CSE 373: Algorithm Classification

Miscellaneous (Chapters 9 & 10)

Algorithm Types

Implementations:

- **recursive** vs. **iterative**

Algorithm Methodology:

- **divide-and-conquer** (*e.g.*, Binary Search, Quicksort)
- **greedy** (*e.g.*, Dijkstra's & Kruskal's Algorithms)
- **dynamic programming** (*e.g.*, efficient fibonacci)

Algorithm Requirements

Space and **Time**:

- asymptotic analysis for primary effects
- evaluation of secondary effects
  - by inspection
  - by experimentation

Q: How fast/space-efficient is "good enough?"

(*e.g.*, O(n) was bad for `Delete()`, but O($n$log$n$) was great for `Sort()`…)

A:

Criteria for Good Running Time

Your resources

- how much time/memory can you afford?

Nature of the problem

- some problems are just harder than others

(sorting is harder than deletion)

Characteristics of your application

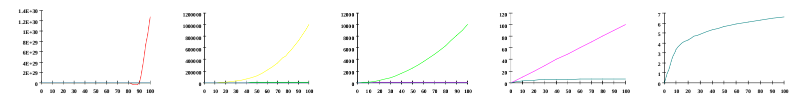
- what problem sizes/input sets will you typically be running on? (be sure to plan for the future)

Maintainability/Elegance

- this tends to dominate software development costs

Evaluating Running Time/Space

O(1)	– ideal
O(log$n$)	– generally as good as ideal
O(n)	– could be better, could be worse
O($n$log$n$)	– could be better, could be worse
O(n^2)	– could be better, could be worse
O(2^n)	– unusable



Games Theoreticians Play

Prove that an algorithm is $\Omega(f(n))$ by nature

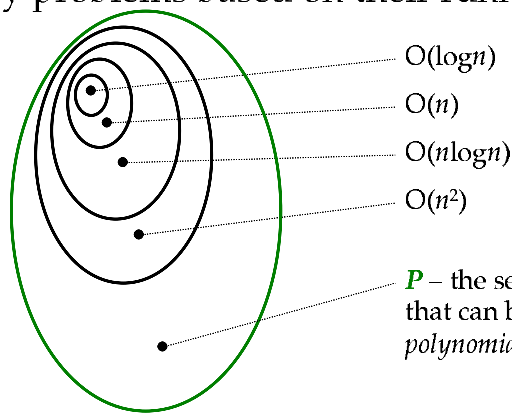
- *e.g.*, sorting using only comparison (<, >, =) cannot be done in less than $n$log$n$ time (Chapter 7)

What's wrong with this claim:

"I wrote a `FindMin()` operation that runs in O(log$n$) time on an unsorted list of integers"

More Games Theoreticians Play

Classify problems based on their running times



What isn't in *P*?

- All problems that require more than polynomial time (*e.g.*, $O(2^n)$)
- All problems that cannot be solved with a computer (*intractable* problems)

And maybe…

- A set of problems (***NP***) that nobody knows whether or not they're in ***P***

Sample Intractable Problem

The Halting Problem: Can you write a function that takes a C program as input and determines whether or not the program will halt?

Answer: No, it's intractable (impossible to solve on a computer)

Proof

Assume that we have such a procedure: **`halt()`**

Write the following program(*`testhalt.c`*):

```
void main() {
  int willhalt;

  willhalt = halt("testhalt.c");
  if (willhalt) {
    while (1) { };
  } else {
    exit(0);
  }
}
```

Intractability Summary

- Lots of intractable problems are of the form "we can't detect property *x* about a program"
- Proofs are similar to that of halting problem
- However, *heuristics* can be used to detect and warn about some simple cases:

```
void main() {
  main();
}
```

```
void main() {
  while (1) {
  }
}
```


NP Problems

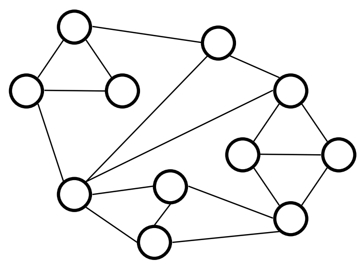
NP:

- A class of problems for which exponential algorithms have been developed
- Nobody has found a polynomial-time algorithm for any of them
- *Yet*, nobody has proven that any of them could not have polynomial time algorithms
- This leads to the <u>*BIG*</u> question:

P = *NP*?

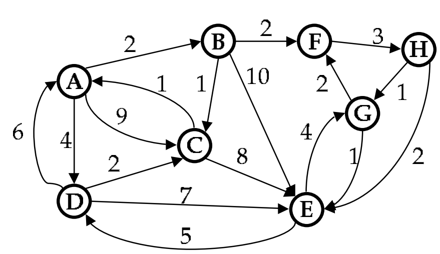
Sample NP Problem

Graph 3-Colorability Problem: Given a graph $G = (V,E)$, is it possible to color its vertices using 3 colors so that no two adjacent nodes are the same color?



Another Sample NP Problem

Traveling Salesperson Problem: Given a graph $G = (V,E)$, find a path that starts and ends at the same vertex, visits each vertex exactly once, and has minimal cost?



Solving NP Problems

- Exponential solution is too slow for any interesting problem size
- The best we can do is come up with heuristics that give us an approximate solution in polynomial time

Good Running Times (Again)

- Whew, our problem is not intractable!
- Whew, our problem is not in ***NP***!
- Now let's get the asymptotic requirements as low as possible*
- Then let's get the secondary effects as good as possible*

* Always keeping code maintenance in mind