Course Overview
Unix & C

15-123

Systems Skills in C and Unix

About the course

Effective Programming in C and UNIX

All Semesters: 9 units

- This course is designed to provide a substantial exposure to the C programming language and the Unix programming environment for students with some prior programming experience but minimal exposure to C.
- **Features of the C language** that are emphasized
  - arrays, structs and unions, dynamic memory allocation (malloc and free), pointers, pointer arithmetic, and casting.
- **Data structures that are emphasized**
  - dynamic lists and hash tables.
- **Algorithmic efficiency is emphasized**
  - Space and time complexity
- Students will develop a sense of proper programming style in the C idiom
- be exposed to cross-platform portability issues.
- learn to use tools such as emacs/vi, make, gdb to assist them in the design, testing and debugging programs. learn about regular expressions and will be able to use scripting languages such as Perl and Shell scripting
- This course serves as the prerequisite for 15-213.

Prerequisites: 15-110

Course material

Primary Course Text Books:
All course textbooks are optional. Lecture notes are available from
(1) http://www.cs.cmu.edu/~guna/15-123S10/lectures

(2) C Programming Language (2nd Edition) by Brian W. Kernighan (Author), Dennis Ritchie (Author)

Other Recommended Text Books are:
(3) "C for Java Programmers" by Thomasz Muldner" ISBN: 0-201-70279-7 - Addison Wesley Longman 2000

(4) ANSI C on UNIX by Paul Wang http://www.sofpower.com/pub_bk01.html

(5) **Learning Perl, Fourth Edition by Randal L. Schwartz, Tom Phoenix, brian d foy** Fourth Edition July 2005 http://www.oreilly.com/catalog/learnperl4/

(6) The UNIX programming Environment by Kernighan and Pike http://cm.bell-labs.com/cm/cs/upe/

Course Components

- 8 programming labs – 40%
- skills labs – 7%
- Quizzes or Salons – 10%
- Written midterm – 10%
- C programming midterm – 7%
- Script programming midterm – 5%
- Final Exam – 20%
- TA points – 1%

Course Objectives

- At the end of this course
  - You should be able to write fairly sophisticated C programs
  - You should have a good understanding of program verification, debugging (tools and process)
  - You should have a good understanding of machine memory model and how programs work
  - You should be able to write useful scripts using languages such as perl and bash
  - You will have some understanding of how assembler s work
  - You should be prepared to go into 15-213

Course Staff

- Professor Guna (http://www.cs.cmu.edu/~guna)
  - Gates 6005, office hrs – T, TR 10:30-12:00 or by appointment, or anytime my door is open
- Course Assistants
  - Section A
    - TBA
  - Section E
    - Emily Grove
  - Section F
    - Kee Young Lee
  - Section G
    - Sylvia Han

How your time should be divided

- This is how you should spend your time on any week (9 units)
  - Attending lecture
    - 3 hours
  - Recitation
    - 1 hour
  - Homework and Coding
    - 5 hours
- Disclaimer
  - It is hard to predict how long it will take you to finish your programming assignment
  - Talk to the course staff, if it is taking an unusually long time (20 hour /week)
  - We will be tracking this time as part of the assignment

Important

- Start assignments early – C programming can be very time consuming
  - Assignments are individual, do not ask others to write code or copy others code w/o permission
  - Sample code given in class can be used in any assignment
- Read notes and annotated notes
- Do homework
  - Not graded
- Attend lectures and recitations
  - DO NOT use laptops other than to take notes in class or write code
  - Any other activity is prohibited
- Seek help early and often

Testing your prior knowledge

What is a function?

- A mathematical notion is that a function takes a given set of inputs and produces one and only one output
  - Hence for the same set of inputs it must always produce the same output
- Functions can be used in programming to
  - Divide and conquer
  - Promote modularity
  - Unit testing
  - proof of correctness of the algorithm
- Functions have overhead
  - Change in execution path
  - Runtime stack use

What is the purpose of the following function?

```
int f(int n) {
        int i = 0, k = 0;
        while (k <= n) {
                k += i*2 + 1;
                i++;
        }
        return i-1;
}
```

- Write down the assumptions you make about this function

What is a Loop?

- A programming constructs that allows one to repeat a task
- What are the types of loops you know? When do you use them?
- Does a loop always ends? Give an example where a loop does not end.
- Does a loop always execute once? Give an example, where a loop may never execute.

for loop syntax (revisited)

```
for (initializations; exit condition; change)
{
        /* loop_ body  */

}
```

while loop syntax (new)

Initialize conditions

```
while  (condition(s))
{
        /* loop body */

}
```

Loop condition changes

When loops go wrong

```
int pdt =1;
for (int i=0; i<=32; i++)
    pdt *= 2;
 System.out.println(pdt);
```

Loop invariant

- A loop invariant is a boolean variable that is true before, during and just after execution of the loop
- Example: What would be a loop invariant for

```
int foo(int n) {
        int i = 0, k = 0;
        while (k <= n) {
                k += i*2 + 1;
                i++;
        }
        return i-1;
}
```

Proving the Loop invariance

```
int foo(int n) {
    int i = 0, k = 0;
    while (k <= n) {
        k += i*2 + 1;
        i++;
    }
    return i-1;
}
```

Check the loop invariant

- Is it true just before loop execution?
- Does it hold during the execution of the loop?
- Is it true just after the execution of the loop

- What are pre and post conditions for this function?

What are Strings?

- String is an array of characters
- Characters come from ASCII (8-bit) or Unicode (16-bit) tables
- Memory is a big long String of bytes
- In Java
  - Strings are objects with their own attributes and operations (methods)
  - Strings are immutable
- Strings are very common in many applications
- In C Strings are not objects and is a byte array of characters ending with NULL character '\0'

What are boolean variables?

- Boolean variables only takes values TRUE or FALSE
- C does not have boolean as a type
  - Use 0 for false and 1 for true
  - Technically we can use a byte to store things
- The condition in an if statement is a boolean variable
- Boolean variables can be combined using
  - Logical AND (&&)
  - Logical OR (||)
  - Logical NOT (!)
- Properties
  - NOT (A and B) = NOT (A) or NOT(B)
  - NOT (A or B) = NOT (A) and NOT(B)
    - Prove these identities

Logic Tables

A	B	A and B
0	0	0
0	1	0
1	0	0
1	1	1

AND

A	B	A or B
0	0	0
0	1	1
1	0	1
1	1	1

OR

A	not A
0	1
1	0

NOT

Source: mathworks

Prove !(A && B) = !A || !B

Homework:

prove

!(A || B) = !A && !B

Understanding UNIX

Operating Systems

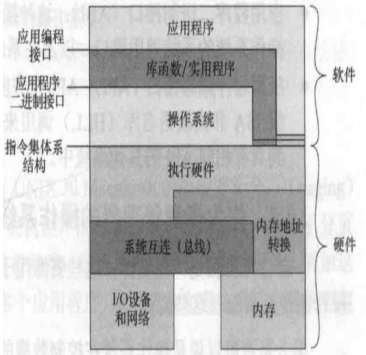
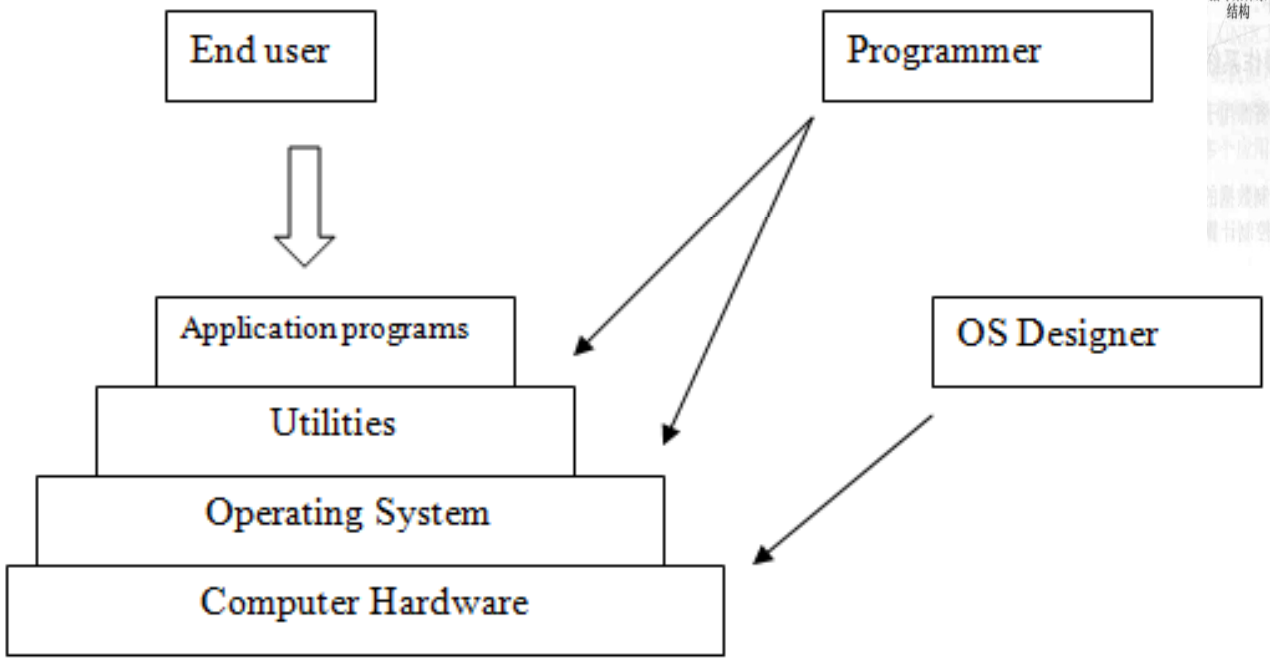


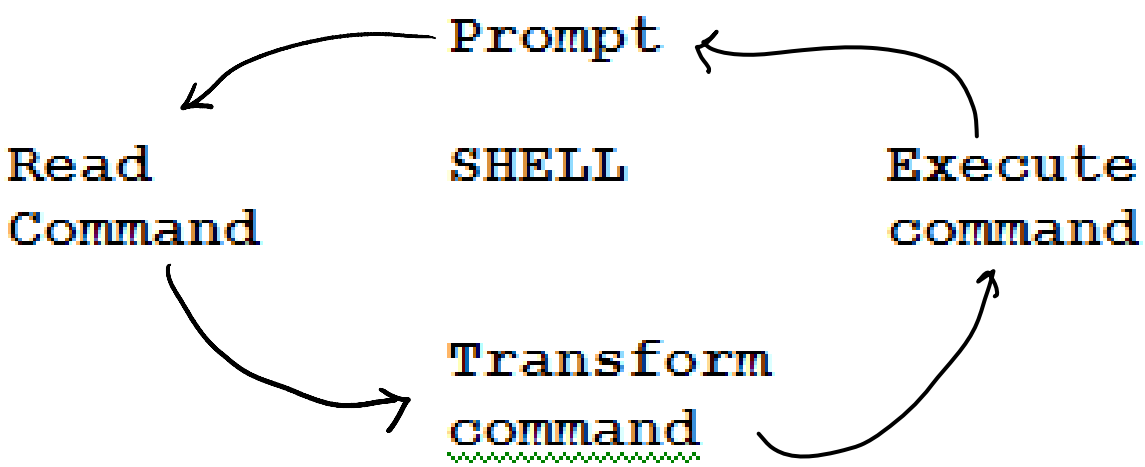
图 2.1 计算机硬件和软件结构



Unix Operating System

- Began at AT & T in 1970's
- Free source code for certain groups
  - Many versions of unix
- Linux version
  - Unix "like" system
  - Free and open source
  - Collaborative development
  - Small kernel

Unix system shell



Accessing unix

- http://www.cmu.edu/myandrew
- Download and install SSH secure shell
- SSH
  - Provides access to unix.andrew.cmu.edu machines
  - Using a shell we can perform various tasks
    - mkdir, cp, quota, mv, ...
  - We develop and test our C and perl programs
  - We write shell scripts to make life easy

What is C?

- A general purpose programming language
  - Developed in 1972 at AT &T for use with unix
- One of most popular programming languages
  - High level procedural programming
  - Direct Access to low memory
- C++ is the object oriented extension to C
  - Popular in industry
  - STL

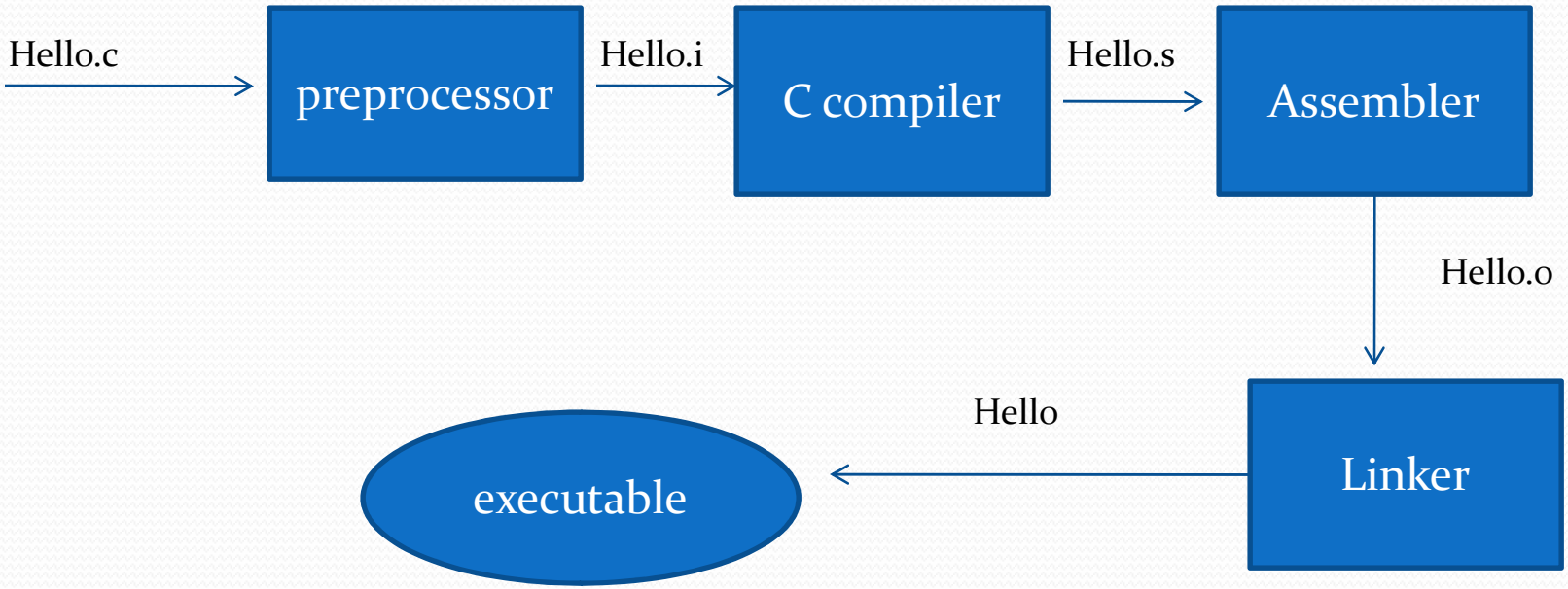
Why learn C?

- Good
  - Flexibility
  - Efficiency
  - Low level access to memory
- Caution
  - Low level access to memory
    - Memory access violations (buffer overflows)
  - Hard to debug C code
    - Use a debugger such as gdb
  - Platform dependent

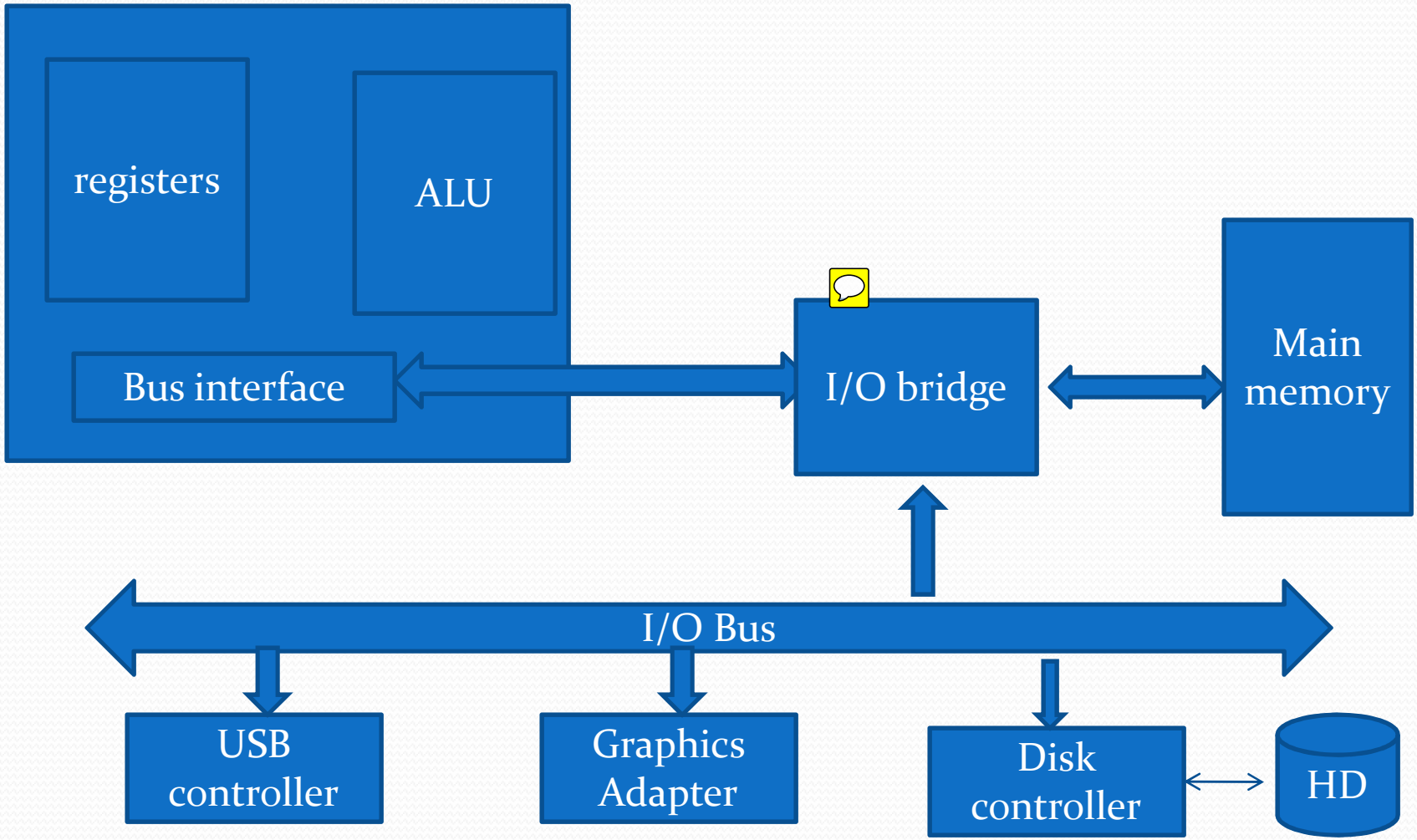
Life of a C program

```
#include <stdio.h>
int main(int argc, char* argv[]) {
    printf("hello world\n");
    return 0;
}
```

Life of a C program



How programs get executed



Program Development Process

- Editing
  - The process of creating the source code
- Compiling
  - The process of translating source code to object code
- Linking
  - The process of linking all libraries and other object codes to generate the executable code
- Executing
  - The process of running the program executable
- Testing/Debugging
  - The process of making sure program does what it is supposed to do
  - Consider all “edge” cases and make sure code does not break for some inputs

The C compiler – gcc

- GNU C compiler
  - Compiles, assemble and produce executable code
- Also can compile
  - C++, Modula-3, FORTRAN, Objective-C, …
- Examples
  - gcc hello.c → a.out
  - gcc –c hello.c → hello.o
  - gcc -S hello.c → hello.s
  - Using various flags
    - gcc –std=c99 hello.c
    - gcc –Wall –pedantic –ansi –O2 program.c

ANSI C

- Standard published by
  - American National Standards institute for C language
- Some ANSI features
  - Do not mix data and code
  - Do not use functions that are not part of the standard libraries

Moving from Java to C

- From object oriented thinking to procedural thinking
- From classes and methods to functions/procedures
- From object oriented decomposition to procedural decomposition
- From a relatively “safe” high level language to fairly low level “unsafe” language
- From no direct access to memory (Java) to direct manipulation of memory.
- Automatic garbage collection to no garbage collection (clean up)

Code Examples

Data Representations

Data representations

- int x = 15;
  - Decimal representation of 15
- int x = 0x0F;
  - Hexadecimal (base-16) representation of 15
- 15 = 0000 … 0000 1111
  - Binary representation of 15
- Typically integers are 32-bits
  - Most significant bit is the sign bit (1-negative, 0-positive)
  - What is the largest signed integer that can be represented by 32-bits?
  - What is the largest unsigned int?
- More about this in skills lab 1 and in lecture 02

Things to do before next class

- Take the background survey from Bb->course information
- Login to salon and complete the prior knowledge assignment
- After you complete, go back to assignment view mode and select up to 3 responses that you like from global questions
- Make your self familiar with course websites
  - Bb and http://www.cs.cmu.edu/~guna/15-123S11
- Go to recitation tomorrow

Next: more on Representation of data