

Lecture 1: Course Overview

Computer Systems Organization (Spring 2017)
CSCI-UA 201, Section 3

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Slides adapted from
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Well, not that kind of organization

Abstraction is good, but ...

- Most CS and CE courses emphasize abstraction
 - Abstract data types
 - Asymptotic analysis (like the Big-O notation)
- These abstractions have limits
 - Especially in the presence of bugs
 - Need to understand details of underlying implementations
- Useful outcomes from taking CS201
 - Become more effective programmers
 - Able to find and eliminate bugs efficiently
 - Able to understand and tune for program performance
- Prepare for later “systems” classes in CS
 - Compilers,
 - Operating Systems,
 - Networks,
 - Computer Architecture,
 - Embedded Systems,
 - etc.

This class adds to your CV:

- C programming
- Unix / Linux familiarity
- X86-64 assembly
- Low level debugging
- Reverse engineering
- Understanding of computer systems
- ...

Programmers' Reality #1:

ints are not integers, floats/doubles are not real numbers

Is $x^2 \geq 0$?

- in a math class: YES (when x is an integer or a real number)
- on a computer: IT DEPENDS on x
 - for example: when x is an int

$$30,000 * 30,000 = 900,000,000$$

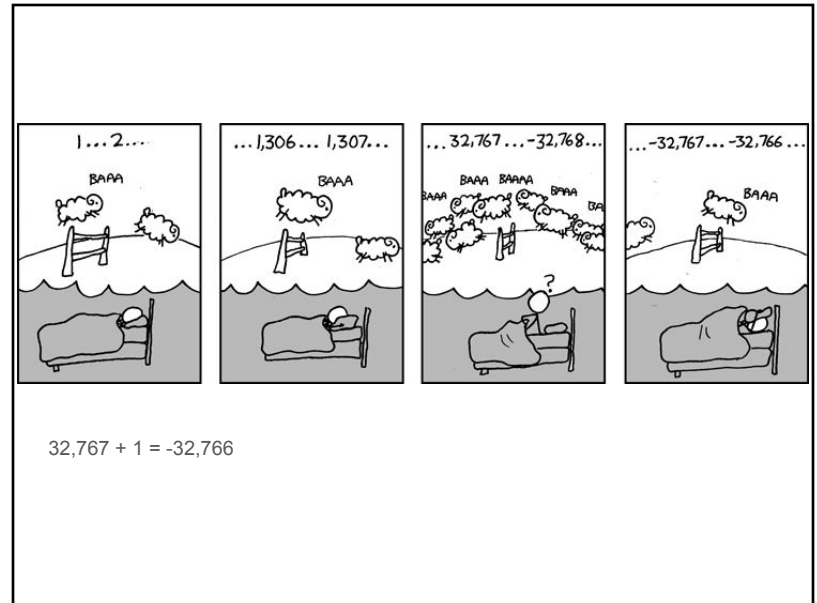
$$50,000 * 50,000 = ???$$

Is $(x+y) + z = x + (y+z)$?

- in math class: YES (when x is an integer or a real number)
- on a computer: IT DEPENDS on x, y, z
 - for example: when x, y, z are of type float

$$(1e20 + -1e20) + 3.14 = 3.14$$

$$1e20 + (-1e20 + 3.14) = ???$$



Programmers' Reality #2:

you need to know assembly

- Chances are, you'll never write programs in assembly
 - Compilers are much better & more patient than you are
- But: understanding assembly is key to machine-level execution model
 - Debugging
 - Performance tuning
 - Writing system software (e.g. compilers, OS)
 - Reverse engineering software
 - Creating / fighting malware

Programmers' Reality #3:

memory matters

- Memory is not unbounded
 - It must be allocated and managed
 - All running applications and data have to be in memory, all applications can address lots of memory. Where does it all go?
- Memory referencing bugs especially wicked
 - Effects are distant in both time and space (i.e., may not happen until much later or in a different part of the program or data structure)
- Memory performance is not uniform
 - Cache and virtual memory effects can greatly affect program's performance
 - Adapting program to characteristics of memory system can lead to major speed improvements

Example: Array access

```
#include <stdio.h>

int main ( ) {
    int d = 3;
    printf("d = %d\n", d);
    int a[1];
    int i;
    for (i = 0; i < 5; i ++ ) {
        a[i] = 214748364;
    }
    printf("d = %d\n", d);
}
```

OUTPUT (one possibility):

```
d = 3
d = 214748364
```

Memory referencing errors

- C and C++ do not provide any memory protection
 - Out of bounds array references
 - Invalid pointer values
 - Abuses of malloc/free
- Can lead to nasty bugs
 - Whether or not bug has any effect depends on system and compiler
 - Action at a distance
 - Corrupted object logically unrelated to one being accessed
 - Effect of bug may be first observed long after it is generated
- How can I deal with this?
 - Program in Java, Ruby, Python, ML, ...
 - Understand what possible interactions may occur
 - Use or develop tools to detect referencing errors (e.g. Valgrind)

Programmers' Reality #4:

there is more to performance than asymptotic analysis

- (But do not tell your teachers in Data Structures and Algorithms courses that I said that!)
- Constant factors matter too!
- Optimization has to happen at multiple levels: algorithm, data representation, details of implementation.
- Optimizing implementation requires understanding of the underlying system.
 - How programs are compiled and executed
 - How to measure program's performance and identify bottlenecks
 - How to improve performance without destroying code modularity and generality

Example: What is Big-O notation of these two programs?

```
void copyij(int src[2048][2048],
            int dst[2048][2048])
{
    int i,j;
    for (i = 0; i < 2048; i++)
        for (j = 0; j < 2048; j++)
            dst[i][j] = src[i][j];
}
```

```
void copyji(int src[2048][2048],
            int dst[2048][2048])
{
    int i,j;
    for (j = 0; j < 2048; j++)
        for (i = 0; i < 2048; i++)
            dst[i][j] = src[i][j];
}
```

**About 7 times faster on
Intel® Core™ i7-3930K CPU @ 3.20GHz × 12 .**

WHY?

Programmers' Reality #5:

computers do more than execute programs

- They need to get data in and out
 - I/O system critical to program reliability and performance
- They communicate with each other over networks
 - Many system-level issues arise in presence of network