Soft Computing
الحوسبة المرنة
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INTRODUCTION TO SOFT COMPUTING

- Concept of computation
- Hard computing
- Soft computing
- How soft computing?
- Hard computing vs. Soft computing
- Hybrid computing

How soft computing can be achieved?

CONCEPT OF COMPUTATION

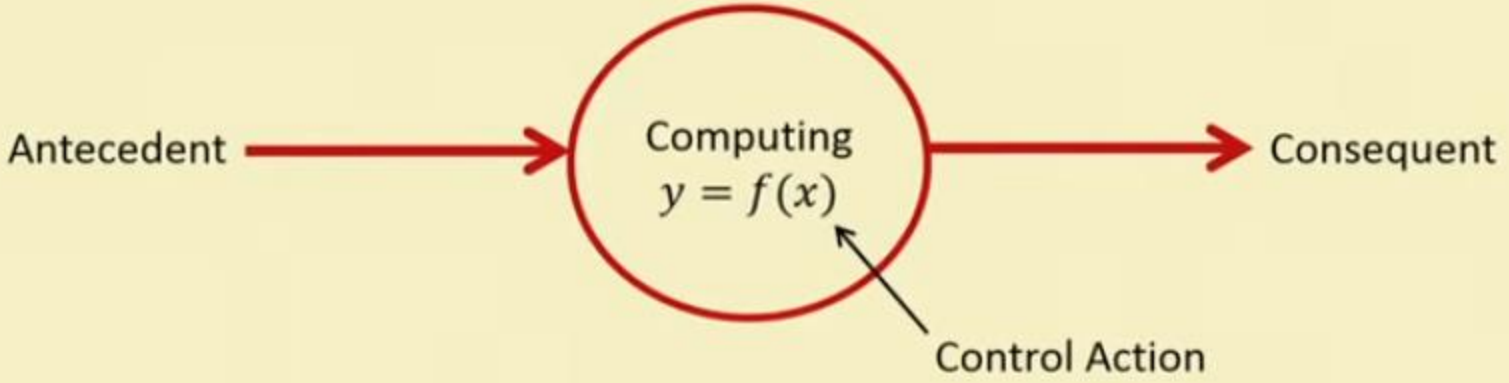


Figure: Basic of computing

Computing means there are certain input and a procedure by which the input can be converted into some output. In this context; the input is called Antecedent and the output is called Consequent, and computing is the mapping .

From the figure above: f is a function which is responsible to convert the input x to some output; which is y.

$y = f(x), f$ is a mapping function.

f is also called a formal method or an algorithm to solve a problem.

i.e. computing is a mapping function, mapping from set of input to output.

Important characteristics of computing

- Should provide precise solution.
- Control action should ne unambiguous and accurate.
- Suitable for problem, which is easy to model mathematically.

For a given input;
It always give a particular Output.

In order to achieve from input to output;
It should follow unambiguous and accurate steps.

This means, there is an algorithm which is available

Hard computing

- In 1996, L. A. Zade (LAZ) introduced the term hard computing.
- According to LAZ: We term a computing as Hard computing, if
  - ✓ Precise result is guaranteed.
  - ✓ Control action is unambiguous.
  - ✓ Control action is formally defined (i.e., with mathematical model or algorithm).

If steps required to solve the problems are unambiguous

Examples of hard computing

- Solving numerical problems (e.g., roots of polynomials, integration, etc.).
- Searching and sorting techniques.
- Solving computational geometry problems (e.g., shortest tour in a graph, finding closet pair of points given a set of points, etc.).
- many more...

Soft computing

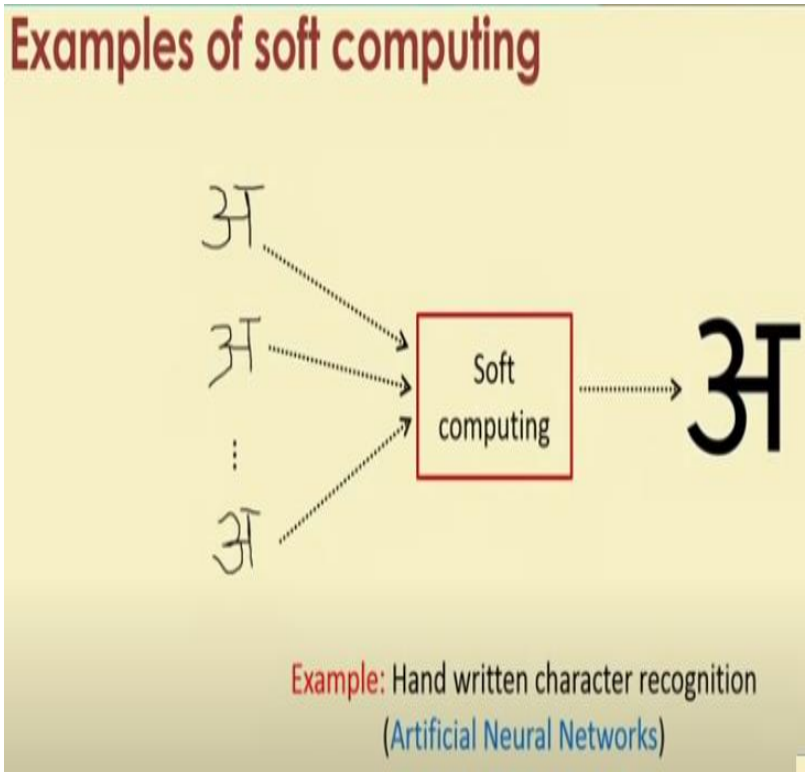
- **The term soft computing was proposed by the inventor of fuzzy logic, Lotfi A. Zadeh. He describes it as follows.**

Definition 1: Soft computing

Soft computing is a collection of methodologies that aim to exploit the tolerance for imprecision and uncertainty to achieve tractability, robustness, and low solution cost. Its principal constituents are fuzzy logic, neuro-computing, and probabilistic reasoning. The role model for soft computing is the human mind.

Characteristics of soft computing

- **It does not require any mathematical modeling of problem solving.**
- **It may not yield the precise solution.**
- **Algorithms are adaptive (i.e., it can adjust to the change of dynamic environment).**
- **Use some biological inspired methodologies such as genetics, evolution, Ant's behaviors, particles swarming, human nervous system, etc.).**


Examples of soft computing
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Soft computing
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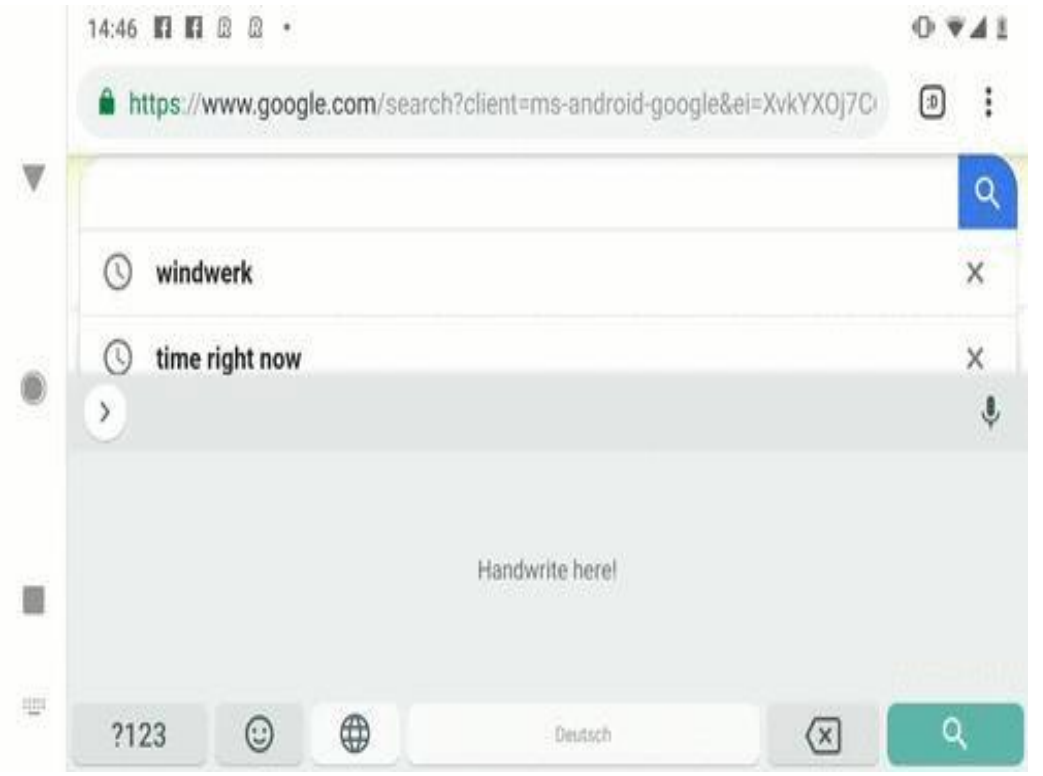
Example: Hand written character recognition
(Artificial Neural Networks)


14:46
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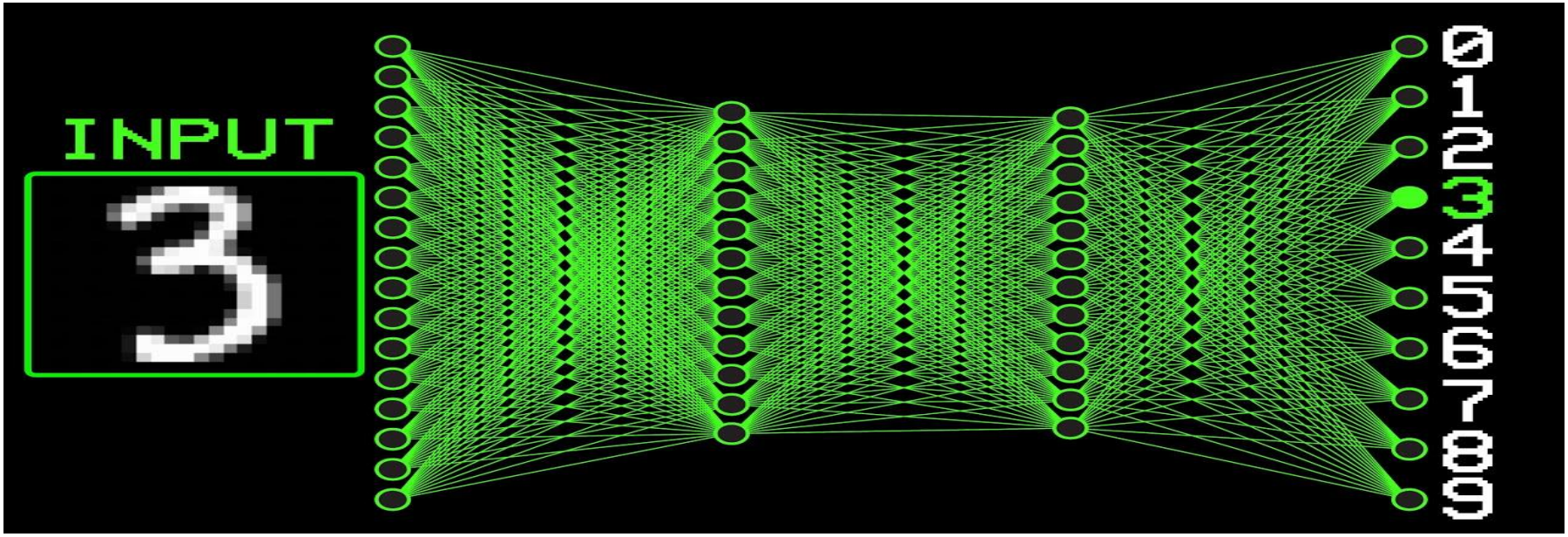
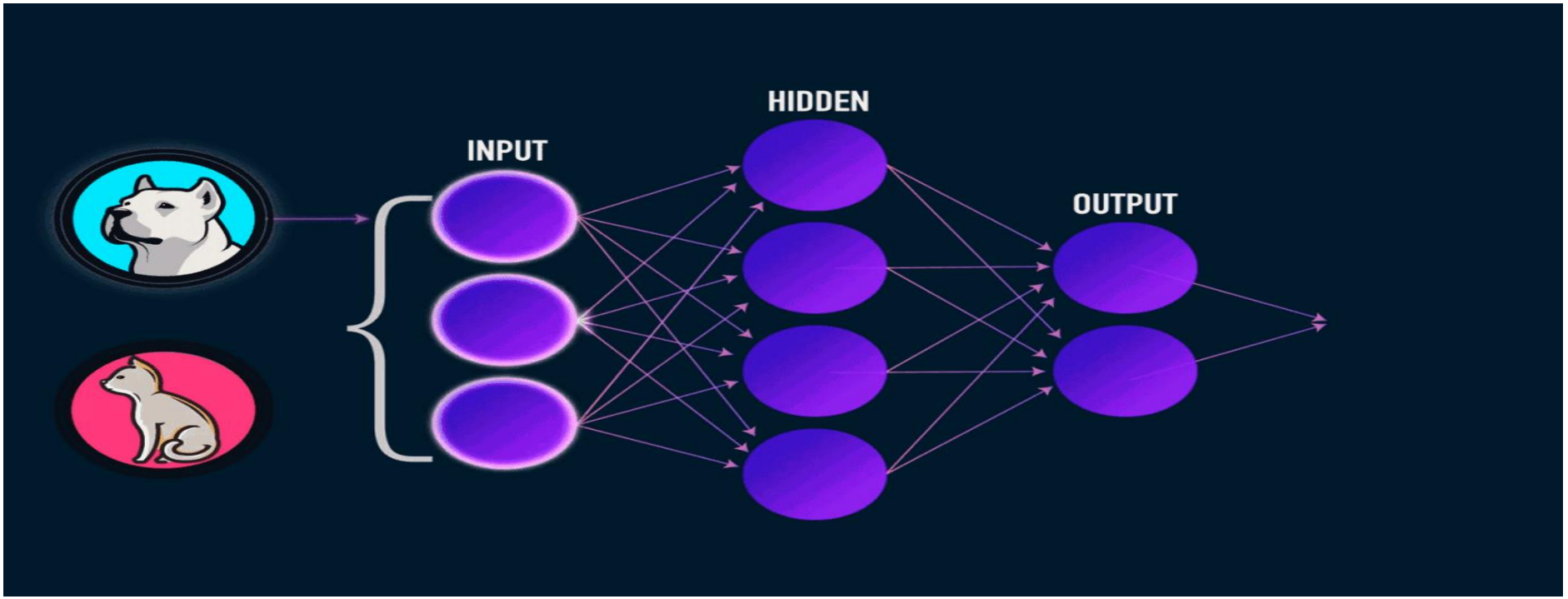
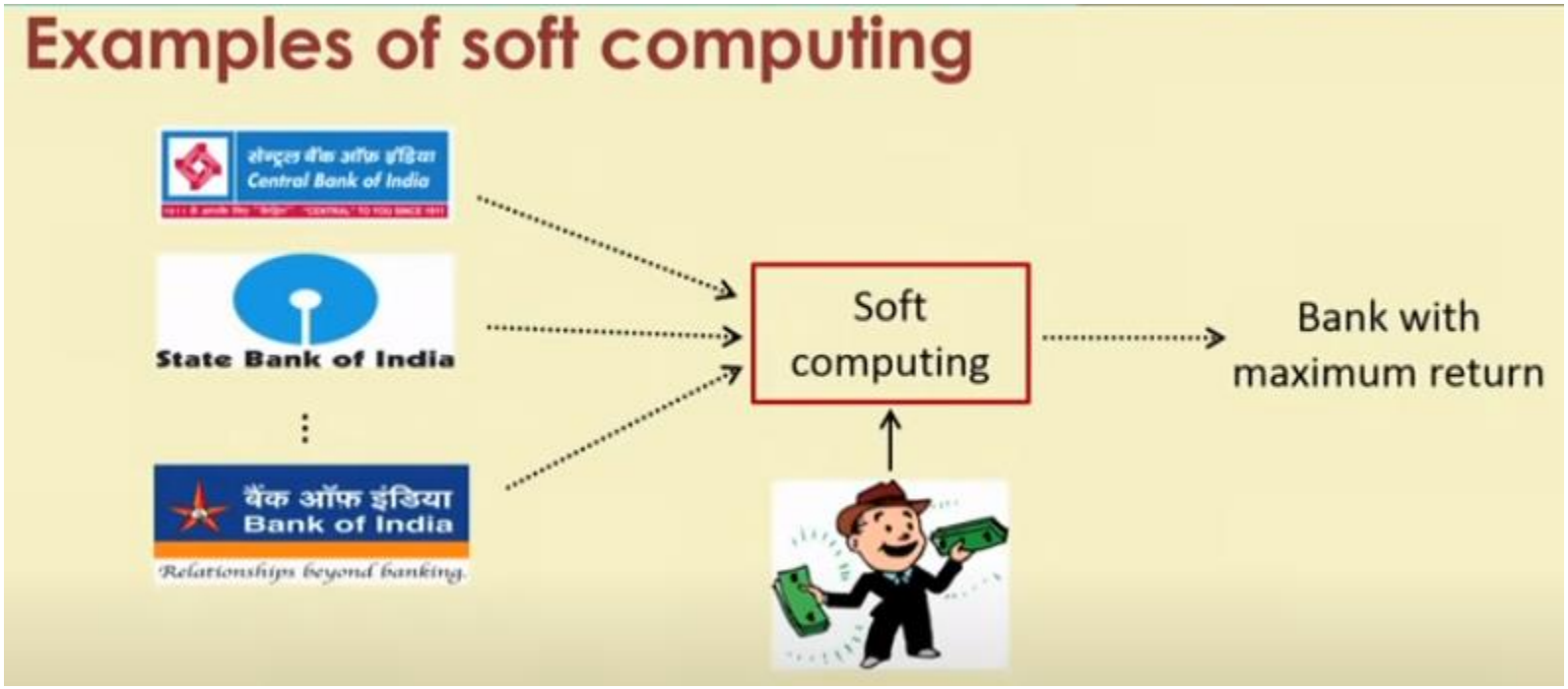
time right now
Handwrite here!
?123
Deutsch

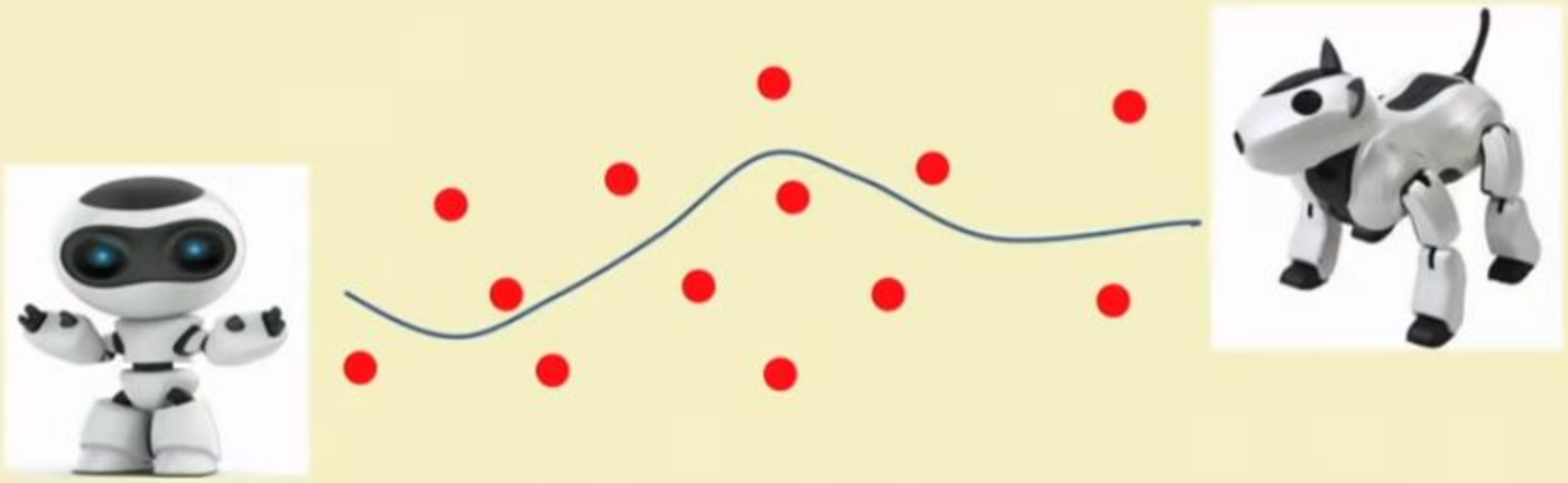

INPUT
3
0 1 2 3 4 5 6 7 8 9





Examole on genetic algorithm

Examples of soft computing



Example: Robot movement
(Fuzzy Logic)

If a robot want to move from one place to another, and there are many obstacles ; so how the robot can calculate his movement and without any collision with any object. How can he move from his current location to the target location within a shortest time.

This kind of problem has lot of uncertainty and impreciseness.

That kind of uncertainty can be solved using fuzzy logic

How soft computing?

- How a student learns from his teacher?
  - Teacher asks questions and tell the answers then.
  - Teacher puts questions and hints answers and asks whether the answers are correct or not.
  - Student thus learn a topic and store in his memory.
  - Based on the knowledge he solves new problems.
- This is the way how human brain works.
- Based on this concept Artificial Neural Network is used to solve problems.

How soft computing?

- How a doctor treats his patient?
  - Doctor asks the patient about suffering.
  - Doctor find the symptoms of diseases.
  - Doctor prescribed tests and medicines.
- This is exactly the way Fuzzy Logic works.
  - Symptoms are correlated with diseases with uncertainty .
  - Doctor prescribes tests/medicines fuzzily.

Hybrid computing

- It is a combination of the conventional hard computing and emerging soft computing.

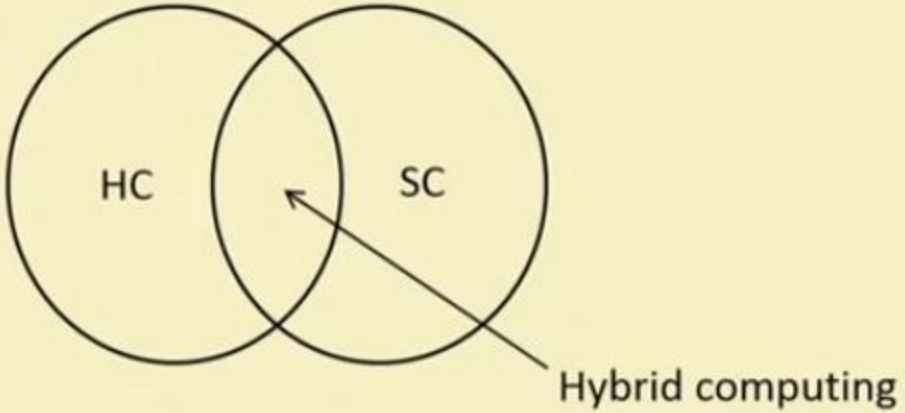
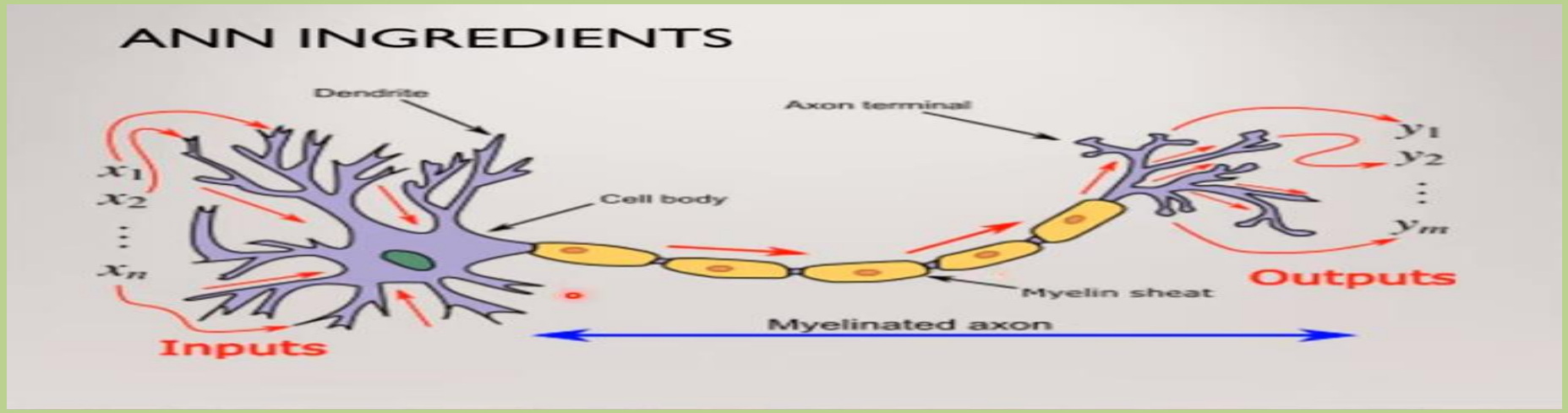


Figure: Concept of Hybrid Computing

Artificial Neural Network الشبكات العصبية الاصطناعية



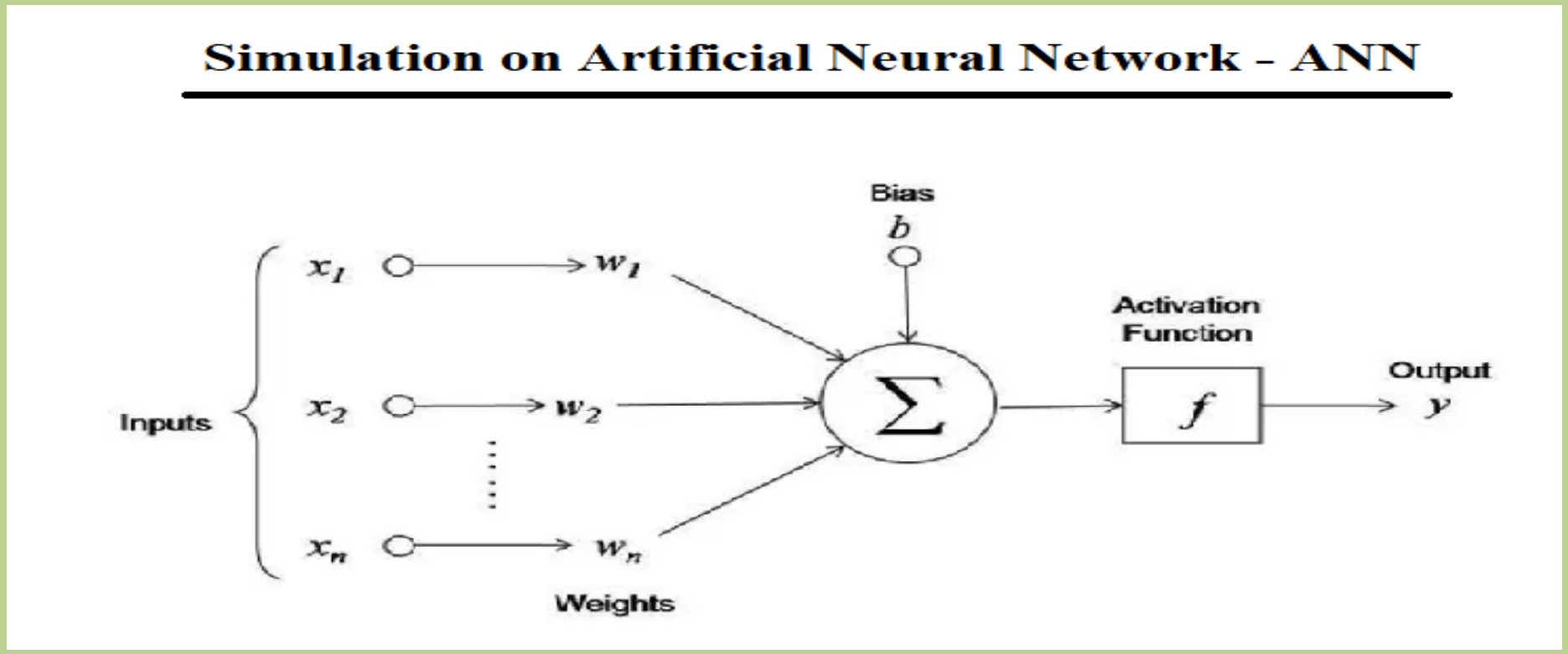
Artificial neural network

- In fact, the human brain is a highly complex structure viewed as a massive, highly interconnected network of simple processing elements called **neurons**.
- Artificial neural networks (ANNs) or simply we refer it as neural network (NNs),
- The behaviour of a biological neural network can be captured by a simple model called artificial neuron or **perceptron**.

A neural network is a computational model inspired by the structure and function of the human brain. It is composed of interconnected nodes, called neurons, organized into layers.

Each neuron receives input, processes it through an activation function, and passes the output to the next layer of neurons. Neural networks are capable of learning from data through a process called training, where they adjust their internal parameters (weights and biases) to minimize the difference between their predictions and the actual target values.

Neural networks have become a fundamental tool in machine learning and artificial intelligence due to their ability to effectively handle complex, nonlinear relationships in data. They are used in various applications such as image and speech recognition, natural language processing, autonomous vehicles, and many more.

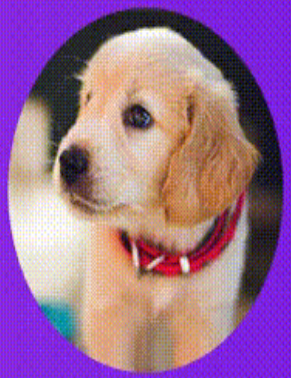


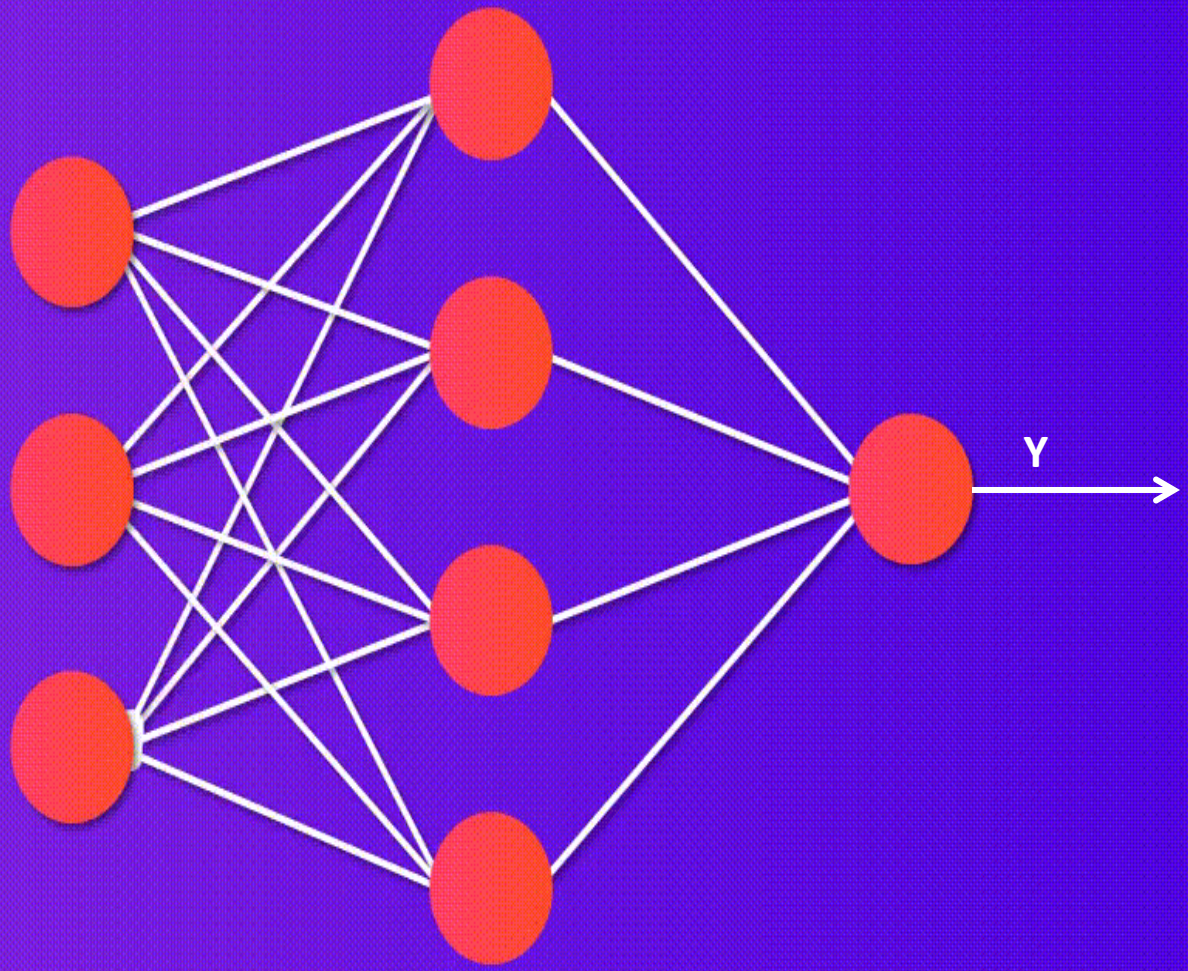
In an Artificial Neural Network (ANN), a perceptron is one of the simplest forms of a neural network unit. It's typically composed of several components:

1. Inputs: These are the features or signals that the perceptron receives from the previous layer or directly from the input data. Each input is associated with a weight, which represents the importance of that input in the overall computation.
2. Weights: Each input to the perceptron is multiplied by a weight. These weights determine the strength of the connection between the inputs and the perceptron. They essentially represent the importance of each input in influencing the perceptron's output. During training, these weights are adjusted to optimize the performance of the perceptron.
3. Summation Function: The weighted sum of the inputs is calculated. This involves multiplying each input by its corresponding weight and summing up these products. Mathematically.
4. Threshold (Activation Function or Transfer Function): Once the weighted sum is calculated, it is passed through an activation function, also known as a threshold function. This function determines whether the perceptron should activate (produce an output) based on the result of the weighted sum. The activation function introduces non-linearity into the model, allowing it to learn complex patterns. Common activation functions include step function, sigmoid function, tanh function, and rectified linear unit (ReLU) function.
5. Output: The output of the perceptron is the result of the activation function applied to the weighted sum. It represents the perceptron's decision or prediction based on the inputs and the weights. For binary classification tasks, the output could be binary (0 or 1), representing the predicted class.

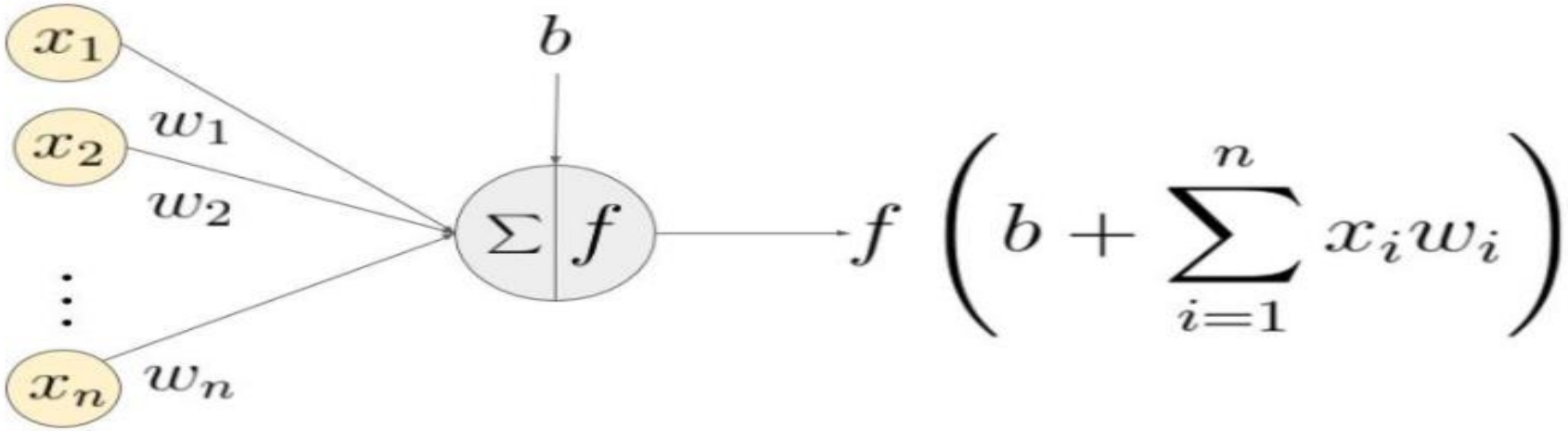
In summary, a perceptron in an ANN takes input signals, multiplies them by corresponding weights, calculates the weighted sum, applies an activation function to determine whether to activate, and produces an output based on this decision. By adjusting the weights during training, perceptron can learn to make accurate predictions or classifications for various tasks.

IF Y=1 THEN DOG
ELSE
IF Y=0 THEN CAT.





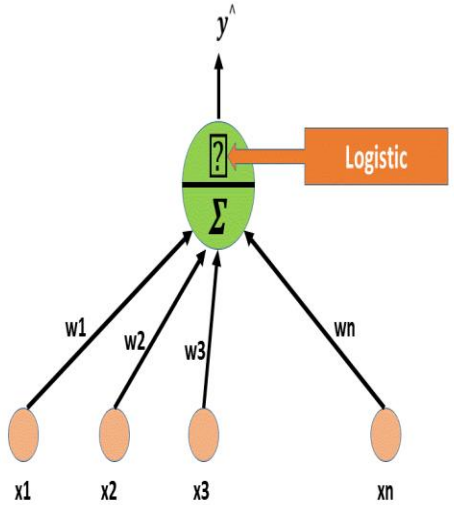
Activation Function (Transfer Function -)



$$I = W_1X_1 + W_2X_2 + \ldots\ldots\ldots\ldots + W_nX_n = \sum_{i=1}^{n} W_iX_i$$

To generate the final output y, the sum is passed to a filter ϕ called transfer function, which releases the output.

That is $y = \phi(I)$



Consider a simple example of an activation function using a threshold, often referred to as a step function.

The step function is defined as follows: $$f(x) = \begin{cases} 1 & \text{if } x \geq \text{threshold} \\ 0 & \text{if } x < \text{threshold} \end{cases}$$

Here's a mathematical example using a step function with a threshold of 0:

Let's say we have a weighted sum of inputs, x = 2 . We'll compare this value to the threshold of 0.

- If $x \geq 0$, the output will be 1.
- If $x < 0$, the output will be 0.

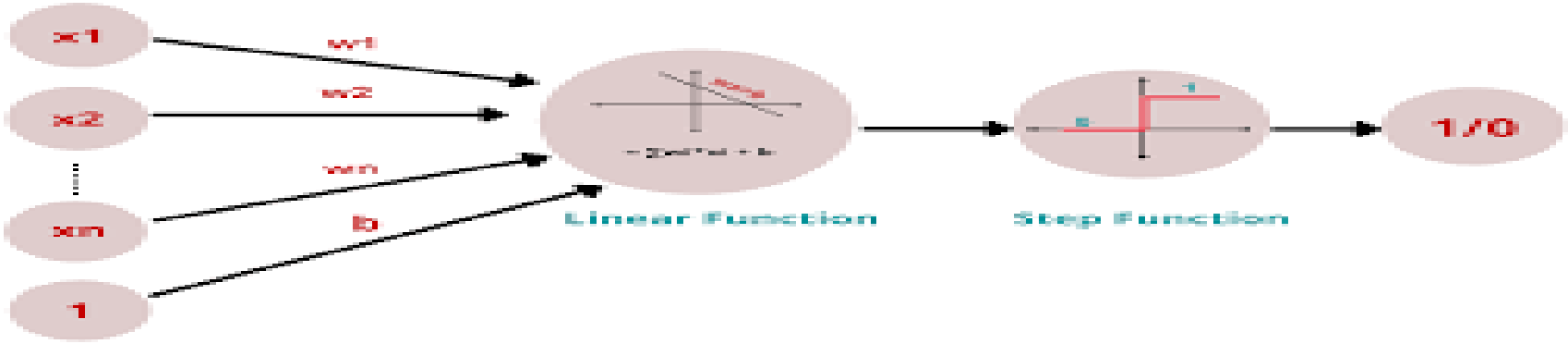
So, for x = 2:

$$f(2) = \begin{cases} 1 & \text{if } 2 \geq 0 \\ 0 & \text{if } 2 < 0 \end{cases} = 1$$

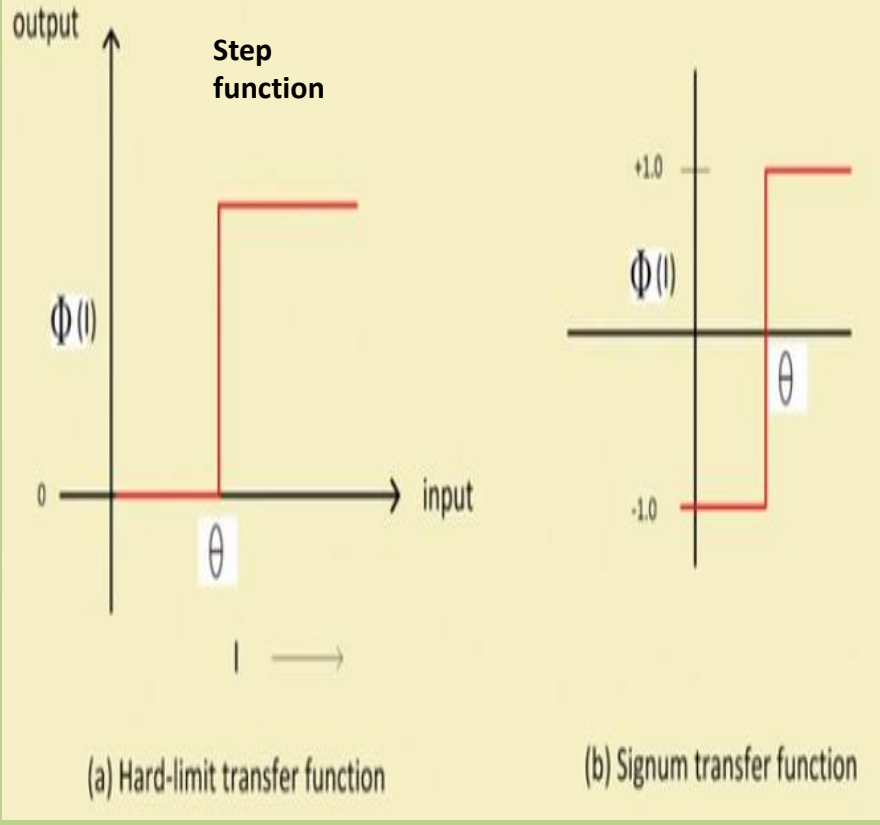
Similarly, for $x = -1$:

$$f(-1) = \begin{cases} 1 & \text{if } -1 \geq 0 \\ 0 & \text{if } -1 < 0 \end{cases} = 0$$

This example demonstrates how the step function with a threshold operates: it outputs 1 if the input is greater than or equal to the threshold, and 0 otherwise. It's a simple binary activation function commonly used in early neural network models like perceptron.



A Simple Neural Network With Step Activation Function



Sigmoid transfer function : This function is a continuous function that varies gradually between the asymptotic values 0 and 1 (called log-sigmoid) or -1 and +1 (called Tan-sigmoid) threshold function and is given by