disease diagnosis, patient monitoring, and drug discovery. They can analyze medical images, predict patient outcomes, and develop personalized treatment plans
- **Finance:** "In finance, intelligent systems are employed for tasks such as fraud detection, risk management, and investment analysis. They can analyze financial data, predict market trends, and optimize investment portfolios
- **Education:** "Intelligent systems are used in education for tasks such as personalized learning, student assessment, and curriculum design. They can adapt to individual student needs, provide feedback, and recommend learning materials
- **Transportation:** "In transportation, intelligent systems are used for tasks such as route optimization, traffic management, and autonomous vehicles. They can analyze traffic patterns, predict congestion, and control vehicle movements
- **Manufacturing:** "Intelligent systems are used in manufacturing for tasks such as quality control, predictive maintenance, and supply chain optimization. They can analyze production data, predict equipment failures, and optimize supply chain logistics

Parallel Computing:

- **Definition of Parallel Computing:**

- Parallel computing is a type of computation where multiple processors work together to solve a problem.
- It involves breaking down a large problem into smaller sub-problems that can be solved simultaneously



Parallel Computing:

- Parallel computing is a type of computation in which many calculations or processes are carried out simultaneously.
- It involves breaking down a problem into smaller sub-problems and solving them concurrently, utilizing multiple processors or computational units.
- The goal is to achieve faster and more efficient processing by dividing the workload among multiple processing elements that work in parallel.
- This contrasts with sequential computing, where tasks are executed one after another by a single processing unit.

Key aspects of Parallel Computing:

Parallelism:

- Task Parallelism: Concurrent execution of subtasks.
- Data Parallelism: Simultaneous processing of different data elements.

Parallel Architectures:

- Shared Memory: Processors share a common memory space.
- Distributed Memory: Processors have separate local memory.

Parallel Processing Models:

- SIMD (Single Instruction, Multiple Data): Same instruction on multiple data.
- MIMD (Multiple Instruction, Multiple Data): Different instructions on different data.

Key aspects of Parallel Computing:

Benefits:

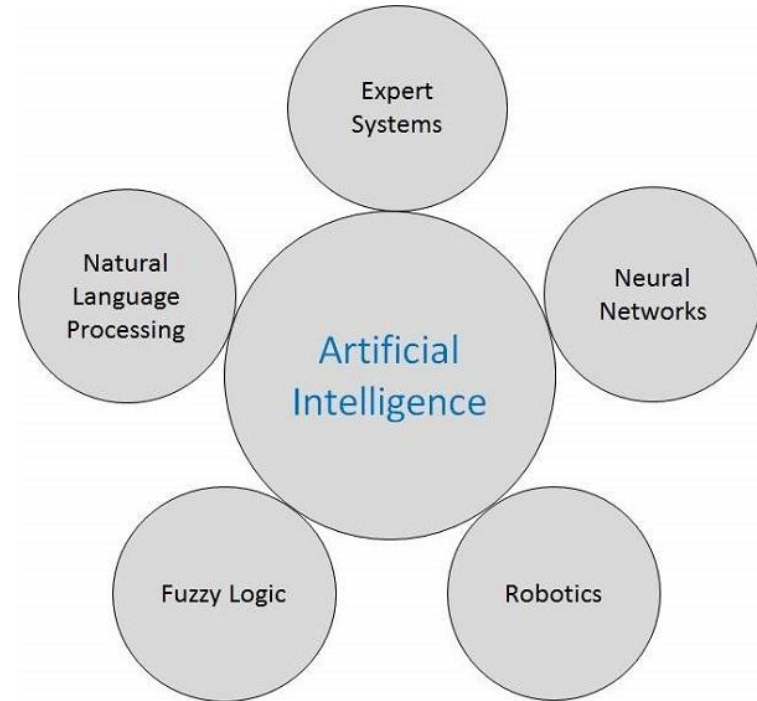
- Speedup: Increased computational speed.
- Scalability: Efficient handling of larger datasets.
- Resource Utilization: Optimal use of multiple processors.

Challenges:

- Synchronization: Coordinating processor activities.
- Communication Overhead: Costs of data transmission.
- Load Balancing: Ensuring even workload distribution.

Research areas in Artificial Intelligence:

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



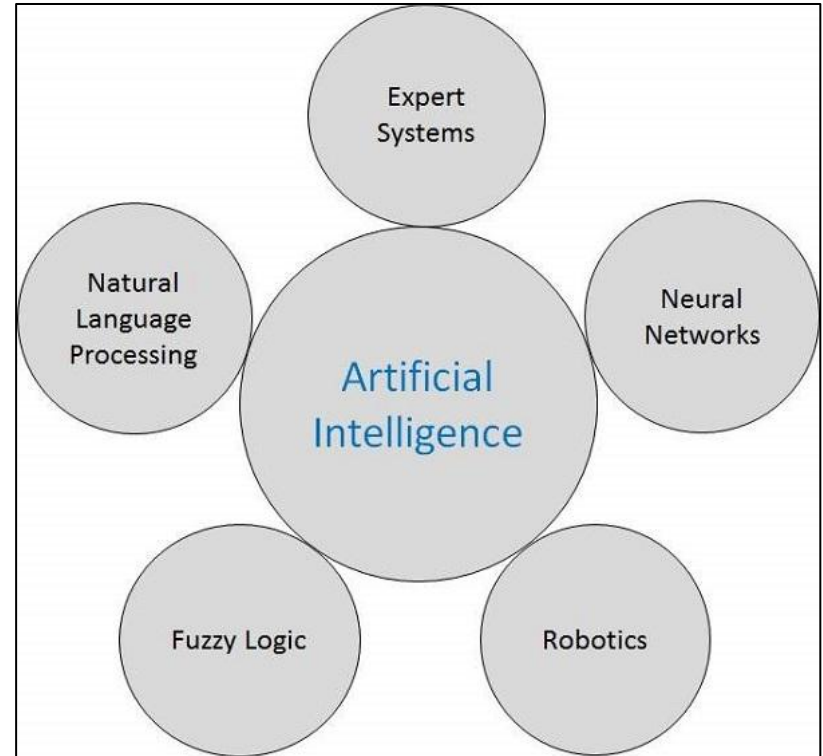
Research areas in Artificial Intelligence:

Real Life Applications of Research Areas:

1. **Expert Systems**
2. **Natural Language Processing**
3. **Neural Networks**
4. **Robotics**
5. **Fuzzy Logic Systems**

Link for reference :

https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_research_areas.htm



Smart Materials:

- Smart materials play a crucial role in enhancing intelligent systems, including artificial intelligence (AI).
- These materials can sense and respond to external stimuli, offering benefits such as adaptability, energy harvesting, and improved user interaction.
- Examples include using piezoelectric materials for sensors and actuators, shape memory alloys for adaptive systems, and electroactive polymers for haptic feedback.
- Smart materials also find applications in structural health monitoring, responsive AI hardware, and wearable electronics, contributing to the overall efficiency and functionality of AI systems.

Examples of Smart Materials:

1. Sensors and Actuators:

- Sensors: Smart materials detect environmental changes, e.g., piezoelectric materials for pressure sensing.
- Actuators: These materials respond to stimuli with mechanical, electrical, or thermal actions, e.g., shape memory alloys for shape-changing.

2. Adaptive Systems:

- Smart materials enable dynamic responses to changing conditions in AI applications.

3. Energy Harvesting:

- Smart materials convert ambient energy into electrical power, useful for self-sustaining AI devices.

4. Haptic Feedback:

- Smart materials provide tactile feedback in interfaces, improving user interaction with AI systems.

Neuromorphic Computing:

Neuromorphic computing is an approach to computer architecture that is inspired by the structure and functioning of the human brain. It aims to mimic the parallel processing and learning capabilities of biological neural networks, enabling machines to perform tasks more efficiently and with a level of adaptability and self-learning. Here's a detailed explanation of neuromorphic computing:

Definition:

Neuromorphic computing involves the design and development of computer architectures and circuits that emulate the architecture and functioning of the human brain. The term "neuromorphic" is derived from "neuron" (nerve cell) and "morph" (form), emphasizing the attempt to replicate the structure and behavior of biological neurons and synapses.

Key Components of neuromorphic computing:

a. Neurons:

In neuromorphic computing, artificial neurons are the fundamental building blocks. These neurons process and transmit information through electrochemical signals, similar to biological neurons.

b. Synapses:

Artificial synapses connect neurons and facilitate the transmission of signals. They play a crucial role in learning and memory, adjusting the strength of connections based on activity.

c. Neural Networks:

Neuromorphic systems often consist of interconnected neural networks, resembling the organization of the human brain. These networks enable parallel processing and distributed computing.

Working Principles of neuromorphic computing:

a. Parallel Processing:

Neuromorphic computing emphasizes parallel processing, where multiple computations occur simultaneously. This is inspired by the brain's ability to process information in parallel across a vast network of neurons.

b. Spike-Based Processing:

Unlike traditional computing, which relies on binary signals (0s and 1s), neuromorphic systems use spikes or pulses of activity. These spikes represent the communication between artificial neurons and contribute to the energy efficiency of the system.

c. Plasticity:

Neuromorphic systems often incorporate synaptic plasticity, allowing the artificial synapses to adapt and change their strength based on the patterns of activity. This mimics the learning and memory capabilities observed in biological systems.

Advantages of neuromorphic computing:

a. Energy Efficiency:

Neuromorphic computing tends to be more energy-efficient than traditional computing architectures, especially for tasks involving pattern recognition and complex data processing.

b. Real-Time Processing:

The parallel processing nature of neuromorphic systems enables real-time processing of information, making them suitable for applications like robotics and sensor networks.

c. Learning and Adaptation:

Neuromorphic systems have the potential for unsupervised learning, allowing them to adapt and improve their performance based on experience.

Challenges of neuromorphic computing:

a. Hardware Complexity:

Designing and implementing neuromorphic hardware with a large number of interconnected neurons and synapses can be challenging.

b. Programming Models:

Developing programming models for neuromorphic systems that can efficiently harness their capabilities is an ongoing challenge.

c. Benchmarking and Standardization:

There is a need for standardized benchmarks and evaluation metrics to compare the performance of different neuromorphic systems.

Applications of neuromorphic computing:

a. Artificial Intelligence (AI):

Neuromorphic computing can enhance AI applications, particularly in areas like image and speech recognition, where parallel processing and pattern recognition are crucial.

b. Robotics:

The real-time processing and adaptability of neuromorphic systems make them suitable for robotic applications, enabling robots to interact with their environment more effectively.

c. Sensor Networks:

Neuromorphic computing can be applied to process data from sensor networks efficiently, making it valuable for applications like environmental monitoring.

Aspect	Von Neumann Computing	Neuromorphic Computing
Architecture	Separate memory and processing units (CPU and RAM)	Mimics the structure of the human brain with interconnected neurons
Processing Model	Sequential execution of instructions	Parallel and distributed processing based on neural networks
Data Movement	Data transfer between memory and processor for each instruction	Parallel processing with data movement and computation in synapses
Flexibility	Suited for general-purpose computing tasks	Primarily designed for specific tasks related to neural processing
Energy Efficiency	Less energy-efficient due to frequent data movement	Potentially more energy-efficient, especially for certain tasks
Learning and Adaptation	Typically requires explicit programming for learning algorithms	Inherently capable of learning and adapting through synaptic connections
Programming Paradigm	Traditional programming languages (e.g., C, Java)	Often requires specialized neuromorphic programming languages or frameworks
Memory Architecture	Separate memory for data and program (RAM and ROM)	Memory is distributed and associative, mimicking synaptic connections
Speed and Parallelism	Limited parallelism, especially for specific tasks	Inherently parallel architecture suitable for neural network processing

Thank You!!