California State University
Los Angeles

Machine Learning

Artificial Neural Network

Nikhil Dhiman
Computational Molecular Biology (COMB) Lab

Agenda Overview

01 What is Artificial Neural Network?

02 Biological Inspiration

03 Structure of a Neural Network

04 Neuron Mathematical Representation

05 Activation Function

06 Feed Forward Neural Network

07 Backpropagation & Cost Function

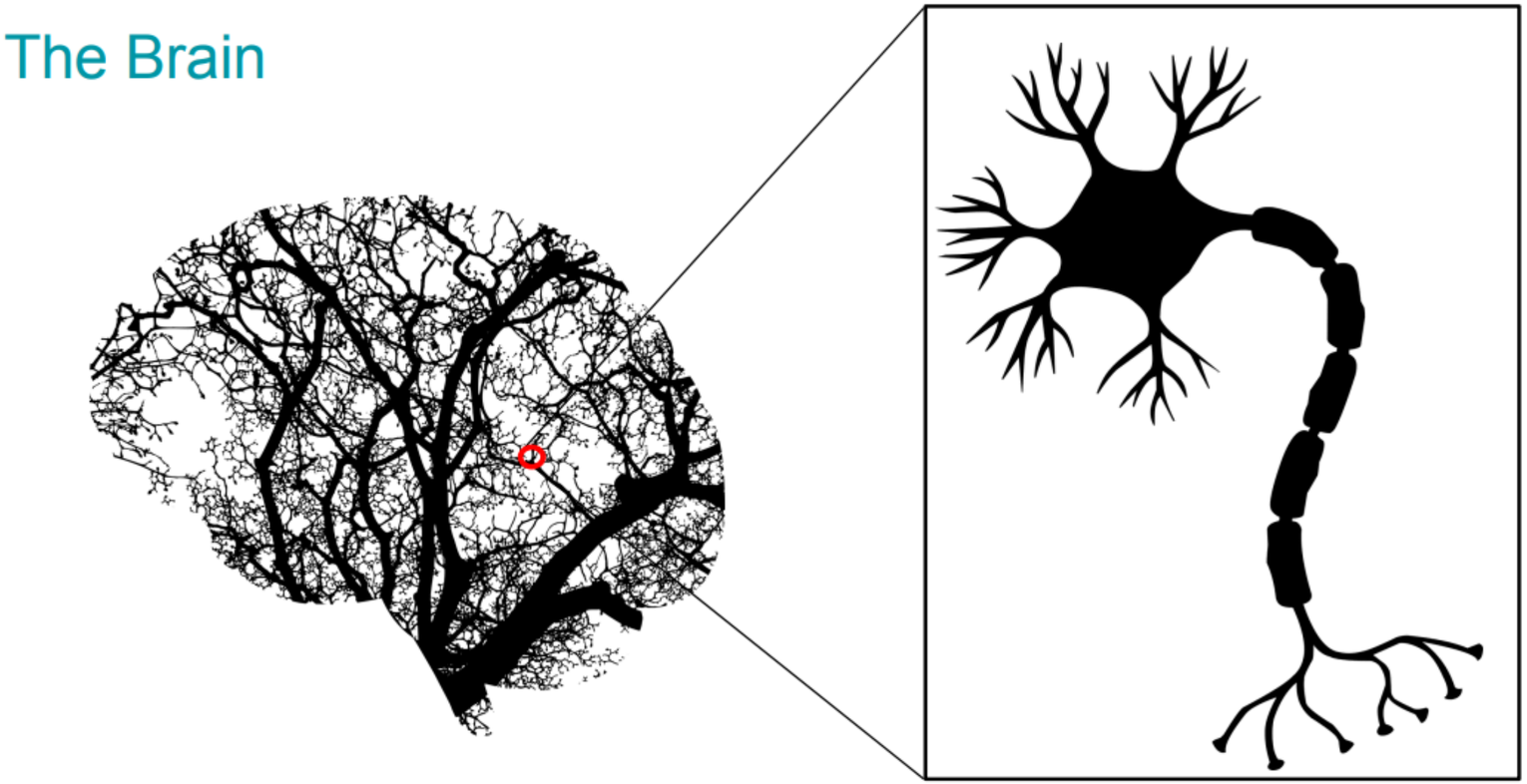
What is Artificial Neural Network?

Definition

- A neural network is a machine learning program, or model, that makes decisions in a manner similar to the human brain, by using processes that mimic the way biological neurons work together to identify phenomena, weigh options and arrive at conclusions.
- In short:
  - Mathematical model inspired by the human brain
  - Consists of interconnected layers of artificial neurons
  - Learns from data through training to predict or classify outcomes

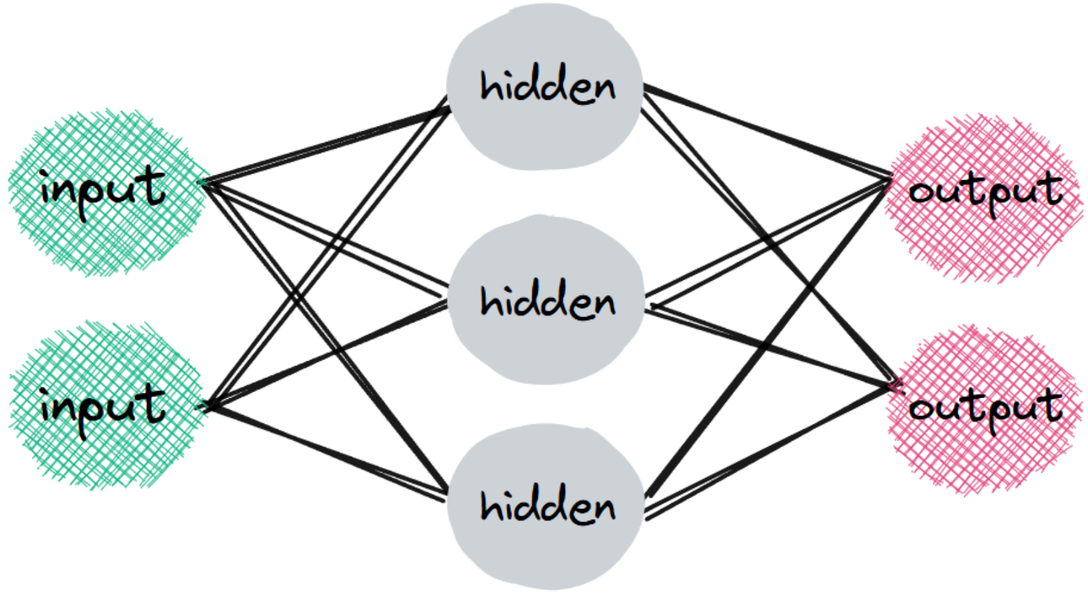
Biological Inspiration

- Human brain: billions of neurons interconnected

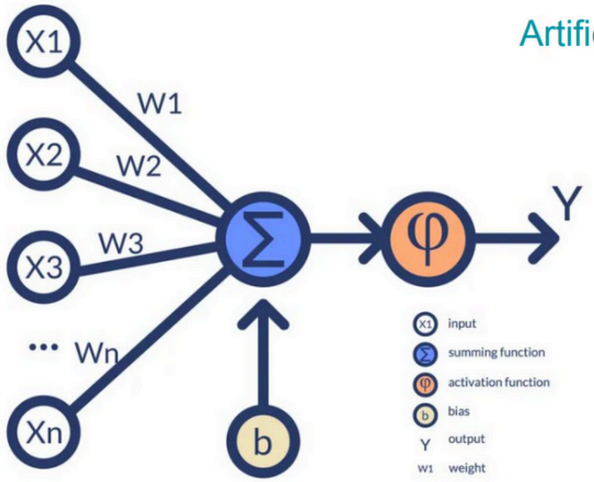


Structure of a Neural Network

- Neural networks consist of interconnected nodes (also called neurons).
- Each node receives signals, processes them, and passes output to connected downstream nodes.
- Nodes are grouped into three types of layers:
  - Input Layer: Receives raw input data
  - Hidden Layers: Perform intermediate computations
  - Output Layer: Produces final result
- Data flows from left to right through the network — known as a forward pass.



Neuron Mathematical Representation



Given inputs $x_1, x_2, \ldots, x_n$ with corresponding weights $w_1, w_2, \ldots, w_n$ and a bias b, the neuron computes:

$$z = \sum_{i=1}^{n} w_i x_i + b = w^T x + b$$

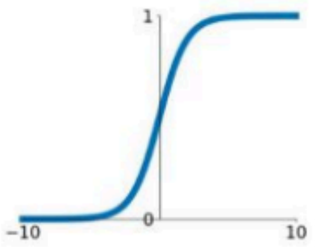
Why Do We Need Non-Linearity in Neural Networks?

- Without non-linearity, a neural network composed of multiple layers would behave like a single-layer linear model
- No matter how many layers, the output would still be a linear transformation of the input.
- Non-linear activation functions:
  - Introduce curved decision boundaries.
  - Allow the model to learn complex mappings from inputs to outputs.
  - Enable networks to stack layers meaningfully — each layer can extract different abstract features.
- Linear model: Can separate data with a straight line (or plane).
- Non-linear model: Can separate complex shapes, like spirals or XOR patterns.

Activation Functions (φ)

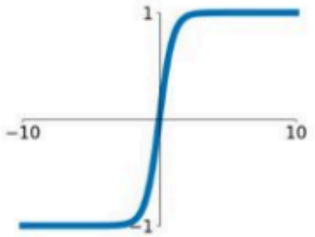
Sigmoid

$$\sigma(x) = \frac{1}{1+e^{-x}}$$



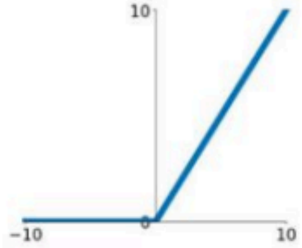
tanh

$$\tanh(x)$$



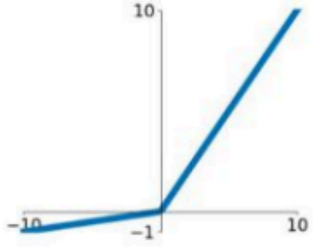
ReLU

$$\max(0, x)$$



Leaky ReLU

$$\max(0.1x, x)$$

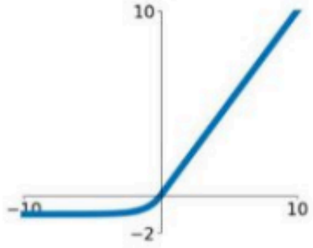


Maxout

$$\max(w_1^T x + b_1, w_2^T x + b_2)$$

ELU

$$\begin{cases} x & x \geq 0 \\ \alpha(e^x - 1) & x < 0 \end{cases}$$

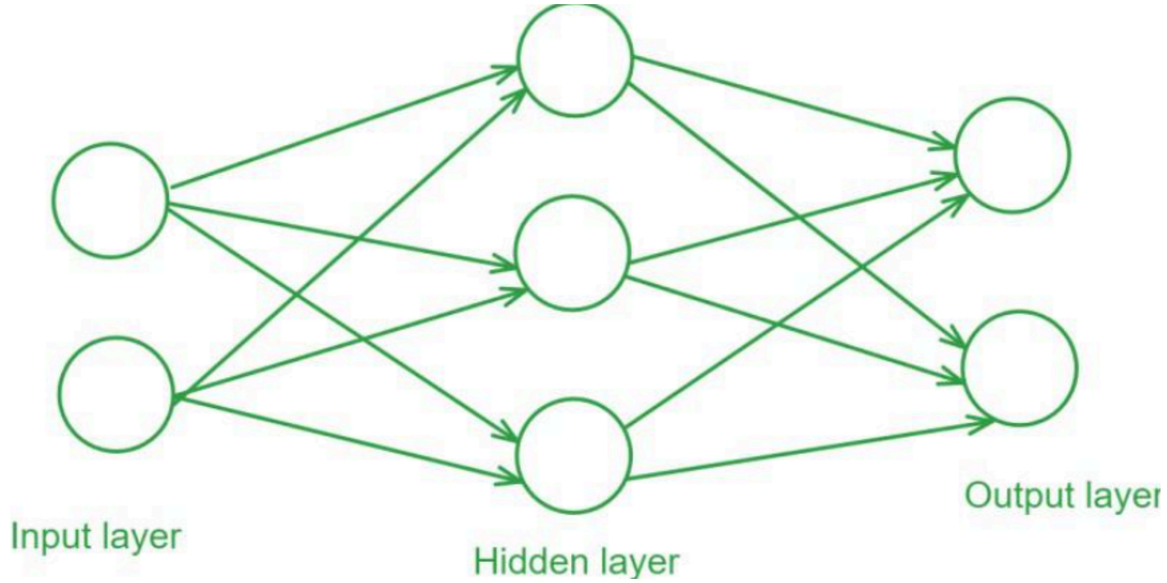


Know more about Activation Functions

Feed Forward Neural Network

- A Feedforward Neural Network (FNN) is the simplest type of artificial neural network where data moves in only one direction:

  Input Layer→Hidden Layers→Output Layer
- No cycles or loops (unlike recurrent networks)
- Each neuron in one layer is connected to every neuron in the next layer (fully connected)
- Ideal for tasks like classification, regression, image recognition



Backpropagation

- Backpropagation (short for “backward propagation of errors”) is the algorithm used to train neural networks by adjusting weights.
- Steps:
  - Forward pass: Compute output using current weights
  - Compute loss: Compare predicted output with actual label using a loss function
  - Backward pass:
    - Calculate error gradients using the chain rule
    - Propagate errors back from output to input
    - **Update weights: Adjust weights using gradient descent:**

$$w = w - \alpha \cdot \frac{\partial L}{\partial w}$$

Cost Function

- A cost function (also called a loss function) measures the difference between predicted outputs and actual target values.
- **It provides a quantitative signal for how well the model is performing.**
- **The goal of training is to minimize this cost over time.**

Task Type	Cost Function	Description
Regression	Mean Squared Error (MSE)	Penalizes large errors heavily
Binary Classification	Binary Cross-Entropy	Measures log loss between true/predicted probs
Multi-Class Classification	Categorical Cross-Entropy	Extension of binary cross-entropy

California State University
Los Angeles

Thank You

Computational Molecular Biology (COMB) Lab