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)
- Graham Blair (TA)
- Sunjay Cauligi (TA)
- Bryan Martin (TA)
- Soumya Vasisht (TA)

Most important: You!!

Overloading

The overload signup sheet is up front

- come sign up after lecture
- I'll hand the sheet in to the ugrad advisors
- by Friday, they'll let me (and you) know who gets in

Welcome!

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Course map: 100,000 foot view

C application

C++ application

Java application

C standard library (glibc)

C++ STL / boost / standard library

JRE

OS / app interface (system calls)

operating system

HW/SW interface (x86 + devices)

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: ~29 of them, MWF in this room
- sections: ~10 of them, Thu (8:30, 9:30, 10:30; rooms on web)

Doing programming projects

- 5 of them, successively building on each other
- 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 (your instructor is a traditionalist)

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, and don't help others do so
- That does *not* mean suffer in silence - you have colleagues, instructor, TAs - work with them; learn from each other!

Course calendar

Linked off of the course web page

- master schedule for the class
- will contain links to:
  - lecture slides
  - code discussed in lectures
  - assignments, exercises (including due dates)
  - optional “self-exercise” solutions

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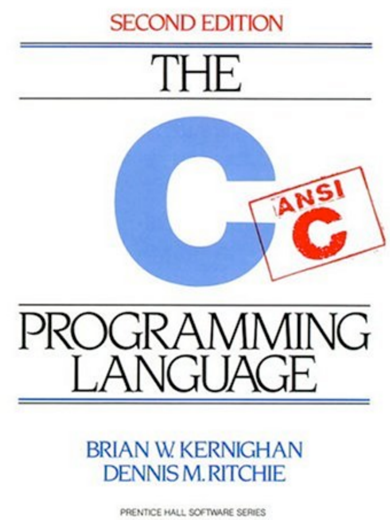
C



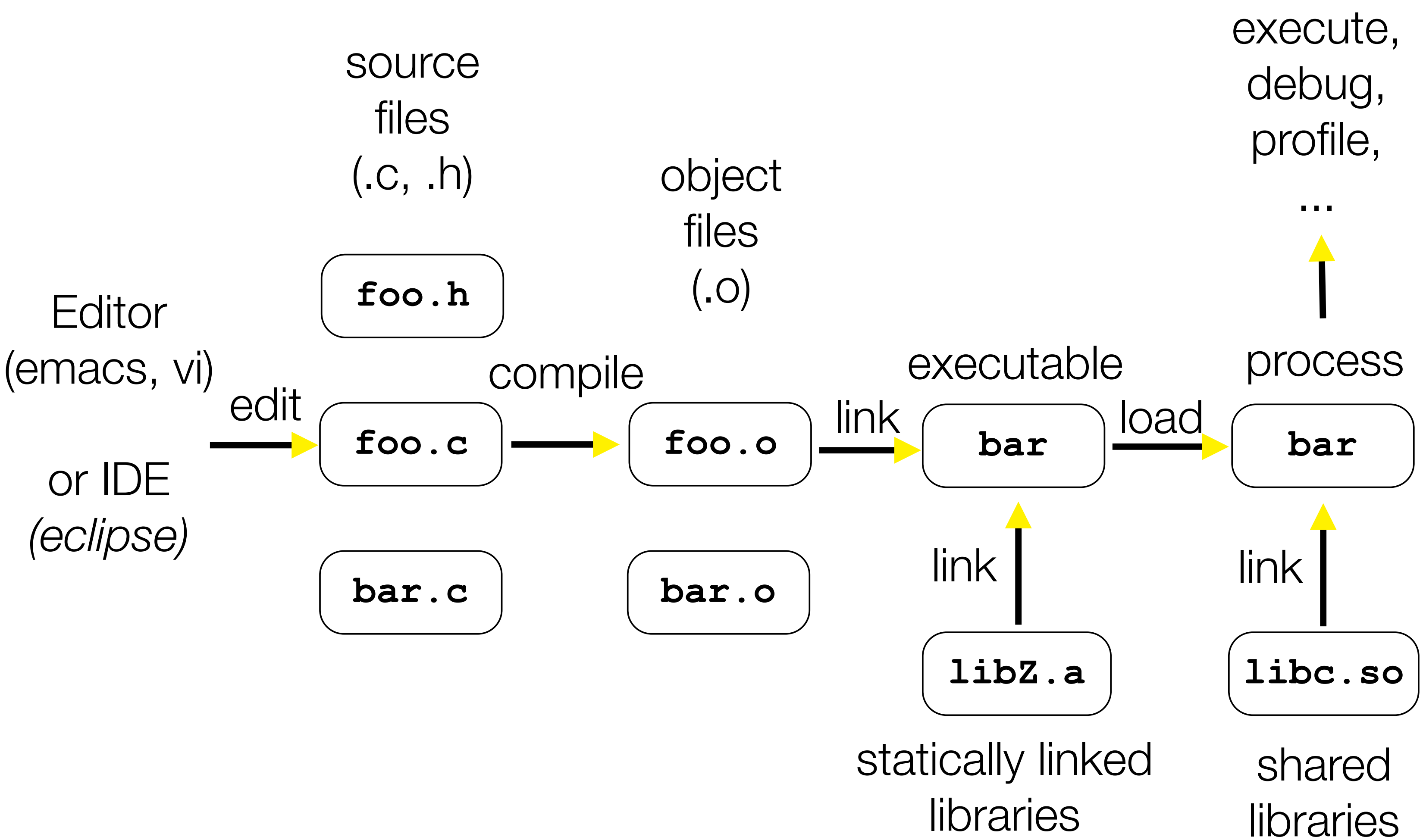
Created in 1972 by Dennis Ritchie

- 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

C workflow


source files (.c, .h)
object files (.o)
execute, debug, profile, ...
Editor (emacs, vi)
or IDE *(eclipse)*
edit
foo.h
foo.c
bar.c
compile
foo.o
bar.o
link
executable
bar
load
process
bar
link
libZ.a
statically linked libraries
link
libc.so
shared libraries

From C to machine code

C source file
(dosum.c)

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

C compiler (gcc -S)

assembly source file
(dosum.s)

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

assembler (as)

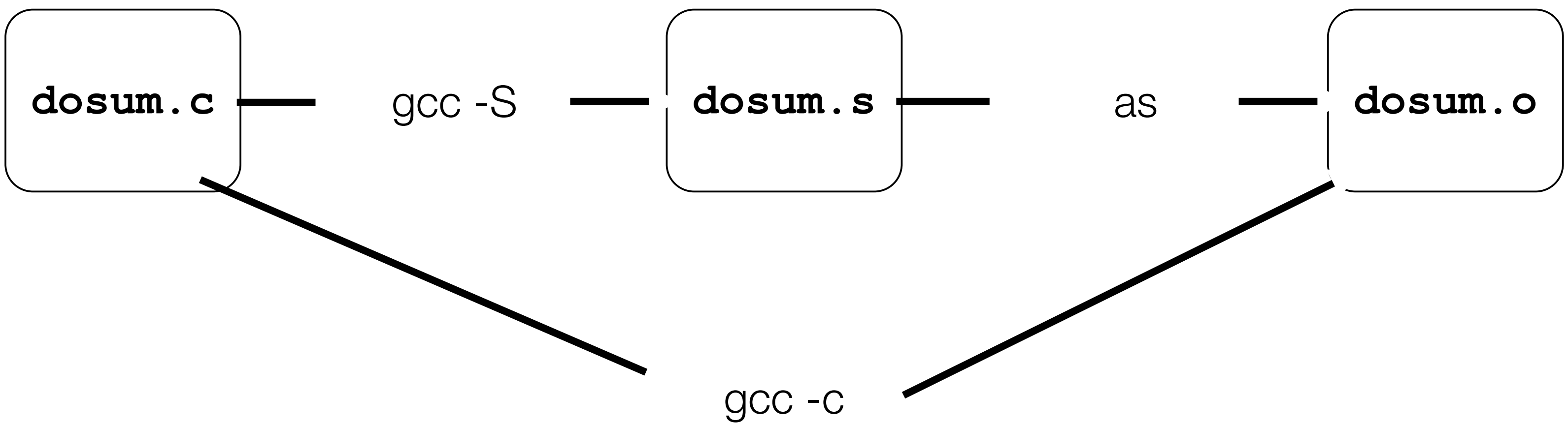
machine code
(dosum.o)

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

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)

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

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

C source file
(sumnum.c)

```
#include <stdio.h>

int dosum(int i, int j);

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)

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

C source file
(sumnum.c)

```
#include <stdio.h>

int dosum(int i, int j);

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

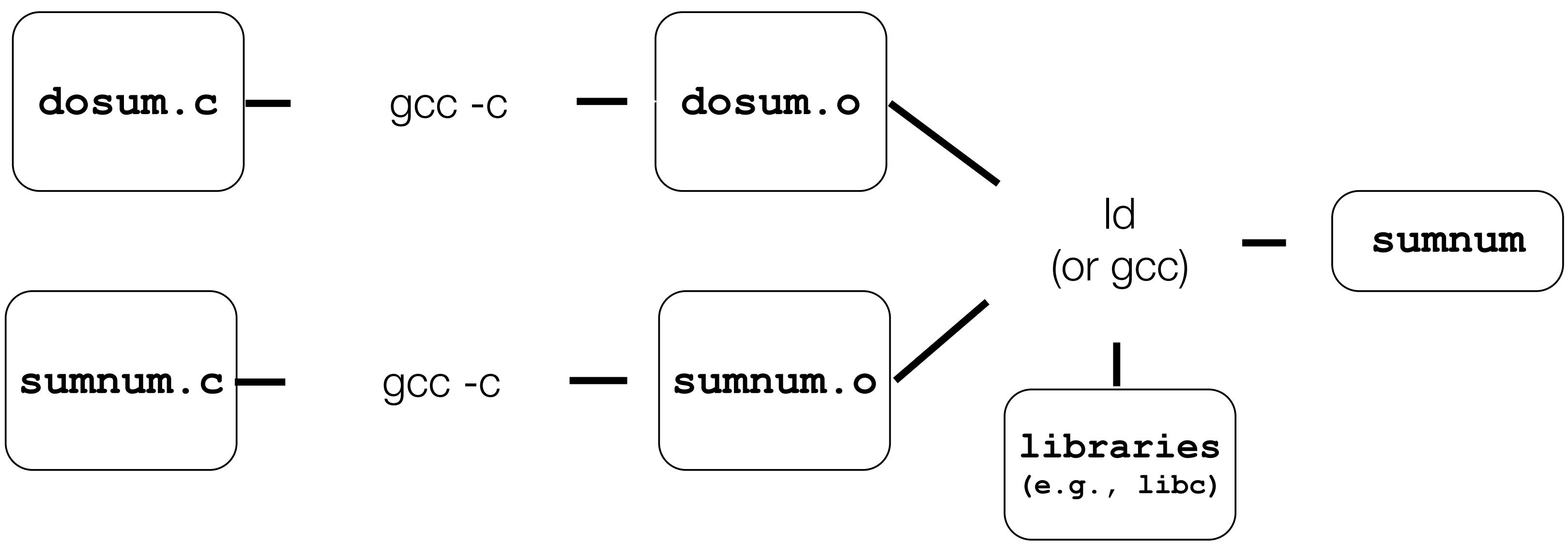
why do we need this #include?

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



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

see sizeofs.c

integer types

- char, int

floating point

- float, double

modifiers

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

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

C99 extended integer types

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

```
#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: don’t have to declare at start of a function or block
  - need not be initialized before use *(gcc -Wall will warn)*

varscope.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?

consty.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;
}
```

Similar to Java...

for loops

- C99: can declare variables in the loop header

if/else, while, and do/while loops

- C99: **bool** type supported, with #include <stdbool.h>
- any type can be used; 0 means **false**, everything else **true**

loopy.c

```
int i;

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

Similar to Java...

pointy.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;
}
```

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

Very different than Java

arrays

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

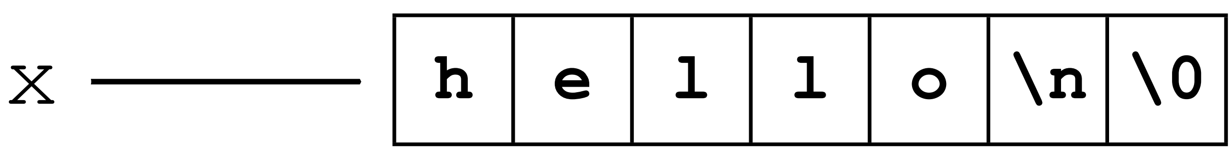
arrays have no methods, do not know their own length

- 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 to 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/cse333/13sp/exercises/ex0.html
- (Easier: look on the calendar or homework page for the link)

Homework 0 out before class Wednesday

- Mostly logistics (get files, fiddle with files, turn in files)
- Watch for email to course mailing list (and you are already subscribed if you are enrolled)

See you on Wednesday!

Sign up now if you aren’t in the class yet