
CSE 390

Lecture 8

Large Program Management: Make; Ant

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<http://www.cs.washington.edu/390a/>

Motivation

- single-file programs do not work well when code gets large
 - compilation can be slow
 - hard to collaborate between multiple programmers
 - more cumbersome to edit
- larger programs are split into multiple files
 - each file represents a partial program or *module*
 - modules can be compiled separately or together
 - a module can be shared between multiple programs
- but now we have to deal with all these files just to build our program...

Compiling: Java

- What happens when you **compile** a Java program?

`$ javac Example.java` $\xrightarrow{\text{produces}}$ `Example.class`

Answer: It produces a .class file.

- `Example.java` is compiled to create `Example.class`
- How do you **run** this Java program?

`$ java Example`

Compiling: C

| command | description |
|---------|----------------|
| gcc | GNU C compiler |

- To **compile** a C program called *source.c*, type:

`gcc -o target source.c` $\xrightarrow{\text{produces}}$ *target*

(where *target* is the name of the executable program to build)

- the compiler builds an actual *executable file* (not a `.class` like Java)
- Example: `gcc -o hi hello.c`
Compiles the file `hello.c` into an executable called “hi”
- To **run** your program, just execute that file:
 - Example: `./hi`

Object files (.o)

- A .c file can also be **compiled** into an *object (.o) file* with **-c** :

```
$ gcc -c part1.c  
$ ls  
part1.c  part1.o  part2.c
```

→
produces

part1.o

- a .o file is a binary “blob” of compiled C code that cannot be directly executed, but can be directly **linked** into a larger *executable* later
- You can **compile** and **link** a mixture of .c and .o files:

```
$ gcc -o myProgram part1.o part2.c → myProgram  
produces
```

Avoids recompilation of unchanged partial program files (e.g. **part1.o**)

Header files (.h)

- **header** : A C file whose only purpose is to be #included (#include is like java import statement)
 - generally a filename with the .h extension
 - holds shared variables, types, and function declarations
 - similar to a java interface: **contains function *declarations* but *not implementations***
- key ideas:
 - every ***name***.c intended to be a module (not a stand alone program) has a ***name***.h
 - ***name***.h declares all global functions/data of the module
 - other .c files that want to use the module will #include ***name***.h

Compiling large programs

- Compiling *multi-file* programs repeatedly is cumbersome:

```
$ gcc -o myprogram file1.c file2.c file3.c
```

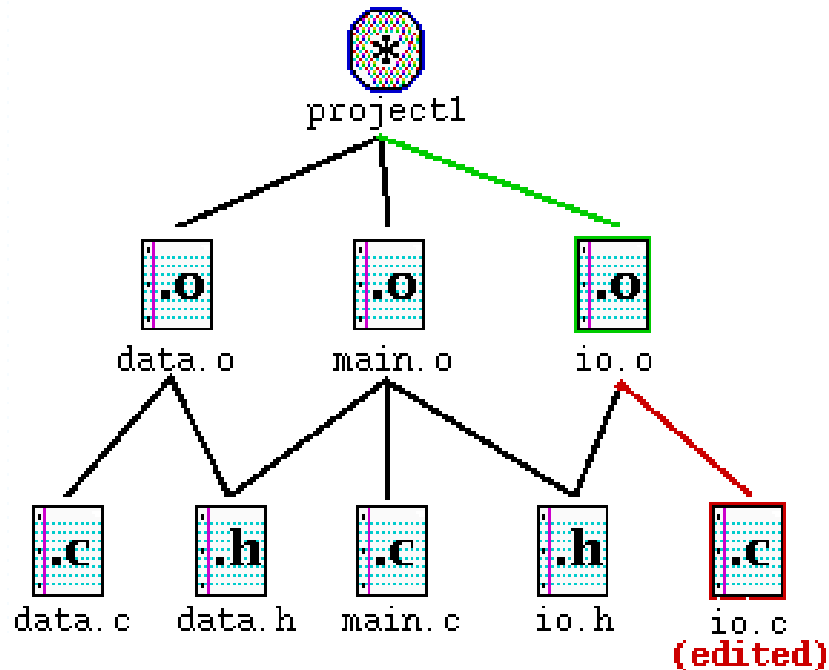
- Retyping the above command is wasteful:
 - for the developer (so much typing)
 - for the compiler (may not need to recompile all; save them as .o)
- Improvements:
 - use up-arrow or history to re-type compilation command for you
 - use an alias or shell script to recompile everything
 - use a system for compilation/build management, such as make

make

- **make** : A utility for automatically compiling ("building") executables and libraries from source code.
 - a very basic compilation manager
 - often used for C programs, but not language-specific
 - primitive, but still widely used due to familiarity, simplicity
 - similar programs: ant, maven, IDEs (Eclipse), ...
- **Makefile** : A script file that defines rules for what must be compiled and how to compile it.
 - Makefiles describe which files depend on which others, and how to create / compile / build / update each file in the system as needed.

Dependencies

- **dependency** : When a file relies on the contents of another.
 - can be displayed as a *dependency graph*
 - to build `main.o`, we need `data.h`, `main.c`, and `io.h`
 - if any of those files is updated, we must rebuild `main.o`
 - if `main.o` is updated, we must update `project1`



make Exercise

- **figlet** : program for displaying large ASCII text (like banner).
 - <http://freecode.com/projects/figlet>
- Download a piece of software and compile it with make:
 - download `.tar.gz` file
 - un-tar it
 - look at README file to see how to compile it
 - (sometimes) run `./configure`
 - for cross-platform programs; sets up make for our operating system
 - run **make** to compile the program
 - execute the program

Makefile rule syntax

```
target : source1 source2 ... sourceN  
    command  
    command  
    ...
```

- *source1* through *sourceN* are the *dependencies* for building *target*
- Make will execute the *commands* in order

Example:

```
myprogram : file1.c file2.c file3.c  
    gcc -o myprogram file1.c file2.c file3.c
```

this is a tab THIS IS NOT spaces!!

- The *command* line must be indented by a single tab
 - not by spaces; **NOT BY SPACES! SPACES WILL NOT WORK!**

Running make

\$ make *target*

- uses the file named Makefile in current directory
- Finds a rule in Makefile for building *target* and follows it
 - if the *target* file does not exist, or if it is older than any of its *sources*, its *commands* will be executed

- variations:

\$ make

- builds the *first* target in the Makefile

\$ make -f *makefileName*

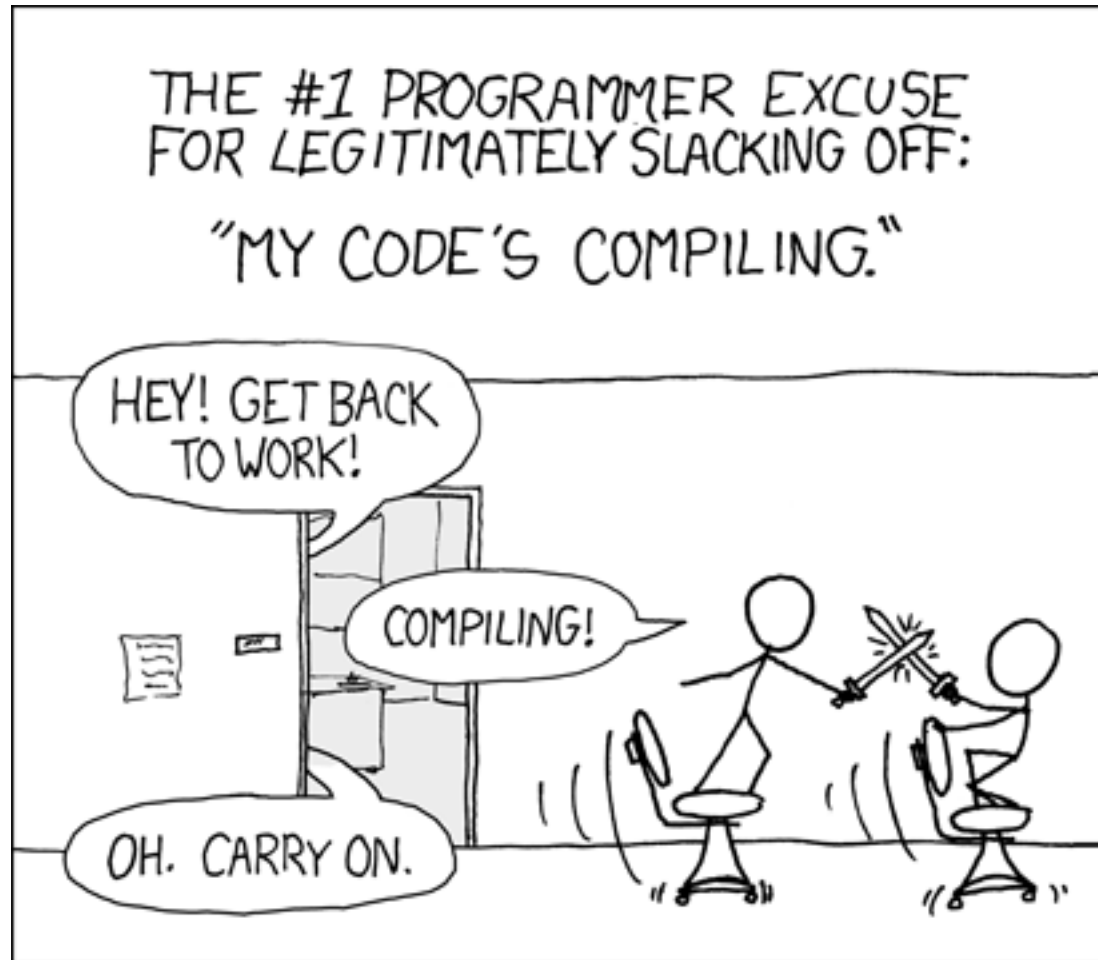
\$ make -f *makefileName target*

- uses a makefile other than Makefile

Making a Makefile

- **Exercise:** Create a basic Makefile to build {hello.c, file2.c, file3.c}
 - Basic works, but is wasteful. What happens if we change file2.c?
 - everything is recompiled. On a large project, this could be a huge waste

Making a Makefile



courtesy XKCD

Making a Makefile

- **Exercise:** Create a basic Makefile to build {hello.c, file2.c, file3.c}
 - Basic works, but is wasteful. What happens if we change file2.c?
 - everything is recompiled. On a large project, this could be a huge waste
 - Augment the makefile to make use of precompiled object files and dependencies
 - by adding additional targets, we can avoid unnecessary re-compilation

Rules with no dependencies

```
myprog: file1.o file2.o file3.o  
    gcc -o myprog file1.o file2.o file3.o
```

clean:

```
rm file1.o file2.o file3.o myprog
```

- make assumes that a rule's command will build/create its target
 - *but if your rule does not actually create its target, the target will still not exist the next time, so the rule will always execute its commands (e.g. clean above)*
 - make `clean` is a convention for removing all compiled files

Rules with no commands

```
all: myprog myprog2
```

```
myprog: file1.o file2.o file3.o  
    gcc -o myprog file1.o file2.o file3.o
```

```
myprog2: file4.c  
    gcc -o myprog2 file4.c
```

...

- `all` rule has no commands, but depends on `myprog` and `myprog2`
 - typing `make all` will ensure that `myprog`, `myprog2` are up to date
 - `all` rule often put first, so that typing `make` will build everything
- **Exercise:** add “clean” and “all” rules to our hello Makefile

Variables

NAME* = *value (declare)

\$(NAME) (use)

Example Makefile:

```
OBJFILES = file1.o file2.o file3.o
```

```
PROGRAM = myprog
```

```
$(PROGRAM): $(OBJFILES)
```

```
    gcc -o $(PROGRAM) $(OBJFILES)
```

```
clean:
```

```
    rm $(OBJFILES) $(PROGRAM)
```

- variables make it easier to change one option throughout the file
 - also makes the makefile more reusable for another project

More variables

Example Makefile:

```
OBJFILES = file1.o file2.o file3.o
```

```
PROGRAM = myprog
```

```
CC = gcc
```

```
CCFLAGS = -g -Wall
```

```
$(PROGRAM): $(OBJFILES)
```

```
    $(CC) $(CCFLAGS) -o $(PROGRAM) $(OBJFILES)
```

- many makefiles create variables for the compiler, flags, etc.
 - this can be overkill, but you will see it "out there"

Special variables

| | |
|---------------------|---|
| <code>\$@</code> | the current target file |
| <code>\$\$</code> | all sources listed for the current target |
| <code>\$<</code> | the first (left-most) source for the current target |

(there are [other special variables](#)*)

Example Makefile:

```
myprog: file1.o file2.o file3.o
       gcc $(CCFLAGS) -o $@ $$
```

```
file1.o: file1.c file1.h file2.h
       gcc $(CCFLAGS) -c $<
```

- **Exercise:** change our hello Makefile to use variables for the object files and the name of the program

* http://www.gnu.org/software/make/manual/html_node/Automatic-Variables.html#Automatic-Variables

Auto-conversions

- Rather than specifying individually how to convert every `.c` file into its corresponding `.o` file, you can set up an *implicit* target:

`# conversion from .c to .o` ← `Makefile comments!`

`.c.o:`

```
gcc $(CCFLAGS) -c $<
```

- "To create `filename.o` from `filename.c`, run `gcc -g -Wall -c filename.c`"
- For making an executable (no extension), simply write `.c :`

`.c:`

```
gcc $(CCFLAGS) -o $@ $<
```

- **Exercise:** simplify our hello Makefile with a single `.c.o` conversion

What about Java?

- Create Example.java that uses a class MyValue in MyValue.java
 - Compile Example.java and run it
 - javac automatically found and compiled MyValue.java
 - Now, alter MyValue.java
 - Re-compile Example.java... does the change we made to MyValue propagate?
 - Yep! javac follows similar timestamping rules as the makefile dependencies. If it can find both a .java and a .class file, and the .java is newer than the .class, it will automatically recompile
 - But be careful about the depth of the search...
- But, this is still a simplistic feature. Ant is a commonly used build tool for Java programs giving many more build options.

Ant

- Similar idea to Make
- Ant uses a `build.xml` file instead of a Makefile

```
<project>  
  <target name="name">  
    tasks  
  </target>  
  
  <target name="name">  
    tasks  
  </target>  
</project>
```

- Tasks can be things like:

- `<javac ... />`
- `<mkdir ... />`
- `<delete ... />`
- A whole lot more...<http://ant.apache.org/manual/tasksoverview.html>

Ant Example

- Create an Ant file to compile our Example.java program
- To run ant (assuming build.xml is in the current directory):

```
$ ant targetname
```

- For example, if you have targets called clean and compile:

```
$ ant clean
```

```
$ ant compile
```

*Refer to: <http://ant.apache.org/manual/taskoverview.html>
for more information on Ant tasks and their attributes.*

Example build.xml file

```
<!-- Example build.xml file -->
<!-- Homer Simpson, cse390a -->
<project>
  <target name="clean">
    <delete dir="build"/>
  </target>

  <target name="compile">
    <mkdir dir="build/classes"/>
    <javac srcdir="src" destdir="build/classes"/>
  </target>
</project>
```

Automated Build Systems

- Fairly essential for any large programming project
 - Why? Shell scripts instead? What are these tools aiming to do?
 - Is timestamping the right approach for determining “recompile”?
 - What about dependency determination?
 - What features would you want from an automated build tool?
 - Should “building” your program also involve non-syntactic checking?
 - Ant can run JUnit tests...