Lecture 1: Introduction to Computer Systems

CS 105

https://cs.pomona.edu/classes/cs105/

Programming on Computers

- We are very comfortable with "coding" by now
  - loops, functions…
- riting programs that run on
- Sometimes, we need more fine-grained control (or at least more precise information) about what is happening
emory
- uations and new subtleties
- This class is to help you handle those times

Correctness

- **Example 1: Is $x^2 \geq 0$?**

- **Example 2: Is $(x + y) + z = x + (y + z)$?**

Performance

```c
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];
    }
  }
}
```

```c
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];
    }
  }
}
```

Security

```
int buggy_authenticate(){
  char password[4]; // allocate space to store a string
  gets(password);   // initialize string from user input

  return 0;         // always returns False
}

void example3(){
  if(buggy_authenticate()){ // equivalent to if False
    printf("The answer is 42\n"); // should never happen
  } else {
    printf("Unauthenticated User (correct behavior)\n");
  }
}
```

BITS

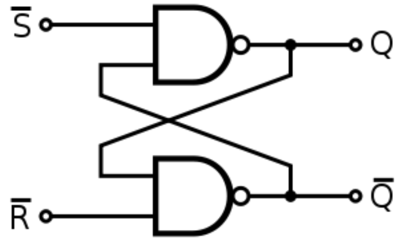
Bits

- a **bit** is a binary digit that can have two possible values

- can be physically represented with a two state device

Storing bits

- Static random access memory (SRAM): stores each bit of data in a flip-flop, a circuit with two stable states
- Dynamic Memory (DRAM): stores each bit of data in a capacitor, which stores energy in an electric field (or not)
- Magnetic Disk: regions of the platter are magnetized with either N-S polarity or S-N polarity
- Optical Disk: stores bits as tiny indentations (pits) or not (lands) that reflect light differently
- Flash Disk: electrons are stored in one of two gates separated by oxide layers



Boolean Algebra

- Developed by George Boole in 19th Century
- Algebraic representation of logic---encode "True" as 1 and "False" as 0

And

&	0	1
0	0	0
1	0	1

Or

|	0	1
0	0	1
1	1	1

Not

~	
0	1
1	0

Exclusive-Or (Xor)

^	0	1
0	0	1
1	1	0

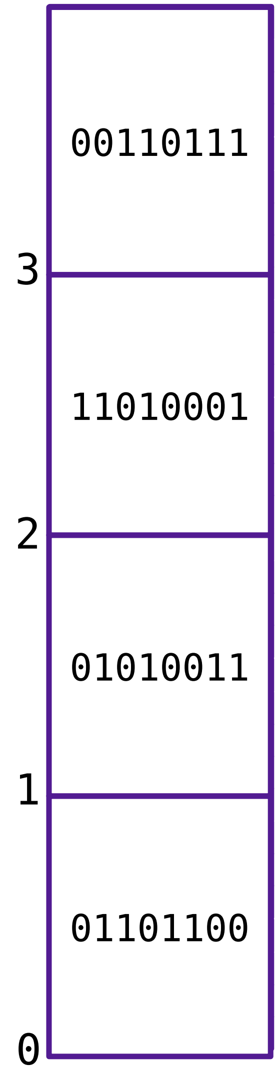
- How does this map to set operations?

Exercise 1: Boolean Operations

- Evaluate each of the following expressions
  1. `1 | (~1)`
  2. `~( 1 | 1)`
  3. `(~1) & 1`
  4. `~( 1 ^ 1)`

Bytes and Memory

- **Memory** is an array of ~~bits~~ bytes
- A **byte** is a unit of eight bits
- An index into the array of memory is an **address**, **location**, or **pointer**
- We speak of the *value* in memory at an address
  - The value may be a single byte …
  - … or a multi-byte quantity starting at that address



General Boolean algebras

- Bitwise operations on bytes

```
  01101001     01101001     01101001
& 01010101   | 01010101   ^ 01010101   ~ 01010101
----------   ----------   ----------   ----------
  01000001     01111101     00111100     10101010
```

Exercise 2: Bitwise Operations

- Assume: `a = 01101100, b = 10101010`

- What are the results of evaluating the following Boolean operations?

  - `~a`
  - `a & b`
  - `a | b`
  - `a ^ b`

Bitwise vs Logical Operations

- Bitwise Operators &, |, ~, ^
  - View arguments as bit vectors
  - operations applied bit-wise in parallel

- Logical Operators &&, ||, !
  - View 0 as “False”
  - View anything nonzero as “True”
  - Always return 0 or 1
  - Early termination

Exercise 3: Bitwise vs Logical Operations

- ` ~01101100`
- ` ~00000000`
- `~~01101100`

- ` !01101100`
- ` !00000000`
- `!!01101100`

- `01101100 & 10101010`
- `01101100 | 10101010`

- `01101100 && 10101010`
- `01101100 || 10101010`

Bit Shifting

- Left Shift: **x << y**
  - Shift bit-vector **x** left **y** positions
  - Throw away extra bits on left
  - Fill with 0's on right

Undefined Behavior if you shift amount < 0 or ≥ word size

- Right Shift: **x >> y**
  - Shift bit-vector **x** right **y** positions
  - Throw away extra bits on right
  - Logical shift: Fill with 0's on left
  - Arithmetic shift: Replicate most significant bit on left

Choice between logical and arithmetic depends on the type of data

Example: Bit Shifting

- 01101001 << 4 — 10010000
- 01101001 >>$_l$ 2 — 00011010
- 01101001 >>$_a$ 4 — 00000110

Exercise 4: Bit Shifting

- `10101010 << 4`
- `10101010` $>>_l$ `4`
- `10101010` $>>_a$ `4`

Bits and Bytes Require Interpretation

10001100 00001100 10101100 00000000

might be interpreted as

- The integer 3,485,745
- A floating point number close to 4.884569×10^{-39}
- The string “105”
- A portion of an image or video
- An address in memory

Information is Bits + Context

LOGISTICS

The Course in a Nutshell

- Textbooks (not required)
    - Bryant and O'Halloran, *Computer Systems: A Programmer's Perspective*, **third edition**, Pearson, 2016
    - Arpaci-Dusseau and Arpaci-Dusseau, *Operating Systems: Three Easy Pieces,* online, 2018
- Classes
    - Tuesday and Thursday, 1:15-2:30pm in SCOM 102
- Labs
    - Fridays in Edmunds 105 at 1:15
    - **Starts this Friday**!
    - Lab nominally ends at 2:30, but we have the space longer
- Office Hours Mo/Fr 9:30-11:30
- Mentor Sessions TBA

Grading

- Assignments (9)
  - Introduced after Wednesday class, due Thursdays at 11:59pm
  - Tremendous fun, work in pairs during lab
  - 10 late days

- Check-ins (5)
  - three-question quizzes (13 topics total)
  - Feb 14, Mar 14, Apr 4, Apr 18, May 1
  - Can improve grade on any topics(s) with "Extra Chance Check-in" (may take after any later check-in or during final class period May 6)

- Grades
  - Must successfully complete all the assignments
  - 40% assignments, 40% check-ins, 15% quizzes, 5% participation

Quiz 1

- What are the main resources you can use to get help in this class?
- What should you do if you think you can't complete an assignment on time?
- Where will you be this Friday from 1:15-2:30?

> Take 5 minutes to answer

> Compare answers with your local group, update if need be

> Self-grade and turn in your papers

Course website

https://cs.pomona.edu/classes/cs105

- All information is on the course website
- All course materials get posted on the course website
- Links from the course page:
  - Slack (#csci105po-2425-sp), for questions and discussion
  - Gradescope, for submitting assignments and seeing grades
  - Additional resources