CMSC 216 Project #7 Spring 2016

A Simple Shell **Deadline: Fri May 6, 8:00 PM**

1 Overview

In this project, you will write the guts of a simple shell that will support simple boolean operations, pipes, and file redirection.

2 Procedure

2.1 Obtain the project files

We have supplied several files for your use in this project, in addition to the usual `.submit` file: (a) `command.h` defines the tree structure that the parser will produce from a command line, and the conjunctions. (b) `d8sh.c` is the main shell loop. You need not modify this file, but it may be useful to inspect for generating test cases. (c) `executor.c` is where you must implement the function `int execute(struct tree *t)`, which will take a tree from the parser and execute the commands in the tree. The return value may be used as you like, e.g., for exit status or for a process id, if you choose to call execute recursively. (d) `executor.h` is the declaration of execute. (e) `lexer.c` is the lexer, which splits a command line into tokens, generated by flex. (f) `lexer.h` is a part of the parser, generated by flex, referenced by d8sh. (g) `parser.tab.c` is the parser, which assembles tokens into a parsed format, generated by bison. (h) `parser.tab.h` is a part of the parser, generated by bison, referenced by lexer.c. (i) `run-all-tests.csh`: checks for Makefile and d8sh, then compares the output of your d8sh using the command lines in the testing subdirectory. These files are contained in `~/216public/project7`. Your code for this project should be contained in your `~/216/project7` subdirectory.

2.2 Create a `Makefile`

Create a `Makefile` that we will use to build your shell. Section 3.1 lists the targets you are required to implement, as well as other requirements for your `Makefile`.

2.3 Implement and test the shell

You must implement your shell program by supplying the necessary code in `executor.c`. As you implement various features of the shell, you can test them by either interactively running `d8sh` while typing in commands, or you can create text files with one command per line, and use redirection to feed them as input to your shell.

3 Specifications

3.1 `Makefile`

Your `Makefile` should be set up so that all programs are built using separate compilation (i.e., source files are turned into object files, which are then linked together in a separate step). All object files should be built using the class flags (note the absence of pedantic-errors):

```
-ansi -Wall -g -O0 -Wwrite-strings -Wshadow -fstack-protector-all
```

You must have the following targets in your `Makefile`:

1. `all`: make all executables
2. `clean`: delete all object files and executables
3. `lexer.o`, `parser.tab.o`, `executor.o`, and `d8sh.o`, the object files for the parsing code and shell code
4. `d8sh`: the executable created by linking the parsing object file with the shell object files

We will use the `Makefile` you provide to build the public test executables on the submit server; if there is no `Makefile`, your shell program will not be built, and you will not receive credit for **any** tests.

You may have other targets, for example "test".

3.2 The Shell

The shell you will implement will include some, but not all features, of the shell you use on grace. The features your shell supports will include pipes, input and output redirection, and the "&&" operator.

The parser may permit a few more operations that you need not support. In particular, the "||" and ";" operators exist in the format, but need not be supported by your code.

To invoke the parser, d8sh uses `yy_scan_string(buffer);` followed by `yyparse()`. (Typically, a bison parser would load a file such as your C source. Here, we are using this system to operate on a string.) When the parser constructs a complete tree from a command line, it invokes your execute() function.

You are given the main shell program in `d8sh.c`: your task is to implement the execute() function called by `main()`. Once the full `d8sh` program is linked together from the four object files, `d8sh` should function as a normal shell, with some limitations as described below.

The syntax for the features we want you to implement is very similar to the shell syntax you should be familiar with from your experience working with the Unix environment. These are the specific features your shell must provide:

1. **File redirection**: by using the < and > tokens, a user should be able to redirect standard input and output in the same manner as is done in the `tcsh` and `bash` shells.

   If a file is created by output redirection, the file should be created using permissions 0664.

   In the case of a multi-program pipeline, file input redirection may be applied to the first program (before the first pipe character), and file output redirection may be applied to the final program. A shell may print "Ambiguous input redirect" or "Ambiguous output redirect" if a user tries to provide a redirected file and a pipe at the same time. For example, the following is illegal "`echo hello > x | cat`".
2. **Piping**: if programs are separated by pipe characters ("|") on a command line, then the standard output of the program to the left of the pipe character is to be connected to the standard input of the program to the right of the pipe character, creating a pipeline.

   When running a pipeline, the shell must start all of the processes, but not return to print another prompt until all processes have exited. You will need to determine how to fork processes and then wait for them to cause similar behavior in your shell.

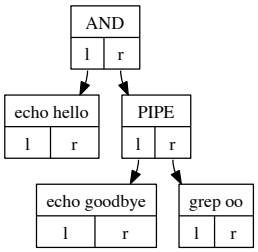
As you can see from the code in `d8sh.c`, the shell prompts the user for a command, parses the command, and then attempts to execute the command. To execute the command, you must use the `struct tree *` parameter to see which options are set, and perform the steps necessary to execute the command as requested.

Should you encounter any errors in executing the command, your shell **must not terminate** – children of the shell may terminate, but the code you write in `execute()` must not cause the parent (shell) process to terminate. A user should not cause the shell to die because he/she, for example, mistyped the name of a program to execute.

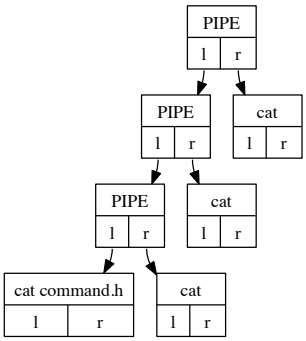
If your shell cannot exec any process, it should print (to standard output), "Failed to execute %s" with the name of the program that failed. Make sure you flush the buffer. Other failed system calls should print using perror, e.g., `perror("fork")`. The shell is already configured for parse errors to print as "Parse error: %s" via the yyerror() function.

4 Example Trees

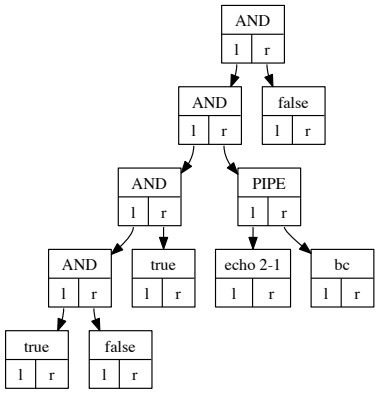
You may want to print out the contents of each parse tree you work on. Here are some examples.



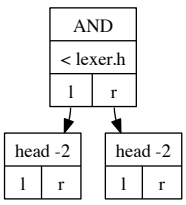
`echo hello && echo goodbye | grep oo`
Note that the pipe operation has a higher precedence than and. As a result, "hello" is printed to stdout and does not pass through grep. The grep command prints all lines that include a given string, so will print "goodbye" because it includes "oo".



`cat command.h | cat | cat | cat | cat`
The "cat" tool can either read input from arguments or from stdin, then pass it to stdout. Using pipe, fork, dup2, and exec to build pipelines in tree form can be subtle. The contents of command.h should appear on the output. (This is a better example than it is a test; tests may use `tac` instead of `cat` to reverse the file.)



`true && false && true && echo 2-1 | bc && false`
Again, pipe has a higher precedence. Execution should stop at the first false. `true` runs the /usr/bin/true program, whose only purpose is to exit(0), a successful result. (See: "man true" and "man false" for more information. There are a few trivial programs like this, for example, `yes` and `seq`.)



`(head -2 && head -2) < lexer.h`
Note how the shell prints the first four lines of lexer.h if given this command.

5 Important Points and Hints

1. Before you write your Makefile you can compile the code by executing gcc *.c. Notice that the code we left in executor.c just prints a simple message. You need to replace that message with the actual shell processing. We also left a print tree function in case you want to see the tree. Make sure you remove this function once you are done with your project.
2. Do not implement the processing of the false and true command by recognizing the ”false” or ”true” string; you must use an exec call to process these commands.
3. Do not use signals for this project.
4. Notice that pressing enter at the command prompt will print ”Parse error: syntax error”. This is expected and you don't need to handle this case.
5. execute() must implement internally (no fork, exec call, nor dup2) the commands “cd” and “exit”. The “cd” command should change to the user's home directory (`getenv("HOME")`) if given no arguments.
6. Be sure to wait for **all** child processes of your shell to complete; failing to do so will cause a collection of zombie processes to accumulate and tie up Grace system resources.
7. Also be careful that any fork loops you write terminate at some point, before a Grace system administrator has to kill them.
8. You can implement the project in different ways. One approach is having an auxiliary function that has two integer parameters that will allow you to pass input and output file descriptors down the tree.
9. When do you fork? When you need to execute a command or when you need a branch of the tree to be process by a different process (e.g., pipe). As long as you implement the expected functionality and you don't limit concurrency, you are fine.
10. You don't need to print messages regarding ”Ambigous input/output redirect”. If you add them is fine, but you don't need to.
11. When a command fails to execute (exec call), just use printf to print the ”Failed to execute” error message without worrying about which file descriptor is associated with STDOUT_FILENO.
12. You may not use system() (int system(const char *command);) in order to execute commands.
13. You may not use global variables.
14. You may wish to print the contents of the tree before execution. Each node is either an internal node of the tree, representing a PIPE or an AND, or a leaf node, representing a command with argv set. Any node, including internal nodes may have input and output redirection. Your shell should mimic real shells for the following commands:

    ```
    (head && head) < lexer.h
    (head < lexer.h && head < lexer.h)
    (cat command.h | cat - command.h)
    (cat < command.h | cat - command.h)
    ```

15. You are permitted to translate the tree structure into whatever representation you prefer. You are permitted to write your own parser, and thus modify d8sh. (Neither of these options are encouraged.)
16. You need not free the data or nodes in the parse tree.
17. Closing the correct file descriptors for a pipe at the correct time can be tricky. All the file descriptors for writing must be closed before a reader will see the end of file and exit. If the shell hangs, there's probably a process waiting for more input that will never come.
18. Don't get excited and modify the shell prompt to make it look more shell like; that will have bad consequences on the submit server.

6 Grading Criteria

Your project grade will be determined by the following formula:

Results of public tests	32%
Results of secret tests	58%
Code style grading	10%

The public tests will be made available shortly after the project is released. You can find out your results on these tests by checking the submit server a few minutes after submitting your project. Secret tests, and their results, will not be released until after the project's late deadline has passed.

Public tests for this project consist of input files to be read by your shell via standard input, and checked against the expected output, for example like this:

```
./d8sh < public00.in | diff - public00.output
```

We've put the public tests in the testing subdirectory, and some of these tests use extra input files from the current directory. The run-all-tests.csh script temporarily links those files to the current directory.

7 Submission

7.1 Deliverables

The only files we will grade are (a) your `Makefile`; and (b) `executor.c`, which contains your shell implementation. We will use our versions of all other files to build tests, so do not make any changes to other files.

7.2 Procedure

To limit the number of processes your shell implementation can create when you run it on the Grace machines, ensure that the line `limit maxproc 20` is present in the `.cshrc.mine` file in your home directory. This is part of the 216 setup script. Run "limit" to check that it is set.[1]

As for previous projects, executing "`submit`" in your project directory will submit your project.

8 Academic Integrity

As noted in the syllabus, any evidence of cheating will be referred to the Student Honor Council and may result in a grade of XF in this course. Submissions will be checked with an automated source code comparison tool to look for evidence of copying, collaborative work, and use of prohibited online materials.

[1] If you use `bash` instead of `tcsh`, the command is `ulimit -u 20` .