Course Overview and The Shell

CMSC398W: Practical Tools For Efficient Development

Mohammad Durrani

June 22, 2026

Icebreaker

Please share in the Zoom chat:

1. Your year (Freshman, Sophomore, Junior, Senior)
2. Either:
   - One thing you did over break, OR
   - What you hope to learn from this class

About The Class

Course Information

CMSC398W: Practical Tools For Efficient Development

- Overview of tools used in development: command line, Git, debuggers, build systems, etc.

About Me - Mohammad

Mohammad Durrani

- Senior
- CS + Math, minor in Robotics
- Previous Experience:
  - Teaching this class since Spring 2025
  - SWE Intern at Google in SF
  - SWE Intern at TRX Systems in Greenbelt

Hobbies:

- Rock climbing
- Basketball
- Robots

What To Expect

Course Structure

Read the syllabus for all course-related information!

- Introduction of topic
- Motivation / real-world example
- Technical details
- Projects focusing on application
- Best way to learn: use them

Course Logistics

Communication & Submission

- All course communication: Piazza
- All assignments submitted: Gradescope
- 10% per-day late penalty (except the last project)

Grade Breakdown

Percentage	Title	Description
80%	Projects (20% per)	4 Major Projects
15%	Application Days (5% per)	Completion of Application Days
5%	Participation	Participation in class

Application Days

Based on Feedback

Based on feedback from the previous iteration, we'll have days focused on using the tools we learn in class on toy problems.

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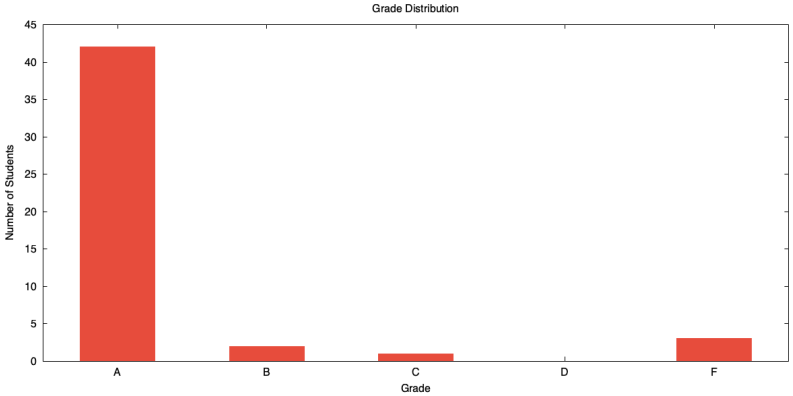
Three Application Days

1. Shell
2. Git
3. Networking

(Subject to change)

Grade Distribution



What is the Shell?

Definition (Shell)

A text-based interface to the operating system.

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Terminal vs Shell

Component	Role	Examples
Terminal	The application that runs the shell	iTerm2, Windows Terminal
Shell	Interprets and runs commands	bash, zsh, fish

Why Do We Need It?

Power & Efficiency

- Speed: Automate repetitive tasks

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We focus on Bash because it's common and the skills are largely transferable. On macOS the default interactive shell is often `zsh`, but the core concepts and scripting translate.

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Power & Efficiency

- Speed: Automate repetitive tasks
- Control: Do things GUIs simply can't
- Remote Machines: The standard way to manage servers

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The Prompt

Anatomy of the Prompt

```
username@host:directory$
```

Component	Description
username	Currently logged in user
@	Separator (convention)
host	Machine name
directory	Current working directory
$	User-level shell indicator
#	Root-level shell indicator

Basic Commands

How It Works

Type command shell splits on whitespace runs program with arguments
Prompts vary and are customizable (your `PS1` controls this).

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Examples

```
date                    # Show date/time
echo hello              # Print text
echo "Hello World"      # Handle spaces
ls -l ~                 # Command with flags
```

File Paths

Types

Absolute: `/home/user/docs` (from root)

Relative: `../other/file.txt` (from current location)

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Special Symbols

Symbol	Meaning
.	Current directory
..	Parent directory
~	Home directory

Essential Navigation Commands

Why?

How do you know where you are in a system with millions of files?

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Commands

Command	Description
`pwd`	Print working directory
`cd <dir>`	Change directory
`ls [dir]`	List directory contents
`ls -l`	Long format listing
`ls -a`	Show hidden files
`ls -lh`	Human-readable sizes

Navigation Examples

Our Filesystem Structure

```
/ (root)
 bin/
 home/
    user/
        docs/
        photos/
 usr/
```

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Our Filesystem Structure

```
/ (root)
 bin/
 home/
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        docs/
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Using Navigation Commands

```
$ pwd
/home/user

$ ls -F          # -F adds / to directo
docs/  photos/

$ cd docs
$ pwd
/home/user/docs

$ cd ..
$ pwd
/home/user
```

Think-Pair-Share: Navigation Puzzle

The Path

You start in `/home/user/docs`. You run the following command:

```
cd .././photos/.././../docs/../../
```

The Question

Where are you now? Work with a partner to trace the path step-by-step.

Answer

/home

1. `..` → `/home/user`
2. `./photos` → `/home/user/photos`

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Answer

/home

1. `..` → `/home/user`
2. `./photos` → `/home/user/photos`
3. `..` → `/home/user`
4. `././docs` → `/home/user/docs`
5. `../../` → `/home`

File and Directory Manipulation

Common Operations

Command	Description
`mkdir <dir>`	Make directory
`touch <file>`	Create empty file / update timestamp
`cp <src> <dst>`	Copy files/directories
`mv <src> <dst>`	Move/rename files
`rm <file>`	Remove files

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- -i: Interactive (ask before delete)

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- -r: Recursive (directories)
- -i: Interactive (ask before delete)
- -f: Force (no prompt)
- -v: Verbose (show progress)

File Manipulation Examples

Examples

```
# Create nested directories
mkdir -p project/src/utils

# Copy a folder and all its contents
cp -r folder1 folder1_backup

# Rename a file
mv old_name.txt new_name.txt

# Remove a folder and its contents (be careful!)
rm -rf temporary_work
```

Time to Explore: File Operations

Challenge

Perform the following tasks using only the shell:

1. Create a directory named `STIC`, and inside it, a directory named `lab1`.
2. Create three empty files in `lab1` named `test1.py`, `test2.py`, and `notes.txt`.
3. Copy `notes.txt` to a new file called `README.md`.
4. Move all `.py` files into a new subdirectory called `src`.
5. Try to remove the `STIC` directory using `rmdir`. Why does it fail?

Solutions: File Operations

Steps

```
# 1. Create nested
mkdir -p STIC/lab1

# 2. Create files
touch STIC/lab1/test1.py STIC/lab1/test2.py STIC/lab1/notes.txt

# 3. Copy
cp STIC/lab1/notes.txt STIC/lab1/README.md

# 4. Move
mkdir STIC/lab1/src
mv STIC/lab1/*.py STIC/lab1/src/

# 5. Why fail?
rmdir STIC  # Fails: "Directory not empty"
```

Viewing File Contents

Why not just use VS Code?

What if the file is on a remote server? What if it's 10GB?

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Viewing Commands

Command	Description
`cat <file>`	Display entire file
`less <file>`	Page through file (q to quit)
`head -n N <file>`	Show first N lines
`tail -n N <file>`	Show last N lines
`tail -f <file>`	Follow file updates (logs)

Viewing Examples

File Viewing

```
# Display entire file
cat file.txt

# Page through file (Search with /, quit with q)
less file.txt

# First 20 lines
head -n 20 file.txt

# Last 15 lines
tail -n 15 file.txt

# Follow log file as it grows
tail -f /var/log/system.log
```

Think-Pair-Share: Which tool when?

Match the tool to the task

1. You want to see the last 5 errors in a log file.
2. You want to read a 1GB text file without crashing your computer.
3. You want to see the first line of every `.txt` file in a directory.
4. You want to watch a log file update in real-time as you run a server.

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4. `tail -f`

PATH: Finding Programs

How does the shell know where 'ls' is?

The `PATH` environment variable is a list of directories the shell searches through every time you type a command.

Key Points

- Colon-separated list: `/usr/local/bin:/usr/bin:/bin`
- First match wins: The shell searches from left to right.
- If it's not in `PATH`, use an explicit path (e.g., `/usr/local/bin/my_prog` or `./my_prog`).

PATH Variable - Example

Exploring PATH

```
# Display your PATH
$ echo $PATH
/usr/local/bin:/usr/bin:/bin:/usr/sbin:/sbin

# Find where a command actually lives (portable)
$ command -v ls
/bin/ls

# Run directly without relying on PATH
$ /bin/date
# sample output: Fri Jan 30 14:00:00 EST 2026
```

Modifying PATH

Adding to PATH

```
export PATH="$HOME/my_tools:$PATH"
```

This adds `my_tools` to the beginning of your PATH, giving it priority.

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Rhetorical Question

Why might it be dangerous to add `.` (current directory) to the start of your PATH?

Environment Variables

Definition (Definition)

Variables that define the environment in which your programs run.

Common Variables

Var	Meaning
`PATH`	Command search
`HOME`	Home directory
`USER`	Username
`PWD`	Current dir

Usage Examples

```
# Display
echo $USER

# Set (local to shell)
MY_VAR="value"

# Export (available to child procs)
export MY_VAR="value"

# View all
env | head
```

Time to Explore: Environment

Challenge

1. Type `env` and look at the output. Can you find `SHELL` and `PWD`?
2. Create a variable: `MY_NAME"Your Name"`. `Try =echo $MY_NAME`.
3. Open a new terminal window. Is `$MY_NAME` still there?
4. Try `export PS1"Ready> "` = (or something fun). What happened to your prompt?

Solutions: Environment

Key Takeaways

- Ephemeral: Variables die when the terminal is closed.
- Local vs Export: Without `export`, child programs (like scripts you run) can't see the variable.

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- Ephemeral: Variables die when the terminal is closed.
- Local vs Export: Without `export`, child programs (like scripts you run) can't see the variable.
- Customization: `PS1` is the variable that controls what your prompt looks like!

Searching and Finding

Why search from the CLI?

Imagine searching through 100,000 lines of logs or finding a specific file in a project with 50 subdirectories.

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Search Commands

Command	Description	Useful Flags
`find`	Find files	`-name`, `-type`, `-size`
`grep`	Search text	`-r` (recursive), `-i` (case), `-n` (line#)
`which`	Find exe	-

find: Locate Files

Examples with Output

```
$ find . -name "*.txt"
./notes.txt
./data/results.txt

# Find directories only
$ find . -type d -name "test*"
./project/tests

# Find files larger than 100MB
$ find /var/log -size +100M
```

grep: Search File Contents

Examples

```
$ grep "error" app.log
Connection error at 10:32

# Show line numbers (-n)
$ grep -n "error" app.log
15:Connection error at 10:32

# Recursive search (-r) in a directory
$ grep -r "TODO" src/
src/main.py: # TODO: optimize this

# Case-insensitive (-i)
$ grep -i "ERROR" app.log
```

Think-Pair-Share: Play With Grep

The Challenge

You are working on a massive project. You need to find a "TODO" comment related to "authentication" in any file.

Task: How would you find this line using only `grep`? Discuss with your neighbor the flags you'd need.

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Possible Solution

```
$ grep -rn "TODO.*authentication" .
```

- -r: Search all files in all subdirectories.
- -n: Show line number with match

Wildcards and Globbing

Glob Patterns

Pattern	Matches
*	Any string (including empty)
?	Any single character
[abc]	Any character in brackets
[a-z]	Any character in range

Globbing Examples

Basic Wildcards

```
# All .txt files
ls *.txt

# Files starting with 'test'
ls test*

# Single character: matches file1.txt but not file10.txt
ls file?.txt
```

Globbing Examples - Advanced

Character Sets and Negation

```
# Match specific numbers
ls file[123].txt

# Match any lowercase letter
ls [a-z]*.txt

# Negation: anything NOT starting with a-z
ls [!a-z]*
```

Time to Explore: Globbing

Files in Directory

`img1.png`, `img10.png`, `img2.png`, `image.png`, `backup_img1.png`

Predict

Which files match these patterns?

1. `img?.png`
2. `img*.png`
3. `img[1-9].png`
4. `*img1.png`

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3. `img1.png`, `img2.png`

Brace Expansion

Definition (Creating Multiple Arguments)

Brace expansion generates multiple strings from a pattern.

Examples

```
# Create multiple files at once
touch file{1,2,3}.txt
# Creates: file1.txt, file2.txt, file3.txt

# Ranges
echo {1..10}
echo {a..z}

# Nested expansion
mkdir -p project/{src,test,docs}
```

Command History

History Features

Key/Command	Action
Up/Down arrows	Navigate history
`!!`	Repeat last command
`!grep`	Execute last command starting with grep
Ctrl+R	Reverse search history
`history`	List command history

History Examples

Using History

```
# View last 20 commands
history 20

# we ALL been there
$ ls /var/root
ls: /var/root: Permission denied
$ sudo !!

# when you typed that super long comand a while ago
(Press Ctrl+R, then type 'ssh')
(reverse-i-search)`ssh': ssh random-user@umd.edu
```

Tab Completion

Note

Tab completion saves time and prevents typos. I really hope you've been using this.

How it works

- Press `Tab` once to complete a unique match.

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How it works

- Press `Tab` once to complete a unique match.
- Press `Tab` twice to see all possibilities if it's ambiguous.
- Example: `cd /u[TAB]l[TAB]b[TAB]` $\rightarrow$ `cd /usr/local/bin/`

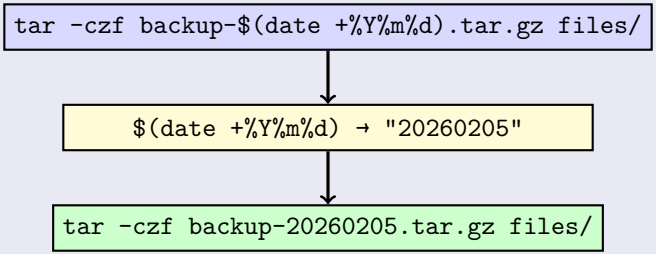
Command Substitution

Definition (Using Command Output)

Command substitution allows you to use the output of a command as an argument to another command.

Command Substitution Execution Order

How It Works



Inner command executes –> output replaces substitution –> full command runs

Command Substitution Examples

Substitution Syntax

```
echo "Today is $(date)"

files=$(ls -1)

echo "Found $(wc -l < file.txt) lines"

echo "User $(whoami) in $(pwd)"
```

Think-Pair-Share: Creative Substitution

Scenario

You want to create a directory named after the current year and month, and then move all your `.log` files into it.

Challenge

How can you do this in one or two lines using command substitution? (Hint: check `man date`)

Think-Pair-Share: Creative Substitution

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Challenge

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Answer

```
mkdir "$(date +%Y-%m)"
mv *.log "$(date +%Y-%m)"
```

Redirection Basics

Problem

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What if we want to use the output of one command as part of a larger data pipeline?

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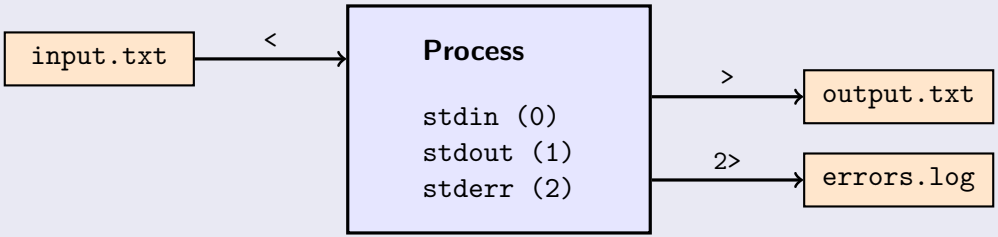
Solution

Operator	Action
>	Overwrite file
>>	Append to file
2>	Redirect errors
&>	Redirect everything
<	Redirect input

File Descriptors & Redirection

Visual Model



- `command > file` stdout to file

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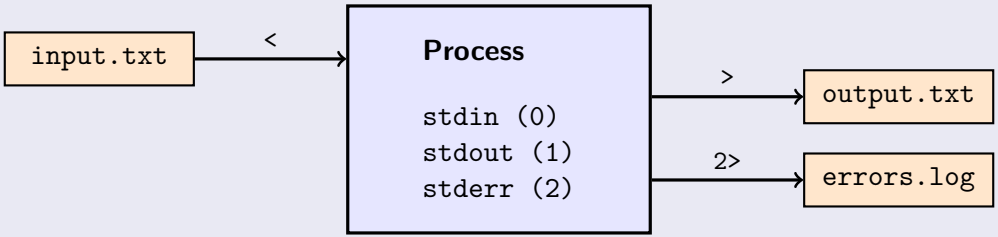

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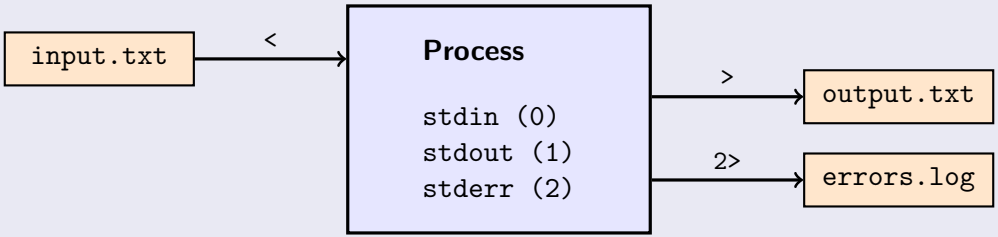

- `command > file` stdout to file
- `command 2>&1` stderr to stdout
- `command &> file` both to file

Redirection Examples

Using Redirection

```
# Redirect output to file
echo "Hello" > output.txt
ls -l >> listing.txt

# Redirect input
sort < unsorted.txt

# Redirect errors
command 2> errors.log

# Combine stdout and stderr
command > all.log 2>&1
command &> all.log  # Shorter syntax
```

Capturing Errors vs Output

Debugging Example

```
# Script that produces both stdout and stderr
$ python buggy_script.py
Processing file1.txt
ERROR: file2.txt not found
Done

$ python buggy_script.py > output.txt 2> errors.txt

$ cat output.txt
Processing file1.txt
Done

$ cat errors.txt
ERROR: file2.txt not found
```

Think-Pair-Share: Redirection Pitfalls

Sequence

```
echo "Hello" > greeting.txt
echo "World" >> greeting.txt
echo "Goodbye" > greeting.txt
```

Discussion

1. What is the final content of `greeting.txt`?
2. What happens if you run `cat greeting.txt > greeting.txt`?
3. How can you save both errors and output to the same file?

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3. `command &> file`

Pipes

Problem

Count .txt files:

- `ls` shows files
- `grep` filters
- `wc -l` counts

How do we connect these?

Solution

Use pipes (|)

```
ls -l | grep txt | wc -l
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Philosophy

"Do one thing well" combine simple tools for complex tasks

How Pipes Work (Visual)

Data Flow

Each command runs simultaneously! Data flows left-to-right.
stdout of left becomes stdin of right.

Pipe Examples

Basic Piping

```
# Count entries in directory listing
ls -1 | wc -l

# Search and sort
cat file.txt | grep "pattern" | sort

# Find largest files
du -h | sort -rh | head -10

# Process logs
cat access.log | grep "404" | wc -l
```

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```

Career Note

Data pipelines are used everywhere: ETL jobs, log analysis, build systems.

Building Pipes Step-by-Step

Progressive Example

```
# 1. See all lines
$ cat app.log
ERROR: connection failed
INFO: started successfully
ERROR: timeout

# 2. Filter errors only
$ cat app.log | grep ERROR
ERROR: connection failed
ERROR: timeout

# 3. Count errors
$ cat app.log | grep ERROR | wc -l
2
```

xargs: Bridging the Gap

Definition

`xargs` builds and executes command lines from standard input. It converts lines of text into arguments for another command.

xargs: Bridging the Gap

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`xargs` builds and executes command lines from standard input. It converts lines of text into arguments for another command.

Why do we need it?

Some commands (like `rm`, `mkdir`, `mv`) don't read from standard input. They only accept arguments. `xargs` bridges this gap.

xargs: Usage and Options

Examples

```
# Delete .tmp files
find . -name "*.tmp" | xargs rm

# Create multiple directories
echo "dir1 dir2 dir3" | xargs mkdir

# Move files to backup/
find . -name "*.txt" | xargs -I {} mv {} backup/
```

xargs: Usage and Options

Examples

```
# Delete .tmp files
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# Create multiple directories
echo "dir1 dir2 dir3" | xargs mkdir

# Move files to backup/
find . -name "*.txt" | xargs -I {} mv {} backup/
```

Common Flags

Option	Description
`-I {}`	Replace {} with each input
`-n N`	Use N arguments per command
`-P N`	Run N commands in parallel

System Health with top

Monitoring System Resources

`top` displays real-time system statistics: CPU, memory, running processes.

```
# macOS: Run top once and exit immediately
$ top -l 1 -n 0
```

Flags: `-l 1` runs top once (1 iteration). `-n 0` displays 0 processes (header stats only).

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Flags: `-l 1` runs top once (1 iteration). `-n 0` displays 0 processes (header stats only).

Common Use Case

Capture CPU and memory usage in scripts for logging or alerting.

Section 3: Data Wrangling

The Goal

"Most of your time as a developer is spent moving data from one format to another."

Key Objectives

- Transform "messy" logs into structured reports.
- Clean and filter large datasets without opening heavy editors.
- Build automated pipelines for repetitive processing.

Data Wrangling Overview

Cleaning, transforming, and analyzing data using command-line tools.

Tasks:

- Extract fields
- Count frequencies
- Filter & Transform
- Reformat output

- Filtering: `grep`, `head`, `tail`
- Sorting: `sort`, `uniq`
- Editing: `sed`, `awk`, `tr`
- Stats: `wc`

Sorting and Uniqueness (sort, uniq)

Examples with Output

```
# Sample file: fruits.txt (apple, banana, apple, cherry, banana)
$ sort fruits.txt | uniq -c
   2 apple
   2 banana
   1 cherry

$ sort fruits.txt | uniq -c | sort -rn
   2 banana
   2 apple
   1 cherry
```

Why?

`uniq` only works on adjacent lines. That's why we almost always `sort` before we `uniq`.

Data Wrangling Example

Real-World Pipeline

```
cat access.log \
  | grep "ERROR" \
  | awk '{print $5}' \
  | sort \
  | uniq -c \
  | sort -rn \
  | head -10
```

Analysis

1. Read: Opens the log file.
2. Filter: Keeps only ERROR lines.
3. Extract: Pulls the 5th column (the error type).
4. Sort: Groups identical messages.
5. Count: Counts unique occurrences.

Regular Expressions (Regex)

Note: Pattern Matching Beyond Wildcards

Regex patterns allow for powerful, flexible text matching. They're used in `grep`, `sed`, `awk`, and many other tools.

Pattern Cheat Sheet

Pattern	Matches
`^` / `$`	Start / End of line
`.`	Any single character
`*`	Zero or more of previous
`[abc]`	Any character in brackets
`[0-9]`	Any digit

Regex Example: What Matches?

Sample Text

```
apple pie
red apple
banana
dog
hot dog
dogwood
error123
ERROR456
```

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Patterns and Their Matches

- `^apple`: "apple pie"
- `apple$`: "red apple"

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- `^apple`: "apple pie"
- `apple$`: "red apple"
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- `dog`: "dog", "hot dog", "dogwood"
- `[0-9]`: "error123", "ERROR456"
- `^[a-z]`: all lowercase starts

Regex Flavors in Shell Tools

Important Note

Different tools use different regex "flavors" with slightly different syntax.

Regex Flavors in Shell Tools

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Basic vs Extended Regular Expressions

Pattern	Basic (BRE)	Extended (ERE)
One or more	`\+`	`+`
Zero or more	`\*`	`*`
Grouping	`\( \)`	`( )`
Example	`grep 'a\+'`	`grep -E 'a+'`

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Different tools use different regex "flavors" with slightly different syntax.

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Key Difference

With Basic regex, special chars like `+`, `?`, `()`, `{}` need backslashes: `\+`, `\?`
With Extended regex (`-E` flag), use them directly: `+`, `?`

What is sed?

Definition

sed is a stream editor for filtering and transforming text. It reads input line by line, applies commands, and outputs the result.

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Basic Syntax

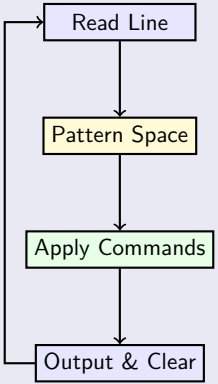
`sed 'command' file`

Common commands:

- `s/pattern/replacement/` - substitute (search and replace)
- `d` - delete matching lines
- `p` - print (usually with `-n` flag)

How sed Works (Execution Model)

The sed Cycle



How sed Works (Execution Model)

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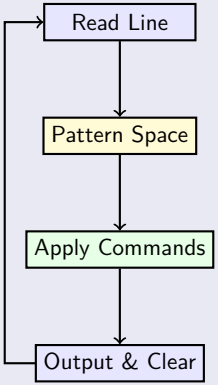

Key Concept

`sed` processes one line at a time. Original file is never modified unless you use `-i` (in-place editing).

sed: Basic Examples

Simple Substitution

```
# Replace first 'foo' with 'bar'
$ echo "foo foo" | sed "s/foo/bar/"
bar foo

# Replace ALL 'foo' with 'bar' (global flag 'g')
$ echo "foo foo" | sed "s/foo/bar/g"
bar bar

# Delete lines matching a pattern
$ printf "line1\n#comment\nline2" | sed '/^#/d'
line1
line2
```

sed: Working with Files

Sample Data (`test/ex-sed/sample_data.txt`)

Try these against `sample_data.txt` locally:

```
# Transform foo to FUBAR (global)
sed 's/foo/FUBAR/g' sample_data.txt

# Delete lines matching a pattern
sed '/^#/d' sample_data.txt
```

sed: Extended Regex Examples

Alternation and Back-references (test/ex-sed/sample_data.txt)

```
# Transform either foo or bar to FUBAR (-E for extended regex)
sed -E 's/(foo|bar)/FUBAR/g' sample_data.txt

# Put double quotes around foo or bar using back-references
sed -E 's/(foo|bar)/"\1"/g' sample_data.txt
```

sed: Addressing and Ranges

Target Specific Lines

```
# Delete only the first 2 lines
$ sed '1,2d' file.txt

# Print only lines 5 through 10
$ sed -n '5,10p' file.txt

# Substitute only on lines containing 'error'
$ sed '/error/s/false/true/' log.txt
```

Practice: config cleanup

1. Task: Remove all comments (#) and empty lines from a file.

sed: Addressing and Ranges

Target Specific Lines

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$ sed '/error/s/false/true/' log.txt
```

Practice: config cleanup

1. Task: Remove all comments (#) and empty lines from a file.

Answer

```
sed -e '/^#/d' -e '/^$/d' config.txt
```

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Definition

`awk` is a powerful text processing tool for extracting and manipulating data in columns.

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Basic Syntax

{awk 'pattern \ action \' file}

Key concepts:

- Automatically splits each line into fields (columns)
- $1 = first field, $2 = second field, etc.
- $0 = entire line

awk: Basic Examples

Simple Field Extraction

```
# Print 1st and 3rd columns (default delimiter: space/tab)
$ awk '{print $1, $3}' data.txt

# Print only the first column
$ awk '{print $1}' data.txt

# Use a custom delimiter (e.g., colon for /etc/passwd)
$ awk -F':' '{print $1}' /etc/passwd
```

awk: Pattern-Action Model

How awk Processes Data

`awk` automatically loops over every line and applies your pattern and action to each line.

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Pattern Examples

```
# Filter by value: print line if 2nd column > 100
$ awk '$2 > 100' data.txt

# Pattern with action: print 1st col if 2nd col > 100
$ awk '$2 > 100 {print $1}' data.txt
```

awk: Context and Math

Built-in Variables

- NR: Number of Records (Line Number)
- NF: Number of Fields (Columns in current line)
- $0: The entire line

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Examples with Output

```
# Print line number and the line
$ awk '{print NR, $0}' file.txt

# Sum values in the first column
$ awk '{sum += $1} END {print "Total:", sum}' numbers.txt
Total: 450

# Calculate average of 1st column
$ awk '{s+=$1; c++} END {print "Avg:", s/c}' numbers.txt
```

Practice: Data Extraction

Challenge

You have a CSV (`Name,Age,Score`) called `class.csv`.

1. Print only the names of students older than 20.
2. Calculate the total number of words in a text file.

Practice: Data Extraction

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Answers

1. `awk -F',' '$2 > 20 {print $1}' class.csv`
2. `awk '{total += NF} END {print total}' file.txt`

More awk Examples

Advanced Features

```
# Formatted printing (printf)
awk '{printf "Name: %-10s ID: %03d\n", $1, $2}' students.txt

# Length of string
awk 'length($0) > 80' file.txt  # Print lines > 80 chars

# Logical conditions (AND/OR)
awk '$1 == "POST" && $9 == 200' access.log

#  Filter by timestamp range and format
awk -F',' '$1 >= "2025-01-08 15:00" && $1 <= "2025-01-08 16:00" {
    printf "%s,%.2f,%.2f\n", $1, $2, $3
}' stats.log
```

Scripting Basics

- Automate repetitive tasks
- Combine multiple commands
- Add logic (if/loops)
- Reproducibility

```
#!/bin/bash
# hello.sh
echo "Hello, $USER!"
echo "Date: $(date)"
```

Making it Executable

```
chmod +x hello.sh
./hello.sh
```

Variables in Scripts

Definition and Scope

```
# Definition: No spaces around =
name="STIC Class"
count=42

# Access: Use the $ sign
echo "Welcome to $name"

# Command Substitution: Use $()
current_user=$(whoami)
```

Important Rules

- Quotes Matter: Use `"$var"` to prevent word splitting if your variable contains spaces.
- Braces: Use `${var}` for clarity or when appending text: `echo "${name}_backup"`.

Positional Arguments

Communicating with Scripts

Variable	Description
`$0`	The script name itself
`$1, $2..`	First, second arguments
`$#`	Number of arguments passed
`$@`	All arguments as a list
`$?`	Exit status of the last command

Practice: Arg Grep

Create a script that takes a word as $1 and a file as $2 and greps for it.

Answer: Arg Grep

Solution

```
grep "$1" "$2"
```

- Use `$@` for looping over all arguments.

Logic and Conditionals

```
if [ "$1" -gt 10 ]; then
  echo "Large"
elif [ -f "$1" ]; then
  echo "It's a file"
else
  echo "Small/Unknown"
fi
```

Test	True if...
`-f`	Regular file
`-d`	Directory
`-eq`	Equal (numeric)
`-z`	Empty string
`=`	Equal (string)

Practice: File Safety

1. Write a script that checks if a directory exists before creating it.

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if [ "$1" -gt 10 ]; then
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Practice: File Safety

1. Write a script that checks if a directory exists before creating it.
2. Answer: `if [ ! -d "$dir" ]; then mkdir "$dir"; fi`

Arithmetic in Bash

```
# $(( )) evaluates arithmetic
x=5
y=3
echo $(( x + y ))   # 8
echo $(( x * y ))   # 15
echo $(( x ** 2 ))  # 25
echo $(( x % y ))   # 2

# Increment / decrement
(( x++ ))
(( x += 10 ))
```

Operator	Meaning
+	Addition
-	Subtraction
*	Multiplication
/	Division (int)
%	Modulo
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Important Note

Bash only does integer arithmetic. For decimals, use `bc` or `awk`: `echo "scale=2; 7/2" | bc` `3.50`

Iteration (for, while)

```
# Range
for i in {1..5}; do
  echo "$i"
done

# Files
for f in *.txt; do
  mv "$f" "${f}.bak"
done
```

```
# Read file line-by-line
while read -r line; do
  echo "PROCESSED: $line"
done < file.txt

# Counter
while [ $c -lt 5 ]; do
  ((c++))
done
```

Practice: Bulk Rename

1. Write a `for` loop that adds a `.old` extension to every file in the current directory.

Iteration (for, while)

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# Range
for i in {1..5}; do
  echo "$i"
done

# Files
for f in *.txt; do
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done
```

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  ((c++))
done
```

Practice: Bulk Rename

1. Write a `for` loop that adds a `.old` extension to every file in the current directory.
2. Answer: `for f in *; do mv "$f" "$f.old"; done`

Functions and Scope

```
greet() {
  local name=$1
  echo "Hello $name"
}

greet "Alice"
```

- Use local variables
- Return status (0-255)
- Arguments are `$1, $2..`
- Name functions clearly

Practice: Math Function

1. Create a function `square` that prints the square of its first argument.

Functions and Scope

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```

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- Return status (0-255)
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Practice: Math Function

1. Create a function `square` that prints the square of its first argument.
2. Answer: `square() { echo $(($1 * $1)); }`

Scripting and Debugging

`set -euo pipefail`

- -e: Exit on error
- -u: Error on unset var
- pipefail: Pipeline fails if ANY part fails

- set -x: Print commands
- bash -n: Check syntax
- shellcheck: (External tool) highly recommended!

Practice: Safety First

1. What happens if you run `rm -rf $DIR/file` and `$DIR` is undefined?

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Practice: Safety First

1. What happens if you run `rm -rf $DIR/file` and `$DIR` is undefined?
2. How does `set -u` prevent this disaster?
3. Answer: Without `-u`, it runs `rm -rf /file`. With `-u`, the script exits immediately.

Example: Auto-Backup

A Robust Backup Script (test/auto_backup.sh)

```
#!/bin/bash
set -euo pipefail

DEST="/backups/$(date +%Y-%m-%d)"
mkdir -p "$DEST"

for dir in "$@"; do
  if [ -d "$dir" ]; then
    echo "Backing up $dir..."
    tar -czf "$DEST/$(basename "$dir").tar.gz" "$dir"
  else
    echo "Warning: $dir is not a directory" >&2
  fi
done
```

Analysis: Auto-Backup

Best Practices

1. Safety: `set -euo pipefail` ensures the script stops if a directory can't be created or a command fails.
2. Dynamic: Uses `$@` to process any number of folders passed as arguments.
3. Error Handling: Redirects warnings to `stderr` (`>&2`) so they don't pollute the standard output.
4. Clean Paths: Uses `basename` to ensure the archive name is clean even if a full path is provided.

Questions?

Thank you!

Ask your questions on Piazza