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 Swift)

to

- **machine code** (machine executable, *e.g.*, x86-64 or ARM).
What does machine code look like? (1/3)

<table>
<thead>
<tr>
<th>85</th>
<th>72</th>
<th>137</th>
<th>229</th>
<th>72</th>
<th>131</th>
<th>236</th>
<th>16</th>
</tr>
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<tbody>
<tr>
<td>72</td>
<td>141</td>
<td>61</td>
<td>55</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>176</td>
</tr>
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<td>0</td>
<td>232</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>69</td>
<td>252</td>
<td>137</td>
<td>200</td>
<td>72</td>
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<td>196</td>
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<td>16</td>
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</tbody>
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(Each byte value ranges from 0 to 255.)
What does machine code look like? (2/3)

(Each byte value ranges from 0x00 to 0xFF.)
What does machine code look like? (2/3)

<table>
<thead>
<tr>
<th>55</th>
<th>48</th>
<th>89</th>
<th>E5</th>
<th>48</th>
<th>83</th>
<th>EC</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>48</td>
<td>8D</td>
<td>3D</td>
<td>37</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>B0</td>
</tr>
<tr>
<td>00</td>
<td>E8</td>
<td>0E</td>
<td>00</td>
<td>00</td>
<td>00</td>
<td>31</td>
<td>C9</td>
</tr>
<tr>
<td>89</td>
<td>45</td>
<td>FC</td>
<td>89</td>
<td>C8</td>
<td>48</td>
<td>83</td>
<td>C4</td>
</tr>
<tr>
<td>10</td>
<td>5D</td>
<td>C3</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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

(These numbers are written in base 16, a/k/a hexadecimal, which uses letters A–F as digits with values 10–15.)
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
Using Unix

For the first few weeks of class, we are going to develop and test our programs under 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.)
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shell  The main program for controlling a Unix computer, using text commands.
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:

```bash
$ mkdir backup
$ cp *.docx backup
```
Advantages of the Unix shell (1/2)

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

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

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

$ dev

# enter development mode

mkdir cs211

# make directory

cd cs211

# change directory

emacs -nw hello.c

# edit (new) file

ls

# list directory contents

cc hello.c

# compile C program

ls

# list directory contents

./a.out

# run compiled program

Hello, CS 211!

(In this week's lab you'll do the necessary setup to enable the dev command.)
Compilation in the Unix shell

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% ls
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% cc hello.c
% ls
a.out hello.c
% ./a.out
Hello, CS 211!
%

(In this week’s lab you’ll do the necessary 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:

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

```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

% 

cc -o hello hello.c 

# Make prints the commands 

% 

make hello 

# and avoids unnecessary work 

make: `hello' is up to date. 

% 

./hello 

Hello, CS 211!
Running a Make recipe

% make hello
Running a Make recipe

% make hello
cc -o hello hello.c  # Make prints the commands
%
Running a Make recipe

%% make hello
cc -o hello hello.c  # Make prints the commands
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Running a Make recipe

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cc -o hello hello.c  # Make prints the commands
% make hello          # and avoids unnecessary work
make: `hello' is up to date.
% ./hello
Hello, CS 211!
%
Cleaning up

% cd ..
# change to parent directory
%
rm -R cs211
# remove recursively
%
mkdir cs211
# make it again
%
Cleaning up

% cd .. # change to parent directory
Cleaning up

% cd ..  # change to parent directory
%

% rm -R cs211  # remove recursively
%

% mkdir cs211  # make it again
%
Cleaning up

% cd .. # change to parent directory
% rm -R cs211 # remove recursively
Cleaning up

% cd .. # change to parent directory
% rm -R cs211 # remove recursively
%
Cleaning up

% cd ..
# change to parent directory
% rm -R cs211
# remove recursively
% mkdir cs211
# make it again
Cleaning up

% cd ..  # change to parent directory
% rm -R cs211  # remove recursively
% mkdir cs211  # make it again
%
Getting & building starter code
Getting a Make project onto eecs

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

```bash
% cd cs211
% curl $LEC211/01compile.tgz | tar zxvk
01compile/
01compile/Makefile
01compile/hello.c
% cd 01compile
% ls
Makefile hello.c
```
Getting a Make project onto eecs

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% cd cs211
Getting a Make project onto ee.cs

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```

```
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01compile/Makefile
01compile/hello.c
```

```bash
% cd 01compile
% ls
Makefile hello.c
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% curl $LEC211/01compile.tgz | tar zxvk
01compile/
01compile/Makefile
01compile/hello.c
%
```
Getting a Make project onto eecs

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

```
% cd cs211
% curl $LEC211/01compile.tgz | tar zxxv
01compile/
01compile/Makefile
01compile/hello.c
% cd 01compile
```
Getting a Make project onto ee.cs

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

```
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% curl $LEC211/01compile.tgz | tar zxvk
01compile/
01compile/Makefile
01compile/hello.c
% cd 01compile
%
```
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01compile/hello.c
% cd 01compile
% ls
```
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```bash
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01compile/
01compile/Makefile
01compile/hello.c
% cd 01compile
% ls
Makefile hello.c
%```
A fancier Makefile

%
A fancier Makefile

% cat Makefile
A fancier Makefile

% cat Makefile
# For building CS 211 Lecture 1

CC   ::= cc
CFLAGS = -std=c11 -pedantic -Wall

all: hello

hello: hello.c
   $(CC) -o $@ $^ $(CFLAGS)

clean:
   rm -f hello

.PHONY: all clean
Building the project using Make

%  

```bash
make
```

```bash
make cc -o hello hello.c -std=c11 -pedant...
```

```bash
./hello
```

```
Hello, CS 211!
```

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

```bash
./hello
```

```
Hello, everyone!
```

```bash
make
```
Building the project using Make

% make

../hello
Hello, CS 211!

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

../hello
Hello, everyone!
Building the project using Make

% make
cc -o hello hello.c -std=c11 -pedant...
%

Hello, CS 211!

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

Hello, everyone!
Building the project using Make

% make
c -o hello hello.c -std=c11 -pedant...
% ./hello
Building the project using Make

% make
cc -o hello hello.c -std=c11 -pedant...
% ./hello
Hello, CS 211!
%
Building the project using Make

% make
cmake -o hello hello.c -std=c11 -pedant...
% ./hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' hello.c
% ./hello
Hello, everyone!
Building the project using Make

```
% make
cmake hello hello.c -std=c11 -pedant...
% ./hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' hello.c
%```

Building the project using Make

% make
c -o hello hello.c -std=c11 -pedant...
% ./hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' hello.c
% ./hello
Building the project using Make

% make
c  c -o hello hello.c -std=c11 -pedant...
% ./hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' hello.c
% ./hello
Hello, CS 211!
%
Building the project using Make

% make
cc -o hello hello.c -std=c11 -pedant...
% ./hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' hello.c
% ./hello
Hello, CS 211!
% make
Building the project using Make

% make
c c -o hello hello.c -std=c11 -pedant...
% ./hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/' hello.c
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% make
c c -o hello hello.c -std=c11 -pedant...
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Building the project using Make

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

Building the project using Make

% make
cc -o hello hello.c -std=c11 -pedant...
% ./hello
Hello, CS 211!
% sed -i -e 's/CS 211/everyone/\' hello.c
% ./hello
Hello, CS 211!
% make
cc -o hello hello.c -std=c11 -pedant...
% ./hello
Hello, everyone!
%
— Next time: C syntax & more compilation —
Appendix
Numeral systems

<table>
<thead>
<tr>
<th>base</th>
<th>counting</th>
</tr>
</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>
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<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11</td>
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<tr>
<td>11 (undecimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, 10, 11, 12, 13, 14, 15, 16, 17</td>
</tr>
<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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