CSE 333

Lecture 1 - Intro, C refresher

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Welcome!

Today's goals:

- **introductions**
- *course syllabus*
- *quick C refresher*

Us

Steve Gribble

Elliott Brossard

Chuong Dao

Overloading

The overload signup sheet is down here

- 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

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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 in MGH or 9:30 in SAV)

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)

Exams

I'm open to alternatives....

- none
- midterm only
- midterm + final

What's your preference?

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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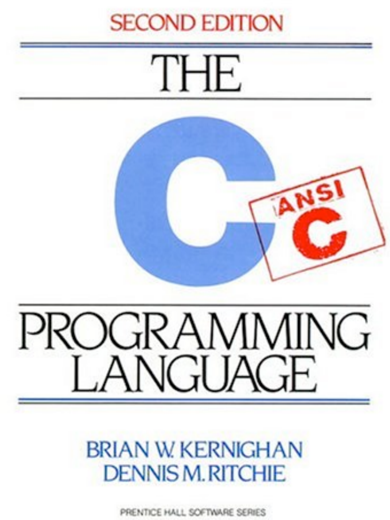
C



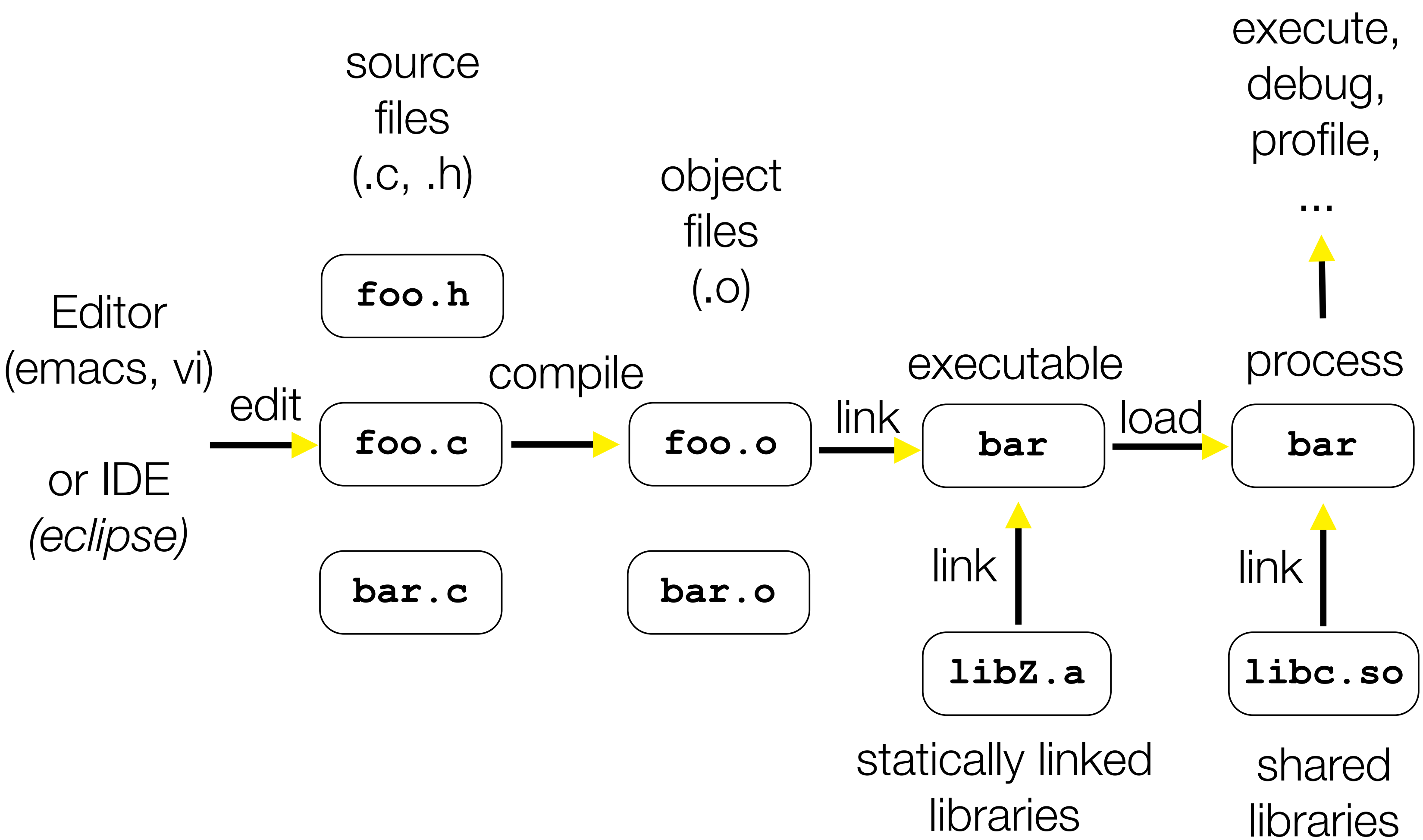
Created in 1972 by Dennis Ritchie

- 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
link
libc.so
statically linked
libraries
shared
libraries

From C to machine code

C source file
(dosum.c)

```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)

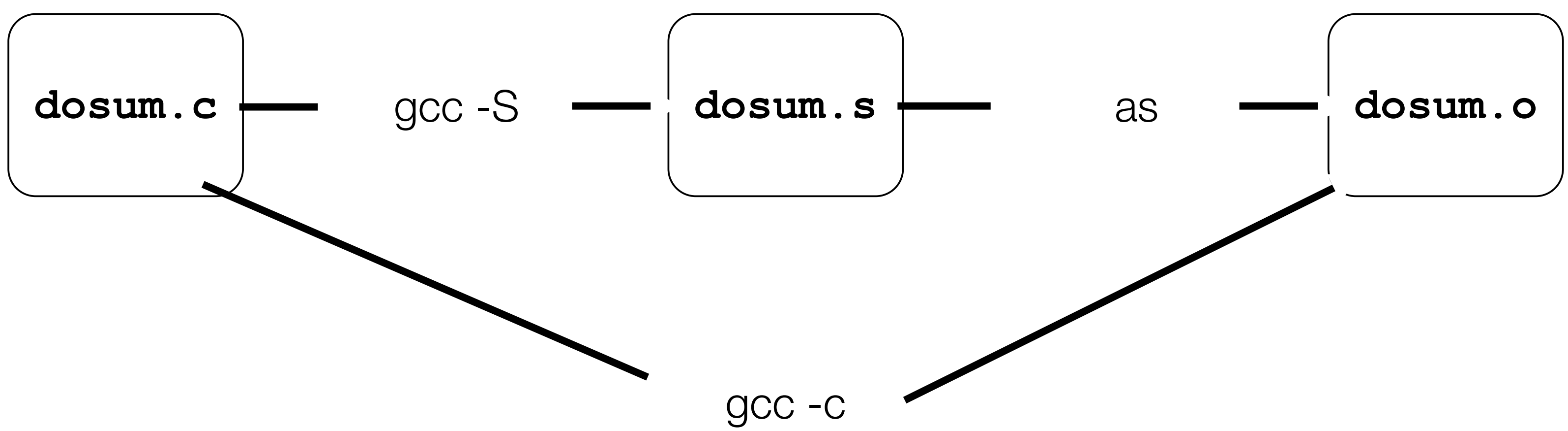
machine code
(dosum.o)

```
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;
}
```

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;
}
```

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

dosum( ) is implemented in sumnum.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;
}
```

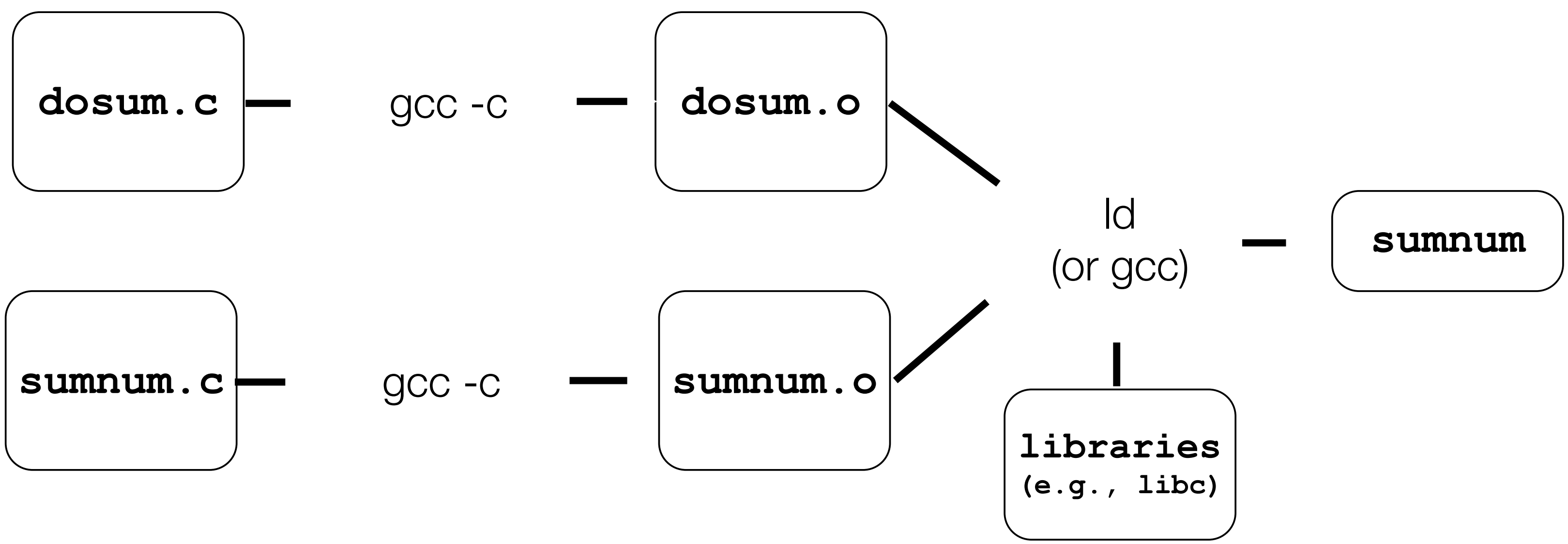
why do we need
this #include?

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

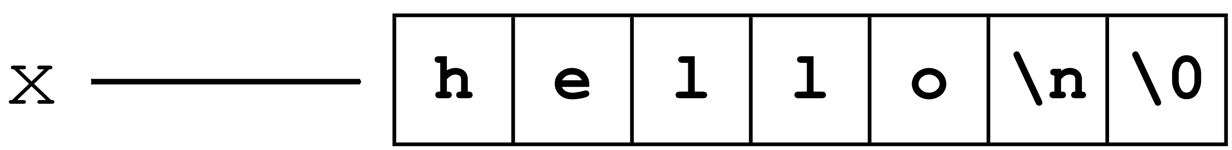
arrays have no methods, do not know their own length

- 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

Homework #0 is due:

- http://www.cs.washington.edu/education/courses/cse333/12au/assignments/hw0/hw0.html

Exercise 0 is due:

- http://www.cs.washington.edu/education/courses/cse333/12au/exercises/ex0.html

See you on Wednesday!