ARTIFICIAL NEURAL NETWORKS

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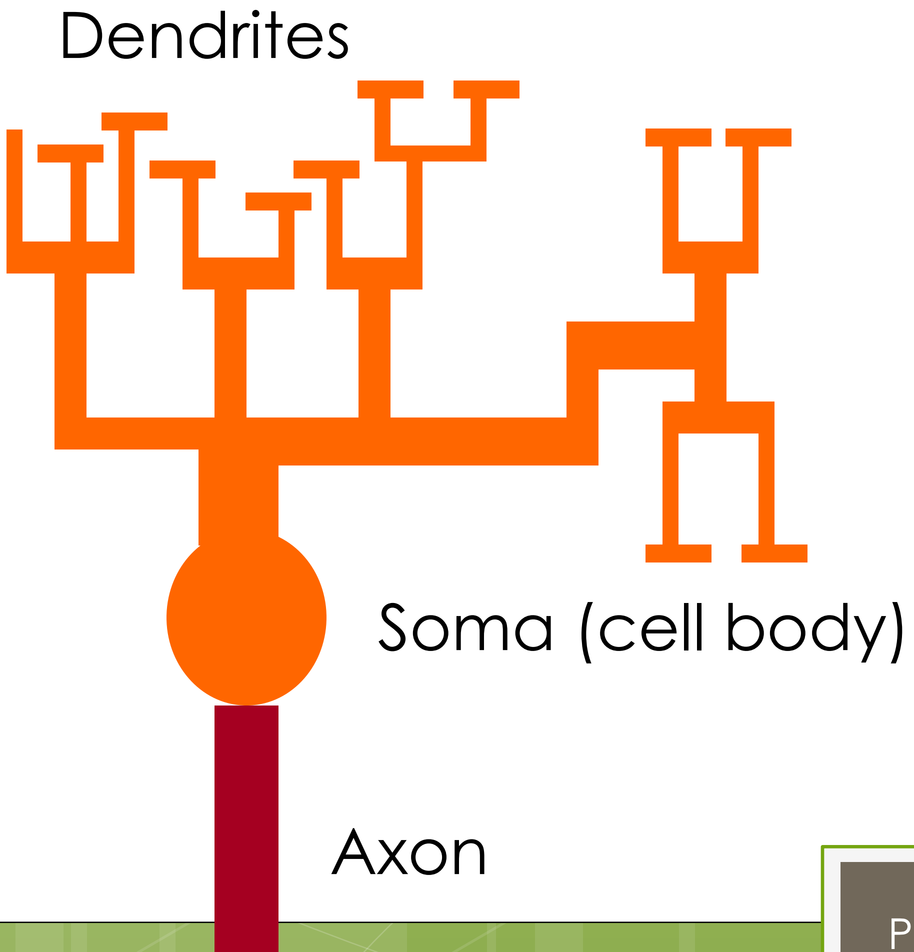
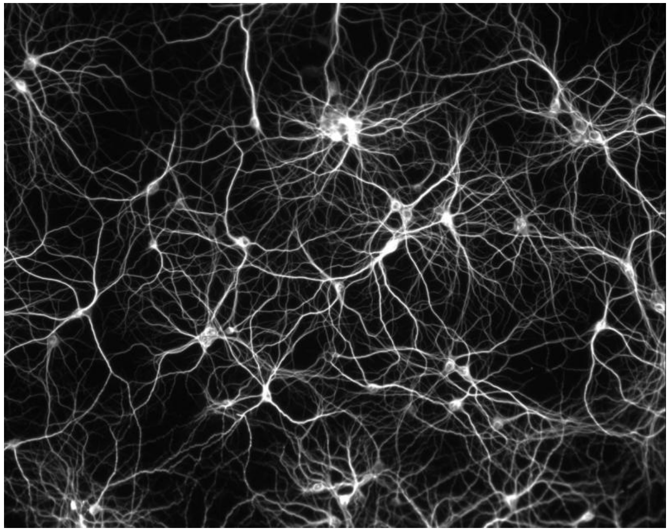
Biological inspiration

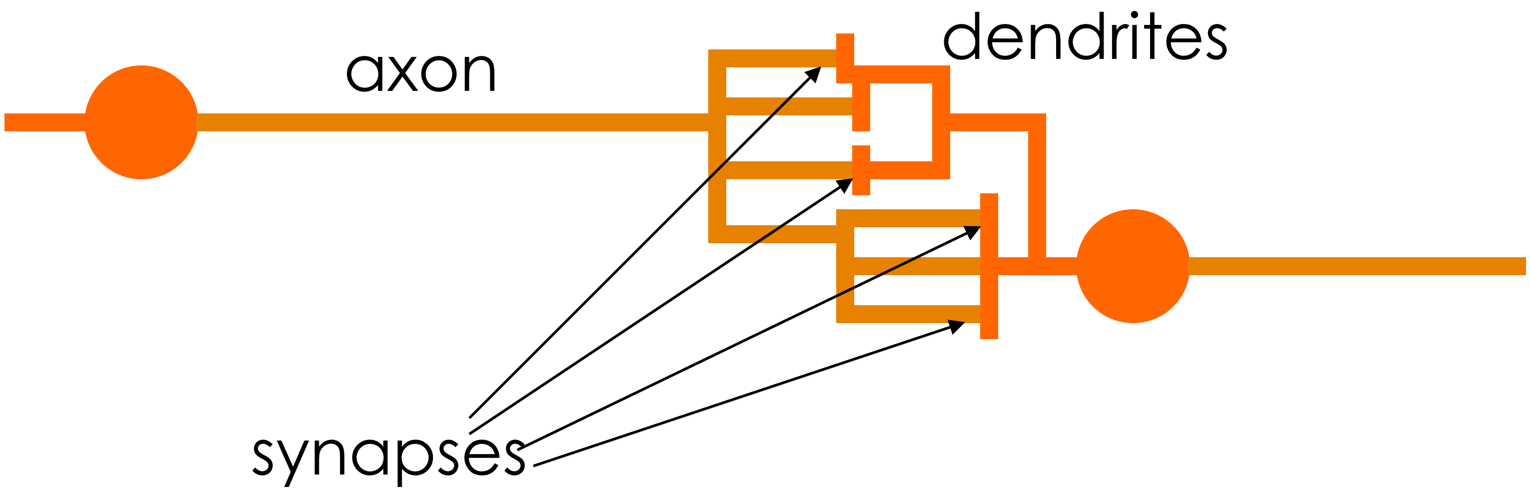
- Animals are able to react adaptively to changes in their external and internal environment, and they use their nervous system to perform these behaviours.
- An appropriate model/simulation of the nervous system should be able to produce similar responses and behaviours in artificial systems.
- The nervous system is built by relatively simple units, the neurons, so copying their behavior and functionality should be the solution

Biological inspiration





Biological inspiration



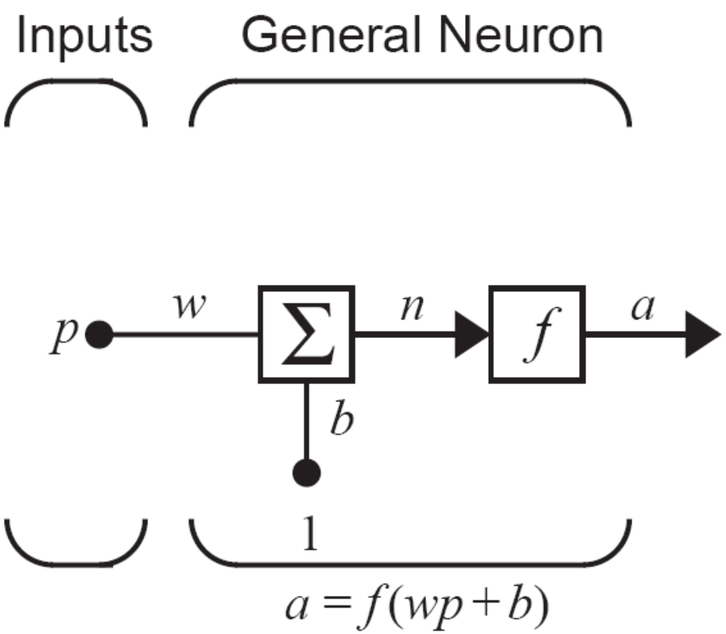
Biological inspiration

- The spikes travelling along the axon of the pre-synaptic neuron trigger the release of neurotransmitter substances at the synapse.
- The neurotransmitters cause excitation or inhibition in the dendrite of the post-synaptic neuron.
- The integration of the excitatory and inhibitory signals may produce spikes in the post-synaptic neuron.
- The contribution of the signals depends on the strength of the synaptic connection

What is a Neural Network?

- A method of computing, based on the interaction of multiple connected processing elements
- Compute a known function
- Approximate an unknown function
- Pattern Recognition
- Signal Processing

Single Input Neuron



Resemblance between biological Neuron and Neuron Model

Strength of Synapse	Weight
Transfer function and summation	Cell body
Signal on axon	Output

f = Transfer function or activation function

Single Input Neuron

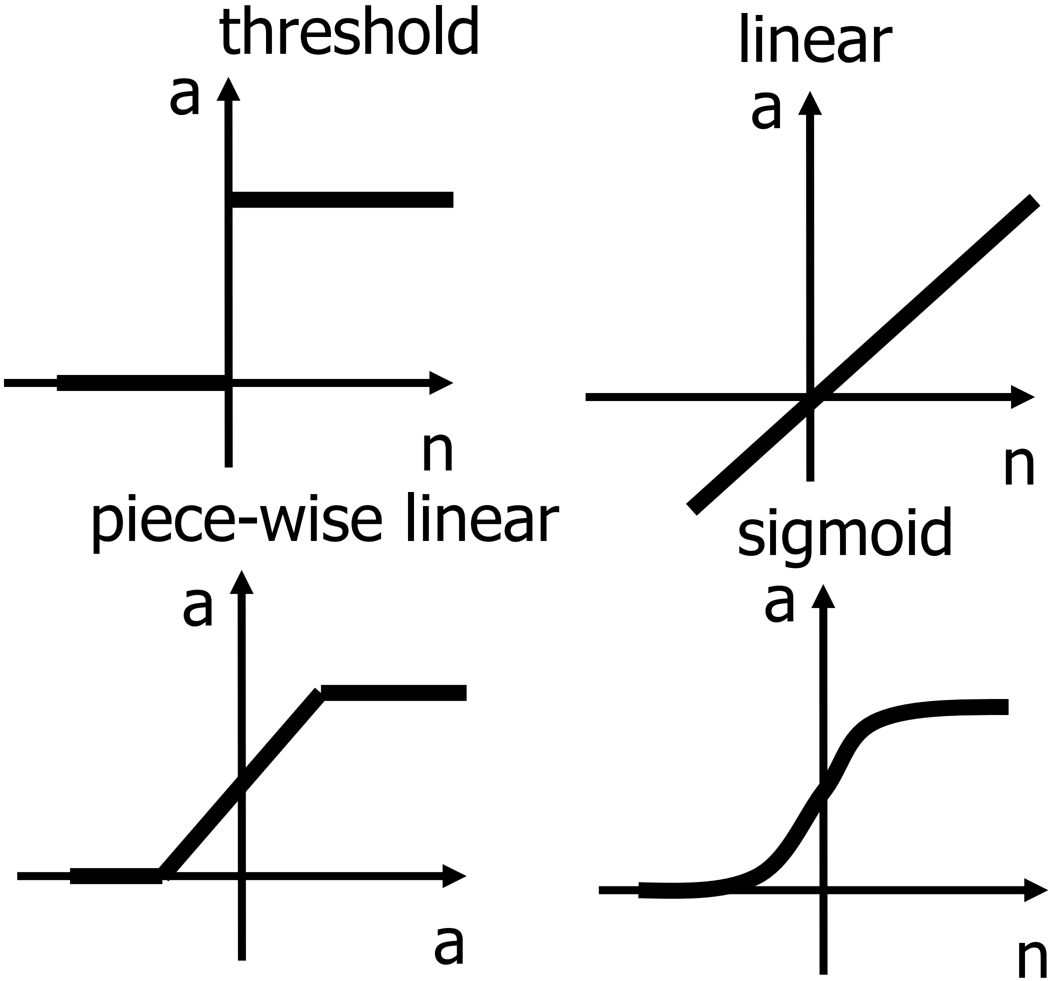
- One can choose neurons with or without biases. The bias gives the network an extra variable, and so you might expect that networks with biases would be more powerful than those without bias. The bias b is like a weight, except that it has constant input 1.

- w and b are both adjustable parameters of the neuron.

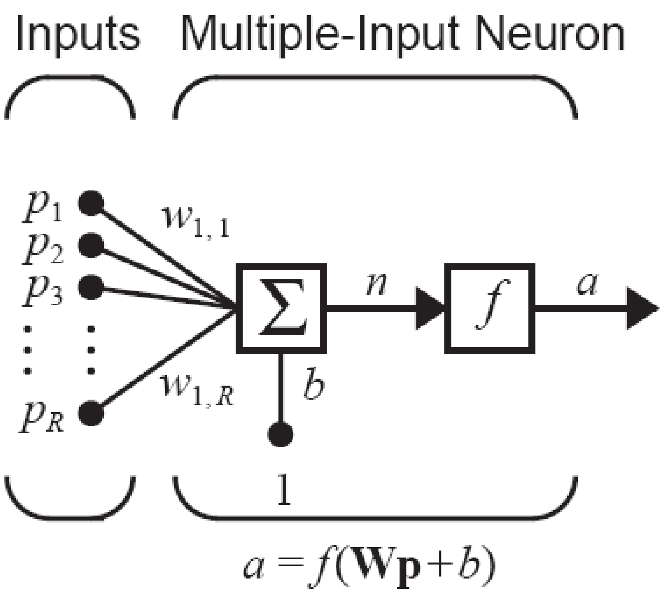
- The activation function may be linear or non linear

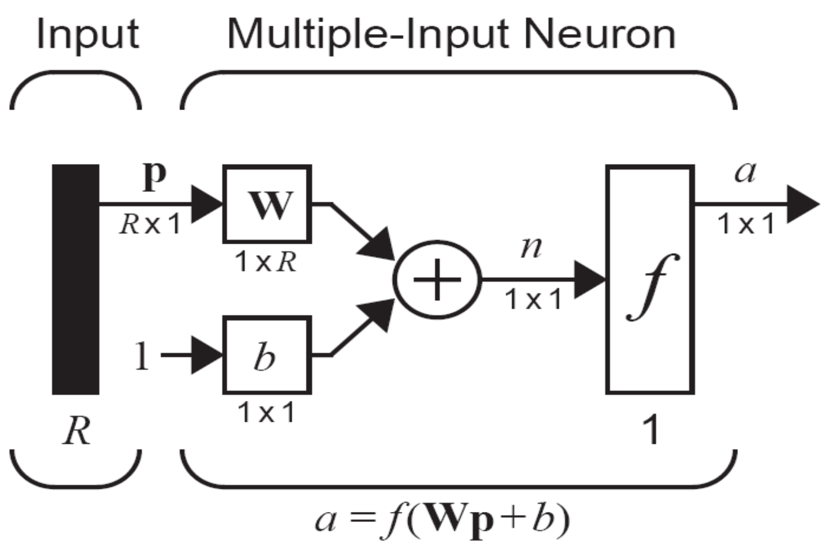
- The transfer function is chosen by the designer and then the parameters will be adjusted by some learning rule so that the neuron input/output relationship meets some specific goal.

Activation Functions



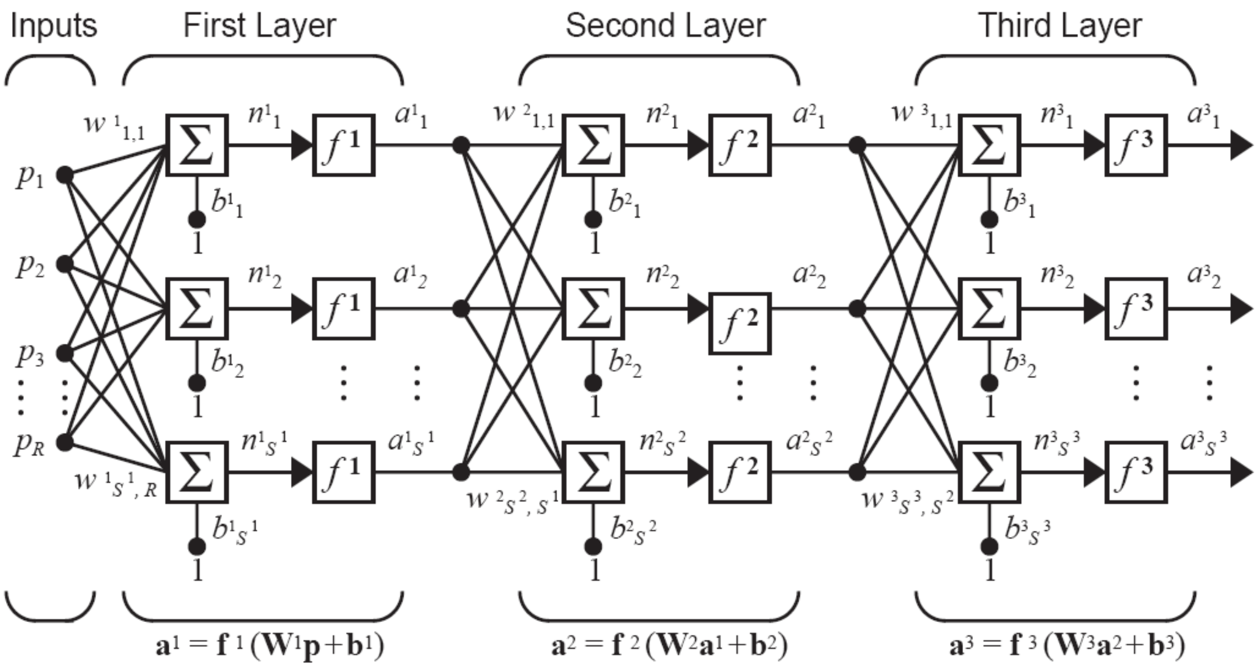
Multiple Input Neuron





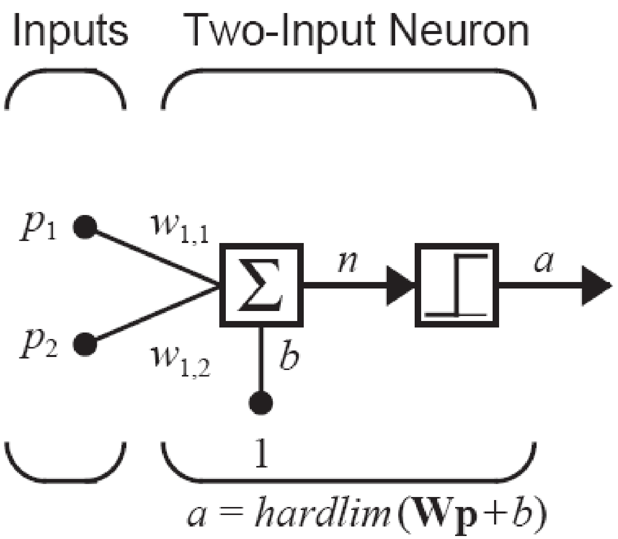
- The first index indicates the particular neuron destination for that weight. The second index indicates the source of the signal fed to the neuron

Multi Layer Neurons



$$\mathbf{a}^3 = \mathbf{f}^3(\mathbf{W}^3\mathbf{f}^2(\mathbf{W}^2\mathbf{f}^1(\mathbf{W}^1\mathbf{p}+\mathbf{b}^1)+\mathbf{b}^2)+\mathbf{b}^3)$$

Perceptron Learning Rules



- Learning rule means a procedure for modifying the weights and biases of a network.

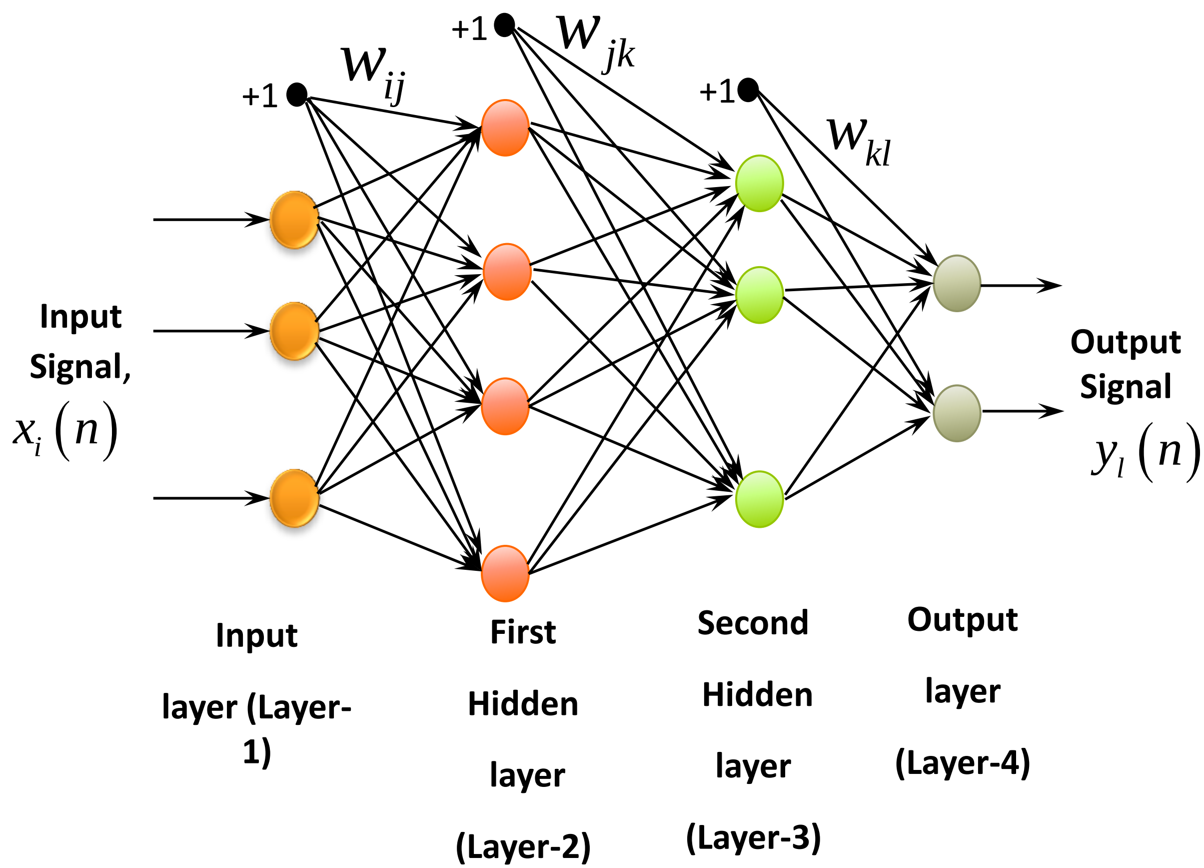
Perceptron Learning Rules

- $w(i+1) = w(i) + \alpha(d-a)x$
- The parameter α is called the learning rate. It determines the magnitude of weight updates Δw_i.
- If the output is correct $(d = a)$ the weights are not changed (Δw_i=0).
- If the output is incorrect $(d \neq a)$ the weights $w(i)$ are changed such that the output of the network for the new weights $w(i+1)$is closer/further to the input x.

Neural Networks

- Massively parallel distributed processor made up of simple processing unit, which has a natural propensity for storing experimental knowledge and making it available for use
- Knowledge is acquired by the network from its environment through a learn process.
- Inter connection strengths, known as synaptic weights are used to store the acquired knowledge.

Neural Networks



Neural Networks

- The output vector of first hidden layer may be calculated as,

$$f_j = \varphi_j \left[\sum_{i=1}^{N} w_{ij} x_i(n) + b_j \right] \qquad i = 1, 2, 3, \ldots N, \; j = 1, 2, 3, \ldots P_1$$

b_j = the threshold to the neurons of the first hidden layer

N = the no. of inputs and

$\varphi(.)$ = the nonlinear activation function in the first hidden layer

P_1 = the number of neurons in the first hidden layer

Neural Networks

- The output of second hidden layer

$$f_k = \varphi_k \left[\sum_{j=1}^{P_1} w_{jk} f_j + b_k \right] \qquad k=1, 2, 3, \ldots, P_2$$

b_k = the threshold to the neurons of the second hidden layer

- The output of final output layer

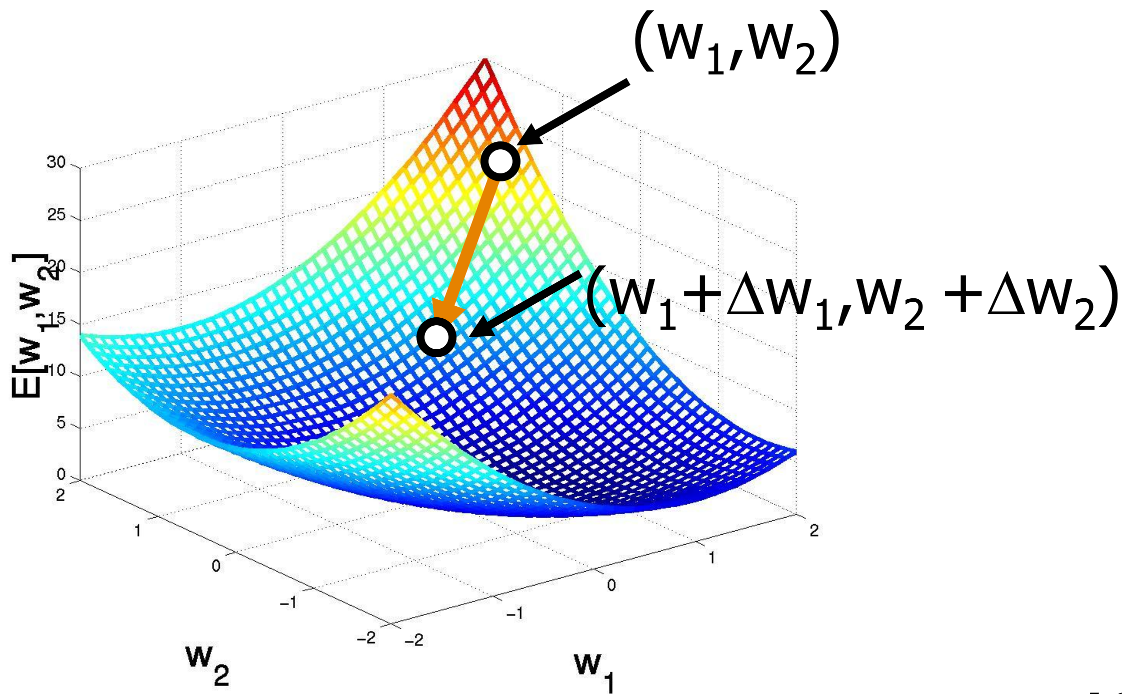
$$y_l(n) = \varphi_l \left[\sum_{k=1}^{P_2} w_{kl} f_k + b_l \right] \qquad l=1, 2, 3, \ldots, P_3$$

Back Propagation

$$\xi(n) = \frac{1}{2}\sum_{l=1}^{P_3} e_l^2(n)$$

- The instantaneous value of the total error energy is obtained by summing all error signals over all neurons(P_3) in the output layer
- This error signal is used to update the weights and thresholds of the hidden layers as well as the output layer.
- The reflected error components at each of the hidden layers is computed using the errors of the last layer and the connecting weights between the hidden and the last layer and error obtained at this stage is used to update the weights between the input and the hidden layer.

Back Propagation



$$\Delta w_{kl}(n) = -2\mu \frac{d\xi(n)}{dw_{kl}(n)} = \mu e(n)\frac{dy_l(n)}{dw_{kl}(n)}$$

$$= \mu e(n)\varphi_l' \left[\sum_{k=1}^{P_2} w_{kl} f_k + \alpha_l\right] f_k$$

Applications

- Investment Analysis
- Signature Analysis
- Process Control
- Monitoring

Summary

- try to imitate the working mechanisms of their biological counterparts.
- Learning can be perceived as an optimisation process
- The optimisation is done with respect to the approximation error measure.

References

1. R. Majhi, B. Majhi and G. Panda, The development and performance evaluation of neural network classifiers for Indian internet shoppers, Expert Systems with Applications, 39(2), pp: 2112-2118, 2012.
2. Babita Majhi and G. Panda, "Robust identification of nonlinear complex systems using low complexity ANN and particle swarm optimization technique", Expert Systems with Applications, 38(1), pp: 321-333, 2011.
3. S. K. Mishra, G. Panda and D. P. Das, "A Novel Method of Extending the Linearity Range of LVDT Using Artificial Neural Network", IEEE Trans. on Instrumentation and Measurement, 59(4), pp: 947-953, 2010.