

CS 241: Systems Programming

Lecture 3. More Shell

Spring 2020

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Anatomy of a single command

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Example: `tar -zcf archive.tar.gz --verbose dir/file1 file2`

Example meaning

```
tar(1) -zcf archive.tar.gz --verbose dir/file1 file2
```

• The GNU version of the tar archiving utility

• -z, --gzip, --gunzip --ungzip

• -c, --create
create a new archive

• -f, --file ARCHIVE
use archive file or device ARCHIVE

-v, --verbose
verbosely list files processed

tar [-] A --catenate --concatenate | c --create | d --diff --compare | --delete | r --append | t --list |
--test-label | u --update | x --extract --get [options] [pathname ...]

[Click to go to explainshell.com](https://explainshell.com)

Shell commands

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Aliases

- ▶ E.g., `alias ls='ls --color=auto'`

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Aliases

- ▶ E.g., `alias ls='ls --color=auto'`

Programs stored on the file system

- ▶ `/bin`, `/usr/bin`, `/usr/local/bin`, `/sbin`, `/usr/sbin`
- ▶ E.g., `ssh`, `cat`, `ls`, `rm`

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]**

Example

ex

```
— a-1.bin  
— a-1.txt  
— a-2.bin  
— a-2.txt  
— a-3.bin  
— a-3.txt  
— b-1.bin  
— b-1.txt  
— b-2.bin  
— b-2.txt  
— b-3.bin  
— b-3.txt  
— README
```

Example

```
$ ls ex/*.txt
```

ex

```
— a-1.bin  
— a-1.txt  
— a-2.bin  
— a-2.txt  
— a-3.bin  
— a-3.txt  
— b-1.bin  
— b-1.txt  
— b-2.bin  
— b-2.txt  
— b-3.bin  
— b-3.txt  
— README
```

Example

```
$ ls ex/*.txt
```

```
ex/a-1.txt  ex/a-2.txt  ex/a-3.txt  ex/b-1.txt  
ex/b-2.txt  ex/b-3.txt
```

```
ex  
├── a-1.bin  
├── a-1.txt  
├── a-2.bin  
├── a-2.txt  
├── a-3.bin  
├── a-3.txt  
├── b-1.bin  
├── b-1.txt  
├── b-2.bin  
├── b-2.txt  
├── b-3.bin  
├── b-3.txt  
└── README
```

Example

```
$ ls ex/*.txt
```

```
ex/a-1.txt  ex/a-2.txt  ex/a-3.txt  ex/b-1.txt  
ex/b-2.txt  ex/b-3.txt
```

```
$ ls ex/?-3.*
```

```
ex  
├── a-1.bin  
├── a-1.txt  
├── a-2.bin  
├── a-2.txt  
├── a-3.bin  
├── a-3.txt  
├── b-1.bin  
├── b-1.txt  
├── b-2.bin  
├── b-2.txt  
├── b-3.bin  
├── b-3.txt  
└── README
```

Example

```
$ ls ex/*.txt
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ex/a-1.txt  ex/a-2.txt  ex/a-3.txt  ex/b-1.txt  
ex/b-2.txt  ex/b-3.txt
```

```
$ ls ex/?-3.*
```

```
ex/a-3.bin  ex/a-3.txt  ex/b-3.bin  ex/b-3.txt
```

```
ex  
├── a-1.bin  
├── a-1.txt  
├── a-2.bin  
├── a-2.txt  
├── a-3.bin  
├── a-3.txt  
├── b-1.bin  
├── b-1.txt  
├── b-2.bin  
├── b-2.txt  
├── b-3.bin  
├── b-3.txt  
└── README
```

Example

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$ ls ex/*.txt
```

```
ex/a-1.txt  ex/a-2.txt  ex/a-3.txt  ex/b-1.txt  
ex/b-2.txt  ex/b-3.txt
```

```
$ ls ex/?-3.*
```

```
ex/a-3.bin  ex/a-3.txt  ex/b-3.bin  ex/b-3.txt
```

```
$ ls ex/[^acd]-[0-9].b*in
```

```
ex  
├── a-1.bin  
├── a-1.txt  
├── a-2.bin  
├── a-2.txt  
├── a-3.bin  
├── a-3.txt  
├── b-1.bin  
├── b-1.txt  
├── b-2.bin  
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$ ls ex/*.txt
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ex/a-1.txt  ex/a-2.txt  ex/a-3.txt  ex/b-1.txt  
ex/b-2.txt  ex/b-3.txt
```

```
$ ls ex/?-3.*
```

```
ex/a-3.bin  ex/a-3.txt  ex/b-3.bin  ex/b-3.txt
```

```
$ ls ex/[^acd]-[0-9].b*in
```

```
ex/b-1.bin  ex/b-2.bin  ex/b-3.bin
```

```
ex  
├── a-1.bin  
├── a-1.txt  
├── a-2.bin  
├── a-2.txt  
├── a-3.bin  
├── a-3.txt  
├── b-1.bin  
├── b-1.txt  
├── b-2.bin  
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Example

```
$ ls ex/*.txt
```

```
ex/a-1.txt  ex/a-2.txt  ex/a-3.txt  ex/b-1.txt  
ex/b-2.txt  ex/b-3.txt
```

```
$ ls ex/?-3.*
```

```
ex/a-3.bin  ex/a-3.txt  ex/b-3.bin  ex/b-3.txt
```

```
$ ls ex/[^acd]-[0-9].b*in
```

```
ex/b-1.bin  ex/b-2.bin  ex/b-3.bin
```

```
$ ls "ex/*"
```

```
ex  
├── a-1.bin  
├── a-1.txt  
├── a-2.bin  
├── a-2.txt  
├── a-3.bin  
├── a-3.txt  
├── b-1.bin  
├── b-1.txt  
├── b-2.bin  
├── b-2.txt  
├── b-3.bin  
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$ ls ex/*.txt
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ex/a-1.txt  ex/a-2.txt  ex/a-3.txt  ex/b-1.txt  
ex/b-2.txt  ex/b-3.txt
```

```
$ ls ex/?-3.*
```

```
ex/a-3.bin  ex/a-3.txt  ex/b-3.bin  ex/b-3.txt
```

```
$ ls ex/[^acd]-[0-9].b*in
```

```
ex/b-1.bin  ex/b-2.bin  ex/b-3.bin
```

```
$ ls "ex/*"
```

```
ls: cannot access 'ex/*': No such file or  
directory
```

```
ex  
├── a-1.bin  
├── a-1.txt  
├── a-2.bin  
├── a-2.txt  
├── a-3.bin  
├── a-3.txt  
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```

```
CP(1) User Commands CP(1)
NAME
cp - copy files and directories

SYNOPSIS
cp [OPTION]... [-T] SOURCE DEST
cp [OPTION]... SOURCE... DIRECTORY
cp [OPTION]... -t DIRECTORY SOURCE...

DESCRIPTION
Copy SOURCE to DEST, or multiple SOURCE(s) to DIRECTORY.
```

Which command copies all Java source files (those whose names end in `.java`) from the directory `a/b` to the directory `/tmp`?

- A. `$ cp a/b/[a-z].java /tmp`
- B. `$ cp a/*/*.java /tmp`
- C. `$ cp a/b/*.java /tmp`
- D. `$ cp a/b/?*.java /tmp`
- E. `$ cp a/b /tmp *.java`

Typical Unix tool behavior

\$ `program`

- ▶ reads from stdin, writes to stdout

\$ `program file1 file2 file3`

- ▶ runs 'program' on the 3 files, write to stdout

\$ `program -`

- ▶ For programs that require filenames, might read from stdin

Standard input/output/error

Every running program has (by default) 3 open "files" referred to by their **file descriptor** number

Input comes from stdin (file descriptor 0)

- ▶ `input()` # Python: Read a line
- ▶ `System.in.read(var)` // Java: Read bytes and store in `var` array
- ▶ `$ IFS= read -r var` # Read a line and store in `var` variable

Standard input/output/error

Standard input/output/error

Normal output goes to stdout (file descriptor 1)

- ▶ `print(var) # Python`
- ▶ `System.out.println(var) // Java`
- ▶ `$ echo "${var}" # Bash`

Standard input/output/error

Normal output goes to stdout (file descriptor 1)

- ▶ `print(var) # Python`
- ▶ `System.out.println(var) // Java`
- ▶ `$ echo "${var}" # Bash`

Error messages traditionally go to stderr (file descriptor 2)

- ▶ `print(var, file=sys.stderr) # Python`
- ▶ `System.err.println(var) // Java`
- ▶ `$ echo "${var}" >&2 # Bash`

Redirection

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`>file` – redirect standard output (stdout) to `file` with truncation

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Redirection

`>file` — redirect standard output (stdout) to `file` with truncation

`>>file` — redirect stdout to `file`, but append

`<file` — redirect input (stdin) to come from `file`

`|` — connect stdout from left to stdin on right

Redirection

`>file` — redirect standard output (stdout) to `file` with truncation

`>>file` — redirect stdout to `file`, but append

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▸ `$ ls | wc`

Redirection

`>file` — redirect standard output (stdout) to `file` with truncation

`>>file` — redirect stdout to `file`, but append

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▸ `$ ls | wc`

`2>file` — redirect standard error (stderr) to `file` with truncation

Redirection

`>file` — redirect standard output (stdout) to `file` with truncation

`>>file` — redirect stdout to `file`, but append

`<file` — redirect input (stdin) to come from `file`

`|` — connect stdout from left to stdin on right

▸ `$ ls | wc`

`2>file` — redirect standard error (stderr) to `file` with truncation

`2>&1` — redirect stderr to stdout

Redirection examples

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```
$ echo 'Hi!' >output.txt
```

Redirection examples

```
$ echo 'Hi!' >output.txt
```

```
$ cat <input.txt
```

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$ grep hello file | sort | uniq -c
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$ echo 'Hi!' >output.txt
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```
$ echo Hello | cut -c 1-4 >>result.txt
```

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$ echo Hello | cut -c 1-4 >>result.txt
```

```
$ ./process <input | tail -n 4 >output
```

(Almost) everything is a file

Files on the file system

Network sockets (for communicating with remote computers, e.g., web browsers, ssh, mail clients etc.)

Terminal I/O

A bunch of special files

- ▶ `/dev/null` — Writes are ignored, reads return end-of-file (EOF)
- ▶ `/dev/zero` — Writes are ignored, reads return arbitrarily many 0 bytes
- ▶ `/dev/urandom` — Reads return arbitrarily many (pseudo) random bytes

Given that `/dev/null` ignores all data written to it, how can we run the program `./foo` and redirect `stderr` so no error messages appear in our terminal?

A. `$./foo >/dev/null`

B. `$./foo 1>/dev/null`

C. `$./foo 2>/dev/null`

D. `$./foo | /dev/null`

E. `$./foo &2>/dev/null`

Some programs read all of their input before terminating. How can we run a program `./foo` such that it has no input at all?

A. `$./foo </dev/null`

B. `$./foo </dev/zero`

C. `$./foo </dev/urandom`

D. `$./foo </dev/eof`

E. `$ echo | ./foo`

In-class exercise

<https://checkoway.net/teaching/cs241/2020-spring/exercises/Lecture-03.html>

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