计算机系统基础

北京邮电大学 计算机学院

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课程目的

- 使学生能从程序员角度出发，理解高级语言中的变量、语句和函数调用等在计算机系统中的实现细节
- 建立C语言程序、汇编语言、编译器和链接器等之间的关联关系
- 初步理解基本输入输出控制方式、I/O函数的用法和设备驱动程序基本原理
- 建立起层次型计算机系统概念，增强在程序设计和程序调试等方面的动手能力，为后续课程打下坚实基础

课程计划

- 总　学　时：32学时
- 课堂教学：32学时
- 作　　业：6 ~ 8次
- 考核方式：期中考试
  期末考试（闭卷）
- 成绩评定：平时作业及考勤30%、期中考试10%
  期末考试60%
- 答　　疑：课前、课间及课后

课程计划 –《计算机系统基础实践》

- 本课程配套实践课
- 总 学 时：12学时
- 课堂教学：8学时
- 实验内容：4次实验
- 考核方式：1、人工验收（实验演示、回答问题）
  2、机器自动评分
- 成绩评定：实验验收60%，实验报告40%

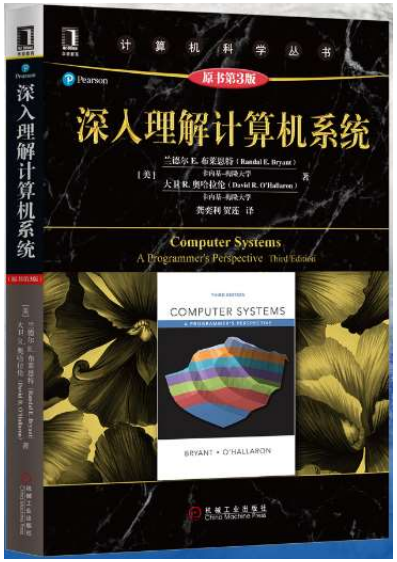
教材及参考书

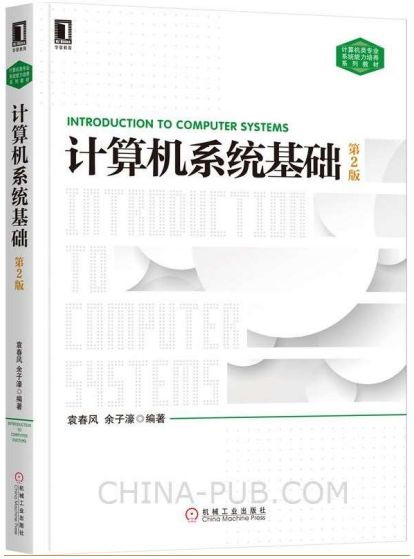
教材

- 《深入理解计算机系统》第3版；Randal E. Bryant 等；机械工业出版社
- http://csapp.cs.cmu.edu

参考书

- 《计算机系统基础》；袁春风；机械工业出版社





课件网址

教材电子版及课件PDF

- 链接:
- 密码:

CMU Class Web page

- **http://www.cs.cmu.edu/~213**

由于课时限制，本课程仅是CMU课程内容的一部分

课堂要求

- 不要迟到、不要随意进出教室
- 自己完成作业、按时交作业、实验报告
- 禁止玩手机

Overview

- **Big Picture**
  - Course theme
  - Five realities
  - How the course fits into the CS curriculum
- **Lab Assignments Overview**
- **Academic integrity**

The Big Picture

Course Theme: (Systems) Knowledge is Power!

- **Systems Knowledge**
  - How hardware (processors, memories, disk drives, network infrastructure) plus software (operating systems, compilers, libraries, network protocols) combine to support the execution of application programs
  - How you as a programmer can best use these resources
- **Useful outcomes from taking this course**
  - 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 & ECE
    - Compilers, Operating Systems, Networks, Computer Architecture, Embedded Systems, Storage Systems, etc.

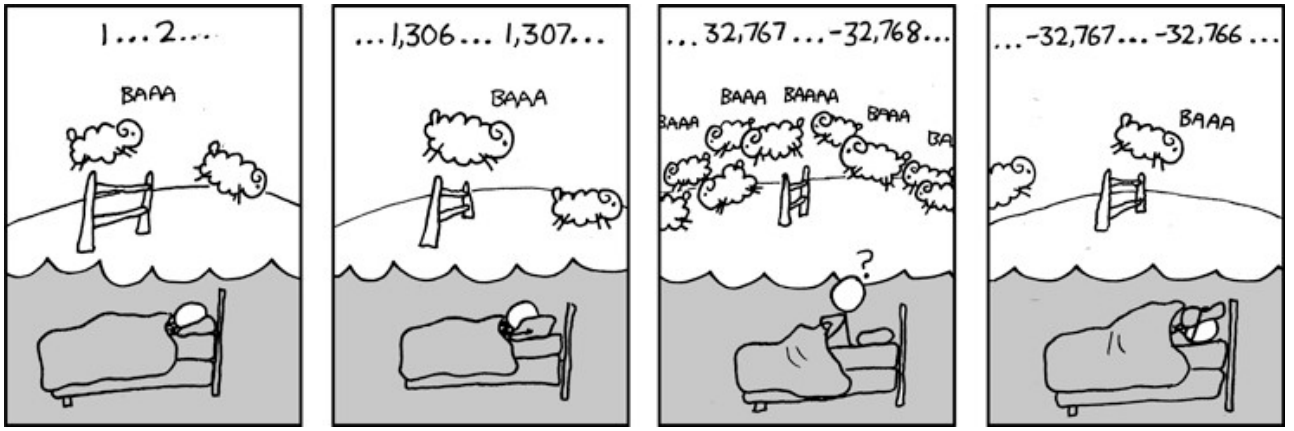
It's Important to Understand How Things Work

- **Why do I need to know this stuff?**
  - Abstraction is good, but don't forget reality
- **Most CS and CE courses emphasize abstraction**
  - Abstract data types
  - Asymptotic analysis
- **These abstractions have limits**
  - Especially in the presence of bugs
  - Need to understand details of underlying implementations
  - Sometimes the abstract interfaces don't provide the level of control or performance you need

Great Reality #1:

Ints are not Integers, Floats are not Reals

- **Example 1: Is $x^2 \geq 0$?**
  - Float's: Yes!
  - Int's:
    - 40000 * 40000 --> 1600000000
    - 50000 * 50000 --> ?



- **Example 2: Is (x + y) + z = x + (y + z)?**
  - Unsigned & Signed Int's: Yes!
  - Float's:
    - (1e20 + -1e20) + 3.14 --> 3.14
    - 1e20 + (-1e20 + 3.14) --> ??

Source: xkcd.com/571

Computer Arithmetic

- **Does not generate random values**
  - Arithmetic operations have important mathematical properties
- **Cannot assume all "usual" mathematical properties**
  - Due to finiteness of representations
  - Integer operations satisfy "ring" properties
    - Commutativity, associativity, distributivity
  - Floating point operations satisfy "ordering" properties
    - Monotonicity, values of signs
- **Observation**
  - Need to understand which abstractions apply in which contexts
  - Important issues for compiler writers and serious application programmers

Great Reality #2:
You've Got 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**
  - Behavior of programs in presence of bugs
    - High-level language models break down
  - Tuning program performance
    - Understand optimizations done / not done by the compiler
    - Understanding sources of program inefficiency
  - Implementing system software
    - Compiler has machine code as target
    - Operating systems must manage process state
  - Creating / fighting malware
    - x86 assembly is the language of choice!

Great Reality #3: Memory Matters

Random Access Memory Is an Unphysical Abstraction

- **Memory is not unbounded**
  - It must be allocated and managed
  - Many applications are memory dominated
- **Memory referencing bugs especially pernicious**
  - Effects are distant in both time and space
- **Memory performance is not uniform**
  - Cache and virtual memory effects can greatly affect program performance
  - Adapting program to characteristics of memory system can lead to major speed improvements

Memory Referencing Bug Example

```
typedef struct {
  int a[2];
  double d;
} struct_t;

double fun(int i) {
  volatile struct_t s;
  s.d = 3.14;
  s.a[i] = 1073741824; /* Possibly out of bounds */
  return s.d;
}
```

```
fun(0) -->      3.14
fun(1) -->      3.14
fun(2) -->      3.1399998664856
fun(3) -->      2.00000061035156
fun(4) -->      3.14
fun(6) -->      Segmentation fault
```

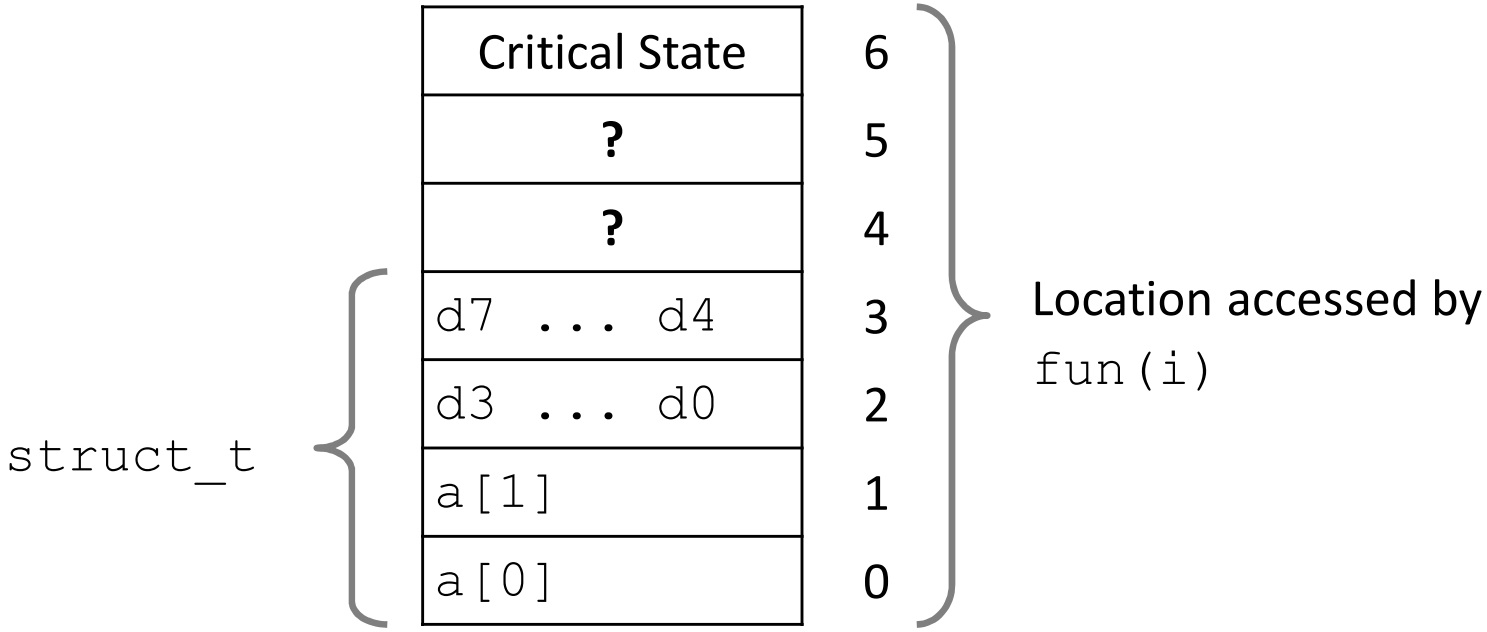
- Result is system specific

Memory Referencing Bug Example

```
typedef struct {
  int a[2];
  double d;
} struct_t;
```

```
fun(0) -->      3.14
fun(1) -->      3.14
fun(2) -->      3.1399998664856
fun(3) -->      2.0000061035156
fun(4) -->      3.14
fun(6) -->      Segmentation fault
```

Explanation:



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)

Great Reality #4: There's more to performance than asymptotic complexity

- **Constant factors matter too!**
- **And even exact op count does not predict performance**
  - Easily see 10:1 performance range depending on how code written
  - Must optimize at multiple levels: algorithm, data representations, procedures, and loops
- **Must understand system to optimize performance**
  - How programs compiled and executed
  - How to measure program performance and identify bottlenecks
  - How to improve performance without destroying code modularity and generality

Memory System Performance Example

```
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];
}
```

4.3ms **81.8ms**

2.0 GHz Intel Core i7 Haswell

- **Hierarchical memory organization**
- **Performance depends on access patterns**
  - Including how step through multi-dimensional array

Great 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
    - Concurrent operations by autonomous processes
    - Coping with unreliable media
    - Cross platform compatibility
    - Complex performance issues

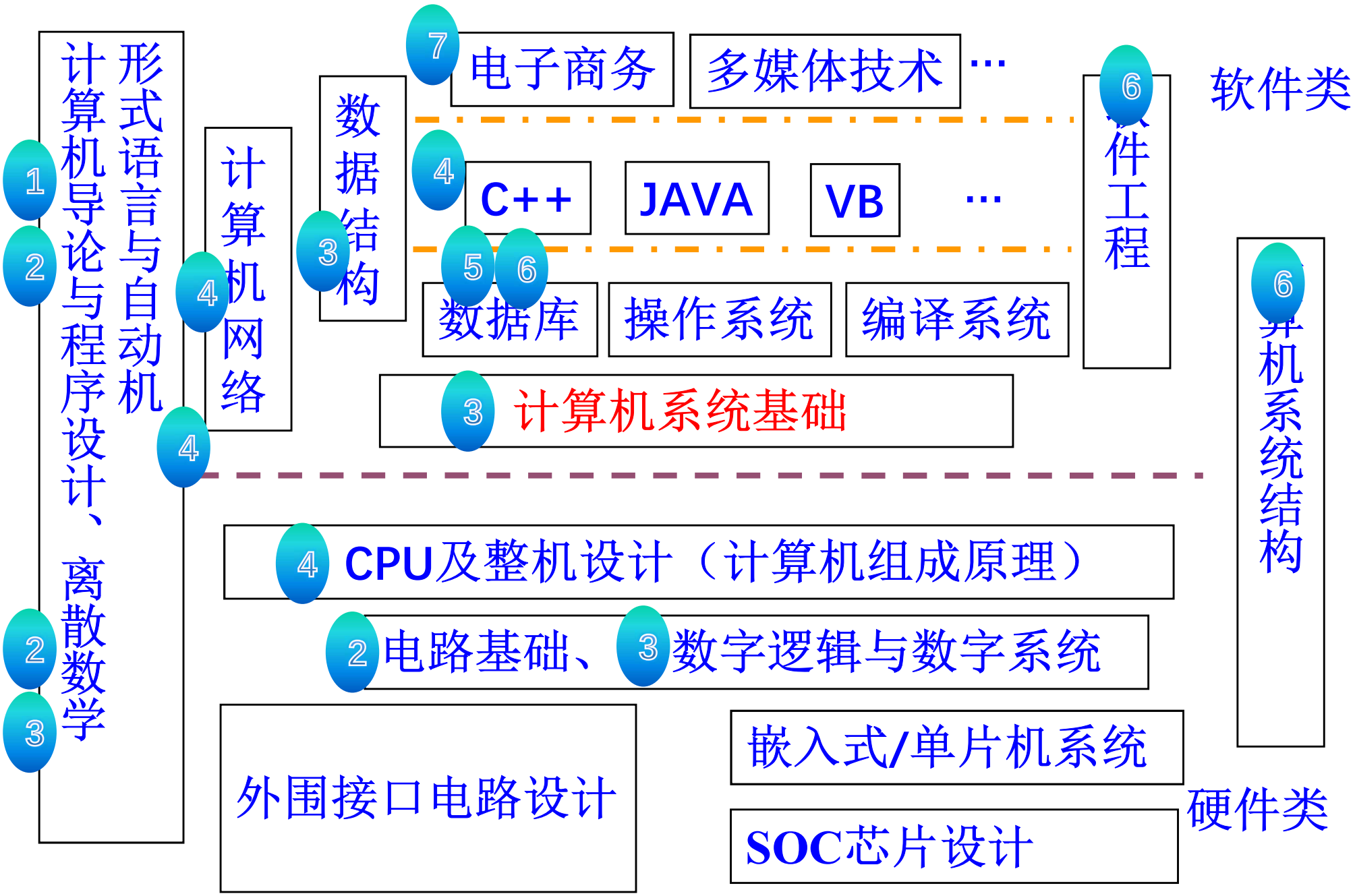
Course Perspective

- **Most Systems Courses are Builder-Centric**
  - Computer Architecture
    - Design pipelined processor in Verilog
  - Operating Systems
    - Implement sample portions of operating system
  - Compilers
    - Write compiler for simple language
  - Networking
    - Implement and simulate network protocols

Course Perspective (Cont.)

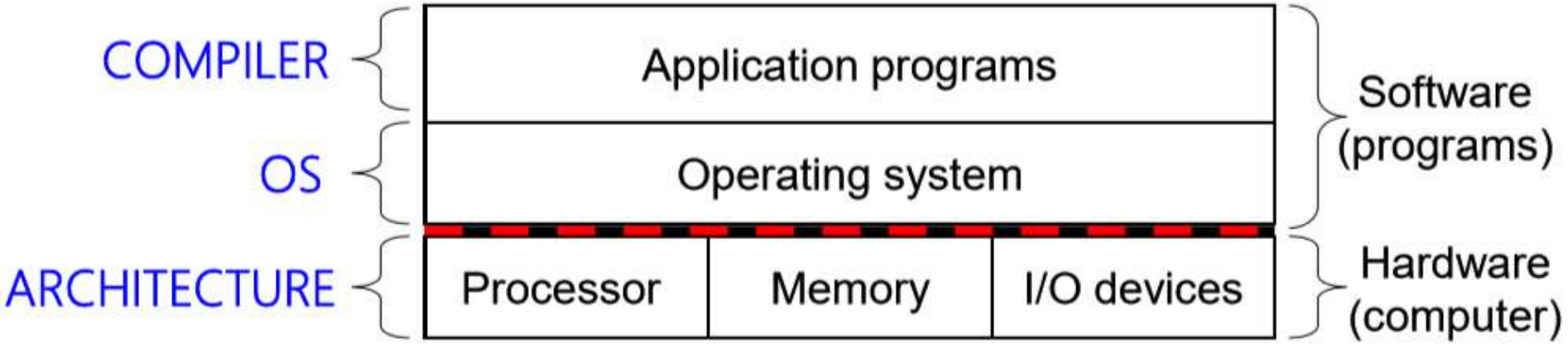
- **Our Course is Programmer-Centric**
  - By knowing more about the underlying system, you can be more effective as a programmer
  - Enable you to
    - Write programs that are more reliable and efficient
    - Incorporate features that require hooks into OS
      - E.g., concurrency, signal handlers
  - Cover material in this course that you won't see elsewhere
  - Not just a course for dedicated hackers
    - **We bring out the hidden hacker in everyone!**

Role within CS Curriculum

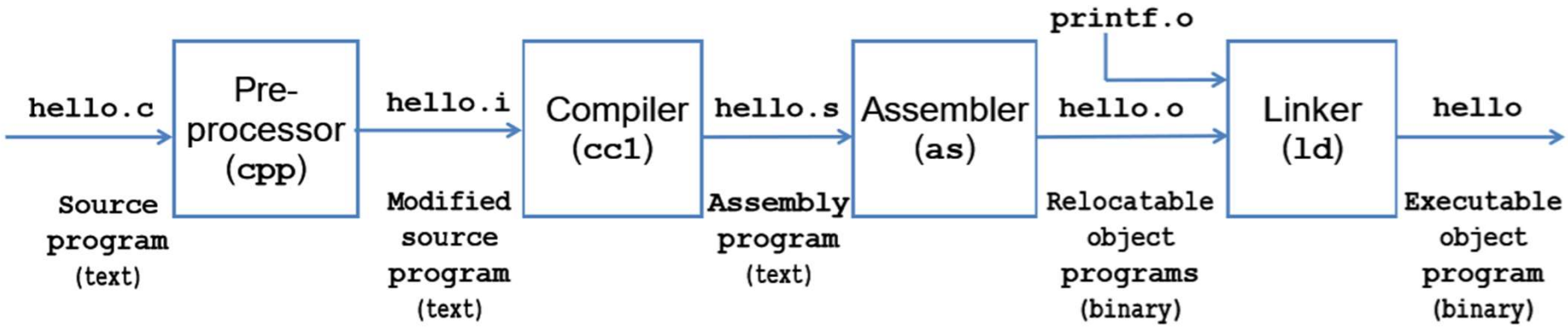


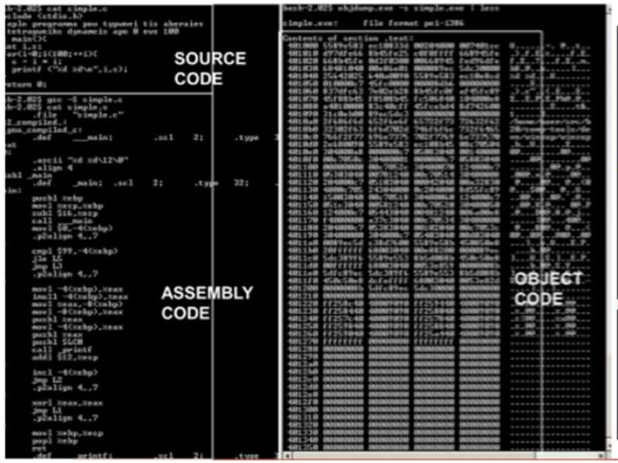
Anatomy of a Computer System

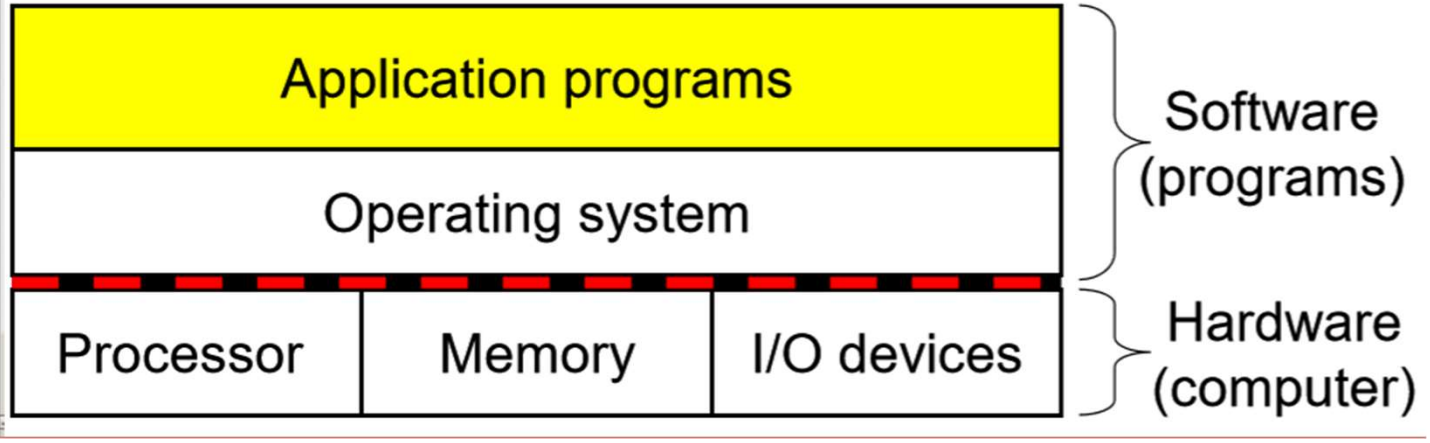
- **What is a Computer System?**
  - Software + Hardware
  - Programs + Computer → [Application program + OS] + Computer
  - Programming Language + Operating Systems + Computer Architecture



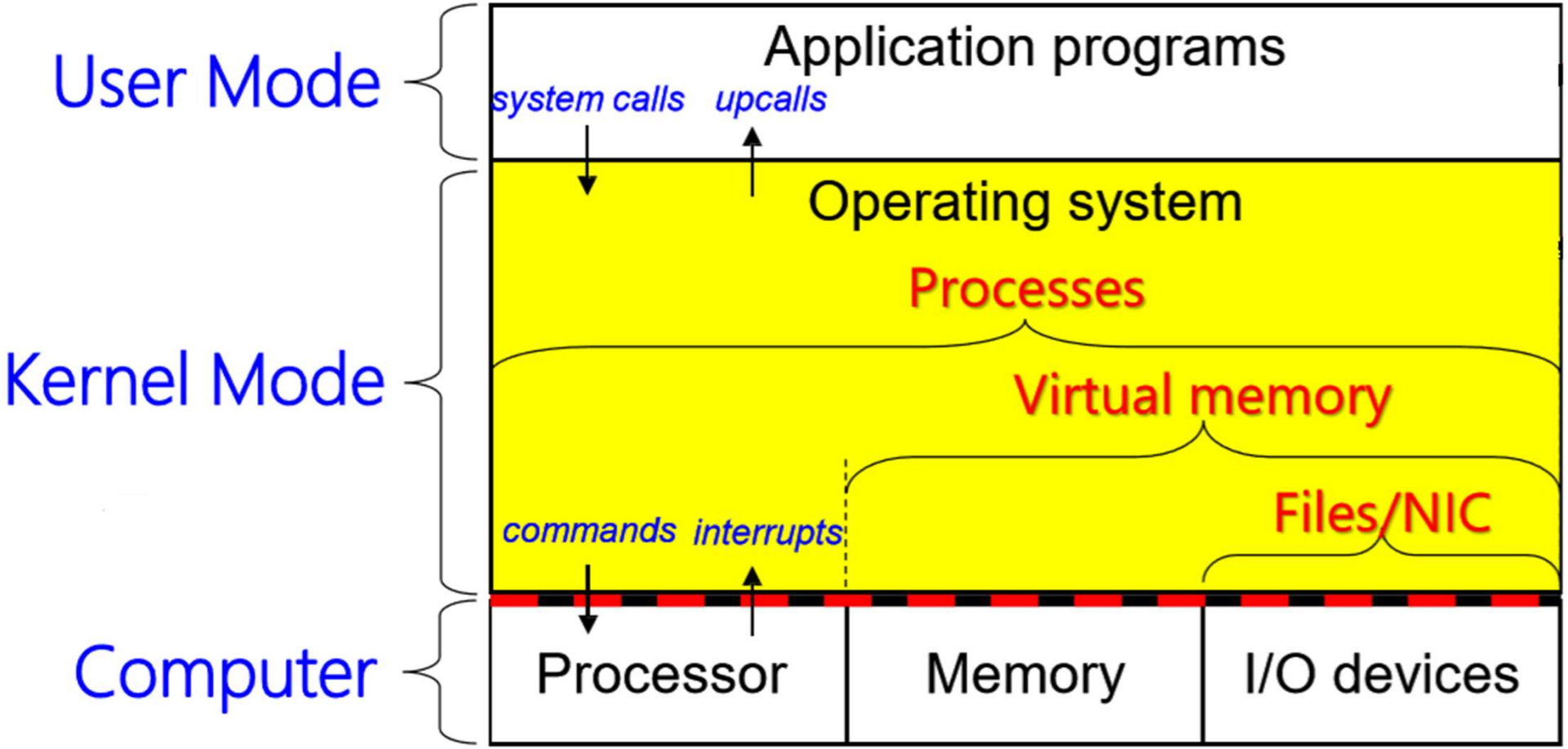
Anatomy of a Computer System: Compiler





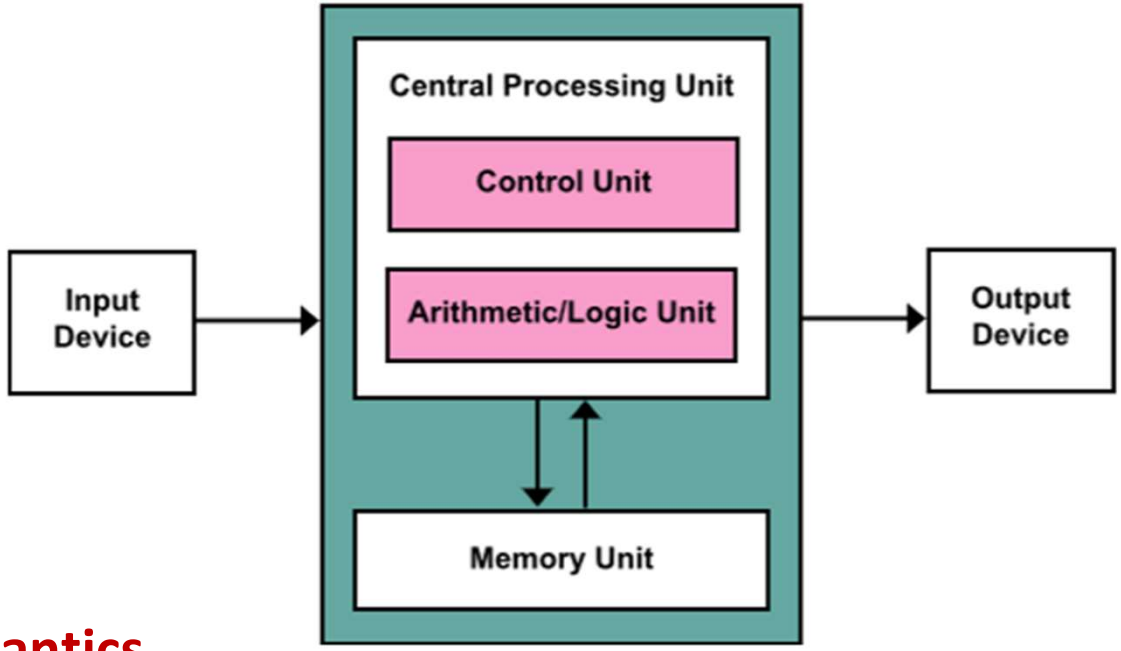


Anatomy of a Computer System: OS

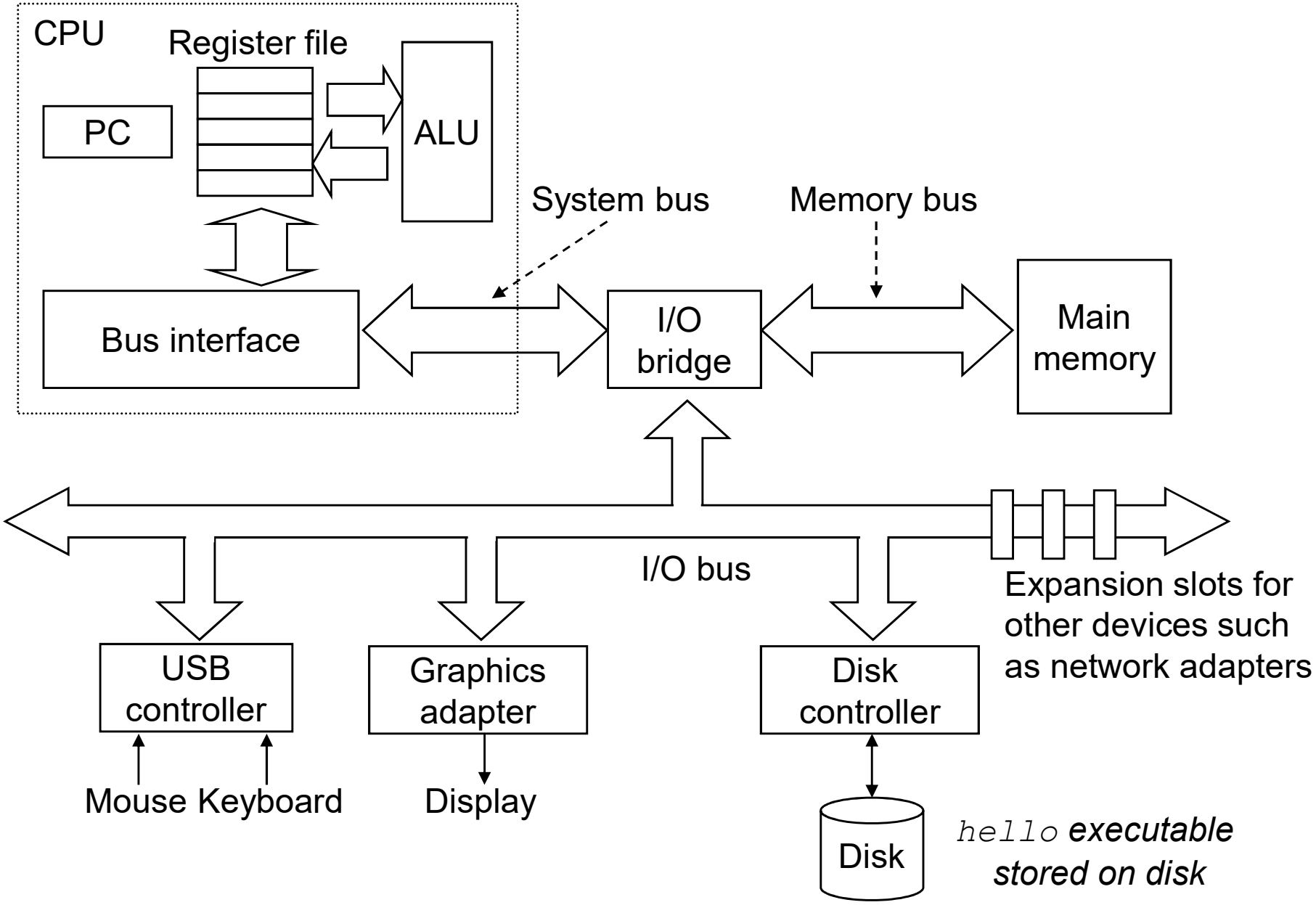


What is a Computer?

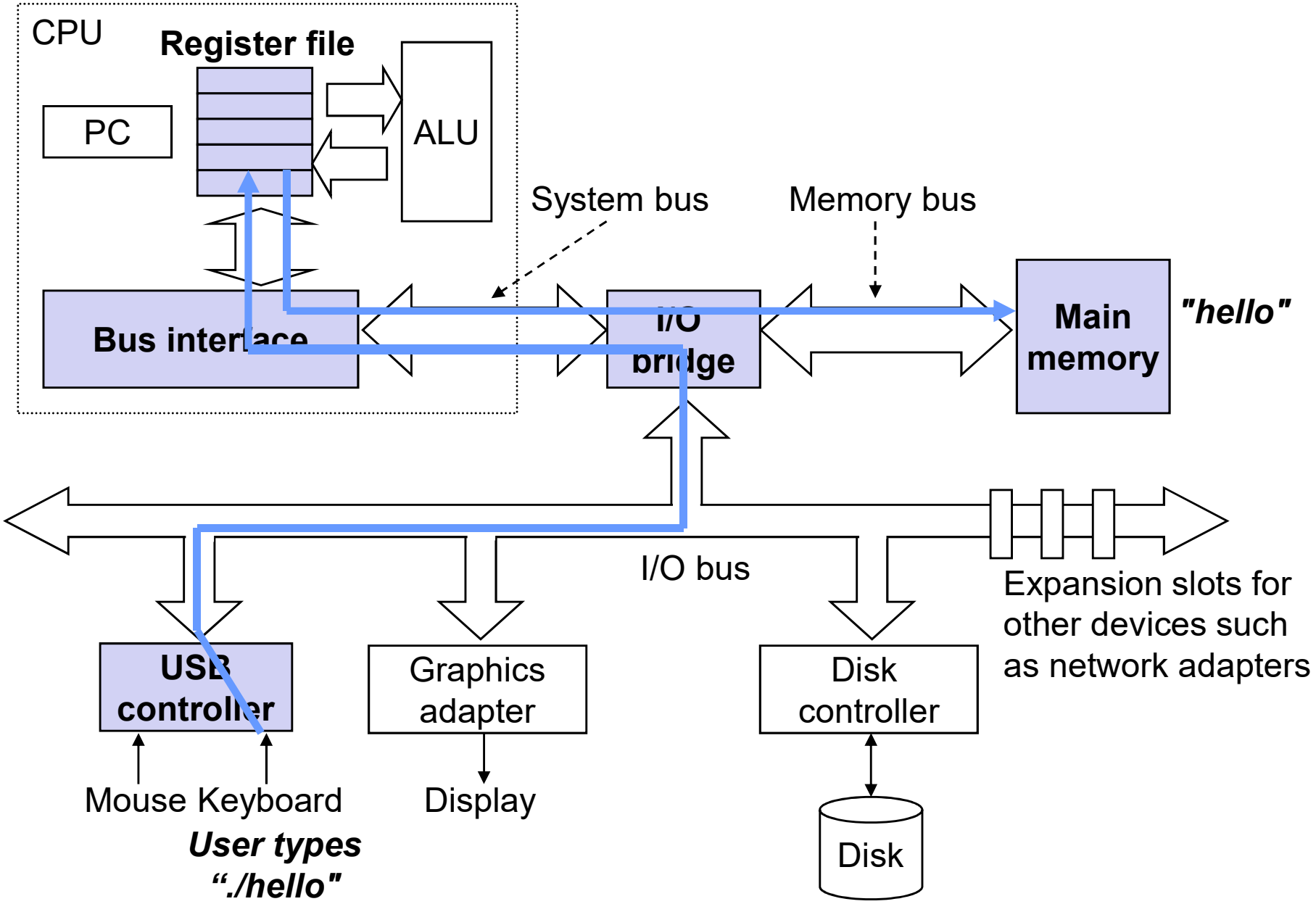
- The Classic Von Neumann Computer Model: Proposed in 1945 by Von Neumann and others (Alan Turing, J. Presper Eckert and Jonn Mauchly).
- A "Stored Program Computer"
  1. One CPU
     - One Control Unit
     - Program Counter
     - Instruction Register
  2. Monolithic Memory
     - Data Store
     - Instruction Store
  3. Sequential Execution Semantics
     - Instructions from an Instruction Set



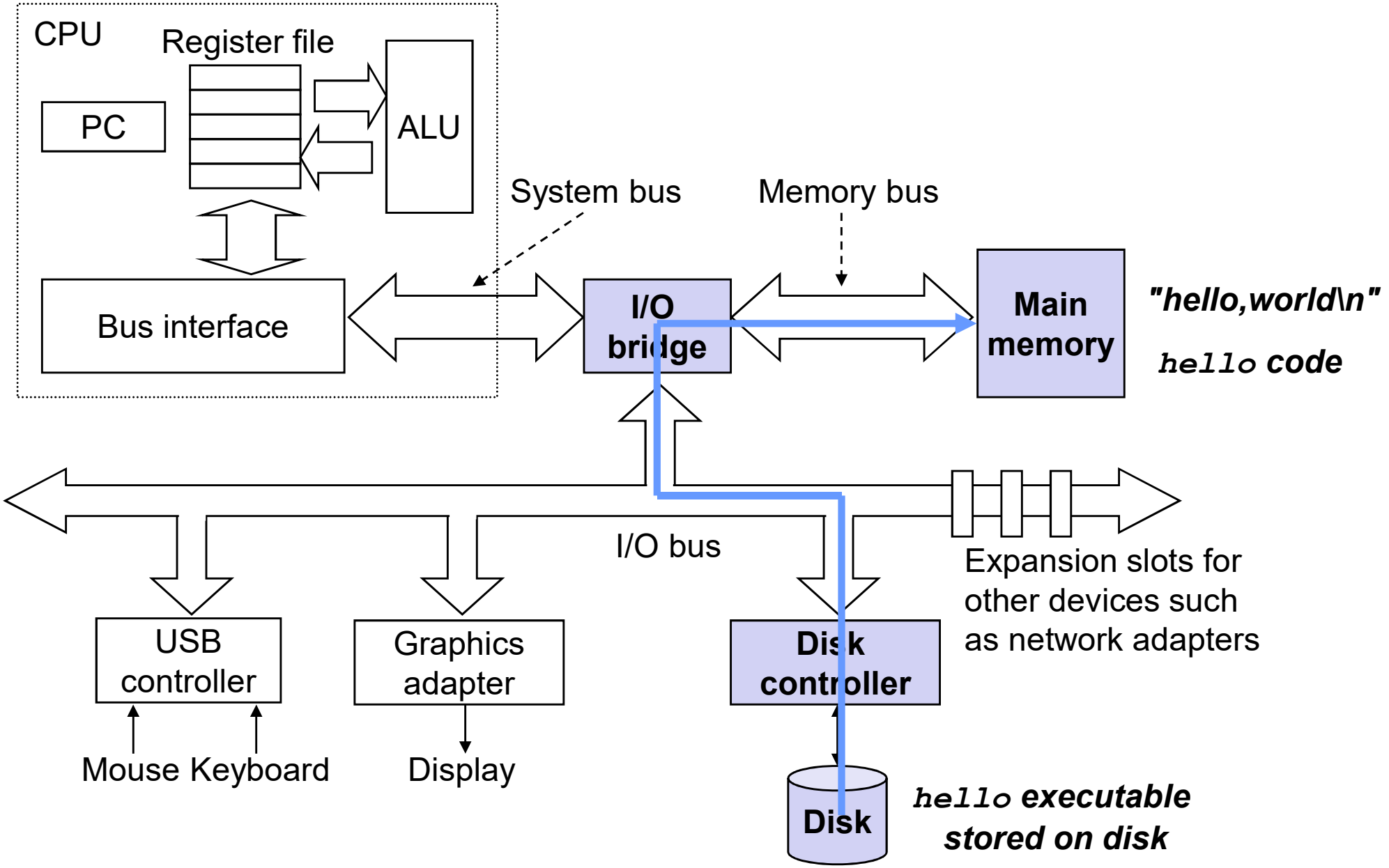
Typical Computer (PC) Today: HW Organization



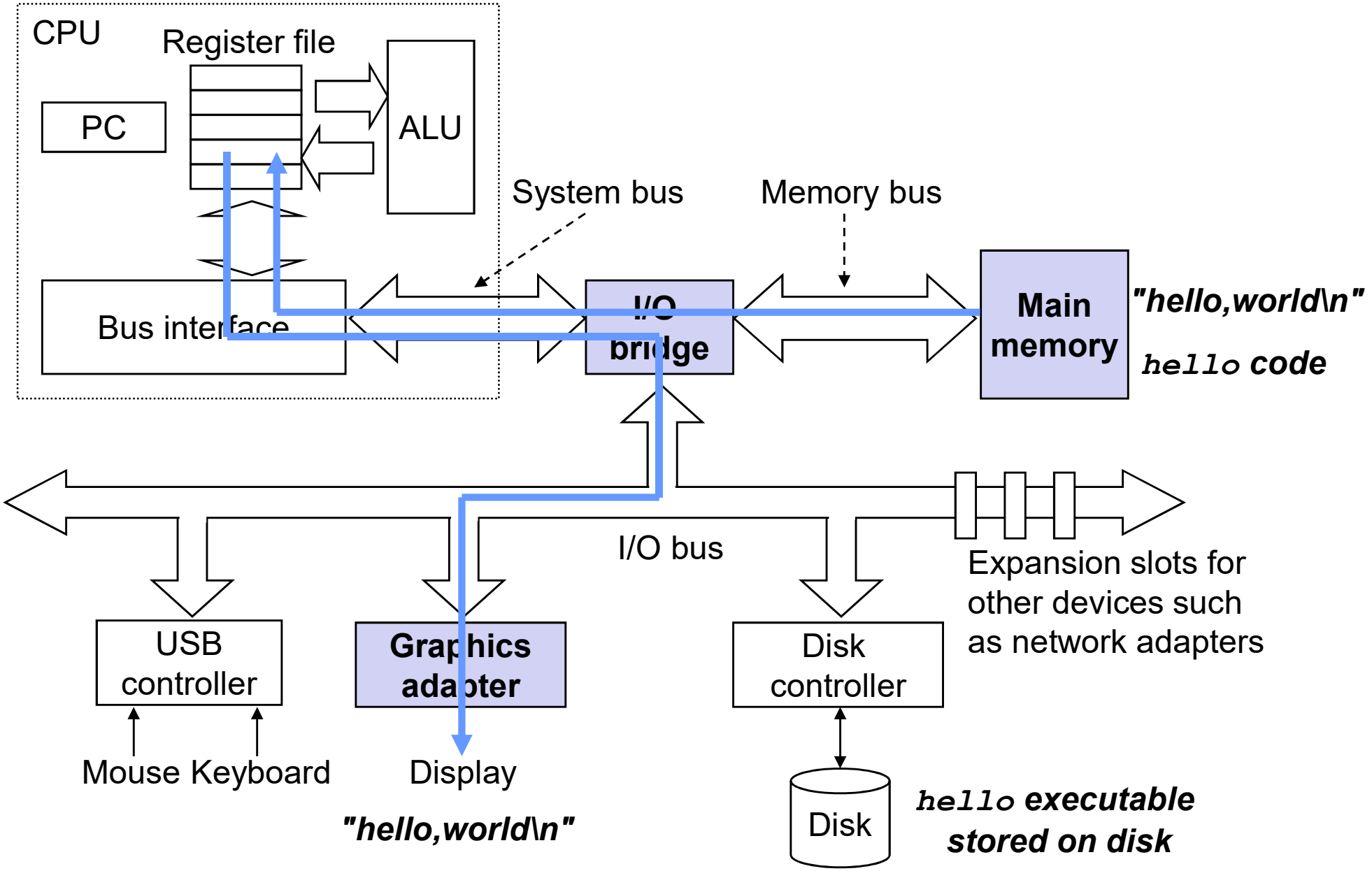
Reading "hello" command from the keyboard



Loading executable from disk to main memory



Writing output string from memory to display



Lab Assignments Overview

Lab Assignments Supporting The Course

Labs

- Lab1 (Linux&GNU Toolchain Lab): Basic usage of linux commands， vi commands and GNU toolchain
- Lab2 (bomblab): Defusing a binary bomb
- Lab3 (attacklab): The basics of code injection attacks
- Lab4 (I/Olab): The basics of I/O control program

Facilities

- Lab1-3 will use bup1 machine (Dell server) with dual Xeon Processor (total 16 Intel Cores) and 32GB. Login bupt1 using your Student ID and password
- Lab4 will use Ubuntu virtual machine on your own computer

Labs Policies

- **Lab schedule**
  - Starts in week 7, two or three weeks for each lab assignment
- **Work groups**
  - You must work alone on all lab assignments
- **Hand-ins**
  - Labs are due at 11:59pm usually on Thursday（Wednesday）
  - Electronic handins using **email**
- **Penalty for late submission**
  - loss of 5 marks per day
- **Autograding and Scoreboards for Lab2 and Lab3**
  - **Autograding: Providing you with instant feedback**
  - **Scoreboards: Real-time, rank-ordered, and summary**

Lab Rationale

- **Each lab has a well-defined goal such as solving a puzzle or winning a contest**
- **Doing the lab should result in new skills and concepts**
- **We try to use competition in a fun and healthy way**
  - Set a reasonable threshold for full credit
  - Post intermediate results on Autolab scoreboard for glory!

Academic Integrity

Please pay close attention, especially if this is your first semester at CMU

了解国外大学对学术诚信的要求

Cheating/Plagiarism: Description

- **Unauthorized use of information**
  - Borrowing code: by copying, retyping, **looking at** a file
  - Describing: verbal description of code from one person to another.
  - Searching the Web for solutions
  - Copying code from a previous course or online solution
  - Reusing your code from a previous semester (here or elsewhere)

Cheating/Plagiarism: Description (cont.)

- **Unauthorized supplying of information**
  - Providing copy: Giving a copy of a file to someone
  - Providing access:
    - Putting material in unprotected directory
    - Putting material in unprotected code repository (e.g., Github)
  - Applies to this term and the future
    - There is no statute of limitations for academic integrity violations

Cheating/Plagiarism: Description

- **What is NOT cheating?**
  - Explaining how to use systems or tools
  - Helping others with *high-level* design issues
  - Using code supplied by us
  - Using code from the CS:APP web site

- **See the course syllabus for details.**
  - Ignorance is not an excuse

Cheating: Consequences

- **Penalty for cheating:**
  - Best case: -100% for assignment
    - You would be better off to turn in nothing
  - Worst case: Removal from course with failing grade
    - This is the default
  - Permanent mark on your record
  - Loss of respect by you, the instructors and your colleagues
  - If you do cheat – come clean asap!

- **Detection of cheating:**
  - We have sophisticated tools for detecting code plagiarism
  - In Fall 2015, 20 students were caught cheating and failed the course.
    - Some were **expelled** from the University
  - In January 2016, 11 students were penalized for cheating violations that occurred as far back as Spring 2014.

- **Don't do it!**
  - Manage your time carefully
  - Ask the staff for help when you get stuck

Some Concrete Examples:

- **This is Cheating:**
  - Searching the internet with the phrase 15-213, 15213, 213, 18213, malloclab, etc.
    - That's right, just entering it in a search engine
  - Looking at someone's code on the computer next to yours
  - Giving your code to someone else, now or in the future
  - Posting your code in a publicly accessible place on the Internet, now or in the future
  - Hacking the course infrastructure
- **This is OK (and encouraged):**
  - Googling a man page for fputs
  - Asking a friend for help with gdb
  - Asking a TA or course instructor for help, showing them your code, …
  - Looking in the textbook for a code example
  - Talking about a (high-level) approach to the lab with a classmate

How it Feels: Student and Instructor

- **Fred is desperate. He can't get his code to work and the deadline is drawing near. In panic and frustration, he searches the web and finds a solution posted by a student. He carefully strips out the comments and inserts his own. He changes the names of the variables and functions. Phew! Got it done!**
- **The course staff run checking tools that compare all submitted solutions to the solutions from this and other semesters, along with ones that are on the Web.**
  - Remember: We are as good at web searching as you are
- **Meanwhile, Fred has had an uneasy feeling: Will I get away with it? Why does my conscience bother me?**
- **Fred gets email from an instructor: "Please see me tomorrow at 9:30 am."**
  - Fred does not sleep well that night

How it Feels: Student and Instructor

- **The instructor feels frustrated. His job is to help students learn, not to be police. Every hour he spends looking at code for cheating is time that he cannot spend providing help to students. But, these cases can't be overlooked**
- **At the meeting:**
  - Instructor: "Explain why your code looks so much like the code on Github."
  - Fred: "Gee, I don't know. I guess all solutions look pretty much alike."
  - Instructor: "I don't believe you. I am going to file an academic integrity violation."
    - Fred will have the right to appeal, but the instructor does not need him to admit his guilt in order to penalize him.
- **Consequences**
  - Fred may (most likely) will be given a failing grade for the course
  - Fred will be reported to the university
  - A second AIV will lead to a disciplinary hearing
  - Fred will go through the rest of his life carrying a burden of shame
  - The instructor will experience a combination of betrayal and distress

A Scenario: Cheating or Not?

Alice is working on malloc lab and is just plain stuck. Her code is seg faulting and she doesn't know why. It is only 2 days until malloc lab is due and she has 3 other assignments due this same week. She is in the cluster.

Bob is sitting next to her. He is pretty much done.

Sitting next to Bob is Charlie. He is also stuck.

- **1. Charlie gets up for a break and Bob makes a printout of his own code and leaves it on Charlie's chair.**
  - Who cheated: Charlie? Bob?
- **2. Charlie finds the copy of Bob's malloc code, looks it over, and then copies one function, but changes the names of all the variables.**
  - Who cheated: Charlie? Bob?

Another Scenario

Alice is working on malloc lab and is just plain stuck. Her code is seg faulting and she doesn't know why. It is only 2 days until malloc lab is due and she has 3 other assignments due this same week. She is in the cluster.

Bob is sitting next to her. He is pretty much done.

Sitting next to Bob is Charlie. He is also stuck.

- **1. Bob offers to help Alice and they go over her code together.**
  - Who cheated: Bob? Alice?
- **2. Bob gets up to go to the bathroom and Charlie looks over at his screen to see how Bob implemented his free list.**
  - Who cheated: Charlie? Bob?

Another Scenario (cont.)

- **3. Alice is having trouble with GDB. She asks Bob how to set a breakpoint, and he shows her.**
  - Who cheated: Bob? Alice?
- **4. Charlie goes to a TA and asks for help**
  - Who cheated: Charlie?

- **If you are uncertain which of these constitutes cheating, and which do not, please read the syllabus carefully. If you're still uncertain, ask one of the staff**

Welcome
and Enjoy!

教材阅读

- 第1章 1.1-1.4