Neural Networks

Contents

Artificial Neural Networks

- An Artificial Neural Network (ANN) **models** **the relationship between a set of input signals** and **an output signal** ***using*** **a model derived from our understanding of how a biological brain responds to stimuli from sensory inputs**.

Contd...

- **Artificial Neural Networks (ANNs)**
  - Takes cues (= inspiration) from how the biological brain receives stimuli from various sensory inputs.
  - Thus, here the **modeling is based on** **biological brain of living things**.
- **Neurons**
  - Brain uses a network of interconnected cells called ***neurons*** to create a massive parallel processing system.
- **Nodes**
  - ANN uses a network of artificial neurons called ***nodes*** to solve learning problems.

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- **Number of neurons**
  - Humans – about 85 billion, this helps in representing a tremendous amount of knowledge.
  - Cats – roughly 1 billion.
  - Mice - about 75 million.
  - Cockroaches – about 1 million.
- But, ANNs contain fewer number of nodes, typically only several hundred (100).

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- Earlier research on ANNs (simulation of brain's approach in problem – solving) could establish simple functions like logical AND or the logical OR.
- However, as research improved, **complexity of ANNs improved**.

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- As **complexity of ANNs improved**, they are frequently applied to practical problems such as:
  - Speech and handwriting recognition programs like those used by voicemail transcription services.
  - The image identification using ANNs…for example in Wuhan city of China, it has installed several surveillance cameras…and the ANN at a computer can identify the details of an absconding person from isolation by inputting several images at the input nodes of the network

Contd...

- The automation of smart devices like an office building's (home's) environmental controls or self – driving cars and self – piloting drones.
- Sophisticated models of weather and climate patterns, tensile strength, fluid dynamics, and many other scientific, social, or economic phenomena.

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- Since they are modeling brain system, ANNs are **versatile learners**.
- So, they can be applied to any learning task such as
  - classification,
  - numeric prediction, and
  - even unsupervised pattern recognition.

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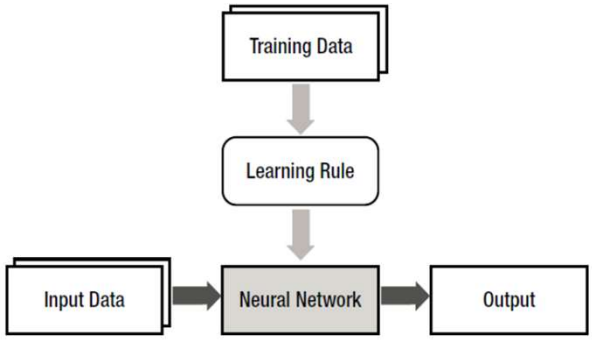
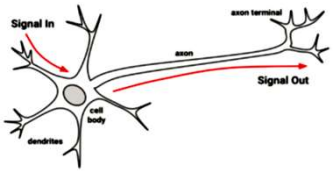
- ANNs are **best applied** to problems where the input data and output data are **well-defined** or at least **fairly simple.**
- But, the process of **relating the input to the output** is extremely complex.

The Relationship b/w ML and Neural Network



Biological Motivation

- Let us first understand, how biological neurons work.
- A neuron (cell) **receives** incoming signals.
- Cell's dendrites do this using a biological process.
- The signal **is weighted** (by this process) according to its relative importance or frequency.
- There is a **limit / threshold** for **accumulating** the incoming signals by the cell body.



APPLICATION OF WEIGHTS means some of the input signals are only accepted, if important; others are masked.

Contd...

- On reaching the threshold, the cell body **fires** and the output signal is transmitted via an electrochemical process down the axon.
- At the axon's terminals, the electric signal is again processed as a chemical signal to be passed to the neighboring neurons across a tiny gap called synapse. (The place where axons connect to the dendritic tree is called a **synapse**.)

Contd...

- Whenever we learn something, our brain **stores** **knowledge**.
- Computer uses its memory for the same knowledge storing.
- But the mechanisms of the storage are very different.
- Computer stores information at specified addressable locations of the memory.
- **Brain alters the association of neurons.**
- Neurons **do not** have storage capacity.
- It just transmits signals from one neuron to the other.
- The brain is a gigantic network of these neurons.
- And, **the association of neurons forms a specific information**.

  Note: Association may be in the form of "selection of some neurons only through weighting…inputs from a few neighboring neurons may be accepted…that are considered important…others are masked…"

Contd...

- The neural network imitates the mechanism of the brain.
- We know, the brain is composed of numerous neurons.
- In the same manner, a neural network is constructed with connections of nodes.
- *Nodes are elements* that correspond to *the neurons of the brain*.
- The neural network **mimics** the neuron's **association** – which is the **most important mechanism of the brain** – using the **weight value**.

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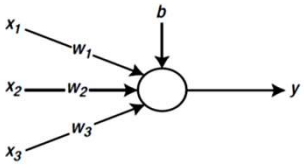
- The following table summarizes the analogy between the brain and the neural network.

Brain	Neural Network
Neuron	Node
Connection of neurons	Connection weight

Design of *a* Neuron

- Below is the simple example explaining the neural network's mechanism.



- The circle denotes the node.
- The arrows signal flow.
- x_1, x_2, x_3 are the input signals; w_1, w_2 and w_3 are the weights for these signals.
- b is the bias, another factor associated with storage of information.

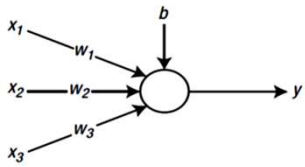
Contd...

- The input signal from the outside is multiplied by the weight before it reaches the node.
- Once the weighted signals are collected at the node, these values are added to be the weighted sum.
- The weighted sum ***(not the output y)*** of this example is calculated as

$$v = (w_1 \times x_1) + (w_2 \times x_2) + (w_3 \times x_3) + b$$

Contd...

- This equation indicates that **the signal with a greater weight has a greater effect.**
- **For instance**, if weight w_1 is 1, and w_2 is 5, then signal x_2 has five times larger effect than that of x_1.
- When w_1 is zero, x_1 is not transmitted to the node at all.
  - This means that x_1 is disconnected from the node.



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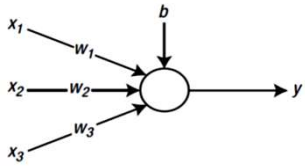
- This example shows that, the weights of the neural network **imitates** how the **brain alters** the association of the neurons *(i.e., selection of some inputs only … in biological brain… selection of some neurons only).*



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- The equation

$$v = (w_1 \times x_1) + (w_2 \times x_2) + (w_3 \times x_3) + b$$

of the weighted sum can now be written **with matrices** as

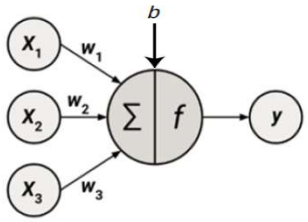
$$v = wx + b$$

where *w* and *x* are defined as

$$w = [w_1 \quad w_2 \quad w_3] \qquad x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

Contd...

- Finally, the node gives the weighted sum into the activation function and yields the output.



- The activation function **determines** the **behavior of the node**.

y = f(v)

Contd...

- ***f(.)*** of this equation **is the activation function**.
- Many types of activation functions are available in the neural network.

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- Now, **reviewing what we did**…
- **The following process is conducted inside the neural net node.**

1. The weighted sum of the input signals is calculated.

$$v = w_1x_1 + w_2x_2 + w_3x_3 + b$$

2. The output from the activation function to the weighted sum is passed outside.

$$y = f(v) = f(w.x) + b$$

OR

$$y = f(\sum_{i=1}^{n} w_i x_i) + b$$

References

1. Machine Learning with R, Second Edition, Brett Lantz, PACKT Publishing.