Key Question

- Some people think that a computer really contains computations when it is computing.
- Computations are objectively present in the physical world.
- Other people think that the presence of computations is a subjective interpretation.
- The computations attributed to a system vary with our subjective interpretation of it.

Key Question

- My interest in this question derives from claims that consciousness is correlated with computations carried out by the brain (Cleeremans 2005; Bor 2012).
- This is only possible if computations are objectively present in the physical world.
- Also has implications for digital physics.

Talk Overview

- Types of computer.
- Which systems are computers?
- Computers as information processors.
- Theories of implementation.

Types of Computer

- Distinguish between three types of computer:
  - Calculators.
  - Special purpose computers.
  - Programmable computers.
Calculators
- Examples:
  - Slide rule
  - Pascaline
  - Abacus
- When you enter the problem the solution is immediately displayed.

Special Purpose Computers
- Systems designed to solve one specific set of problems, generally with a delay.
- Examples:
  - Difference Engine (Babbage)
  - Bombe (Turing)
  - Soap bubble computer (Bern and Graham 1989)
  - Turing machine

Difference Engine (Babbage)
- Calculates polynomial functions

Bombe (Turing)
- Identifies settings of Enigma machine

Soap Bubble Computer
- Identifies shortest path between multiple points (Bern and Graham 1989).
Key Features of Special Purpose Computers
- Carefully engineered piece of physical world.
- Put into starting state that encodes problem.
- Allow it to 'compute'.
- Read off solution from final state.

Programmable Computer
- Allows the dynamic construction of special purpose computers.
- Operator specifies the program by:
  - Connecting wires.
  - Punching cards
  - Typing code into a terminal.
- Each program is a special purpose computer.

Programmable Computer
- Examples:
  - Analytical engine (Babbage)
  - ENIAC
  - Manchester Baby
  - Modern digital computer
  - Universal Turing machine

ENIAC
- First general purpose computer.
- Programmed by manipulating switches and cables.

Manchester Baby
- First stored program computer.
- Program stored in a cathode ray tube

Special Purpose vs Programmable Computers
- Same computations are carried out by special purpose and general purpose computers.
- If computations are objectively present in the physical world, they must be objectively present in special purpose computers.
**Which Systems are Computers?**

**Special Purpose Computer**
- Special purpose computer:
  - Object in the physical world.
  - Put into starting state that encodes problem.
  - Allow it to 'compute'.
  - Read off solution from final state.
- According to this definition, any system can be interpreted as a special purpose computer.

**Computer Model of the Solar System**
- Want to calculate the position of the planets at time $t + 1$.
- Procedure:
  - Map starting state of planets onto state of computer.
  - Allow computer to compute.
  - Map state of computer onto state of the planets at time $t + 1$. 

**Diagram:**
- Mass of planets & sun
- Newton's equations
- Positions at time $t$
- Velocities at time $t$
- Positions at time $t + 1$
- Velocities at time $t + 1$
Which Systems are Computers?
- Whether the solar system is a special purpose computer depends on whether we are using it to compute.
- This suggests that computing is not an intrinsic property that some objects possess.
- We use physical objects to solve problems.

Information Processing
- Computing is often understood as information processing or as information technology.
- Perhaps this is a unique property of the systems that we call computers?
- To examine this claim, need to clarify what is meant by information.

What is Information?
- We read information from a physical system by applying an interface to it.
- This defines:
  - The material that holds the information.
  - The type of the information.
  - How information of the appropriate type can be read from spatiotemporal patterns in the material.
- An interface is similar to Floridi’s (2008) level of abstraction.

Information in Physical Systems
- The information read through an interface is determined by the interface and by the state of the physical system.
- Different interfaces can be applied to the same physical system to extract different sets of information.
- An infinite number of different information sets can be extracted from a physical system in a given state.

Interface Example
Information-Processing in Physical Systems

- When the physical state of a physical system changes, the information that we read from the system also changes.
- We can use physical systems for information processing:
  - Write information to system through interface.
  - Allow system to change.
  - Read back modified information through interface.
- The information processing that is carried out by a system is relative to the interface.

Information-Processing Example

Subjectivity of Information Processing

- The information processing that a system carries out is relative to the interface selected by the user.
- There is not a unique fact of the matter about the information processing that is carried out by a given physical system.

Information Processing and Computers

- A state change of any physical system can be interpreted as information processing.
- Nothing special about the information processing of the systems that we currently call computers.

Computing as Use

- This analysis of information processing reinforces idea that computing is a use that we make of physical objects.
- A system’s computational properties depend on the subjective interpretation of the human user (Horsman et al. 2014).
- Computations are not an objective feature of the physical world.
Theories of Implementation

Theory of Implementation
- A theory of implementation:
  - Specifies what it is for a pattern to be computational.
  - Enables the identification and comparison of computational patterns.
- Use theory of implementation to:
  - Ground digital physics
  - Identify computational correlates of consciousness in the brain.

Theories of Implementation
- Finite state automata.
- Combinatorial state automata (Chalmers 2011).
- Applying instructions to strings (Piccinini 2007).
- Pattern matching (Boyle 1995).
- Realization of a function (Scheutz 1999)
- Cellular automata (Schule 2014).

Conclusions
- Some of these are good at picking out our modern digital computers.
- Others are more applicable to natural systems.
- Not obvious that any of them establish that computations are an objectively present in the physical world.
- None of them are a workable approach for identifying computational correlates of consciousness in the brain.

Computation is a Pattern
- Some people claim that computation is a particular kind of pattern in the physical world.
- For example, digital physics.
- To make this work you need a theory of implementation.
Conclusions

- Any part of the physical world can be used as a special purpose computer.
- Any part of the physical world can be interpreted as a information processor.
- We lack a plausible theory of implementation that could identify computational patterns in the physical world.

Computing as Use

- We use the state changes of physical objects to solve problems:
  - Use an interface to write information to a physical system.
  - Allow physical system to change state.
  - Read back modified information through same interface.

What is a Computer?

- Computers are not objects that contain computations.
- Computers are physical objects that have been engineered to carry out fast and flexible information-processing using one particular interface.

What is a Hammer?

- Virtually any physical object can be used as a hammer.
- The physical objects that we typically call hammers are parts of the physical world that have been engineered to bang in nails efficiently.
- Hammers do not contain hammerations!

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References

More Information

- Slides: www.davidgamez.eu/talks/
- Some papers related to this material: www.davidgamez.eu/publications/
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