

Artificial Neural Networks in Artificial Intelligence

Artificial Intelligence involves several different approaches, including

- **Symbolic artificial intelligence** is the collection of all methods in artificial intelligence research that are based on high-level "symbolic" (human-readable) representations of problems, logic and search.
- **Bayesian decision networks** are graphical models that represent a set of variables and their dependencies ... ideal for taking an event that occurred and predicting the likelihood that any one of several possible causes was the contributing factor.
- **Evolutionary algorithms** use mechanisms inspired by biological evolution, such as reproduction, mutation, recombination, and selection. Candidate solutions play the role of individuals in a population, and the fitness function determines the quality of the solutions. Evolution of the candidate population then takes place after the repeated application of the mechanisms.

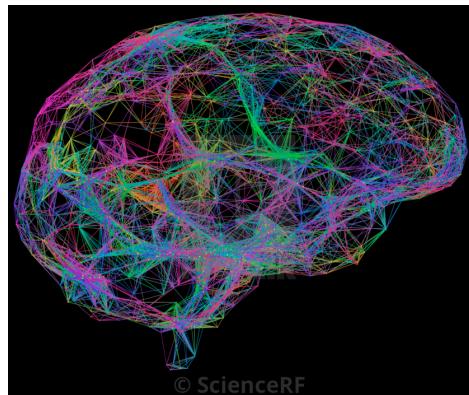
Wikipedia

Here we illustrate a fourth approach

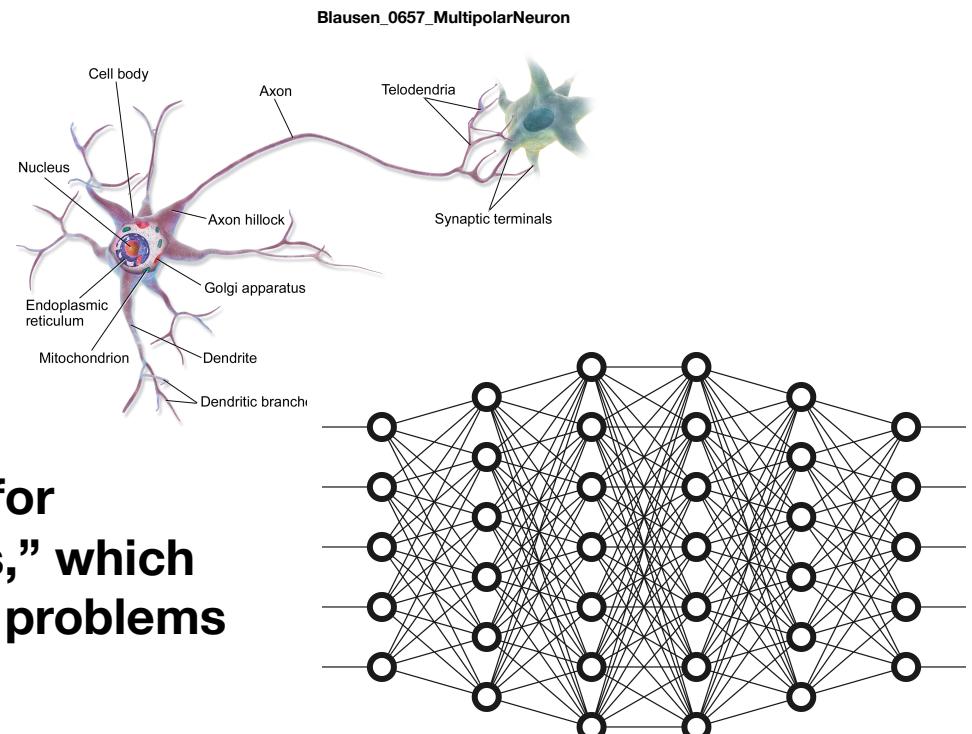
- **Artificial Neural Networks**



www.braininjuryaustralia.org.au



Our brains sense and think using connected networks of cells called neurons



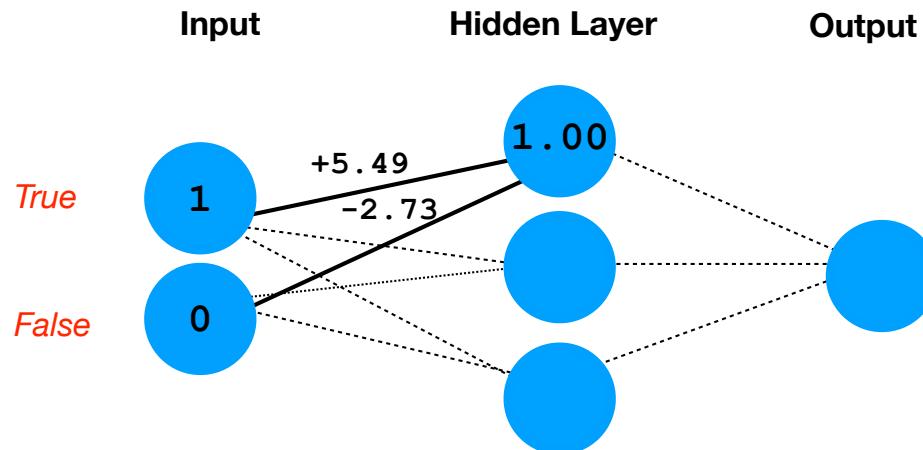
These networks are the inspiration for computer simulations of “neural networks,” which can be trained to sense and solve complex problems

Neural Network

Simulates XOR logic - exclusive or

Output is TRUE when one input is TRUE but not both

**2 inputs, 1 output,
1 hidden layer
with 3 neurons &
9 synapses**



EXAMPLE for input of
1
0

These sums over all nodes in a layer are the product of matrix multiplication. Matrix multiplication is well suited to being accelerated in hardware Graphical Processing Units, since graphic transformations also involve matrix multiplication.

node value = sigmaFunc(sum of (node activation * connection weight))

where $\text{sigmaFunc}(x) = \exp(x) / (1 + \exp(x))$ >> converts all input x values into range 0 to 1

INPUT > HIDDEN LAYER

$\text{sigmaFunc}(1 * 5.4868 + 0 * (-2.7276)) = 0.9959$ = hidden node 1 activation

The neuron and synapse values are held in memory locations and the CPU executes the math - there are no physical, hardware neurons and synapses.

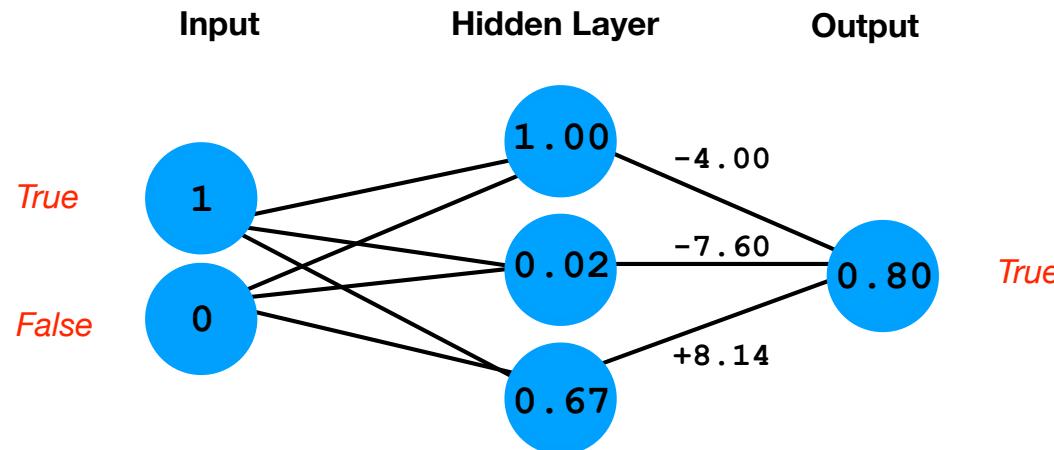
The connection - synapse - weights for a network are determined as the network is “trained” using combinations of known inputs and outputs.

Neural Network

Simulates XOR logic - exclusive or

Output is TRUE when one input is TRUE but not both

**2 inputs, 1 output,
1 hidden layer
with 3 neurons &
9 synapses**



HIDDEN LAYER > OUTPUT

$$\text{sigmaFunc}(0.9959 * (-4.0030) + 0.0153 * (-7.5988) + 0.6719 * 8.1402) = 0.7969 = \text{output node}$$

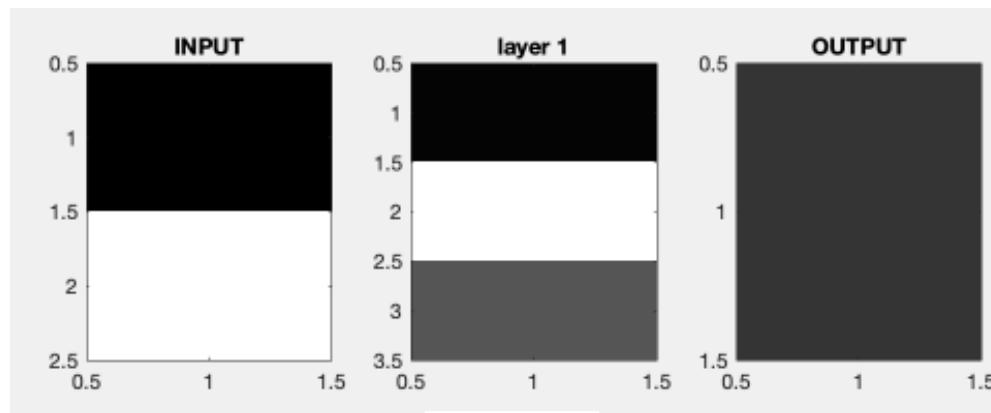
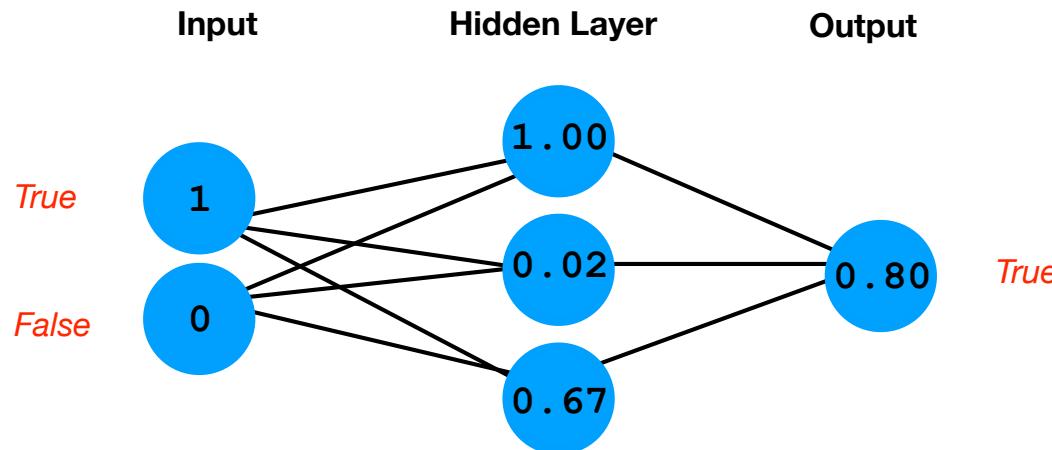
Output is TRUE when one input is TRUE but not both

Neural Network

Simulates XOR logic - exclusive or

Output is TRUE when one input is TRUE but not both

**2 inputs, 1 output,
1 hidden layer
with 3 neurons &
9 synapses**



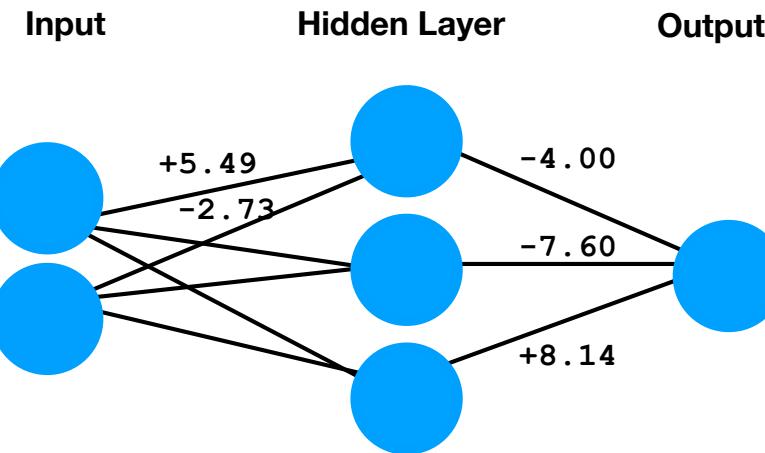
| | | |
|---|--------|-------------|
| 1 | 0.9959 | |
| 0 | 0.0153 | 0.7969 |
| | 0.6719 | True |

Neural Network

Simulates XOR logic - exclusive or

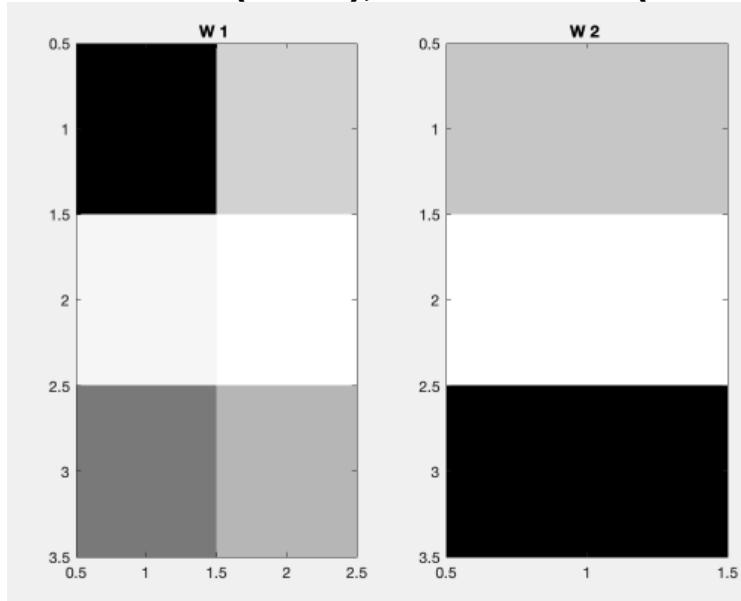
Output is TRUE when one input is TRUE but not both

**2 inputs, 1 output,
1 hidden layer
with 3 neurons &
9 synapses**

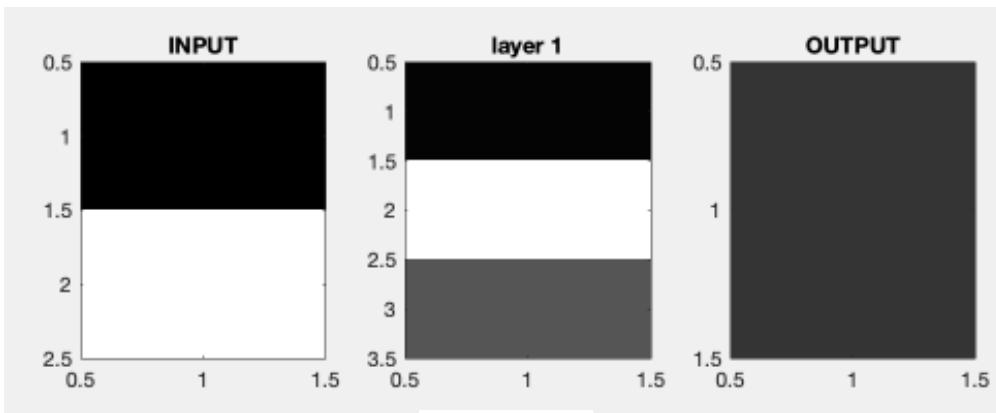


**Synapse weights to hidden
layer and to output,
min = -7.60 (white), max = +8.14 (black)**

| | |
|---------|---------|
| 5.4868 | -2.7276 |
| -4.1663 | -4.4991 |
| 0.7169 | -1.5748 |



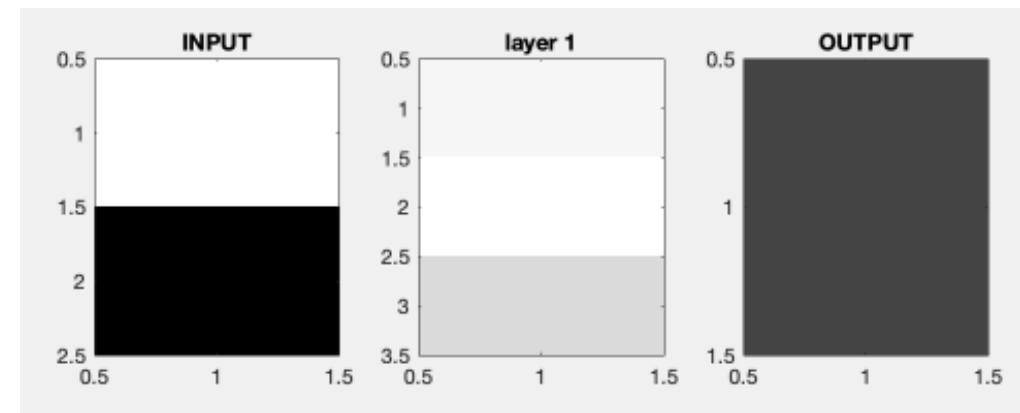
Below are node values: input > hidden layer > output



1
0

0.9959
0.0153
0.6719

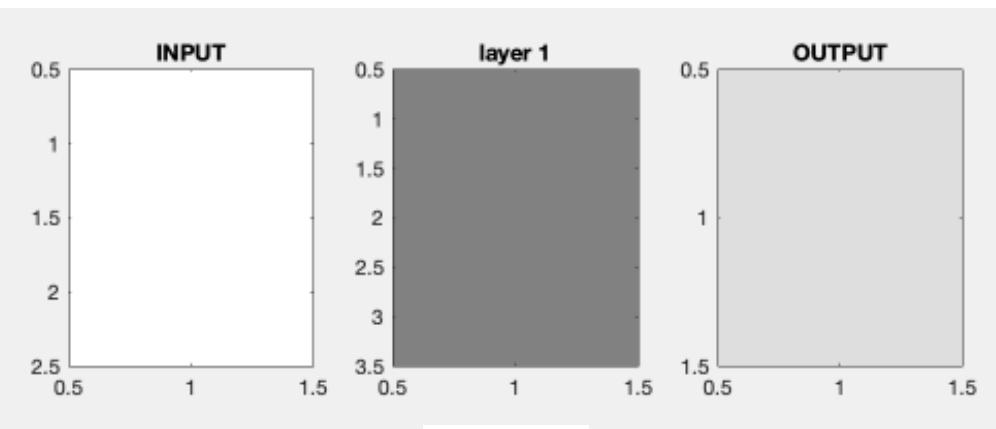
0.7969
True



0
1

0.0614
0.0110
0.1715

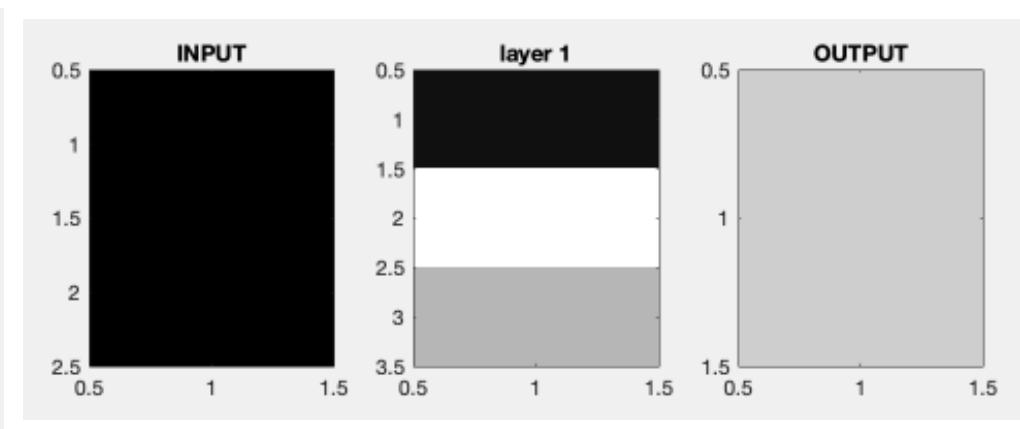
0.7440
True



0
0

0.5000
0.5000
0.5000

0.1505
False



1
1

0.9404
0.0002
0.2978

0.2072
False

Output is TRUE when one input is TRUE but not both

Neural Network

4 inputs, 4 outputs

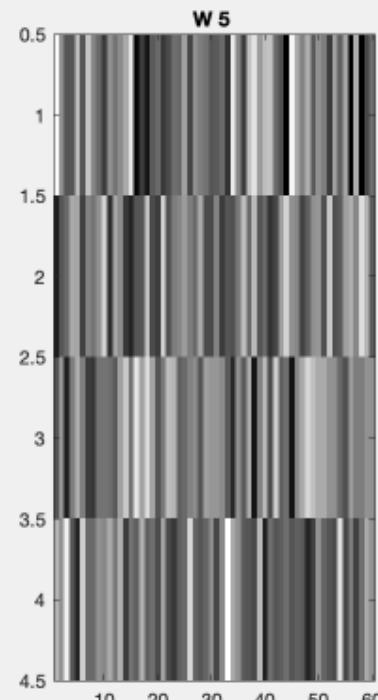
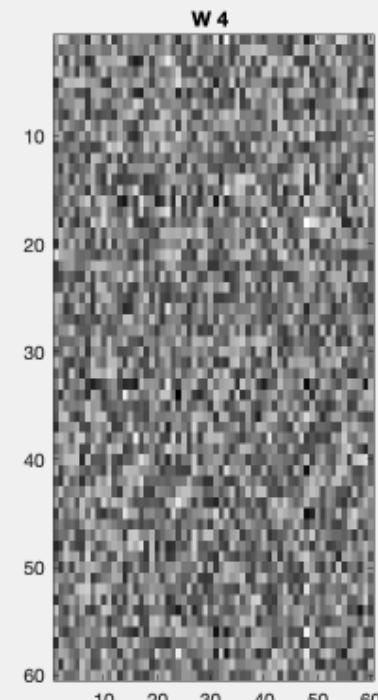
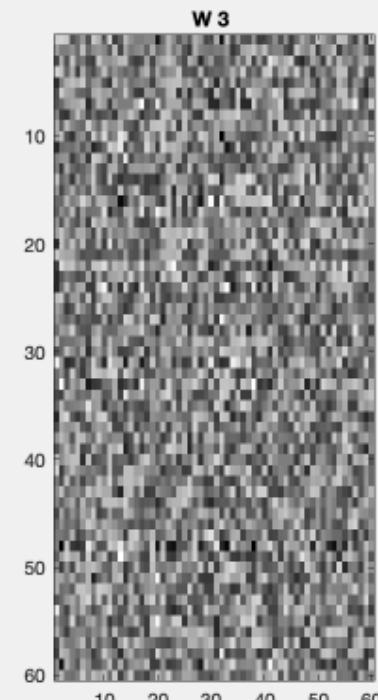
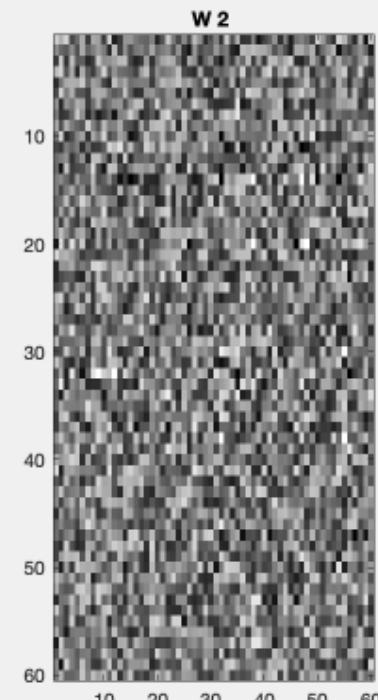
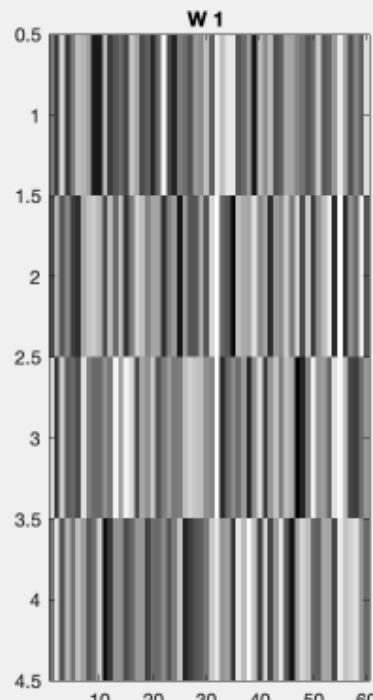
**4 hidden layers, each
with 60 neurons =
240 neurons &
11,280 synapses**

*A little more complex network which
detects diagonal, horizontal and vertical
inputs to a 2 x 2 “touch screen”*



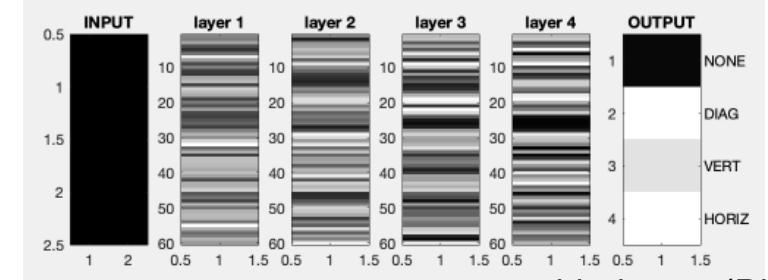
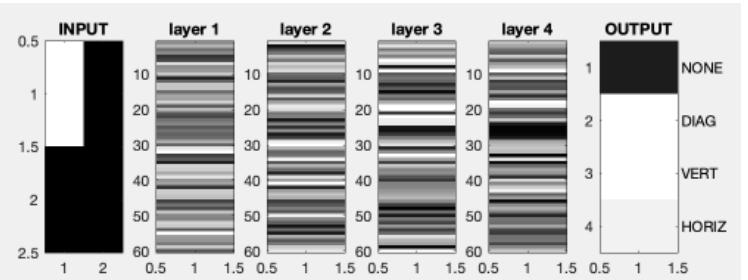
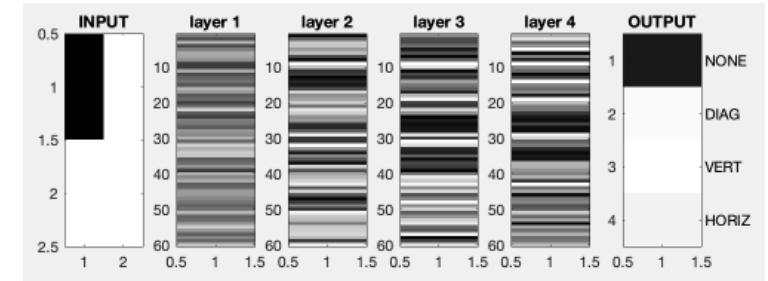
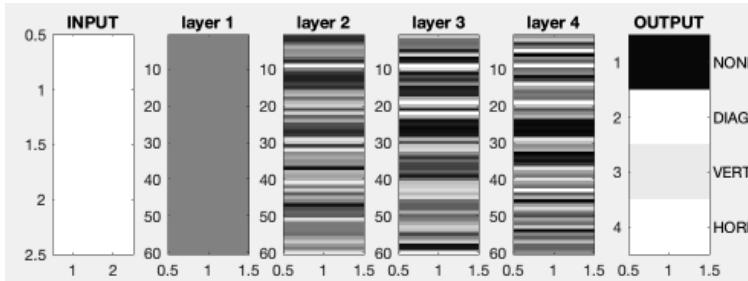
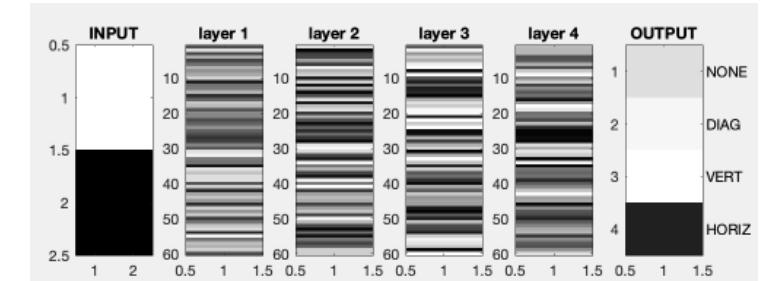
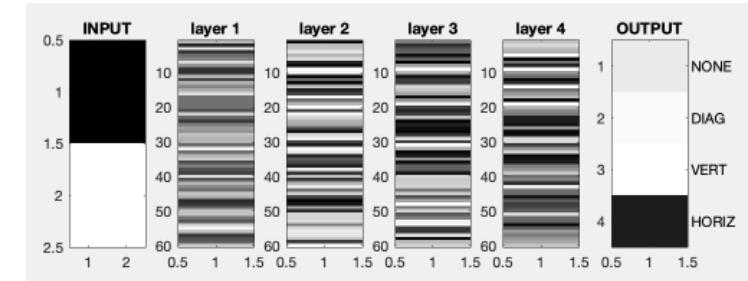
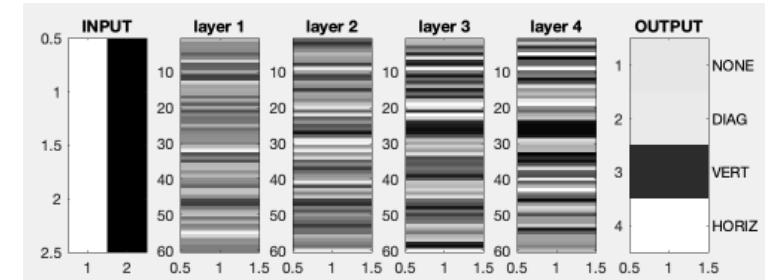
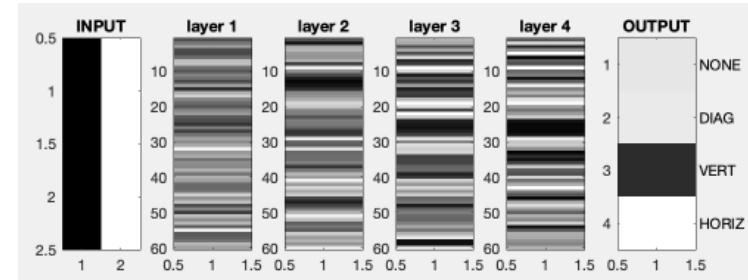
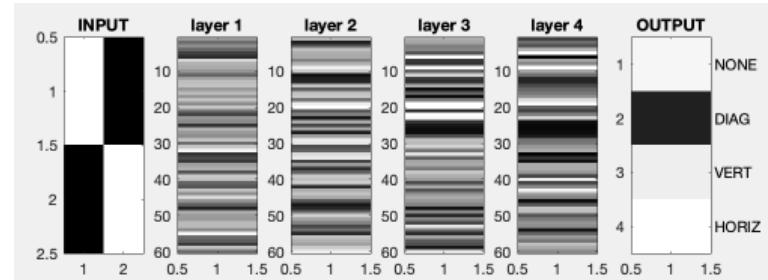
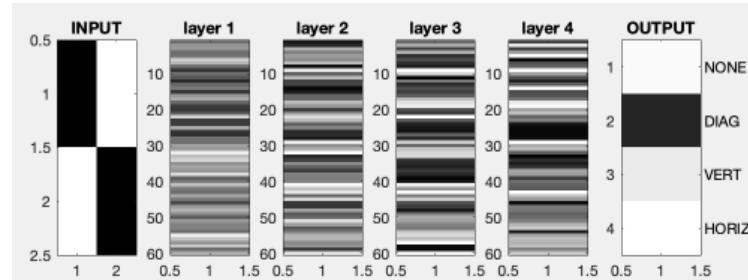
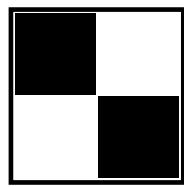
**Synapse weights to hidden
layers 1-4 and to output,**

min = -1.23 (white), max = +1.25 (black)



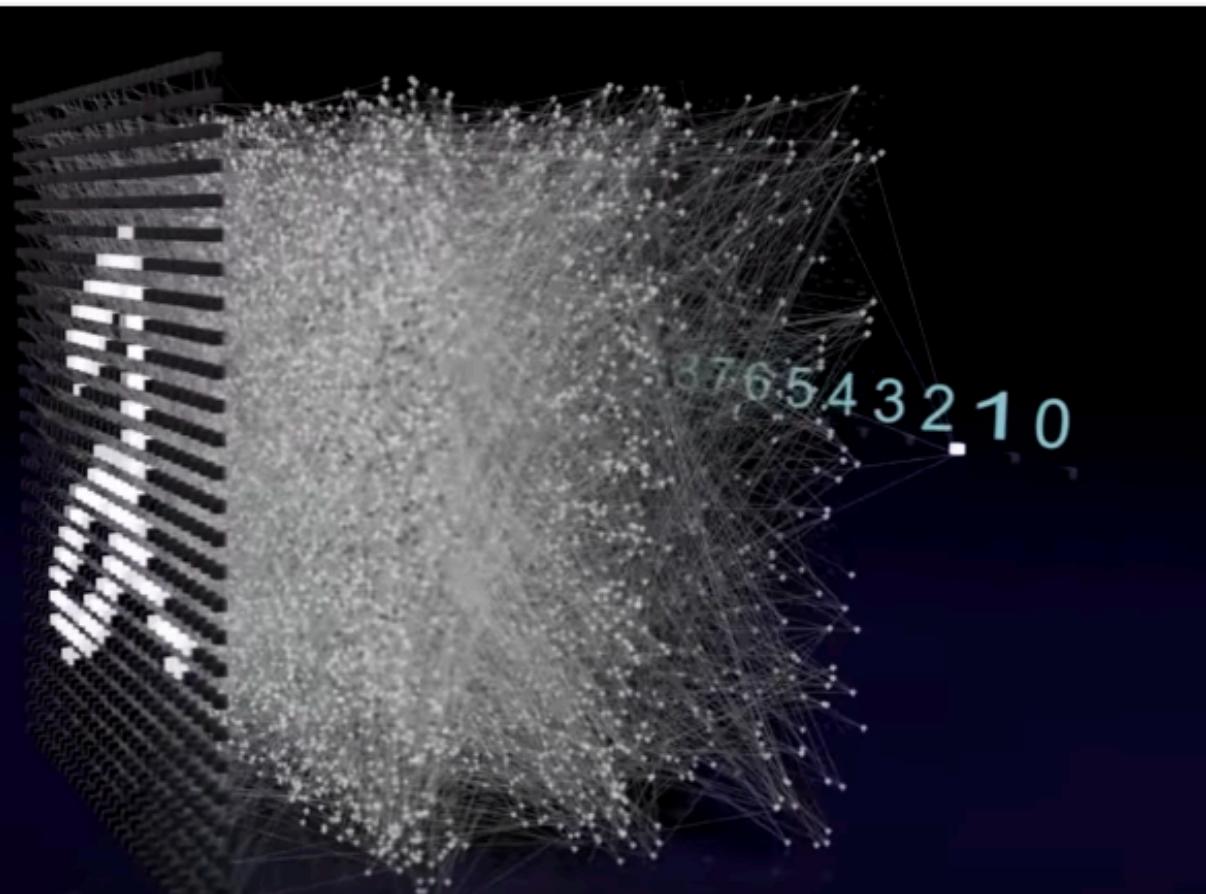
*Prior to training the network with known input and output cases,
the connection weights were assigned random values in the range -1 to +1.
Then the weights were adjusted during training in order to match input cases
with their corresponding outputs. The resulting weights are not random.
Different sets of weights may be obtained with different random
initializations*

Below are node activations: input > 4 hidden layers > output



**A neural network for a 28 x 28 “touch screen”
note that only 2% of the 24+ million “synapses” are shown**

Type: ML Perceptron
Data Set: MNIST
Hidden Layers: 3
Hidden Neurons: 10000
Synapses: 24864180
Synapses shown: 2%
Learning: BP



Denis Dmitriev <https://youtu.be/3JQ3hYko51Y>

A neural network represents a large number of coupled equations which, when given a set of input values, can produce a set of desired output values.

The more neurons and synapses - the more equations - and the greater complexity of inputs and outputs which can be "fit" by the system of equations. Note the significant increase in complexity going from the above XOR example to the 2 x 2 “touch screen” example to the 28 x 28 touch screen in the figure above.

"Deep learning" refers to solving complex problems using many hidden layers of neurons and, thus, many equations.