Artificial Intelligence
(Machine Learning: Neural Networks)

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February 13, 2025
Lecture #5b

Neural Networks

- Artificial Neural Networks (ANN) is a brain model.
- Science of machine learning (ML) is mostly experimental as there is a no universal learning algorithm yet.
- Humans are fairly good at "general learning abilities" due to which they are able to master number of tasks, like playing chess and playing cards.
- A knowledge-acquisition algorithm is always required to be tested on learning tasks and data.
- There is "no method to prove that the given algorithm will be consistently better for all the situations."
- These arguments suggest and might serve as inspirations for building machines with some form of general intelligence.

Neural Networks...

- Basic unit of brain for performing computation is a cell, called *neuron*, each one of them sends a signal to other neurons through very small gaps between the cells, called *synaptic clefts* (Fig. 1).
- Property of any neuron of sending signal through this gap, and the amplitude of the signal together, is called signal *synaptic strength*.
- As a neuron learns enough, its synaptic strength increases, and in that situation, if it is stimulated by an electrical *impulse*, there are better chances that it would send signal to its neighbor neurons.
- A Neural Network (NN) consists of two or more layers: an input layer, ≥ 0 hidden layers, and an output layer.
- Data is ingested through input layer, modified in hidden layers and sent to output layer, based on the weights applied.
- Using *iterations*, a neural network continuously adjusts weights and makes inferences until some stopping pt. reached.

Architecture of a simple NN

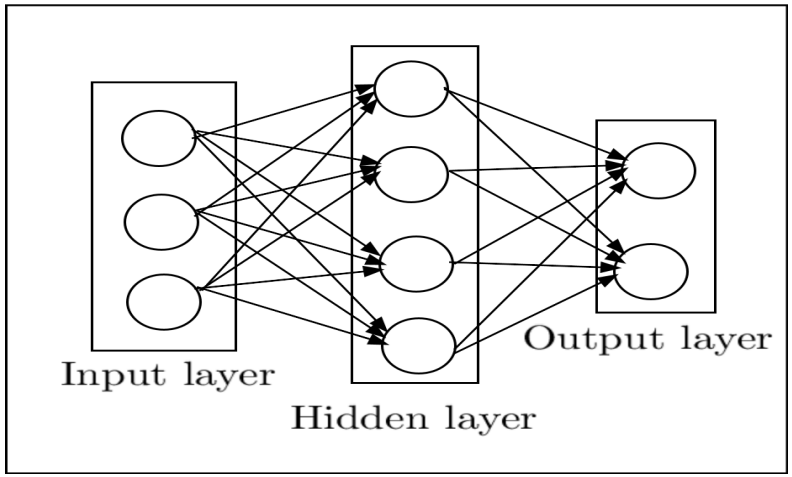

Figure 1: Architecture of a simple neuron

- Majority of NN algorithms are based on *supervised learning*.
- Assume that picture of sunrise is associated with caption: "Sunrise", and goal of learning algorithm is: take any sunrise image as input, and produce name of object in the image, as output, e.g., "sunrise."
- Process of transforming an input to output is a math. *function*.
- Synaptic strength (a numerical value) produce this function, which is the solution to the learning through ANN.
- When we want to teach the algorithm "what sunrise is", then algorithm should recognize any sunrise, even one for which we have not trained it! This is the goal of ML.

NN: Properties

Important properties:

- Learning ability,
- Massive parallelism,
- Adaptability,
- Fault tolerance,
- Distributed representation and computation,
- Generalization ability, and
- Low energy consumption.

The most common application of NN is in learning and computation. Each processing unit has following properties:

- an activity-level to represent neuron's polarization state,
- an output value represents firing rate,
- a set of input connections,
- synapses on the cell and its dendrite,
- a bias value to represent an internal resting level of a neuron, and
- output connections to represent neuron's *axonal* projections.

Basic Model of an Artificial Neuron

• Each connection of a neuron has an associated weight, called *synaptic strength* or weight w_i of *ith* input, that influences the effect of the incoming input on the activity of the unit. The weight is either +ve (excitatory) or -ve (inhibitory).

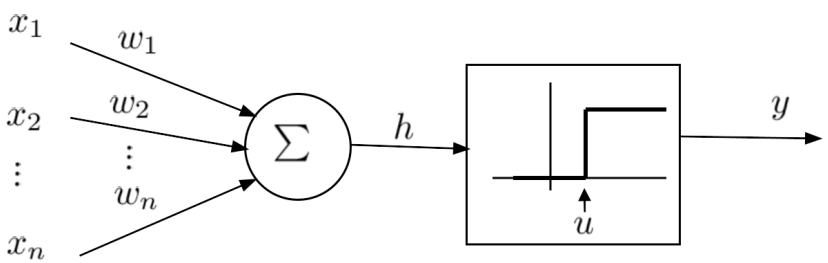

Figure 2: Basic model of Artificial Neuron with binary threshold

• Mathematical model of neuron computes the weight as *sum* of its n-input signals $x_1, ..., x_n$.

• Generated output is 1, if the *sum* > *threshold* u, else, output is 0. The output y is:

$$y = \theta\Big(\sum_{i=1}^{n} w_i x_i - u\Big), \qquad (1)$$

• $\theta(.)$ is *unit step* function at 0. Threshold u is other weight; $w_0 = -u$ is attached to the neuron with a constant input $x_0 = 1$.

Simplified version of biological neuron

- Properly chosen weights allows such neurons to perform universal computations.
- There is a crude analogy of this neuron model to biological neurons as follows: wires and interconnections model the *axons* and *dendrites*, respectively, in the biological neuron.
- *Connection weights* correspond to *synapses* in biological neuron, and threshold function approximates the activity in biological neuron.
- ANNs can be considered as weighted directed graphs, where artificial neurons act as nodes, and directed edges with weights are connections between neurons, and between outputs and inputs of neuron (Fig. 1).
- Based on the connection pattern an ANN can be classified as:

- *Feed-forward networks:* The direct graphs have no loops.
- *Recurrent feedback networks:* Have loops, due to feedback connections.

References

[1] Chowdhary, K.R. (2020). Statistical Learning Theory. In: Fundamentals of Artificial Intelligence. Springer, New Delhi. https://doi.org/10.1007/978-81-322-3972-7_14