The Edit–Compile–Run Cycle

CS 211

Spring 2020
Road map

Compilation

The Unix shell

Building with Make

Getting & building starter code

Appendix: Numeral systems
Compilation
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)

<p>| | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>85</td>
<td>72</td>
<td>137</td>
<td>229</td>
<td>72</td>
<td>131</td>
<td>236</td>
<td>16</td>
</tr>
<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>
<tr>
<td>0</td>
<td>232</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>49</td>
<td>201</td>
</tr>
<tr>
<td>137</td>
<td>69</td>
<td>252</td>
<td>137</td>
<td>200</td>
<td>72</td>
<td>131</td>
<td>196</td>
</tr>
<tr>
<td>16</td>
<td>93</td>
<td>195</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(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)

(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)

(Machine code printed as **assembly language mnemonics.**)

```assembly
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
```
The Unix shell
Using Unix

For the first few weeks of class, we are going to develop and test our programs under 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.)
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.
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
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 "thumbs/$file"
    done
  )
done
```
Compilation in the Unix shell

$ 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

$ dev  # enter development mode

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

$ dev  # enter development mode
%

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

$ dev  # enter development mode
% mkdir cs211  # make directory

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

$ dev          # enter development mode
% mkdir cs211  # make directory
%

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

$ dev  # enter development mode
% mkdir cs211  # make directory
% cd cs211  # change directory

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

```bash
$ dev
% mkdir cs211
% cd cs211
%
```

# enter development mode
# make directory
# change directory

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

$ dev  # enter development mode
% mkdir cs211  # make directory
% cd cs211  # change directory
% emacs -nw hello.c  # edit (new) file

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

$ dev
% mkdir cs211
% cd cs211
% emacs -nw hello.c
%

# enter development mode
# make directory
# change directory
# edit (new) file

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

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

$ dev
% mkdir cs211
% cd cs211
% emacs -nw hello.c
% ls
hello.c
%

(In this week's lab you'll do the necessary 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

(In this week's lab you'll do the necessary 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
%

# enter development mode
# make directory
# change directory
# edit (new) file
# list directory contents
# compile C program

(In this week's lab you’ll do the necessary setup to enable the dev command.)
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
hello.c
% cc hello.c  # compile C program
% ls
# list directory contents

(In this week’s lab you’ll do the necessary 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
% ls
a.out hello.c
%

(In this week's lab you'll do the necessary 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
% ls
a.out  hello.c
% ./a.out

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

The simplest possible Makefile:

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

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

```bash
make hello
# 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
%

Hello, CS 211!
Running a Make recipe

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

% make hello
cc -o hello hello.c  # Make prints the commands
% make hello        # and avoids unnecessary work
make: 'hello' is up to date.
%

>Hello, CS 211!
Running a Make recipe

% make hello
cc -o hello hello.c  # Make prints the commands
% make hello        # and avoids unnecessary work
make: `hello' is up to date.
% ./hello
Running a Make recipe

% make hello
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

18
Cleaning up

% cd .. # change to parent directory
Cleaning up

% cd ..                      # change to parent directory
%
%
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

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:

```bash
% cd cs211
%
```
Getting a Make project onto eecs

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

% cd cs211
% curl $LEC211/01compile.tgz | tar zxvk
Getting a Make project onto eecs

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

```
% cd cs211
% curl $LEC211/01compile.tgz | tar zxv k
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 zxv
01compile/
01compile/Makefile
01compile/hello.c
% cd 01compile
```
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
%```
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 zxv
01compile/
01compile/Makefile
01compile/hello.c
% cd 01compile
% ls
```
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
%```
A fancier 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
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

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

% make

Hello, CS 211!

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

% make

Hello, everyone!
Building the project using Make

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

Hello, everyone!
% make
cc -o hello hello.c -std=c11 -pedant...
% ./hello

Building the project using Make
Building the project using Make

% make
c -o hello hello.c -std=c11 -pedant...  
% ./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, everyone!
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
%
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
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
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
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...
%
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 –
Appendix: Numeral systems
## 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>
<td>10 (decimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11</td>
</tr>
</tbody>
</table>
# 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>
<td>10 (decimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11</td>
</tr>
<tr>
<td>10 (decimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17</td>
</tr>
<tr>
<td>11 (undecimal)</td>
<td>0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, 10, 11, 12, 13, 14, 15, 16</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>
</tr>
</tbody>
</table>