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 - please use this address, not individual email)

Hal Perkins (Instructor)
Derek Coley (TA)
Renshu Gu (TA)
Megan McGrath (TA)
Joshua Rios (TA)
Colin Summers (TA)

Most important: You!!

Anyone still trying to register or add the class? You need the magic word!
Welcome!

Today’s goals:

* introductions

* course syllabus (highlights only - read the whole thing on the web [yes, really do read it])

* quick C refresher
Course map: 100,000 foot view

OS / app interface (system calls)

HW/SW interface (x86 + devices)

C application

C standard library (glibc)

operating system

C++ application

C++ STL / boost / standard library

Java application

JRE

hardware

CPU memory storage network

GPU clock audio radio peripherals
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: ~28 of them, MWF here
- sections: ~10 of them, Thur.; watch time schedule for possible changes
  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 in the morning before the next lecture
  coarse-grained grading (0,1,2,3)

Midterm and a final exam
Deadlines & Conduct

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

- Programming assignments: 4 late days, \textbf{2 max per project}

  Intended for unusual circumstances, not routine procrastination

- Exercises: \textbf{no late days} (max benefit that way)

Academic Integrity (details on the web; \textbf{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 \textbf{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 (might change slightly)

links to:

lecture slides

code discussed in lectures

assignments, exercises (including due dates)

optional “self-exercise” solutions

various C/C++/Linux/git/CSE resources

Explore!!!
Labs, office hours, &c

Office hours: plan is to have something Mon.-Fri.

Past quarters - late afternoons worked. OK this time?

Discussion board: stay in touch outside of class

See main web page for link, post followup to welcome msg

Mailing list for announcements

You are automatically subscribed when you are registered
Welcome!

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C

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
Editor (emacs, vi)
or IDE (eclipse)

C workflow

- **source files** (.c, .h)
  - `foo.h`
  - `bar.c`
- **object files** (.o)
  - `foo.o`
  - `bar.o`
- **executable**
  - `bar`
- **link**
  - `libZ.a`
  - `libc.s`
  - **load**
  - **process**
  - **execute, debug, profile, ...**
int dosum(int i, int j) {
    return i+j;
}

assembly source file
(dosum.s)

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

```
$ gcc -S dosum.c
$ gcc -c dosum.s
$ as dosum.o
```
Multi-file C programs

C source file (dosum.c)

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

C source file (sumnum.c)

```c
#include <stdio.h>

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

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

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

Dosum() is implemented in dosum.c.
#include <stdio.h>

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

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

C source file (sumnum.c)

C source file (dosum.c)
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

```
 dosum.c  gcc -c  dosum.o

 sumnum.c  gcc -c  sumnum.o
```

ld
(or gcc)

sumnum

libraries
(e.g., libc)
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 = (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]

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<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>

*typical sizes – see sizeofs.c*
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;
}
```
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?

```
#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;
}
```
Similar to Java...

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

if/else, while, and do/while loops
- C99/C11: \texttt{bool} type supported, with \#include <stdbool.h>
- any type can be used; 0 means \texttt{false}, everything else \texttt{true}

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

```c
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 in the morning, 10am, *before* class:

http://courses.cs.washington.edu/courses/cse333/17sp/exercises/ex00.html

(Easier: look on the calendar or homework page for the link)

Not registered? Do the exercise and submit it anyway!

Post a message on the discussion board

Get it to keep track of new messages for you!

HW0 out soon - will announce when ready

Mostly logistics (get files via git, change files, turn in files via git); demos/discussion during sections this week
See you on Wednesday!