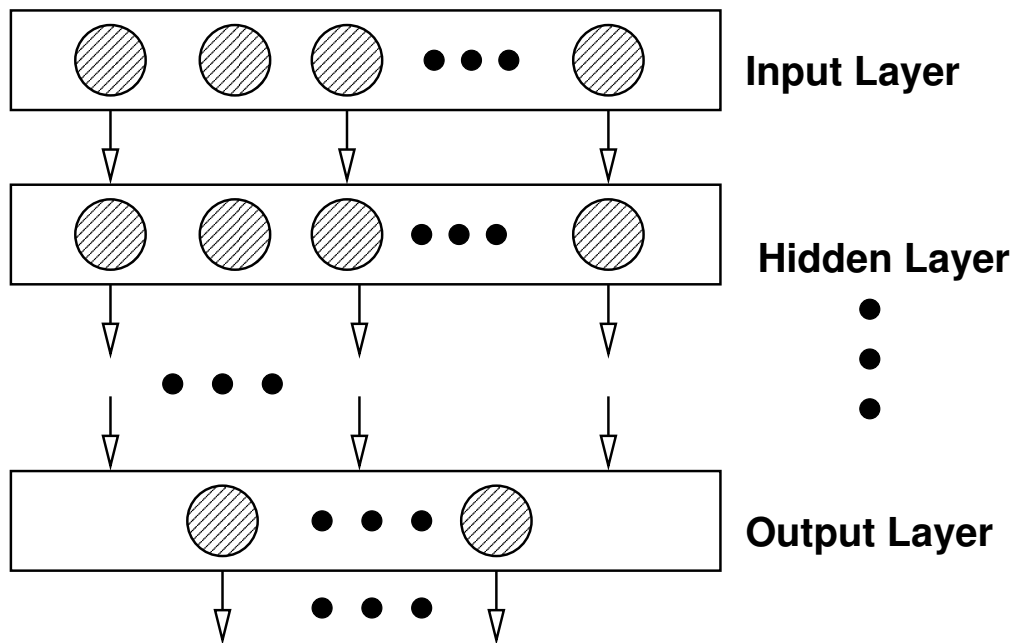
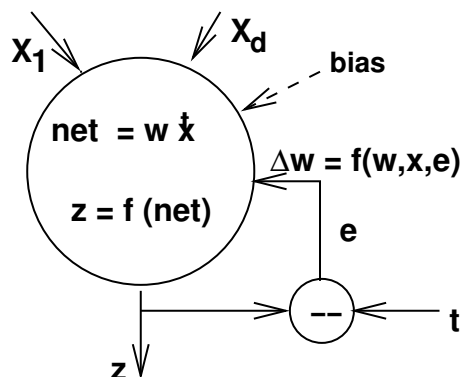


Neural Networks



A set of input **Neurodes**, a set of output neurodes and one or more sets of hidden neurodes organized as interconnected layers. Each neurode has a learning rule, an activation function and a unique memory vector.

A Single Neurode



- The x vector is the input to the neurode.
- The weight vector, w represents the memory of the neurode.
- net is the internal response of the neurode to the inputs, which is typically $w^t x + b$.
- $f(net)$ converts the internal response into an output value that can be discrete (0,1), (-1,+1), etc. or continuous. Typically, continuous values are limited to a small range, such as $[0,1]$ or $[-1,+1]$.

A Single Neurode

- The error is a function of the difference between the output and the target output t .
- Δw is a function of w, x and e and modifies the weight vector.
- The *bias* input, b is not necessary but it is typically used to ensure that the weight vector doesn't degenerate into a point solution.
- Training often takes many iterations through the input set which should be randomized.

Perceptron

The Perceptron was the earliest proposed neural network (Rosenblatt 1952). Panned by Minsky and Papert as useless because a single neuron can't solve the XOR problem.

- Traditionally, the Perceptron inputs are zero and one, but it works for continuous inputs also.
- $net = w^t * x + b$
- Outputs are zero or one, using $f(net) = Sgn(net)$.
- The Learning Rule:

$$\begin{aligned}w(k+1) &= w(k) + \eta(t - z)x \\ b(k+1) &= b + \eta(t - z)\end{aligned}$$

where η is a learning rate between 0 and 1.

Perceptron Example

$$x = \left[\begin{array}{cc|cc|cc|cc|c} 1 & 2 & 2 & 3 & 3 & 5 & 5 & 6 & 6 & 7 \\ 3 & 2 & 4 & 3 & 4 & 0 & 3 & 2 & 4 & 2 \end{array} \right]$$

$$\eta = 0.5, b = 0, w(1) = \left[\begin{array}{c} 0.3 \\ 0.7 \end{array} \right]$$

$$k = 1, x = \left[\begin{array}{c} 1 \\ 3 \end{array} \right]$$

$$net = w^t x = 2.4$$

$$z = Sgn(2.4) = 1$$

$$e = t - z = 1 - 1 = 0$$

$$\Delta w = \eta e = 0$$

Perceptron Example

$$k = 2, x = \begin{vmatrix} 5 \\ 0 \end{vmatrix}$$

$$net = w^t x = 1.5$$

$$z = \text{Sgn}(1.5) = 1$$

$$e = t - z = 0 - 1 = -1$$

$$\Delta w = \eta e = -0.5$$

$$w = \eta e = -0.5 \begin{vmatrix} 5 \\ 0 \end{vmatrix} = \begin{vmatrix} -2.2 \\ 0.7 \end{vmatrix} =$$