The Edit–Compile–Run Cycle

CS 211

Winter 2020

Road map

- Compilation
- Using the shell
- Using Make
- Using starter code

So you've written a C program:

```c
#include <stdio.h>

int main()
{
    printf("Hello, CS 211!\n");
}
```

What now?

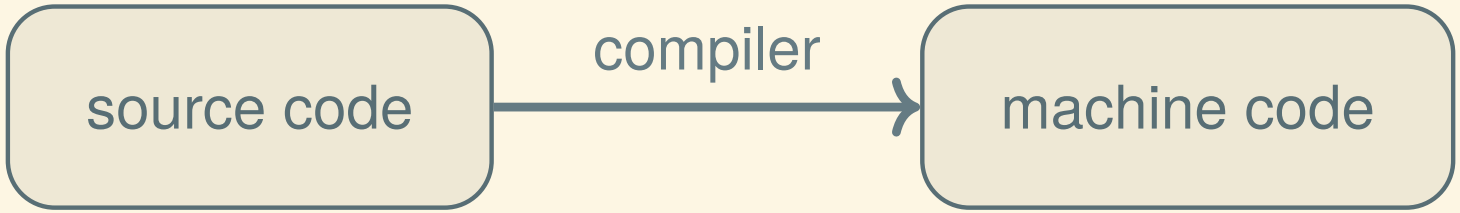
Compilation

We need to translate our program from

- source code (human readable, *e.g.,* C or Rust)

to

- machine code (machine executable, *e.g.,* x86-64 or ARM).



What does machine code look like? (1/3)

85	72	137	229	72	131	236	16
72	141	61	55	0	0	0	176
0	232	14	0	0	0	49	201
137	69	252	137	200	72	131	196
16	93	195					

(Each byte value ranges from 0 to 255.)

What does machine code look like? (2/3)

55	48	89	E5	48	83	EC	10
48	8D	3D	37	00	00	00	B0
00	E8	0E	00	00	00	31	C9
89	45	FC	89	C8	48	83	C4
10	5D	C3					

(Each byte value ranges from 0x00 to 0xFF.)

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55	48	89	E5	48	83	EC	10
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(Each byte value ranges from 0x00 to 0xFF.)

(These numbers are written in base 16, a/k/a hexadecimal, which uses letters A–F for digits greater than 9.)

What does machine code look like? (3/3)

```
55                          pushq %rbp
48 89 e5                    movq  %rsp,      %rbp
48 83 ec 10                 subq  $16,       %rsp
48 8d 3d 37 00 00 00        leaq  55(%rip), %rdi
b0 00                       movb  $0,        %al
e8 0e 00 00 00              callq 14
31 c9                       xorl  %ecx,      %ecx
89 45 fc                    movl  %eax,      -4(%rbp)
89 c8                       movl  %ecx,      %eax
48 83 c4 10                 addq  $16,       %rsp
5d                          popq  %rbp
c3                          retq
```

(Machine code printed as assembly language mnemonics.)

The Unix shell

Using Unix

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shell The main program for controlling a Unix computer, using text commands.

Using Unix

For the first few weeks of class, we are going to develop and test our programs under Unix.

Unix	A style of multi-user operating system with half a century of development. (Modern variants include Linux and macOS.)
shell	The main program for controlling a Unix computer, using text commands.
terminal	A program (or historically, device) for displaying text-based interactions with a Unix computer, often remote.

Advantages of the Unix shell (1/2)

Compared to point-and-click, you can say more with less:

```
$ mkdir backup
$ cp *.docx backup
```

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Compared to point-and-click, you can say more with less:

```
$ mkdir backup
$ cp *.docx backup

$ mkdir thumbs
$ for i in *.png; do
>   convert -geometry 128x128 "$i" "thumbs/$i"
> done
```

Advantages of the Unix shell (2/2)

You can automate repeated tasks by putting common sequences of commands in *shell scripts*:

```
#!/bin/sh

for dir in "$@"; do
  (
    cd "$dir"
    mkdir -p thumbs
    for file in *.png; do
      convert -geometry 128x128 \
          "$file" "thumbs/$file"
    done
  )
done
```

Compilation in the Unix shell

$

Compilation in the Unix shell

```
$ dev
```

You'll need to do some setup to enable the `dev` command…

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```
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% ls
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% cc hello.c -o hello
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You'll need to do some setup to enable the `dev` command…

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Compilation in the Unix shell

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% mkdir cs211
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% ls
hello.c
% cc hello.c -o hello
% ls
hello  hello.c
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```

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Compilation in the Unix shell

```
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% mkdir cs211
% cd cs211
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% ls
hello.c
% cc hello.c -o hello
% ls
hello  hello.c
% ./hello
```

You'll need to do some setup to enable the `dev` command…

Compilation in the Unix shell

```
$ dev
% mkdir cs211
% cd cs211
% emacs -nw hello.c
% ls
hello.c
% cc hello.c -o hello
% ls
hello  hello.c
% ./hello
Hello, CS 211!
%
```

You'll need to do some setup to enable the `dev` command…

Building with Make

Build management

As programs get larger, builds get more complicated:

- More files to compile, in complex combinations
- Want to just recompile the changed files
- Different compilers/machines want different options and work differently

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- More files to compile, in complex combinations
- Want to just recompile the changed files
- Different compilers/machines want different options and work differently

We'll use a software building system called Make to automate builds for us.

The `Makefile`

Make is configured using a file called `Makefile`, which is a set of rules that say what you can build, what it's built from, and how.

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The simplest possible `Makefile`:

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hello: hello.c
	cc -o hello hello.c
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The simplest possible `Makefile`:

```
hello: hello.c
	cc -o hello hello.c
```

(Meaning: To build `hello` from `hello.c`, run the command `cc -o hello hello.c`.)

Running a Make recipe

%

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```
% make hello
```

Running a Make recipe

```
% make hello
cc -o hello hello.c
%
```

Running a Make recipe

```
% make hello
cc -o hello hello.c
% make hello
```

Running a Make recipe

```
% make hello
cc -o hello hello.c
% make hello
make: `hello' is up to date.
%
```

Running a Make recipe

```
% make hello
cc -o hello hello.c
% make hello
make: `hello' is up to date.
% ./hello
```

Running a Make recipe

```
% make hello
cc -o hello hello.c
% make hello
make: `hello' is up to date.
% ./hello
Hello, CS 211!
%
```

Cleaning up

```
%
```

Cleaning up

```
% cd ..
```

Cleaning up

```
% cd ..
%
```

Cleaning up

```
% cd ..
% rm -Rf cs211
```

Cleaning up

```
% cd ..
% rm -Rf cs211
%
```

Cleaning up

```
% cd ..
% rm -Rf cs211
% mkdir cs211
```

Cleaning up

```
% cd ..
% rm -Rf cs211
% mkdir cs211
%
```

Getting & building starter code

Getting a Make project onto eecs

You can download an example Make project from the course website:

```
%
```

Getting a Make project onto `eecs`

You can download an example Make project from the course website:

```
% cd cs211
```

Getting a Make project onto eecs

You can download an example Make project from the course website:

```
% cd cs211
%
```

Getting a Make project onto `eecs`

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
```

Getting a Make project onto `eecs`

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
…
%
```

Getting a Make project onto `eecs`

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
…
% tar zxf 01compile.tgz
```

Getting a Make project onto eecs

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
…
% tar zxf 01compile.tgz
%
```

Getting a Make project onto eecs

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
…
% tar zxf 01compile.tgz
% cd 01compile
```

Getting a Make project onto eecs

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
…
% tar zxf 01compile.tgz
% cd 01compile
%
```

Getting a Make project onto eecs

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
…
% tar zxf 01compile.tgz
% cd 01compile
% ls
```

Getting a Make project onto eecs

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
…
% tar zxf 01compile.tgz
% cd 01compile
% ls
Makefile  src
%
```

Getting a Make project onto eecs

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
…
% tar zxf 01compile.tgz
% cd 01compile
% ls
Makefile  src
% ls src
```

Getting a Make project onto eecs

You can download an example Make project from the course website:

```
% cd cs211
% wget $URL211/lec/01compile.tgz
…
% tar zxf 01compile.tgz
% cd 01compile
% ls
Makefile  src
% ls src
hello.c
%
```

A fancier `Makefile`

%

A fancier `Makefile`

```
% cat Makefile
```

A fancier `Makefile`

```
% cat Makefile
# For building CS 211 Lecture 1

CFLAGS = -std=c11 -pedantic -Wall

all: build/hello

build/hello: src/hello.c
	mkdir -p build
	cc -o build/hello src/hello.c $(CFLAGS)

clean:
	rm -Rf build

.PHONY: all clean
%
```

Building the project using Make

```
%
```

Building the project using Make

```
% make
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
%
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, CS 211!
%
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' src/hello.c
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' src/hello.c
%
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' src/hello.c
% build/hello
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' src/hello.c
% build/hello
Hello, CS 211!
%
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' src/hello.c
% build/hello
Hello, CS 211!
% make
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' src/hello.c
% build/hello
Hello, CS 211!
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
%
```

Building the project using Make

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% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' src/hello.c
% build/hello
Hello, CS 211!
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
```

Building the project using Make

```
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' src/hello.c
% build/hello
Hello, CS 211!
% make
mkdir -p build
cc -o build/hello src/hello.c -std=c11 -pedant…
% build/hello
Hello, everyone!
%
```

– Next time: C syntax & more compilation –

Appendix

Numeral systems

base	counting
2 (binary)	0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011
3 (ternary)	0, 1, 2, 10, 11, 12, 20, 21, 22, 100, 101, 102
5 (quinary)	0, 1, 2, 3, 4, 10, 11, 12, 13, 14, 20, 21
8 (octal)	0, 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13
9 (nonary)	0, 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12
10 (decimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

Numeral systems

base	counting
2 (binary)	0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011
3 (ternary)	0, 1, 2, 10, 11, 12, 20, 21, 22, 100, 101, 102
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10 (decimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

base	counting
10 (decimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
11 (undecimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, 10, 11, 12, 13, 14, 15, 16
12 (duodecimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, 10, 11, 12, 13, 14, 15
14 (tetradecimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, 10, 11, 12, 13
15 (pentadecimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, 10, 11, 12
16 (hexadecimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F, 10, 11
17 (heptadecimal)	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F, G, 10