

Homework 7

Build Systems

Submission Instructions

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For this assignment, we will experiment in the EECS 280 W15 repository you created for Homework 2.

1 Expressing Dependencies

1. Run `make` to build everything.
2. Run `make` again (nothing happens).
3. Edit `p2.cpp` and make a change (add a comment or something).
4. Run `make` again.
5. Edit `p2.h` and make a change (add a comment or something).
6. Run `make` again.

Why did `make` rebuild things after step 4 but not after step 6? Why is this a problem?

All of the test targets depend on `p2.cpp`, so when it changed they rebuilt. None of them list `p2.h` as a dependency in the Makefile, so when it changed `make` did not know it needed to do anything.

This can be a particularly frustrating issue if a header file `#define`'s a constant that is used by code files, but the code does not rebuild correctly to use the new constant.

Rewrite the rule for **`simple_test`** so that `make` rebuilds correctly for any changes you make:¹

```
simple_test: simple_test.cpp p2.cpp Recursive_list.cpp Binary_tree.cpp \
            recursive.cpp test_helpers.cpp \
            p2.h Binary_tree.h Recursive_list.h recursive.h test_helpers.h
```

Notice that you need more than just `p2.h`, you also need the header files that `p2.h` includes, `recursive.h`, and then the header files that `recursive.h` includes...

Think this is a pain? Check out the advanced homework for a *BetterWay*TM.

2 From Build Engine to Rules Engine

Makefiles are often asked to do more than simply build your software. A common example is a rule named `clean` that deletes everything built by the Makefile.

1. Run `make` to build everything.
2. Run `make clean` to delete everything that was built.
3. Run `make` to build everything.
4. Run `touch clean`
5. Run `ls` (do you understand what `touch` does?)
6. Run `make clean`

Why did `make` run the `clean` rule after step 2 but not after step 5?

What flag can you pass to `make` so that it unconditionally “builds” the `clean` target?

```
make -__ clean
```

`-B`, `--always-make` — Unconditionally make all targets.

Describe how to fix the Makefile so that fake targets like `clean` work correctly.

`Make` understands that some targets, such as “clean”, are not actually files that it needs to build, you just have to tell `make` that. These are called “phony targets”. To fix the Makefile, add:

```
.PHONY: clean
```

¹You do not need to worry about system header files

3 Removing Duplicated Effort

Notice that currently the `all` target and the `test` target have the same list of dependencies.

List all the changes you have to make to the Makefile so that the `test` target correctly depends on the `all` target in all cases.

There are two changes you should make to the original Makefile.

1. Change `test` so that it depends on the `all` target:

```
-test: filter_test simple_test tree_insert_test p2-tests
+test: all
```

2. Mark the `all` target as phony (you aren't actually making a thing called "all" anywhere):

```
+.PHONY: all
```

A different (but equally correct) approach would be to define a variable that holds all of the targets, and use that variable for both rules:

```
TARGETS = filter_test simple_test tree_insert_test p2-tests

all: $(TARGETS)

test: $(TARGETS)
...
```

4 Anything Special about All?

Currently, if you just type `make`, `make` will run `make all`. One might wonder why `make` chooses the `all` goal by default. While you could look this up, we are computer *scientists*. Make changes to the Makefile until you are confident that you understand how `make` chooses the default goal.

Describe the experiments you ran in order to determine what target `make` builds by default.

Note that this question asks about the experiments you ran, some good tests:

Rename the "all" rule to something else, what runs?

Move the "all" rule to a different location, what runs?

As a bonus, check out what happens if you rename the rule to ".all". What runs by default? Can you still "make all"?

5 Manipulating `make`'s environment

One neat feature of `make` is that it ships with a large number of *implicit rules*. `make` understands that `foo.c` \rightarrow `foo.o` \rightarrow `foo` without you writing any rules. In fact, you can actually run `make` without a `Makefile`! Let's play with this a little.

First let's get a simple environment set up and try some things out:

```
@>@ mkdir /tmp/wk4 && cd $_
@>@ echo -e '#include <stdio.h>\n\nint main() {\n\tprintf("Howdy\\n");\n\treturn 0;\n}\n' > hello.c
@>@ cat hello.c    # just so you can see what that did
@>@ make
@>@ make hello
@>@ ./hello
```

Does `make` clean work? Why not?

Now try

```
@>@ rm hello
@>@ make -r hello
```

What does the `-r` flag do?

Next try

```
@>@ rm hello
@>@ make CFLAGS=-O3 hello
```

What changed when `hello` was built this time?

Finally run

```
@>@ make hello -p | less
```

Make an educated guess at which built-in rule is used to create “`hello`” from “`hello.c`” and copy it here. What makes you think this rule is responsible?

```
%.c: %.c
#  commands to execute (built-in):
    $(LINK.c) $^ $(LOADLIBES) $(LDLIBS) -o $@
```

Now let's add an additional file to the mix, only a C++ file this time:

(This example uses a [special shell syntax](#) for easily writing multiple lines to a shell command)

```
@>@ cat << MARKER > wazzup.cpp
#include <iostream>
```

```
int main() {
    std::cout << "Wazzup?" << std::endl;
    return 0;
}
```

MARKER

```
@>@ cat wazzup.cpp
```

Using what you have learned, write a single `make` command (i.e. only call `make` once) that, without a `Makefile`, will build both “`hello`” and “`wazzup`”, but builds `hello` optimized for speed (`-O3`) and `wazzup` optimized for size (`-Os`). *Hint: One is a C program and one is a C++ program...*

Using some more of what we learned from the previous question:

```
LINK.c = $(CC) $(CFLAGS) $(CPPFLAGS) $(LDFLAGS) $(TARGET_ARCH)
LINK.cc = $(CXX) $(CXXFLAGS) $(CPPFLAGS) $(LDFLAGS) $(TARGET_ARCH)
```

Notice that `CFLAGS` appears only for building C files and `CXXFLAGS` appears only for building C++ files (however, `CPPFILES` appears for both, which can also be useful).

```
make CFLAGS=-O3 CXXFLAGS=-Os hello wazzup
```

Roughly how long did you spend on this assignment? _____