CS11 Intro C++

Spring 2018 – Lecture 4

Build Automation

- When a program grows beyond a certain size, compiling gets annoying…

```
g++ -std=c++14 -Wall units.cpp testbase.cpp \
    hw3testunits.cpp -o hw3testunits
g++ -std=c++14 -Wall units.cpp convert.cpp -o convert
```

  - Also, if only **`units.cpp`** changes, why recompile **`testbase.cpp`** / **`hw3testunits.cpp`** / **`convert.cpp`** source files?
- Typical development process:
  - Write or modify some code
  - Compile
  - Test
  - Repeat until done…
- Automating this process saves lots of time and effort

`make`

- **`make`** is a standard tool for automating builds
  - Command-line utility, very ubiquitous!
  - Takes input files and produces output files, based on a “makefile”
  - Several versions of **`make`**: GNU, BSD, …

- **`make`** is often used for C and C++ projects
  - Sometimes other build tools are used for C/C++
  - CMake is becoming increasingly popular
  - Visual C++ provides **`nmake`** command-line build program
  - Other languages typically have their own build tools

Makefiles

- **`make`** requires a **makefile** that describes how to build your program
  - Typical filenames are **`Makefile`** (preferred) or **`makefile`**
  - Can specify a nonstandard makefile name with:
    `make -f *some-other-makefile*`
- The makefile describes **build targets**
  - Files that need to be generated from other files
- Each target specifies its **dependencies** – the files needed to build the target
- Can also specify how to build the target from its dependencies

Example Makefile

- Example **`Makefile`**:

```
convert : units.o convert.o
        g++ -std=c++14 -Wall units.o convert.o \
                -o convert

units.o : units.cpp units.h
        g++ -std=c++14 -Wall -c units.cpp

... (more rules for other .o files)

clean :
        rm -f convert hw3testunits *.o *~
```

- Lines are indented with tab characters – spaces won't work!
- A line can be wrapped to next line by ending with \
- Can specify multiple commands in a rule, as long as rules are separated by blank lines

Running **`make`**

- When **`make`** is run, it automatically looks for the makefile in the current directory
- **`make`** will automatically try to build the first target specified in the makefile

- Usually, the first target in the makefile is named **`all`**, and it builds everything of interest

```
all : convert hw3testunits
```

  - (this rule doesn't need to specify any commands)

- Can optionally specify one or more build targets to **`make`**:

```
make clean convert
```

Real Build Targets

- From our example makefile:

```
units.o : units.cpp units.h
        g++ -std=c++14 -Wall -c units.cpp
```

- In this case, **`units.o`** is a real file
- **`make`** will only build what is needed
  - If a target file's date is older than any dependency, **`make`** will rebuild that target
  - **`make`** will only rebuild the parts of the program that *actually changed*
- To force a file to be rebuilt, you can **`touch`** it

```
touch units.cpp
```

  - Sets file's modification-time to current system time
  - Touching a nonexistent file will create a new empty file

Phony Build Targets

- From our example:

```
clean :
        rm -f convert hw3testunits *.o *~
```

- In this case, **`clean`** is not a real file
- What if there happened to be a file named **`clean`** ?
  - Our rule wouldn't run!
  - **`make`** would see the "build-target" file, with no dependencies, and assume that nothing needed to be done
- Use **`.PHONY`** to say that the **`clean`** target isn't a real file

```
.PHONY: clean
```

  - Now if a file named **`clean`** exists, **`make`** ignores it
  - (The **`all`** target should also be marked as phony…)

Chains of Build Rules

- make figures out the graph of dependencies

```
convert : units.o convert.o
        g++ -std=c++14 -Wall units.o convert.o \
                -o convert
```

- If any of **`convert`**'s dependencies don't exist, **`make`** will use their build rules to make them

```
units.o : units.cpp units.h
    g++ -std=c++14 -Wall -c units.cpp
```

- **`make`** will give up if:
  - A dependency can't be found, and there's no build rule that shows how to make it
  - It finds a cycle in the graph of dependencies

Makefile Variables

- Makefiles can define variables

```
CONVERT_OBJS = units.o convert.o
```

- Can use variables in build rules

```
convert : $(CONVERT_OBJS)
        g++ $(CONVERT_OBJS) -o convert
```

- **`$(`*`var-name`*`)`** tells **`make`** to expand the variable
  - Use variables to avoid listing the same things over and over again, all over the place
  - Same reasons as code reuse: state things once, so we only have to change things in one place
- Makefile variable names are usually **`ALL_CAPS`**

Implicit Build Rules

- **`make`** already knows how to build certain targets
  - Those targets have built-in rules for building them
  - These built-in rules are called **implicit build rules**

- Example:
  - A makefile has **`units.o`** as a dependency, but no corresponding build rule
  - If **`units.c`** exists, **`make`** uses **`gcc`** to generate **`units.o`**
  - If **`units.cpp`** exists, **`make`** uses **`g++`** to generate **`units.o`**

- **`make`** has quite a few built-in implicit build rules!
  - Read **`make`** documentation for more details

Using Implicit Build Rules

- Implicit build rules make your makefiles much shorter

```
CONVERT_OBJS = units.o convert.o

all : convert hw3testunits

convert : $(CONVERT_OBJS)
        g++ -std=c++14 -Wall $(CONVERT_OBJS) \
                -o convert

clean :
        rm -f convert hw3testunits *.o *~

.PHONY: all clean
```

  - Can leave out the rules for all the object files!

Definitions of Implicit Rules

- Example definitions of implicit build rules:

```
# C compilation implicit rule
%.o : %.c
        $(CC) -c $(CPPFLAGS) $(CFLAGS) $< -o $@

# C++ compilation implicit rule
%.o : %.cpp
        $(CXX) -c $(CPPFLAGS) $(CXXFLAGS) $< -o $@
```

- Variables are used for compiler and options!
  - **CC** is the C compiler to use, **CXX** is the C++ compiler to use
  - **CFLAGS** are C compiler options, **CXXFLAGS** are C++ compiler options
  - **CPPFLAGS** are the preprocessor flags
  - Default values are for **gcc** and **g++**

Leveraging Variables in Implicit Rules

- **We want to use the implicit-rule variables in our makefiles!** ☺
- Example: specify **`-Wall`** and **`-std=c++14`** for compilation

```
CXXFLAGS = -Wall -std=c++14
CONVERT_OBJS = units.o convert.o

all : convert hw3testunits

convert : $(CONVERT_OBJS)
        $(CXX) $(CXXFLAGS) $(CONVERT_OBJS) \
                -o convert $(LDFLAGS)

clean :
        rm -f convert hw3testunits *.o *~

.PHONY : all clean
```

Definitions of Implicit Rules (2)

- Examples of implicit build rules:

```
# C++ compilation implicit rule
%.o : %.cpp
        $(CXX) -c $(CPPFLAGS) $(CXXFLAGS) $< -o $@
```

- Special syntax for pattern-matching
  - `%` matches the filename
  - **`$<`** is the first prerequisite in the dependency list
  - **`$@`** is the filename of the target
- These **`$...`** values are called **automatic variables**
  - Other automatic variables too!
  - e.g. **`$^`** is list of all prerequisites in the dependency list

Using Automatic Variables

- Can use automatic variables to link our program

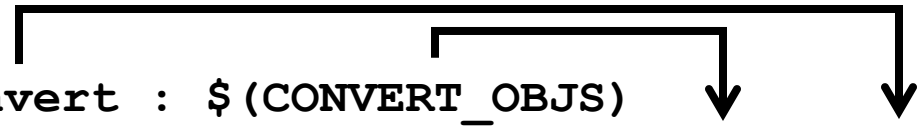
```
CXXFLAGS = -Wall -std=c++14
CONVERT_OBJS = units.o convert.o

all : convert hw3testunits

convert : $(CONVERT_OBJS)
        $(CXX) $(CXXFLAGS) $^ -o $@ $(LDFLAGS)

clean :
        rm -f convert hw3testunits *.o *~

.PHONY : all clean
```



`make` Reference

- For more details, see the GNU `make` manual
  - http://www.gnu.org/software/make/manual/

Automatic Document Generation

- Automating API-doc generation is a very powerful technique
  - Comment your code according to a specified style
  - Run a documentation-generator on your code
  - Produces API documentation of your code, in HTML, PDF, etc. formats, ready for distribution!
- The documentation is in one place – your source
  - Tools can use the code as well as your comments in the generated output
- Several different options for doc-generation
- We will use doxygen: http://www.doxygen.org

Doxygen Configuration

- Doxygen is driven by a config file
  - It will generate a template file for you:

    `doxygen -g [`*`filename`*`]`
  - Default filename is **`Doxyfile`**
- Customize the config file for your project
  - Set different configuration parameters as needed
  - Parameters are well documented in the config file
- Parameter names are **`ALL_CAPS`**
  - (just like makefile variables)
  - Parameter-value can extend to next line, if current line ends with \ (backslash) character
  - Switches are specified with **`YES`** or **`NO`**

Doxygen Config Tips

- You should set:
  - **`INPUT`** (input files/directories)
  - **`OUTPUT_DIRECTORY`** (where results go)
  - **`PROJECT_NAME`**

- Other good settings to use:
  - **`JAVADOC_AUTOBRIEF = YES`**
  - **`EXTRACT_ALL = YES`**
  - **`EXTRACT_PRIVATE = YES`**
  - **`EXTRACT_STATIC = YES`**

Commenting Your Code

- Several different formats are recognized

```
/**
 * This is a comment for my class.  It is spiffy.
 */
class MyClass { ... };
```

  - **`/**`** starts the comment (javadoc style)
  - Can also start with **`/*!`** (Qt style)
  - Also several other options (see doxygen manual)
- Classes, types, functions have a brief comment, and a detailed comment
  - If **`JAVADOC_AUTOBRIEF`** is defined in doxygen config, first sentence is used as brief comment.
  - Otherwise, must use **`\brief`** keyword in your comments

Structural Commands

- "Structural commands" specify what a comment is associated with
  - "This is a comment for the source file."
  - "This is a comment for class C."
  - "This is a comment for parameter x of the function."
  - etc.
- Allows Doxygen comments to be separated from entities that are being commented. (Not always recommended…)
- Two different formats for structural commands
  - Doxygen format: **`\cmd`**
  - Javadoc format: **`@cmd`**
  - Can use either format, but be consistent! ☺

What Can Be Commented?

- Files can be given comments
  - Must do this for doxygen to pick up certain comments
  - Examples:

```
/*! \file ... */
```
(Qt/Doxygen format)

```
/** @file ... */
```
(Javadoc format)

- Any type can be given a doxygen comment
  - Classes, structs, enums, typedefs, unions, namespaces
- Comment should immediately precede the type
  - …unless you are using structural commands
- Preprocessor definitions can also be commented!
  - **`#define`** symbols, macros

Commenting Variables and Functions

- Global/static variables, and member variables
  - Comments can precede the variable:

```
/** My special widget. */
SpecialWidget sw;
```

  - Or they can follow the variable, on the same line:

```
SpecialWidget sw;  /**< My special widget. */
```

    - (Note the **<** character)
- Functions and their parameters/return values
  - Parameters follow this pattern:

```
@param name Description
\param name Description
```

  - Return value is documented with **`\return`** or **`@return`**

Running Doxygen

- Doxygen is simple to run:

  `doxygen [`*`filename`*`]`

  - **`doxygen`** uses **`Doxyfile`** if no config file is given
  - Basically no command-line arguments; config file contains all the details!
- Results are stored in output directory
  - Each format gets its own subdirectory
  - **`html`** for HTML output, **`latex`** for LaTeX, etc.
  - Can specify alternate output directories if desired.

Doxygen References

- For more details, see the doxygen manual
  - http://www.stack.nl/~dimitri/doxygen/manual.html
  - http://www.doxygen.org

This Week's Homework

- Write a **`Makefile`** for your project
  - Build **`convert`** and **`hw3testunits`** from their sources
  - Create an **`all`** target and a **`clean`** target
  - Create a **`test`** target that runs **`hw3testunits`**
  - Make sure that everything works properly

- Update your documentation to use Doxygen style comments
  - Create a **`Doxyfile`** configuration file
  - Add a **`docs`** build rule that generates HTML documentation