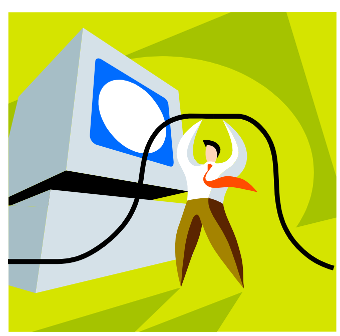
COS 217: Introduction to Programming Systems

Goals for Today's Class

- Course overview
  - Introductions
  - Course goals
  - Resources
  - Grading
  - Policies



- Getting started with C
  - C programming language overview

Introductions

- Instructor-of-Record
  - Jaswinder Pal Singh
    - jps@cs.princeton.edu
- Preceptors (in alphabetical order)
  - Robert Dondero, Ph.D. (Lead Preceptor)
    - rdondero@cs.princeton.edu
  - Christopher Moretti, Ph.D.
    - cmoretti@cs.princeton.edu
  - Vivek Pai, Ph.D. (former Instructor-of-Record)
    - vivek@cs.princeton.edu
  - Cole Schlesinger
    - cschlesi@princeton.edu
  - Richard Wang
    - rwthree@princeton.edu

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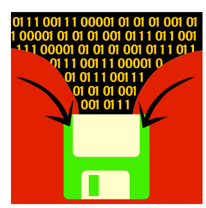
Course Goal 1: “Programming in the Large”



- Learn how to write large programs
- Specifically, help you learn how to:
  - Write modular code
    - Hide information
    - Manage resources
    - Handle errors
  - Write portable code
  - Test and debug your code
  - Improve your code’s performance (and when to do so)
  - Use tools to support those activities

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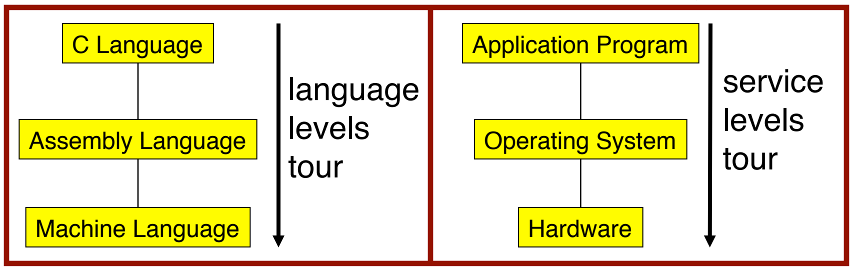
Course Goal 2: "Under the Hood"

- Learn what happens "under the hood" of computer systems
- Specifically, two downward tours



- Goal 2 supports Goal 1
  - Reveals many examples of effective abstractions

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Course Goals: Why C?

- Q: Why C instead of Java?
- A: C supports Goal 1 better
  - C is a lower-level language
    - Provides more opportunities to create abstractions
  - C has some flaws
    - The flaws motivate discussions of software engineering principles
- A: C supports Goal 2 better
  - Facilitates language levels tour
    - C is closely related to assembly language
  - Facilitates service levels tour
    - Linux is written in C

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Course Goals: Why Linux?

- Q: Why Linux instead of Microsoft Windows?
- A: Linux is good for education and research
  - Linux is open-source and well-specified
- A: Linux has good open-source programming tools
  - Linux is a variant of Unix
  - Unix has GNU, a rich open-source programming environment

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Course Goals: Summary

- Help you to become a...

Power Programmer

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Resources: Lectures and Precepts

- Lectures
  - Describe concepts at a high level
  - Slides available online at course Web site
- Precepts
  - Support lectures by describing concepts at a lower level
  - Support your work on assignments
- Note: Precepts begin on Monday

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Resources: Website and Listserv

- Website
  - Access from http://www.cs.princeton.edu
    - Academics → Course Schedule → COS 217
- Listserv
  - cos217@lists.cs.princeton.edu
  - Subscription is required
  - Instructions provided in first precept

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Resources: Books

- Required book
  - *C Programming: A Modern Approach (2nd Edition),* King, 2008.
    - Covers the C programming language and standard libraries
- Highly recommended books
  - *The Practice of Programming,* Kernighan and Pike, 1999.
    - Covers "programming in the large"
    - (Required for COS 333)
  - *Computer Systems: A Programmer's Perspective (Second Edition)*, Bryant and O'Hallaron, 2010.
    - Covers "under the hood"
    - Some key sections are on electronic reserve
    - First edition is sufficient
  - *Programming with GNU Software*, Loukides and Oram, 1997.
    - Covers tools
- *All books are on reserve in Engineering Library*

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Resources: Manuals

- Manuals (for reference only, available online)
  - *IA32 Intel Architecture Software Developer's Manual, Volumes 1-3*
  - *Tool Interface Standard & Executable and Linking Format*
  - *Using 'as,' the GNU Assembler*
- See also
  - Linux **`man`** command
    - **`man`** is short for "manual"
    - For more help, type **`man man`**

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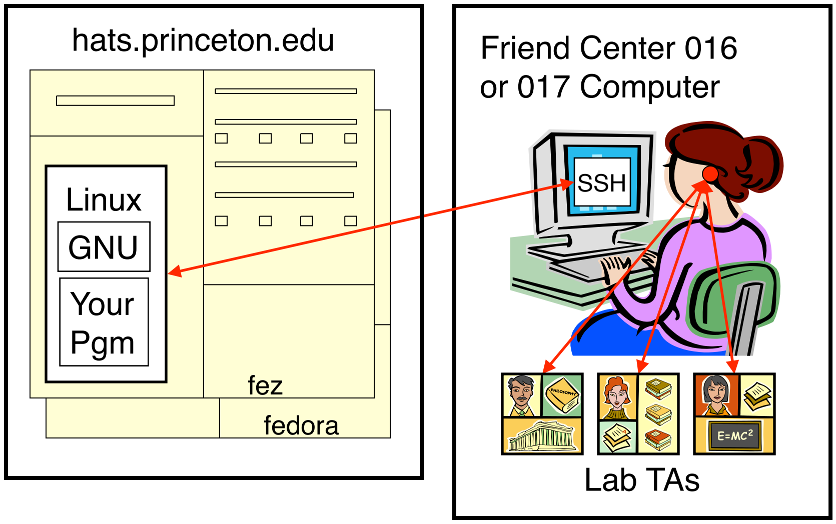
Resources: Programming Environment

- Option 1



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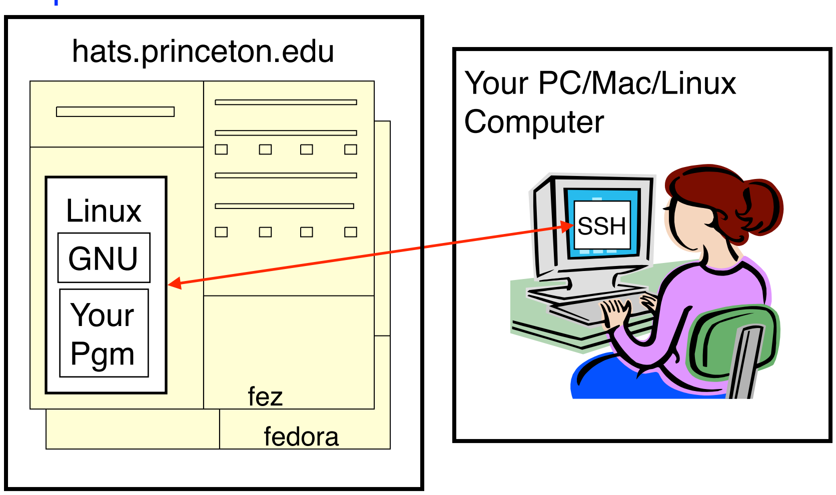
Resources: Programming Environment

- Option 2



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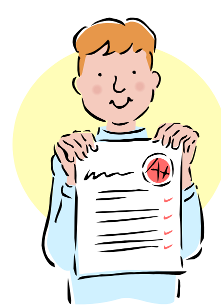
Resources: Programming Environment

- Other options
  - Use your own PC/Mac/Linux computer; run GNU tools locally; run your programs locally
  - Use your own PC/Mac/Linux computer; run a non-GNU development environment locally; run your programs locally
  - Etc.
- Notes
  - Other options cannot be used for some assignments (esp. timing studies)
  - Instructors cannot promise support of other options
  - Strong recommendation: Use Option 1 or 2 for **all** assignments
  - First precept provides setup instructions

Grading

- Seven programming assignments (50%)
  - Working code
  - Clean, readable, maintainable code
  - On time (penalties for late submission)
  - Final assignment counts double (12.5%)
- Exams (40%)
  - Midterm (15%)
  - Final (25%)
- Class participation (10%)
  - Lecture and precept attendance is ***mandatory***
  - Sign-up sheets will be used for both. Attendance is a key part of class participation.



Programming Assignments

- Programming assignments
  1. A “de-comment” program
  2. A string module
  3. A symbol table module
  4. IA-32 assembly language programs
  5. A buffer overrun attack
  6. A heap manager module
  7. A Unix shell
- Key part of the course
- See course “Schedule” web page for due dates/times
- First assignment is available now
- Advice: Start early to ensure you understand the assignment fully and to allow time for debugging.

Why Debugging is Necessary…

Policies

Study the course “Policies” web page

- Especially the assignment collaboration policies
  - Violation involves **trial by Committee on Discipline**
  - Typical penalty is **suspension from University** for 1 academic year
- Some highlights:
  - Don’t view anyone else’s work during, before, or after the assignment time period
  - Don’t allow anyone to view your work during, before, or after the assignment time period
  - In your assignment “readme” file, acknowledge all resources used
- Ask your preceptor for clarifications if necessary

Study the course “Policies” web page

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Course Schedule

- Very generally…

Weeks	Lectures	Precepts
1-2	Intro to C (conceptual)	Intro to Linux/GNU Intro to C (mechanical)
3-6	“Pgmming in the Large”	Advanced C
6	Midterm Exam	
7	Recess	
8-13	“Under the Hood”	Assembly Language assignments
	Reading Period	
	Final Exam	

- See course “Schedule” web page for details

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Any questions before we start?

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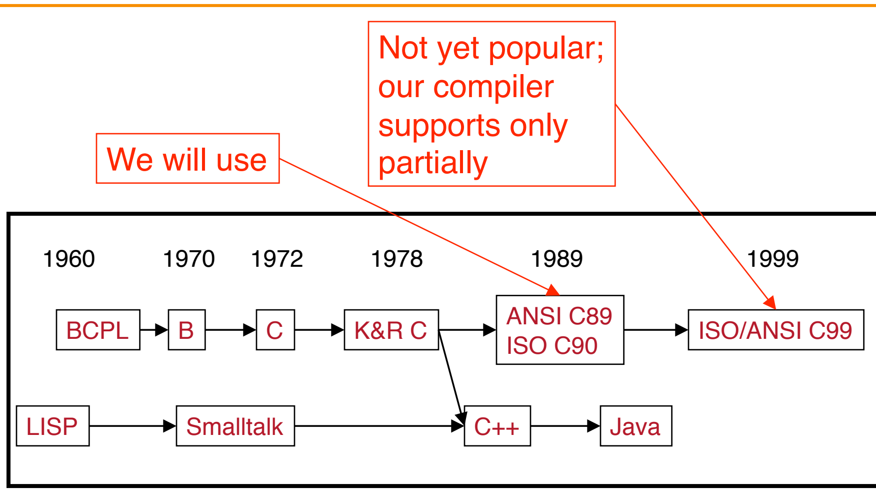
C vs. Java: History



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C vs. Java: Design Goals

- Java design goals
  - Support object-oriented programming
  - Allow same program to be executed on multiple operating systems
  - Support using computer networks
  - Execute code from remote sources securely
  - Adopt the good parts of other languages (esp. C and C++)
- Implications
  - Good for application-level programming
  - High-level
    - Virtual machine insulates programmer from underlying assembly language, machine language, hardware
  - Portability over efficiency
  - Security over efficiency
  - Security over flexibility

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C vs. Java: Design Goals

- C design goals
  - Support structured programming
  - Support development of the Unix OS and Unix tools
    - As Unix became popular, so did C
- Implications for C
  - Good for system-level programming
    - But often used for application-level programming – sometimes inappropriately
  - Low-level
    - Close to assembly language; close to machine language; close to hardware
  - Efficiency over portability
  - Efficiency over security
  - Flexibility over security

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C vs. Java: Design Goals

- Differences in design goals explain many differences between the languages
- C's design goal explains many of its eccentricities
    - We'll see examples throughout the course

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C vs. Java: Overview

- Dennis Ritchie on the nature of C:
    - "C has always been a language that never attempts to tie a programmer down."
    - "C has always appealed to systems programmers who like the terse, concise manner in which powerful expressions can be coded."
    - "C allowed programmers to (while sacrificing portability) have direct access to many machine-level features that would otherwise require the use of assembly language."
    - "C is quirky, flawed, and an enormous success. While accidents of history surely helped, it evidently satisfied a need for a system implementation language efficient enough to displace assembly language, yet sufficiently abstract and fluent to describe algorithms and interactions in a wide variety of environments."

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C vs. Java: Overview (cont.)

- Bad things you **can** do in C that you **can't** do in Java
  - Shoot yourself in the foot (safety)
  - Shoot others in the foot (security)
  - Ignore wounds (error handling)
- Dangerous things you **must** do in C that you **don't** in Java
  - Explicitly manage memory via `malloc()` and `free()`
- Good things you **can** do in C, but (more or less) **must** do in Java
  - Program using the object-oriented style
- Good things you **can't** do in C but **can** do in Java
  - Write completely portable code

C vs. Java: Details

- Remaining slides provide some details
  - Suggestion: Use for future reference
- Slides covered briefly now, as time allows…

C vs. Java: Details (cont.)

	Java	C

Overall Program Structure	`Hello.java:`
	`public class Hello {`
	`  public static void`
	`    main(String[] args) {`
	`      System.out.println(`
	`        "Hello, world");`
	`  }`
	`}`
		`hello.c:`
		`#include <stdio.h>`
		`int main(void) {`
		`  printf("Hello, world\n");`
		`  return 0;`
		`}`

Building	`% javac Hello.java`
	`% ls`
	`Hello.class`
	`Hello.java`
	`%`
		`% gcc217 hello.c`
		`% ls`
		`a.out`
		`hello.c`
		`%`

Running	`% java Hello`
	`Hello, world`
	`%`
		`% a.out`
		`Hello, world`
		`%`

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C vs. Java: Details (cont.)

	Java	C
Character type	`char // 16-bit unicode`	`char /* 8 bits */`

Integral types	`byte // 8 bits`
	`short // 16 bits`
	`int // 32 bits`
	`long // 64 bits`
		`(unsigned) char`
		`(unsigned) short`
		`(unsigned) int`
		`(unsigned) long`

Floating point types	`float // 32 bits`
	`double // 64 bits`
		`float`
		`double`
		`long double`

Logical type	`boolean`	`/* no equivalent */` `/* use integral type */`
Generic pointer type	`// no equivalent`	`void*`

Constants	`final int MAX = 1000;`	`#define MAX 1000`
		`const int MAX = 1000;`
		`enum {MAX = 1000};`

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C vs. Java: Details (cont.)

	Java	C

Arrays	`int [] a = new int [10];`
	`float [][] b =`
	`    new float [5][20];`
		`int a[10];`
		`float b[5][20];`

Array bound checking	`// run-time check`	`/* no run-time check */`
Pointer type	`// Object reference is an` `// implicit pointer`	`int *p;`

Record type	`class Mine {`
	`    int x;`
	`    float y;`
	`}`
		`struct Mine {`
		`    int x;`
		`    float y;`
		`}`

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C vs. Java: Details (cont.)

	Java	C

Strings	`String s1 = "Hello";`
	`String s2 = new`
	`    String("hello");`
		`char *s1 = "Hello";`
		`char s2[6];`
		`strcpy(s2, "hello");`

String concatenation	`s1 + s2` `s1 += s2`	`#include <string.h>` `strcat(s1, s2);`
Logical ops	`&&, ||, !`	`&&, ||, !`
Relational ops	`=, !=, >, <, >=, <=`	`=, !=, >, <, >=, <=`
Arithmetic ops	`+, -, *, /, %, unary -`	`+, -, *, /, %, unary -`
Bitwise ops	`>>, <<, >>>, &, |, ^`	`>>, <<, &, |, ^`
Assignment ops	`=, *=, /=, +=, -=, <<=,` `>>=, >>>=, =, ^=, |=, %=`	`=, *=, /=, +=, -=, <<=,` `>>=, =, ^=, |=, %=`

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C vs. Java: Details (cont.)

	Java	C

if stmt	`if (i < 0)`
	`    statement1;`
	`else`
	`    statement2;`
		`if (i < 0)`
		`    statement1;`
		`else`
		`    statement2;`

switch stmt	`switch (i) {`
	`  case 1:`
	`      ...`
	`      break;`
	`  case 2:`
	`      ...`
	`      break;`
	`  default:`
	`      ...`
	`}`
		`switch (i) {`
		`  case 1:`
		`      ...`
		`      break;`
		`  case 2:`
		`      ...`
		`      break;`
		`  default:`
		`      ...`
		`}`

goto stmt	`// no equivalent`	`goto SomeLabel;`

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C vs. Java: Details (cont.)

	Java	C

for stmt	`for (int i=0; i<10; i++)`
	`    statement;`
		`int i;`
		`for (i=0; i<10; i++)`
		`    statement;`

while stmt	`while (i < 0)` `    statement;`	`while (i < 0)` `    statement;`

do-while stmt	`do {`
	`    statement;`
	`    …`
	`} while (i < 0)`
		`do {`
		`    statement;`
		`    …`
		`} while (i < 0);`

continue stmt	`continue;`	`continue;`
labeled continue stmt	`continue SomeLabel;`	`/* no equivalent */`
break stmt	`break;`	`break;`
labeled break stmt	`break SomeLabel;`	`/* no equivalent */`

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C vs. Java: Details (cont.)

	Java	C
return stmt	`return 5;` `return;`	`return 5;` `return;`

Compound stmt (alias block)	`{`
	`statement1;`
	`statement2;`
	`}`
		`{`
		`statement1;`
		`statement2;`
		`}`

Exceptions	`throw, try-catch-finally`	`/* no equivalent */`
Comments	`/* comment */` `// another kind`	`/* comment */`

Method / function call	`f(x, y, z);`
	`someObject.f(x, y, z);`
	`SomeClass.f(x, y, z);`
		`f(x, y, z);`

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Example C Program

```
#include <stdio.h>
#include <stdlib.h>

const double KMETERS_PER_MILE = 1.609;

int main(void) {
   int miles;
   double kmeters;
   printf("miles: ");
   if (scanf("%d", &miles) != 1) {
      fprintf(stderr, "Error: Expect a number.\n");
      exit(EXIT_FAILURE);
   }
   kmeters = miles * KMETERS_PER_MILE;
   printf("%d miles is %f kilometers.\n",
      miles, kmeters);
   return 0;
}
```

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Summary

- Course overview
  - Goals
    - Goal 1: Learn “programming in the large”
    - Goal 2: Look “under the hood”
    - Goal 2 supports Goal 1
    - Use of C and Linux supports both goals
  - Learning resources
    - Lectures, precepts, programming environment, course listserv, textbooks
    - Course Web site: access via http://www.cs.princeton.edu

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Summary

- Getting started with C
  - C was designed for system programming
    - Differences in design goals of Java and C explain many differences between the languages
    - Knowing C design goals explains many of its eccentricities
  - Knowing Java gives you a head start at learning C
    - C is not object-oriented, but many aspects are similar

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Getting Started

- Check out course Web site **soon**
  - Study “Policies” page
  - First assignment is available

- Establish a reasonable computing environment **soon**
  - Instructions given in first precept

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