

Quantum Computing Since Democritus

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Chapter 4: Mind and Machines

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Oracles!

- Like black boxes (not fairies!).
- Immediately solve any hard computational problem.
- Studied first by Turing in his 1938 PhD thesis.

Turing Terms

- A is **Turing Reducible** to B
 - if A is solvable by a Turing machine given an oracle for B
 - A is no harder than B
- **Turing Equivalent**
 - if each is Turing Reducible to the other.
 - Example: Proving statements from set theory axioms is TE to halting problem.
- **Turing Degree** is set of all problems that are Turing equivalent to a given problem.
Example:
 - The set of problems that are Turing equivalent to the halting problem.
 - The set of computable problems

Super Halting Problem

- Turing degree above the 2 discussed?
- Problems that can't be solved even given an oracle to the Halting Problem: SH Problem!
- Given a Turing machine with an oracle for the halting problem, decide if it halts!
- Can we prove its unsolvable?
- Take proof of halting problem, and shift everything up a level.
- Proof “relativizes.”

Intermediate Turing Degrees

- Any problem of intermediate difficulty between the computable problems and the halting problem?
- Yes! Proved by Friedberg and Muchnik.
- 2 problems A and B, both solvable with an oracle for HP, none solvable with an oracle of the other.
- Extremely contrived, impractical problems.

Church-Turing Thesis

- Any function “naturally to be regarded as computable” is computable by a Turing machine.
- Can convert any “real world computation” to a Turing computation.
- Is this a definitional claim? About physically real problems?
- Challenge (non-serious) posed by QC.

Challenges: Hypercomputation

- Infinite computation in 2 seconds!
- Would nature give us these powers in such an uninteresting way?
- Real explanation lies in entropy bounds and quantum gravity
- No serious challenges to the thesis in 75 years!

Problems at the Planck Scale

- Concept of time breaks at 10^{-43} seconds (Planck scale).
- No quantitative idea for when quantum computing breaks, so maybe it *won't* break?
- Always limited in practise by noise and imperfection?
- Why? Why can't I model a real number in a register?
- Physical interpretation of CT Thesis, claims it can encompass everything in reality.

Turing's Thought of AI

- Conceptualized right alongside computers.
- Everyone understood computers weren't any other machine. (Universality, remember?)
- Turing's second famous paper: 'Computing machinery and intelligence'
- Epistemological, mathematical, but mostly **moral** argument.
- Dilemma: the computer isn't "really" thinking, but are you?

Arguments against brains!

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- Back at you: are you disregarding race?

Turing's Predictions

- What he got right: BY 2000, storage capacity of 10^9 (a gig).
- ELIZA by Weizenbaum in 1966: therapist program.
- Turing Test: machine's ability to exhibit intelligent behaviour like that of a human.
- Turing test needs to be revised (baseline intelligence of the human interrogator).

Loebner's test

- Interrogator needs to actively distinguish between human and computer.
- Hugh Loebner running tests similar to Turing tests from 15 years.
- Here testers *know* they're distinguishing human from computer.

CAPTCHAs

- What if a computer was doing the differentiating job?
- In 2006, Luis von Ahn won a MacArthur Award for his work on CAPTCHAs.
- Key property: computer should be able to generate the squiggly text CAPTCHA tests, not pass them! (inverting one-way functions)
- Eventually led to race between the CAPTCHA programmers and the AI programmers.

Success of AI

- Kasparov and Deep Blue, and IBM's Watson
- Otter used to solve a 60-year-old open algebra problem 'Robbins Conjecture'. (whiteboard)
- Wasn't like proof of Four-Colour Theorem, 17 lines of proof after 1000s of computations.
- Another AI: Google. Disagree? Would someone from the 1960s also disagree? (Philosophers' problem).

Chinese Room

- The hardest tasks for AI are the ones trivial for 5-year olds.
- Searle's Chinese Room: symbol manipulation doesn't produce understanding.
- Strong AI proponent vs Searle banter (whiteboard)

Scott's Annoyances with Chinese Room

- unselfconscious appeal to intuition (*Just* a rulebook?)
- How does a bundle of nerve cells understand Chinese?
- Sidestepping computational complexity issue: how big is the rulebook? Size of the Earth?

Consciousness

- Most fascinating thing we know about AND the only thing we know about.
- I can hallucinate my shirt being blue, but I can't hallucinate my hallucination of it.
- Similarity between this subjective experience and Math: feeling of certainty!
- Doubting Four-Color Theorem proof: different *senses* of actual proof and understanding of it.
- Not by physical processes, statements proved using the perception of its truth.

Objection to AI & Solution

- People's anti-AI beliefs rise from:
 - The certainty that *they're* conscious.
 - If they were a computation, they could not be conscious this way.
- Granting consciousness to a robot means: *one is not conscious themselves!*
- Solution: David Chalmers' "philosophical NP-completeness reduction" (reduction of one mystery to another).
- If computers can emulate humans in every way, they're conscious just like we are.

Puzzles!

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