

Biological Neural Networks

Artificial neural networks (ANNs or NNs) were inspired by information processing in our brains.

The human brain has about 10^{11} neurons and 10^{14} synapses.

A neuron consists of a soma (cell body), axons (sends signals), and dendrites (receives signals).

A synapse connects an axon to a dendrite.

Given a signal, a synapse might increase (excite) or decrease (inhibit) electrical potential.

A neuron fires when its electrical potential reaches a threshold.

Learning might occur by changes to synapses and connections.

Artificial Neural Networks

An artificial NN consists of neurons, connections, and weights.

Biological NN	Artificial NN
soma	neuron
axon, dendrite	connection
synapse	weight
potential	weighted sum
threshold	bias weight
signal	output

A typical neuron:

receives inputs x_1, x_2, x_3, \dots

performs a weighted sum

$$u = b + \sum w_i x_i = b + w_1 x_1 + w_2 x_2 + \dots$$

and applies an activation function $o = a(u)$.

Learning is performed by changing b, w_1, w_2, w_3, \dots

The output o might be input to other neurons.

Learning Problem

Given input \mathbf{x} , produce the desired output \mathbf{d} .

An input-output pair (\mathbf{x}, \mathbf{y}) is called a pattern.

Given patterns, solve for the weights \mathbf{w} .

[Note: \mathbf{w} , \mathbf{x} , and \mathbf{y} are vectors or matrices.]

It is rare to find an exact solution for \mathbf{w} .

Instead, find values for \mathbf{w} that minimizes error.

This is an optimization problem.

Learning in NNs means finding a value for \mathbf{w} .

Learning Issues

Network Architecture: number of layers, activation function, number of hidden units, learning method

Type of Learning

supervised learning: learn from i-o patterns

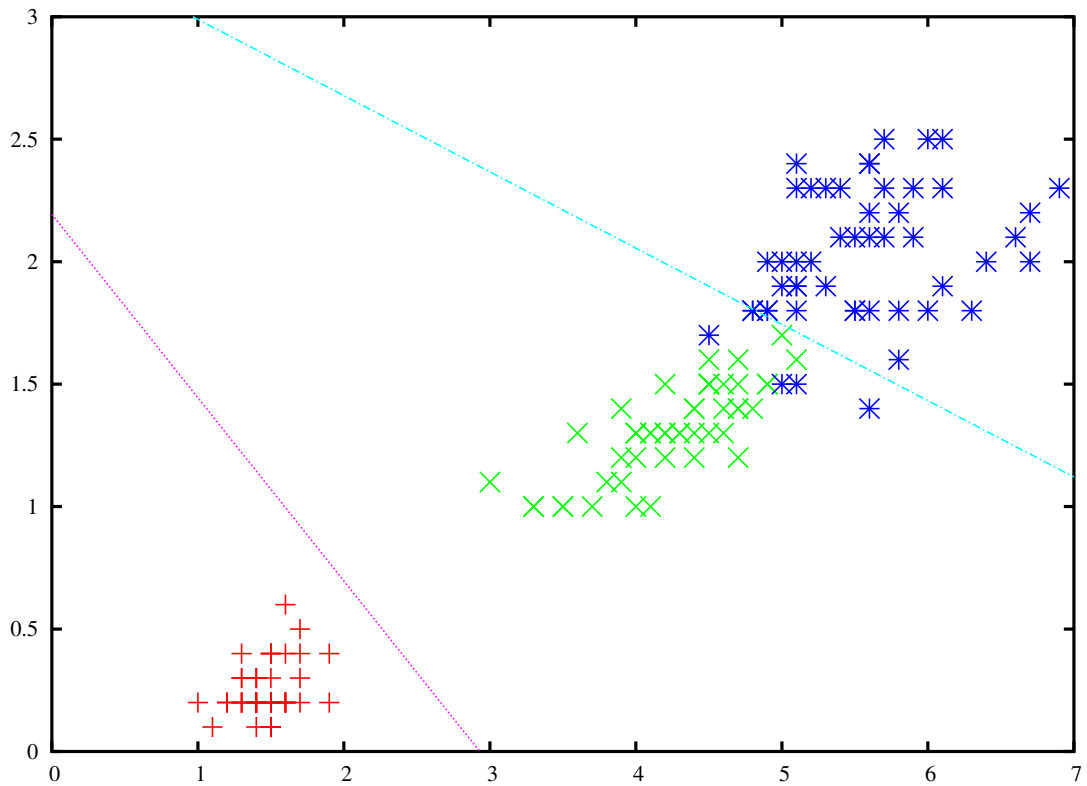
unsupervised learning: learn only from inputs

clustering: partition patterns into groups

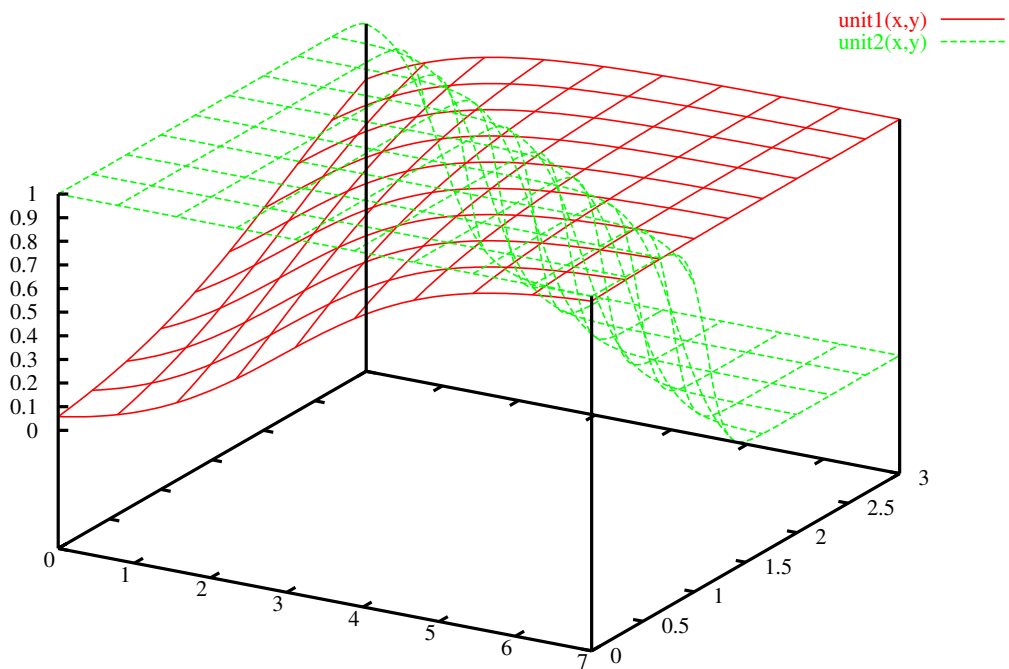
How to Train: validation sets

How to Test: holdout, cross-validation

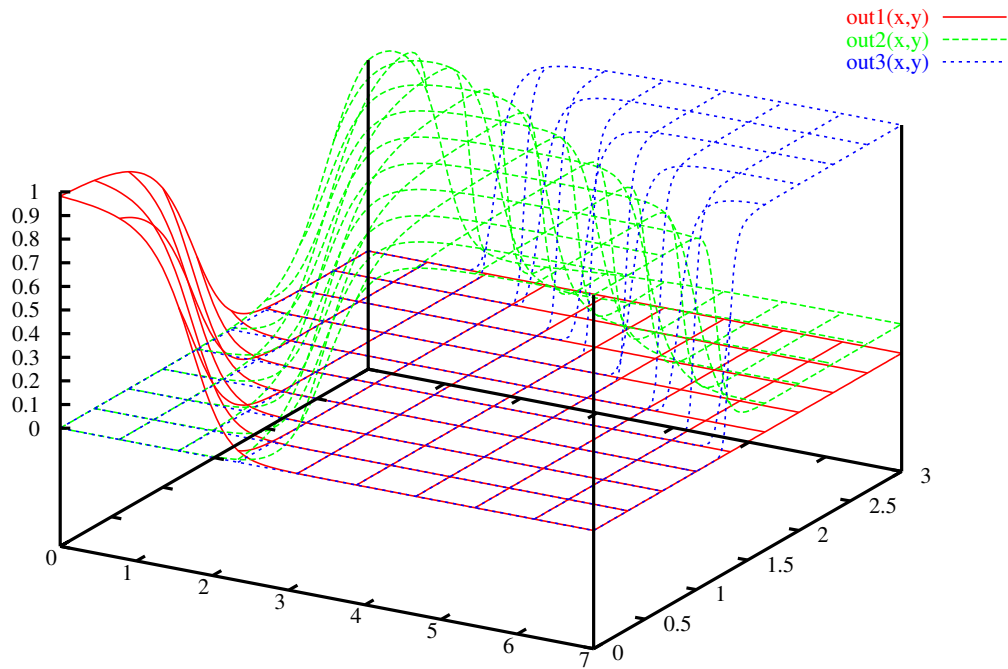
Example Data



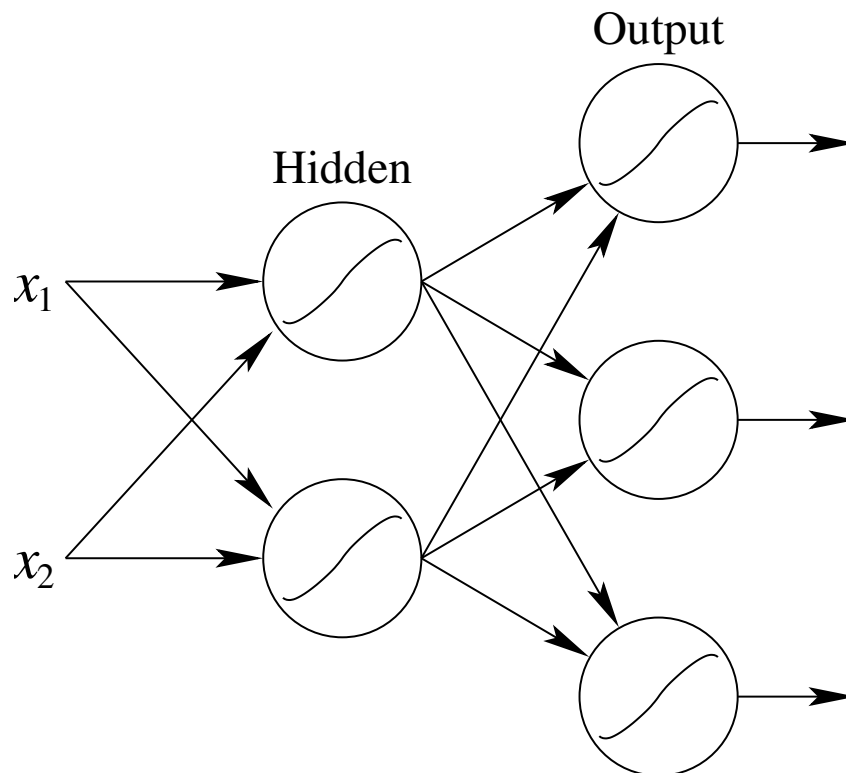
Example Neural Network Units



Example Neural Network Outputs



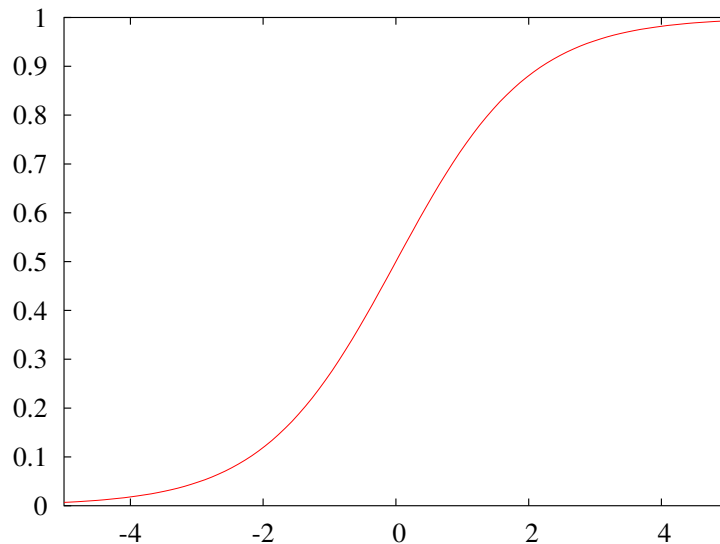
Example Neural Network Diagram



Example Neural Network Expressions

$$\text{Let } \sigma(u) = \frac{1}{1 + e^{-u}}$$

This is called the sigmoid or logistic function.



Let \mathbf{V} be a matrix. Let \mathbf{x} , \mathbf{w} , \mathbf{b} , and \mathbf{c} be vectors (matrices with one row). Let \mathbf{o} be the output vector, then:

$$\mathbf{o} = \sigma \left(\left(\sigma \left(\mathbf{xV} + \mathbf{b} \right) \right) \mathbf{W} + \mathbf{c} \right)$$

$$\text{or: } o_k = \sigma \left(\left(\sum_j h_j w_{jk} \right) + c_k \right)$$

$$\text{where: } h_j = \sigma \left(\left(\sum_i x_i v_{ij} \right) + b_j \right)$$

Many parameters need to be learned: \mathbf{V} , weights from inputs to hidden layer; \mathbf{b} , bias weights of hidden neurons; \mathbf{W} , weights from hidden layer to outputs; and \mathbf{c} , bias weights of outputs.