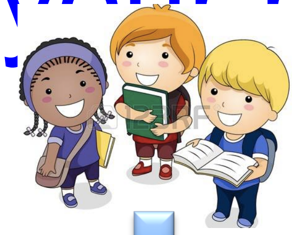
Computer Systems Organization

Jinyang Li

Slides are based on Tiger Wang's class

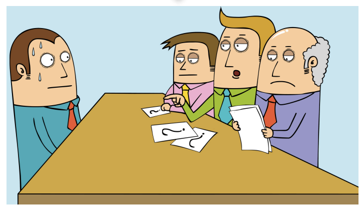
Why study CSO?

The path of your next few years



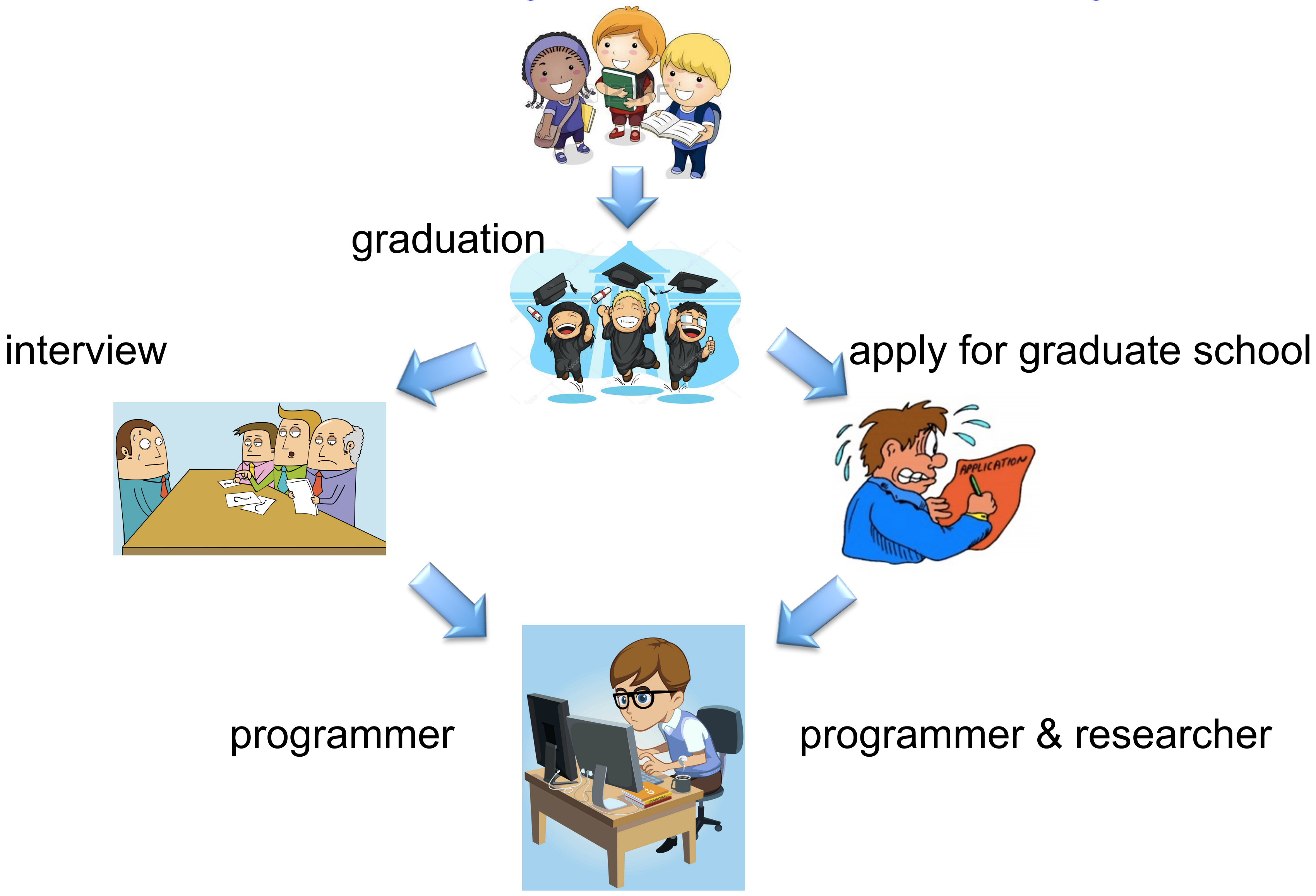
graduation

interview

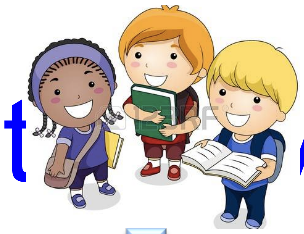


programmer

The path of your next few years



The pat your next few years

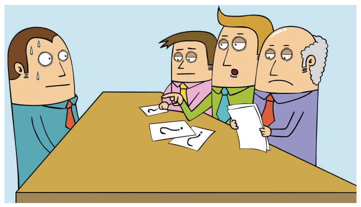


graduation

interview

graduate school

startup

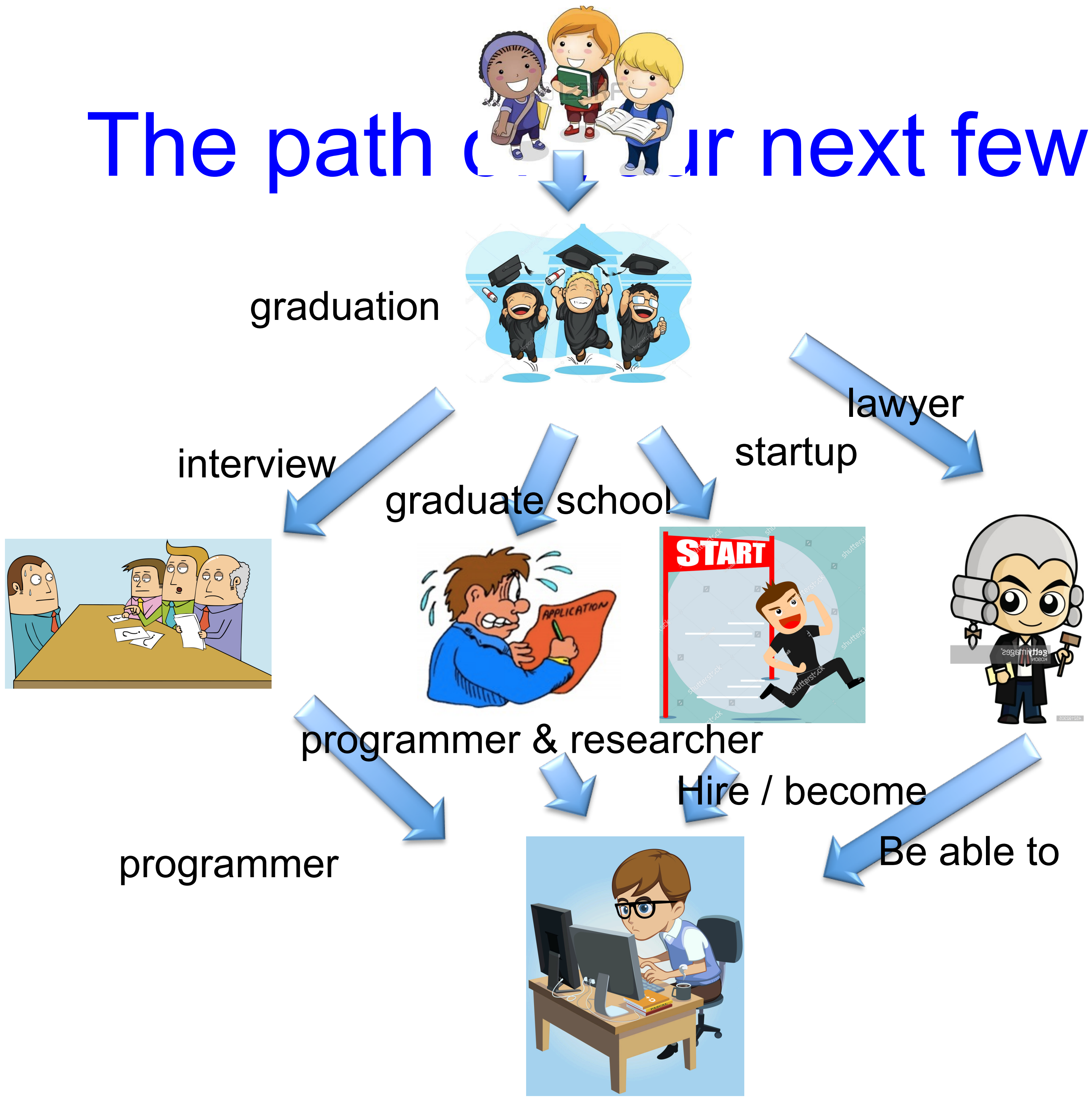


programmer & researcher

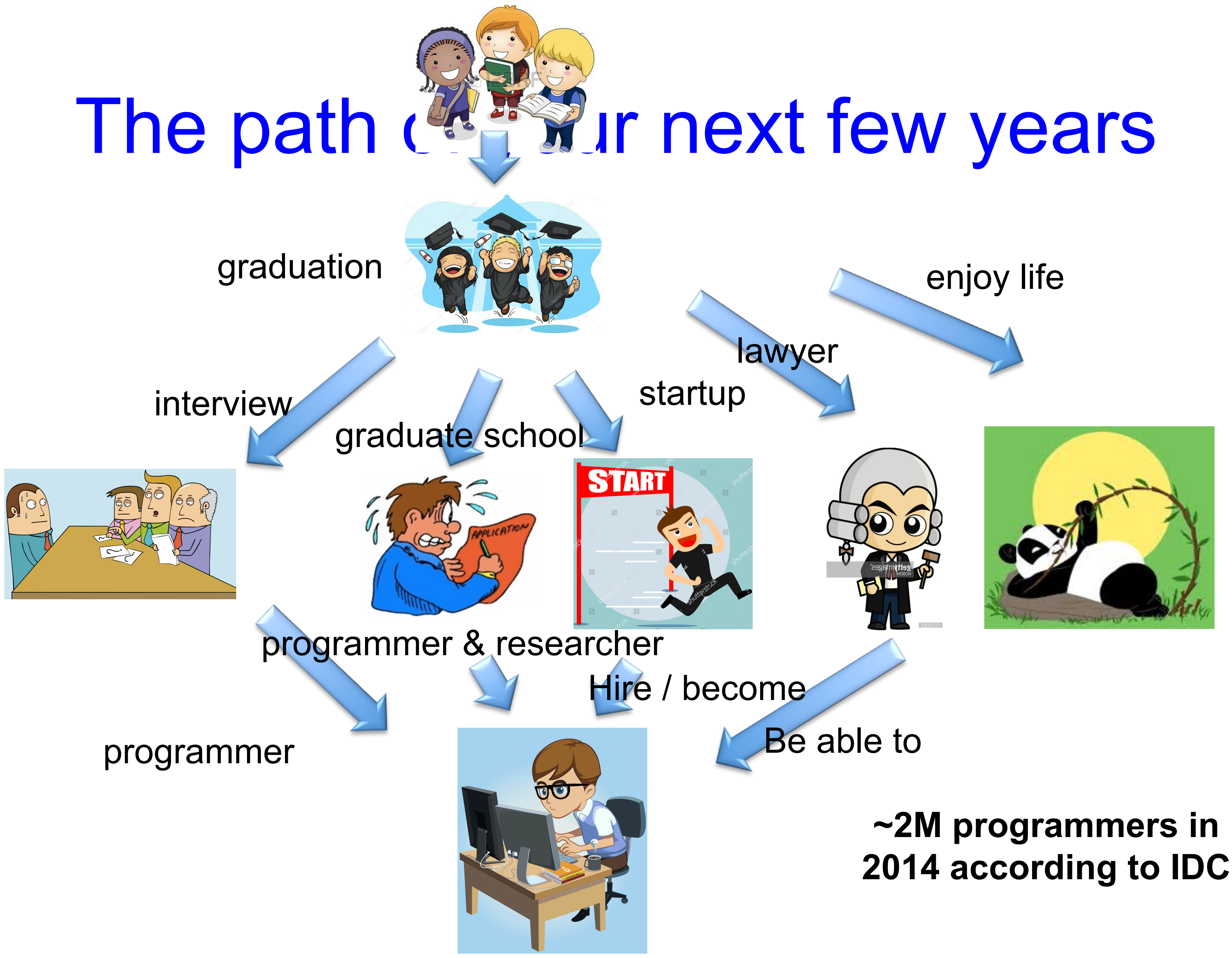
programmer

Hire / become

The path of your next few years



The path of your next few years



~2M programmers in 2014 according to IDC

The path of your next few years

graduation

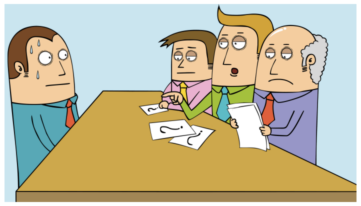
enjoy life

lawyer

startup

interview

graduate school



programmer & researcher

Hire / become

Be able to

programmer

be in a relationship with

Taking CSO will affect each step in the path!

For Graduation

- Required class
  - For CS Major
  - Also for CS minor ☹
- Prepare for your later system classes
  - Operating Systems, Compilers, Networks, Computer Architecture, Distributed Systems

For Interview

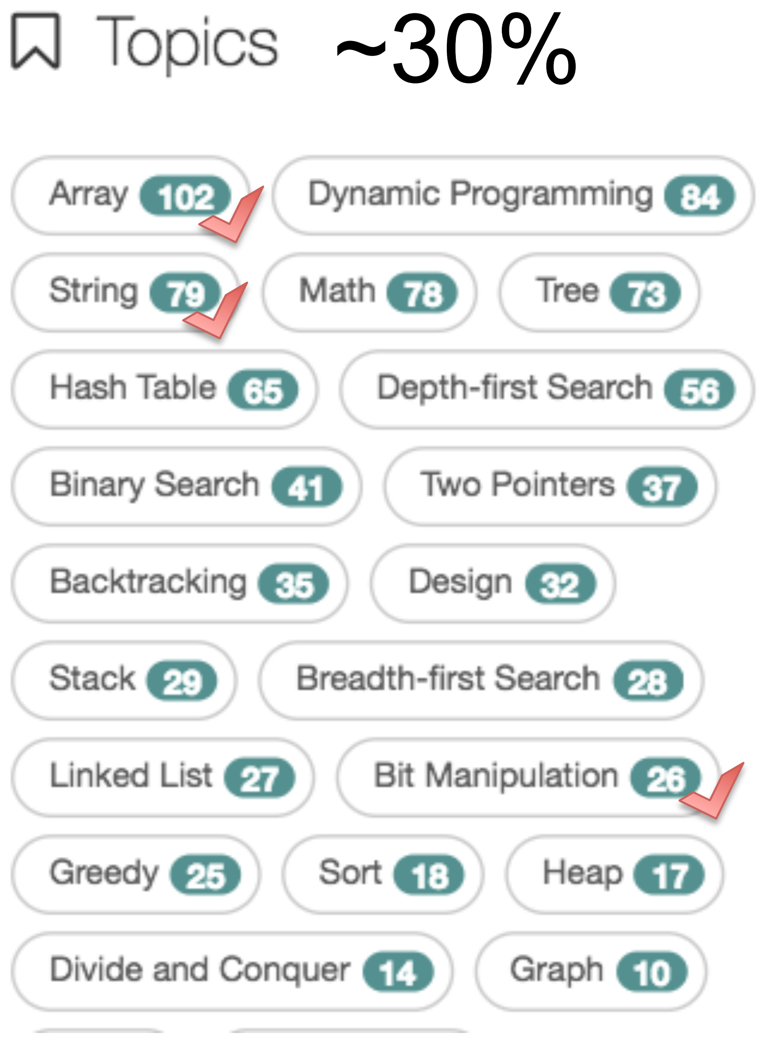
This class adds to your CV

– C Programming, UNIX, X86 Assembly …

Interview related topics

– Basic knowledge of Array, String, Bit Manipulation

Topics Distribution From LeetCode



Topics ~30%

[✓ Array 102] Dynamic Programming 84

[✓ String 79] Math 78 Tree 73

Hash Table 65 Depth-first Search 56

Binary Search 41 Two Pointers 37

Backtracking 35 Design 32

Stack 29 Breadth-first Search 28

Linked List 27 [✓ Bit Manipulation 26]

Greedy 25 Sort 18 Heap 17

Divide and Conquer 14 Graph 10

Some examples and exercises in this class are derived from the real interview questions !

Our text books are considered as the bibles of job interview.

For Graduate School Application

- This class adds to your CV
  - A
- Research related topics
  - Performance optimization
    - Memory layout, code optimization, memory allocation, concurrent programming
  - Security
    - Buffer Overflow

Startup

The life you imagine

CEO

CTO

CFO

COO

Startup

Your real life: full stack programmer

Server

Website

Phone’s App

Optimizations

My lawyer friend

Take >10 hours each day to extract information from the documents

My lawyer friend

I want to study programming.

My lawyer friend

I want to study programming.

Ok, you need to study CSO first.

My lawyer friend

I want to study programming.

Ok, you need to study CSO first.

Hmm…, I want to marry a programmer.

My lawyer friend

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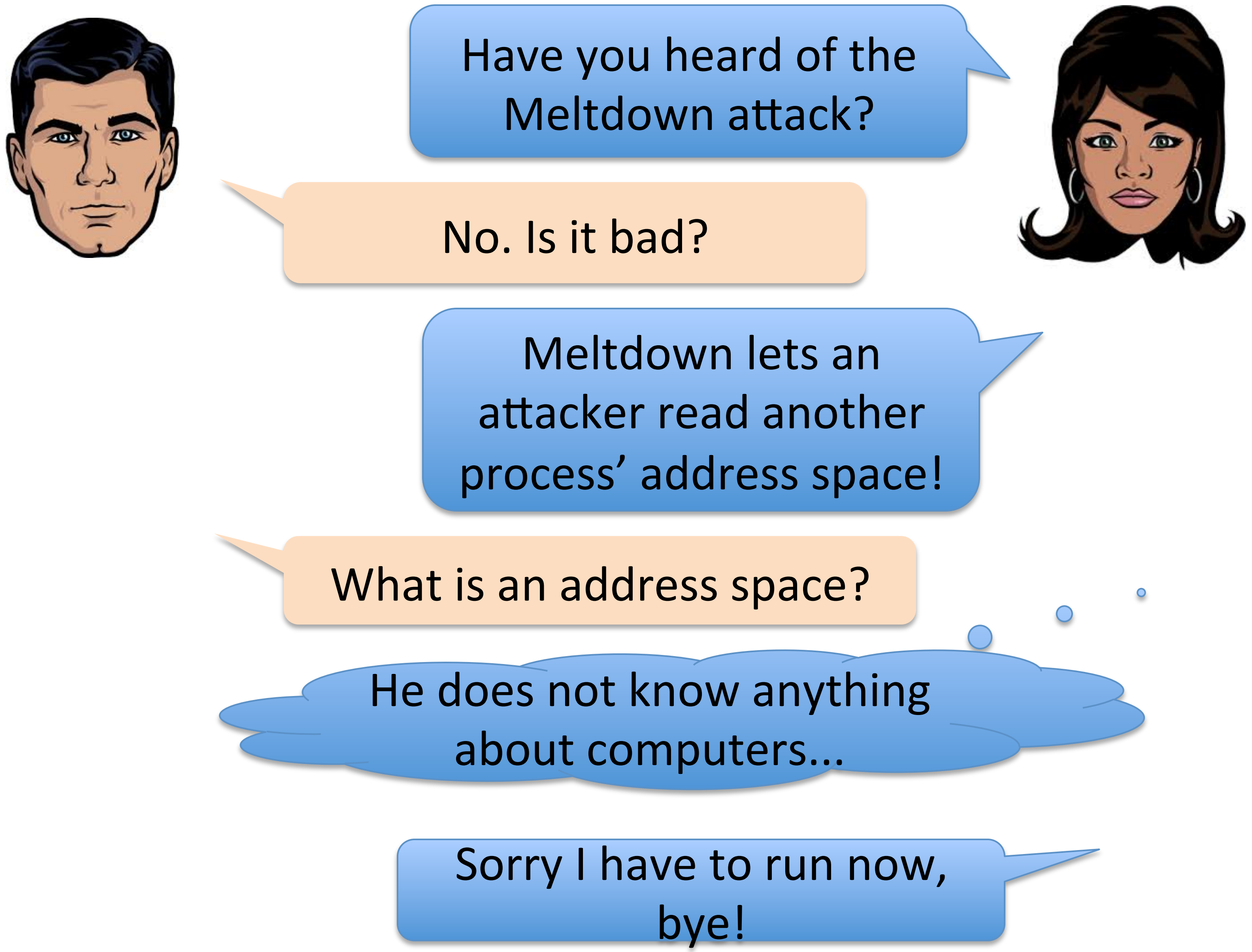
Ok, you need to study CSO first.

Hmm…, I want to marry a programmer.

Ok, you need to study CSO first.

…The user is offline

Conversation between programmers


Have you heard of the Meltdown attack?
No. Is it bad?
Meltdown lets an attacker read another process’ address space!
What is an address space?
He does not know anything about computers...
Sorry I have to run now, bye!

For Programming

Understand how your program runs on the hardware

- Why it fails
- Why it is slow

Why it fails?

What is the result of 1000,000 * 1000,000 ?

Why it fails?

What is the result of 1000,000 * 1000,000 ?

Expected answer: 1000,000,000,000 (1 trillion)

Why it fails?

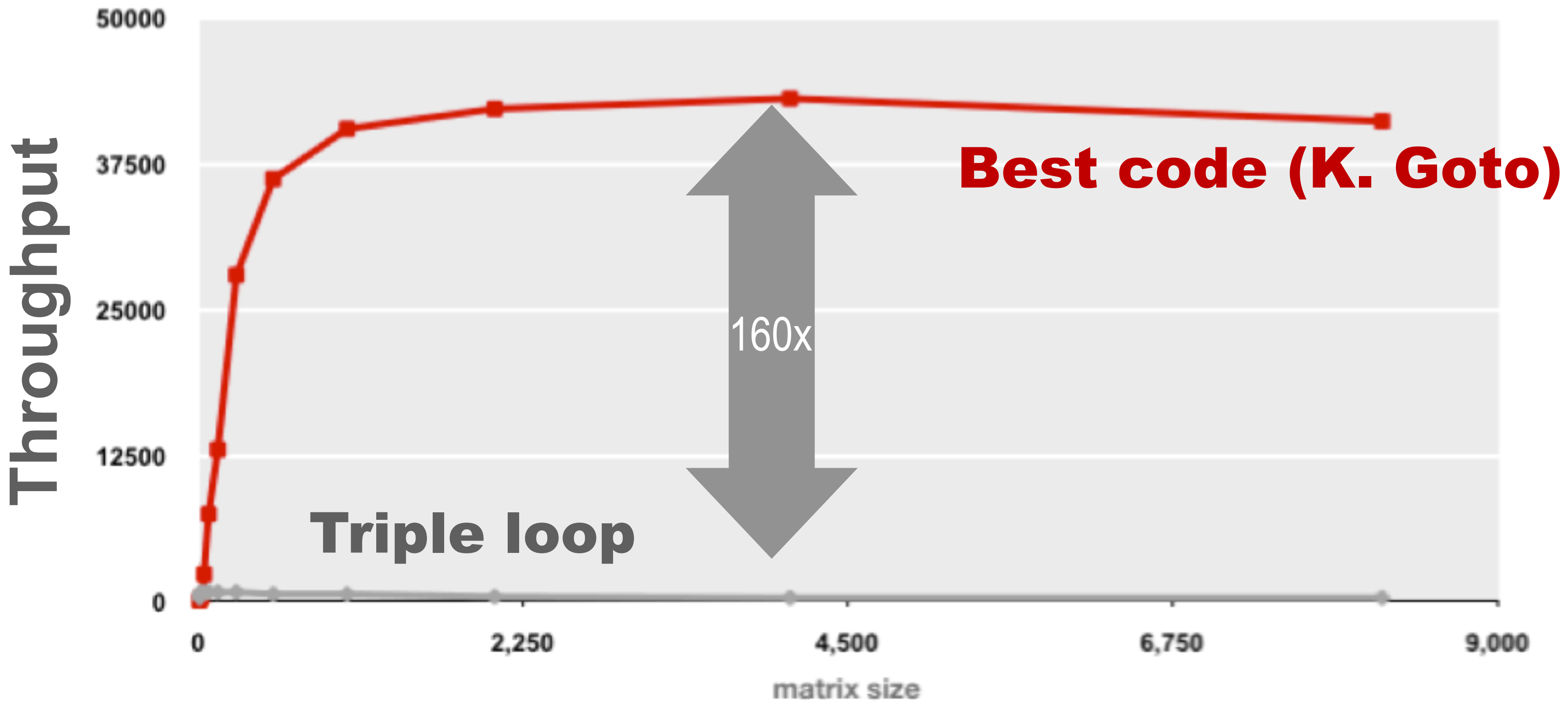
What is the result of 1000,000 * 1000,000 ?

Expected answer: 1000,000,000,000 (1 trillion)

```
int main()
{
   int a = 1000000;
   int b = 1000000;
   int r = a * b;
   printf("result is %d\n", r);
   return 0;
}
```

Why it is slow?

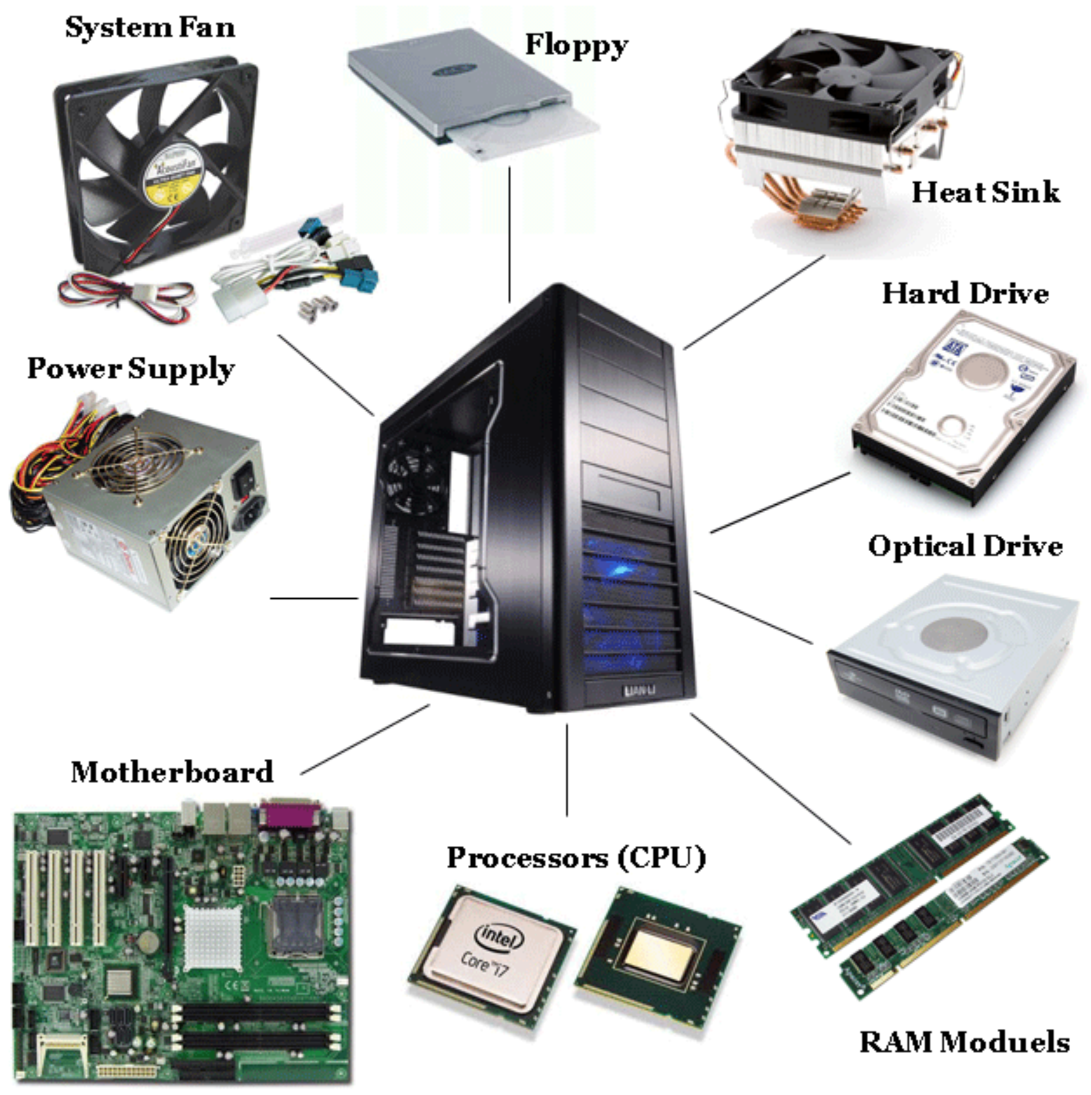
Example Matrix Multiplication



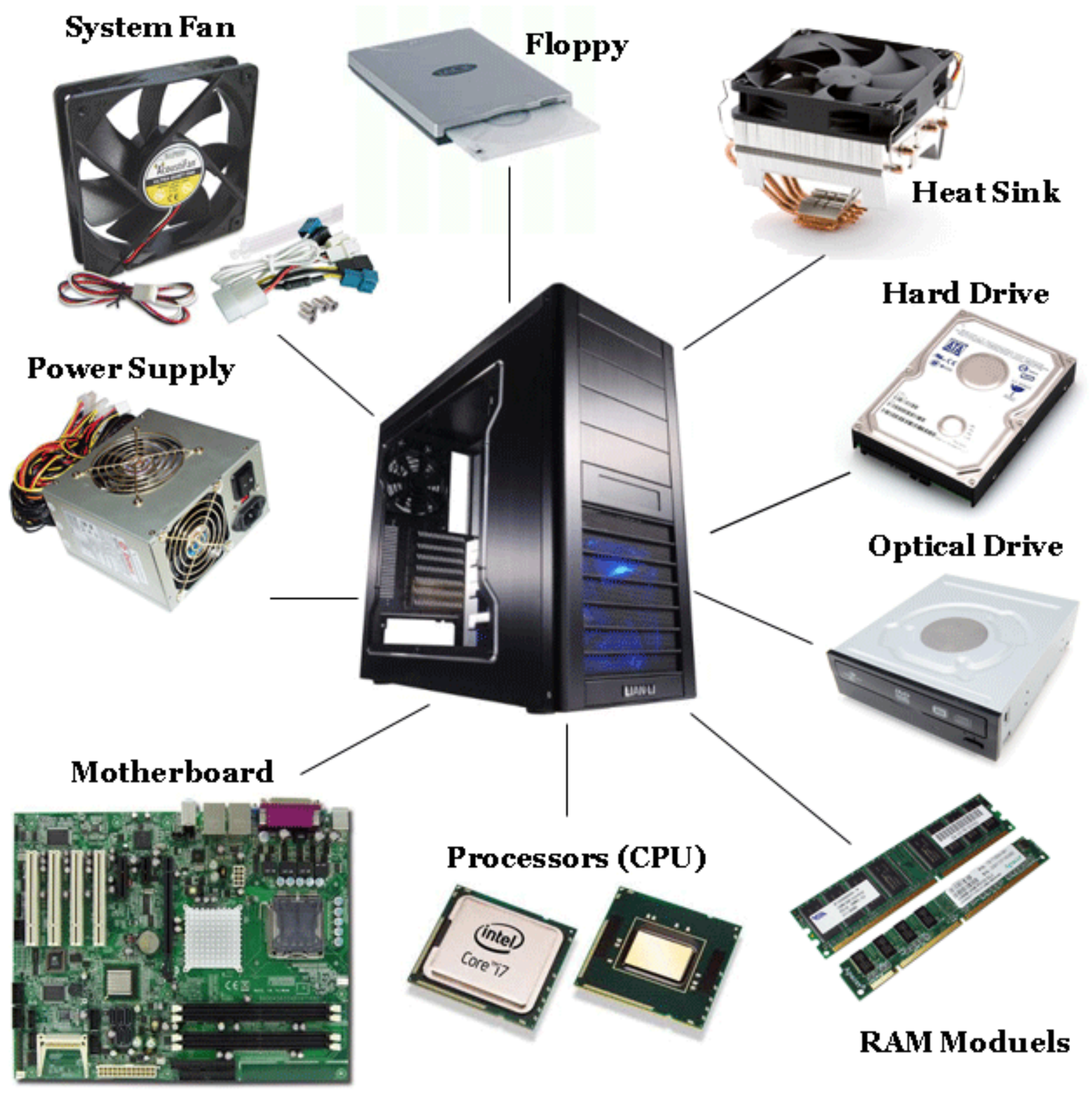
Both implementations have exactly the same operations count ($2n^3$)

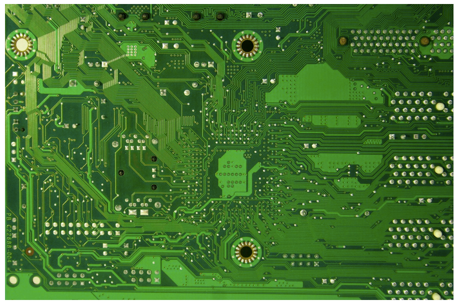
What is CSO about?

Computer System Organization



Computer System Organization





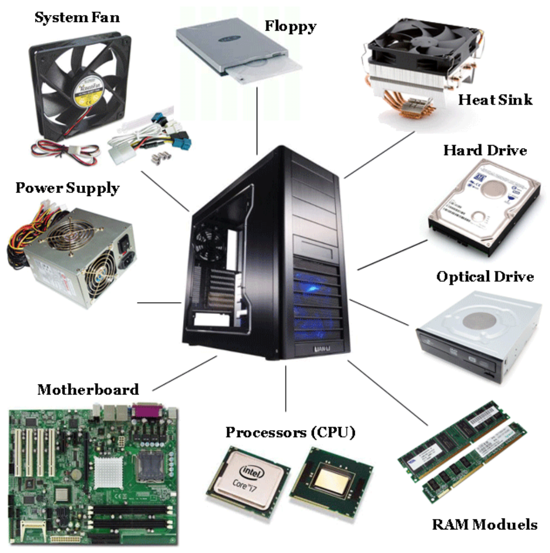
Printed Circuit

Computer System Organization

Layered Organization

Software

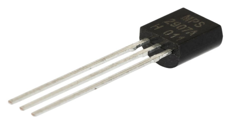
Hardware



Layered Organization

Software

Hardware


Transistors

Diodes

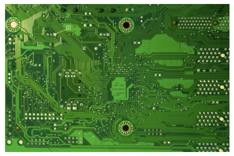
Resistors

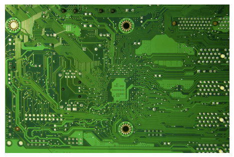
Layered Organization

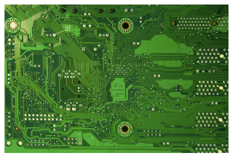
Software

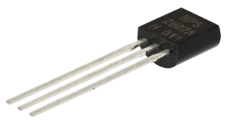
Hardware

Logical Circuits, Flip-Flops, Gates









Transistors

Diodes

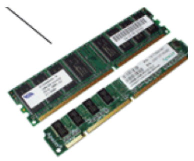
Resistors

Layered Organization

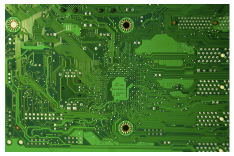
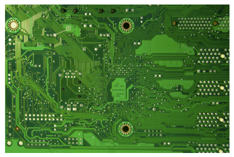
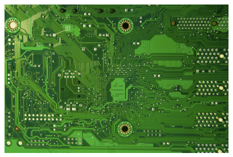
Software

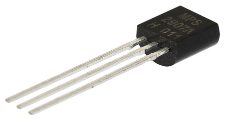
Hardware

CPU, Memory, Disk



Logical Circuits,
Flip-Flops, Gates



Transistors Diodes Resistors

Layered Organization

Software

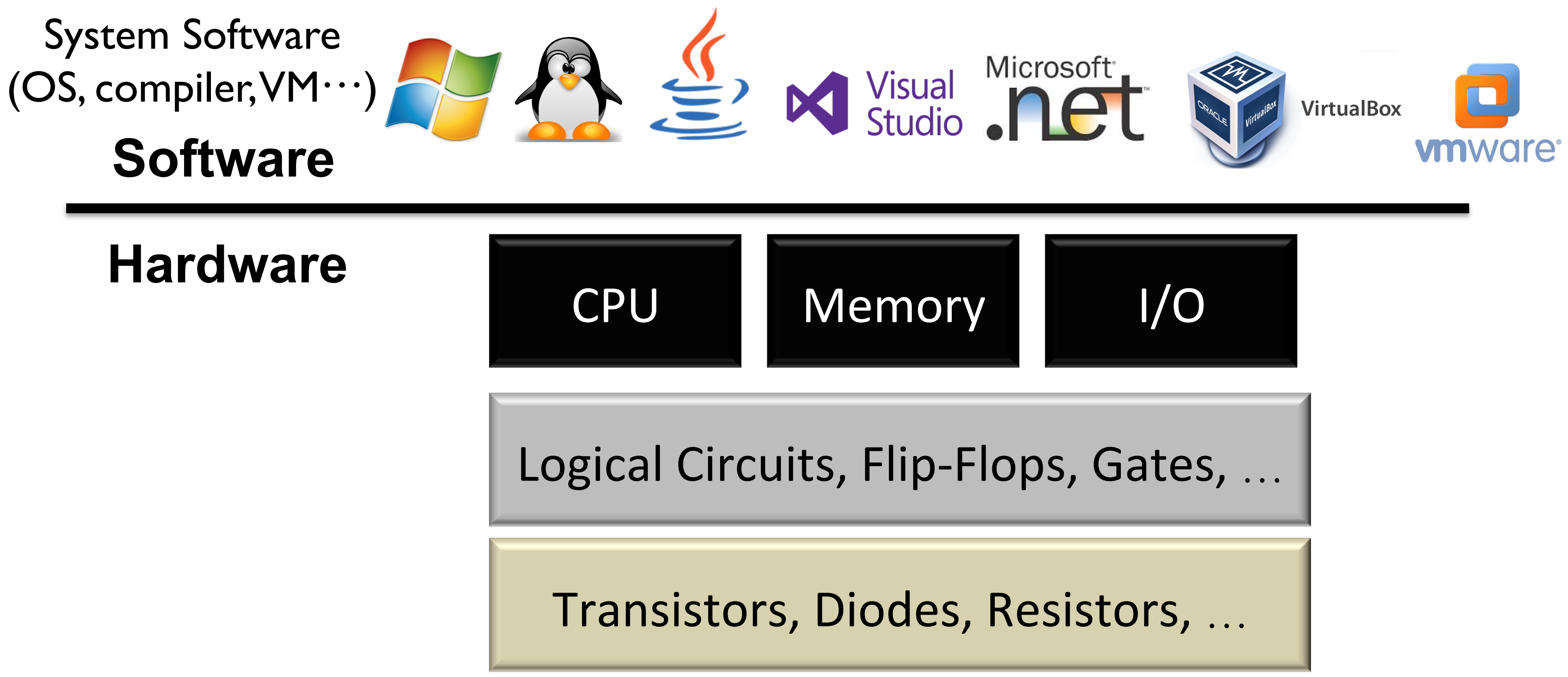
Hardware

CPU | Memory | I/O

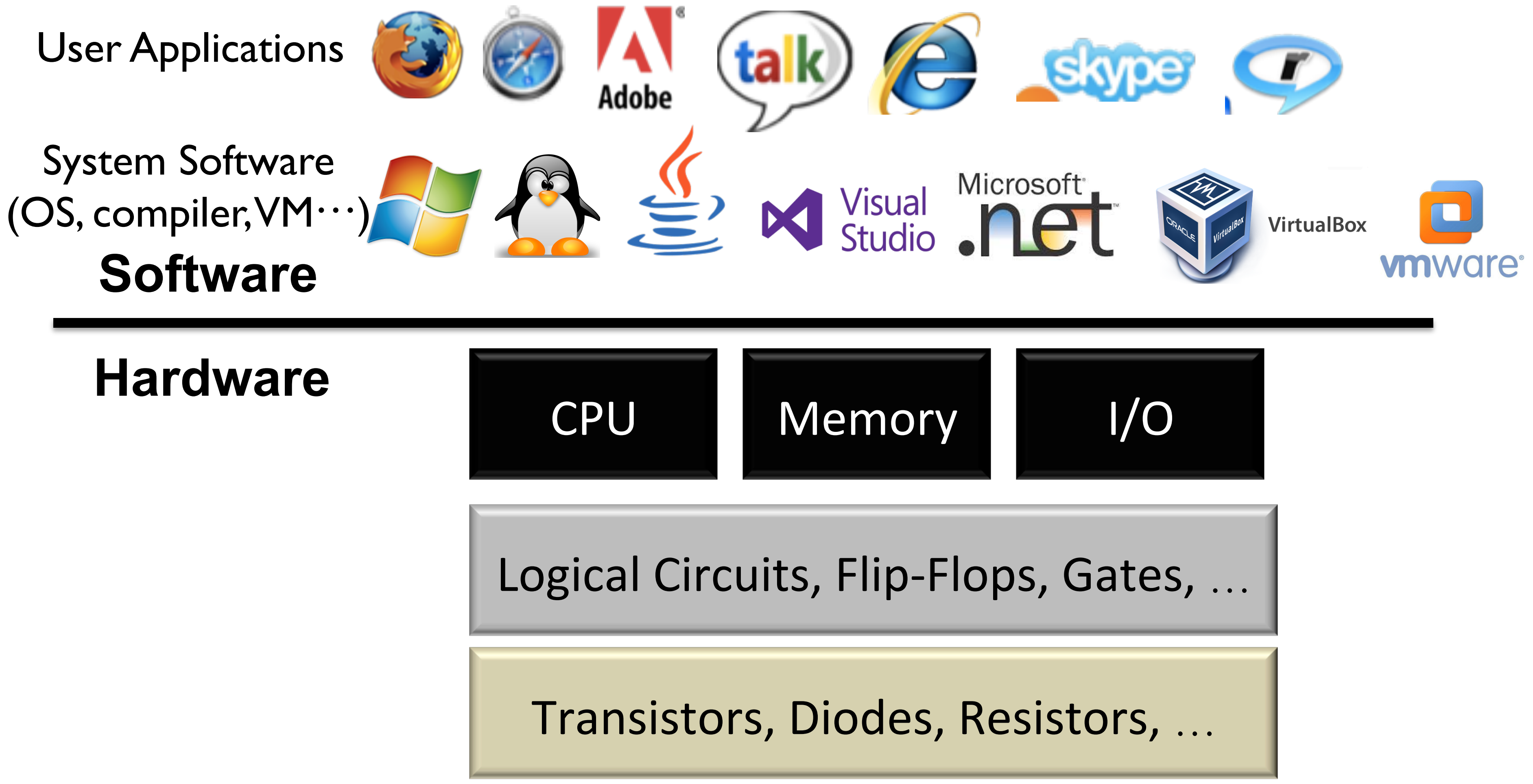
Logical Circuits, Flip-Flops, Gates, …

Transistors, Diodes, Resistors, …

Layered Organization



Layered Organization



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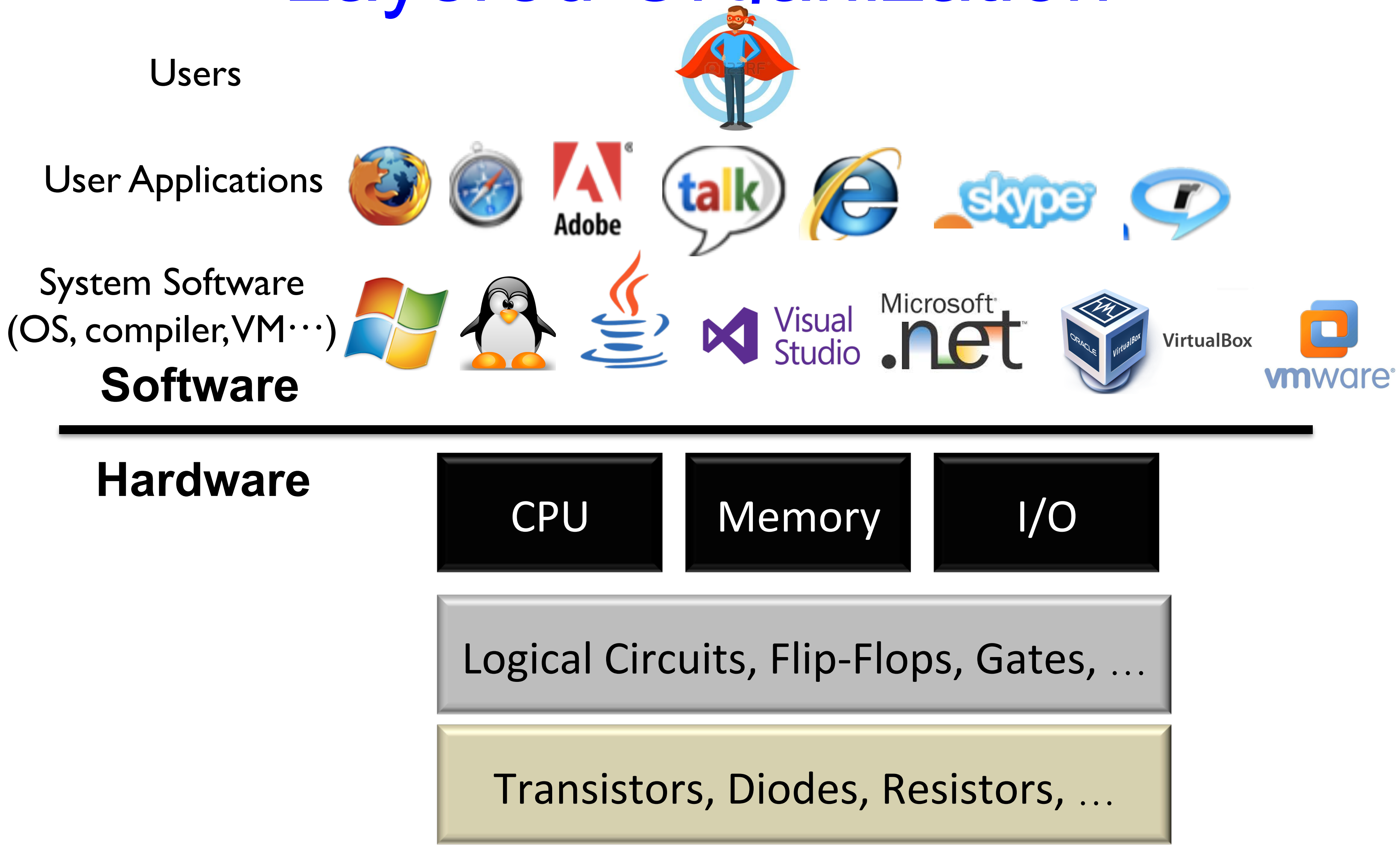

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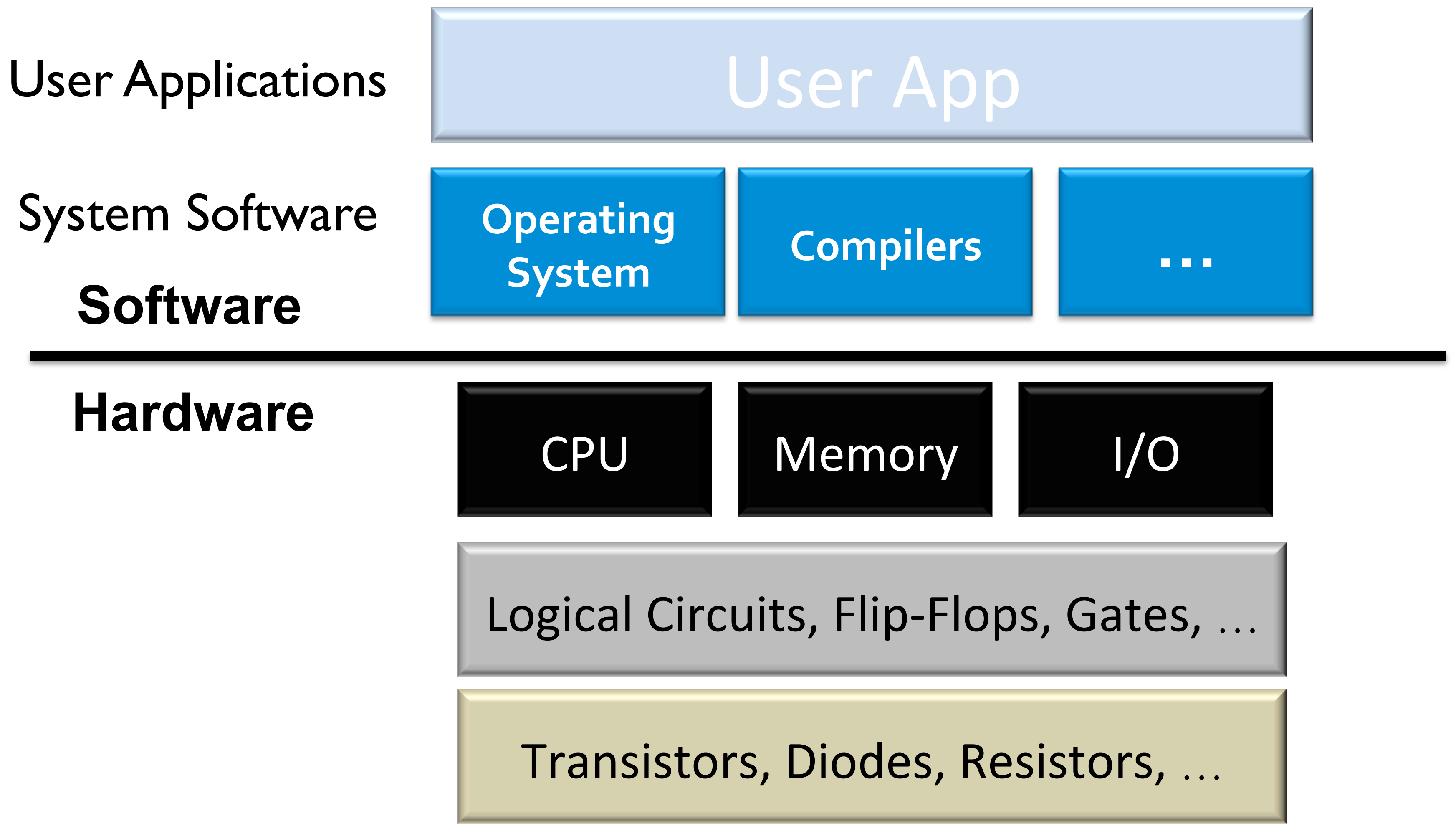
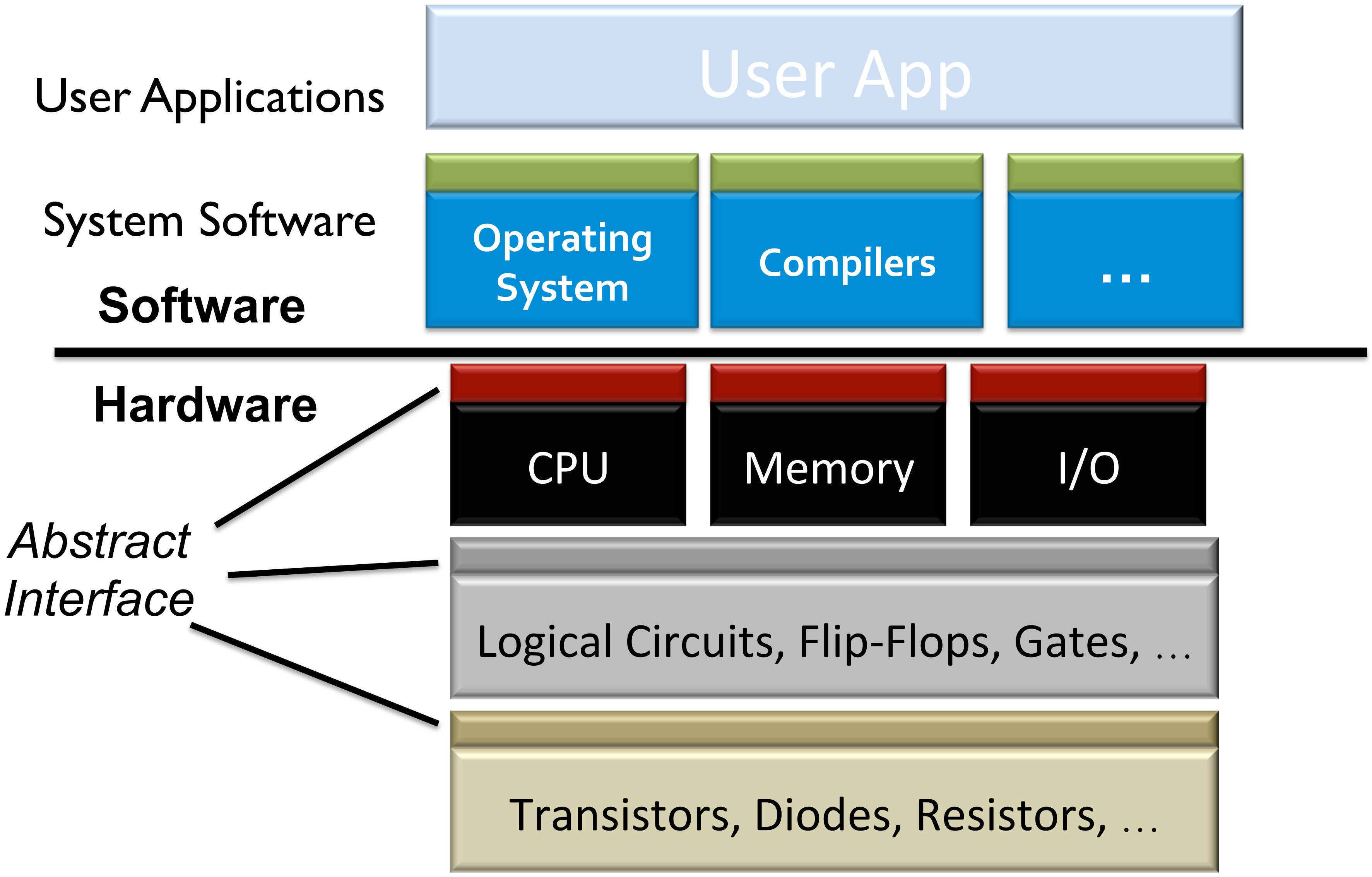
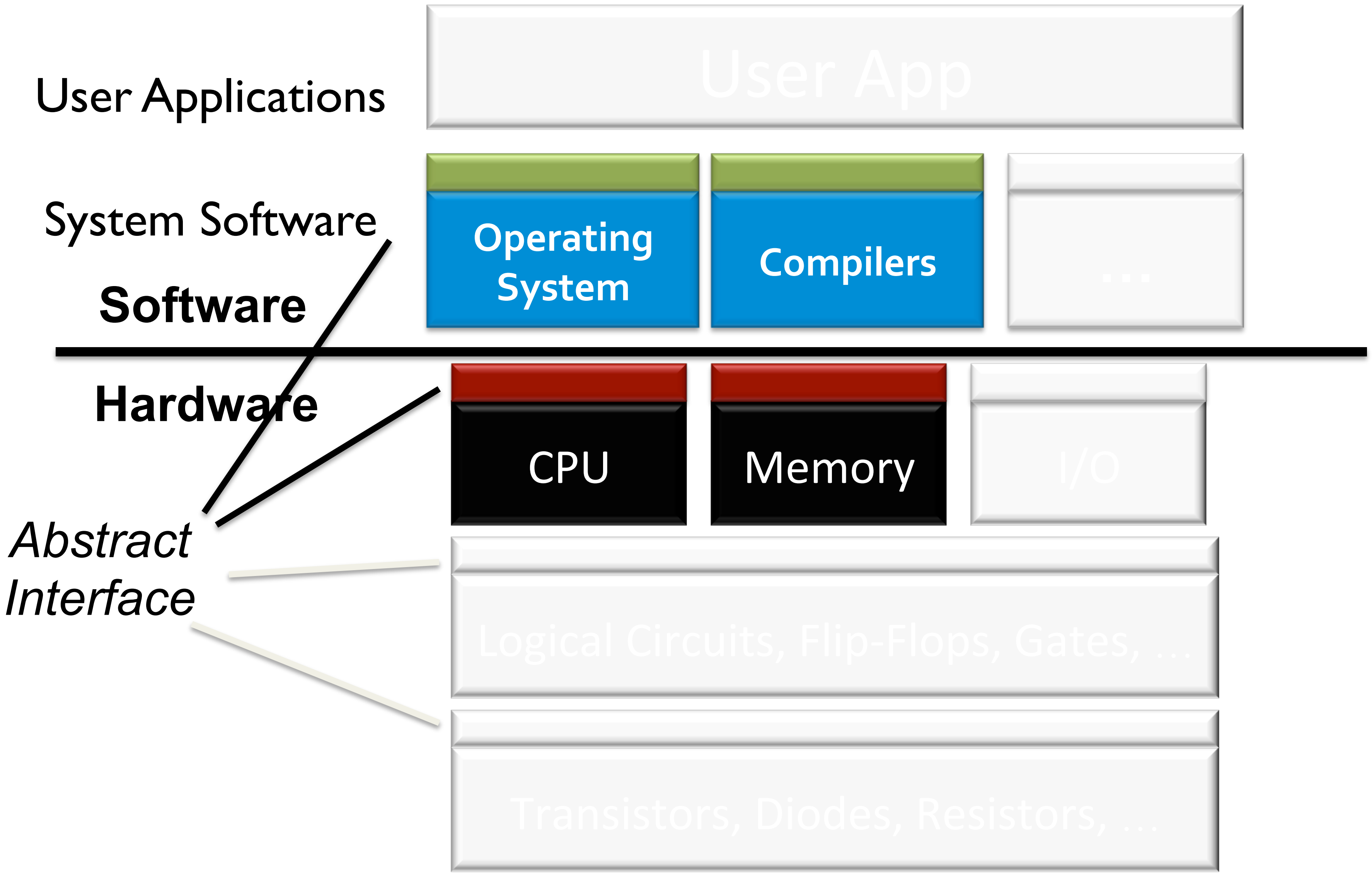


Abstraction



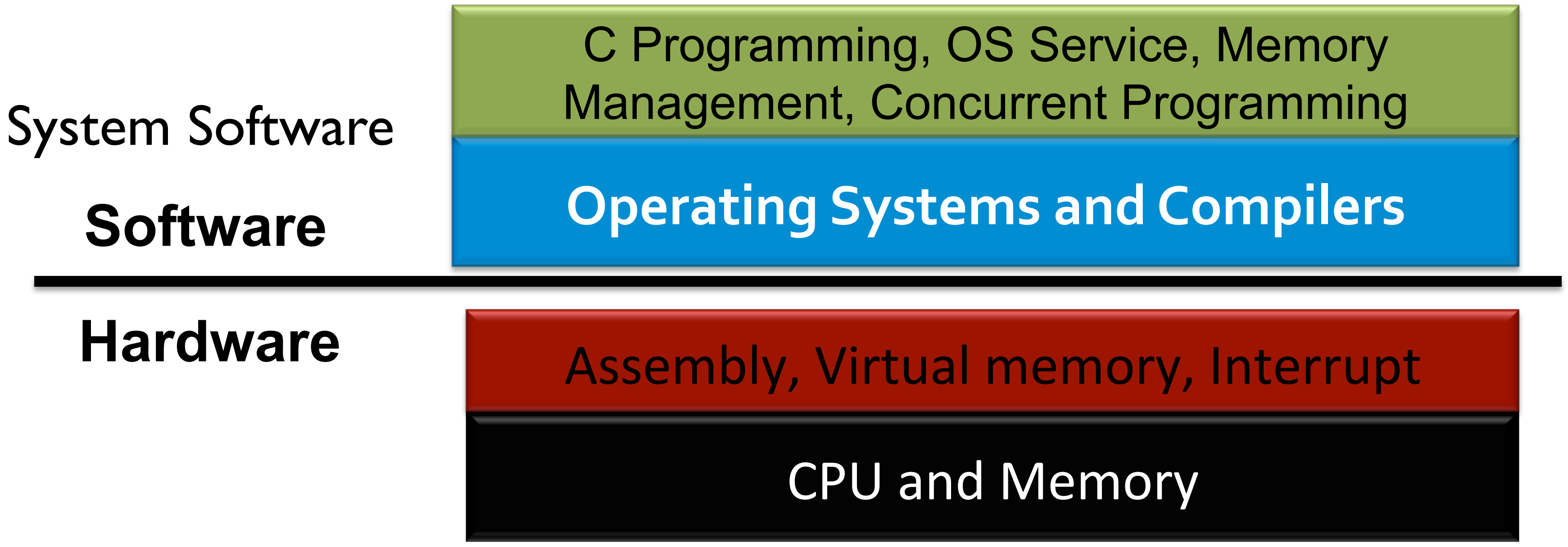
The Scope of This Class



The Scope of This class

Focus on abstract interfaces exposed by

- CPU and Memory
- Operating System, Compilers


C Programming, OS Service, Memory Management, Concurrent Programming
System Software
Operating Systems and Compilers
Software
Hardware
Assembly, Virtual memory, Interrupt
CPU and Memory

Schedule of Our Class

http://news.cs.nyu.edu/~jinyang/sp18-cso/schedule.html

overview
bit, byte and int
float point
[C] basics, bitwise operator, control flow
[C] scopes rules, pointers, arrays
[C] structs, mallocs
[C] large program (linked list)

C Programming

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Machine Prog: ISA, Compile, movq
Machine Prog: Control Code (condition, jump instruction)
Machine Prog: Array allocation and access
Machine Prog: Procedure calls
Machine Prog: Structure, Memory Layout
Machine Prog: Buffer Overflow
Code optimizations

C Programming

$\downarrow$

Assembly (X86)

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Machine Prog: Buffer Overflow
Code optimizations
Virtual memory: Address Spaces/ Translation, Goal
Virtual memory: Page table/physcial to virtual
Process

$$\begin{tikzcd}
\text{C Programming} \arrow[d] \\
\text{Assembly (X86)} \arrow[d] \\
\text{Virtual Memory}
\end{tikzcd}$$

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Dynamic Memory Allocation I: malloc, free
Dynamic Memory Allocation II: design allocator
Dynamic Memory Allocation III: futher optimization

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Virtual memory: Address Spaces/ Translation, Goal
Virtual memory: Page table/physcial to virtual
Process
Dynamic Memory Allocation I: malloc, free
Dynamic Memory Allocation II: design allocator
Dynamic Memory Allocation III: futher optimization
Concurrent Programming I: thread, race
Concurrent Programming II: lock
Concurrent Programming III: conditional variable
Concurrent Programming IV: Other primitives

$$\begin{tikzcd}
\text{C Programming} \arrow[d] \\
\text{Assembly (X86)} \arrow[d] \\
\text{Virtual Memory} \arrow[d] \\
\text{Memory Management} \arrow[d] \\
\text{Concurrent Programming}
\end{tikzcd}$$

Course Perspective

Most Systems Courses are Builder-Centric

- Computer Architecture
  - Design pipelined processor in Verilog
- Operating Systems
  - Implement large portions of operating system
- Compilers
  - Write compiler for simple language
- Networking
  - Implement and simulate network protocols

Course Perspective

Most Systems ler-Centric

- Computer
  - Design pi og
- Operating
  - Implemen ng system
- Compilers
  - Write com
- Networking
  - Implemen otocols

Course Perspective (Cont.)

This course is programmer-centric

– Understanding of underlying system makes a more effective programmer

– Bring out the hidden hacker in everyone

To be a happy programmer, you should

- Attend
  - Lectures (T/Th 11:00-12:15pm)
  - Recitation (M 3:30-4:45 pm)
    - In-class exercises provide hands-on instruction
- Do
  - 5 Programming labs
  - Recitation exercises
- Pass
  - Quiz 1 (2/27)
  - Quiz 2 (3/27)
  - Final exam

Grade Breakdown

Recitation and Exercises 15%

Labs 40%

Quiz before midterm 10%

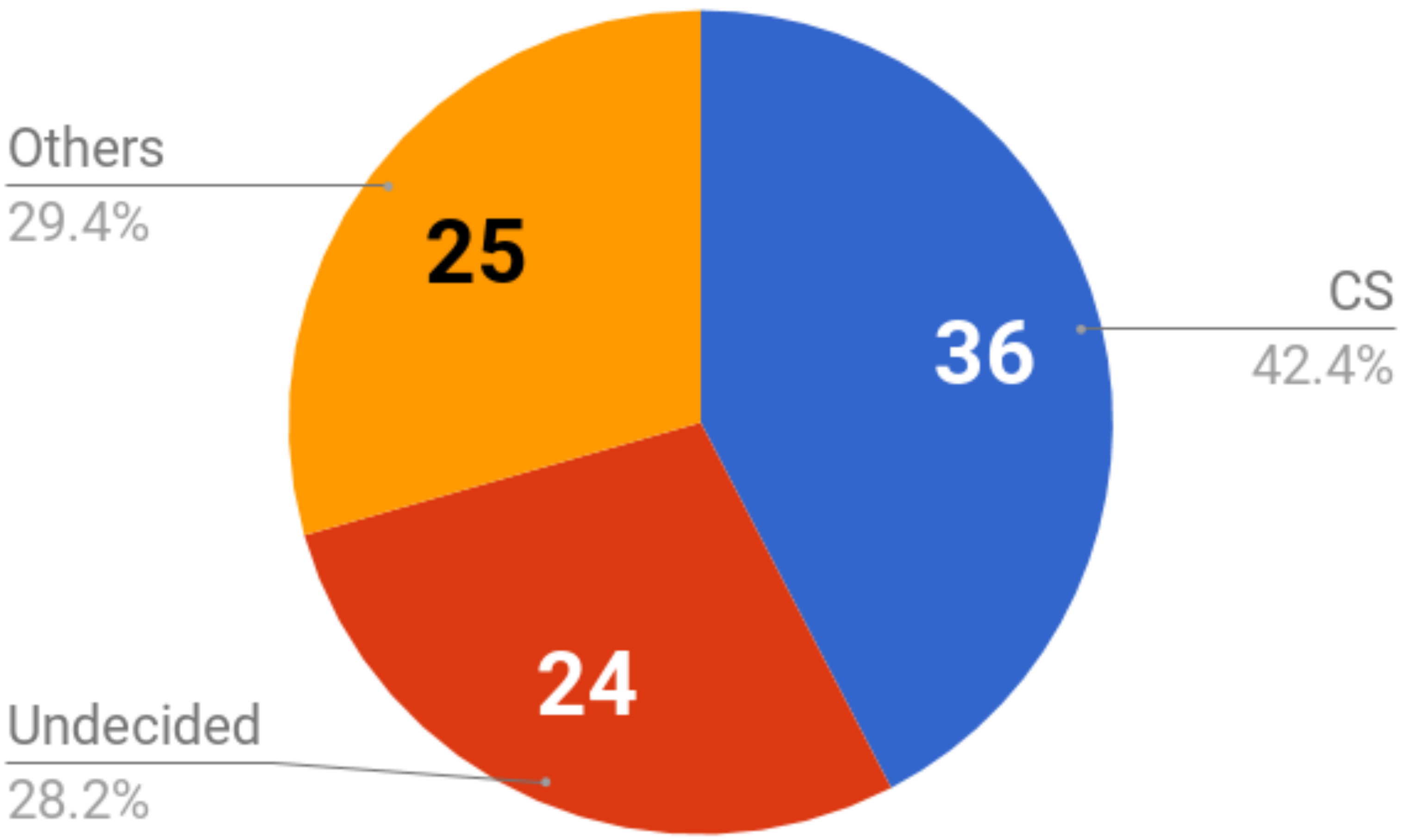
Midterm 15%

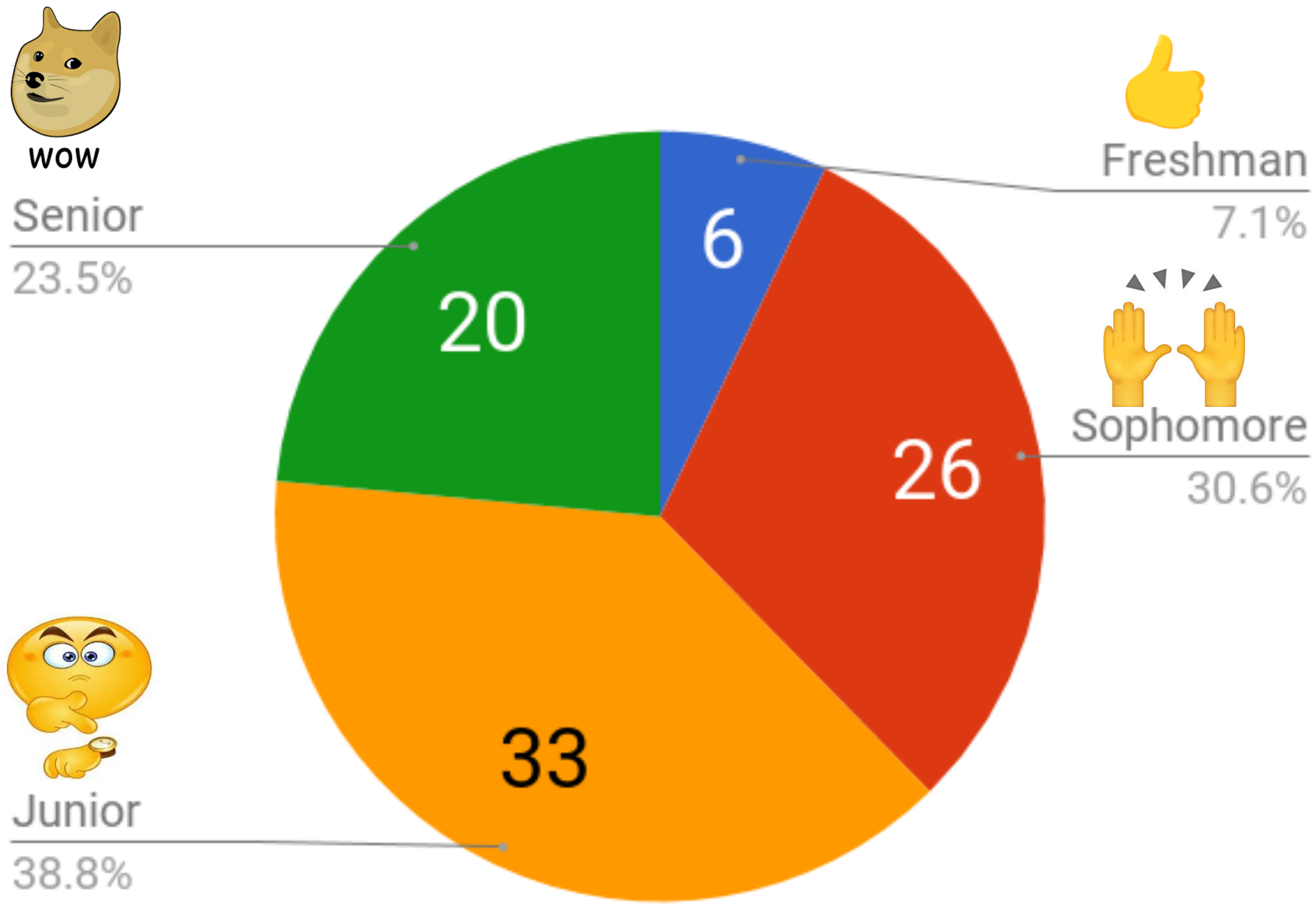
Final 20%

Bonus I: lecture and piazza participation 5%

Bonus II: extra-credit lab questions (points vary)

Is CSO going to be hard?


Others
29.4%
25
36
CS
42.4%
24
Undecided
28.2%


WOW
Senior
23.5%
20
6
Freshman
7.1%
26
Sophomore
30.6%
33
Junior
38.8%

Time to work hard

We (the course staff) are here to help

Who are we?

Jinyang Li

Lecturer

Chien-chin Huang

Recitation Leader
Head grader

Gu Jin

Grader

Chengchen Li

Grader

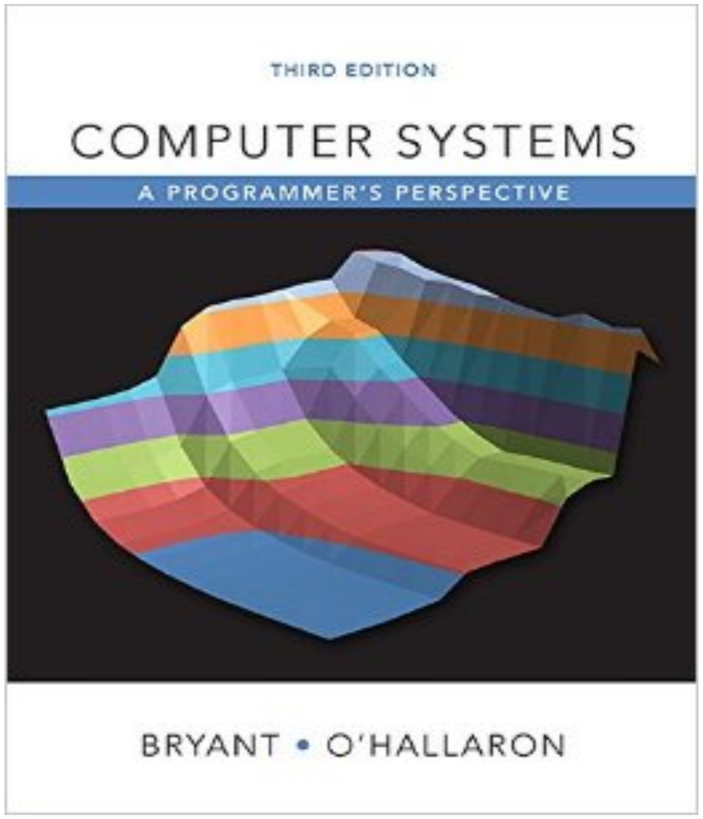
Zekun Zhang

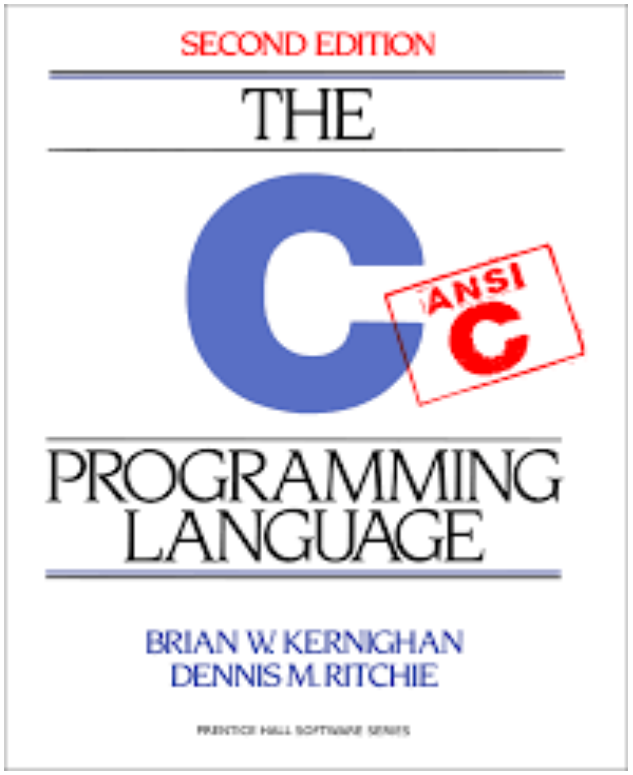
Grader

cso-staff@cs.nyu.edu

Before Class

Read the related sections in the text books





"Computer Systems: A Programmer's Perspective, 3nd Edition", http://csapp.cs.cmu.edu

"The C Programming Language, 2nd Edition", Prentice Hall, 1988, Reserved at NYU library

Be Active In Class

Raise your hand at any time

- Ask me to repeat, repeat and repeat
- Ask questions
- Answer questions from me or others

Have discussion and make friends with each others

After Class

Finish all labs / exercises

– By yourself

Attend the recitations

– Any issue of doing labs or exercises

Getting help

– Office hour, Piazza

Policies

You must work alone on all assignments

- You may post questions on Piazza,
- You are encouraged to answer others' questions, but refrain from explicitly giving away solutions.

Labs & Exercises

- Assignments due at 11:59pm on the due date
- Everybody has 5 grace days
- Zero score after the due

Class Info

http://news.cs.nyu.edu/~jinyang/sp18-cso/

Recitation starts next Mon

Integrity and Collaboration Policy

We will enforce the policy strictly.

1. The work that you turn in must be yours
2. You must acknowledge your influences
3. You must not look at, or use, solutions from prior years or the Web, or seek assistance from the Internet
4. You must take reasonable steps to protect your work
   – You must not publish your solutions
5. If there are inexplicable discrepancies between exam and lab performance, we will over-weight the exam and interview you.

Do not turn in labs/exercises that are not yours
You won't fail because of one missing labs

Integrity and Collaboration Policy

We will enforce this policy strictly and report violators to the department and Dean.