

CS 246 Spring 2018 — Tutorial 2

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1 Bash Variables

- In bash, a variable is assigned a value as follows: `var=42`. You do not need to declare a variable before assigning a value.

Note: There cannot be spaces on either side of the equals symbol.

- All variables are stored as strings.
- Unlike C variables, bash variables persist outside of the scope of if statements, loops, and scripts.
- Accessing the value in a variable: `$var` or `${var}`.
- `${var%<end>}` removes the suffix `<end>` from the string stored in `var`. If `<end>` is not at the end of `var`, the string is unchanged.
- In addition to using variables as arguments, we can also treat the value of a variable as a command and run it:

```
greet="echo hello"
$greet
```

2 Bash Scripting

- A bash script is a series of commands saved in a file so that we can accomplish the same task without having to manually type all the commands.

- The first line of every shell script is the “shebang line” — `#!/bin/bash`. This line is telling the shell what program the file should be invoked with.
- To call a bash script, give the file executable permission using `chmod` and call the file by giving either an absolute path or a relative path to it. You can also invoke a bash script without making it executable by calling `bash <script_name>`.

Note: if the relative path consists of only the file name (e.g. `script_name`), we need to add `./` before the path to call it: `./script_name`.

- Command line arguments are `$1`, `$2`, etc. The number of command line arguments is stored in `$#`.

2.1 Subroutines in Bash Scripts

- Format:


```
subroutine() {
    ...
}
```
- A subroutine is a series of commands which can be called at any time in a bash script.
- They can be given command line arguments the same way a program would be given command line arguments. A subroutine cannot access the command line arguments to the script. All other variables can be accessed.
- **Exercise:** Write a bash script which takes in two arguments, `ext1` and `ext2`. For each file (not directory) in the current directory which ends with an `.ext1`, rename the file to end with `.ext2`.

2.2 Debugging

- Debugging mode can be activated when running a bash script by placing `-x` at the end of the shebang line, or calling it using `bash -x`.
- When running the script, each command is printed to the screen with variables expanded.
- If a script is not doing what you expect it to do, using this debugging mode can be an easy way to see what is happening in the script.

3 Bash Loops and If Statements

- For the condition in both if statements and while loops, the result is checked, and if it's **true**, the program will go into the body of the if statement or while loop.

– Form of an if statement in bash:

```
if [ <cond1> ]; then
    ...
elif [ <cond2> ]; then
    ...

.....
else
    ...
fi
```

– Form of a while loop in bash:

```
while [ <cond> ]; do
    ...
done
```

– Form of a for loop in bash:

```
for <var> in <words>; do
    ...
done
```

Where **<words>** is a list of whitespace separated strings. The body of the loop runs once for each string in **<words>**.

- You can use the **seq** command to generate a list of numbers.

<pre># prints 1 to 10 for num in \$(seq 1 10); do echo \$num done</pre>	<pre># alternatively for num in {1..10}; do echo \$num done</pre>
---	---

- Note: **[<cond>]** can be replaced by any command and the exit code will be checked. For example:

```
# prints "done" if cat succeeded
if cat file.txt; then
    echo done
fi
```

3.1 Test Command

- **test** is a bash command. The program is implicitly referred to using **[** (though it can also be explicitly referred to using **test**) and is called in the form **[cond]** whose exit code is 0 if **cond** is true and 1 if **cond** is false. It may be useful to review the **man** page for **test** (**man [** brings up the same page).
- A few conditions you can use for test:

```
num1 -gt num2    num1 > num2
str1 = str2      str1 == str2 (string equality)
```

4 Program Exit Codes

- When a program completes, it always returns a status code to signify if the program was a success.
- This is true of any C program you have written before now. The exit code is the value returned from `main`, hence the contract `int main();`. In C and C++, if you do not explicitly return from `main`, the exit code is 0.
- In bash, if a program is successful, the exit code is 0. Otherwise, the exit code is non-zero. The exit code is stored in the variable `$?` .

Remember: this is opposite from the definition of true in C. In C a non-zero integer represents true, while in bash zero represents success.

- The exit code cannot be larger than 255. In bash if you return some return code larger than 255, you will get the code modulo 256.

5 Make and Makefiles

- With single-file programs, compilation is a breeze:

```
g++14 change.cc -o change
```

- However, when we have a project across multiple files, compilation may become a pain to type out. Surely there is a better way to compile a project without typing all `.cc` files.
- You should use separate compilation which looks something like

```
g++14 -c main.cc
g++14 -c book.cc
...
g++14 book.o main.o textbook.o ... -o main
```

- When we do this, we only have to recompile the modules that change. This means less time compiling but more time remembering what we have recently compiled.
- Surely there must be a better way to keep track of changes. This is a bigger issue when we would constantly be recompiling everything when we don't have to.
- **make** can help here. It allows us to specify the dependencies of targets (the files produced by the build process) and the command for producing each target in a **Makefile**. **make** will automate the building process and avoid unnecessary compilation by keeping track of changed files based on last modified time ¹.

¹i.e. if a target is newer than its dependencies, then there is no need to rebuild this target

A Makefile will look something like:

```
# example1/Makefile

# means main depends on these dependencies
# if all of the dependencies are up to date, then execute
# the build command below
main: main.o book.o textbook.o comic.o
    # specifies how to build main
    g++ -std=c++14 main.o book.o textbook.o comic.o -o main

book.o: book.cc book.h
    g++ -std=c++14 -c book.cc
textbook.o: textbook.cc textbook.h book.h
    g++ -std=c++14 -c textbook.cc
comic.o: comic.cc comic.h book.h
    g++ -std=c++14 -c comic.cc
main.o: book.h textbook.h comic.h main.cc
    g++ -std=c++14 -c main.cc
```

- The whitespaces before the build command (in this case, `g++ ...`) **MUST** be a tab.
- On the command line, run `make`. This will build our project.
- If `book.cc` changes, what happens?
 - compile `book.cc`
 - relink `main`
- What happens when we execute the command `make`?
 - Builds first target in our Makefile, in this case `main`.
 - What does `main` depend on?
 - * `book.o textbook.o comic.o main.o`
 - If `book.cc` changes:
 - * `book.cc` is newer (timestamp) than `book.o`; rebuilds `book.o`
 - * `book.o` is newer (timestamp) than `main`; rebuilds `main`
- **Tip:** We can build specific targets using `make`:
`make textbook.o`
- Common practice: put a `clean` target at the end of a makefile to remove all binaries²
`clean:`
`rm *.o main`

²The description found in https://www.gnu.org/software/make/manual/html_node/Phony-Targets.html

```
# clean is a "phony target": it is not name of a file but
# a recipe to be executed when an explicit request is made
.PHONY: clean
```

- To do a full rebuild:

```
make clean && make
```

- While Makefile can make our compilation process easier, writing out all of the dependencies and individual compilation commands can be time consuming.
- Conveniently, we can generalize a Makefile with variables.

```
# example2/Makefile
CXX=g++                                     #compiler name
CXXFLAGS=-std=c++14 -Wextra -Wpedantic -Wall -Werror -g #options to pass
...
book.o: book.cc book.h
    ${CXX} ${CXXFLAGS} -c book.cc
...
```

- **Shortcut:** For any rule of the form `x.o: x.cc a.h b.h`, we can leave out the build command. `make` will guess that it is `${CXX} ${CXXFLAGS} -c book.cc -o book.o`

```
# example3/Makefile
CXX=g++                                     #compiler name
CXXFLAGS=-std=c++14 -Wextra -Wpedantic -Wall -Werror -g #options to pass

# This one is not in the generic form, so have to list it
${EXEC}: ${OBJECTS}
    ${CXX} ${OBJECTS} -o ${EXEC} ${CXXFLAGS}

...
book.o: book.h book.cc

textbook.o: textbook.h textbook.cc book.h
...
```

- Issue: how to track dependencies and updating them as they change
 - `g++` can help. `g++ -MMD -c comic.cc` will create `comic.o` `comic.d`.
 - What will `comic.d` contain?

```
comic.o: comic.cc book.h comic.h
```

- Looking at this `.d` file, we can see it is exactly what we need in our Makefile. We just need to include all `.d` files in our Makefile. This means our Makefile will look like

```
# example4/Makefile
```

```

CXX=g++
CXXFLAGS=-std=c++14 -Wextra -Wpedantic -Wall -Werror -MMD -g
OBJECTS=main.o book.o textbook.o comic.o
DEPENDS=${OBJECTS:.o=.d}
EXEC=main

```

```

${EXEC}: ${OBJECTS}
    ${CXX} ${CXXFLAGS} ${OBJECTS} -o ${EXEC}

```

```

-include ${DEPENDS}

```

```

clean:
    rm ${OBJECTS} ${DEPENDS} ${EXEC}
.PHONY: clean

```

- Testing: Assuming there is a testing folder in the directory the makefile is in, we can add a test target similar to clean

```

# example5/Makefile
CXX=g++
CXXFLAGS=-std=c++14 -Wextra -Wpedantic -Wall -Werror -MMD -g
OBJECTS=main.o book.o textbook.o comic.o
DEPENDS=${OBJECTS:.o=.d}
EXEC=main

# feel free to change these directories to your liking
# this setup assumes that in the directory with the Makefile, there is
# 1) A directory called tests where all the tests are
#    a) Inside that directory, there is a suite.txt to be used
#    b) There is also the scripts produceOutputs and runSuite
# 2) A directory called executables one level above this one
#    that contains the given executable with the same name
TESTDIR=test
EXECSDIR=../executables
EXECGIVEN=${EXEC}
SUITE=suite.txt

```

```

${EXEC}: ${OBJECTS}
    ${CXX} ${CXXFLAGS} ${OBJECTS} -o ${EXEC}

```

```

-include ${DEPENDS}

```

```

clean:
    rm ${OBJECTS} ${DEPENDS} ${EXEC}
.PHONY: clean

```

```
# @ silences output
test:
    @cp ${EXECS_DIR}/${EXEC_GIVEN} ${TESTDIR}           # copy over given exec
    @mv ${TESTDIR}/${EXEC_GIVEN} ${TESTDIR}/sol_${EXEC_GIVEN} # prefix it with sol_
    @cp ${EXEC} ${TESTDIR}                               # copy over your exec
    @(cd ${TESTDIR}\                                     # go into test dir
    && ./produceOutputs ${SUITE} ./sol_${EXEC_GIVEN}\      # run produceOutputs
    && ./runSuite ${SUITE} ./${EXEC})                    # run runSuite
.PHONY: test
```

- To test:

```
make test
```
- This is the final version of our Makefile. Altering the variables of this Makefile, we can use this exact Makefile for basically any program we want to create.

6 Vim Tips of the Week: More Normal Mode Commands

- In vim nearly all the most useful and commonly-used commands are in normal mode. Try to get into the habit of pressing **Esc** to go back to normal mode whenever you finish inserting text.
- Some more normal modes command useful for editing code:
 - yy** copies the current line.
 - dd** copies and deletes the current line.
 - cc** copies and deletes the current line, then enter insert mode.
 - cw** deletes all characters from the current character to the end of the word and enters insert mode.
 - dw** deletes all characters from the current character to the end of the word.
 - p** pastes the copied content. If the content is full lines then it will be placed after the current line. Otherwise it will be after the current character.
 - *** searches the current word under cursor. Similar to pressing the **/** key followed by the current word and pressing **Enter**, but only finds words that match as a whole (i.e. not substrings).
 - .** repeats the last change.
 - C-r** (Ctrl-R) redo (undo the last undo operation by the **u** key).