

31YB: Biologically-Inspired Computing

Lecture 1

Administrative Details

- My name: Dr. Amir Hussain
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Lectures (1-2) per week at the following times and locations

Monday 15:00, room 2B84A

Thursday 10:00, room 2A87B

Tutorials: Three in total – will take place during some of the lecture slots as above

Practicals: 3-4 (schedule announced during lectures & on course website)

Assignment: One Assignment accounting for 50% of final mark

Submission deadline 19 November (will be handed out during week beginning 13 October and available on-line too)

Textbooks:

The ones below have been placed in the library reserve room (RBR):

- *An Introduction to Neural Networks*, K. Gurney, UCL Press, 1997. (*Non-maths introduction*)
- *Introduction to Neural Networks*, R.Beale and T.Jackson, IOP Press, 1990 (*Good overall text*)

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 brains can do
 - but does that make them brains?

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.

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 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

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?

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!

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

Course Overview

- Introduction
- Neural Networks – What, Why, When
- Simple model neurons and networks of simple model neurons
- Learning and generalization
- Perceptrons and multi-layer Perceptrons
- Radial basis functions
- Recurrent and/or Self-organised systems (briefly)
- Genetic Algorithms (briefly)
- Neuromorphic Systems (briefly)
