ECM3412/ECMM409
Nature Inspired Computation

Lecture 13

Neural Networks 1: AI, The Brain and Neural Computing

Simple Tasks?

- What is 6783*4592?
- How about 4398549/394?
- OK then, where exactly were you and what were you doing at 1.04pm on the 19th November 1998?

Simple Tasks?

- Catch!
- Find the faces in the CCTV image
- Find the car in the images below

Artificial Intelligence

- It's clear that we have very different capabilities to computing machinery

- Computers are able to significantly outperform us in certain domains…
  - Complex calculations
  - Memory tasks
  - Communications

- But are worse to hopeless in others…
  - Perception
  - Reasoning
  - Learning

In fact…

- Most of what we would deem ‘intelligent’ behaviour is beyond a standard computer
- Independent of computational power
  - Moore’s Law
- What about the architecture?
  - Computers, generally, are very fast serial machines
  - The brain is slower but massively parallel

Key Aspects of a Computer

- Can perform tasks sequentially incredibly quickly
- Doesn’t make mistakes (well most of the time – Pentium floating point errors)
- Memory and processing are separated
- Has a large capacity for storing information indefinitely (e.g. hard disk, optical drives)

Key Aspects of Humans

- Has a distributed architecture
- Has an ability to learn
- Has an ability to generalise
- The structures responsible for Memory/Processing are not necessarily separated
- Will forget unimportant information over time

Brain Structure

- Contains around 10,000,000,000 neurons
  - Approx. the number of raindrops to fill an olympic swimming pool
- Each of which is connected to around 10,000 others
- Neurons communicate through synapses – effectively a configurable chemical junction between neurons

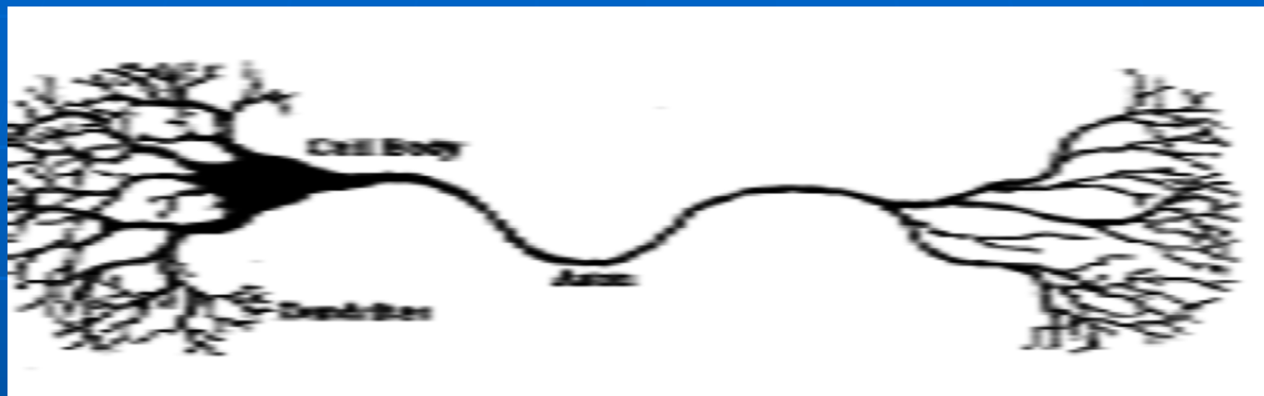
Neurons

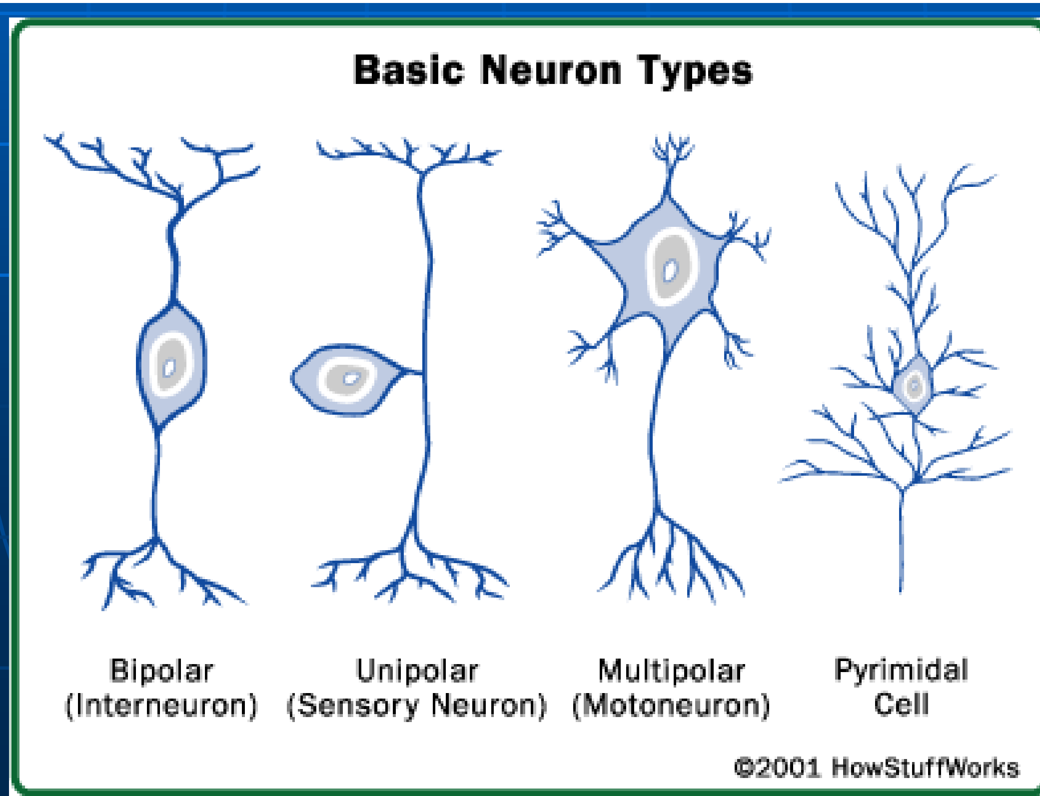
- Neuron systems for signal processing and memory

- Connectionism was proposed based on the research outcome in neuron science about how the information is processed, stored and communicated among neurons.

1. A brain is composed of trillions of cells which interact with each other
2. A cell is composed of three parts
   (a) Dendritic tree: receive signals
   (b) Cell body: process signals
   (c) Axon: transmit signals

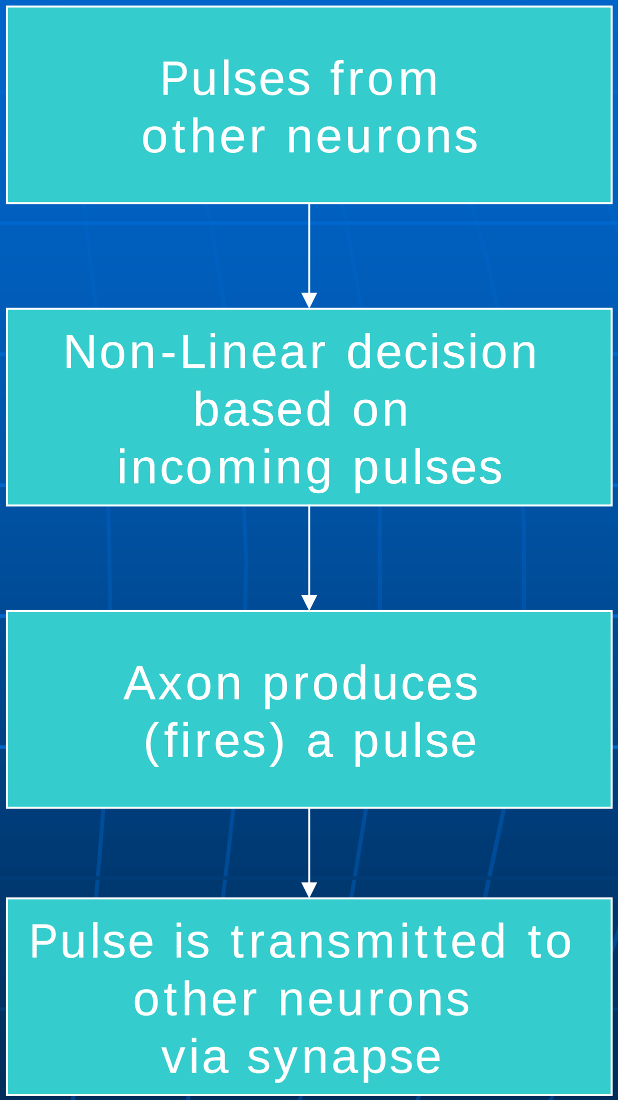
Neuron Structure





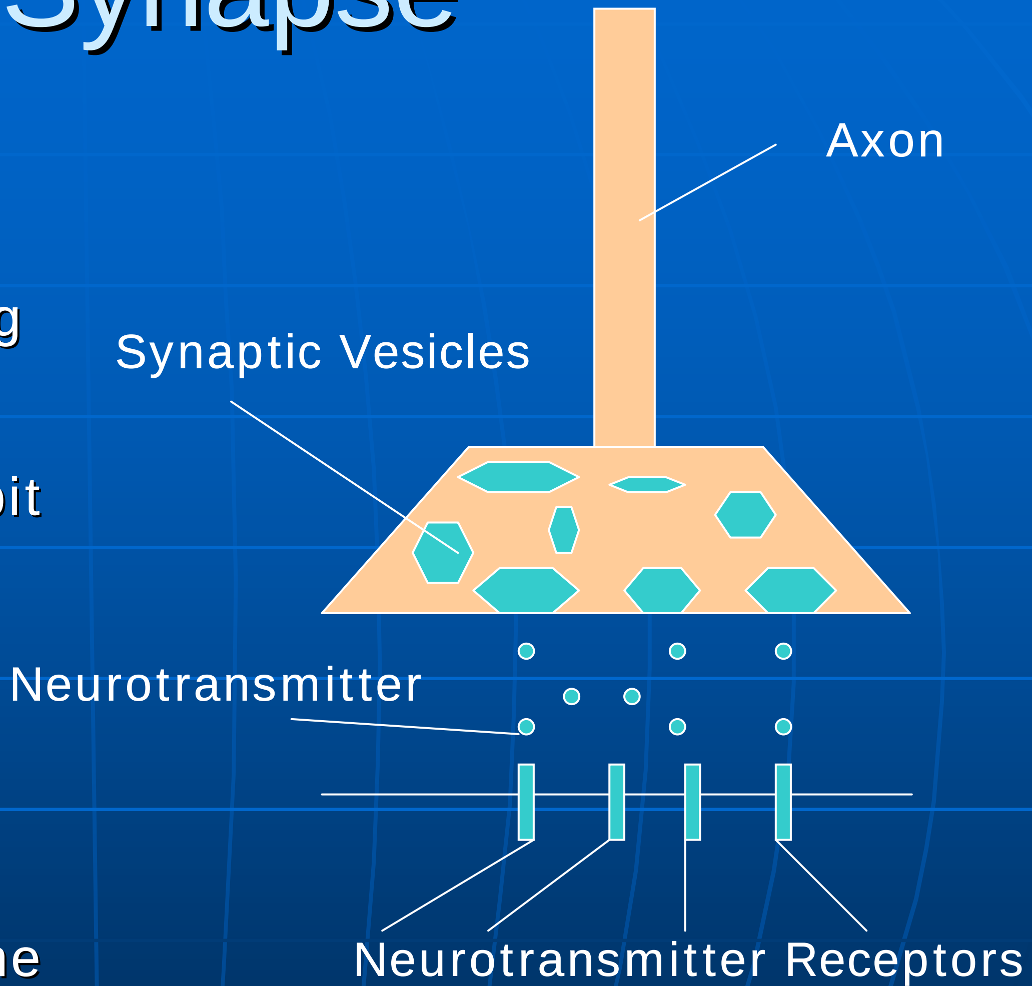
Neuronal Function

- A neuron receives electrical activity from other neurons along its dendrites
- The axon (effectively the output of the neuron) will produce a pulse based on the strength of the incoming pulse
- This is then passed to other neurons connected to this one

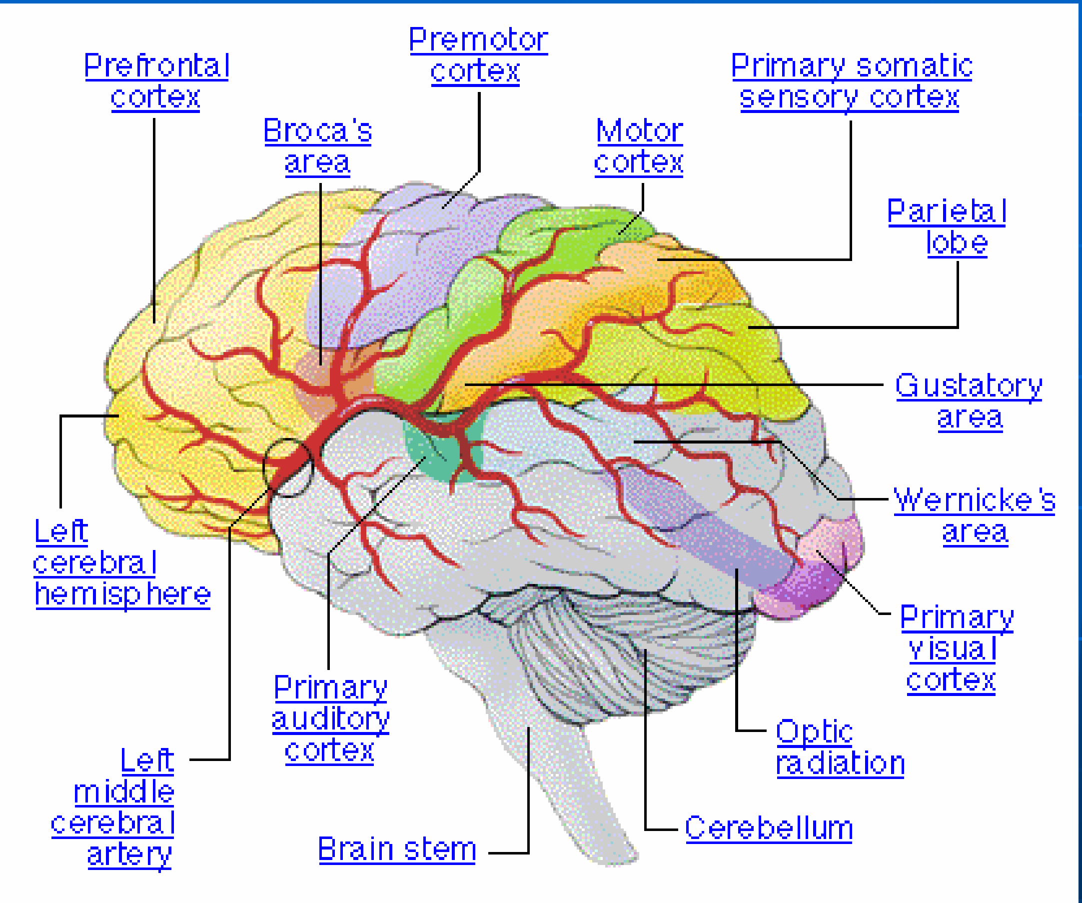


The Synapse

- The synapse is a chemical junction which can be modified and therefore is thought to be where learning takes place.
- Synapses can excite or inhibit the dendrite
- The synapse can release more neurotransmitter to enhance the coupling between cells
- This is where it is thought the brain has the ability to learn



Organisation of the Brain



Brain stem - Mainly controls unconscious vital functions such as blood pressure and breathing

Broca's area - Controls speech

Cerebellum - Maintains posture, balance and coordination of movement

Gustatory area- Controls the sense of taste

Left cerebral hemisphere - Together with right cerebral hemisphere, controls most conscious and mental activities

Left middle cerebral artery - A major source of blood supply to the brain

Motor cortex - Sends instructions to muscles to cause voluntary movements

Optic radiation - Tract of nerve fibers involved in vision

Parietal lobe - Involved in sensations of pain and touch, spatial orientation, and speech

Prefrontal cortex - Provides ability to plan, reason, concentrate, and adjust behavior

Premotor cortex - Coordinates series of movements or intricate, complex movements

Primary auditory cortex - Distinguishes sound qualities (eg, loudness and tones)

Primary somatic sensory cortex - Receives information from skin receptors, distinguishing different types of sensations

Primary visual cortex- Detects basic parts of a visual scene (eg, outlines and light or dark)

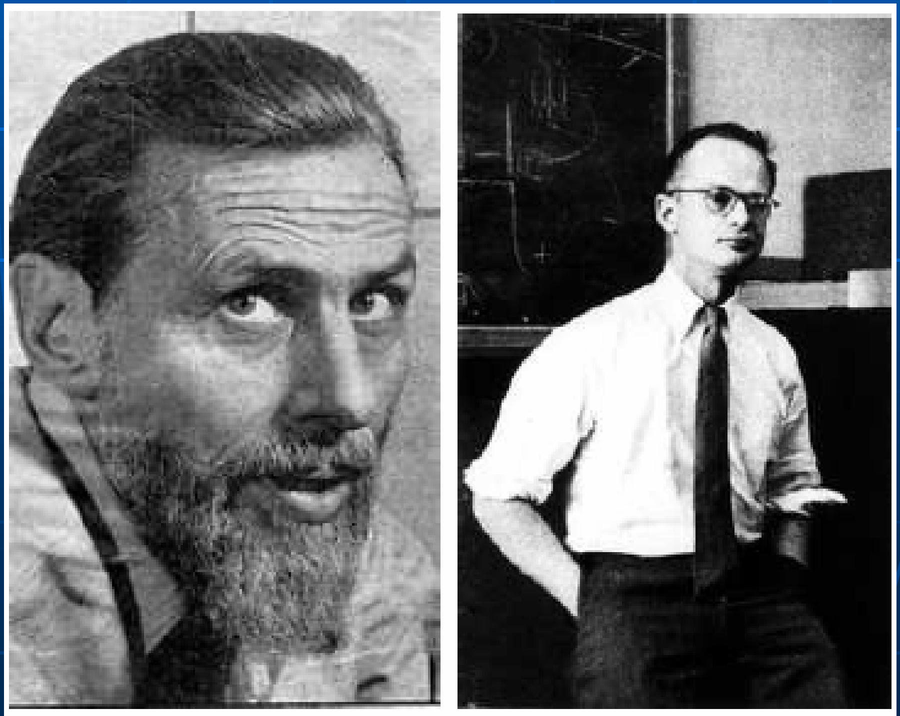
Wernicke's area - Interprets sensory information

Creating Learning Machines

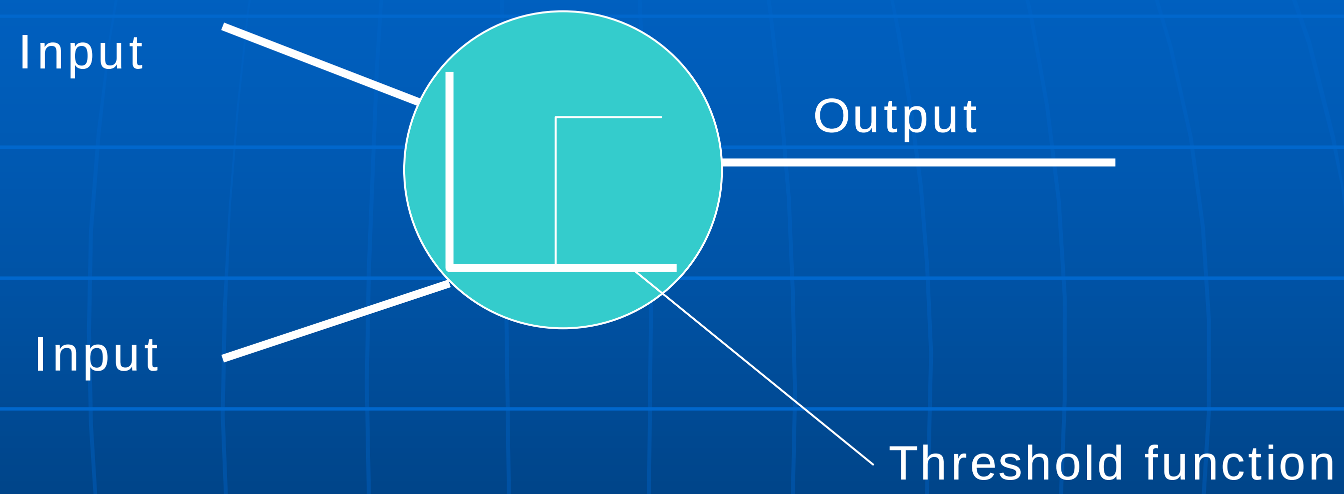
- There are a number of desirable properties we as humans possess
- However, clearly we have very different hardware to computers
- Some (moderately successful) attempts have been made to recreate neural architecture in hardware
- However, the most popular method is to simulate neural processes on a standard computer – neural networks

The Beginning

- McCulloch and Pitts (1943) created the artificial neuron. This was capable of processing simple logical expressions.



Artificial Neuron



If Threshold = 1 OR Functionality

Input 1	Input 2	Output
0	0	0
0	1	1
1	0	1
1	1	1

If Threshold = 2 AND Functionality

Input 1	Input 2	Output
0	0	0
0	1	0
1	0	0
1	1	1

Hebbian Learning (1949)

"When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased."[1]

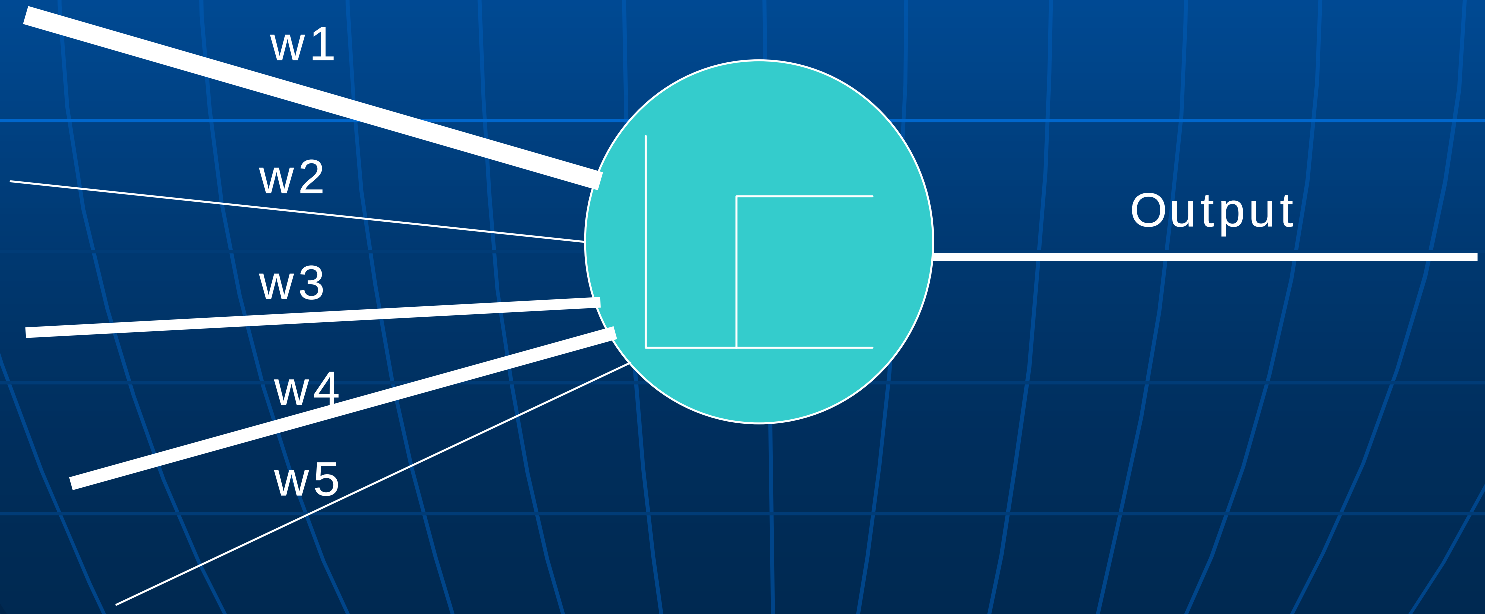
Donald Hebb – The Organisation of Behaviour (1949)

- This means:

1. when two neurons fire together the connection between the neurons is strengthened
2. the activity of firing is one of the fundamental operations necessary for learning and memory

Rosenblatt’s Perceptron

- In 1962 Frank Rosenblatt described a ‘perceptron’ in his book *Principles of Neurodynamics.*
- This resulting system was able to learn by means of weighted connections:



Problems with the Perceptron

- Rosenblatt made some rather outlandish claims for the perceptron
- Minsky and Papert in 1969 published *Perceptrons: An Introduction to Computational Geometry* which highlighted the shortcomings of the technique
- In particular, it was shown that the perceptron could not correctly solve the XOR function:

XOR Function

Input 1	Input 2	Output
0	0	0
0	1	1
1	0	1
1	1	0

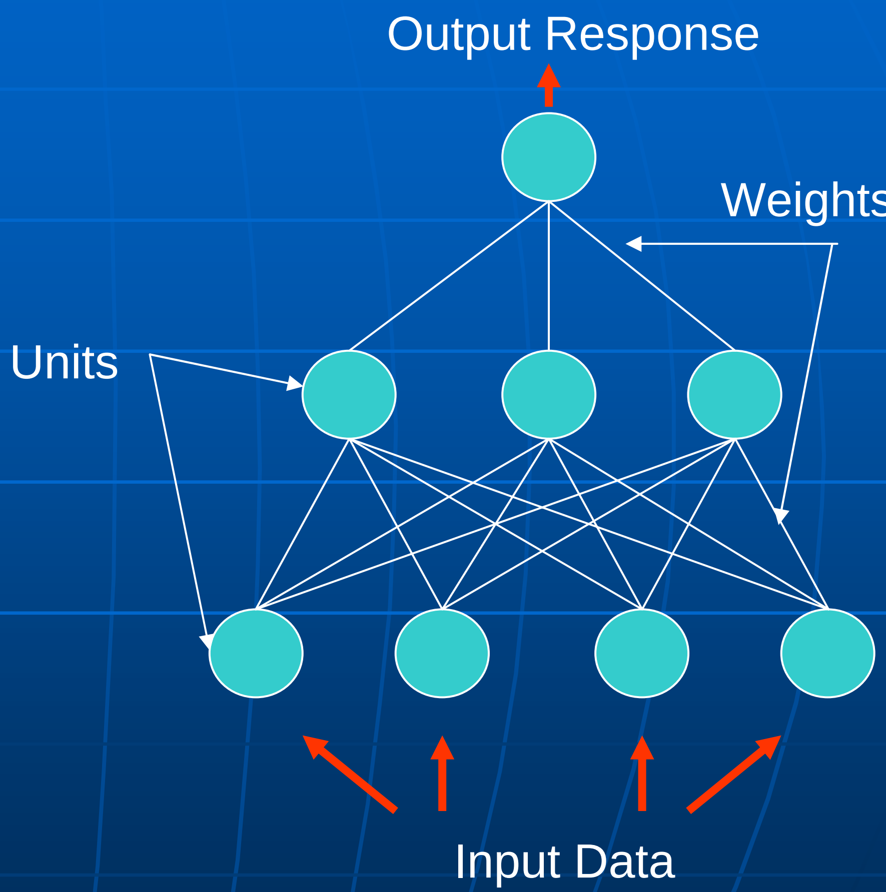
Dark Ages for Neural Computing

- Two paradigms of AI research presented themselves:
  - The classical symbolic method
  - The non-classical connectionist (neural) method

- Due to Minsky and Papert's arguments, hardly any research was conducted into neural computing until the 1980s....

1986 - a Resurgence in Connectionism

- In 1986, Rumelhardt and McClelland published their seminal text – "*Parallel distributed processing: Explorations in the microstructure of cognition*"
- In which they solved the problem of computing XOR - Add a further layer of neurons to the network and create a **MultiLayer Perceptron**
  - One of the most widely applied AI techniques



Applications of Neural Computing

- Almost too numerous to mention, but the main ones:
  - Data analysis
  - Classification/Prediction
  - Pattern Detection
  - AI Studies – investigating learning in infants (e.g. language and perception tasks)
  - Image Analysis (e.g. face recognition)
  - Control systems in engineering applications (e.g. power stations and other safety critical systems)

- We'll be concentrating on the first few

Variations on the Perceptron

- Multi-Layer Perceptrons
- Recurrent Neural Networks
- Self-Organising Maps
- Kohonen Networks
- Boltzmann Machines
- Probabilistic Neural Networks
- Many more...

Neural Computing/Connectionism Summary

- Computational paradigm based loosely on the workings of the human brain – not exactly (temporal effects are ignored)
- Have shown to have human-like qualities, also making similar mistakes (e.g. optical illusions)
- Have a significantly different method of computation than traditional rule-based AI.
- Have been successfully used in a huge number of application areas