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)

(Each byte value ranges from 0 to 255.)

<table>
<thead>
<tr>
<th>85</th>
<th>72</th>
<th>137</th>
<th>229</th>
<th>72</th>
<th>131</th>
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What does machine code look like? (2/3)

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

```
pushq %rbp
movq %rsp, %rbp
subq $16, %rsp
leaq 55(%rip), %rdi
movb $0, %al
callq 14
xorl %ecx, %ecx
movl %eax, -4(%rbp)
movl %ecx, %eax
addq $16, %rsp
popq %rbp
retq
```

(Machine code printed as assembly language mnemonics.)
The Unix shell
For the first few weeks of class, we are going to develop and test our programs under Unix.
Using Unix

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

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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:

```bash
$ 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:

```bash
#!/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

$ 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…
Compilation in the Unix shell

$ dev

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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

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

```make
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

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

% make hello

cc -o hello hello.c

make hello
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Hello, CS 211!
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Cleaning up

% cd ..
% rm -Rf cs211
% mkdir cs211
Cleaning up

% cd ..
Cleaning up

% cd ..
%
Cleaning up

% cd ..
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Cleaning up

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Cleaning up

```bash
% cd ..
% rm -Rf cs211
% mkdir cs211
```
Cleaning up

% cd ..
% rm -Rf cs211
% mkdir cs211
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Getting & building starter code
Getting a Make project onto eecs

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

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

```bash

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

```
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
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

```bash
# 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, everyone!
```
Building the project using Make

```bash
% make

build/hello
Hello, CS 211!

sed -i -e 's/CS 211/everyone/' src/hello.c

build/hello
Hello, everyone!
```

```bash
% make

build/hello
```
Building the project using Make

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

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% build/hello
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% make
mkdir -p build
cmake -o build/hello src/hello.c -std=c11 -pedant...
% build/hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' src/hello.c
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% make
mkdir -p build
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% build/hello
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% build/hello
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c -o build/hello src/hello.c -std=c11 -pedant...
% build/hello
Hello, everyone!
%
– Next time: C syntax & more compilation –
Appendix
Numeral systems

<table>
<thead>
<tr>
<th>base</th>
<th>counting</th>
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</thead>
<tbody>
<tr>
<td>2 (binary)</td>
<td>0, 1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011</td>
</tr>
<tr>
<td>3 (ternary)</td>
<td>0, 1, 2, 10, 11, 12, 20, 21, 22, 100, 101, 102</td>
</tr>
<tr>
<td>5 (quinary)</td>
<td>0, 1, 2, 3, 4, 10, 11, 12, 13, 14, 20, 21</td>
</tr>
<tr>
<td>8 (octal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13</td>
</tr>
<tr>
<td>9 (nonary)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12</td>
</tr>
<tr>
<td>10 (decimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11</td>
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</tr>
<tr>
<td>11 (undecimal)</td>
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<tr>
<td>12 (duodecimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, 10, 11, 12, 13, 14, 15</td>
</tr>
<tr>
<td>14 (tetradecimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, 10, 11, 12, 13</td>
</tr>
<tr>
<td>15 (pentadecimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, 10, 11, 12</td>
</tr>
<tr>
<td>16 (hexadecimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F, 10, 11</td>
</tr>
<tr>
<td>17 (heptadecimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F, G, 10</td>
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