CSE 303: Concepts and Tools for Software Development

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Lecture 14—Makefiles continued; Breakpoint debugging & gdb
Where are We

- Basics of make, particular the concepts (last lecture, slides 18–23)
- Some fancier make features (revenge of funky characters)
- Start debuggers, particular `gdb`

Debuggers on the final, not the midterm.

- Can be very useful for homework (and in general, of course)
Precise review

A Makefile has a bunch of these:

target: source1 ... sourcen
    shell_command

Running make target does this:

- For each source, if it is a target in the Makefile, recur with it.
- Then:
  - If some source does not exist, error.
  - If some source is newer than the target (or target does not exist), run shell_command (presumably updates target, but that is up to you).
make variables

You can define variables in a Makefile. Example:

CC = gcc
CFLAGS = -Wall
foo.o: foo.c foo.h bar.h

$(CC) $(CFLAGS) -c foo.c -o foo.o

Why do this?

• Easy to change things once and affect many commands.

• Can change variables on the command-line (overrides definitions in file). (For example `make CFLAGS=-g`.)

• Easy to reuse most of a Makefile from one “homework” to the next.

• Can use conditionals to set variables (using inherited environment variables):
make conditionals

EXE=
ifdef WINDIR # assume we are on a Windows machine
    EXE=.exe
endif

myprog$(EXE): foo.o bar.o
    $(CC) $(CFLAGS) -o myprog$(EXE) foo.o bar.o

Other forms of conditionals exist (e.g., are two strings equal)
more variables

It’s also common to use variables to hold list of filenames:

MYOBJFILES = foo.o bar.o baz.o

myprog:  $(MYOBJFILES)
        gcc -o myprog $(MYOBJFILES)

clean:
        rm $(MYOBJFILES) myprog

clean is a convention: remove any generated files, to “start over” and have just the source.

It’s “funny” because the target doesn’t exist and there are no sources, but that’s okay:

• If target doesn’t exist, it must be “remade” so run the commands

• These “phony” targets have several uses, another is an “all” target:
“all” example

all: prog B.class someLib.a # notice no commands this time

prog: foo.o bar.o main.o
    gcc -o prog foo.o bar.o main.o

B.class: B.java
    javac B.java

someLib.a: foo.o baz.o
    ar r foo.o baz.o

foo.o: foo.c foo.h header1.h header2.h
    gcc -c -Wall foo.c

... (similar targets for bar.o, main.o, baz.o) ...
Revenge of funny characters

UNIX hackers just can’t get enough of funny metacharacters can they?

In commands:

- $@ for target
- $^ for all sources
- $< for left-most source
- ...

Examples:

```
myprog$(EXE): foo.o bar.o
    $(CC) $(CFLAGS) -o $@ $^

foo.o: foo.c foo.h bar.h
    $(CC) $(CFLAGS) -c $<
```
More fancy stuff

- There are a lot of “built-in” rules. E.g., make just “knows” to create `foo.o` by calling `$\texttt{CC}$ `$\texttt{CFLAGS}$` on `foo.c`. (Opinion: more confusing than helpful.)

- There are “suffix” rules and “pattern” rules. Example:

  `%.class: %.java
    javac $<` # Note we need $<$ here

- Remember you can put any shell command on the command-line, even whole scripts

- You can repeat target names to add more dependencies (useful with automatic dependency generation).

Often this stuff is more useful for reading makefiles than writing your own (until some day...)

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Dependency generation

So far, we are still listing dependencies manually, e.g.:

foo.o: foo.c foo.h bar.h

If you forget, say, bar.h, you can introduce subtle bugs in your program (or if you’re lucky, get confusing errors).

This is not make’s problem: It has no understanding of different programming languages, commands, etc., just file-mod times.

But it does seem too error-prone and busy-work to have to remember to update dependencies, so there are often language-specific tools that do it for you...
Dependency-generator example

gcc -M

- Actually lots of useful variants, including -MM and -MG. See man gcc
- Automatically creates a rule for you.
- Then include the resulting file in your Makefile.
- Typically run via a phony depend target, e.g.:

```
depend: $(MY_C_FILES)
    gcc -M $^```

- The program makedepend combines many of these steps; again it is C-specific but some other languages have their own.
Build-script summary

Always script complicated tasks.

Always automate “what needs rebuilding” via dependency analysis.

`make` is a text-based program with lots of bells and whistles for doing this. It is not language-specific. Use it.

With language-specific tools, you can automate dependency generation.

`make` files have this way of starting simple and ending up unreadable. It is worth keeping them clean.

There are conventions like `make all` and `make clean` common when distributing source code.
An execution monitor?

What would like to “see from” and “do to” a running program?

Why might all that be helpful?

What are reasonable ways to debug a program?

A “debugger” is a tool that lets you stop running programs, inspect (sometimes set) values, etc.
Issues

- Source information for compiled code. (Get compiler help.)
- Stopping your program too late to find the problem. (Art.)
- Trying to “debug” the wrong algorithm.
- Trying to “run the debugger” instead of understanding the program.

It’s an important tool. I use it sometimes.

Debugging C vs. Java

- Eliminating crashes does not make your C program correct.
- Debugging Java is “easier” because crashes and memory errors do not exist.
- But programming Java is “easier” for the same reason!
gdb

Gnu debugger) is on attu and supports several languages, including C compiled by gcc.

Modern IDEs have fancy GUI interfaces, which help, but concepts are the same.

Compiling with debugging information: gcc -g

• Otherwise, gdb can tell you little more than the stack of function calls.

Running gdb: gdb executable

• Source files should be in same directory (or use the -d flag).

At prompt: run args

Note: You can also inspect core files, which is why they get saved. (I never do.)
Basic functionality

- backtrace
- frame, up, down
- print expression, info args, info locals

Often enough for “crash debugging”

Also often enough for learning how “the compiler does things” (e.g., stack direction, malloc policy, ...)

Breakpoints

- break function (or line-number or ...)
- conditional breakpoints (break XXX if expr)
  1. to skip a bunch of iterations
  2. to do assertion checking
- going forward: continue, next, step, finish
  - Some debuggers let you “go backwards” (typically an illusion)

Often enough for “binary search debugging”

Also useful for learning program structure (e.g., when is some function called)

*Why not skim the manual for other features.*
Advice

Understand what the tool provides you.

Use it to accomplish a task, for example “I want to know the call-stack when I get the NULL-pointer dereference”

Optimize your time developing software.

Use development environments that have debuggers?

See also: jdb for Java (on attu)