

CompSci 6

Programming Design and Analysis

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What is Computer Science?

- Computer science is no more about computers than astronomy is about telescopes.



Edsger Dijkstra

- Computer science is not as old as physics; it lags by a couple of hundred years. However, this does not mean that there is significantly less on the computer scientist's plate than on the physicist's: younger it may be, but it has had a far more intense upbringing!



Richard Feynman

<http://www.wordiq.com>

Scientists and Engineers

- **Scientists build to learn, engineers learn to build**

- Fred Brooks



Computer Science and Programming

- **Computer Science is more than programming**
 - The discipline is called *informatics* in many countries
 - Elements of both science and engineering
 - Elements of mathematics, physics, cognitive science, music, art, and many other fields
- **Computer Science is a young discipline**
 - Fiftieth anniversary in 1997, but closer to forty years of research and development
 - First graduate program at CMU (then Carnegie Tech) in 1965
- **To some programming is an art, to others a science, to others an engineering discipline**

What is Computer Science?

What is it that distinguishes it from the separate subjects with which it is related? What is the linking thread which gathers these disparate branches into a single discipline? My answer to these questions is simple --- *it is the art of programming a computer*. It is the art of designing efficient and elegant methods of getting a computer to solve problems, theoretical or practical, small or large, simple or complex.

C.A.R. (Tony)Hoare

Algorithms as Cornerstone of CS

- **Step-by-step process that solves a problem**
 - more precise than a recipe
 - eventually stops with an answer
 - general process rather than specific to a computer or to a programming language
- **Searching: for phone number of G. Samsa, whose number is 929-9338, or for the person whose number is 489-6569**
 - Are these searches different?
- **If the phone book has 8 million numbers in it (why are there only 7.9 million phone numbers with area code 212?)**
 - How many queries to find phone number of G. Samsa?
 - How many queries to find person with number 929-9338
 - What about IP addresses?

Search, Efficiency, Complexity

- Think of a number between 1 and 1,000
 - respond high, low, correct, how many guesses needed?
- Look up a word in a dictionary
 - Finding the page/word, how many words do you look at?
- Looking up a phone number in the Manhattan, NY directory
 - How many names are examined?
- How many times can 1,024 be cut in half?
 - $2^{10} = 1,024$, $2^{20} = 1,048,576$

Themes and Concepts of CS

- **Theory**
 - properties of algorithms, how fast, how much memory
 - average case, worst case: sorting cards, words, exams
 - *provable* properties, in a mathematical sense
- **Language**
 - programming languages: Java, C++, Perl, Fortran, Lisp, Scheme, Visual BASIC, ...
 - Assembly language, machine language,
 - Natural language such as English
- **Architecture**
 - Main memory, cache memory, disk, USB, SCSI, ...
 - pipeline, multi-processor

Theory, Language, Architecture

- **We can prove that in the worst case quicksort is bad**
 - doesn't matter what machine it's executed on
 - doesn't matter what language it's coded in
 - unlikely in practice, but worst case always possible
- **Solutions? Develop an algorithm as fast as quicksort in the average case, but has good worst case performance**
 - quicksort invented in 1960
 - introsort (for introspective sort) invented in 1996
- **Sometimes live with worst case being bad**
 - bad for sorting isn't bad for other algorithms, needs to be quantified using notation studied as part of the theory of algorithms

Abstraction, Complexity, Models

- **What is an integer?**
 - In mathematics we can define integers easily, infinite set of numbers and operations on the numbers (e.g., +, -, *, /)
{...-3, -2, -1, 0, 1, 2, 3, ...}
 - In programming, finite memory of computer imposes a limit on the magnitude of integers.
 - Possible to program with effectively infinite integers (as large as computation and memory permit) at the expense of efficiency
 - At some point addition is implemented with hardware, but that's not a concern to those writing software (or is it?)
- **Floating-point numbers have an IEEE standard, it's more expensive to do arithmetic with 3.14159 than with 2**

Alan Turing (1912--1954)

- Instrumental in breaking codes during WW II
- Developed mathematical model of a computer called a Turing Machine (before computers)
 - solves same problems as a Pentium III (more slowly)
- Church-Turing thesis
 - All “computers” can solve the same problems
- Showed there are problems that cannot be solved by a computer
- Both a hero and a scientist/mathematician, but lived in an era hard for gay people



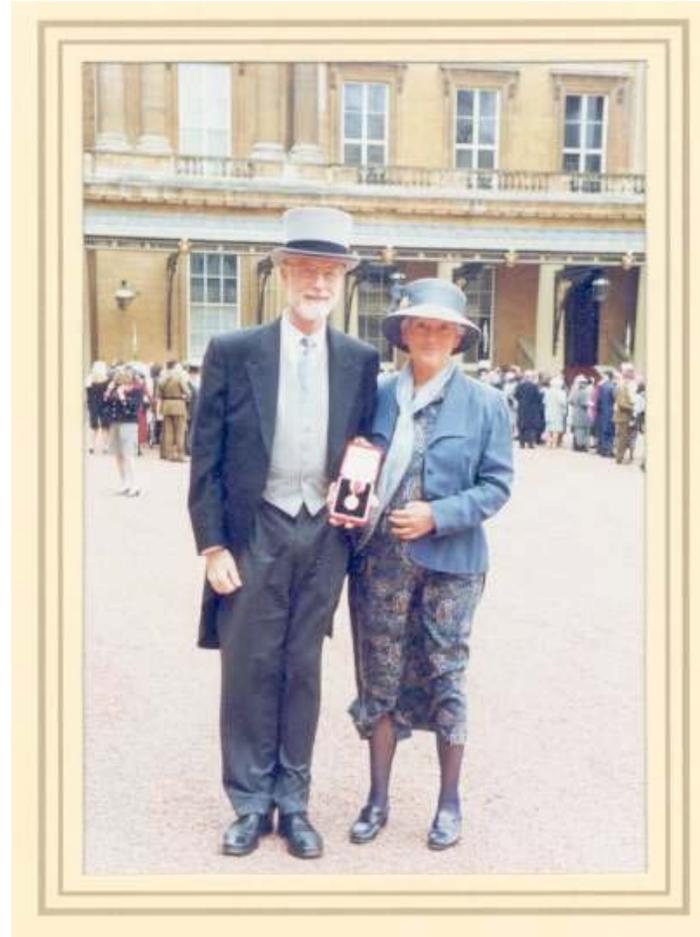
Complexity: What's hard, what's easy?

- **What is a prime number?**
 - 2, 3, 5, 7, 11, 13, ...
 - Largest prime?
- 48112959837082048697
- 671998030559713968361666935769
- **How do we determine if these numbers are prime?**
 - Test 3, 5, 7, ...
 - If we can test one million numbers a second, how long to check a 100 digit #?
- **Why do we care?**
- 671998030559713968361666935767 is not prime, I can prove it but I can't give you the factors.
- **Finding factors is "hard", determining primality is "easy"**
 - What does this mean?
 - Why do we care?
- **Encryption depends on this relationship, without encryption and secure web transactions where would we be?**

C.A.R. (Tony) Hoare (b. 1934)

- Won Turing award in 1980
- Invented quicksort, but didn't see how simple it was to program recursively
- Developed mechanism and theory for concurrent processing
- In Turing Award speech used "Emperor's New Clothes" as metaphor for current fads in programming

"Beginning students don't know how to do top-down design because they don't know which end is up"



What is digital?

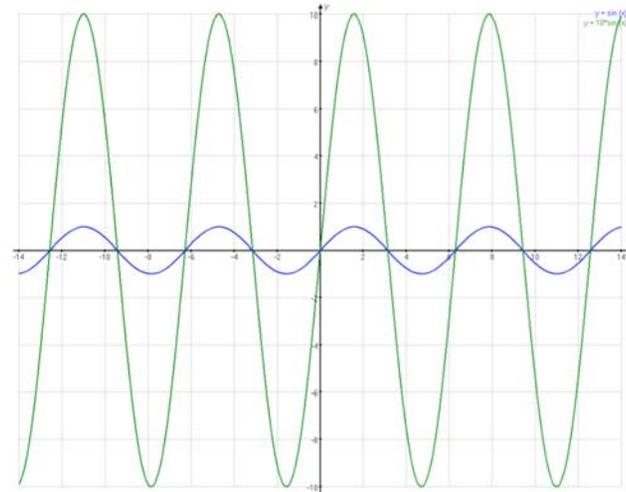
- **What's the difference between**

- Vinyl LP and CD/DVD?
- Rolex and Timex?

- **Sampling analog music for CD's**

- $44,100 \text{ samples/channel/second} * 2 \text{ channels} * 2 \text{ bytes/sample} * 74 \text{ minutes} * 60 \text{ seconds/minute} = 783 \text{ million bytes}$

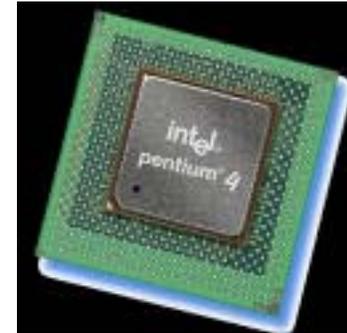
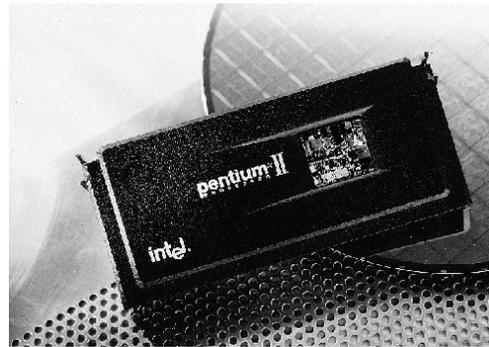
- **How does MP3 help?**



Chips, Central Processing Unit (CPU)

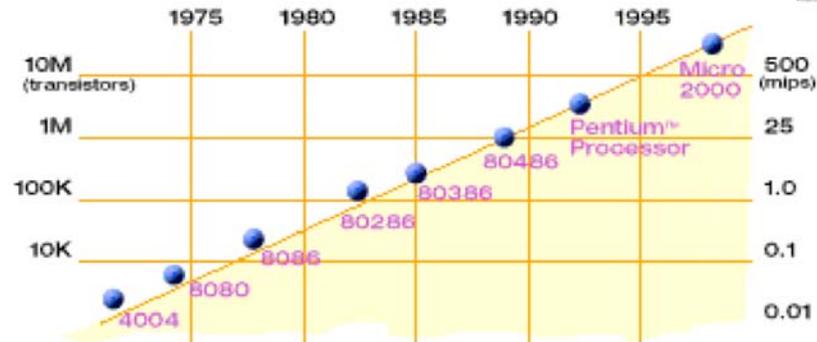
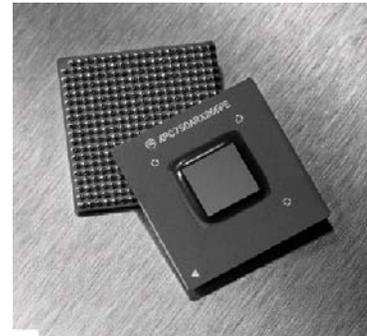
- CPU chips

- Pentium (top)
- G4 (bottom)
- Sound, video, ...



- Moore's Law

- chip "size" (# transistors) doubles every 12--18 months (formulated in 1965)
- 2,300 transistors Intel 4004, 42 million Pentium 4



Why is programming fun?

What delights may its practitioner expect as a reward?

First is the sheer joy of making things

Second is the pleasure of making things that are useful

Third is the fascination of fashioning complex puzzle-like objects of interlocking moving parts

Fourth is the joy of always learning

Finally, there is the delight of working in such a tractable medium. The programmer, like the poet, works only slightly removed from pure thought-stuff.