From Turing Machines to “Building a Brain”

Including an introduction to

Philosophy of Mind

Church-Turing Thesis

- Turing was beaten to the punch in his solution to the Entscheidungsproblem
  - Alonzo Church announced the same result at Princeton earlier in 1936
  - Used purely mathematical techniques (lambda-calculus)
  - Turing drew from ideas beyond mathematics
  - “bringing the physical world into the picture”
    - What does Hodges mean by this? (Also see Henderson p. 33)
- Church and Turing commonly share credit
The Universal Turing Machine

- Turing Machine accomplishments
  - Solved Hilbert's Entscheidungsproblem
  - Created the mathematical field of computability
  - Offered a new analysis of human mental activity
    - Contributed to the “Philosophy of Mind”, soon to be our main topic…
  - Laid out the principle of the modern, stored program computer
- Universal Turing Machine
  - A TM that takes as input:
    - Encoding of another Turing Machine
    - Input on that TM's tape
  - Then simulates the behavior of the TM on its input

Think about the TM simulator that we experimented with:
- Followed the instructions of a TM table of behavior
- But were there more instructions “behind” those instructions?

- A single TM = a computer program
- A universal TM = a ___________________________ ?
- A basic set of general instructions that can run any well-formed program
- Key idea: the idea of a TM encoded as data to be input into another machine ➔ stored program concept
  - What is the alternative for programmable machines?
- Remember: Turing was modeling the basic actions of human minds
Philosophy of Mind

- Turing’s next paper (after the Turing Machine paper)
  - “Systems of logic based on ordinals”
- Turing considered only a specific type of behavior of the mind in his TM work:
  - Working on a ‘definite method’
  - Other words for this?
  - What functions of the human mind does this leave open?
- In this paper Turing tried to build a formal model of intuition
  - Difference between intuition and ingenuity?
  - Relationship to “seeing the truth” of a Gödel sentence?
- What appears to be Turing’s philosophy of mind at this point in his life?
  - And what influence did the war have on it? (Coming up…) 

Applications of Mathematics

- “Turing’s mathematical interests flowed not only into philosophy, but into practical engineering.”
- Letter to his mother about encryption in 1936
  - Why “doubtful about the morality of such things”?
- Machine for the Riemann hypothesis
- “an unworldly person found a perfect application in the heart of the world crisis” – Hodges
  - Analysis of this quote?
Impact of the War

- Turing had a “substantial influence on the course of the war”
- Key points in this argument?
- Demands of cooperation and organization
  - Turing not well suited
  - Going over heads to Churchill
- War “broke peacetime boundaries”
  - Examples? Benefits?
  - Effect of war on history of the computer?
  - Other examples of the “needs of the day determining new ideas”
- What does Hodges suggest is the key feature of a computer, allowing Turing to lay claim to its invention?
  - Key term – “modifiable”. Any ideas why so significant?

Origins of Digital Computers

- Abacus, first developed in Babylonia 3,000-5,000 years ago
- Early computing devices designed to aid numeric computation
- Euclid: Earliest known mathematical algorithms (300 B.C.)
  - Greatest common divisor of two positive integers
Early Calculating Machines

William Oughtred 1621

- Slide rule, did not become obsolete for nearly 350 years (pocket calculator in 1970)
- July 20, 1969

Early Calculating Machines

William Schickard
(1592–1635) a 3 function mechanical calculator (+ - *)

- Separate units, intermediate results, awkward
- Killed by Plague, Notes lost for years
Blaise Pascal

- **Blaise Pascal** (1623–1662)
  - Addition and subtraction
  - He was 19 years old (1642)
  - Commercial failure
    - Expensive and delicate

Gottfried Leibniz

- **G. W. F. Leibniz** (1646–1716)
  - First full-featured mechanical calculator (+-*/) 
  - *Steppe Reckoner*, full-featured calculator
  - “Leibniz wheel” for multiplication
Industrial Revolution

- Embodiment of skills in machines
  - Replacement of human expertise
- Joseph-Marie Jacquard – Jacquard’s Loom (1801)
- Punched card system to aid weavers
- “Programmed” pattern woven in fabric

Charles Babbage (1791–1871)

- First true pioneer of modern digital computing machines
- Designed two prototype calculating machines:
  - Difference Engine
  - Analytical Engine
Difference Engine

- 1822
- automated both the computation of tables and their printing
- employed the method of differences to calculate polynomials
- special-purpose calculating machine

Analytical Engine

- 1833
- Ada Lovelace
  - Suggested “programming” machine
  - Wrote first algorithms for a computer
- Programmable, general purpose calculating machine
- Programmed by punched cards based on Jacquard loom
Legacy of Babbage/Lovelace

- Designed the first, general-purpose digital computing device
- Ideas and achievements were overlooked by successors
- “tinkering”, funding prevented success

Handling the “Information Explosion”

- Rapid evolution towards a general-purpose, fully electronic, digital computing device
  - Morse’s telegraph (idea of electronic information) 1838
  - 1880 census
  - Early computers
  - Military computers
Herman Hollerith

- 1880 Census disaster
- Used punched cards for tabulating data
  - Electro-mechanical operation
- 1890 Census finished in 6 weeks
- Formed Tabulating Machine Company
  - evolved into International Business Machines

1838 – Morse invents telegraph
1876 - Bell invents telephone
1883 - Edison invents lightbulb

Konrad Zuse (1910–1995)

- Designed a series of automatic general-purpose computing machines (Z1, Z2, Z3, Z4)
- Electro-mechanical devices
  - Electro-mechanical relays (switches)
- Binary internal encoding
- Z3 (1941) was programmed using punched 35mm film
- Multiply only took 3 seconds!
- Realized Babbage’s Analytical Engine vision

1930’s WWII
John V. Atanasoff (1903–1995)

- Built the ABC machine with Clifford Berry in 1939 at Iowa State Univ.
- First all electronic digital computing machine
- Special-purpose: solving simultaneous linear equations
- Not fully automatic; may not have fully worked

Mark I and Mark II

- Mark I
  - Harvard, 1944
  - Commissioned by Navy for weather prediction
  - Special-purpose, electro-mechanical
- Mark II
  - Grace Murray Hopper part of the team
Mauchly and Eckert

- John W. Mauchly (1907–1980) and J. Presper Eckert (1919– ) headed the ENIAC team at the Moore School of Engineering, University of Pennsylvania
- ENIAC (Electronic Numerical Integrator And Computer), the first electronic, general-purpose digital computer
- Commissioned by the Army in 1944 for computing ballistic firing tables

ENIAC

- noted for massive scale and redundant design
  - 1,500 sq. ft.
  - 18,000 vacuum tubes
  - 150 kw
- decimal internal coding
- operational in 1946
Manual programming of boards, switches, and “function table”

- Compare and contrast:
  - Analytical Engine
  - ENIAC
  - Universal Turing Machine

Colossus

- Used to break Lorenz code
  - Max Newman and Tommy Flowers
  - (Turing?)
  - “first programmable electronic digital computer” – Henderson
- Programmed by switches and cables
- Compare to ENIAC
John Von Neumann

- Von Neumann visits the Moore School in 1944
- Also studied with Turing at Princeton
- Prepares a draft for an automatic programmable device
  - EDVAC Report, June 1945

  Championed Concepts:
  - Stored program concept
  - Binary coding
  - Sequential Uniprocessor
    (Fetch/Decode/Execute)
  - Functional design:
    Input/Output/Storage/Processing

  *Sound familiar?*

ACE – Automatic Computing Engine

- National Physics Lab
- Design outline published in 1946
- Featured:
  - Stored program concept
  - Binary coding
  - RISC design
- Compare to EDVAC
  - More emphasis on speed and software than hardware
Manchester “Baby” – 1948

- University of Manchester
  - Frederic Williams and Tom Kilburn
- Small Scale Experimental Machine (SSEM)
  - Stored program concept (first “true” implementation claimed)
  - Advances in memory techniques
  - UNIVAC was the American contemporary
    - Commercial product
- Notable for innovative programs
  - Christopher Strachey
    - Text and audio processing
  - Turing
    - Biological pattern simulation and game playing

Alan Turing (1912–1954)

- Proposed a simple abstract universal machine model for defining computability (1936)
  - Stored program concept?
- Special-purpose electromechanical digital computer broke the code for the Enigma machine (1943)
- Design of ACE (1946), including first complete machine language and design of RISC processing
- Innovative programs for Manchester “Baby” (1948)
- Devised the “Turing Test” for AI (1950)
- Conclusion?
Building a Brain

- Worked for National Physical Laboratory post-war
- Automatic Computing Engine (ACE) report, March 1946
  - Designed to be a universal machine
  - Included a theory of programming
  - “no fresh engineering, just fresh codes”
- Referred openly to “building a brain”
  - An embarrassment to NPL (Why?)
  - Evidence of a shift in philosophy regarding the mind and machines?

Philosophical Discussion

- How did Turing’s views change during the war, according to Hodges?
  - Related back to earlier Turing Machine discussion
- What contributed to these changes?
- What evidence is there for the computability or uncomputability of creative, original thought?
- Turing suggested that machines could “evolve” into behavior not explicitly programmed
  - Relate back to his BBC lecture. To the UTM.
- Does a computer that learns to play chess well demonstrate intelligence? What did Turing think?