

09 – Expansions and Regular Expressions

CS 2043: Unix Tools and Scripting, Spring 2019 [2]

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As always: Everybody! ssh to wash.cs.cornell.edu

- Quiz time! Everybody! run **quiz-02-11-19**
- You can just explain a concept from last class, doesn't have to be a command this time.

Shell Expansion

Expansion Special Characters

- There are various special characters you have access too in your shell to expand phrases to match patterns, such as:

```
* ? ^ { } [ ]
```

- These special characters let you match many types of patterns:
 - Any string.
 - A single character.
 - A phrase.
 - A restricted set of characters.
 - Many more, as we will see!

The * Wildcard

- The * matches any *string*, including the null *string*.
- It is a “greedy” operator: it expands as far as it can.
- Is *related* to the **Kleene Star**, matching *0 or more* occurrences.
- For shell, * is a *glob*. See [3] for more.

```
# Does not match: AlecBaldwin
```

```
$ echo Lec*
```

```
Lec.log Lecture1.tex Lecture1.txt Lecture2.txt Lectures
```

```
# Does not match: sure.txt
```

```
$ echo L*ure*
```

```
Lecture1.tex Lecture1.txt Lecture2.txt Lectures
```

- This is the greedy part: $L^* \Rightarrow \text{Lect}$

```
# Does not match: tex/ directory
```

```
$ echo *.tex
```

```
Lecture1.tex Presentation.tex
```

- Matches **existing files/dirs**, does *not* define sequence

The ? Wildcard

- The ? matches a *single* character.

```
# Does not match: Lec11.txt
```

```
$ echo Lec?.txt
```

```
Lec1.txt Lec2.txt Lec3.txt
```

- Lec11 not matched because it would have to *consume* two characters, the ? is *exactly one* character
 - Which character, though, doesn't matter.

```
# Does not match: ca cake
```

```
$ echo ca?
```

```
can cap cat
```

- Again matches existing files/dirs!

Creating Sets

- **[brackets]** are used to define *sets*.
 - Use a dash to indicate a range of characters.
 - Can put commas between characters / ranges (**[a-z,A-Z]**).
 - Means *either* one lower case or one upper case letter.
 - **[a-z]** only matches **one** character.
 - **[a-z][0-9]**: “find exactly **one** character in **a..z**, *immediately* followed by **one** character in **0..9**”

Input	Matched	Not Matched
[SL] ec*	Lecture Section	Vector.tex
Day [1-3]	Day1 Day2 Day3	Day5
[a-z][0-9].mp3	a9.mp3 z4.mp3	az2.mp3 9a.mp3

Inverting Sets

- The ^ character is represents *not*.
 - **[abc]** means *either a, b, or c*
 - So **[^abc]** means *any character that is not a, b, or c*.

Input	Matched	Not Matched
[^A-P] ec*	Section.pdf	Lecture.pdf
[^A-Za-z] *	9Days.avi	vacation.jpg

- sets, inverted or not, again match existing files/dirs

Brace Expansion

- **Brace Expansion:** `{... , ...}` matches any pattern inside the comma-separated braces.
- Supports ranges such as `11..22` or `t..z` as well!
- Brace expansion needs at least two options to choose from.

Input	Output
<code>{Hello,Goodbye}\ World</code>	Hello World Goodbye World
<code>{Hi,Bye,Cruel}\ World</code>	Hi World By World Cruel World
<code>{a..t}</code>	Expands to the range a ... t
<code>{1..99}</code>	Expands to the range 1 ... 99

- **Note:** NO SPACES before / after the commas!
- Mapped onto following expression where applicable:
 - Following expression must be *continuous* (whitespace escaped)
 - See next slide.
- Braces **define a sequence**, unlike previous!

Brace Expansion in Action

```
# Extremely convenient for loops:
# prints 1 2 3 ... 99
$ for x in {1..99}; do echo $x; done
# bash 4+: prints 01 02 03 .. 99
$ for x in {01..99}; do echo $x; done

# Expansion changes depending on what is after closing brace:
# Automatic: puts the space between each
$ echo {Hello,Goodbye}
Hello Goodbye
# Still the space, then *one* 'World'
$ echo {Hello,Goodbye} World
Hello Goodbye World
# Continuous expression: escaped the spaces
$ echo {Hello,Goodbye}\ Milky\ Way
Hello Milky Way Goodbye Milky Way
# Yes, we can do it on both sides. \\n: lose a \ in expansion
$ echo -e {Hello,Goodbye}\ Milky\ Way\ {Galaxy,Chocolate\ Bar\\n}
Hello Milky Way Galaxy Hello Milky Way Chocolate Bar
    Goodbye Milky Way Galaxy Goodbye Milky Way Chocolate Bar
```

Combining Them

- Of course, you can combine all of these!
- `cd /course/cs2043/demos/09-demos/combined`

```
# Doesn't match: hello.txt
```

```
$ ls *h[0-9]*
```

```
h3 h3llo.txt
```

```
# Doesn't match: foo.tex bar.tex
```

```
$ ls [bf][ao][row].t*t
```

```
bar.text bar.txt foo.text foo.txt
```

```
# Careful with just putting a * on the end...
```

```
$ ls [bf][ao][row].t*
```

```
bar.tex bar.text bar.txt foo.tex foo.text foo.txt
```

```
# Doesn't match: foo.text bar.text
```

```
$ ls {foo,bar}.t{xt,ex}
```

```
bar.tex bar.txt foo.tex foo.txt
```

Special Characters Revisited

- The special characters are

```
# Expansion related special characters
* ? ^ { } [ ]
# Additional special characters
$ < > & ! #
```

- The shell interprets them in a special way unless we escape them (`\$`), or place them in **single** quotes (`'$'`).
- When executing a command in your shell, the expansions happen **before** the command is executed. Consider `ls *.txt`:
 1. Starts parsing: `ls` is a command that is known, continue.
 2. Sees `*.txt`: expand **now** e.g. `*.txt` \Rightarrow `a.txt b.txt c.txt`
 3. `ls a.txt b.txt c.txt` is *then* executed.
- Shell expansions are your friend, and we'll see them again...

Shell Expansion Special Characters Summarized

Symbols	Meaning
*	Multiple character wildcard: 0 or more of <i>any</i> character.
?	Single character wildcard: exactly one, don't care which.
[]	Create a set, e.g. [abc] for <i>either a, or b, or c</i> .
^	Invert sets: [^abc] for anything <i>except a, b, or c</i> .
{ }	Used to create enumerations: {hello,world} or {1..11}
\$	Read value: echo \$PWD reads PWD variable, then echo
<	Redirection: create stream out of file tr -dc '0-9' < file.txt
>	Redirection: direct output to a file. echo "hiya" > hiya.txt
&	Job control.
!	Contextual. In Shell history, otherwise usually negate.
#	Comment: anything after until end of line not executed.

- Non-exhaustive list: see [4] for the full listing.

Single vs Double Quotes

- Special characters inside *double* quotes “prefer” not to expand
 - some still need escaping
- Special characters in *single* quotes are **never** expanded.

```
# prints the letters as expected
$ for letter in {a..e}; do echo "$letter"; done
# escaping the money sign means give literal $ character
$ for letter in {a..e}; do echo "\$letter"; done
# $ is literal now, so doesn't read variable
$ for letter in {a..e}; do echo '$letter'; done
```

- Pay attention to your text editor when writing scripts.
 - Like the slides, there is syntax highlighting.
 - It *usually* changes if you alter the meaning of special characters.
- If you remember anything about shell expansions, remember the difference between single and double quotes.

tr Revisited with Sets

Useful POSIX Sets

Set Name	Set Value
<code>[:lower:]</code>	lowercase letters
<code>[:upper:]</code>	uppercase letters
<code>[:alpha:]</code>	alphabetic characters (upper and lower)
<code>[:digit:]</code>	digits 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9
<code>[:alnum:]</code>	alphanumeric characters
<code>[:punct:]</code>	punctuation characters
<code>[:space:]</code>	whitespace characters

```
# Get excited. Note single quotes because of !
$ echo 'I am excited!' | tr [[:lower:]] [[:upper:]]
I AM EXCITED!

# Component-wise: e->3, t->7, a->4, o->0, s->5
$ echo 'leet haxors' | tr [etaos] [37405]
l337 h4x0r5
```


grep and Regular Expressions

Time for the Magic

Globally Search a Regular Expression and Print

`grep <pattern> [input]`

- Searches **input** for all lines containing **pattern**.
- As easy as searching for a **string** in a **file**.
- Or it can be much more, using regular expressions.
- Common use:

`<command> | grep <thing you need to find>`

- You have some **command** or sequence of commands producing a large amount of output.
 - The output is longer than you want, so filter through **grep**.
 - Reduces the output to only what you really care about!
- Understanding how to use **grep** is **really** going to save you a lot of time in the future!

Some Useful Grep Options

- **-i**: ignores case.
- **-A 20 -B 10**: print 10 lines **B**efore, 20 lines **A**fter each match.
- **-v**: inverts the match.
- **-o**: shows only the matched substring.
- **-w**: “word-regexp” – exclusive matching, **read the man page**.
- **-n**: displays the line number.
- **-H**: print the filename.
- **--exclude <glob>**: ignore **glob** e.g. **--exclude *.o**
- **-r**: recursive, search subdirectories too.
 - **Note**: your Unix version may differentiate between **-r** and **-R**, check the **man** page.
 - **grep -r [other flags] <pattern> <directory>**
 - That is, you specify the **pattern** first, and where to search after (just like how the **file** in non-recursive **grep** is specified last).

Regular Expressions

- **grep**, like many programs, takes in a **regular expression** as its **input**. Pattern matching with regular expressions is more sophisticated than shell expansions, and also uses different syntax.
- More precisely, a regular expression *defines* a set of strings – if any part of a line of text is *in the set*, **grep** returns a **match**.
- When we use regular expressions, it is (usually) best to enclose them in quotes to stop the shell from expanding it before passing it to **grep** / other tools.

WARNING

When using a tool like **grep**, the shell expansions we have learned *can* and do still occur! I **strongly** advise using *double quotes* to circumvent this. Or if you want the literal character (e.g. the *), use *single quotes* to disable all expansions entirely.

Regular Expression Similarities

- Some **regex** patterns are similar / the same.

Single Characters are Different

Shell Expansion:	<code>?</code>
Regular Expressions:	<code>.</code>

- `?` means something different in regex (Differences slide).
- Example: **grep** `"t.a"` \Rightarrow lines with **tea**, **taa**, and **steap**

Sets are almost the Same

Shell Expansion:	<code>[a-z]</code>
Regular Expressions:	<code>[a-z]</code>

- Matches one of the indicated characters.
- Don't separate multiple characters with commas in the **regex** form (e.g. `[a,b,q-v]` becomes `[abq-v]`).

A Note on Ranges in Sets

- Like shell wildcards, regex is case-sensitive.
- How would you match any letter, regardless of case?
 - If you take a look at the ASCII codes ([1]), you will see that the lower case letters come **after** the upper case letters.
 - You should be careful about trying to do something like **[a-Z]**.
 - Instead, just do **[a-zA-Z]**.
 - Or use the POSIX set **[[:alpha:]]**.
 - **Note:** some programs *may* accept the range **[a-Z]**.
 - But it may not actually be the range you think. It depends.

Regular Expression Differences

- Some of the shell expansion tools are **completely** different.

Modifiers Apply to the Expression *Before* Them

? is 0 or 1 occurrences:	$a? \Rightarrow 0 \text{ or } 1 \text{ } a$
* is 0 or more occurrences:	$a^* \Rightarrow 0, 1, \dots n \text{ } a\text{'s}$
+ is 1 or more occurrences:	$a^+ \Rightarrow 1, 2, \dots n \text{ } a\text{'s}$

- Note:** + and ? are *extended* regular expression characters.
- Must escape (\+ and \?) or use -E or **egrep**.

Nothing happens, they weren't escaped

```
$ grep "f?o+" combined/*.*
```

f\? can be 0, so h{e,3}llo are found

```
$ grep "f\?o\+" combined/*.*
```

```
combined/foo.tex:1:foo
```

```
combined/foo.text:1:foo
```

```
combined/foo.txt:1:foo
```

```
combined/h3llo.txt:1:h3llo
```

```
combined/hello.txt:1:hello
```

Curly Braces in Pattern Creation

- Recall that curly braces are an expansion:

```
$ echo h{e,3}llo
hello h3llo
$ echo "h{e,3}llo"
h{e,3}llo
```

- However, you cannot use them with **grep** like this:

```
# Second expansion: treated as file input to grep
# You can only supply *ONE* pattern!
$ grep h{e,3}llo combined/*.*
grep: h3llo: No such file or directory
combined/hello.txt:1:hello
# Double quotes won't save you: that's the literal
# string 'h{e,3}llo' at this point (so no match).
$ grep "h{e,3}llo" combined/*.*
```

- AKA you cannot *easily* do these expansions when using **grep**.
- {}**.bash are *fundamentally different* from the other expansions
 - defines a sequence, does not match existing targets.

Final Thoughts and Additional Resources

- The regular expressions we use in our shell are the “Perl Regular Expressions.”
 - There are other regular expression syntaxes.
 - **Most** tools / languages use **perl** RE syntax.
- “Regular” regular expressions
- *Extended* regular expressions
- Python **re** (Regular Expression) module
 - Many **excellent** examples, and thorough explanations.
 - Topics of interest:
 - Greedy vs non-greedy,
 - Positive lookahead vs negative lookahead
 - Capturing vs non-capturing
- Probably the **best step-by-step tutorial there is**

Cutting and Pasting

Chopping up Input

cut out sections of input (filtering)

cut <options> [**file**]

- Must specify list of *bytes* (**-b**), *characters* (**-c**), or *fields* (**-f**).
- The **file** is optional, uses **stdin** if unspecified.

N	Only N^{th} byte, character, or field, counted from 1.
N-	N^{th} byte, character, or field, to end of line.
M-N	M^{th} to N^{th} (inclusive) byte, character, or field.
-N	First to N^{th} (inclusive) byte, character, or field.
M,N,...,X	Extract individual items (1,4,6 : first, fourth, and sixth bytes, characters, or fields).

- E.g., **-b 2** is “2nd byte”, **-f 3-** is “3rd field to end of line”.
- Use **-d** to specify a delimiter (**TAB** by default).
 - E.g., **echo 'a:b:c:d' | cut -d : -f 2** \Rightarrow **b**

cut Examples

employees.csv

```
Alice,female,607-123-4567,11 Sunny Place,Ithaca,NY,14850
Bob,male,607-765-4321,1892 Rim Trail,Ithaca,NY,14850
Andy,n/a,607-706-6007,1 To Rule Them All,Ithaca,NY,14850
Bad employee data without proper delimiter
```

- `/course/cs2043/demos/09-demos/employees.csv`
- Get names, ignore improper lines:

```
$ cut -d , -f 1 -s employees.csv
```

- Get names and phone numbers, ignore improper lines:

```
$ cut -d , -f 1,3 -s employees.csv
```

- Get address (4th col and after), ignore improper lines:

```
$ cut -d , -f 4- -s employees.csv
```

Merge Lines of Files

```
paste [options] [file1] [file2] ... [fileN]
```

- Neither **options** nor **files** are *required*.
- Use **-d** to specify the delimiter (**TAB** by default).
- Use **-s** to concatenate serially instead of side-by-side.
- No **options** and one **file** specified: same as **cat**.
 - Use with **-s** to join all lines of a file.

paste Examples I

names.txt

Alice

Bob

Andy

phones.txt

607-123-4567

607-765-4321

607-706-6007

- `paste cut_paste/names.txt` and
`cu_pates/phones.txt` line by line:

```
$ paste -d , names.txt phones.txt > result.csv
```

```
$ cat result.csv
```

```
Alice,607-123-4567
```

```
Bob,607-765-4321
```

```
Andy,607-706-6007
```

paste Examples II

names.txt

Alice

Bob

Andy

phones.txt

607-123-4567

607-765-4321

607-706-6007

- `paste names.txt` and `phones.txt` *serially* (-s):

```
$ paste -d , -s names.txt phones.txt > result.csv
```

```
$ cat result.csv
```

```
Alice,Bob,Andy
```

```
607-123-4567,607-765-4321,607-706-6007
```

Splitting and Joining

Splitting Files

split a file into pieces

split [options] [file [prefix]]

- Use **-l** to specify how many lines in each file
 - Default: **1000**
- Use **-b** to specify how many *bytes* in each file.
- The **prefix** is prepended to *each file* produced.
- If no **file** provided (or if **file** is **-**), **stdin** is used.
- Use **-d** to produce numeric suffixes instead of lexographic.
 - Not available on BSD / macOS.

split Examples I

ages.txt

Alice 44
Bob 30
Candy 12

- `split split_join/ages.txt` into files of one line each:

```
$ split -l 1 ages.txt
$ ls
ages.txt  salaries.txt  xaa  xab  xac
$ cat xaa
Alice 44
$ cat xab
Bob 30
$ cat xac
Candy 12
```

split Examples II

ages.txt

Alice 44
Bob 30
Candy 12

- `split split_join/ages.txt` into files of one line each,
 - with numeric suffixes (`-d`) (GNU / Linux), and with `ages_` prefix

```
$ split -l 1 -d ages.txt ages_  
$ ls  
ages_00  ages_01  ages_02  ages.txt  salaries.txt  
$ cat ages_00  
Alice 44  
$ cat ages_01  
Bob 30  
$ cat ages_02  
Candy 12
```

Joining Files

join lines of two files on a common field

join [**options**] **file1 file2**

- Join two files at a time, no more, no less.
- Default: files are assumed to be delimited by *whitespace*.
- Use **-t <char>** to specify alternative *single-character* delimiter.
- Use **-1 n** to join by the n^{th} field of **file1**.
- Use **-2 n** to join by the n^{th} field of **file2**.
 - Field numbers start at **1**, like **cut** and **paste**.
- Use **-a f_num** to display unpaired lines of file **f_num**.

join Examples I

ages.txt

Alice 44

Bob 30

Candy 12

salaries.txt

Bob 300,000

Candy 120,000

- join split_join/ages.txt and split_join/salaries.txt files into results.txt:

```
$ join ages.txt salaries.txt > results.txt
```

```
$ cat results.txt
```

```
Bob 30 300,000
```

```
Candy 12 120,000
```

join Examples II

ages.txt

Alice 44

Bob 30

Candy 12

salaries.txt

Bob 300,000

Candy 120,000

- join split_join/ages.txt and split_join/salaries.txt files into results.txt:

```
$ join -a1 ages.txt salaries.txt > results.txt
```

```
$ cat results.txt
```

Alice 44

Bob 30 300,000

Candy 12 120,000

The Stream Editor (**sed**)

Introducing...

The Stream Editor

`sed [options] [script] [file]`

- Stream editor for filtering and transforming text.
- If no **file** provided, **stdin** is used.
- We will focus on **sed**'s `'s/<regex>/<replacement>/'`:
 - Replace anything matching `<regex>` with `<replacement>`.
 - E.g., `echo 'hello' | sed 's/lo/p!/'` \Rightarrow `help!`
- **sed** goes line by line searching for the regular expression.
- Only covering *basics*, **sed** is a full programming language.
- Main difference between **sed** and **tr** for scripting?
 - **sed** can match regular expressions, and perform *captures*!
- Extended regular expressions: use the **-E** flag (not **-r**).
 - GNU **sed** supports both **-r** and **-E**, BSD **sed** only **-E**.
- See examples for more.

A Basic Example

- Luke, there is *no spoon* (demo file `no_spoon.txt`).

```
$ head -1 no_spoon.txt
There is no spoon. There is no spoon. There is no spoon. There is no spoon.

$ sed 's/no spoon/a fork/g' no_spoon.txt
There is a fork. There is a fork. There is a fork. There is a fork.
...
There is a fork. There is a fork. There is a fork. There is a fork.
```

- Replaces **no spoon** with **a fork** for every line.
- No ending `/g`? Only one substitution per line:

```
$ sed 's/no spoon/a fork/' no_spoon.txt
There is a fork. There is no spoon. There is no spoon. There is no spoon.
...
There is a fork. There is no spoon. There is no spoon. There is no spoon.
```

- **Caution:** get in habit of using *single-quotes* for with **sed**.
 - Otherwise special shell characters (like `*`) may expand in *double-quotes* causing you sadness and pain.

Deletion

- Delete all lines that contain regex: `sed '/regex/d'`

david.txt

```
Hi, my name is david.  
Hi, my name is DAVID.  
Hi, my name is David.  
Hi, my name is dAVID.
```

- Delete all lines in demo file `david.txt` matching `[Dd]avid`:

```
$ sed '/[Dd]avid/d' david.txt
```

```
Hi, my name is DAVID.  
Hi, my name is dAVID.
```

- To delete pattern per-line, just do an empty replacement:

```
$ sed 's/[ ]\?[Dd][Aa][Vv][Ii][Dd].//g' david.txt
```

```
Hi, my name is  
Hi, my name is  
Hi, my name is  
Hi, my name is
```

Regular Expressions

- What does this **REMOVED** from demo file **data.txt**?

```
$ sed 's/[a-zA-Z]\{1,3\}[0-9]*@cornell\.edu/REMOVED/g' data.txt
```

- Only removes **netID@cornell.edu** emails, not the others!
- “Regular” regex: escape specials ((**parens**), {**braces**}, etc.).

```
$ sed 's/[[:alnum:]]\{1,11\}@/REMOVED@g' data.txt
```

- We have to escape the curly braces: **\{1,11\}**
- “Extended” regex (using **-E** flag): escaping rules **reversed**!

```
$ sed -E 's/[[:alnum:]]\{1,11\}@/REMOVED@g' data.txt
```

- No replacements, **\{1,11\}** now means literal string **{1,11}**.

```
$ sed -E 's/[[:alnum:]]{1,11}@/REMOVED@g' data.txt
```

- Works! **\{1,11\} ⇒ {1,11}**

Capture Groups

- Like most regular expressions, **(parens)** form capture groups.
- You can use the capture groups in the replacement text.
 - If you have one capture group: `\1` in replacement text.
 - Two groups? `\1` and `\2` are available in replacement text.
- A contrived example:

```
$ echo 'hello world' | \
    sed 's/\(hello\) \(world\)/\2 say \1 back/'
world say hello back
```

- And using regular expressions?

```
$ echo 'I have a spoon.' | \
    sed -E 's/([a-z+)\. /super shiny silver \1!/'
I have a super shiny silver spoon!
```

- Notice that those **(parens)** are not escaped because of `-E`!

More sed

- Can specify lines to check by numbers or with regex:

```
# checks lines 1 to 20
$ sed '1,20s/john/John/g' file

# checks lines beginning with 'The'
$ sed '/^The/s/john/John/g' file
```

- The & corresponds to the pattern found:

```
# replace words with words in double quotes
$ sed 's/[a-zA-Z]\+/"&"/g' no_spoon.txt
"There" "is" "no" "spoon". ....
```

- Many more resources [available here](#).

Additional **sed** Practice

See **sed Practice** demo folder.

References

- [1] ASCII Table. *ASCII Character Codes and html, octal, hex, and decimal chart conversion*. 2010. URL: <http://www.asciitable.com/>.
- [2] Stephen McDowell, Bruno Abrahao, Hussam Abu-Libdeh, Nicolas Savva, David Slater, and others over the years. “Previous Cornell CS 2043 Course Slides”.
- [3] The Linux Documentation Project. *Globbing*. 2017. URL: <http://www.tldp.org/LDP/abs/html/globbingref.html>.
- [4] The Linux Documentation Project. *Special Characters*. 2017. URL: <http://www.tldp.org/LDP/abs/html/special-chars.html>.