Big Bio-Data Analysis (Artificial Intelligence and Machine Learning)

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Introduction to Neural Networks

By

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Neural Networks

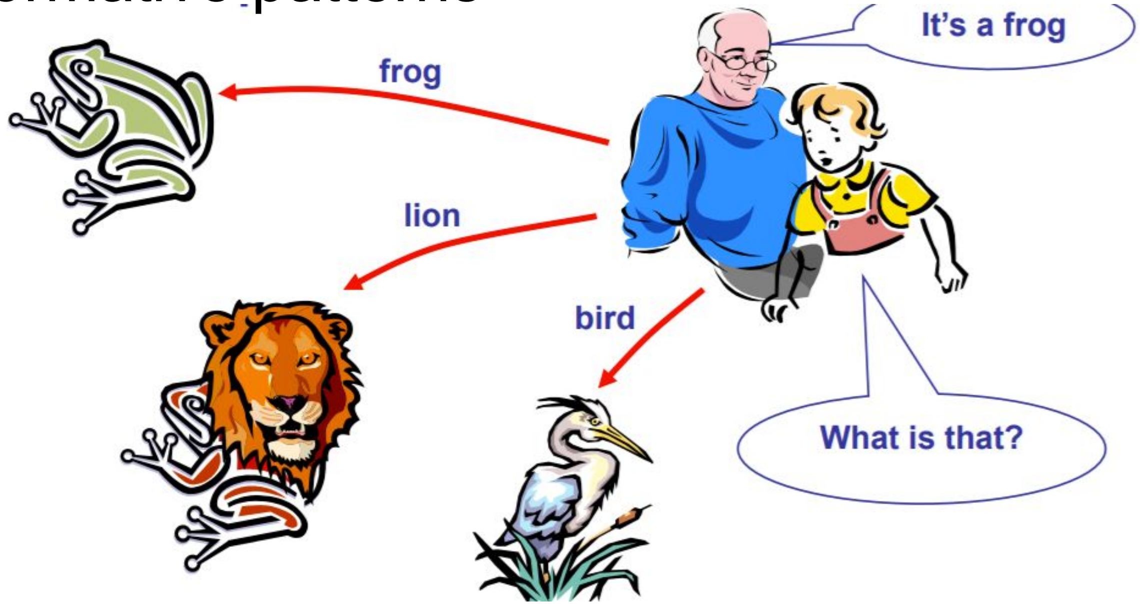
Neural Networks : information processing paradigm inspired by biological nervous systems, such as our brain

Structure : large number of highly interconnected processing elements (neurons) working together

Like people, they learn from experience (by example)

The idea of Neural Networks

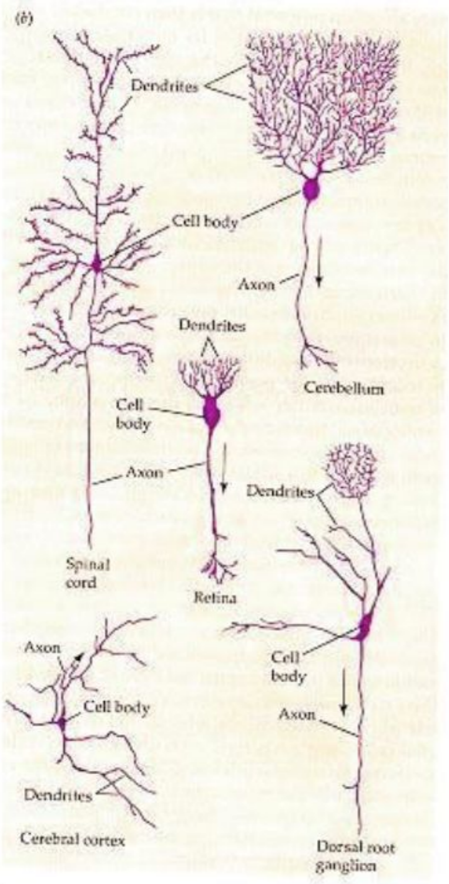
Neural Networks learn relationship between cause & effect or organize large volumes of data into orderly and informative patterns

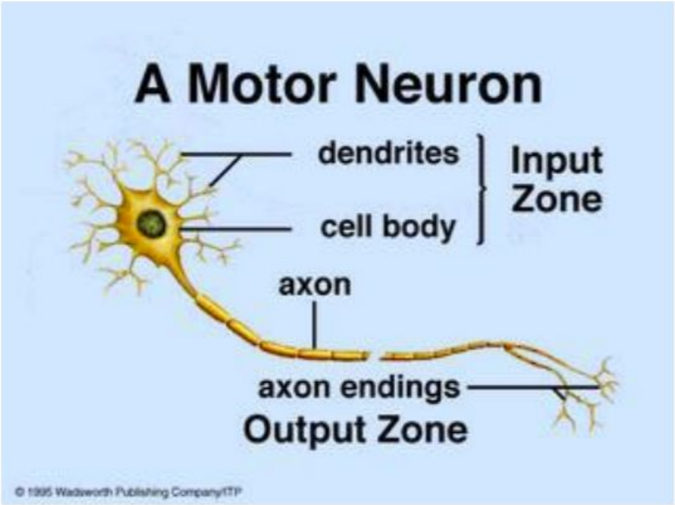


Motivation for Neural Networks

- Use biology as inspiration for mathematical model
- Get signals from previous neurons
- Generate signals (or not) according to inputs
- Pass signals on to next neurons
- By layering many neurons, can create complex model

Biological Neural Networks





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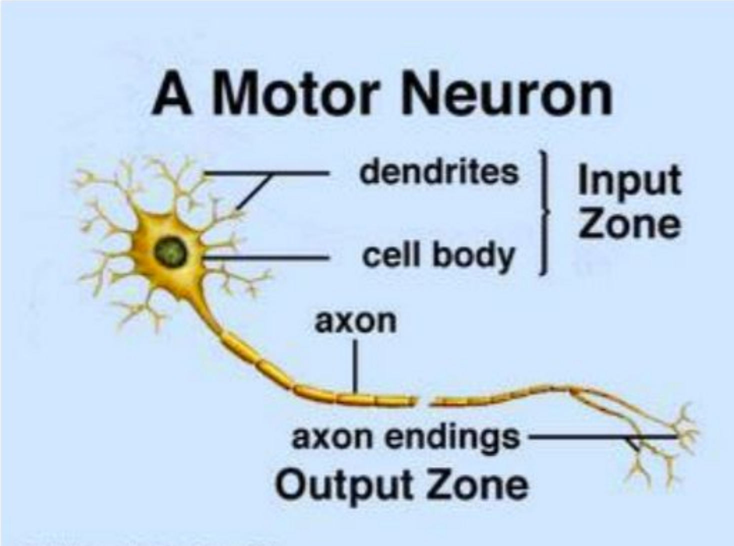
Biological neuron

Biological Neural Networks (Cont'd)

- A biological neuron has 3 types of main components; dendrites, soma (cell body) & axon
- **Dendrites** receives signals from other neurons.
- **The soma,** sums the incoming signals.



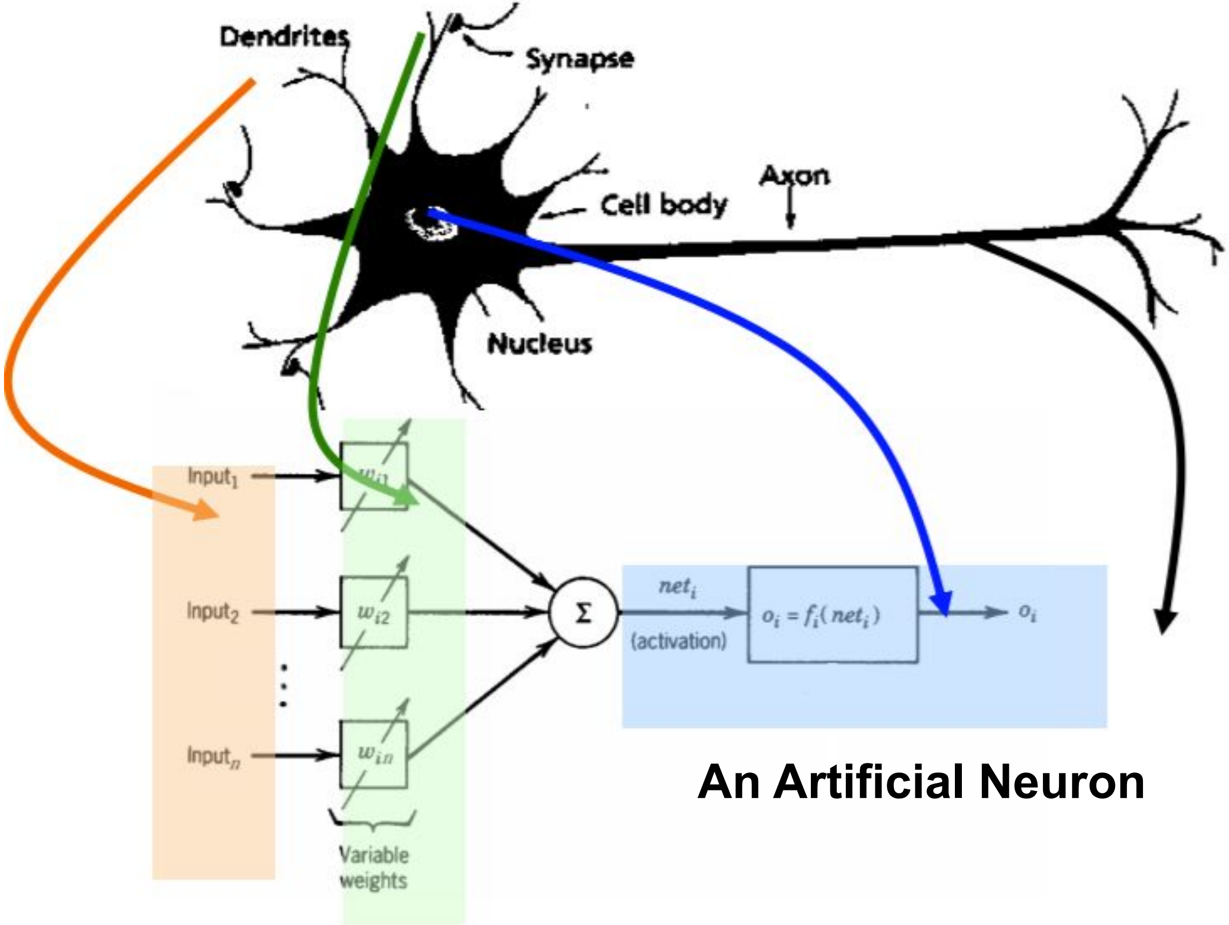
When sufficient input is received, the cell fires;

that is it transmit a signal over its axon to other cells

Several key features of the processing elements of NN are suggested by the properties of biological neurons:

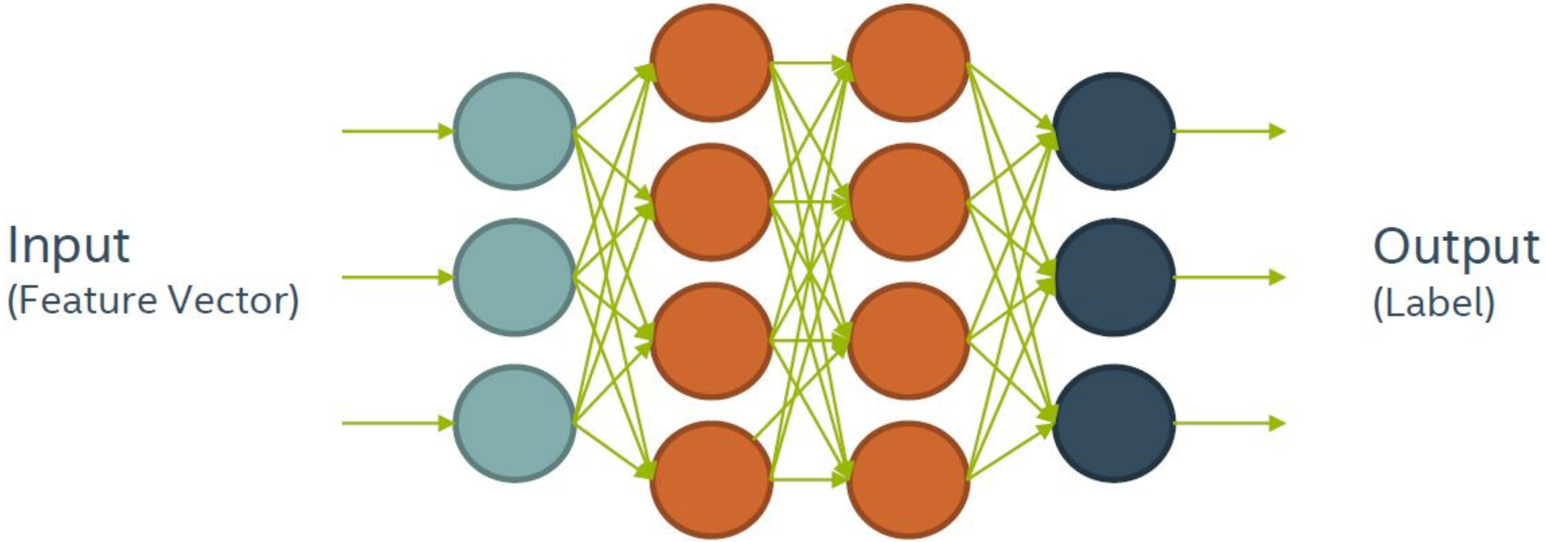
1. The processing element receives many signals
2. Signals may be modified by a weight at the receiving synapse
3. The processing element sums the weighted inputs.
4. Under appropriate circumstances (sufficient input), the neuron transmits a single output
5. The output from a particular neuron may go to many other neurons

A physical neuron



An Artificial Neuron

Structure of Neural Network

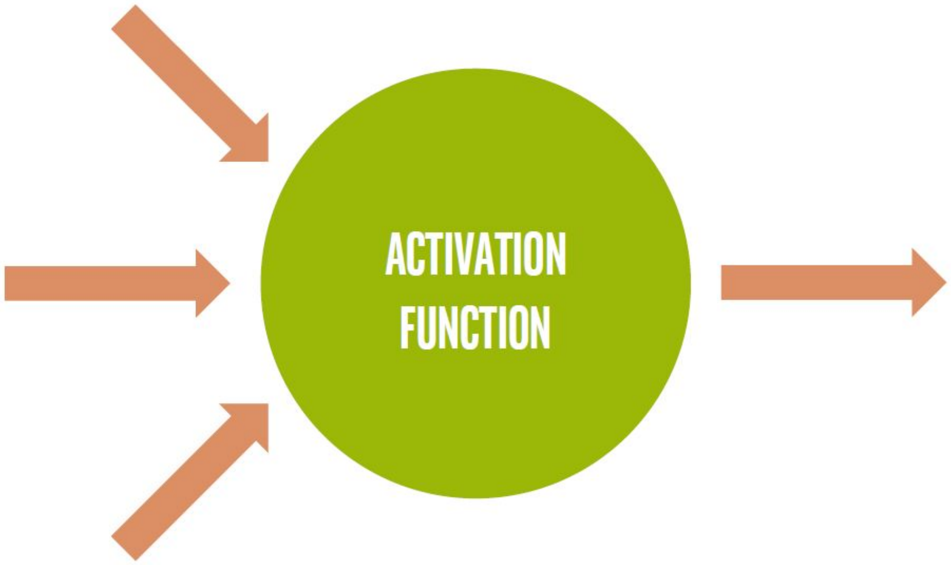


Can think of it as a complicated computation engine

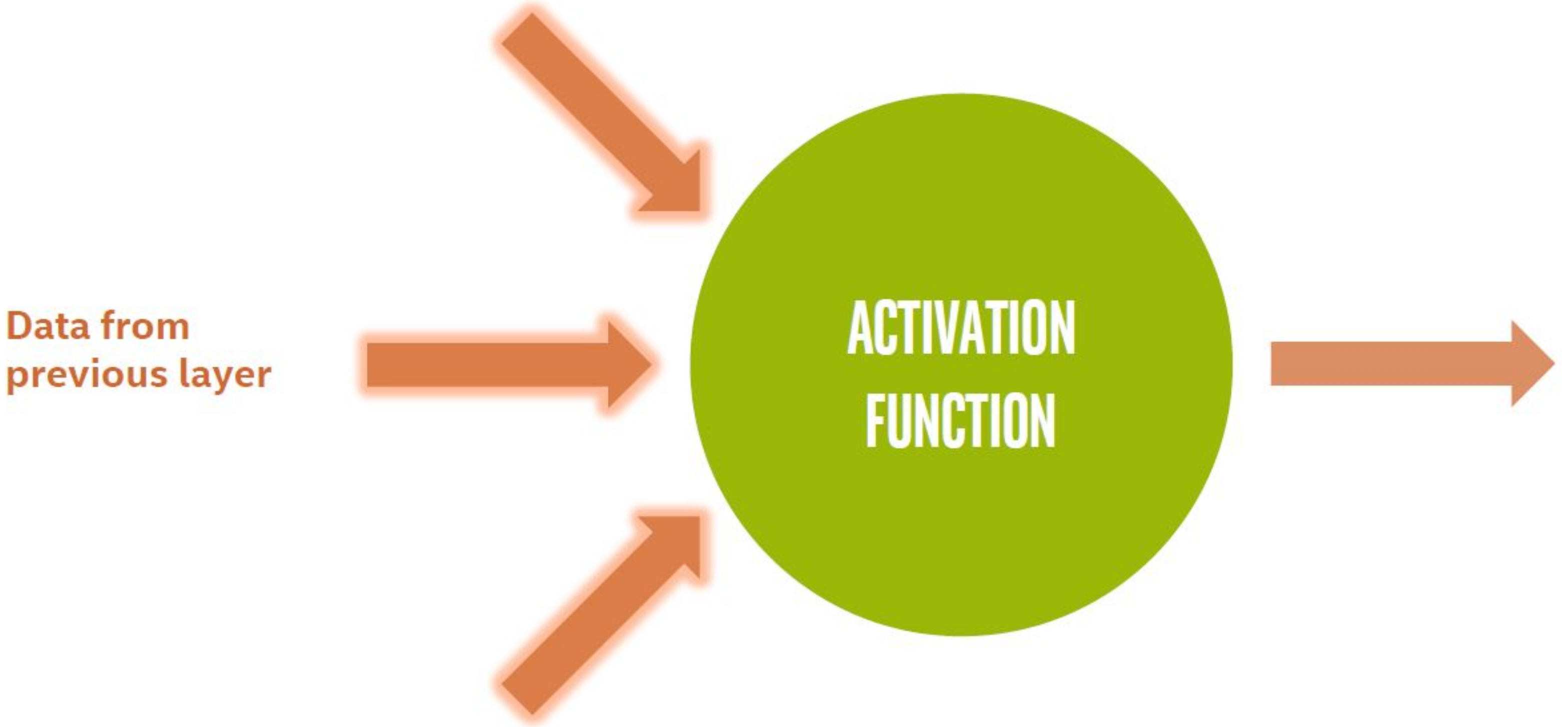
Structure of Neural Network(Cont’d)

- Information processing occurs at many simple elements called **neurons**.
- Signals are passed between neurons over connection **links**
- Each connection link has an associated **weight,** which, in typical neural network, multiplies the signal transmitted
- Each neuron applies an **activation function** to its net input to determine its output signal

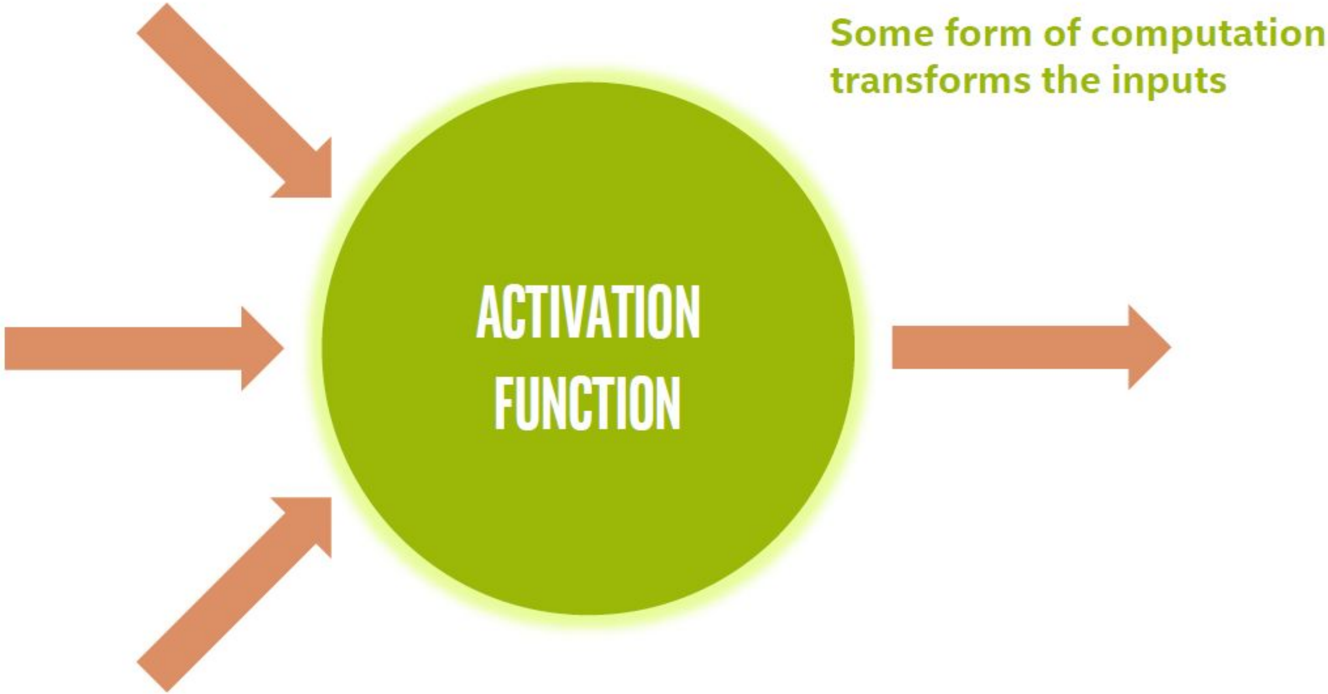
Basic Neuron Visualization



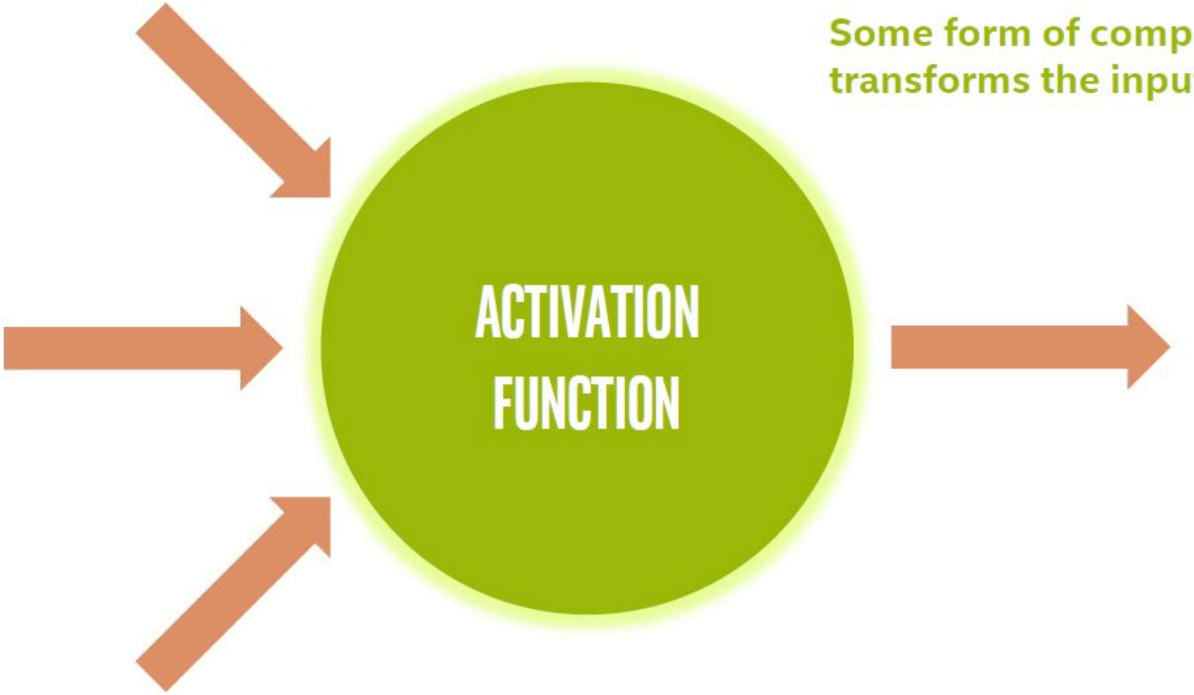
Basic Neuron Visualization



Basic Neuron Visualization

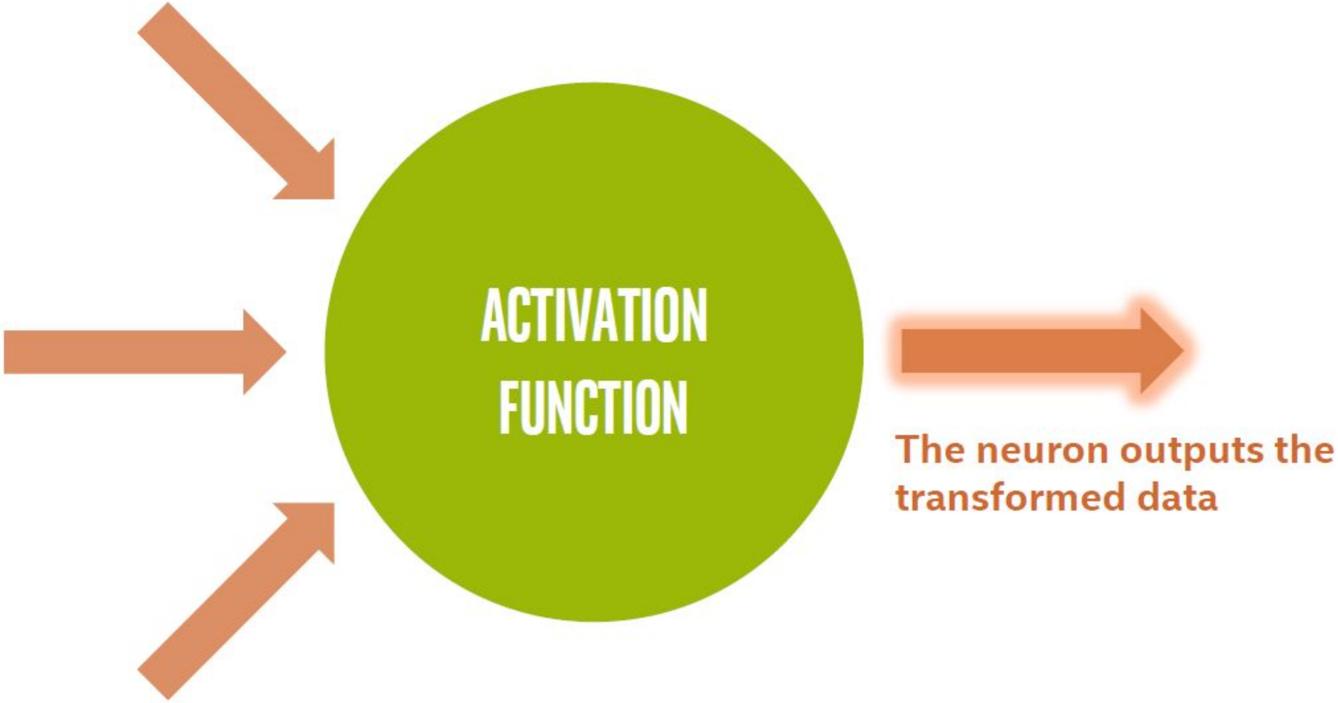


Basic Neuron Visualization

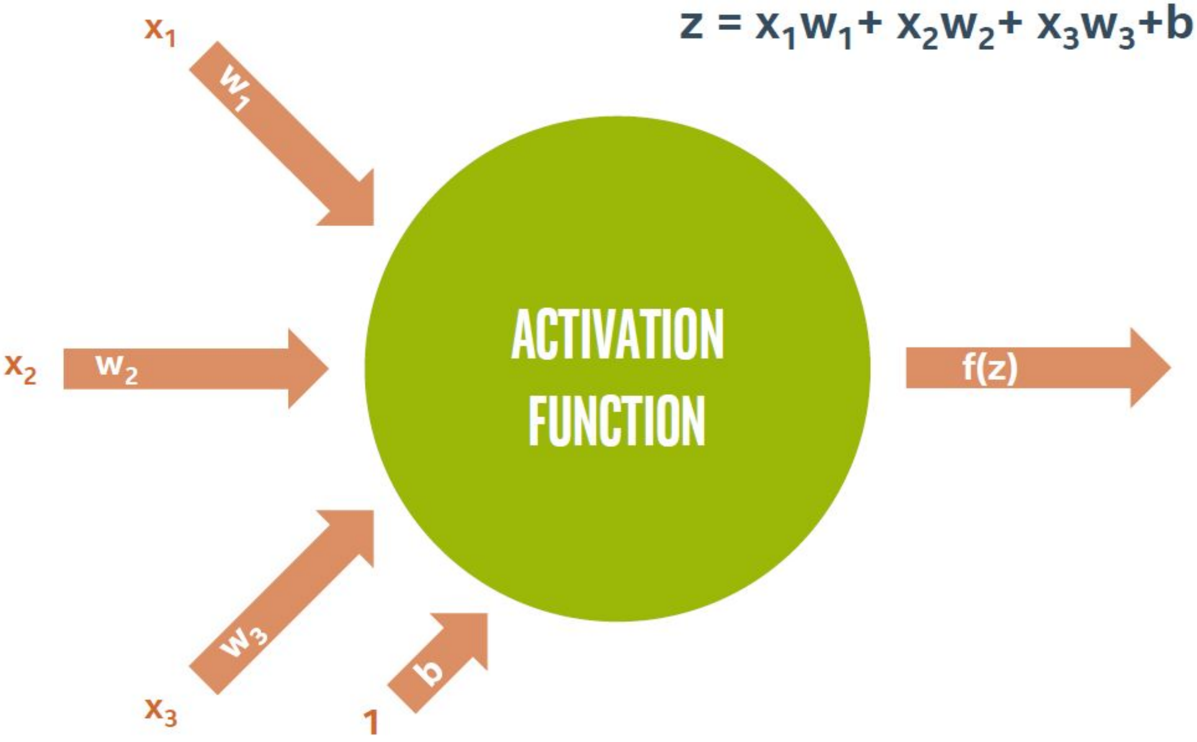


Some form of computation transforms the inputs

Basic Neuron Visualization



Basic Neuron Visualization



$$z = x_1w_1 + x_2w_2 + x_3w_3 + b$$

In Vector Notation

$$z = b + \sum_{i=1}^{m} x_i w_i$$

$$z = b + x^T w$$

$$a = f(z)$$

z = “net input”

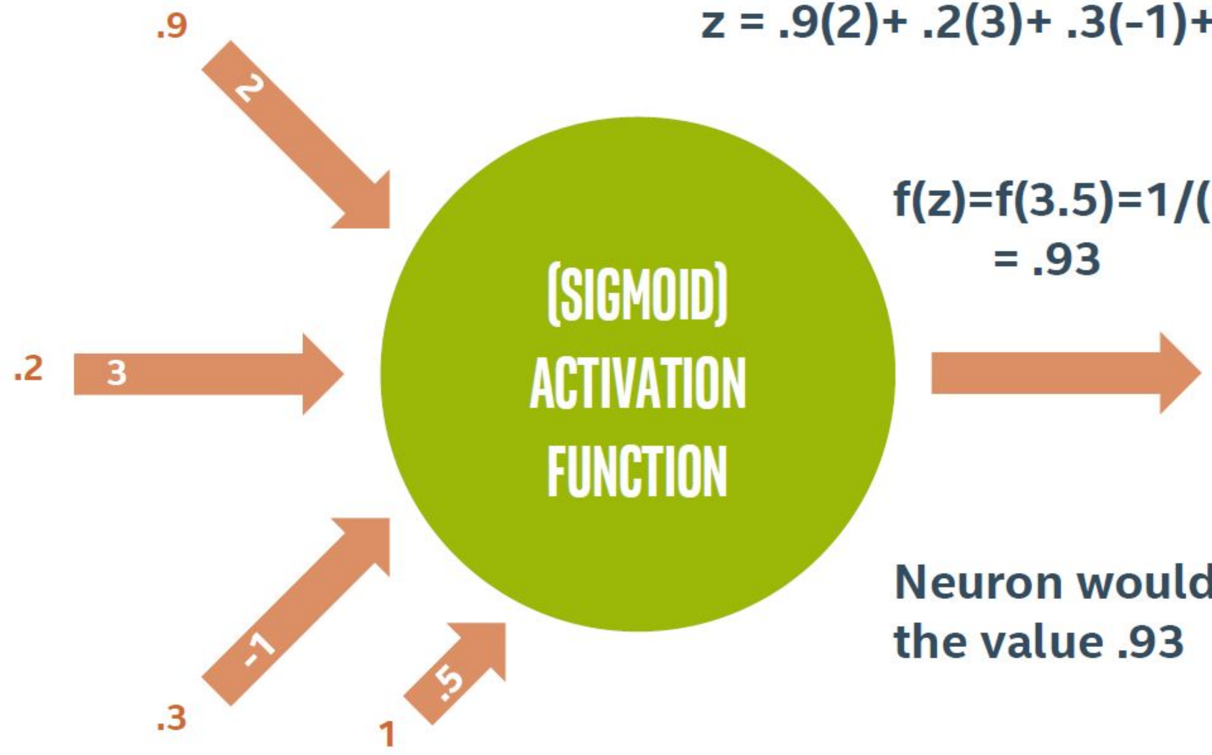
b = “bias term”

f = activation function

a = output to next layer

Example Neuron Computation

$z = .9(2)+ .2(3)+ .3(-1)+.5 = 2.6$



(SIGMOID) ACTIVATION FUNCTION

$f(z)=f(3.5)=1/(1+\exp(-2.6))$
$= .93$

Neuron would output the value .93

Types of Neurons

- **Input and Output Neurons**
  - Nearly every neural network has input and output neurons.
  - The input neurons accept data from the program for the network.
  - The output neuron provides processed data from the network back to the program

Types of Neurons (Cont’d)

- **Hidden Neurons**

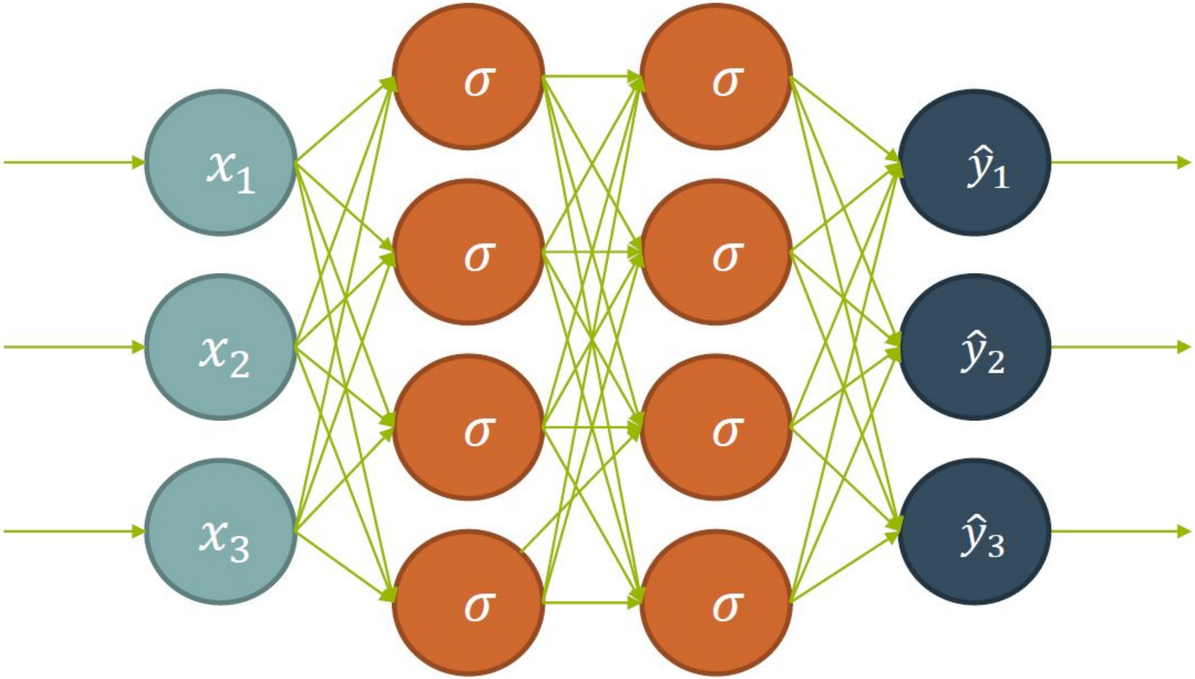
  Hidden neurons have two important characteristics.

  - Hidden neurons only receive input from other neurons, such as input or other hidden neurons.
  - Hidden neurons only output to other neurons, such as output or other hidden neurons.

They help the neural network understand the input, and they form the output.

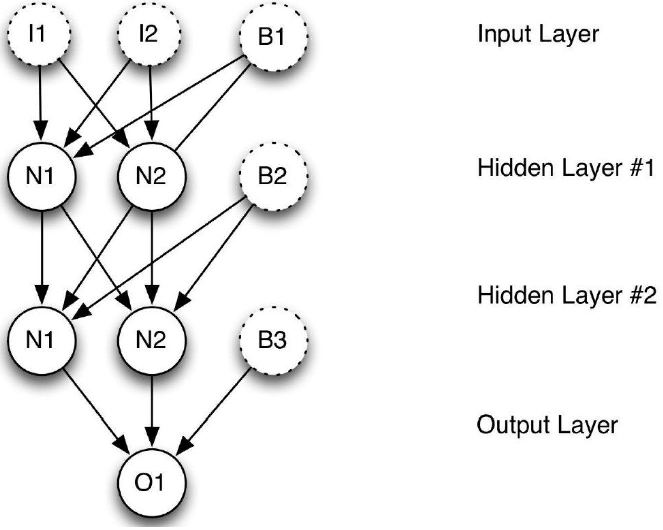
They are not directly connected to the incoming data or to the eventual output

Types of Neurons (Cont’d)



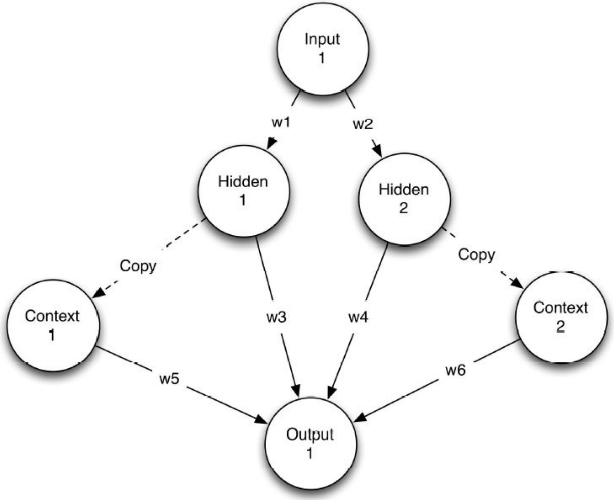
Types of Neurons (Cont'd)

- **Bias Neurons**
  - Bias neurons function like an input neuron that always produces the value of 1
  - They are not connected to the previous layer, Because the bias neurons have a constant output of 1
  - Not all neural networks have bias neurons



Types of Neurons (Cont’d)

- **Context Neurons**
  - Used in recurrent neural networks.
  - This type of neuron allows the NN to maintain state.
  - As a result, a given input may not always produce exactly the same output.
  - This inconsistency is similar to the workings of biological brains



Characterization of Neural Networks

Architecture

- A pattern of connections between neurons
  - Single Layer Feedforward
  - Multilayer Feedforward
  - Recurrent

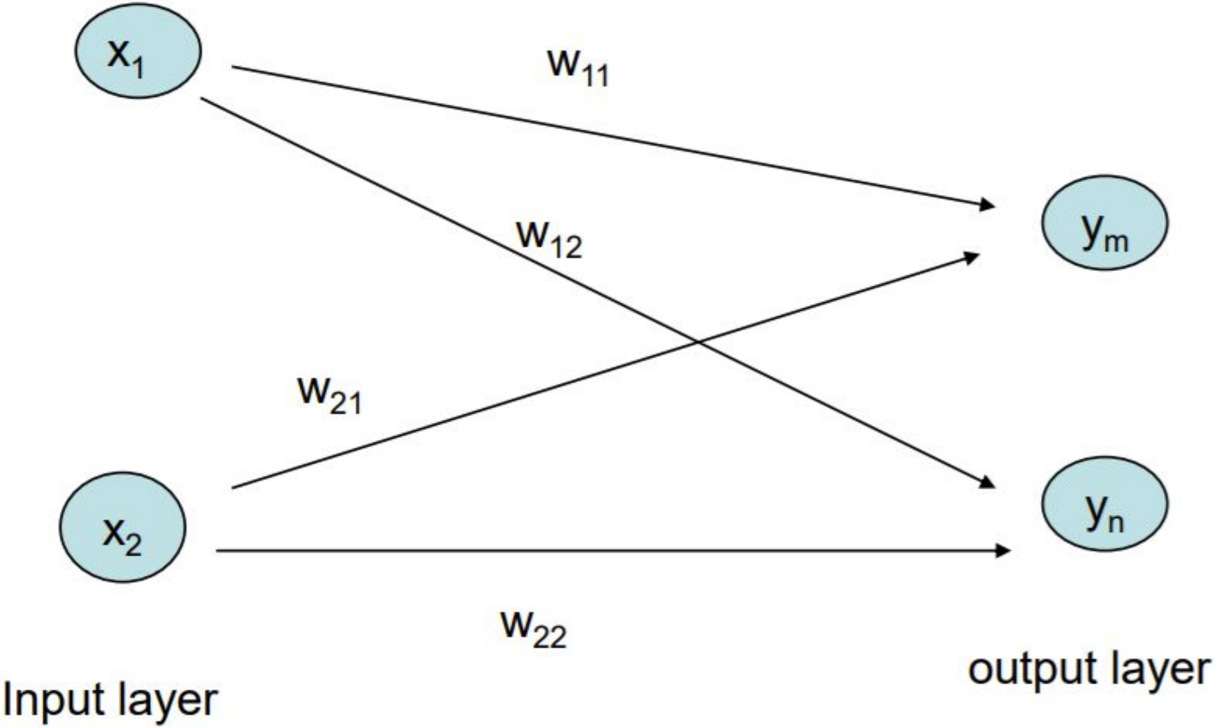
Strategy / Learning Algorithm

- A method of determining the connection weights.
  - Supervised (Feedforward, Perceptron)
  - Unsupervised (e.g Self Organising Maps)

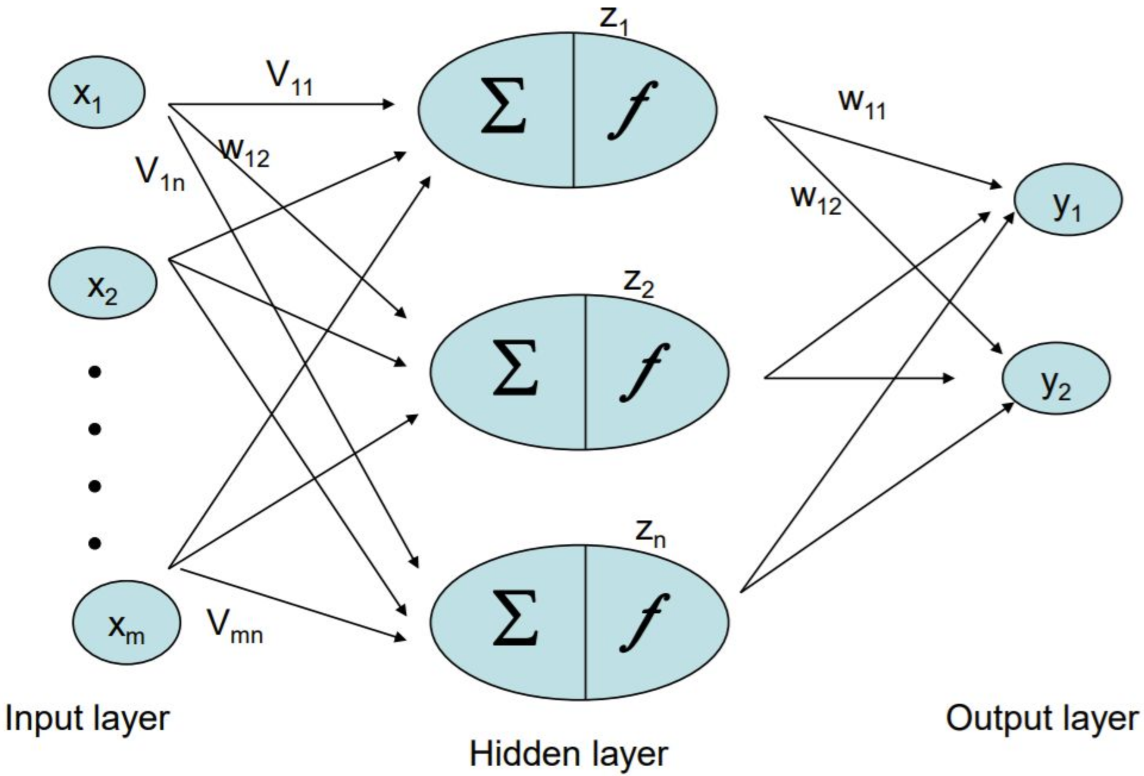
Activation Function

Function to compute output signal from input signal

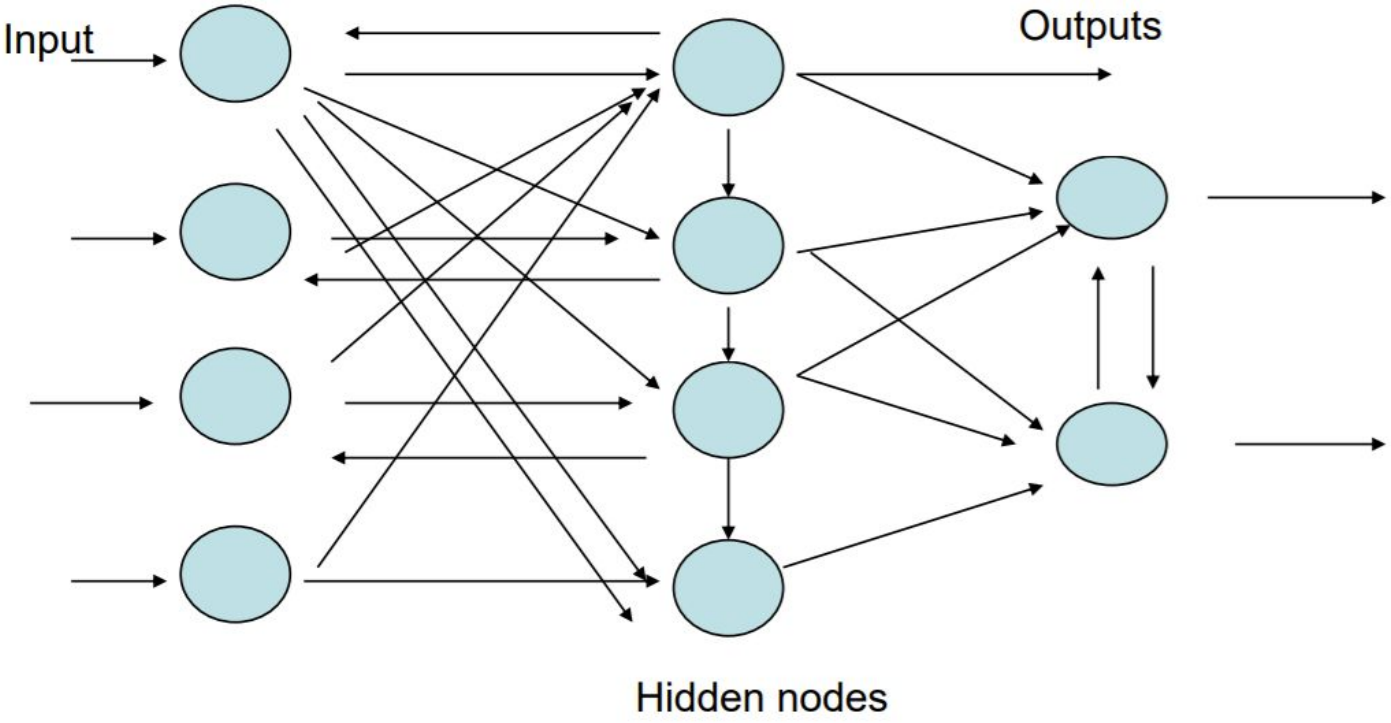
Single Layer Feedforward NN



MultiLayer Feedforward NN



Recurrent NN



Activation Functions

- **Activation or transfer functions** establish bounds for the output of neurons.
- Neural networks can use many different activation functions.
- Most common activation functions : ~6
    - Linear Activation Function, Step Activation Function
    - Sigmoid Activation Function, Hyperbolic Tangent Activation Function,
    - Rectified Linear Units (ReLU), Softmax Activation Function

Activation Functions (Cont'd)

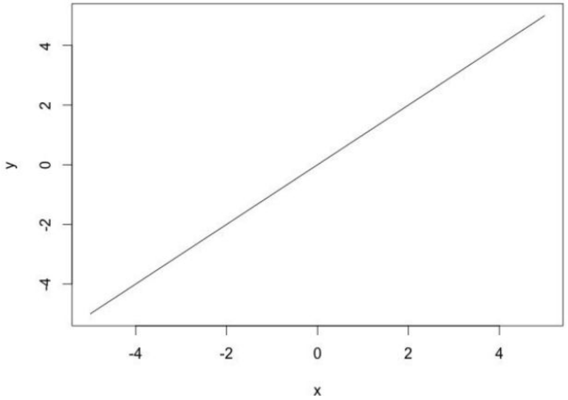
Linear Activation Function

- Most basic activation function is the linear function.

- It does not change the neuron output at all

$$\phi(x) = x$$

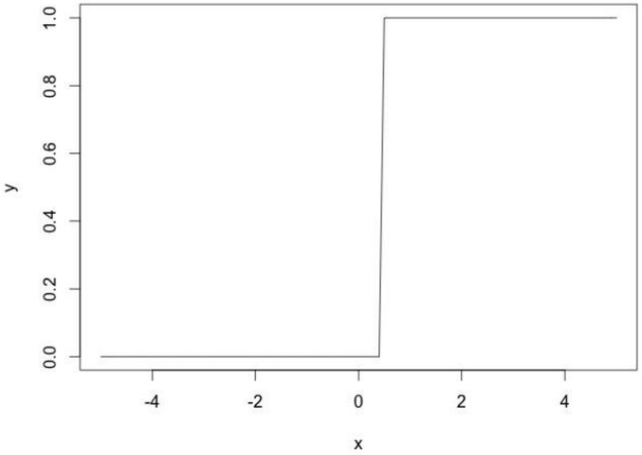
- Eqn shows how the program typically implements a linear activation function



Activation Functions (Cont’d)

Step Activation Function

- The step or threshold activation function is another simple activation function.
- Outputs a value of 1 for incoming values of 0.5 or higher and 0 for all other values.

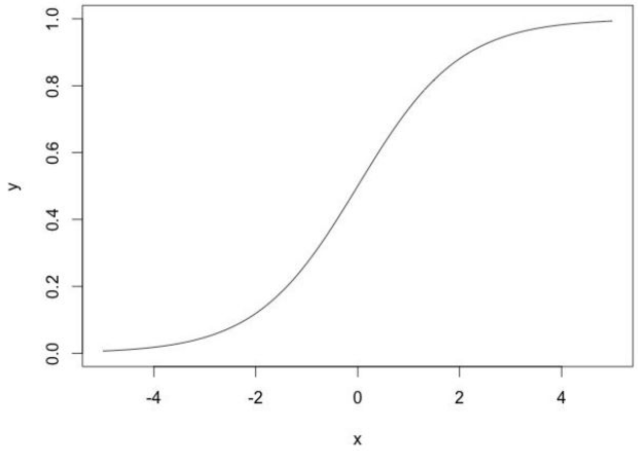


$$\phi(x) = \begin{cases} 1, \text{if } x \geq 0.5. \\ 0, \text{otherwise.} \end{cases}$$

Activation Functions (Cont'd)

Sigmoid Activation Function

- The sigmoid or logistic activation function is a very common choice for feedforward neural networks that need to output only positive numbers
- It ensures that values stay within a relatively small range



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

Activation Functions (Cont'd)

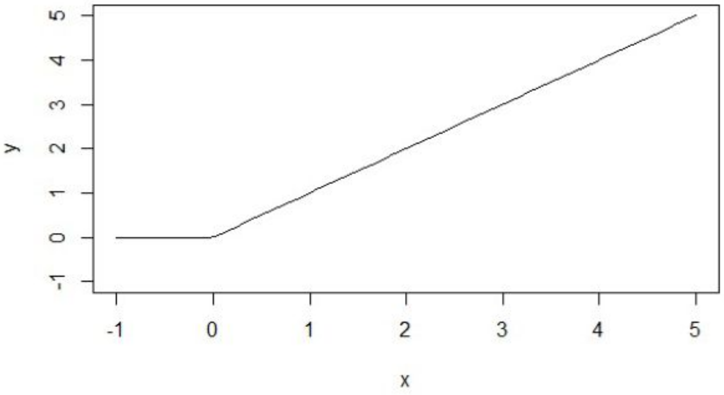
Rectified Linear Units (ReLU)

- ReLU activation function is a linear, non-saturating function

- Most current research now recommends the ReLU due to superior training results.

$$\phi(x) = \max(0, x)$$

- Unlike the sigmoid & the hyperbolic tangent activation functions, the ReLU does not saturate to -1, 0, or 1



Activation Functions (Cont'd)

Softmax Activation Function

- Softmax is usually found in the output layer of a neural network.
- The softmax function is used on a classification neural network.
- The neuron that has the highest value claims the input as a member of its class.

$$\phi_i = \frac{e^{z_i}}{\sum_{j \in group} e^{z_j}}$$

Typical Activation Function

Problem	Final-Layer Activation	Loss Function
Binary Classification	sigmoid	Binary_crossentropy
Multiple Classes but One Label	softmax	Categorical_crossentropy
Multiple Classes and Multiple Labels	sigmoid	Binary_crossentropy
Logistic Regression (numbers 0-1)	NONE	Mean Square Error (MSE)
Regression (arbitrary numbers)	sigmoid	MSE or binary_crossentropy

Why Neural Networks?

- Why not just use a single neuron?
- Why do we need a larger network?
  - A single neuron (like logistic regression) only permits a linear decision boundary.
  - Most real-world problems are considerably more complicated!

Applications of Neural Networks

- Signal processing
- Pattern recognition, e.g. handwritten characters or face identification.
- Diagnosis or mapping symptoms to a medical case.
- Speech recognition
- Human Emotion Detection

Applications of Neural Networks

- Prediction of Protein Secondary Structure
- Prediction of Signal Peptides and Their Cleavage Sites
- Applications for DNA and RNA Nucleotide Sequences
    - Eukaryotic Gene Finding and Intron Splice Site Prediction
    - Prediction of Intron Splice Sites by Combining Local and Global Sequence Information

References

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- Intel Academy Deep Learning Course
- Lecture notes by **Prof**. Sai Saranya
- Bioinformatics: The machine learning approach (Pierre Baldi and Søren Brunak)
- Introduction to Machine Learning and Bioinformatics

Thank you!

If you have any questions feel free to email me:

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