CMSC 330
Algorithms: Design & Practice
Or
Algorithms: Truth, Beauty & Engineering

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Algorithms:
Truth, Beauty & Engineering

• Truth
  – History
  – Ethics

• Beauty
  – Elegance
  – Communication

• Engineering
  – Tricks of the trade
  – Eyes open to the world

History & Ethics

• Is China an Enron? (Part 2)
  By THOMAS L. FRIEDMAN, NY Times

If China forces out Google and suppresses the nation’s flow of knowledge, then it will be time to short the Chinese Communist Party.


Who is this guy??

Edward Snowden

What did he do?
NY Times Editorial
Edward Snowden, Whistle Bowler
January 2, 2014

"When someone reveals that government officials have routinely and deliberately broken the law, that person should not face life in prison at the hands of the same government. That's why Rick Ledgett, who leads the N.S.A.'s task force on the Snowden leaks, recently told CBS News that he would consider amnesty if Mr. Snowden would stop any additional leaks. And it's why President Obama should tell his aides to begin finding a way to end Mr. Snowden's vilification and give him an incentive to return home."

Elegance

- Gordon Bell: The cheapest, fastest and most reliable components are those that aren't there.
- Antoine de Saint Exupéry: A designer knows he has arrived at perfection not when there is no longer anything to add, but when there is no longer anything to take away.
- Albert Einstein: Everything should be made as simple as possible, but no simpler.

A C++ Program


The code is 3 1/2 pages long

Contains these Functions:

main, CountLetters, CountLettersInString, RecordLetter, DisplayLetterCounts, LetterIndex, ClearIntegerArray

A Longer Program
Kernighan & Pike’s Version

```c
unsigned long count[ UCHAR_MAX+1 ];
/* freq main: display byte frequency counts */
int main(void)
{
    int c;
    while ((c = getchar()) != EOF)
        count[c]++;
    for (c = 0; c <= UCHAR_MAX; c++)
        if (count[c] != 0)
            printf("%.2x  %c  %lu
", c, isprint(c) ? c : '-', count[c]);
    return 0;
}
```

Communication

- How to talk about algorithms & computing?
- How to write about it?
- How to do presentations?
- How to exchange ideas?

Strunk & White’s Rule 17

Vigorous writing is concise. A sentence should contain no unnecessary words, a paragraph no unnecessary sentences, for the same reason that a drawing should have no unnecessary lines and a machine no unnecessary parts. This requires not that the writer make all sentences short, or avoid all detail and treat subjects only in outline, but that every word tell.

Algorithms:
Truth, Beauty & Engineering

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  - History
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- Beauty
  - Elegance
  - Communication
- Engineering
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A Quiz

- A TV Commercial
  - "U.S. college students eat 60 million slices of pizza per month."
  - Is this reasonable?
- How much does a one-hour lecture cost?
- A program sorts 1 million integers in one second. How long to sort 2 million? 10 Million?
- How long will an exhaustive search take to solve a TSP of size 10? 20? 30?
- How much do CS110 texts cost?
Eyes open to the world

- Cracking iPhones
  - How do iPhones work?
    - Mathematics, science, technology
  - Back of the Envelope
    - Capacity of an iPhone (how many songs)?
  - History of music and protection
  - Ethics

iPhone 5

Algorithms

A Bird’s Eye View

Information Processing

Problem Solving (Investigation of Processes)

- Given a dictionary of English words, what are all the anagram classes? (e.g., earthling, haltering, lathering)
- Given the details of a tropical depression, can you predict if it will become a hurricane? What path will it take?
- Can you play the game of chess in a way that guarantees a win or a draw?
- How does the mind work?
- What is the most optimal way to get from here to there?
- What is the square root of 42?
- If the Fed raises the short term interest rates, what impact will it have on international currencies?
- What is the meaning of life?

Investigation: Asking Questions

Given: A problem/process.
- Does it have a model?
- Is the model solvable?
- Is it computable?
- What is the best algorithm for it?
- Write a computer program that implements the algorithm.
- Is the program equivalent to the model?
- Does the model lend any new insights into the problem/process?
Given: A Problem

Does it have a model?

Is the model solvable?

Is it computable?

What is the best algorithm?

Write a program that implements the algorithm that models the problem.

Is the program correct?

Do the solutions offered by the program work in the real world?

Does the model/program offer any new insights into the problem?

Information Processing

Program that implements the model that solves the problem.

Input  Process  Output

Information Processing

Program that implements the model that solves the problem.

Input  Process  Output

World's Fastest Computer

As of June 2013, China’s National University of Defense Technology’s Tianhe-2 (aka Milky Way 2) operates at ~34 Peta Flops/Second.

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Computers & Clocks

- 1 flop = 1 floating-point operation (+, -, *, /) per second.
- 1 megaflop = 1 MF = 10^6 flops
- 1 gigaflop = 1 GF = 10^9 flops
- 1 teraflop = 1 TF = 10^12 flops
- 1 petaflop = 1 PF = 10^15 flops

- The fastest PC can give a peak performance of 1GF/second
- World’s fastest computer operates at approximately ~34PF/sec (as of June 2013): China’s National University of Defense Technology’s Tianhe-2 (aka Milky Way 2) with ~3.1 million cores.
- Examining a single board of a chess game is roughly equivalent to 1000 FLOPS.
- To make one move the computer will have to examine approximately 10^65 board situations.
- This will take the Jaguar approximately 10^45 years to make one move!
Computability:
Problems that can be solved by algorithms (Turing Machines)

Complexity Theory:
Computational Resources required to solve a given problem (time & space)

What is an algorithm?
A set of instructions arranged in a specific order is a procedure.
Similar to a recipe, process, method, technique, procedure, routine, rigmarole, except the word “algorithm” connotes just a little something different.

An algorithm is a finite, definite, effective procedure, with some output.

Algorithm (origins)
Abu 'Abd Allah Muhammad ibn Musa al-Khwarizmi, ~780-850 A.D.
(Father of Abdullah, Mohammad, son of Moses, native of Khwarizm)
Was a member of Dar Al Hikmah (House of Wisdom) in Baghdad.
Kitab al jabr wa'l-muqabala (Rules of restoring and equating)

Algorithm (properties)
Finite
there must be an end to it within a reasonable time
Definite
Precisely definable in clearly understood terms, no “pinch of salt” type vagaries, or possible ambiguities
Effective
It must be possible to actually carry out the steps
Procedure
The sequence of specific steps
Output
unless there is something coming out of the computation, the result will be unknown.
**Problem Size**

- Time complexity of a problem is the number of steps that it takes to solve an instance of the problem as a function of the size of the input. i.e. if the input is of size, \( n \), it will take \( f(n) \) steps to solve it.

**Complexity Classes**

(If steps it takes to solve a problem)

- Constant time: \( O(1) \)
- Logarithmic time: \( O(\log n) \)
- Linear time: \( O(n) \)
- Quadratic Time: \( O(n^2) \)
- Polynomial time (P): \( O(n^c) \)
- Non-deterministic Polynomial Time (NP): \( O(n^c) \) on some inputs.
- Exponential time: \( O(2^n) \)
- Exponential time (in general): \( O(2^{O(n)}) \)

**Algorithms: Performance**

**P = NP?**

“We did not invent the algorithm. The algorithm consistently finds Jesus. The algorithm killed Jeeves. The algorithm is banned in China. The algorithm is from Jersey. The algorithm constantly finds Jesus. This is not the algorithm. This is close.”