Alan Turing: Scientist Unlimited

Mathai Joseph
Advisor
Tata Consultancy Services
1912

• 100 years ago
  – first theoretical computer scientist born in London

• ACM Centenary event in San Francisco in 2012
  – attended by 32 of 36 living Turing laureates

Quite simply, Turing is why we are here today
Alan Turing 1912 -- 1954
Turing’s Contributions

Turing led the way:

– invented a simple abstract computing machine
– redefined computability, decidability
– defined the universal computing machine
– gave a computational view of many problems
And ...

Many interests:

- statistical methods for code breaking
- artificial intelligence, chess playing programs
- computer design
- formal program proofs
- morphogenesis ...
His school headmaster had complained:

“he must aim at becoming educated. If he is to be solely a Scientific Specialist, he is wasting his time at public school”
Turing ran a marathon in 2hr 46min 3sec

(11 sec more than Olympic winner)
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(11 sec more than Olympic winner)

He sometimes ran 40 miles to London for a meeting
Computability

Turing machines (1936):

- Abstract computation device
  - Machine has an internal state
  - Head can read or write one cell
  - Tape can move one cell left or right
  - Next state & action depend on current state & tape symbol
Turing used this idea to prove basic properties:

- **computability**,
  Any computable problem can be computed by a Turing Machine
- **decidability**, etc.
  Example: *Halting Problem*
  Given any program and any input to the program, will the program will eventually stop when given that input?
  This is an *undecidable* problem.
Cambridge, Princeton

All this work was done in Cambridge

before Turing completed his PhD

The world’s greatest undergraduate project!
Church-Turing Thesis

- 1936: Turing went to Princeton to work with Alonzo Church
- Church had proved the computability result using lambda calculus
- Church, Kleene and Rosser had used recursive functions

Turing showed it could be done more simply using his abstract machine.
Princeton

PhD at Princeton in 1938

Turing provided:

– Mathematical basis for computing
– Intuitively understandable solution
Bletchley Park

Turing moved to Bletchley Park in 1938
  – arranged by Max Newman

Soon became leader of cryptanalysis work
  – deciphering Enigma messages
  – Naval Enigma: more difficult

Machines used to reduce possibilities
  – Colossus
  – Bombe
Bletchley Park

Human analysis still critical
  – knowledge of possible content
  – familiarity with previous encryption keys

Huge teams used for cryptanalysis
Bletchley Park

Human analysis still critical
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Huge teams used for cryptanalysis

Reliance on Turing for new methods
  – suffered from hay fever
  – sometimes came to work in pyjamas wearing gas mask
Manchester

Worked on

– computer design
– artificial intelligence
– program verification

Finally on morphogenesis

Reason for death not certain

– suicide?
– accident?
Algorithms, complexity

Known from the Greeks, later Kerala mathematicians:

- e.g. Euclid’s algorithm for GCD (350B.C.)

Lame’s Theorem (1845)

- Euclid’s algorithm takes at most \( 4.2 \frac{\log(n)}{\log(10)} - 0.32 \) steps

Long history of mathematical interest in complexity:

- Cantor, Hilbert, Pocklington, Post, Church, Gödel, Turing, ...

Given a new basis in the 1960’s:

- Yamaha, Myhill, Smullyan, Cobham, Edmonds ...
1960’s: Complexity

Can all computable problems be solved equally easily?

Hartmanis & Stearns (1965):

– formally quantified time & space of a computation
  • *Time*: number of steps that the tape moves
  • *Space*: number of cells of the tape that are used

Hartmanis: “We struggled with the mathematics and then saw that Turing machines made it all so simple”
Complexity

Developed into decision problems about classes of algorithms, e.g.

- **P**
  - polynomial time algorithms

- **NP**
  - nondeterministic polynomial time algorithms
Computer Science without Turing?

– Time: number of steps that the tape moves
– Space: number of cells of the tape that are used

What measures would be used if there were no Turing machines?
Computer Science without Turing?

– Time: number of steps that the tape moves
– Space: number of cells of the tape that are used

*What measures would be used if there were no Turing machines?*

Something would have evolved ... but
– Taken longer to find
– Been harder to understand
– Perhaps of less practical use
Turing Centenary

ACM Turing awards started in 1966
   – First winner: Alan Perlis

32 past winners attended the function:
   Charles Bachman (1973)
   Donald Knuth (1974)
   Dana Scott (1976), …

ACM India sponsored two PhD students to attend

More details: http://turing100.acm.org/index.cfm?p=program
Turing Award Winners Who Lectured in India

- Maurice Wilkes
- John McCarthy
- C.A.R. Hoare*
- John Hopcroft
- Robin Milner
- Butler Lampson*
- Juris Hartmanis

- Raj Reddy
- Amir Pnueli*
- Joseph Sifakis*
- Barbara Liskov
- Charles Thacker
- ...  

* In Pune
Finally,

• Turing was 42 when he died.
• We can only guess what he might have done if he had lived longer
• A remarkable mind: mathematician, scientist, engineer, all genius
100 years on

Turing would have been 100 in 2012
He showed the world how to look forward:
– Gave computing secure foundations
– Showed that many problems have a computational basis

If he had lived, what would he have been working on today?
ALAN TURING
1912 - 1954

Founder of computer science
and cryptographer, whose work
was key to breaking the
wartime Enigma codes,
lived and died here.