CSE 333
Lecture 1 - Intro, C refresher

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Welcome!

Today’s goals:

- introductions
- course syllabus
- quick C refresher
Introductions

Us (cse333-staff@cs)

- Hal Perkins (Instructor)
- Catie Baker (TA)
- Lauren Milne (TA)
- Soumya Vasisht (TA)

Most important: You!!
Welcome!

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Course map: 100,000 foot view

**Operating System**
- C application
  - C standard library (glibc)
- C++ application
  - C++ STL / boost / standard library
- Java application
  - JRE

**Hardware**
- CPU
- memory
- storage
- network
- GPU
- clock
- audio
- radio
- peripherals

**HW/SW interface (x86 + devices)**

**OS / app interface (system calls)**
Systems programming

The programming skills, engineering discipline, and knowledge you need to build a system

- **programming**: C / C++
- **discipline**: testing, debugging, performance analysis
- **knowledge**: long list of interesting topics
  - concurrency, OS interfaces and semantics, techniques for consistent data management, distributed systems algorithms, ...
  - most important: a deep understanding of the “layer below”
  - quiz: is data safely on disk after a “write( )” system call returns?
Discipline?!?

Cultivate good habits, encourage clean code

- coding style conventions
- unit testing, code coverage testing, regression testing
- documentation (code comments, design docs)
- code reviews

Will take you a lifetime to learn

- but oh-so-important, especially for systems code
  - avoid write-once, read-never code
What you will be doing

Attending lectures and sections
- lecture: ~24 of them, MWF here
- sections: ~9 of them, Thur., same time, same place
- Take notes!!!! Don’t expect everything to be on the web

Doing programming projects
- 4 of them, successively building on each other, plus a warmup
- includes C, C++; file system, network

Doing programming exercises
- one per lecture, due before the next lecture begins
- coarse-grained grading (0,1,2,3)

Midterm and a final exam (1 hour each, weighted equally)
- No final exam period during summer so 2nd exam will be the last day of class
Deadlines & Conduct

Need to get things done on time (very hard to catch up)

- Programming assignments: 4 late days, 2 max per project
- Exercises: no late days (max benefit that way)

Academic Integrity (details on the web; read them)

- I trust you implicitly; I will follow up if that trust is violated
- The rules boil down to: don’t attempt to gain credit for something you didn’t do; don’t help others to do so
- That does not mean suffer in silence - you have colleagues, instructor, TAs - work with them; learn from each other!
Course web/calendar

Linked off of the course web page

- master schedule for the class
- links to:
  - lecture slides
  - code discussed in lectures
  - assignments, exercises (including due dates)
  - optional “self-exercise” solutions
  - various C/C++/Linux resources
Labs, office hours, &c

CSE 003 is the primary instructional lab this summer

Office hours: plan is to have something Mon.-Fri.
- What works best with your schedules?

Discussion board to stay in touch outside of class
- See main web page for link

Mailing list for announcements
- You are automatically subscribed when you are registered
Welcome!

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Created in 1972 by Dennis Ritchie

- designed for creating system software
- portable across machine architectures
- most recently updated in 1999 (C99) and 2011 (C11)

Characteristics

- low-level, smaller standard library than Java
- procedural (not object-oriented)
- typed but unsafe; incorrect programs can fail spectacularly
C workflow

Source files (.c, .h)

Editor (emacs, vi) or IDE (eclipse)

Compile

Object files (.o)

Link

Executable

Load

Process

Execute, debug, profile, ...

Statically linked libraries

Shared libraries

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From C to machine code

C source file
(dosum.c)

```c
int dosum(int i, int j) {
    return i+j;
}
```

C compiler (gcc -S)

dosum:
pushl %ebp
movl %esp, %ebp
movl 12(%ebp), %eax
addl 8(%ebp), %eax
popl %ebp
ret

assembly source file
(dosum.s)

```asm
80483b0: 55 89 e5 8b 45 0c 03 45 08 5d c3
```

machine code
(dosum.o)
Skipping assembly language

Most C compilers generate .o files (machine code) directly
- i.e., without actually saving the readable .s assembly file
Multi-file C programs

C source file (dosum.c)

```c
#include <stdio.h>
int dosum(int i, int j) {
    return i+j;
}
```

dosum() is implemented in dosum.c

this “prototype” of dosum() tells gcc about the types of dosum’s arguments and its return value

C source file (sumnum.c)

```c
int main(int argc, char **argv) {
    printf("%d\n", dosum(1,2));
    return 0;
}
```

dosum() is implemented in dosum.c
Multi-file C programs

C source file (dosum.c)

```c
#include <stdio.h>
int dosum(int i, int j) {
    return i+j;
}
```

C source file (sumnum.c)

```c
#include <stdio.h>
int dosum(int i, int j);
int main(int argc, char **argv) {
    printf("%d\n", dosum(1,2));
    return 0;
}
```

why do we need this `#include`?

where is the implementation of `printf`?
Compiling multi-file programs

Multiple object files are **linked** to produce an executable

- standard libraries (libc, crt1, ...) are usually also linked in
- a library is just a pre-assembled collection of .o files

```
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```
Object files

sumnum.o, dosum.o are **object files**

- each contains machine code produced by the compiler
- each might contain references to external symbols
  - variables and functions not defined in the associated .c file
  - e.g., sumnum.o contains code that relies on printf() and dosum(), but these are defined in libc.a and dosum.o, respectively
- linking resolves these external symbols while smooshing together object files and libraries
Let’s dive into C itself

Things that are the same as Java

- syntax for statements, control structures, function calls
- types: int, double, char, long, float
- type-casting syntax: float \( x = (\text{float}) 5 / 3; \)
- expressions, operators, precedence
  
  + - * / % ++ -- = += -= *= /= %= < <= == != > >= && || !

- scope (local scope is within a set of \{\} braces)
- comments: /* comment */ // comment
# Primitive types in C

## integer types
- char, int

## floating point
- float, double

## modifiers
- short [int]
- long [int, double]
- signed [char, int]
- unsigned [char, int]

## Table of Primitive Types in C

<table>
<thead>
<tr>
<th>Type</th>
<th>bytes (32 bit)</th>
<th>bytes (64 bit)</th>
<th>32 bit range</th>
<th>printf</th>
</tr>
</thead>
<tbody>
<tr>
<td>char</td>
<td>1</td>
<td>1</td>
<td>[0, 255]</td>
<td>%c</td>
</tr>
<tr>
<td>short int</td>
<td>2</td>
<td>2</td>
<td>[-32768, 32767]</td>
<td>%hd</td>
</tr>
<tr>
<td>unsigned short int</td>
<td>2</td>
<td>2</td>
<td>[0, 65535]</td>
<td>%hu</td>
</tr>
<tr>
<td>int</td>
<td>4</td>
<td>4</td>
<td>[-214748648, 2147483647]</td>
<td>%d</td>
</tr>
<tr>
<td>unsigned int</td>
<td>4</td>
<td>4</td>
<td>[0, 4294967295]</td>
<td>%u</td>
</tr>
<tr>
<td>long int</td>
<td>4</td>
<td>8</td>
<td>[-2147483648, 2147483647]</td>
<td>%ld</td>
</tr>
<tr>
<td>long long int</td>
<td>8</td>
<td>8</td>
<td>[-9223372036854775808, 9223372036854775807]</td>
<td>%lld</td>
</tr>
<tr>
<td>float</td>
<td>4</td>
<td>4</td>
<td>approx [10^{-38}, 10^{38}]</td>
<td>%f</td>
</tr>
<tr>
<td>double</td>
<td>8</td>
<td>8</td>
<td>approx [10^{-308}, 10^{308}]</td>
<td>%lf</td>
</tr>
<tr>
<td>long double</td>
<td>12</td>
<td>16</td>
<td>approx [10^{-4932}, 10^{4932}]</td>
<td>%Lf</td>
</tr>
<tr>
<td>pointer</td>
<td>4</td>
<td>8</td>
<td>[0, 4294967295]</td>
<td>%p</td>
</tr>
</tbody>
</table>

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C99 extended integer types

Solves the conundrum of “how big is a long int?”

```c
#include <stdint.h>

void foo(void) {
    int8_t  w;       // exactly 8 bits, signed
    int16_t x;       // exactly 16 bits, signed
    int32_t y;       // exactly 32 bits, signed
    int64_t z;       // exactly 64 bits, signed
    uint8_t a;       // exactly 8 bits, unsigned
    ...etc.
}
```
similar to Java...

- variables
  - C99/C11: don’t have to declare at start of a function or block
  - need not be initialized before use  \((gcc -Wall will warn)\)

```c
#include <stdio.h>

int main(int argc, char **argv) {
  int x, y = 5;   // note x is uninitialized!
  long z = x+y;

  printf("z is '%ld'\n", z); // what's printed?
  {
    int y = 10;
    printf("y is '%d'\n", y);
  }
  int w = 20;  // ok in c99
  printf("y is '%d', w is '%d'\n", y, w);
  return 0;
}
```

`varscape.c`
Similar to Java...

**const**

- a qualifier that indicates the variable’s value cannot change
- compiler will issue an **error** if you try to violate this
- why is this qualifier useful?

```c
#include <stdio.h>

int main(int argc, char **argv) {
    const double MAX_GPA = 4.0;
    printf("MAX_GPA: %g\n", MAX_GPA);
    MAX_GPA = 5.0; // illegal!
    return 0;
}
```

`consty.c`
Similar to Java…

for loops

- C99/C11: can declare variables in the loop header

if/else, while, and do/while loops

- C99/C11: `bool` type supported, with `#include <stdbool.h>`

- any type can be used; 0 means `false`, everything else `true`

```c
int i;
for (i = 0; i < 100; i++) {
    if (i % 10 == 0) {
        printf("i: %d\n", i);
    }
}
```

loopy.c
Similar to Java...

parameters / return value

- C always passes arguments by value
- "pointers"
  - lets you pass by reference
  - more on these soon
  - least intuitive part of C
  - very dangerous part of C

```c
#include <stdio.h>

void add_pbv(int c) {
    c += 10;
    printf("pbv c: %d\n", c);
}

void add_pbr(int *c) {
    *c += 10;
    printf("pbr *c: %d\n", *c);
}

int main(int argc, char **argv) {
    int x = 1;
    printf("x: %d\n", x);
    add_pbv(x);
    printf("x: %d\n", x);
    add_pbr(&x);
    printf("x: %d\n", x);
    return 0;
}
```
Very different than Java

arrays

- just a bare, contiguous block of memory of the correct size
- an array of 10 ints requires $10 \times 4$ bytes $= 40$ bytes of memory

arrays have no methods, do not know their own length

- C doesn’t stop you from overstepping the end of an array!!
- many, many security bugs come from this
Very different than Java

strings
- array of char
- terminated by the NULL character ‘\0’
- are not objects, have no methods; string.h has helpful utilities

```
char *x = "hello\n";
```
Very different than Java

errors and exceptions
- C has no exceptions (no try / catch)
- errors are returned as integer error codes from functions
- makes error handling ugly and inelegant

crashes
- if you do something bad, you’ll end up spraying bytes around memory, hopefully causing a “segmentation fault” and crash

objects
- there aren’t any; **struct** is closest feature (set of fields)
Very different than Java

memory management

- **you** must worry about this; there is no garbage collector
- local variables are allocated off of the stack
  ‣ freed when you return from the function
- global and static variables are allocated in a data segment
  ‣ are freed when your program exits
- you can allocate memory in the heap segment using `malloc()`
  ‣ you must free `malloc`ed memory with `free()`
  ‣ failing to free is a leak, double-freeing is an error (hopefully crash)
Very different than Java

Libraries you can count on

- C has very few compared to most other languages
- no built-in trees, hash tables, linked lists, sort, etc.
- you have to write many things on your own
  ‣ particularly data structures
  ‣ error prone, tedious, hard to build efficiently and portably
- this is one of the main reasons C is a much less productive language than Java, C++, python, or others
For Wednesday

Exercise 0 is due:
-  http://www.cs.washington.edu/education/courses/cse333/14su/exercises/ex00.html
-  (Easier: look on the calendar or homework page for the link)

Post a message on the discussion board
-  Get it to keep track of new messages for you!

HW0 out later today or tomorrow; due Thur.
-  Mostly logistics (get files, fiddle with files, turn in files)
-  Watch for announcement to class mailing list
See you on Wednesday!