Modelling the Brain

Informatics 1 Cognitive Science

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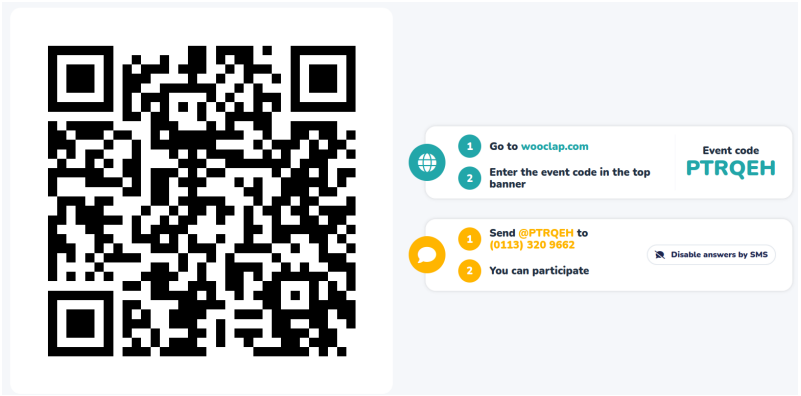
About myself

- Matthias Hennig (m.hennig@ed.ac.uk)
- studied physics
- did a PhD in Computational Neuroscience
- then started to collaborate with experimental neuroscientists as a postdoc
- taught Computational Neuroscience, Cognitive Science and Bioinformatics courses here at Edinburgh
- working on tools for neuroscientists and models of brain function
- also act as Deputy Head of School of Informatics

Course Part 2 Contents

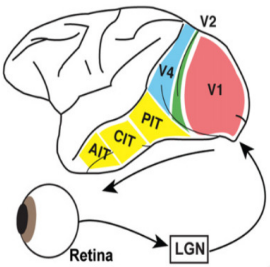
- Introduction to the brain and its function
- How we measure brain activity
- Visual perception and the visual system
- Learning and memory
- Learning goal-directed behaviour
- Ethics in Cognitive Science
- Wrap-up and Q/A

Brain models - your thoughts!



An everyday task for the brain

Sensory input



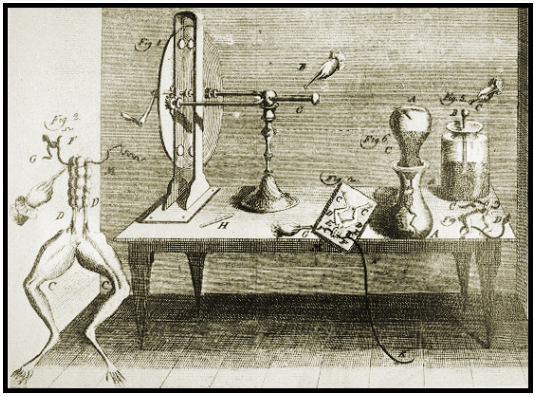
Motor output

perception $\rightarrow$ cognition $\rightarrow$ decision making $\rightarrow$ action

Analogies and Models: Hydraulics

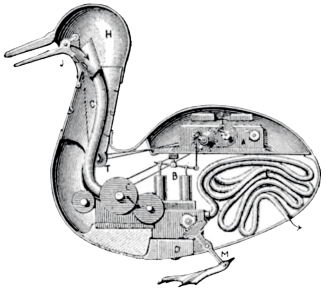
- From ancient Greeks to René Descartes.
- Cells transmit a fluid between parts of the body.
- The brain as connector between soul and body.
- Mechanisms based on hydraulics.

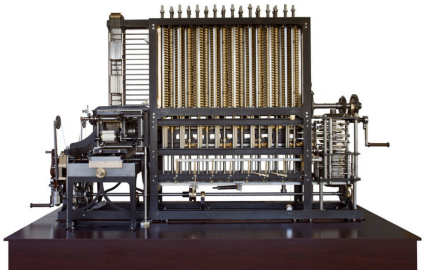
Analogies and Models: Electricity



- 1791: The Galvanis established the role of electricity in the nervous system.
- The brain as an electrical device.
- Telegraph metaphor, focus on communication.

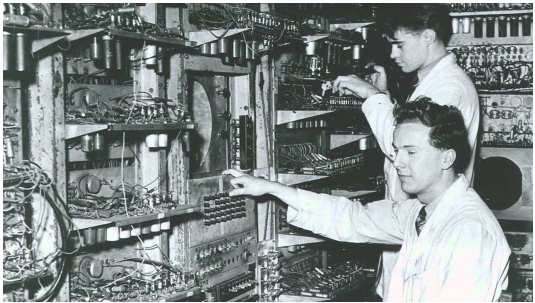
Analogies and Models: Mechanics and early Computers





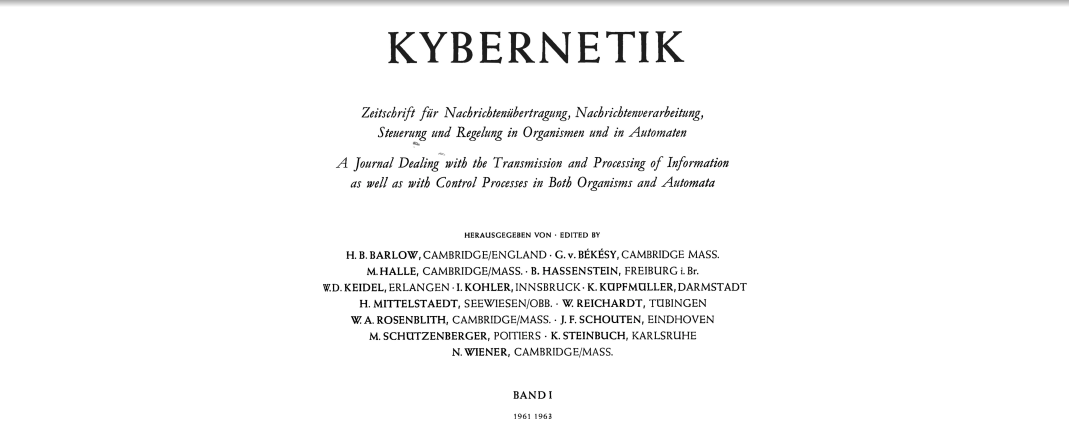
- 1800s: The brain as a calculator.
- Inspired by clockworks, steam engines and other mechanical artifacts.
- Formalised by Lovelace and Babbage who wanted to build a mechanical brain.
- Lovelace also realised: *The Analytical Engine has no pretensions whatever to originate anything. It can do whatever we know how to order it to perform.*

Analogies and Models: Computer and the Turing Machine



- 1930s - now: The brain as a computer, it stored and processes information.
- Early results in neural networks established mechanistic foundations.
- Turing 1951: *The whole thinking process is still rather mysterious to us, but I believe that the attempt to make a thinking machine will help us greatly in finding out how we think ourselves.*

Is the Brain a Computer? Is a Computer a Brain?



KYBERNETIK

Zeitschrift für Nachrichtenübertragung, Nachrichtenverarbeitung, Steuerung und Regelung in Organismen und in Automaten

A Journal Dealing with the Transmission and Processing of Information as well as with Control Processes in Both Organisms and Automata

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BAND I

1961 1963

- 1960s - now: New disciplines enter the field, e.g. control theory, statistics and statistical physics, logic

David Marr's Levels of Analysis

Poggio, Marr and Crick, about 1979

1. Computational: Problem specification.
2. Algorithmic: Solution of the problem in mathematical terms.
3. Implementational: Physical substrate, computations performed by neurons.

Marr's Levels capture complementary cognitive science approaches

1. Computational: The problem to be investigated, e.g. object recognition or navigating an environment. Used to design experiments and organise knowledge.
2. Algorithmic: A concrete model, which ideally predicts (or post-dicts) experiments. Often the question determines the choice of model:
   - Logic, e.g. language
   - Bayesian, e.g. reasoning
   - Information and communication theory, e.g. sensory systems
   - Fluid dynamics, e.g. large scale brain activity
   - ...and many other approaches
3. Implementational: Which neural circuit can implement the algorithmic level? BackProp is currently hotly debated.

Is the Brain a Computer? Is a Computer a Brain?

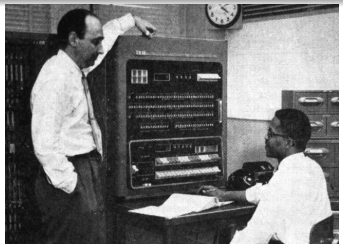
Electronic 'Brain' Finds Lost Planets

Cincinnati, Jan. 8 (U.P.)—Astronomers are finding more "lost" planets today because an "electronic brain" has been put to work tracking them down.

The General Electric Co., Schenectady, has developed a giant computing device called the IBM 701 which figures out their orbits in a matter of minutes.

The Cincinnati Observatory director, Paul Herget, used it to rediscover the planet Athalia, lost for some 50 years.

Another expert, Herbert R. J. Grosch, spent more than 1,000 man-hours on calculations that rediscovered Jupiter's eighth satellite in 1941. Grosch said it would take him just one minute to do the job today by using the "electronic brain."



Brooklyn Daily Eagle (1955)

1. Can a computer program produce intelligent behaviour?
2. What level of description is sufficient or necessary?
3. Are there generalisable principles or is the brain a patchwork of specialised modules?
4. Does brain function depend on a specific implementation?
5. The "Cartesian Error" – separation of mind and body?