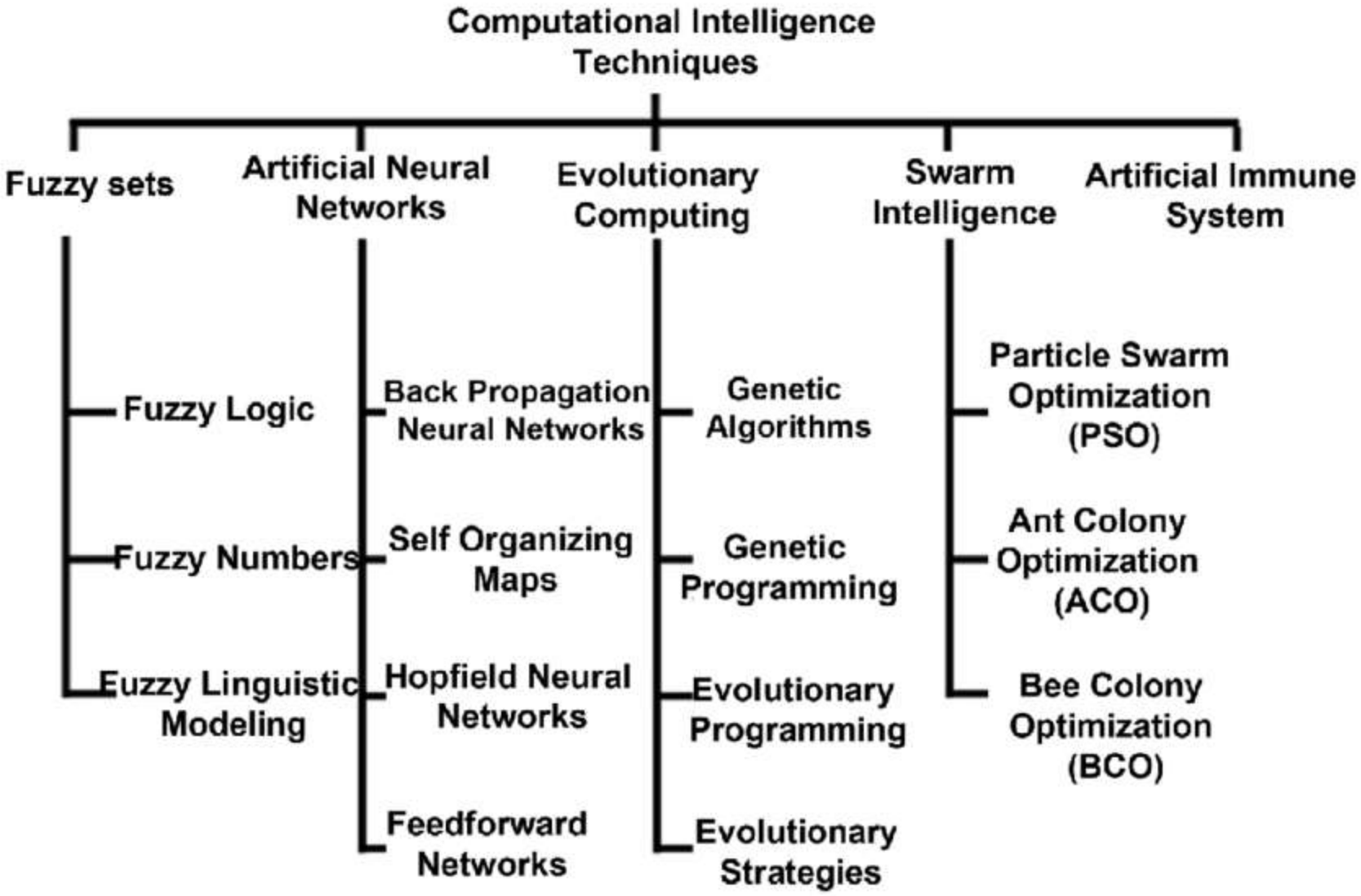
MODULE 1

Computational intelligence

Computational intelligence (**CI**) usually refers to the ability of a computer to learn a specific task from data or experimental observation. Even though it is commonly considered a synonym of soft computing.

Computational intelligence, also known as *soft computing*, is a form of computing modeled on the methods by which humans learn. As computers learn from processes based on logic and science, they become more intelligent.

- This differs from artificial intelligence in its perspective on imperfection: computational intelligence focuses on the growth of a system and does not use Boolean values (0s and 1s) to achieve learning, where AI does. Computational intelligence uses different branches of science, such as math and logic, to develop machine learning algorithms.


Computational Intelligence Techniques
Fuzzy sets
Artificial Neural Networks
Evolutionary Computing
Swarm Intelligence
Artificial Immune System
Fuzzy Logic
Fuzzy Numbers
Fuzzy Linguistic Modeling
Back Propagation Neural Networks
Self Organizing Maps
Hopfield Neural Networks
Feedforward Networks
Genetic Algorithms
Genetic Programming
Evolutionary Programming
Evolutionary Strategies
Particle Swarm Optimization (PSO)
Ant Colony Optimization (ACO)
Bee Colony Optimization (BCO)

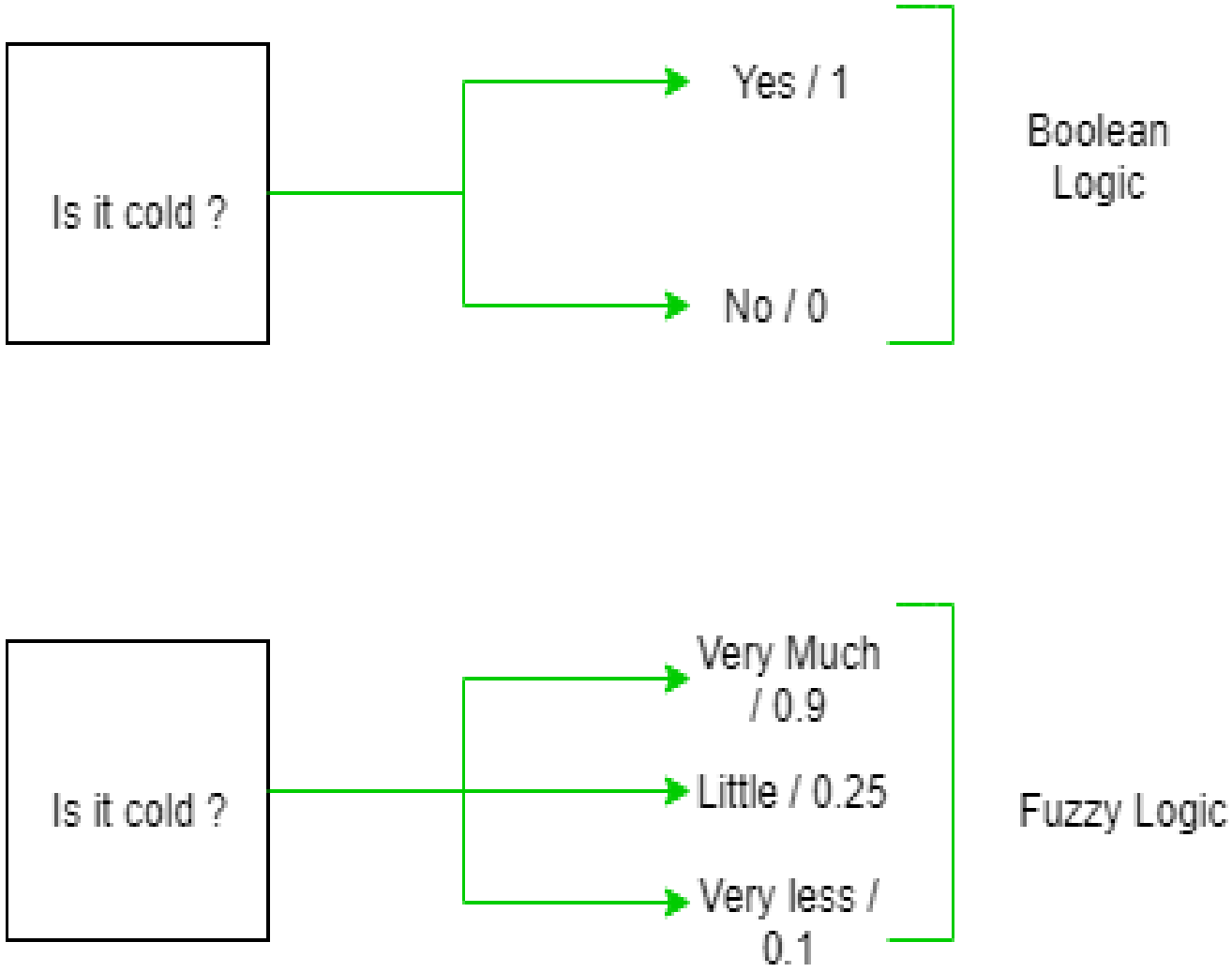
- **Difference between Computational and Artificial Intelligence**
- Although Artificial Intelligence and Computational Intelligence seek a similar long-term goal: reach general intelligence, which is the intelligence of a machine that could perform any intellectual task that a human being can; there's a clear difference between them. According to Bezdek (1994), Computational Intelligence is a subset of Artificial Intelligence.
- There are two types of machine intelligence: the artificial one based on hard computing techniques and the computational one based on soft computing methods, which enable adaptation to many situations.
- Hard computing techniques work following binary logic based on only two values (the Booleans true or false, 0 or 1) on which modern computers are based. One problem with this logic is that our natural language cannot always be translated easily into absolute terms of 0 and 1.

- Soft computing techniques, based on fuzzy logic can be useful here. Much closer to the way the human brain works by aggregating data to partial truths (Crisp/fuzzy systems), this logic is one of the main exclusive aspects of CI.
- Within the same principles of fuzzy and binary *logics* follow crispy and fuzzy *systems*. Crisp logic is a part of artificial intelligence principles and consists of either including an element in a set, or not, whereas fuzzy systems (CI) enable elements to be partially in a set. Following this logic, each element can be given a degree of membership (from 0 to 1) and not exclusively one of these 2 values.

- **The five main principles of CI and its applications**

• Fuzzy logic

- The term **fuzzy** refers to things that are not clear or are vague. In the real world many times we encounter a situation when we can't determine whether the state is true or false, their fuzzy logic provides very valuable flexibility for reasoning. In this way, we can consider the inaccuracies and uncertainties of any situation.
- In the Boolean system truth value, 1.0 represents the absolute truth value and 0.0 represents the absolute false value. But in the fuzzy system, there is no logic for the absolute truth and absolute false value. But in fuzzy logic, there is an intermediate value too present which is partially true and partially false.


Is it cold ?
Yes / 1
No / 0
Boolean Logic
Is it cold ?
Very Much / 0.9
Little / 0.25
Very less / 0.1
Fuzzy Logic

• Neural networks

- Neural networks, also known as artificial neural networks (ANNs) or simulated neural networks (SNNs), are a subset of machine learning and are at the heart of deep learning algorithms. Their name and structure are inspired by the human brain, mimicking the way that biological neurons signal to one another.
- A neural network is a method in artificial intelligence that teaches computers to process data in a way that is inspired by the human brain.
- It is a type of machine learning process, called deep learning, that uses interconnected nodes or neurons in a layered structure that resembles the human brain.

- It creates an adaptive system that computers use to learn from their mistakes and improve continuously. Thus, artificial neural networks attempt to solve complicated problems, like summarizing documents or recognizing faces, with greater accuracy.
- Neural networks reflect the behavior of the human brain, allowing computer programs to recognize patterns and solve common problems in the fields of AI, machine learning, and deep learning.

- Why are neural networks important?
- Neural networks can help computers make intelligent decisions with limited human assistance.
- This is because they can learn and model the relationships between input and output data that are nonlinear and complex.

• Evolutionary computation

- Evolutionary computation is a general name for a group of problem-solving techniques whose principles are based on the theory of biological evolution, such as genetic inheritance and natural selection.
- These techniques are applied to a variety of problems, from practical industry applications such as analytics and prediction algorithms to leading-edge scientific research such as protein folding.

- Evolutionary computation is usually implemented on computer systems that are used to solve problems, implementing techniques such as evolutionary algorithms, differential evolution, genetic algorithms and harmony search.
- Techniques in this field are used on problems that have too many variables for traditional algorithms to consider and in times where the approach to solving a particular problem is not well understood.

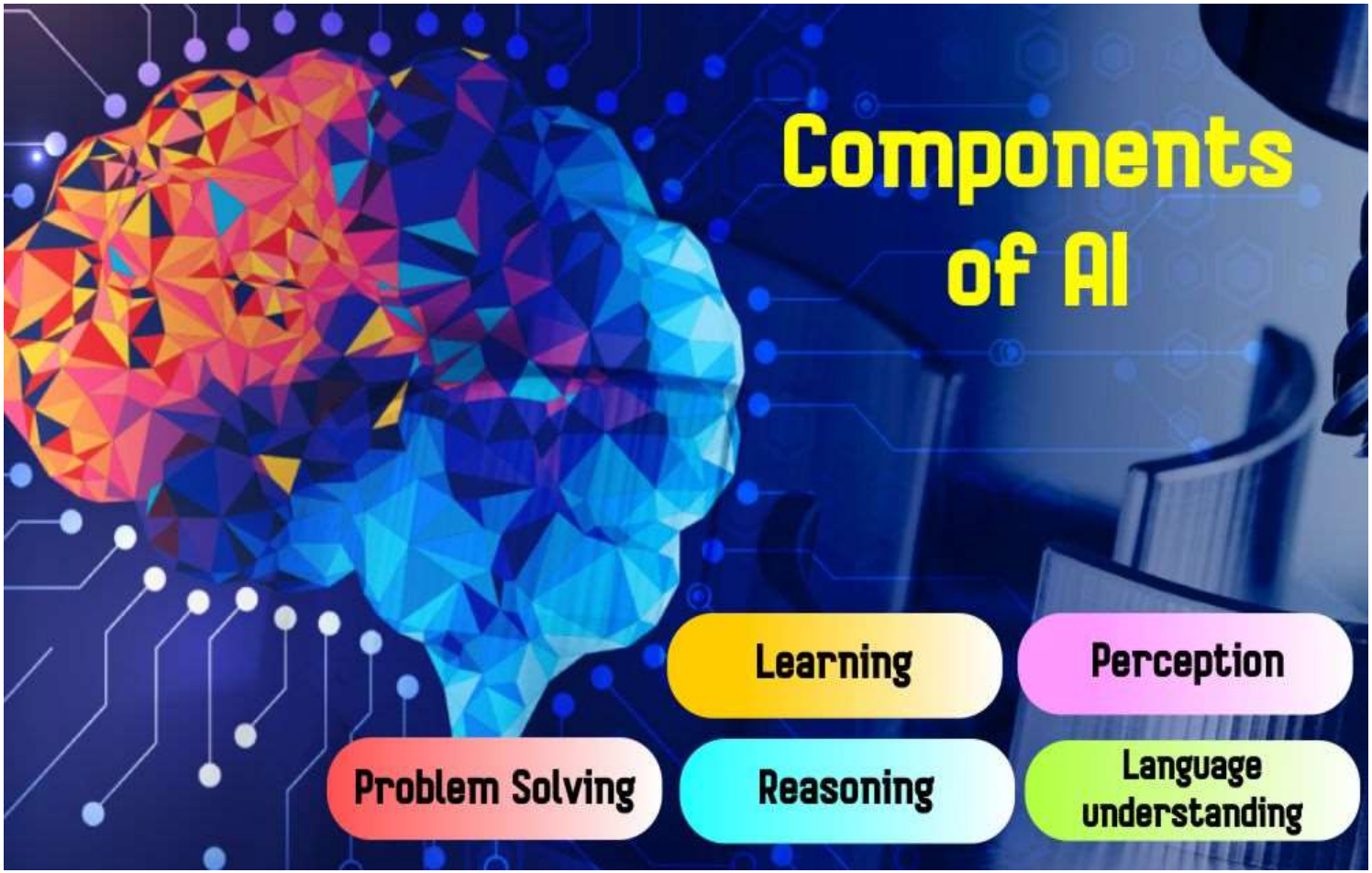
Learning theory

- Learning theory is one of the main approaches of CI.
- In psychology, learning is the process of bringing together cognitive, emotional and environmental effects and experiences to acquire, enhance or change knowledge, skills, values and world views .
- Learning theories then helps understanding how these effects and experiences are processed, and then helps making predictions based on previous experience.

- **Probabilistic methods**

- Being one of the main elements of fuzzy logic, probabilistic methods firstly introduced by Paul Erdos and Joel Spencer(1974), aim to evaluate the outcomes of a Computation Intelligent system, mostly defined by randomness.
- Therefore, probabilistic methods bring out the possible solutions to a problem, based on prior knowledge.

Components of Computational intelligence



• a. Learning

- Similar to humans, computer programs also learn in different manners.
- Talking of AI, learning by this platform is further segregated into a varied number of forms. One of the essential **components of AI,** learning for AI includes the trial-and-error method.
- The solution keeps on solving problems until it comes across the right results. This way, the program keeps a note of all the moves that gave positive results and stores it in its database to use the next time the computer is given the same problem.
- The learning component of AI includes memorizing individual items like different solutions to problems, vocabulary, foreign languages, etc., also known as rote learning. This learning method is later implemented using the generalization method.

• b. Reasoning

- Artificial intelligence (AI) is a field of computer science that aims to create machines that can perform tasks that normally require human intelligence, such as understanding natural language, recognizing images, and solving problems.
- One of the most important aspects of AI is Reasoning, which refers to deriving new information from existing information using logical rules and principles.
- The reasoning is critical for many applications of AI, including natural language processing, computer vision, and decision-making.

- The reasoning is deriving new information from existing information using logical rules and principles. In artificial intelligence, *Reasoning is critical to many applications, including natural language processing, computer vision, and decision-making.* AI systems use Reasoning to make inferences, draw conclusions, and solve problems.
- Reasoning in AI involves the manipulation of symbols and rules. *Symbols represent objects, concepts, and relationships, while rules specify how these symbols can be combined to form more complex representations.* The symbols and rules used in Reasoning are often based on mathematical logic, which provides a formal framework for Reasoning.

• c. Problem-solving

- In its general form, the AI's problem-solving ability comprises data, where the solution needs to find x.
- AI witnesses a considerable variety of problems being addressed in the platform. The different methods of 'Problem-solving' count for essential **artificial intelligence components** that divide the queries into special and general purposes.
- Further, the problem-solving component in AI allows the programs to include step-by-step reduction of difference, given between any goal state and current state.

• d. Perception

- In using the ‘perception’ component of Artificial Intelligence, the element scans any given environment by using different sense-organs, either artificial or real.
- Further, the processes are maintained internally and allow the perceiver to analyze other scenes in suggested objects and understand their relationship and features.
- This analysis is often complicated as one, and similar items might pose considerable amounts of different appearances over different occasions, depending on the view of the suggested angle.

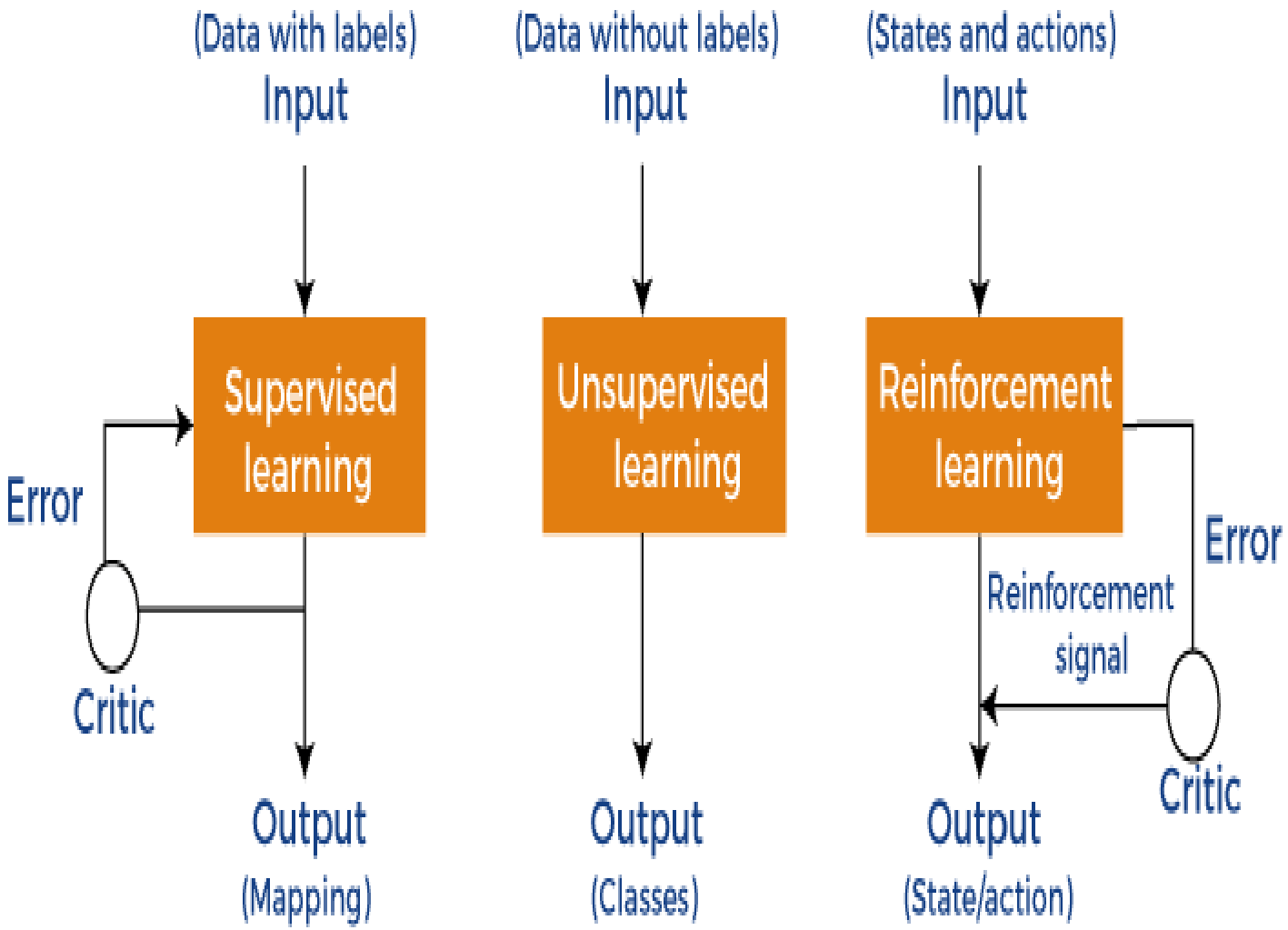
• e. Language-understanding

- In simpler terms, language can be defined as a set of different system signs that justify their means using convention.
- Occurring as one of the widely used **artificial intelligence components**, language understanding uses distinctive types of language over different forms of natural meaning, exemplified overstatements.
- One of the essential characteristics of languages is humans' English, allowing us to differentiate between different objects.
- Similarly, AI is developed in a manner that it can easily understand the most commonly used human language, English. This way, the platform allows the computers to understand the different computer programs executed over them easily.

Types of Artificial Intelligence Learning Models

- Learning is one of the fundamental building blocks of artificial intelligence (AI) solutions.
- From a conceptual standpoint, learning is a process that improves the knowledge of an AI program by making observations about its environment.
- From a technical/mathematical standpoint, AI learning processes focused on processing a collection of input-output pairs for a specific function and predicts the outputs for new inputs.
- Most of the artificial intelligence(AI) basic literature identifies two main groups of learning models: supervised and unsupervised. However, that classification is an oversimplification of real world AI learning models and techniques.

- **Classification of Machine Learning Models:**
- Based on different business goals and data sets, there are three learning models for algorithms. Each machine learning algorithm settles into one of the three models:
- Supervised Learning
- Unsupervised Learning
- Reinforcement Learning


(Data with labels)
Input
Supervised learning
Error
Critic
Output
(Mapping)
(Data without labels)
Input
Unsupervised learning
Output
(Classes)
(States and actions)
Input
Reinforcement learning
Error
Reinforcement signal
Critic
Output
(State/action)

- To understand the different types of AI learning models, we can use two of the main elements of human learning processes: knowledge and feedback.
- From the knowledge perspective, learning models can be classified based on the representation of input and output data points.
- In terms of the feedback, AI learning models can be classified based on the interactions with the outside environment, users and other external factors.

- **AI Learning Models: Feedback-Based Classification**
- Based on the feedback characteristics, AI learning models can be classified as supervised, unsupervised, semi-supervised or reinforced.
- — Unsupervised Learning: Unsupervised models focus on learning a pattern in the input data without any external feedback. Clustering is a classic example of unsupervised learning models.
- — Supervised Learning: Supervised learning models use external feedback to learning functions that map inputs to output observations. In those models the external environment acts as a “teacher” of the AI algorithms.

- — Semi-supervised Learning: Semi-Supervised learning uses a set of curated, labeled data and tries to infer new labels/attributes on new data data sets. Semi-Supervised learning models are a solid middle ground between supervised and unsupervised models.
- — Reinforcement Learning: Reinforcement learning models use opposite dynamics such as rewards and punishment to “reinforce” different types of knowledge. This type of learning technique is becoming really popular in modern AI solutions.
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- ## 1. Supervised Machine Learning Models
- Supervised Learning is the simplest machine learning model to understand in which input data is called training data and has a known label or result as an output.
- So, it works on the principle of input-output pairs. It requires creating a function that can be trained using a training data set, and then it is applied to unknown data and makes some predictive performance. Supervised learning is task-based and tested on labeled data sets.
- We can implement a supervised learning model on simple real-life problems. For example, we have a dataset consisting of age and height; then, we can build a supervised learning model to predict the person's height based on their age.

- **2. Unsupervised Machine learning models**
- Unsupervised Machine learning models implement the learning process opposite to supervised learning, which means it enables the model to learn from the unlabeled training dataset.
- Based on the unlabeled dataset, the model predicts the output. Using unsupervised learning, the model learns hidden patterns from the dataset by itself without any supervision.

• Reinforcement Learning

- In reinforcement learning, the algorithm learns actions for a given set of states that lead to a goal state. It is a feedback-based learning model that takes feedback signals after each state or action by interacting with the environment.
- This feedback works as a reward (positive for each good action and negative for each bad action), and the agent's goal is to maximize the positive rewards to improve their performance.
- The behavior of the model in reinforcement learning is similar to human learning, as humans learn things by experiences as feedback and interact with the environment.

• Parametric versus Non-Parametric Models

• Parametric models

- Assumptions about the form of a function can ease the process of learning. Parametric models are characterized by the simplification of the function to a known form. A parametric model is a learner that summarizes data through a collection of parameters.
- These parameters are of a fixed-size. This means that the model already knows the number of parameters it requires, regardless of its data. The parameters are also independent of the number of training instances.
- With parametric models, there are two steps involved. The first is choosing the function form. Learning the function coefficients from training data is the second step.

- **Non-Parametric models**

- Algorithms that do not make particular assumptions about the kind of mapping function are known as non-parametric algorithms. These algorithms do not accept a specific form of the mapping function between input and output data as true.
- They have the freedom to choose any functional form from the training data. As a result, for parametric models to estimate the mapping function they require much more data than parametric ones.
- One might think that non-parametric means that there are no parameters. However, this is not true. Rather, it simply means that the parameters are (not only) adjustable but can also change.

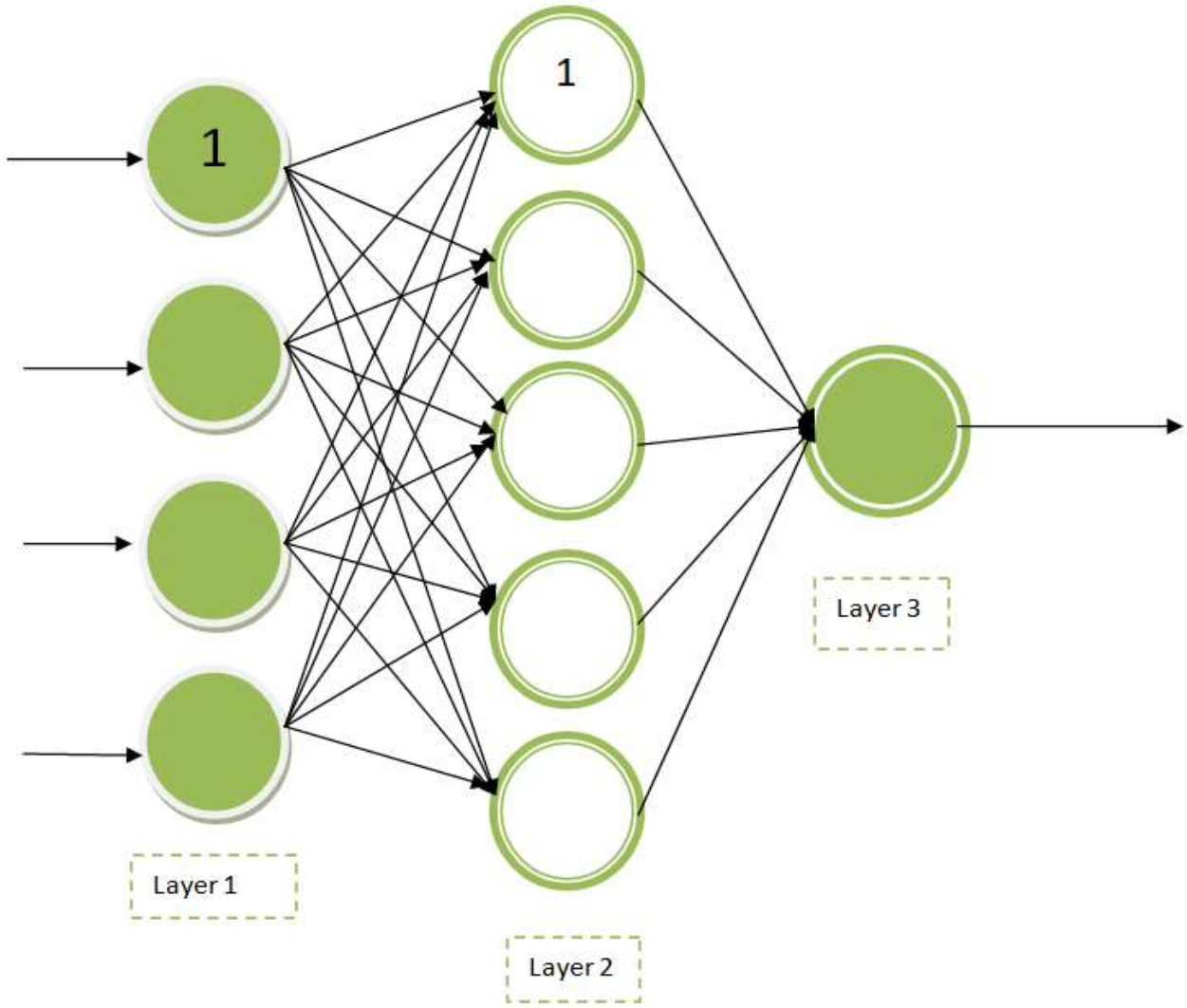
- However, in the case of non-parametric ones, the number of parameters is dependent on the amount of training data. The more training data, the greater the number of parameters. A consequence of this is that non-parametric algorithms may take much longer to train.

• Multi-Layer Neural Network

- Neural Networks can be classified into multiple types based on their Layers and depth activation filters, Structure, Neurons used, Neuron density, data flow, and so on. The types of Neural Networks are as follows:
- Perceptron
- Multi-Layer Perceptron or Multi-Layer Neural Network
- Feed Forward Neural Networks
- Convolutional Neural Networks
- Radial Basis Function Neural Networks
- Recurrent Neural Networks
- Sequence to Sequence Model
- Modular Neural Network

- **Multi-Layer Neural Network**

- To be accurate a fully connected Multi-Layered Neural Network is known as Multi-Layer Perceptron.
- A Multi-Layered Neural Network consists of multiple layers of artificial neurons or nodes. Unlike Single-Layer Neural networks, in recent times most networks have Multi-Layered Neural Network.
- The following diagram is a visualization of a multi-layer neural network.


1
1
Layer 1
Layer 2
Layer 3

- **Explanation:**
- Here the nodes marked as “1” are known as **bias units**. The leftmost layer or Layer 1 is the **input layer**, the middle layer or Layer 2 is the **hidden layer** and the rightmost layer or Layer 3 is the **output layer**. It can say that the above diagram has **3 input units** (leaving the bias unit), **1 output unit, and 4 hidden units(1 bias unit is not included).**
- A Multi-layered Neural Network is a typical example of the **Feed Forward Neural Network**. The number of neurons and the number of layers consists of the hyper parameters of Neural Networks which need tuning.
- In order to find ideal values for the hyper parameters, one must use some cross-validation techniques. Using the Back-Propagation technique, weight adjustment training is carried out.

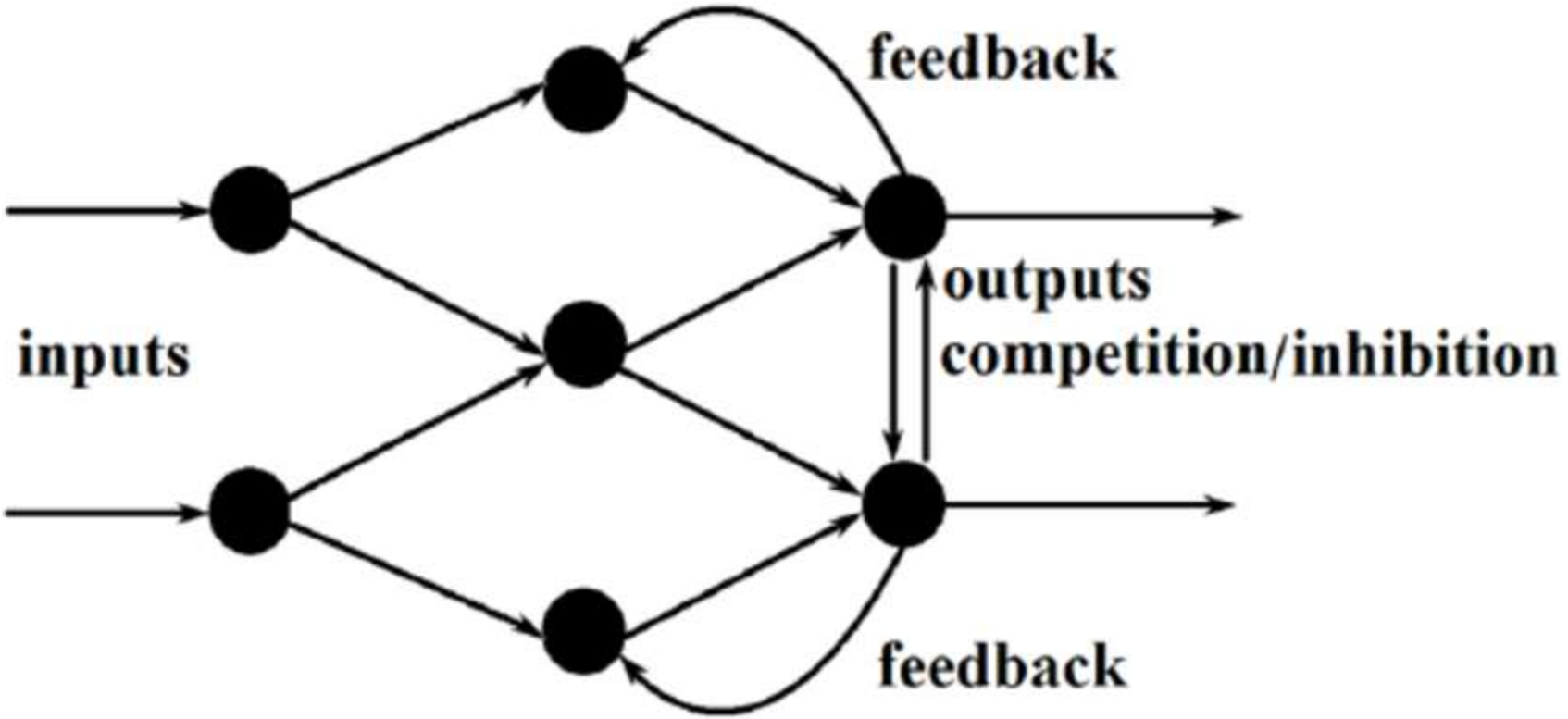
• Feed-forward network

- Feed-forward neural networks enable signals to travel one method only, from input to output.
- There is no feedback (loops) i.e., the output of any layer does not affect that same layer. Feed-forward networks influence to be easy networks that relate inputs with outputs.
- They are extensively used in pattern recognition. This type of organization is also defined as bottom-up or top-down.
- The weighted outputs of these units are fed simultaneously to the second layer of neurons like units known as the hidden layer. The hidden layer is weighted output which can be input to another hidden layer and so on. The number of hidden layers is arbitrary and usually, one is used.

- The weighted outputs of the last hidden layer are inputs to units making up the output layer, which emits the network's prediction for given samples.
- The units in the hidden layers and output layer are defined as neurodes, because of their symbolic biological basis or as output units.
- Multilayer feed-forward networks of linear threshold functions given through hidden units can closely approximate any function.

• Feedback Neural Network

- Signals can travel in both the directions in Feedback neural networks.
- Feedback neural networks are very powerful and can get very complicated.
- Feedback neural networks are dynamic. The ‘state’ in such network keep changing until they reach an equilibrium point.
- They remain at the equilibrium point until the input changes and a new equilibrium needs to be found.
- Feedback neural network architecture is also referred to as interactive or recurrent, although the latter term is often used to denote feedback connections in single-layer organizations.
- Feedback loops are allowed in such networks. They are used in content addressable memories.


feedback
outputs
competition/inhibition
inputs
feedback