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Tutorial: „Bashing“ the Killer from the Command Line

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A short Resume of the Presenters

Prof. Dr. **Andreas Schmidt** is a professor at the Department of Computer Science and Business Information Systems of the Karlsruhe University of Applied Sciences (Germany). He is lecturing in the fields of database information systems, data analytics and model-driven software development. Additionally, he is a senior research fellow in computer science at the Institute for Applied Computer Science of the Karlsruhe Institute of Technology (KIT). His research focuses on database technology, knowledge extraction from unstructured data/ text, Big Data, and generative programming. Andreas Schmidt was awarded his diploma in computer science by the University of Karlsruhe in 1995 and his PhD in mechanical engineering in 2000. Dr. Schmidt has numerous publications in the field of database technology and information extraction. He regularly gives tutorials on international conferences in the field of Big Data related topics and model driven software development. Prof. Schmidt followed sabbatical invitations from renowned institutions like the Systems-Group at ETH-Zurich in Switzerland, the Database Group at the Max-Planck-Institute for Informatics in Saarbrukken/Germany and the Data-Management-Lab at the University of Darmstadt.

Dr. **Lisa Ehrlinger** is senior researcher at the Johannes Kepler University (JKU) Linz and at the Software Competence Center Hagenberg (SCCH) in Austria. At JKU, she conducts research about the automation of DQ measurement and knowledge graphs and teaches courses about information systems, ontologies, and data modeling. At SCCH, she leads the multi-firm project SEBISTA (Secure Big Stream Data Processing), where she applies finding from her scientific work, and drives the research focus “Data Management and Data Quality”. Her research interests and publications cover the topics data quality, knowledge graphs, and information integration.

A short Resume of the Presenters

Prof. Dr. **Fritz Laux** was professor (now emeritus) for Database and Information Systems at Reutlingen University from 1986 - 2015. He holds an MSc (Diplom) and PhD (Dr.rer. nat.) in Mathematics.

His research focuses on database modeling and technology, transaction processing, data warehousing and data analytics. He has published a number of of papers in peer reviewed conferences and journals on the above topics, some of them have received Best Paper Awards. He is a regular contributor and speaker at DBKDA.

Prof. Laux is a co-founder of DBTechNetDB, an initiative of European universities and and IT-companies to set up a transnational collaboration scheme of higher level education in Databases. Together with colleagues from 5 European countries he was conducting projects supported by the European Union on state-of-the teaching and hands-on labs on database technology.

Prof. Laux received the 2012 Research Award from Reutlingen University and he is an IARIA fellow.

Resources available

https://www.smiffy.de/dbkda-2021/ [1]

- Slideset
- Exercises
- Command refcard
- Example datasets

[1] all materials copyright 2017, 2018, 2019,2020, 2021 by andreas schmidt

Outlook

- Introduction
- Functionality Overview
- Filter & Pipes Architecure
- Command Overview Part I
- Exercise I: Start solving a criminal case using the shell
- Command overview Part II
- Exercise II: Solve the criminal case from Exercise I
- sed & awk
- Summary & Outlook

Why Should I use these Tools (Coreutils)?

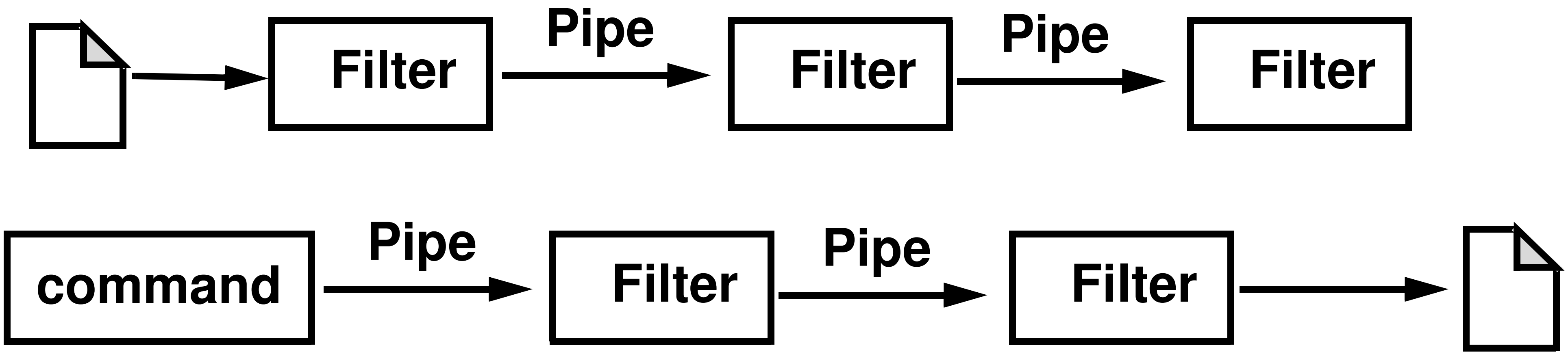
With R and Python, there exist great tools that can perform the same job (and much more)

- It’s already on your computer and nothing needs to be installed[1]
- You don’t need to learn a programming language
- You don’t need an editor, compiler or interpreter
- Low main memory footprint
- You got first results after 20 sec.
- Intuitive iterative development cycle (add filter by filter) ... like lego blocks
- It makes fun !!!!

[1] ıf you have a Linux or Mac-computer. Windows users have to install cygwin to use theese tools.

Filter and Pipes Architecture

- Architectural Pattern: Filter and Pipes (Douglas McIlroy, 1973)
- Data exchange between processes
- Loose coupling
- POSIX Standard
- Filter represent data-sources and data-sinks

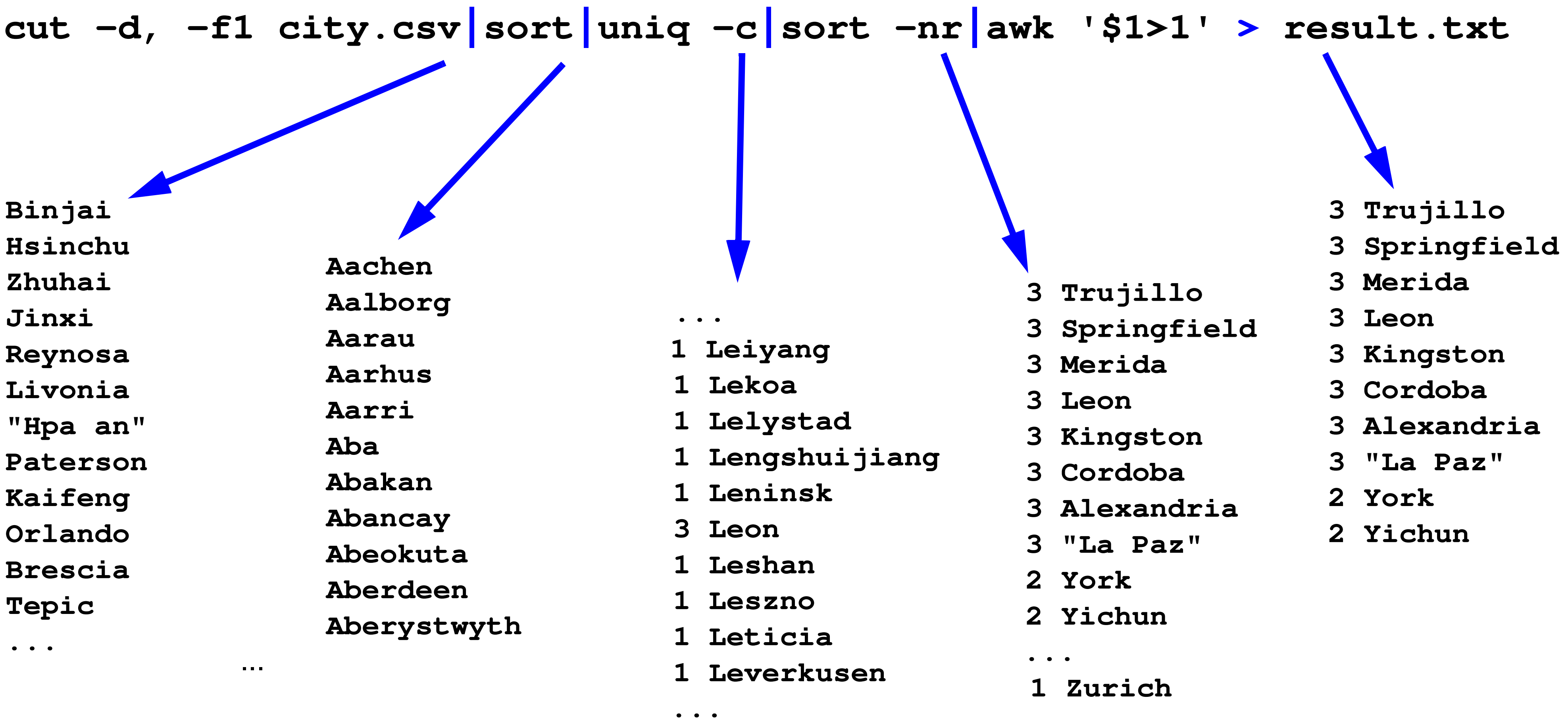


Communication Channels/Redirection

- In-/Output Redirection
  - | : Pipe operator: Connect STDOUT of a command with STDIN of the next command
  - > : Redirect Standard Output (into file)
  - < : Redirect Standard Input (from file)
  - 2> : Redirect Standard Error (into file)
  - >> : Redirect Standard Output (append into file)
- Example:

```
cut -d, -f1 city.csv | sort | uniq -c | \
    sort -nr | awk  '$1>1' > result.txt
```

Retrieving the names of cities which have „name siblings“



```
cut -d, -f1 city.csv|sort|uniq -c|sort -nr|awk '$1>1' > result.txt
```

```
Binjai
Hsinchu
Zhuhai
Jinxi
Reynosa
Livonia
"Hpa an"
Paterson
Kaifeng
Orlando
Brescia
Tepic
...
```

...

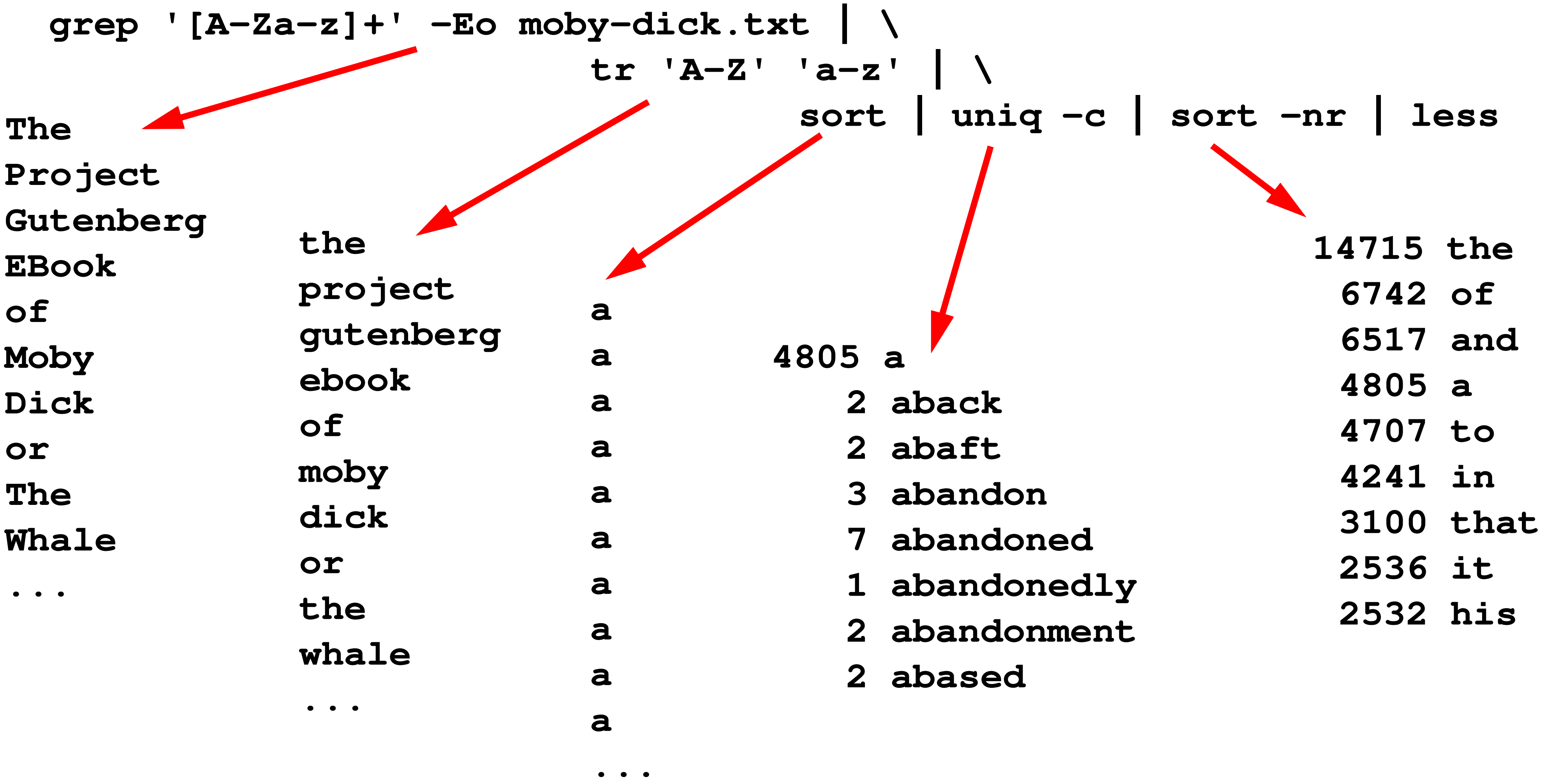
```
Aachen
Aalborg
Aarau
Aarhus
Aarri
Aba
Abakan
Abancay
Abeokuta
Aberdeen
Aberystwyth
```

```
...
1 Leiyang
1 Lekoa
1 Lelystad
1 Lengshuijiang
1 Leninsk
3 Leon
1 Leshan
1 Leszno
1 Leticia
1 Leverkusen
...
```

```
3 Trujillo
3 Springfield
3 Merida
3 Leon
3 Kingston
3 Cordoba
3 Alexandria
3 "La Paz"
2 York
2 Yichun
...
1 Zurich
```

```
3 Trujillo
3 Springfield
3 Merida
3 Leon
3 Kingston
3 Cordoba
3 Alexandria
3 "La Paz"
2 York
2 Yichun
```

Another example: Word count



```
grep '[A-Za-z]+' -Eo moby-dick.txt | \
                    tr 'A-Z' 'a-z' | \
                            sort | uniq -c | sort -nr | less
```

```
The
Project
Gutenberg
EBook
of
Moby
Dick
or
The
Whale
...
```

```
the
project
gutenberg
ebook
of
moby
dick
or
the
whale
...
```

```
a
a
a
a
a
a
a
a
a
a
...
```

```
4805 a
   2 aback
   2 abaft
   3 abandon
   7 abandoned
   1 abandonedly
   2 abandonment
   2 abased
```

```
14715 the
 6742 of
 6517 and
 4805 a
 4707 to
 4241 in
 3100 that
 2536 it
 2532 his
```

General comment

- Most of the commands accept the input from file or from STDIN. If no (or not enough) input files are given, it is expected that the input comes from STDIN (some commands like *join*, *comm* expect a „-“ character as parameter, if the input comes from STDIN)

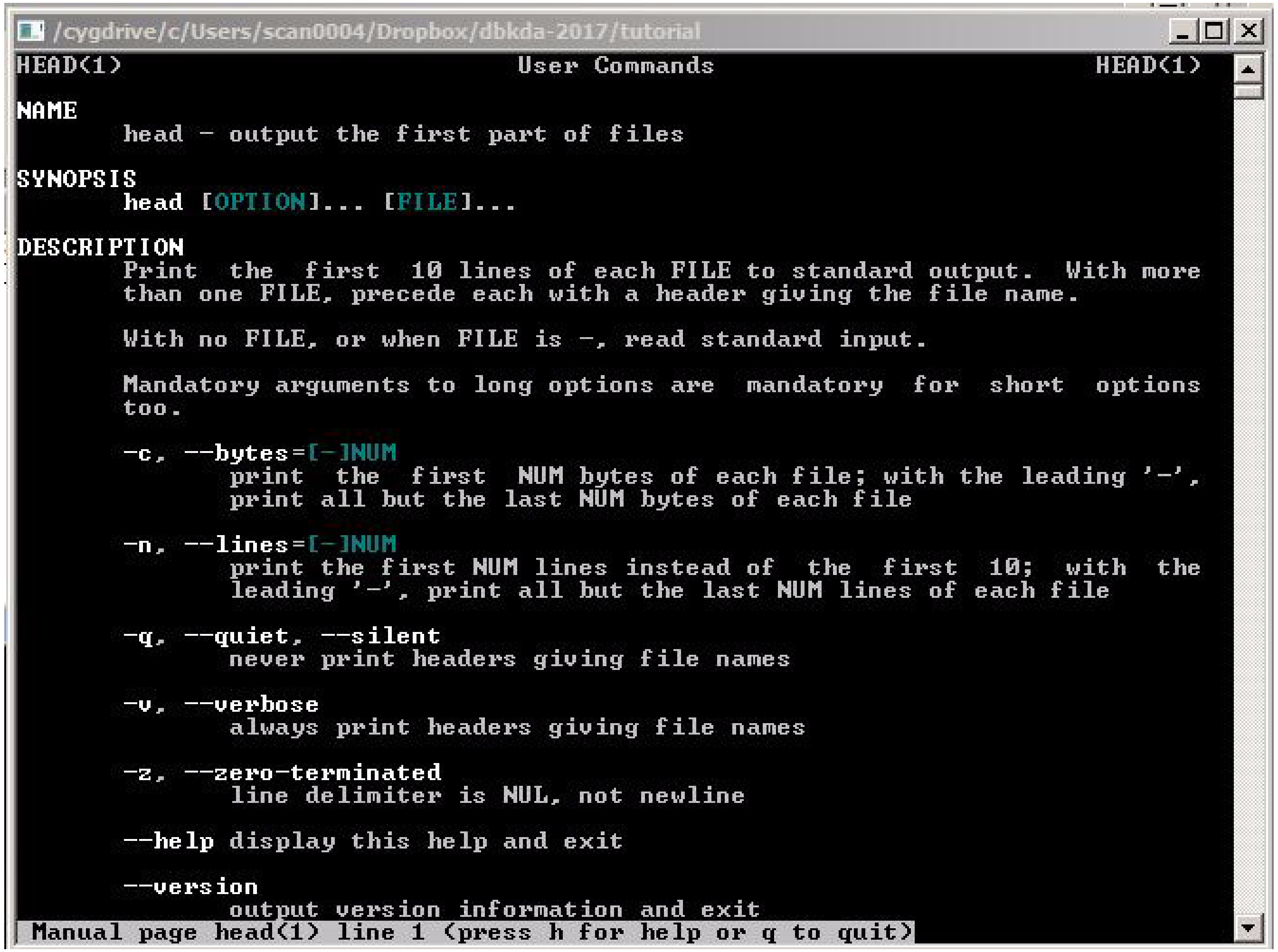
```
head -n4 my-file.txt
cat -n my-file.txt | head -n4
```

- Most of the commands have a lot of options which can’t be explained in detail. To get an overview of the possibilities of a command, simple type

```
man command
```

- Example:

```
man head
```



```
HEAD(1)                          User Commands                         HEAD(1)

NAME
       head - output the first part of files

SYNOPSIS
       head [OPTION]... [FILE]...

DESCRIPTION
       Print  the  first  10 lines of each FILE to standard output.  With more
       than one FILE, precede each with a header giving the file name.

       With no FILE, or when FILE is -, read standard input.

       Mandatory arguments to long options are  mandatory  for  short  options
       too.

       -c, --bytes=[-]NUM
              print  the  first  NUM bytes of each file; with the leading '-',
              print all but the last NUM bytes of each file

       -n, --lines=[-]NUM
              print the first NUM lines instead of  the  first  10;  with  the
              leading '-', print all but the last NUM lines of each file

       -q, --quiet, --silent
              never print headers giving file names

       -v, --verbose
              always print headers giving file names

       -z, --zero-terminated
              line delimiter is NUL, not newline

       --help display this help and exit

       --version
              output version information and exit
 Manual page head(1) line 1 (press h for help or q to quit)
```

cat command

- Print content of file to STDOUT

```
cat HelloWorld.java
```

- Concatenate files and writes them via redirection (>) to a file

```
cat german_cities.csv french_cities.csv > cities.csv
cat *_cities.csv > cities.csv
```

- Add line numbers to each line in file(s)

```
cat -n city.csv
```

- Create a file with input from STDIN:

```
cat > grep-search-words.txt
Obama
Climate
CTRL-D
```

- More example:
  www.smiffy.de/dbkda-2021/command-examples/cat,%20head,%20tail,%20less,%20wc

head/tail/wc command

- **head: view first *n* lines or skip last *n* lines of a file.**
  - View first 5 lines from file:

    ```
    head -n5 city.csv
    ```

  - Print all but the last 20 lines:

    ```
    head -n -20 city.csv
    ```

    to remove trailing line(s)

- **tail: view last *n* lines or start from line *n***
  - View last 10 lines of a file

    ```
    tail -n 10 city.csv
    ```

- **wc:** Count the number of lines, words[1] and bytes

  ```
  wc city.csv
  ```

[1] from the manual page: `A word is a non-zero-length sequence of characters delimited by white space.`

less command

- Page by page scrolling of a file or STDIN (also with search capability)
- Examples:

```
less city.csv
ls -l | less

man head       # inspection of man-pages with less !!
```

- Commands:
  - q : quit less
  - > : Goto end of file
  - < : Goto begin of file
  - f: Scroll forward one page
  - b: scroll backwards on page
  - *e, ret*,↓ : scroll forward one line
  - y,↑: scroll backwards one line
  - *n*d : scroll forward *n* lines (i.e. 20n)
  - *m*b : scroll backwards *m* lines
  - *n*g: Goto line <n>

less commands (2)

- /*pattern* : Search forward the next line with *pattern*
- ?*pattern* : Search backward the previous line with *pattern*
- n : repeat previous search
- N : repeat previous search in reverse direction
- &*pattern* : Display only lines containing the *pattern* (type &*<ret>* to quit)
- !*command* : executes shell command
- v : invokes standard editor for file (at current position, if supported)

type **`man less`** for complete reference

grep command

- Print lines matching pattern (case sensitive)

```
grep USA city.csv
```

- Print lines containing the regular expression (City starting with ’S’, ending with ’g’)

```
grep -E 'S[a-z]+g,' city.csv
```

- Print only lines, not containing the String NULL

```
grep -v NULL city.csv
```

- Print name of files which contain the pattern ’Agassi’

```
grep Agassi bbcsport/tennis/*.txt
```

**when multiple files are queried,
the filename is part of the
result (<filename>:<line matching pattern)>**

Search

- Print only matching part (i.e. ’Salzburg’ instead of whole line)

```
grep -E -o 'S[a-z]+g' city.csv
```

- Look for lines containing words from a file
- `grep -f grep-search-words.txt -E newsCorpora.csv`

  - file: grep-search-words.txt

```
Obama
Climate
```

More example:

```
https://www.smiffy.de/dbkda-2021/command-examples/grep
```

File operations

- Split file by number of rows (here, after each 10 lines, all generated files have the prefix *tmp/city-part-*)

```
csplit -k -f tmp/city-part- city.csv 10 {*}
```

prefix of generated files

number of lines per split

# repetitions

- Split file at every empty line (all generated files have the prefix *tmp/person*)

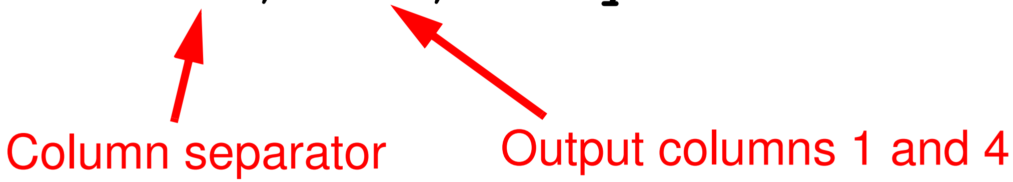
```
csplit -f tmp/person address-book.txt '/^ *$/' {*}
```

split pattern

File operations

- Print selected parts of lines from each file to standard output.

```
cut -d',' -f1,4 city.csv
```



Column separator

Output columns 1 and 4

- Output bytes 10 to 20 from each line

```
cut -b10-20 data.fixed
```

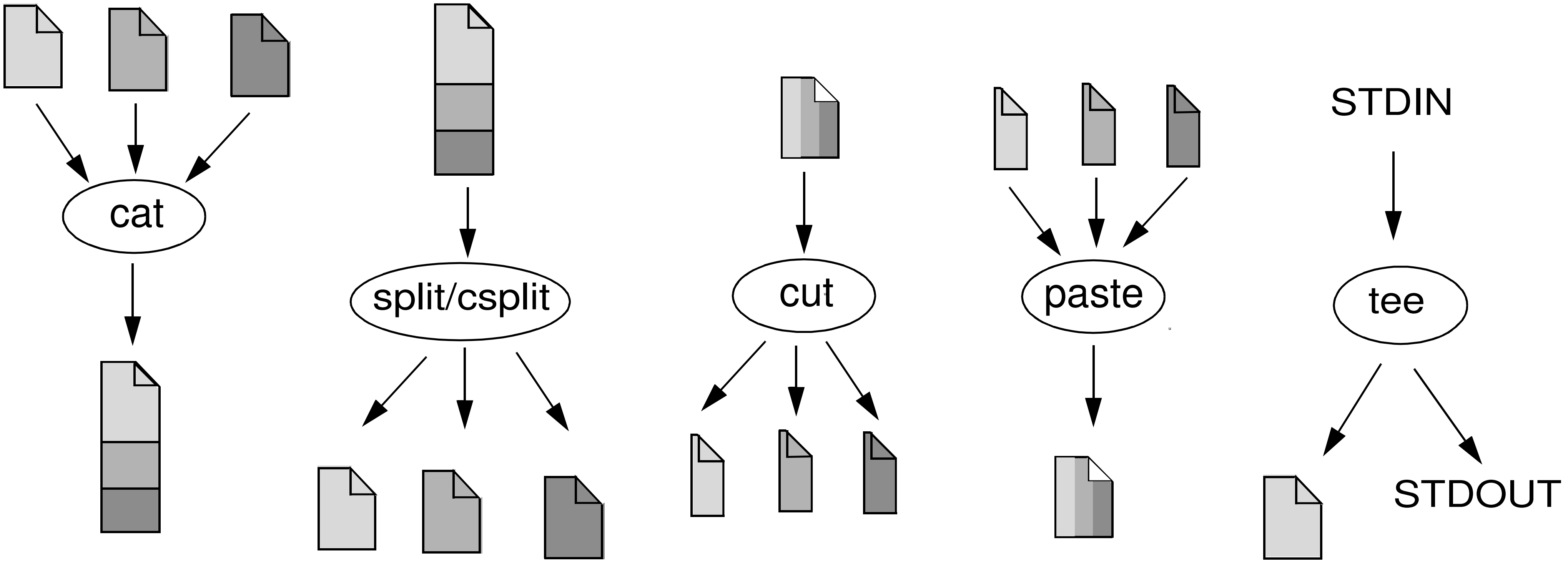
- Output bytes 1-5 and starting from position 21 to the end of line:

```
cut -b1-5,20- data.fixed
```

- More examples:

```
https://www.smiffy.de/dbkda-2021-ce/cut,%20paste
```

Summary of Fundamental File Operations



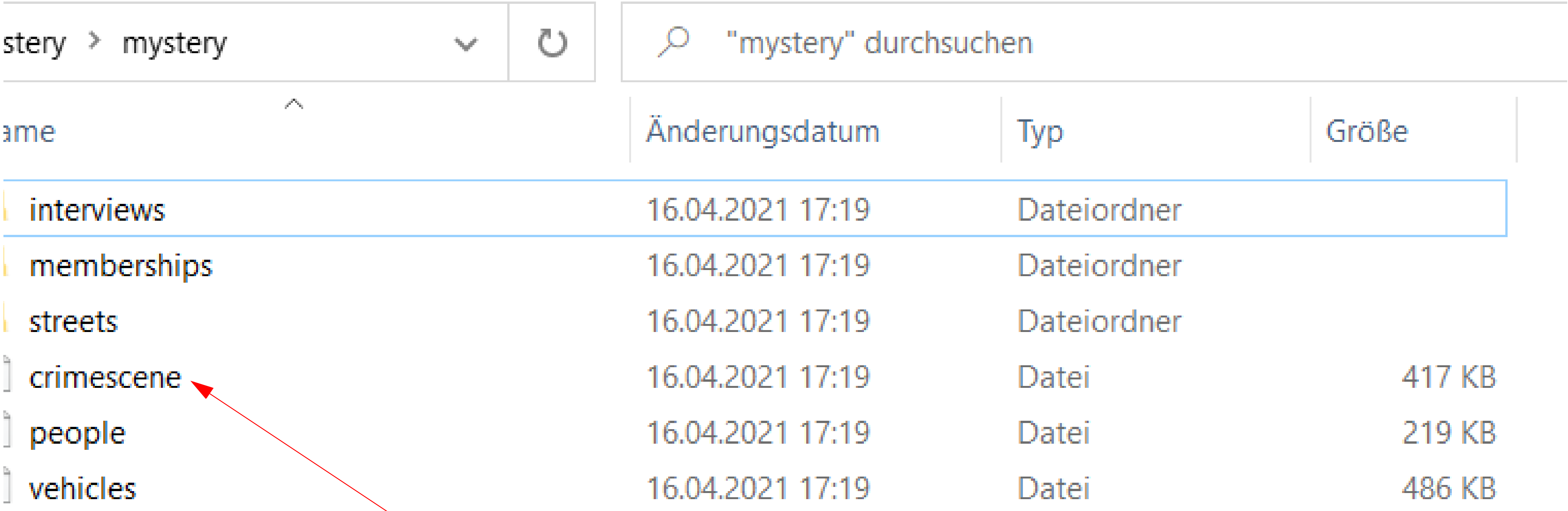
And now you are prepared for a ...

*thrilling exercise** *!!!!!!*

Go to the page www.smiffy.de/dbkda-2021, open Exercise I and start solving the criminal case ...

(*) command line murders by Noah Veltman,
https://github.com/veltman/clmystery

mystery File/Directory Structure



ame	Änderungsdatum	Typ	Größe
interviews	16.04.2021 17:19	Dateiordner	
memberships	16.04.2021 17:19	Dateiordner	
streets	16.04.2021 17:19	Dateiordner	
crimescene	16.04.2021 17:19	Datei	417 KB
people	16.04.2021 17:19	Datei	219 KB
vehicles	16.04.2021 17:19	Datei	486 KB

starting point

- mystery/people$

```
head mystery/people
***************
To go to the street someone lives on, use the file
for that street name in the 'streets' subdirectory.
To knock on their door and investigate, read the line number
they live on from the file.  If a line looks like gibberish, you're at the wrong
house.
***************

NAME       GENDER   AGE       ADDRESS
Alicia Fuentes   F         48       Walton Street, line 433
Jo-Ting Losev    F         46       Hemenway Street, line 390
...
Annabel Fuglsang M        40      Haley Street, line 176
Diego Michan      M        74      Wyola Place, line 25
```

File mystery/streets/Haley_Street, lines 174 - 179

```
 ...
 pinto simile fuzing pestering neutralized atriums
nted
 irradiates liquidates flimflams dispossessed
 SEE INTERVIEW #871877
 balmy metamorphosis nervier pilfered
 proofreaders steeping editorialized solutions
```

- Interviews:

```
$ ls mystery/interviews/interview-*| head -n5
mystery/interviews/interview-000296
mystery/interviews/interview-00448418
...
mystery/interviews/interview-871877
```

```
$ cat mystery/interviews/interview-871877
Mr. Fuglsang is male and has brown hair ...
```

sort

- Sort lines of text files
- Write sorted concatenation of all FILE(s) to standard output.
- With no FILE, or when FILE is -, read standard input.
- sorting alpabetic, numeric, ascending, descending, case (in)sensitive
- column(s)/bytes to be sorted can be specified
- Random sort option (-R)
- Remove of identical lines (-u)
- Examples:
  - sort the entries in file

    ```
    sort member-list.txt
    ```
  - sort the entries in file (Format: <fist-name> <last-name>) by second column

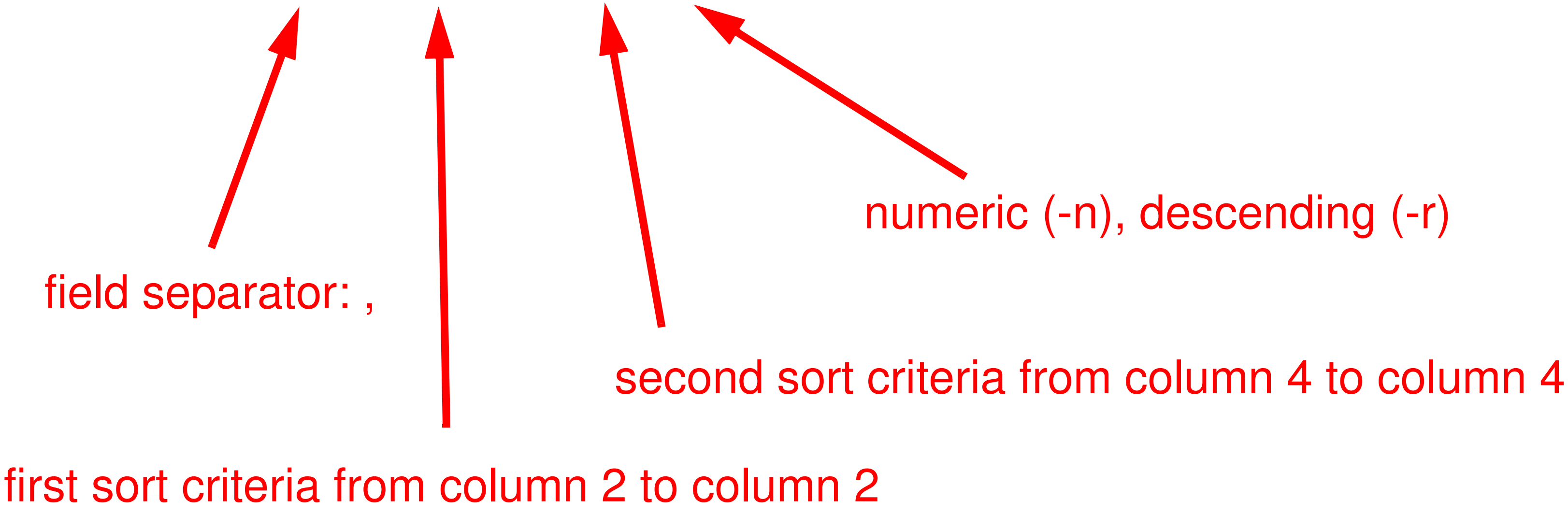
    ```
    sort -t' ' -k2 member-list.txt
    ```

Column separator

sort - examples

- sort file by country code, and as a second criteria population (numeric, descending)

```
sort -t, -k2,2 -k4,4nr  city.csv
```



numeric (-n), descending (-r)

field separator: ,

second sort criteria from column 4 to column 4

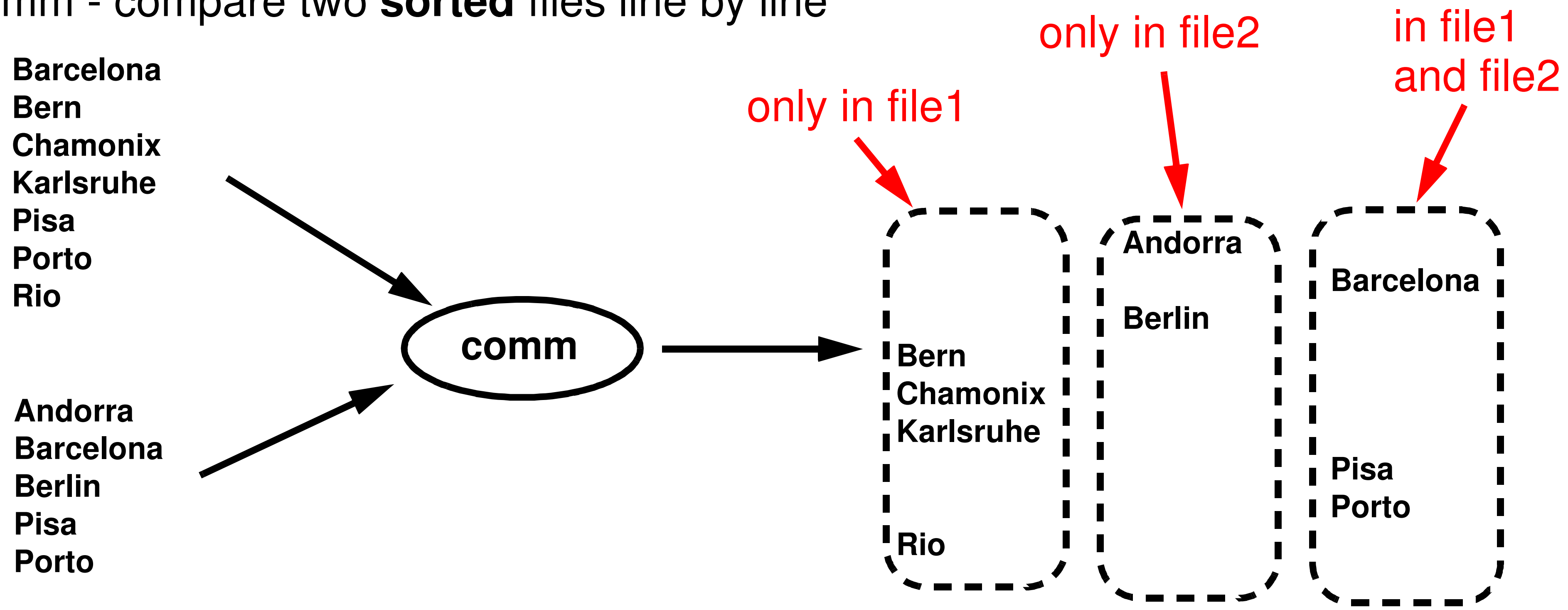
first sort criteria from column 2 to column 2

- More example:

```
https://www.smiffy.de/dbkda-2021/command-examples/sort
```

Compare Operator

- comm - compare two **sorted** files line by line



Barcelona
Bern
Chamonix
Karlsruhe
Pisa
Porto
Rio

Andorra
Barcelona
Berlin
Pisa
Porto

comm

only in file1

Bern
Chamonix
Karlsruhe
Rio

only in file2

Andorra
Berlin

in file1
and file2

Barcelona
Pisa
Porto

- Options:
  - -1: supress column 1
  - -2: supress column 2
  - -3: supress column 3
  - --total: output a summary

set semantic with sorted input !!!

uniq

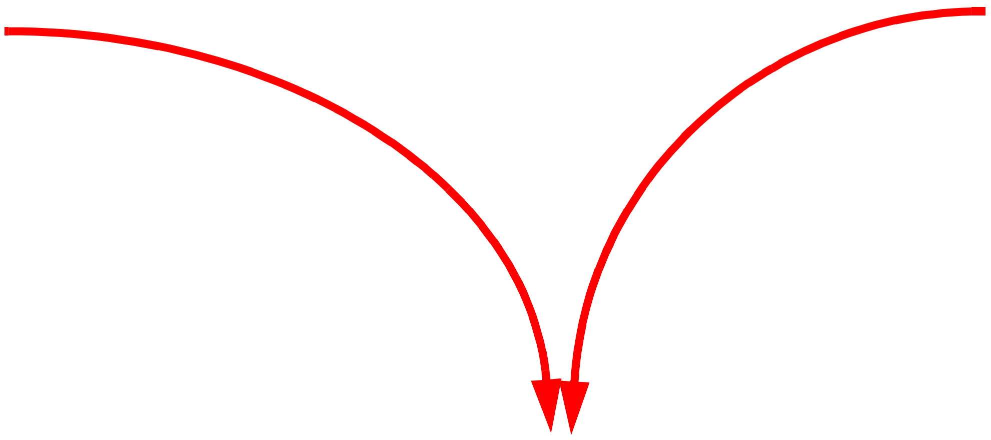
- report or omit **repeated** lines
- Filter adjacent matching lines from INPUT
- Range of comparision can be specified (first n chars, skip first m chars)
- options:
  - -c: count number of occurences
  - -d: only print duplicate lines
  - -u: only print unique line
  - -i: ignore case

set semantic with sorted input !!!

uniq - Example

- file1.txt

```
Barcelona
Bern
Chamonix
Karlsruhe
Pisa
Porto
Rio
```



- file2.txt

```
Andorra
Barcelona
Berlin
Pisa
Porto
```

More example:

`https://www.smiffy.de/dbkda-2021/command-examples/comm,%20uniq`

Exercise Part II and III

continue solving the case from the first exercise (Exercise II) ...

... still thrilling ;-)

... and with your actual knowledge, you can also try Exercise III ...

sed Principles

- sed - Stream Editor
- non interactiv, controlled by a script
- line oriented text processing
- A loop executes script commands on each matching (by address) input line
- short scripts are typically given as parameter, longer scripts as files (-f option)
- Possible operations: Insert, Substitude, Delete, Append, Change, Print, Delete
- Commands in script can take an optional *address*, specifying the line(s) to be performed.
- *Address* can be a a single line number or a regular expression
- *Address* can be an interval (start, stop)
- Default behavior: printing each processed line to stdout (suppress with: -n)

sed commands

s: substitude

- Replace all occurences of D with GER

```
sed 's/\bD\b/GER/g' city.csv > city2.csv
```

- Replace all occurences of NULL in a line with \N (Inplace Substitution)

```
sed -i 's/\bNULL\b/\\N/g' city.cs
```

- Replace „Stuttgart“ with „Stuttgart am Neckar“ (extended regexp)

```
sed -E '/^Stuttgart/ s/^([^,]+)/\1 am Neckar/' city.csv
```

p: print (typically used with default printing behaviour off (-n option))

- print from line 10 to 20 (resp.: 5-10, 23, 56-71)

```
sed -n 10,20p city.csv
sed -n '5,10p;23p;56,71p' city.csv
```

sed Examples

i: insert

- Insert dataset about Karlsruhe at line 2

```
sed '2i Karlsruhe,D,"Baden Wuerttemberg",312005,49.0,6.8' city.csv
```

d: delete

- delete the city Aachen (inplace)

```
sed -i '/^Aachen/ d' city.csv
```

- delete all empty lines

```
sed '/^ *$/d' The-Adventures-of-Tom-Sawyer.txt
```

- delete lines 2-10

```
sed '2,10d' city.csv
```

sed Examples

c: change

- Replace entry of Biel

```
sed '/^Biel,/ c Biel,CH,BE,53308,47.8,7.14' city.csv
```

a: append

- Underline each CHAPTER

```
sed '/^CHAPTER/ a ------------' The-Adventures-of-Tom-Sawyer.txt
```

r: read file

- insert the content from file city-D.csv starting at line 3

```
sed '3 r city-D.csv' city.csv'
```

awk

- like sed, but with powerful programming language
- filter and report writer
- flexible record definition (i.e. line with columns, record with fields, ...)
- full programming language, support for associative arrays
- structure: one or multiple *pattern* { *action* } blocks
- special BEGIN, END pattern match **before** the first record is read and **after** the last record is read
- Access to column values via $1, $2, ... variables ($0: whole record)
- Examples:

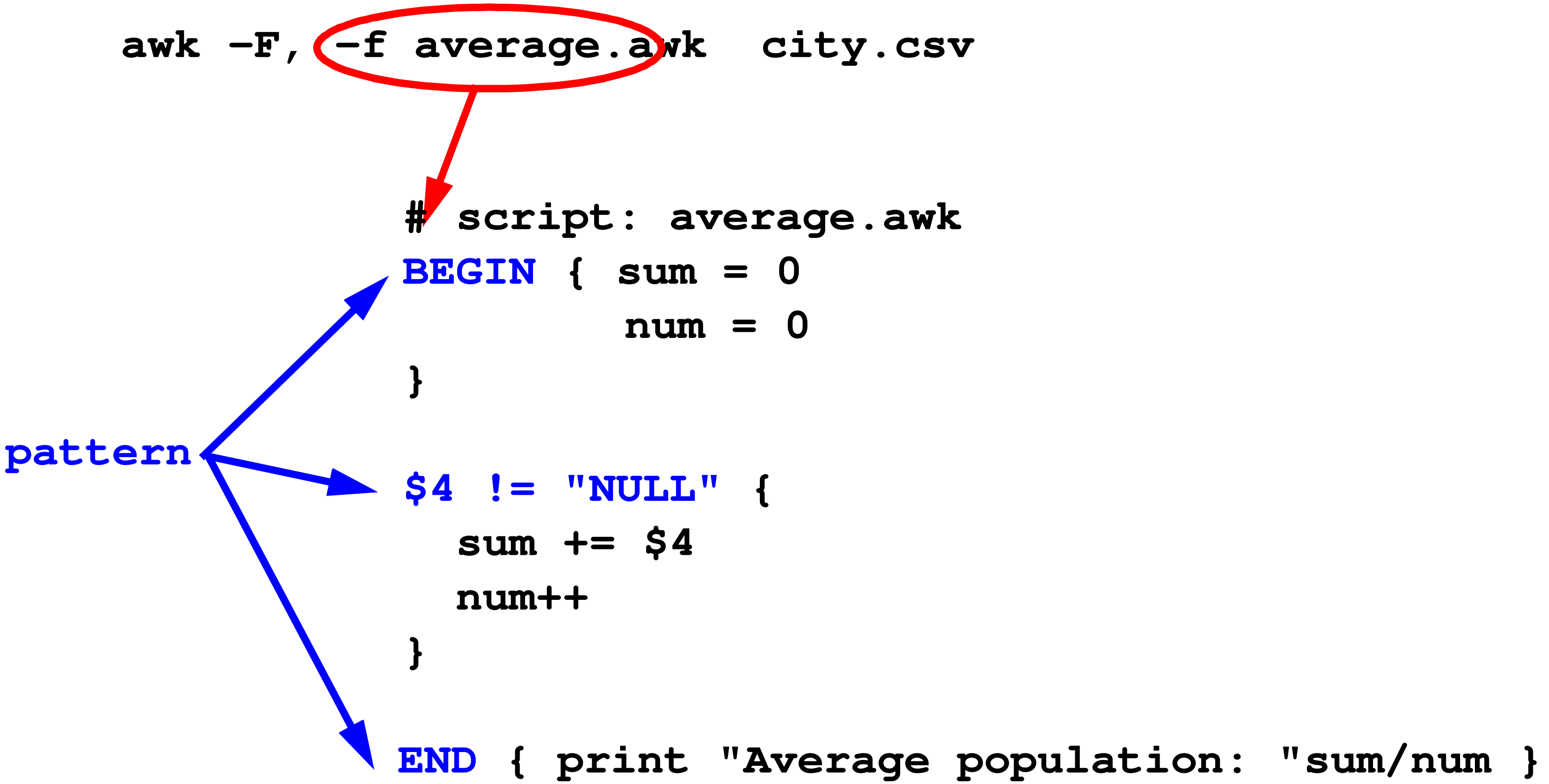
```
awk -F, '$3=="Bayern" && $4 < 1000000 { print $1, $4 }' city.csv
```

action

pattern

awk

- Calculating average population



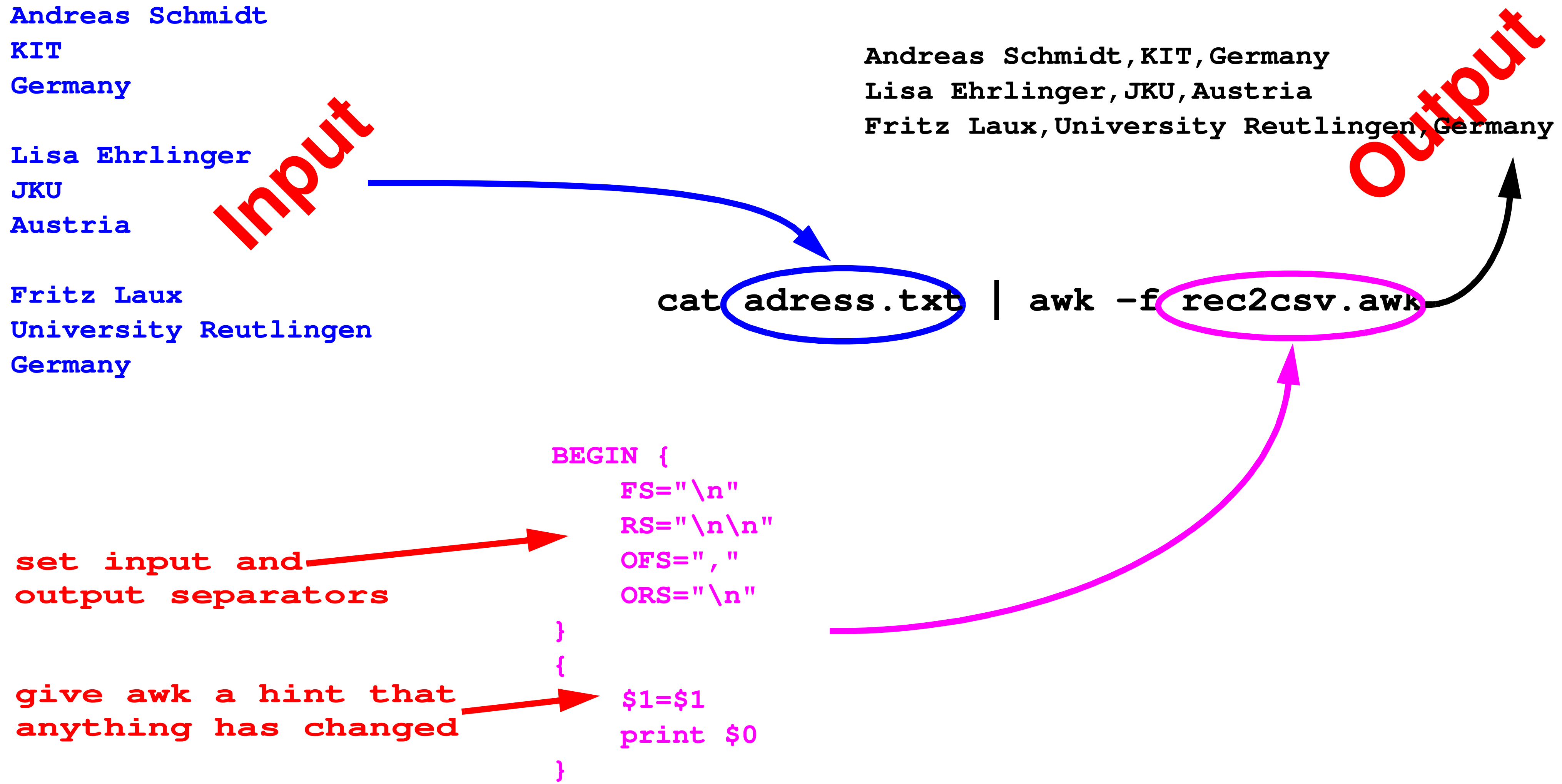
```
awk -F, -f average.awk  city.csv
```

```
# script: average.awk
BEGIN { sum = 0
        num = 0
}

$4 != "NULL" {
  sum += $4
  num++
}

END { print "Average population: "sum/num }
```

awk

- predefined variables
  - NF: number of fields
  - NR: number of records
  - FS: field separator (default: " ", same as -F from command line)
  - RS: record separator (default: \n)
  - ORS: output record separator
  - OFS: output field separator
  - FPAT: Field pattern (alternative way to specify a field instead of use of FS)
  - FILENAME: contains the file that is actually read

awk Example: Multi-Line Records



```
Andreas Schmidt
KIT
Germany

Lisa Ehrlinger
JKU
Austria

Fritz Laux
University Reutlingen
Germany
```

Input

```
cat adress.txt | awk -f rec2csv.awk
```

Output

```
Andreas Schmidt,KIT,Germany
Lisa Ehrlinger,JKU,Austria
Fritz Laux,University Reutlingen,Germany
```

```
BEGIN {
    FS="\n"
    RS="\n\n"
    OFS=","
    ORS="\n"
}
{
    $1=$1
    print $0
}
```

set input and output separators

give awk a hint that anything has changed

And again its time for crime* ...

As homework: You have solved the case, but there is room for improvement for future cases. So continue with Exercise IV ...

(*) command line murders by Noah Veltman,
https://github.com/veltman/clmystery

Commands not Covered (not complete)

- **xargs:** build and execute command lines from standard input

```
grep -l Agassi bbcsport/tennis/*.txt | xargs grep -l Federer
```

- **tr:** translate, squeeze, and/or delete characters from standard input, writing to standard output.

```
tr 'A-Z' 'a-z' < moby-dick.txt
```

- **paste:** merge lines of files

```
paste -d',' col1.txt col2.txt col3.txt > col_1-3.txt
```

- **find:** search for files in a directory hierarchy

```
find ./misc -name \*.txt -print
```

- **join:** join lines of two files on a common field

join Example

city.csv

```
Aachen,D,"Nordrhein Westfalen",247113,NULL,NULL
Aalborg,DK,Denmark,113865,10,57
Aarau,CH,AG,NULL,NULL,NULL
Aarhus,DK,Denmark,194345,10.1,56.1
Aarri,WAN,Nigeria,111000,NULL,NULL
...
```

- country.csv

```
...
Germany,D,Berlin,Berlin,356910,83536115
Djibouti,DJI,Djibouti,Djibouti,22000,42764
Denmark,DK,Copenhagen,Denmark,43070,52496
Algeria,DZ,Algiers,Algeria,2381740,291830
Spain,E,Madrid,Madrid,504750,39181114
...
```

```
sort -k2 -t, city.csv | join -t, -12 -22 - country.csv \
                        -o1.1,2.1,1.3,1.4
```

```
Aachen,Germany,"Nordrhein Westfalen",247113
Aalborg,Denmark,Denmark,113865
Aarau,Switzerland,AG,NULL
Aarhus,Denmark,Denmark,194345
Aarri,Nigeria,Nigeria,111000
Aba,Nigeria,Nigeria,264000
Abakan,Russia,"Rep. of Khakassiya",161000
```

Summary & Outlook

- Summary
  - Powerful filter and pipes architecture
  - Allows easy incremental development
  - Suitable for structured and unstructured data, ETL process
- Outlook
  - Utility make to handle dependencies between files
  - bash control flow elements like conditional execution, loops
  - bash functions
  - Seamless visualization using gnuplot
  - Easily extensible with own filters in any language

References & Further Readings

- http://www.theunixschool.com/p/awk-sed.html
- Dale Dougherty, Arnold Robbinssed & awk, 2nd Edition UNIX Power Tools. O'Reilly, 2nd Edition 1997
- Arnold Robbins. Sed and Awk: Pocket Reference, 2nd Edition Paperback – June , O'Reilly, 2002
- Ramesh Natarajan. sed and awk 101 hacks. http://www.thegeekstuff.com/sed-awk-101-hacks-ebook/
- gnuplot homepage: http://www.gnuplot.info/