CS 241: Systems Programming Lecture 4. Environment and expansion

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Commands, again

Recall we said a simple command has the form:

⟨variable assignments⟩ ⟨words and redirections⟩ ⟨control operator⟩

Examples

- `FOO=blah BAR=okay cmd aaa >out bbb 2>err ccc <in ;`
- `FOO=blah BAR=okay cmd aaa bbb ccc <in >out 2>err`
- Real example: `$ IFS= read -r var`

Environment variables

A (second) method for passing data to a program

Essentially a key/value store (i.e., a hash map)

- `$ FOO=blah BAR=okay cmd aaa bbb ccc`
- `cmd` has access to the `FOO` and `BAR` environment variables plus args

Environment variables are inherited from the parent

- Every program started from the shell has access to a copy of the shell's environment

Bash variables

Setting and using variables in bash

- ```
  $ place=Earth
  $ echo "Hello ${place}."
  Hello Earth.
  ```

By default, variables set in bash aren't inherited by children

- ```
  $ bash # Start a new shell
  $ echo "Hello ${place}."
  Hello . # ${place} expanded to the empty string
  ```

Exporting variables

We can export a variable which causes it to appear in the environment of children

```
$ place=World
$ export place
$ bash          # Starting a new shell
$ echo "Hello ${place}."
Hello World.
```

Equivalently, `$ export place=World`

Summarizing

```
$ FOO=bar cmd1
$ cmd2
```

- `FOO` available to `cmd1` but not `cmd2`

```
$ FOO=bar
$ cmd1
$ cmd2
```

- `FOO` not available to either `cmd1` or `cmd2`

```
$ export FOO=bar
$ cmd1
$ cmd2
```

- `FOO` available to both `cmd1` and `cmd2`

Useful environment variables

`EDITOR` — Used when some commands need to launch an editor (e.g., git)
`HOME` — Your home directory
`LANG` — The language programs should use (this is complicated!)
`PAGER` — A program like less that's used to display pages of text
`PATH` — Colon-separated list of directories to search for commands
`PS1` — The shell's prompt
`PWD` — The current working directory
`SHELL` — The shell you're using
`TERM` — The terminal type, used to control things like color support
`UID` — The real user ID number
`USER` — User name

Bash expansion

Bash first splits lines into words by (unquoted) space or tab characters

```
$ echo 'quoted   string' unquoted   string
```

- Word 1: `echo`
- Word 2: `'quoted   string'`
- Word 3: `unquoted`
- Word 4: `string`

Most words then undergo **expansion**

- The values in variable assignment `var=value` (but not the names)
- The command and arguments
- The right side of redirections, e.g., `2>path`

Bash expansion

Order of expansion

- Brace expansion
- In left-to-right order, but at the same time
  - Tilde expansion
  - Variable expansion
  - Arithmetic expansion
  - Command expansion
  - Process substitution
- Word splitting (yes, this happens after the shell split the input into words!)
- Pathname expansion

And then each of the results undergoes quote removal

Brace expansion

Unquoted braces { } expand to multiple words

- `{foo,bar,baz}.txt` → `foo.txt bar.txt baz.txt`
- `foo{a,b,,c}bar` → `fooabar foobbar foobar foocbar`
- `'{a,b}'` → `'{a,b}'`
- `"{a,b}"` → `"{a,b}"`
- `{1..5}` → `1 2 3 4 5`
- `{x..z}` → `x y z`
- `{1,2}{x..z}` → `1x 1y 1z 2x 2y 2z`
- `{a,b{c,d}}` → `a bc bd`

Tilde expansion

Words starting with unquoted tildes expand to home directories

- `~` → `/usr/users/noquota/faculty/steve`
- `~steve` → `/usr/users/noquota/faculty/steve`
- `~aeck` → `/usr/users/noquota/faculty/aeck`
- `\~steve` → `\~steve`
- `'~steve'` → `'~steve'`

Parameter/variable expansion

We can assign variables via `var=value` (e.g., `class='CS 241'`) the shell defines others like `HOME` and `PWD`

Words containing `${var}` or `$var` are expanded to their value, even in double quoted strings

- `${HOME}` → `/usr/users/noquota/faculty/steve`
- `x${PWD}y` → `x/tmpy` # the current working directory
- `x$PWDy` → `x` # no `PWDy` variable so it expands to the empty string
- `'${class}'` → `'${class}'`
- `\${class}` → `\${class}`
- `"${class}"` → `"CS 241"`

Command substitution

Replaces `$(command)` with its output (with the trailing newline stripped)

- `"Hello $(echo ${class} | cut -c 4-)"` → `"Hello 241"`

These can be nested

You can also use `` `command` `` instead, but don't do that, use `$(...)`

Arithmetic expansion

$((arithmetic expression)) expands to the result, assume `x=10`

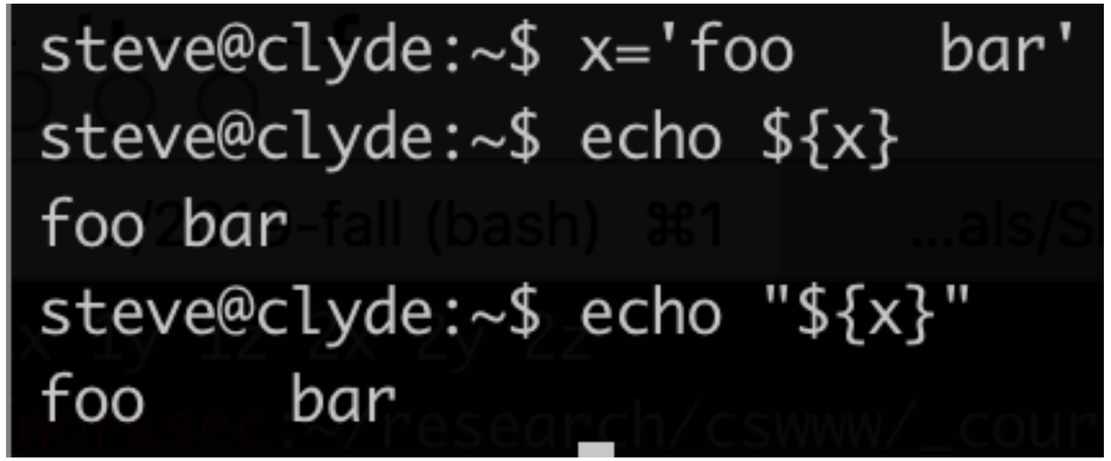
- `$((3+x*2 % 6))` → 5
- `\$((3+x*2 % 6))` → # syntax error
- `'$((3+x*2 % 6))'` → '$((3+x*2 % 6))'
- `"$((3+x*2 % 6))"` → `"5"`

Process substitution

Read the man page for bash if you want, we may come back to it

Word splitting

A misfeature in bash!



The results of
- parameter/variable expansion ${…},
- command substitution $(…), and
- arithmetic expansion $((…))

not in double quotes is split into words by splitting on (by default) space, tab, and newline

You never want word splitting! If you're using a $, put it in double quotes!

Pathname expansion

We saw this last time!

Pathname expansion/globbing

Bash performs pathname expansion via pattern matching (a.k.a. globbing) on each unquoted word containing a wild card

Wild cards: `*`, `?`, `[`

- `*` matches zero or more characters
- `?` matches any one character
- `[…]` matches any single character between the brackets, e.g., `[abc]`
- `[!…]` or `[^…]` matches any character not between the brackets
- `[x-y]` matches any character in the range, e.g., `[a-f]`

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Quote removal

Unquoted ', ", and \ characters are removed in the final step

- `'foo  bar'` → `foo  bar (one word)`
- `"foo  bar"` → `foo  bar (one word)`
- `"${class}"` → `CS 241 (one word)`
- `"${class} is"' fun'` → `CS 241 is fun (one word)`

Expansion summary

Braces form separate words [{a,b,c}] → [a] [b] [c]

Tildes give you home directories ~ → /home/steve

Variables expand to their values `"${class}"` → `"CS 241"`

Commands expand to their output `"$(ls *.txt | wc -l)"` → `"3"`

Wildcards expand to matching file names `*.txt` → `a.txt b.txt c.txt`

Put literal strings in `'single quotes'`

Put strings with variables/commands in `"${double} $(quotes)"`

If we have set a variable

```
books='Good books'
```

and we want to create a directory with that name, which command should we use?

A.
```
$ mkdir "${books}"
```

B.
```
$ mkdir "$(books)"
```

C.
```
$ mkdir ${books}
```

D.
```
$ mkdir $(books)
```

E.
```
$ mkdir $books
```

In-class exercise

https://checkoway.net/teaching/cs241/2019-fall/exercises/Lecture-04.html

Grab a laptop and a partner and try to get as much of that done as you can!