Biologically-Inspired Computing

- What forms of Computing has biology "breathed life into"?
  - All forms!
  - All are the brainchildren of people, in that sense biologically-inspired
    - tautology: all forms of human endeavour would be equally biologically-inspired
- so what do I mean by Biologically-Inspired Computing?
  - Forms of computation whose basis is a straightforward abstraction of biological information processing systems
  - There are many forms that such systems take
    - there are many different forms of "abstraction of biological information processing systems"

What's different from von Neumann Computers?

- VN machines are based on an abstraction of the brain which consists of
  - memory
  - processing
- ...and what von Neumann did was to put the information in both on the same footing
- the abstraction is from a ***reflective*** viewpoint of what computing is
  - not one based on the mechanism of nervous systems in any way
  - von Neumann was interested in this area as well:
  - see "The computer and the Brain" von Neumann, 1958.

Brains and computers

- People do talk of the brain as a "sophisticated computer" but
  - structurally they are entirely different
  - no central processor
  - no visible memory
  - no clear distinction between software and hardware
- There is no evidence that the brain is a computer
- Ask the question in the reverse: are computers brains?
  - They can and do control subsystems
    - but one can achieve this in clockwork, or with hardwired logic
  - they process information
  - They can certainly do many things that computers can do
    - but does that make them computers?

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More formally:

- Computers can perform any sequence of logical operations on binary strings
- This makes them able to simulate any system that can be mapped to binary strings
- So: computers can (to some level) simulate any finite system
  - and that includes brains
- But: this is just a simulation
  - a finite approximation
  - lacks the complexity of the original system
    - some aspects will necessarily be omitted
    - for example: noise will be omitted
      - does this matter?
    - And the system will not be "grounded" - I.e. attached to its environment
      - does this matter?
- Biological systems often perform information processing very differently from how a computer might achieve the same ends.

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Simple systems

- Considering designing a robot which navigates towards a light.
  - Is this a simple or a complex task?
- Clearly we need
  - light sensor(s)
  - motor(s)
    - or some form of propulsion
  - and something which connects the two together
- but how complex does the system need to be
- …or how simple could we make such a system
- Might we use some sort of microcontroller which
  - senses where the the light source is?
  - makes a map of its environment?
  - Adjusts the power to the motors as a function of the above?
- Primitive biological systems tend to solve these type of tasks in a primitive way

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Braitenberg's vehicles

- Valentino Braitenberg, retired head of the Max Planck Institute for Biological Cybernetics (Tübingen, Germany)
- Book: Vehicles: Experiments in Synthetic Perception (1984) (RBR)
  - suggested interesting forms of simple solutions for simple perceptual problems.
- Light-seeking vehicle:
  - two sensors
    - sensor nearer the light makes opposite rear wheel drive faster in response to stronger input
    - vehicle therefore turns towards the light.
  - Can easily make a light-avoiding vehicle
- solution is simple and elegant
  - is it computing?

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What is the message here?

- Complex and sophisticated behaviour need not come from complex and sophisticated systems
  - (note that this statement is true the other way round as well!)
- Emergent behaviour
  - system behaviour that emerges as the result of simple rules
- Consider a population of vehicles
  - some attracted to light, some repelled by light
  - each with a light on the front of the vehicle
    - the light not visible to the vehicle's own sensors
- How would this population behave?
  - Complex!

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Complex behaviour can come from simple systems

- (not that biological systems are simple either!)
- Note that digital electronics is all based on a single component
  - a 3-terminal switch called a field effect transistor
- difference between biological systems and these systems is that biological systems are grown, and adapt,
- electronic systems are designed and built.
- Adaptation is also possible in electronic systems
  - but more difficult to achieve.
- Biological systems generally consist of a large number of
  - relatively
- ..simple components
- Much of this course will be concerned with achieving interesting behaviour from large numbers of relatively simple components

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Course Overview

- Introduction
- 2 lectures on real nervous systems (Dr. Breslin)
- Simple model neurons and networks of simple model neurons
- Perceptrons and multi-layer Perceptrons
- Radial basis functions
- Self-organised systems
- Genetic Algorithms

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