Neural Networks

COMP4211

Science Fiction

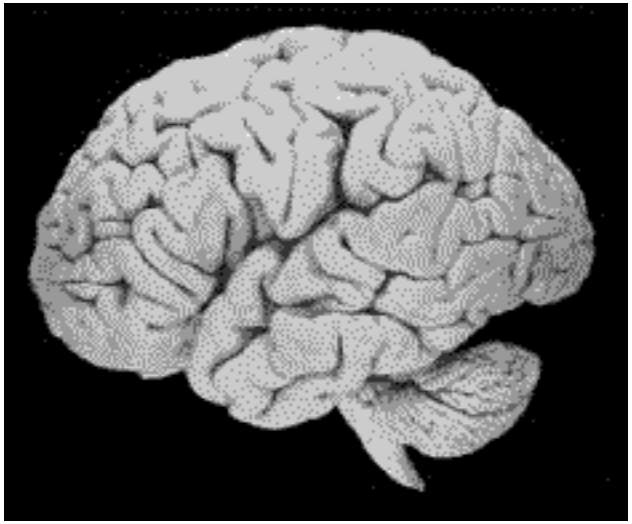
"Science fiction is the great opportunity to speculate on what could happen" $\sim$ Ray Kurzweil (Director of Engineering, Google)

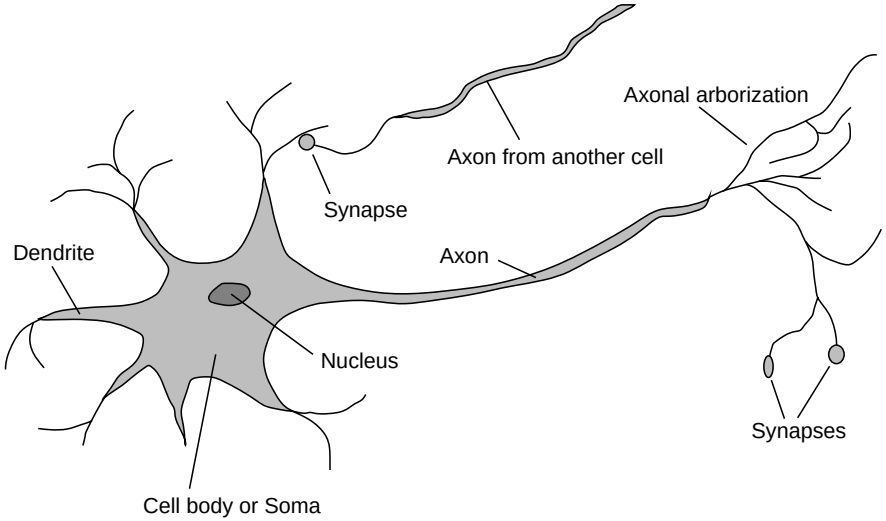
Terminator 2 (1991)

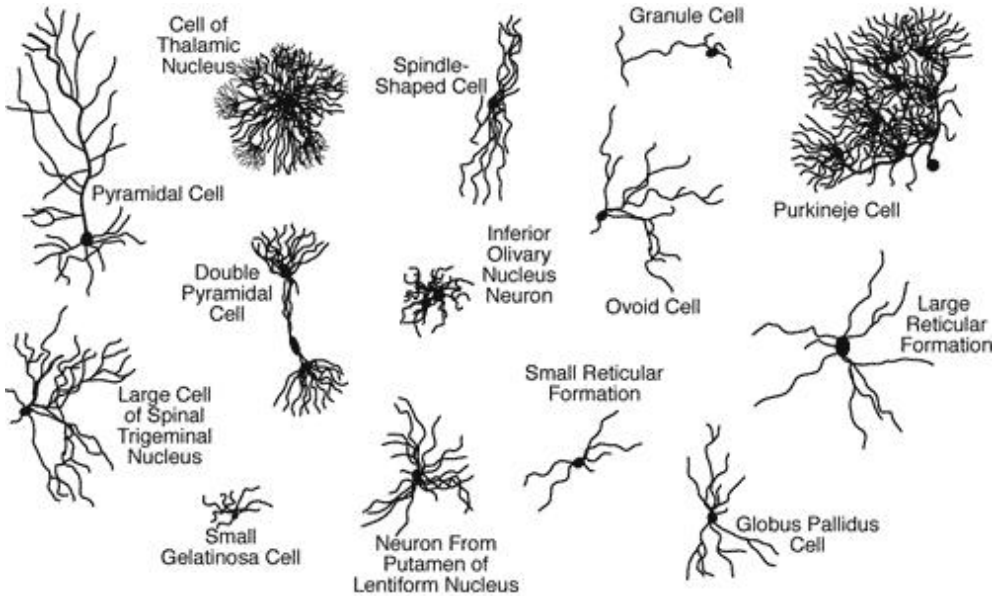
My CPU is a neural-net processor ... a learning computer.

Biological Neurons

Human brain: 100,000,000,000 neurons

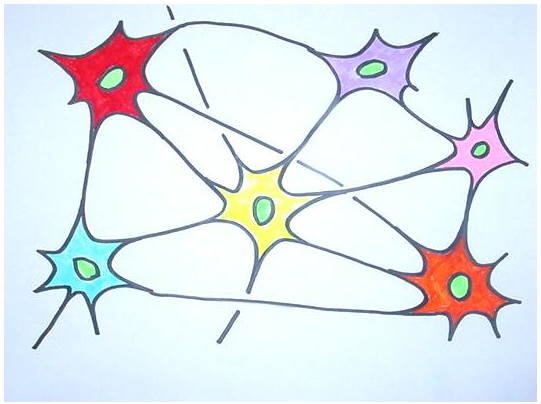




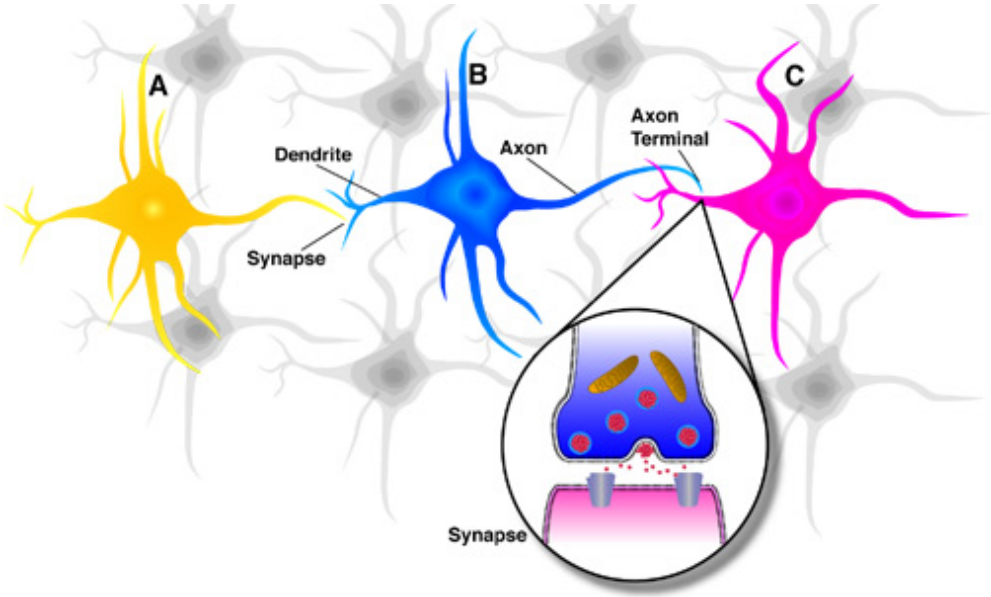


Neuron-to-Neuron

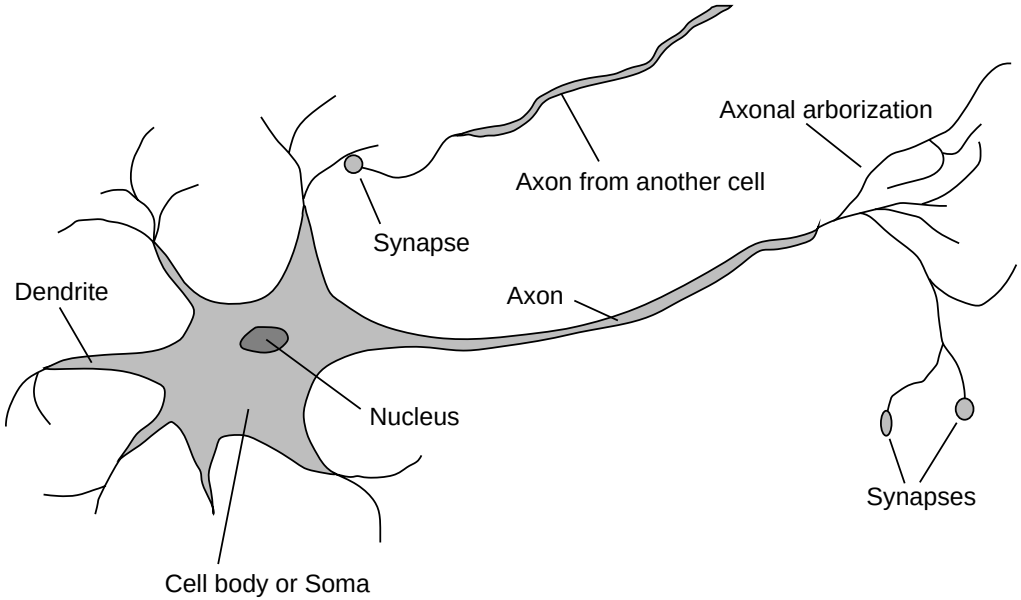
- each neuron receives input from 1,000 others



- the pulse forms the input to other neurons
- the interface of two neurons is called a synapse



Structure



dendrite

- allows the neuron to receive information from other cells

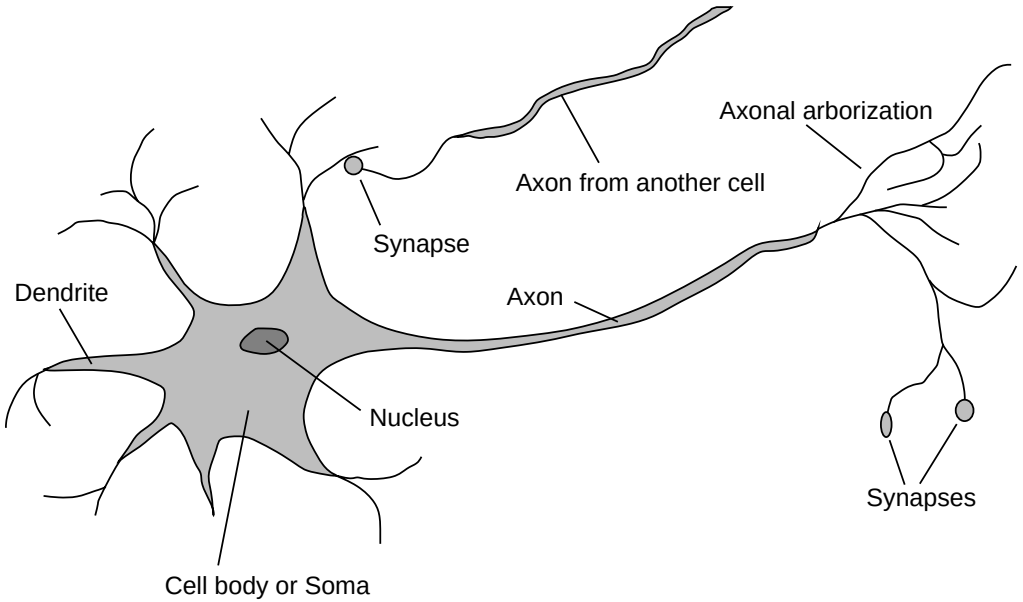
axon

- each cell has only one axon
- transmit information that it receives from the cell body

synapse

- contain packages of chemical substances that when released influence the activity of other cells

Signal Transmission



- impulses arrive simultaneously
- added together
- chemical transmitter substances are released from the synapses and enter the dendrite
- if sufficiently strong, an electrical pulse is sent down the axon
- the pulse spreads out along the branches of the axon, reaches the synapses and releases transmitters into the bodies of other cells

Comparison with the Computer

	Computer	Human Brain
Computational units	1 CPU, 10^5 gates	10^{11} neurons
Storage units	10^9 bits RAM, 10^{10} bits disk	10^{11} neurons, 10^{14} synapses
Cycle time	10^{-8} sec	10^{-3} sec
Bandwidth	10^9 bits/sec	10^{14} bits/sec
Neuron updates/sec	10^5	10^{14}

a brain can perform a complex task in less than a second

- this is only enough time for a few hundred cycles
- cf. a serial computer requires billions of cycles to perform the same task less well
- neural networks $\longrightarrow$ massively parallel computation

Comparison...

fault-tolerant

- brain cells die all the time with no ill effect to the overall functioning of the brain

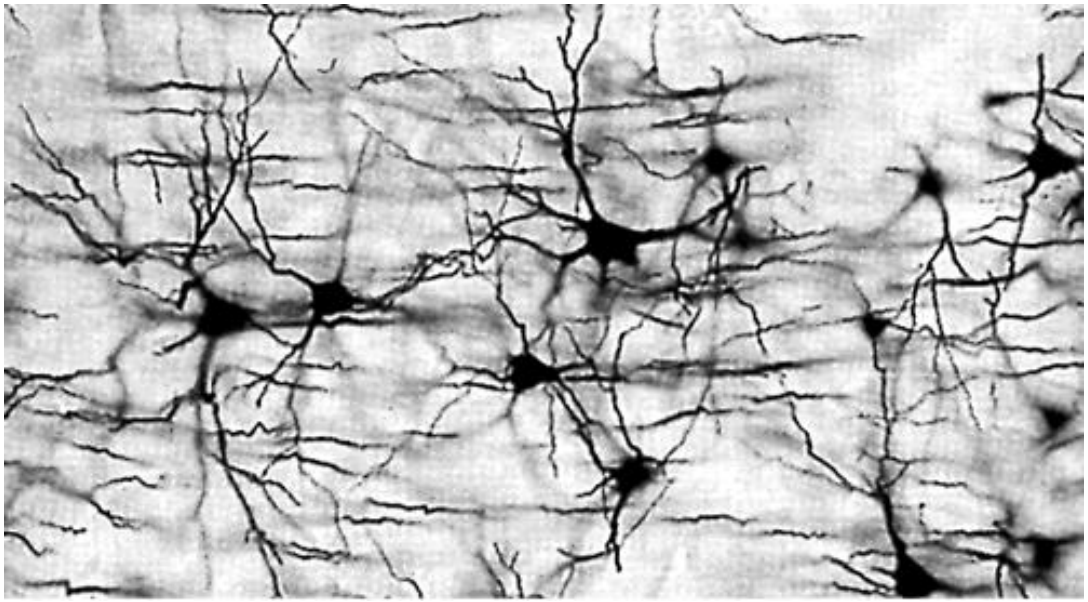
graceful degradation

- have a gradual rather than sharp drop-off in performance as conditions worsen

learning capability

- after the network is initialized, it can be modified to improve its performance on input/output pairs

"Artificial" Neural Networks

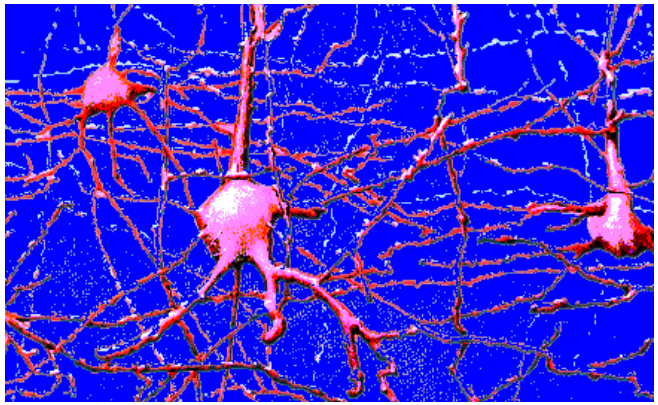


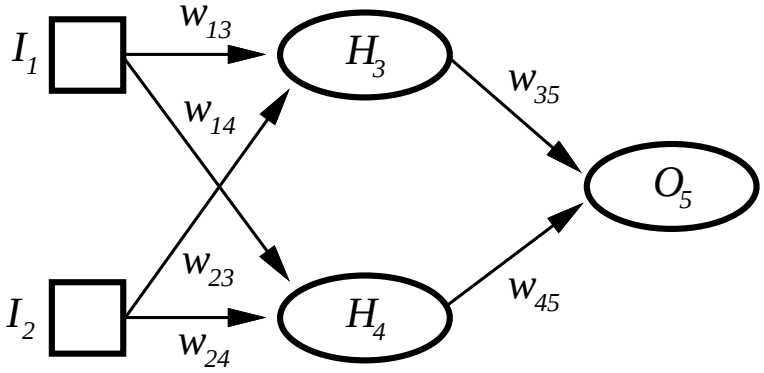
Google Brain

Google official blog on
Using large-scale brain simulations for machine learning and A.I.

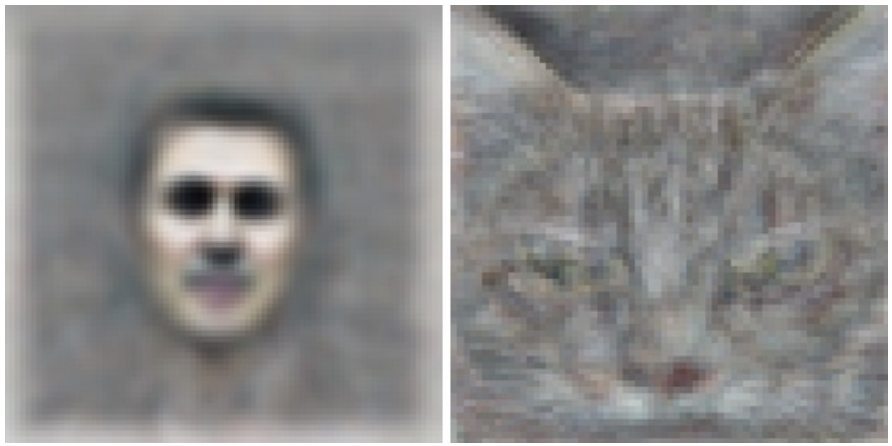
Artificial Neural Networks

- use complex networks of simple computing elements as mathematical models to mimic the functions of the brain

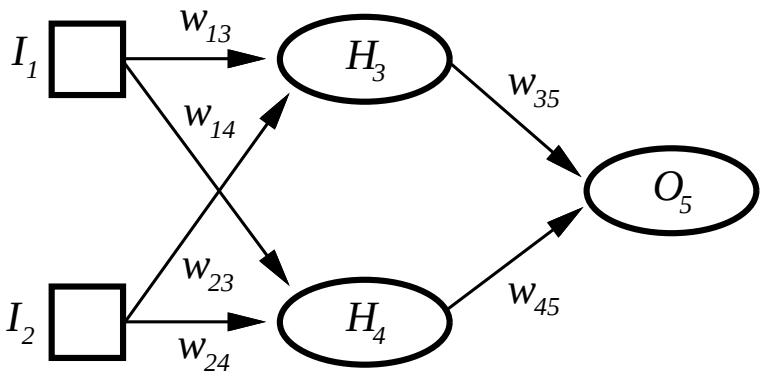




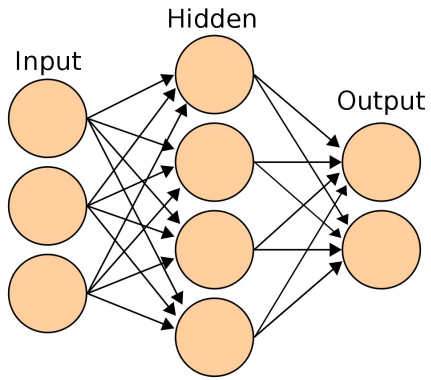
what can artificial neurons in a google brain learn to detect?



Artificial Neural Networks...



- structure: Unit, Link, Weight
  - unit types: input units, hidden units, output units

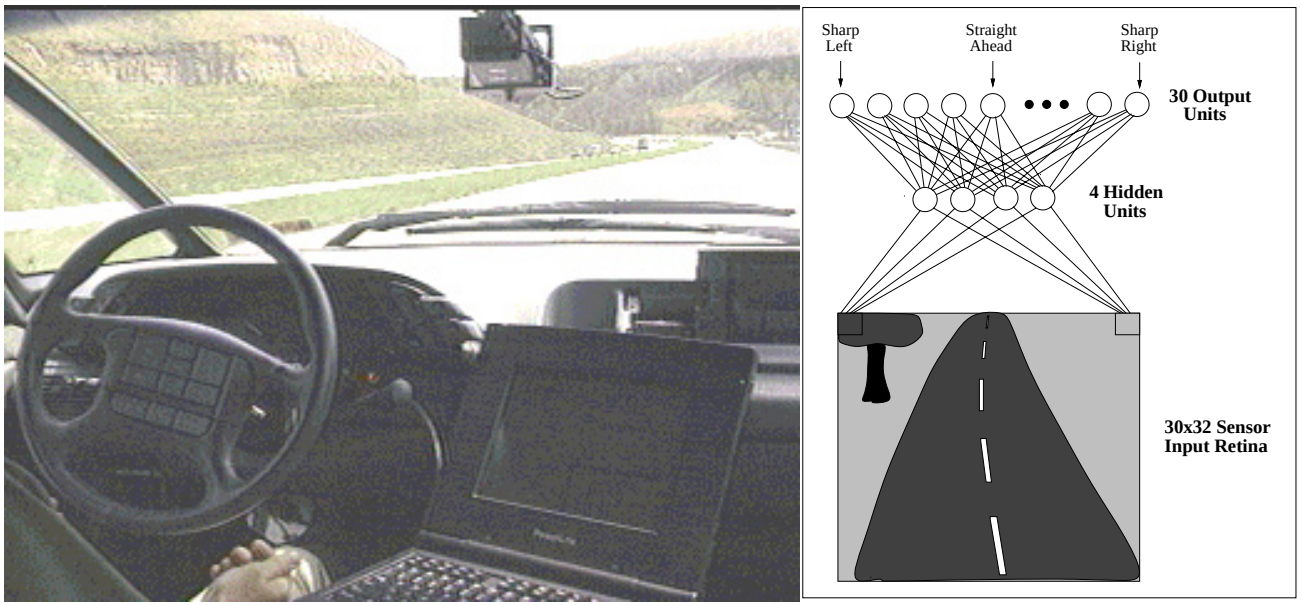


- learning usually takes place by updating the weights

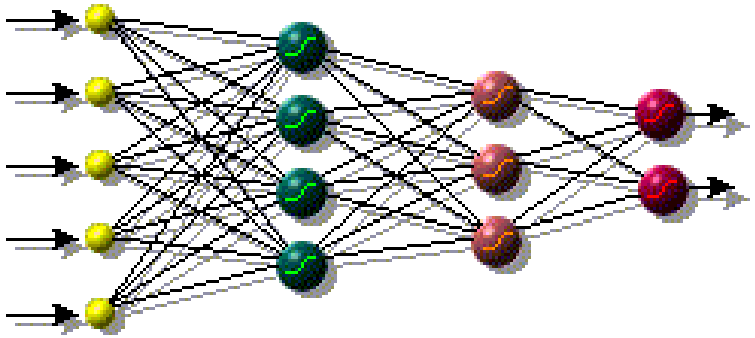
Example Application

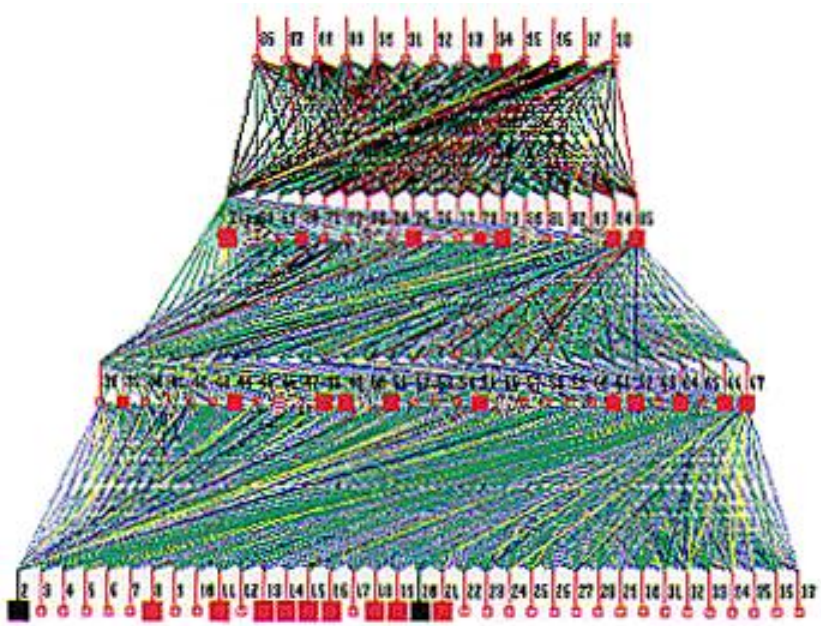
ALVINN (Autonomous Land Vehicle In a Neural Network)

- learns to control a vehicle by watching a person drive
- input: video images and steering direction



Examples

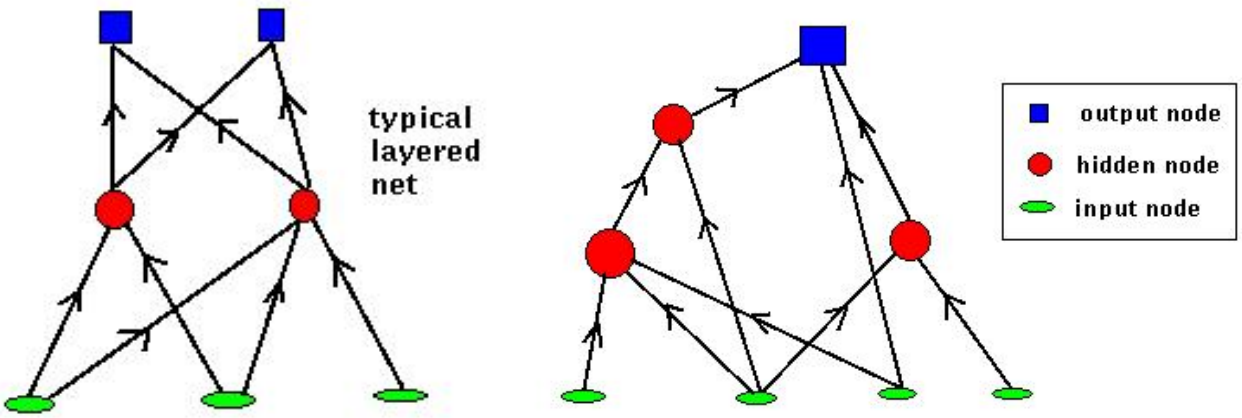




- deep learning (MIT Tech Review)
- google brain: more than 1 billion connections

Feedforward vs Feedback

Feedforward



Feedback