Chapter 3: Searching/Substitution: regular expression

CISC3130, Spring 2013

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Outline

- Shell globbing, or pathname expansion
- Grep, egrep, fgrep
- regular expression
- sed
- cut, paste, comp, uniq, sort

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Globbing, *filename expansion*

- Globbing: shell expands filename patterns or templates containing special characters.
  - e.g., example.??? might expand to example.001 and example.txt
- Demo using echo command: echo *
  - Globbing is carried out by shell
- recognizes and expands *wild cards*.
  - *** (asterisk):** matches every filename in a given directory.
  - ?: match a single-character
  - [ab]: match a or b
  - ^ : negating the match.
- Strings containing * will not match filenames that start with a dot

Examples

$ **ls**

a.1 b.1 c.1 t2.sh test1.txt

$ **ls t?.sh**

t2.sh

$ **ls [ab]***

a.1 b.1

$ **ls [a-c]***

a.1 b.1 c.1

$ **ls [^ab]***

c.1 t2.sh test1.txt

$ **ls {b*,c*,*est*}**

b.1 c.1 test1.txt

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Filter programs

- **Filter**: program that takes input, transforms input, produces output.
  - default: input=stdin, output=stdout
  - e.g.: grep, sed, awk
- Typical use:

```
$ program pattern_action filenames
```

program scans files (if no file is specified, scan standard input), looking for lines matching pattern, performing action on matching lines, printing each transformed line.

grep/egrep/fgrep commands

- **grep** comes from **ed** (Unix text editor) search command "**g**lobal **r**egular **e**xpression **p**rint" or g/re/p
  - so useful that it was written as a standalone utility
- two other variants
  - **grep** - pattern matching using Basic Regular Expression
  - **fgrep** – file (fast, fixed-string) grep, does not use regular expressions, only matches fixed strings but can get search strings from a file
  - **egrep** - extended grep, uses a Extended Regular Expression (more powerful, but does not support backreferencing)

grep syntax

- Syntax

  grep [-hilnv] [-e expression] [filename], or

  grep [-hilnv] expression [filename]

- Options
  - **-E** **use extended regular expression (replace egrep)**
  - **-F** **match using fixed string (replace fgrep)**
  - **-h** do not display filenames
  - **-i** Ignore case
  - **-l** List only filenames containing matching lines
  - **-n** Precede each matching line with its line number
  - **-v** Negate matches
  - **-x** Match whole line only (*fgrep* only)
  - **-e** *expression* Specify expression as option
  - **-f** *filename* Take regular expression (egrep) or a list of strings (fgrep) from *filename*

A quick exercise

- How many users in storm has same first name or last name as you ?

- In which C++ source file is a certain variable used?
  - In which file is the variable defined?

- We can specify pattern in regular expression
  - How many users have no password ?
  - Extract all US telephone numbers listed in a text file?
    - 718-817-4484
    - 718,817,4484,
    - 718,8174484, ….

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- grep, egrep, fgrep
- regular expression
  - Basics: BRE and ERE
  - Common features of BRE and ERE
  - BRE backreference
  - ERE extensions
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What Is a Regular Expression?

- A **regular expression (*regex*)** describes **a set of possible input strings, i.e., a pattern**
  - e.g., ls –l | grep ^d ## list only directories
  - e.g., grep MAX_INT *.h ## where is MAX_INT defined
- Regular expressions are endemic to Unix
  - vi, ed,
  - grep, egrep, fgrep; sed
  - emacs, awk, tcl, perl, Python
  - more, less, page, pg
- Libraries for matching regular expressions: GNU C Library, and POSIX.2 interface (link)

POSIX: BRE and ERE

- Basic Regular Expression
  - Original
  - Supported by grep
- Extended Regular Expression
  - more powerful, originally supported in egrep

Table 3-8. Unix programs and their regular expression type

Type	grep	sed	ed	ex/vi	more	egrep	awk	lex
BRE	•	•	•	•	•			
ERE						•	•	•
\< \>	•	•	•	•	•			

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BRE/ERE common**metacharacters**

^ (Caret) match expression at start of a line, as in ^d.

$ (Dollar) match expression at end of a line, as in A$.

\ (Back slash) turn off special meaning of next character, as in \^.

[ ] (Brackets) match any one of the enclosed characters, as in [aeiou], use hyphen "-" for a range, as in [0-9].

[^] match any one character except those enclosed in [ ], as in [^0-9].

. (Period) match a single character of any value, except end of line.

***(Asterisk)** match zero or more of preceding character or expression.

Protect Metacharacters from Shell

- Some regex metachars have special meaning for shell: globbing and variable reference

```
$grep e*  .bash_profile  ## suppose there are files email.txt, e_trace.txt
                         # under current dir
```

Actual command executed is:

```
grep email.txt e_trace.txt .bash_profile
```

```
$grep $PATH  file        ## $PATH will be replaced by value of PATH…
```

- Solution: single quote regexs so shell won't interpret special characters

```
grep 'e*'  .bash_profile
```

  - double quotes differs from single quotes: allows for variable substitution whereas single quotes do not.

Escaping Special Characters

- \ (backslash): match special character literally, i.e., *escape* it
  - E.g., to match character sequence 'a*b*‘
  - 'a*b*' : ## match zero or more ‘a’s followed by zero or more
    ## ‘b’s, *not what we want*
  - 'a*b*' ## asterisks are treated as regular characters
- Hyphen when used as first char in pattern needs to be escaped
  - ls –l | grep '\-rwxrwxrwx'

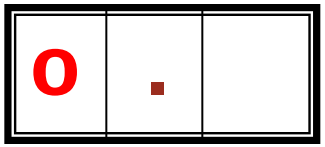
  # list all regular files that are readable, writable and executable to all
- To look for reference to shell variable PATH in a file

  grep '\$SHELL' file.txt

Regex special char: Period (.)

- Period . in regex matches any character.
  - grep 'o. ' file.txt

regular expression →



For me to poop on.

match 1 *match 2*

- How to list files with filename of 5 characters ?
  - ls | grep '..... ' ## actually list files with filename 5 or more chars long? Why?
- How to list normal files that are executable by owners?
  - ls –l | grep '\-..x '

Character Classes

- **Character classes** `[]` can be used to match any char from the specific set of characters.
  - `[aeiou]` will match any of the characters `a`, `e`, `i`, `o`, or `u`
  - `[kK]orn` will match `korn` or `Korn`
- Ranges can be specified in character classes
  - `[1-9]` is the same as `[123456789]`
  - `[abcde]` is equivalent to `[a-e]`
  - You can also combine multiple ranges
    - `[abcde123456789]` is equivalent to `[a-e1-9]`
  - Note `-` has a special meaning in a character class ***but only*** if it is used within a range,
    `[-123]` would match the characters `-`, `1`, `2`, or `3`

Character Classes (cont'd)

- Character classes can be negated with the **`[^ ]`** syntax
  - [^1-9] ##match any non-digits char
  - [^aeiou] ## match with letters other than a,e,i,o,u
- Commonly used character classes can be referred to by name (*alpha*, *lower*, *upper*, *alnum*, *digit*, *punct*, *cntrl*)
- Syntax **`[:`*name*`:]`**
  - **`[a-zA-Z]`** **`[[:alpha:]]`**
  - **`[a-zA-Z0-9]`** **`[[:alnum:]]`**
  - **`[45a-z]`** **`[45[:lower:]]`**

Anchors

- Anchors: match at beginning or end of a line (or both).
  - **^** means beginning of the line
  - **$** means end of the line
- To display all directories only

  ls –ld | grep ^d ## list all lines start with letter d
- To display all lines end with period

  grep '\.$' .bash_profile ## lines end with .

Exercise

- To display all empty lines

  grep '^$' .bash_profile ## empty lines
- How to list files with filename of 5 characters ?
  - ls | grep '^.....$ ' ## Now it's right
- Find all executable files under current directory ?

Repetition

- * match **zero or more** occurrences of *character or character class* preceding it.
  - x* ## match with zero or more x
  - grep 'x*' .bash_profile ## *display all lines, as all lines have zero or more x*
  - abc* ## *match with ab, abc, abccc, …*
  - .*x ## *matches anything up to and include last x in the line*
- Ex: How to match C/C++ one-line comments, starting from // ? (use sed to remove all comments…)

Interval Expression

- Interval expression: specify # of occurences
- BRE:
  - \{n,m\}: between n and m occurrence of previous exp
  - \{n\}: exact n occurrence of previous exp
  - \{n,\}: at least n occurrence of previous exp
- ERE:
  - **{*n*}** means exactly *n* occurrences
  - **{*n*,}** means at least *n* occurrences
  - **{*n*,*m*}** means at least *n* occurrences but no more than *m* occurrences
  - Example:
    - **.{0,}** same as **.***
    - **a{2,}** same as **aaa***
    - .{6} same as ……

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BRE: Backreferences

- **Backreferences:** refer to a match made earlier in a regex
  - E.g., to find lines starting and ending with same words
- How:
  - Use \(and \) to mark a sub-expression that we want to back reference
  - Use ***\n*** to refer to n-th marked subexpression
  - one regex can have multiple backreferences
- Ex: to search for lines that start with two same characters

```
grep '^\(.\)\1' file.txt
```

Back-references

- Recall /etc/passwd stores info. about user account

  [zhang@storm ~]$ head /etc/passwd

  root:x:0:0:root:/root:/bin/bash

  bin:x:1:1:bin:/bin:/sbin/nologin

- To find accounts whose uid is same as groupid
  - grep '^[^:]*:[^:]*:\([0-9]*\):\1' /etc/passwd
- Find five-letter long palindrome in **`wordlist`**

  grep '\(.\)\(.\).$2$1' wordlist

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ERE: Grouping, Subexpressions

- ( ) group part of an expression to a sub-expression
- Sub-expresssions are treated like a single character
  - `*` or `{ }` can be applied to them
- **`Example:`**
  - `a*` matches 0 or more occurrences of `a`
  - `abc*` matches `ab`, `abc`, `abcc`, `abccc`, …
  - `(abc)*` matches `abc`, `abcabc`, `abcabcabc`, …
  - `(abc){2,3}` matches `abcabc` or `abcabcabc`

ERE: Alternation

- Alternation character **`|`** : matching one or another sub-expression
  - **`(T|Fl)an`** will match 'Tan' or 'Flan'
  - **`^(From|Subject):`** will match lines starting with From or Subject, followed by a :
- Sub-expressions are used to limit scope of alternation
  - **`At(ten|nine)tion`** then matches "Attention" or "Atninetion"
    - not "Atten" or "ninetion" as would happen without the parenthesis - **`Atten|ninetion`**

ERE: Repetition Shorthands

- **`*`** (asterisk): (BRE and ERE) match zero or more occurrences of preceding char (or expression for ERE)
- **`+`** (plus) : one or more of preceding char/expression
  - **`abc+d`** will match 'abcd', 'abccd', or 'abcccccd' but will not match 'abd'
  - Equivalent to **`{1,}`**
- '**`?`**' (question mark): single character that immediately precedes it is optional
  - **`July?`** will match 'Jul' or 'July'
  - Equivalent to **`{0,1}`**

egrep Examples

- Find all lines with signed numbers

```
$ egrep '[-+][0-9]+\.?[0-9]*' *.c
bsearch. c: return -1;
compile. c: strchr("+1-2*3", t-> op)[1] - '0', dst,
convert. c: Print integers in a given base 2-16
(default 10)
convert. c: sscanf( argv[ i+1], "% d", &base);
strcmp. c: return -1;
strcmp. c: return +1;
```

A good help with Crossword

- How many words have 3 a's one letter apart?
  - **`egrep a.a.a`** wordlist**`| wc –l`**
    - 54
  - **`egrep u.u.u`** wordlist
    - Cumulus
- Words of 7 letters that start with g, 4th letter is a, and 7th letter is h
  - egrep 'g..a..h$' wordlist

Practical Regex Examples

- Variable names in C
  - **`[a-zA-Z_][a-zA-Z_0-9]*`**
- Dollar amount with optional cents
  - **`\$[0-9]+(\.[0-9][0-9])?`**
- Time of day
  - **`(1[012]|[1-9]):[0-5][0-9] (am|pm)`**
- HTML headers <h1> <H1> <h2> …
  - **`<[hH][1-4]>`**

Table 3-5. BRE operator precedence from highest to lowest

Operator	Meaning
`[..] [==] [::]`	Bracket symbols for character collation
`\metacharacter`	Escaped metacharacters
`[]`	Bracket expressions
`\(\)  \digit`	Subexpressions and backreferences
`*  \{\}`	Repetition of the preceding single-character regular expression
no symbol	Concatenation
`^ $`	Anchors

Table 3-6. ERE operator precedence from highest to lowest

Operator	Meaning
`[..] [==] [::]`	Bracket symbols for character collation
`\metacharacter`	Escaped metacharacters
`[ ]`	Bracket expressions
`( )`	Grouping
`* + ? { }`	Repetition of the preceding regular expression
no symbol	Concatenation
`^ $`	Anchors
`|`	Alternation

```
This is one line of text
```

input line

```
o.*o
```

regular expression

x xyz	Ordinary characters match themselves (NEWLINES and metacharacters excluded) Ordinary strings match themselves	*fgrep, grep, egrep*
\m ^ $. [xy^$x] [^xy^$z] [a-z] r* r1r2	Matches literal character *m* Start of line End of line Any single character Any of x, y, ^, $, or z Any one character other than x, y, ^, $, or z Any single character in given range zero or more occurrences of regex r Matches r1 followed by r2	*grep, egrep*
\(r\) \n \{n,m\}	Tagged regular expression, matches r Set to what matched the *n*th tagged expression (n = 1-9) Repetition	*grep*
r+ r? r1|r2 (r1|r2)r3 (r1|r2)* {n,m}	One or more occurrences of r Zero or one occurrences of r Either r1 or r2 Either r1r3 or r2r3 Zero or more occurrences of r1|r2, e.g., r1, r1r1, r2r1, r1r1r2r1,…) Repetition	*egrep*

Quick Reference

Examples

- Interesting examples of grep commands
  - To search lines that have no digit character:
    - grep -v '^[0-9]*$' filename
  - Look for users with uid=0 (root permission)
    - grep '^[^:]*:[^:]*:0:' /etc/passwd
  - To search users without passwords:
    - grep '^[^:]*::' /etc/passwd
  - To search for binary numbers
  - To search for telephone numbers
  - To match time of day, e.g., 12:14 am, 9:02pm, …

Extensions supported by GNU implementations

- Usually use \ followed by a letter
- Word matching
  - \<chop chop appears at beginning of word
  - chop\> chop appears at end of word

Table 3-7. Additional GNU regular expression operators

Operator	Meaning
`\w`	Matches any word-constituent character. Equivalent to `[[:alnum:]_]`.
`\W`	Matches any nonword-constituent character. Equivalent to `[^[:alnum:]_]`.
`\< \>`	Matches the beginning and end of a word, as described previously.
`\b`	Matches the null string found at either the beginning or the end of a word. This is a generalization of the `\<` and `\>` operators. Note: Because `awk` uses `\b` to represent the backspace character, GNU `awk` (`gawk`) uses `\y`.
`\B`	Matches the null string between two word-constituent characters.
`\' \` `	Matches the beginning and end of an `emacs` buffer, respectively. GNU programs (besides `emacs`) generally treat these as being equivalent to `^` and `$`.

Specify pattern in files

- -f option: useful for complicated patterns, also don't need to worry about shell interpretation.
- Example
  - $ cat alphvowels
    ^[^aeiou]*a[^aeiou]*e[^aeiou]*i[^aeiou]*o[^aeiou]*u[^aeiou]*$
  - $ egrep -f alphvowels /usr/share/dict/words
    abstemious … tragedious

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Introduction to sed: substitution

- **S**tream **Ed**itor: perform text substitution in batch mode
  - E.g., formatting data
  - E.g., batch modification, change variable names, function names in source code
- Replace occurrence of a pattern in standard input with a given string, and display result in standard output
  - sed s/regular_expression/replace_string/
- Substitute "command": *s*
  - changes all occurrences of a regular expression into a new string
  - to change "day" in file old to "night" in "new" file:

```
sed s/day/night/ <old >new
```

Delimiter

sed s/regular_expression/replace_string/

- One can use any letter to delimit different parts of command s
- If delimiter appears in regular expr or replace str, escape them
  - To change /usr/local/bin to /common/bin:
  - sed 's/\/usr\/local\/bin/\/common\/bin/' <old >new
- It is easier to read if you use other letter as a delimiter:
  - sed 's_/usr/local/bin_/common/bin_' <old >new
  - sed 's:/usr/local/bin:/common/bin:' <old >new
  - sed 's| /usr/local/bin| /common/bin|' <old >new

Introduction to sed: substitution

- If you have meta-characters in the command, quotes are necessary
  - sed 's/3.1415[0-9]*/PI/' <old >new
- To mark a matching pattern
  - grep –n count mylab1.cpp | sed s/count/<count>/

How sed works?

- sed, like most Unix utilties, read a line at a time
- By default, sed command applies to first occurrence of the pattern in a line.

```
[zhang@storm ~]$ sed 's/aa*/bb/'
ab ab
bbb ab
```

- To apply to every occurrence, use option g (global)
  - sed 's/aa*/bb/g
- To apply to second occurence:
  - sed 's/aa*/bb/2

aggressive matching

- sed finds longest string in line that matches pattern, and substitute it with the replacing string
- Pattern aa* matches with 1 or more a's

```
[zhang@storm ~]$ sed 's/aa*/bb/'
aaab
bbb
```

Substitution with referencing

- How to mark all numbers (integers or floating points) using angled brackets?
  - E.g., 28 replaced by <28>, 3.1415 replaced by <3.1415>
  - Use special character "&“, which refer to string that matches the pattern (similar to backreference in grep.)
  - sed 's/[0-9][0-9]*\.[0-9]*/(&)/g'
- You can have any number of "&" in replacement string.
  - You could also double a pattern, e.g. the first number of a line:

```
$echo "123 abc" | sed 's/[0-9]*/& &/'
123 123 abc
```

Multiple commands

- To combine multiple commands, use *-e* before each command:
  - sed -e 's/a/A/' -e 's/b/B/' <old >new
- If you have a large number of *sed* commands, you can put them into a file, say named as **sedscript**

  # sed comment - This script changes lower case vowels to upper case

  s/a/A/g

  s/e/E/g

  s/i/I/g

  s/o/O/g

  s/u/U/g

  each command must be on a separate line.
- Invoke sed with a script:
  - sed -f sedscript <file.txt >file_cap.txt

sed interpreter script

- Alternatively, starts script file (named CapVowel) with

```
#!/bin/sed -f
s/a/A/g
s/e/E/g
s/i/I/g
s/o/O/g
s/u/U/g
```

and make file executable

- Then you can evoke it directly:
  - CapVowel <old >new

Restrict operations

- Restrict commands to certain lines
  - Specifying a line by its number.

  sed '3 s/[0-9][0-9]*//' <file >new
  - Specifying a range of lines by number.

  sed '1,100 s/A/a/' All lines containing a pattern.
  - To delete first number on all lines that start with a "#," use:
    - sed '/^#/ s/[0-9][0-9]*//'
  - Many other ways to restrict

Command d

- Command d: deletes every line that matches patten
- To look at first 10 lines of a file, you can use:
  - sed '11,$ d' <file
  - i.e., delete from line 11 to end of file
- If you want to chop off the header of a mail message, which is everything up to the first blank line, use:
  - sed '1,/^$/ d' <file

Command q

- abort editing after some condition is reached.
- Ex: another way to duplicate the head command is:
  - sed '11 q' which quits when eleventh line is reached.

Backreference

- To keep first word of a line, and delete the rest of line, mark first word with the parenthesis:
  - sed 's/\([a-z]*\).*/\1/'
- Recall: regular expr are greedy, and try to match as much as possible.
  - "[a-z]*" matches zero or more lower case letters, and tries to be as big as possible.
  - ".*" matches zero or more characters after the first match. Since the first one grabs all of the lower case letters, the second matches anything else.
  - Ex:

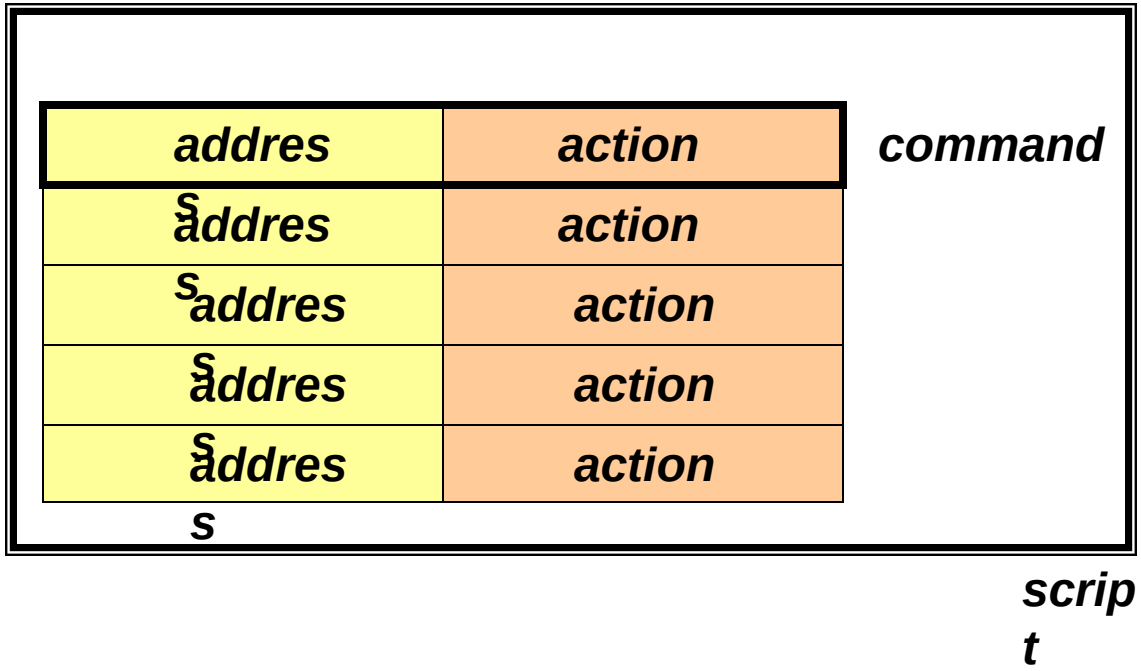
```
$echo abcd123 | sed 's/\([a-z]*\).*/\1/'
abcd
```

Backreference (cont'd)

- If you want to switch two words around, you can remember two patterns and change the order around:
  - sed 's/\([a-z][a-z]*\) \([a-z][a-z]*\)/\2 \1/'
- To eliminate duplicated words:
  - sed 's/\([a-z]*\) \1/\1/'
- If you want to detect duplicated words, you can use
  - sed -n '/\([a-z][a-z]*\) \1/p'
- Up to nine backreference: 1 thru 9
  - To reverse first three characters on a line, you can use
  - sed 's/^\(.\)\(.\)\(.\)/\3\2\1/'

Sed commands & scripts

- Each sed command consists of up to two *addresses* and an *action*, where the *address* can be a regular expression or line number.
- A script is nothing more than a file of commands



sed: a conceptual overview

- All editing commands in a **sed** script are applied in order to each input line.
- If a command changes input, subsequent command address will be applied to current (modified) line in the pattern space, not original input line.
- Original input file is unchanged (sed is a filter), and the results are sent to standard output (but can be redirected to a file).

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Store Info in text file

- Convention: one record per line, separate different fields using a delimiter (space, tab, or other characters)
  - Ex. /etc/passwd,
    - Each user's record takes a line
    - Fields (Userid, numeric id, user name, home directory) by ;
  - Output generated by ls, ps, …
- Recall a design philosophy of Unix is use textual file, and providing a rich small filters working on such files …

Command cut

- **cut:** displays selected columns or fields from each line of a file
  - Delimit-based cut
    - cutting one of several columns from a file (often a log file) :

    cut -d ' ' -f 2-7

    - Retrieves second to seventh field assuming that each field is separated by a single space
    - Fields are numbered starting from one.
  - Character column cut

    cut -c 4,5,20 foo **# cuts foo at columns 4, 5, and 20.**
  - How to choose file name and size from "ls –l" output?

Command paste

- **paste**: merging two files together, line by line
  - E.g., Suppose population.txt stores world population info, GDP.txt stores GDP,

Population.txt	GDP
Country population	Country GDP
…	…

```
paste f1 f2 > pop_GDP
```

  - Need to make sure info for same country are merged:
    - Sort files using country name first (if same set of countries are listed in both files, this solves problem)

Command join

- join: for each pair of input lines with identical join fields, write a line to standard output.

join [OPTION]… FILE1 FILE2

-e EMPTY replace missing input fields with EMPTY

-i, --ignore-case ignore differences in case when comparing fields

-j FIELD equivalent to `-1 FIELD -2 FIELD‘

-1 FIELD join on this FIELD of file 1

-2 FIELD join on this FIELD of file 2

Command tr

- tr - Translate, squeeze, and/or delete characters from standard input, writing to standard output.
  - cat file | tr [a-z] [A-Z] ## translate all capital letter to lower case
  - cat file | tr -sc A-Za-z '\n'

    ## replace all non-letter characters with newline

    ## -c: complement

    ## -s: squeeze

Command tr and uniq

- **uniq**: report or omit repeated lines
  - -c: precede each unique line with the number of occurrences

wf (word frequency)

Ex: Get a letter frequency count on a set of files given on command line. (No file names means that std input is used.)

```
#!/bin/bash
cat $* |
tr -sc A-Za-z '\012' |
tr A-Z a-z|
sort |
uniq -c |
sort -nr -k 1
```

Uncomment the last two lines to get letters (and counts) from most frequent to last frequent, rather than alphabetical.

What is being generated at second command ?

* Command tee can be inserted into pipeline, to save the streams of input/output into a file.

Command tee

- tee – copy standard input to standard output and file

  tee [OPTION]… [FILE]…
- Option:

  -a, --append

  append to given FILEs, do not overwrite
- Useful for insert into pipes for testing, and for storing intermediate results
  - ls –l | wc –l
  - To save output of ls –l
    - ls –l | tee lsoutput.txt | wc –l

Capture intermediate result in file

```
#!/bin/bash
cat $* |
tr -sc A-Za-z '\012' |
tr A-Z a-z|
sort | tee aftersort |
uniq -c |
sort -nr -k 1
```

For example: add the parts in red to store output of sort command to aftersort, and feed them to next command in the pipeline (uniq)…

Usage of tee

- In shell script, sometimes you might need to process standard input for multiple times: count number of lines, search for some pattern:

```
#!/bin/bash
# usage: tee_ex pattern
echo Number of lines `wc –l`
echo Searching for $1
grep $1
```

- Problems: standard input to the script (might be redirected from file/pipe) will be processed by wc (the first command in scripts that reads standard input). Subsequence command (grep here) does not get it ☹

tee to rescue

```
#!/bin/bash
# Usage: tee_ex pattern
echo Number of lines `tee tmp | wc –l`
echo Searching for $1
grep $1 tmp
rm tmp
```

Use tee to save a copy of standard input to file tmp, while at the same time copy standard input to standard output, i.e., fed into pipe to wc

Another solution

```
#!/bin/bash
# Usage: tee_ex pattern
# save standard input to file for later processing
cat > tmpfile

echo Number of lines `wc –l tmpfile`
echo Searching for $1
grep $1 tmpfile
rm tmpfile ## always clean up temporary file created …
```

Summary

- Regular expression and Finite state automata
- Single quote search patterns so that shell do not interpret characters that have special meaning to him:
  - *, ., $, ?, …
  - Be sure to distinguish regex and shell globbing
- We look at grep regex, egrep regex
  - egrep regex is generally a superset of grep regex, except back reference
- Some other useful filter commands