

CS 241: Systems Programming

Lecture 3. More Shell

Fall 2023

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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

Shell commands

Shell builtins

- Functionality built into bash (all listed in the manual)
- E.g., `cd`, `alias`, `echo`, `pwd`

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Aliases

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

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- 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., **[a-tz]**
- ▶ **[!...]** 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  
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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-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  
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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  
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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  
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```

```
$ 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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$ 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  
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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
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├── a-2.bin
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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 Rust source files (those whose names end in `.rs`) from the directory `a/b` to the directory `/tmp`?

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

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

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

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▸ `$ ls | wc`

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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
```

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

```
$ cat <input.txt
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$ grep hello file | sort | uniq -c
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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 but we continue to see normal output on `stdout`?

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 on stdin before terminating. If `foo` is such a program, how can we run `foo` such that it has no input at all? (`foo` is just an example, not a real program.)

A. `$ foo </dev/null`

B. `$ foo </dev/zero`

C. `$ foo </dev/urandom`

D. `$ foo </dev/eof`

E. `$ echo | foo`