The Unix and GNU/Linux command line

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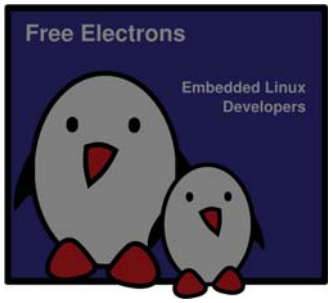

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Latest update: 9/5/2017,
Document sources, updates and translations:
http://free-electrons.com/docs/command-line
Corrections, suggestions, contributions and translations are welcome!

Command memento sheet

It is a useful companion to this presentation.

Examples for the most useful commands are given in just one sheet.

Suggestions for use

Stick this sheet on your wall, use it as desktop wallpaper, make it a mouse mat, print it on clothing, slice it into bookmarks...

Caution

Store away from mice!

Get it on
http://free-electrons.com/doc/legacy/command-line/command_memento.pdf

Training Contents (1)

Shells, filesystem and file handling

Training contents (2)

Standard I/O, redirections, pipes

Training Contents (3)

Task control

Training contents (4)

Miscellaneous

The Unix and GNU / Linux command line

Unix filesystem

Everything is a file

Almost everything in Unix is a file!

- Regular files
- Directories
  Directories are just files listing a set of files
- Symbolic links
  Files referring to the name of another file
- Devices and peripherals
  Read and write from devices as with regular files
- Pipes
  Used to cascade programs
  cat *.log | grep error
- Sockets
  Inter process communication

File names

File name features since the beginning of Unix

- Case sensitive
- No obvious length limit
- Can contain any character (including whitespace, except /).
  File types stored in the file (“magic numbers”).
  File name extensions not needed and not interpreted. Just used for user convenience.
- File name examples:
  README .bashrc
  Windows Buglist
  index.htm index.html index.html.old

File paths

A *path* is a sequence of nested directories with a file or directory at the end, separated by the / character

- Relative path: documents/fun/microsoft_jokes.html
  Relative to the current directory
- Absolute path: /home/bill/bugs/crash9402031614568
- / : *root directory*.
  Start of absolute paths for all files on the system (even for files on removable devices or network shared).

GNU / Linux filesystem structure (1)

Not imposed by the system. Can vary from one system to the other, even between two GNU/Linux installations!

/ Root directory
/bin/ Basic, essential system commands
/boot/ Kernel images, initrd and configuration files
/dev/ Files representing devices
/dev/hda: first IDE hard disk
/etc/ System configuration files
/home/ User directories
/lib/ Basic system shared libraries

GNU / Linux filesystem structure (2)

/lost+found Corrupt files the system tried to recover
/media Mount points for removable media:
/media/usbdisk,
/media/cdrom
/mnt/ Mount points for temporarily mounted filesystems
/opt/ Specific tools installed by the sysadmin
/usr/local/ often used instead
/proc/ Access to system information
/proc/cpuinfo,
/proc/version ...
/root/ root user home directory
/sbin/ Administrator-only commands
/sys/ System and device controls
(cpu frequency, device

GNU / Linux filesystem structure (3)

/tmp/ Temporary files
/usr/ Regular user tools (not essential to the system)
/usr/bin/, /usr/lib/, /usr/sbin...
/usr/local/ Specific software installed by the sysadmin (often preferred to /opt/)
/var/ Data used by the system or system servers
/var/log/, /var/spool/mail (incoming mail), /var/spool/lpd (print jobs)...

The Unix filesystem structure is defined by the Filesystem Hierarchy Standard (FHS):
http://www.pathname.com/fhs/

The Unix and GNU / Linux command line

Shells and file handling

Command line interpreters

- Shells: tools to execute user commands
- Called “shells” because they hide the details on the underlying operating system under the shell's surface.
- Commands are input in a text terminal, either a window in a graphical environment or a text-only console.
- Results are also displayed on the terminal. No graphics are needed at all.
- Shells can be scripted: provide all the resources to write complex programs (variable, conditionals, iterations...)

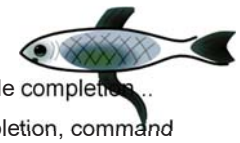
Well known shells

Most famous and popular shells

- sh: The Bourne shell (obsolete)
  Traditional, basic shell found on Unix systems, by Steve Bourne.
- csh: The C shell (obsolete)
  Once popular shell with a C-like syntax
- tcsh: The TC shell (still very popular)
  A C shell compatible implementation with evolved features (command completion, history editing and more...)
- bash: The Bourne Again shell (most popular)
  An improved implementation of sh with lots of added features too.

fish: a great new shell

The Friendly Interactive SHell
http://www.fishshell.org/



- Standard features: history, command and file completion...
- Brand new features: command option completion, command completion with short description, syntax highlighting..
- Easier to any open files: open built-in command.
- Much simpler and consistent syntax (not POSIX compliant) Makes it easier to create shell scripts.

Command line beginners can learn much faster!
Even experienced users should find this shell very convenient.

ls command

Lists the files in the current directory, in alphanumeric order, except files starting with the “.” character.

- ls -a (all)
  Lists all the files (including .* files)
- ls -l (long)
  Long listing (type, date, size, owner, permissions)
- ls -t (time)
  Lists the most recent files first
- ls -S (size)
  Lists the biggest files first
- ls -r (reverse)
  Reverses the sort order
- ls -ltr (options can be combined)
  Long listing, most recent files at the end

File name pattern substitutions

Better introduced by examples!

- ls *txt

The shell first replaces *txt by all the file and directory names ending by txt (including .txt), except those starting with ., and then executes the ls command line.

- ls -d .*

Lists all the files and directories starting with .
-d tells ls not to display the contents of directories.

- cat ?.log

Displays all the files which names start by 1 character and end by .log

Special directories (1)

./

- The current directory. Useful for commands taking a directory argument. Also sometimes useful to run commands in the current directory (see later).
- So ./readme.txt and readme.txt are equivalent.

../

- The parent (enclosing) directory. Always belongs to the . directory (see ls -a). Only reference to the parent directory.
- Typical usage:
cd ..

Special directories (2)

~/

- Not a special directory indeed. Shells just substitute it by the home directory of the current user.
- Cannot be used in most programs, as it is not a real directory.

~sydney/

- Similarly, substituted by shells by the home directory of the sydney user.

The cd and pwd commands

- cd <dir>

Changes the current directory to <dir>.

- cd -

Gets back to the previous current directory.

- pwd

Displays the current directory ("working directory").

- Pushd

Pushes current directory on stack and cd's to new directory.

- popd

The cp command

- cp <source_file> <target_file>

Copies the source file to the target.

- cp file1 file2 file3 ... dir

Copies the files to the target directory (last argument).

- cp -i (interactive)

Asks for user confirmation if the target file already exists

- cp -r <source_dir> <target_dir> (recursive)

Copies the whole directory.

mv and rm commands

- mv <old_name> <new_name> (move)

Renames the given file or directory.

- mv -i (interactive)

If the new file already exits, asks for user confirm

- rm file1 file2 file3 ... (remove)

Removes the given files.

- rm -i (interactive)

Always ask for user confirm.

- rm -r dir1 dir2 dir3 (recursive)

Removes the given directories with all their contents.

Creating and removing directories

- mkdir dir1 dir2 dir3 ... (make dir)

Creates directories with the given names.

- rmdir dir1 dir2 dir3 ... (remove dir)

Removes the given directories
Safe: only works when directories and empty.
Alternative: rm -r (doesn't need empty directories).

Displaying file contents

Several ways of displaying the contents of files.

- cat file1 file2 file3 ... (concatenate)

Concatenates and outputs the contents of the given files.

- more file1 file2 file3 ...

After each page, asks the user to hit a key to continue.
Can also jump to the first occurrence of a keyword (/ command).

- less file1 file2 file3 ...

Does more than more with less.
Doesn't read the whole file before starting.
Supports backward movement in the file (? command).

The head and tail commands

- head [-<n>] <file>

Displays the first <n> lines (or 10 by default) of the given file.
Doesn't have to open the whole file to do this!

- tail [-<n>] <file>

Displays the last <n> lines (or 10 by default) of the given file.
No need to load the whole file in RAM! Very useful for huge files.

- tail -f <file> (follow)

Displays the last 10 lines of the given file and continues to display new lines when they are appended to the file.
Very useful to follow the changes in a log file, for example.

- Examples

head windows_bugs.txt
tail -f outlook_vulnerabilities.txt

The grep command

- grep <pattern> <files>

Scans the given files and displays the lines which match the given pattern.

- grep error *.log

Displays all the lines containing error in the *.log files

- grep -i error *.log

Same, but case insensitive

- grep -ri error .

Same, but recursively in all the files in . and its subdirectories

- grep -v info *.log

Outputs all the lines in the files except those containing info.

The sort command

- sort <file>

Sorts the lines in the given file in character order and outputs them.

- sort -r <file>

Same, but in reverse order.

- sort -ru <file>

u: unique. Same, but just outputs identical lines once.

- More possibilities described later!

The sed command

- sed is a Stream EDitor
- It parses text files and implements a programming language to apply transformations on the text.
- One of the most common usage of sed is text replacement, which relies on regular expressions
- sed -e 's/abc/def/' testfile will replace every string “abc” by “def” in the file testfile and display the result on the standard output.
- sed 's/^[\t]*//' testfile will remove any tabulation or space at the beginning of a line
- sed 's/^|\([^|]*\)|\([^|]*\)|$/\1 -> \2/' testfile replace lines like
  |string1|string2|
  by string1 -> string2

sed : regular expressions

- Regular expressions are useful in many Unix tools, not only sed. They allow to match the input text against an expression.
- . matches any character
- [ ] matches any character listed inside the brackets
- [^] matches any character not listed inside the brackets
- ^ matches the beginning of the line
- $ matches the end of the line
- * matches the previous element zero or more times, + matches the previous element one or more times, ? matches the previous element zero or one time
- \(\) defines a sub-expression that can be later recalled by using \n, where n is the number of the sub-expression in the regular expression
- More at http://www.regular-expressions.info/

Symbolic links

A symbolic link is a special file which is just a reference to the name of another one (file or directory):

- Useful to reduce disk usage and complexity when 2 files have the same content.
- Example:
anakin_skywalker_biography -> darth_vador_biography
- How to identify symbolic links:
- ls -l displays -> and the linked file name.
- GNU ls displays links with a different color.

Creating symbolic links

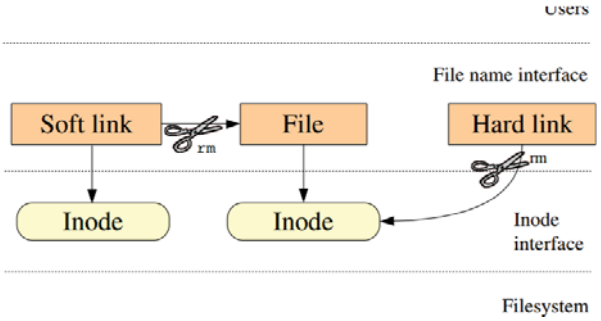
- To create a symbolic link (same order as in cp):
ln -s file_name link_name
- To create a link with to a file in another directory, with the same name:
ln -s ../README.txt
- To create multiple links at once in a given directory:
ln -s file1 file2 file3 ... dir
- To remove a link:
rm link_name
Of course, this doesn't remove the linked file!

Hard links

- The default behavior for ln is to create *hard links*
- A *hard link* to a file is a regular file with exactly the same physical contents
- While they still save space, hard links can't be distinguished from the original files.
- If you remove the original file, there is no impact on the hard link contents.
- The contents are removed when there are no more files (hard links) to them.

Files names and inodes

Makes hard and symbolic (soft) links easier to understand!



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Command documentation

Command help

Some Unix commands and most GNU / Linux commands offer at least one help argument:

- -h

(- is mostly used to introduce 1-character options)

- --help

(-- is always used to introduce the corresponding “long” option name, which makes scripts easier to understand)

You also often get a short summary of options when you input an invalid argument.

Manual pages

man <keyword>

Displays one or several manual pages for <keyword>

- man man

Most available manual pages are about Unix commands, but some are also about C functions, headers or data structures, or even about system configuration files!

- man stdio.h
- man fstab (for /etc/fstab)

Manual page files are looked for in the directories specified by the MANPATH environment variable.

Info pages

- In GNU, man pages are being replaced by info pages.

Some manual pages even tell to refer to info pages instead.

info <command>

- info features:
- Documentation structured in sections (“nodes”) and subsections (“subnodes”)
- Possibility to navigate in this structure: top, next, prev, up
- Info pages generated from the same texinfo source as the HTML documentation pages

Searching the Internet for resources (2)

Looking for documentation

- Look for <tool> or <tool> page to find the tool or project home page and then find the latest documentation resources.
- Look for <tool> documentation or <tool> manual in your favorite search engine.

Looking for generic technical information

- WikiPedia: http://wikipedia.org

Lots of useful definitions in computer science. A real encyclopedia! Open to anyone's contributions.

Searching the Internet for resources (1)

Investigating issues

- Most forums and mailing list archives are public, and are indexed on a very frequent basis by Google.
- If you investigate an error message, copy it verbatim in the search form, enclosed in double quotes (“error message”). Lots of chances that somebody else already faced the same issue.
- Don't forget to use Google Groups: http://groups.google.com/

This site indexes more than 20 years of newsgroups messages.

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Users and permissions

File access rights

Use ls -l to check file access rights

3 types of access rights

- Read access (r)
- Write access (w)
- Execute rights (x)

3 types of access levels

- User (u): for the owner of the file
- Group (g): each file also has a “group” attribute, corresponding to a given list of users
- Others (o): for all other users

Access right constraints

- x is sufficient to execute binaries
Both x and r and required for shell scripts.
- Both r and x permissions needed in practice for directories:
r to list the contents, x to access the contents.
- You can't rename, remove, copy files in a directory if you don't have w access to this directory.
- If you have w access to a directory, you CAN remove a file even if you don't have write access to this file (remember that a directory is just a file describing a list of files). This even lets you modify (remove + recreate) a file even without w access to it.

Access rights examples

- -rw-r--r--
Readable and writable for file owner, only readable for others
- -rw-r-----
Readable and writable for file owner, only readable for users belonging to the file group.
- drwx------
Directory only accessible by its owner
- -------r-x
File executable by others but neither by your friends nor by yourself.
Nice protections for a trap...

chmod: changing permissions

- chmod <permissions> <files>
2 formats for permissions:
- Octal format (abc):
a,b,c = r*4+w*2+x (r, w, x: booleans)
Example: chmod 644 <file>
(rw for u, r for g and o)
- Or symbolic format. Easy to understand by examples:
chmod go+r: add read permissions to group and others.
chmod u-w: remove write permissions from user.
chmod a-x: (a: all) remove execute permission from all.

More chmod (1)

chmod -R a+rX linux/
Makes linux and everything in it available to everyone!

- R: apply changes recursively
- X: x, but only for directories and files already executable
Very useful to open recursive access to directories, without adding execution rights to all files.

More chmod (2)

chmod a+t /tmp

- t: (sticky). Special permission for directories, allowing only the directory and file owner to delete a file in a directory.
- Useful for directories with write access to anyone, like /tmp.
- Displayed by ls -l with a t character.

File ownership

Particularly useful in (embedded) system development when you create files for another system.

- chown -R sco /home/linux/src (-R: recursive)
  Makes user sco the new owner of all the files in /home/linux/src.
- chgrp -R empire /home/askywalker
  Makes empire the new group of everything in /home/askywalker.
- chown -R borg:aliens usss_entreprise/
  chown can be used to change the owner and group at the same time.

Beware of the dark side of root

- root user privileges are only needed for very specific tasks with security risks: mounting, creating device files, loading drivers, starting networking, changing file ownership, package upgrades...
- Even if you have the root password, your regular account should be sufficient for 99.9 % of your tasks (unless you are a system administrator).
- In a training session, it is acceptable to use root. In real life, you may not even have access to this account, or put your systems and data at risk if you do.

Using the root account

In case you really want to use root...

- If you have the root password:
  su - (switch user)
- In modern distributions, the sudo command gives you access to some root privileges with your own user password.
  Example: sudo mount /dev/hda4 /home

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Standard I/O, redirections, pipes

Standard output

More about command output

- All the commands outputting text on your terminal do it by writing to their *standard output*.
- Standard output can be written (redirected) to a file using the > symbol
- Standard output can be appended to an existing file using the >> symbol

Standard output redirection examples

- ls ~saddam/* > ~gwb/weapons_mass_destruction.txt
- cat obiwan_kenobi.txt > starwars_biographies.txt
  cat han_solo.txt >> starwars_biographies.txt
- echo “README: No such file or directory” > README
  Useful way of creating a file without a text editor.
  Nice Unix joke too in this case.

Standard input

More about command input

- Lots of commands, when not given input arguments, can take their input from *standard input*.
- sort

```
windows
linux
[Ctrl][D]
linux
windows
```

sort takes its input from the standard input: in this case, what you type in the terminal (ended by [Ctrl][D])

- sort < participants.txt

The standard input of sort is taken from the given file.

Pipes

- Unix pipes are very useful to redirect the standard output of a command to the standard input of another one.
- Examples
- cat *.log | grep -i error | sort
- grep -ri error . | grep -v “ignored” | sort -u \ > serious_errors.log
- cat /home/*/homework.txt | grep mark | more
- This one of the most powerful features in Unix shells!

The tee command

tee [-a] file

- The tee command can be used to send standard output to the screen and to a file simultaneously.
- make | tee build.log

Runs the make command and stores its output to build.log.

- make install | tee -a build.log

Runs the make install command and appends its output to build.log.

Standard error

- Error messages are usually output (if the program is well written) to *standard error* instead of standard output.
- Standard error can be redirected through 2> or 2>>
- Example:

```
cat f1 f2 nofile > newfile 2> errfile
```

- Note: 1 is the descriptor for standard output, so 1> is equivalent to >.
- Can redirect both standard output and standard error to the same file using &> :

```
cat f1 f2 nofile &> wholefile
```


The yes command

Useful to fill standard input with always the same string.

- yes <string> | <command>

Keeps filling the standard input of <command> with <string> (y by default).

- Examples

```
yes | rm -r dir/
bank> yes no | credit_applicant
yes "" | make oldconfig
```

(equivalent to hitting [Enter] to accept all default settings)

Special devices (1)

Device files with a special behavior or contents

- /dev/null

The data sink! Discards all data written to this file.
Useful to get rid of unwanted output, typically log information:

```
mplayer black_adder_4th.avi &> /dev/null
```

- /dev/zero

Reads from this file always return \0 characters
Useful to create a file filled with zeros:

```
dd if=/dev/zero of=disk.img bs=1k count=2048
```

See man null or man zero for details

Special devices (2)

- /dev/random

Returns random bytes when read. Mainly used by cryptographic programs. Uses interrupts from some device drivers as sources of true randomness (“entropy”).
Reads can be blocked until enough entropy is gathered.

- /dev/urandom

For programs for which pseudo random numbers are fine.
Always generates random bytes, even if not enough entropy is available (in which case it is possible, though still difficult, to predict future byte sequences from past ones).

See man random for details.

Special devices (3)

- /dev/full

Mimics a full device.
Useful to check that your application properly handles this kind of situation.

See man full for details.

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Task control

Full control on tasks

- Since the beginning, Unix supports true preemptive multitasking.
- Ability to run many tasks in parallel, and abort them even if they corrupt their own state and data.
- Ability to choose which programs you run.
- Ability to choose which input your programs takes, and where their output goes.

Processes

“Everything in Unix is a file
Everything in Unix that is not a file is a process”

Processes

- Instances of a running programs
- Several instances of the same program can run at the same time
- Data associated to processes:

Open files, allocated memory, stack, process id, parent, priority, state...

Running jobs in background

Same usage throughout all the shells

- Useful
- For command line jobs which output can be examined later, especially for time consuming ones.
- To start graphical applications from the command line and then continue with the mouse.
- Starting a task: add & at the end of your line:

```
find_prince_charming --cute --clever --rich &
```

Background job control

- jobs

Returns the list of background jobs from the same shell

```
[1]-  Running ~/bin/find_meaning_of_life --without-god &
[2]+  Running make mistakes &
```

- fg

fg %<n>

Puts the last / nth background job in foreground mode

- Moving the current task in background mode:

[Ctrl] Z

bg

- kill %<n>

Aborts the nth job.

Job control example

```
> jobs
[1]-  Running ~/bin/find_meaning_of_life --without-god &
[2]+  Running make mistakes &

> fg
make mistakes

> [Ctrl] Z
[2]+  Stopped make mistakes

> bg
[2]+ make mistakes &

> kill %1
[1]+  Terminated ~/bin/find_meaning_of_life --without-god
```


Listing all processes

... whatever shell, script or process they are started from

- ps -aux

Lists all the processes running on the system

- ps -aux | grep bart | grep bash

```
USER      PID %CPU %MEM   VSZ  RSS TTY      STAT START   TIME COMMAND
bart     3039  0.0  0.2  5916 1380 pts/2    S    14:35   0:00 /bin/bash
bart     3134  0.0  0.2  5388 1380 pts/3    S    14:36   0:00 /bin/bash
bart     3190  0.0  0.2  6368 1360 pts/4    S    14:37   0:00 /bin/bash
bart     3416  0.0  0.0     0    0 pts/2    RW   15:07   0:00 [bash]
```

- PID: Process id
- VSZ: Virtual process size (code + data + stack)
- RSS: Process resident size: number of KB currently in RAM
- TTY: Terminal
- STAT: Status: R (Runnable), S (Sleep), W (paging), Z (Zombie)...

Live process activity

- top - Displays most important processes, sorted by cpu percentage (**`htop`**)

```
top - 15:44:33 up  1:11,  5 users,  load average: 0.98, 0.61, 0.59
Tasks:  81 total,   5 running,  76 sleeping,   0 stopped,   0 zombie
Cpu(s): 92.7% us,  5.3% sy,  0.0% ni,  0.0% id,  1.7% wa,  0.3% hi,  0.0% si
Mem:    515344k total,   512384k used,     2960k free,    20464k buffers
Swap:  1044184k total,        0k used,  1044184k free,   277660k cached

  PID USER      PR  NI  VIRT  RES  SHR S %CPU %MEM    TIME+  COMMAND
 3809 jdoe      25   0  6256 3932 1312 R 93.8  0.8   0:21.49 bunzip2
 2769 root      16   0  157m  80m  90m R  2.7 16.0   5:21.01 X
 3006 jdoe      15   0 30928  15m  27m S  0.3  3.0   0:22.40 kdeinit
 3008 jdoe      16   0  5624  892 4468 S  0.3  0.2   0:06.59 autorun
 3034 jdoe      15   0 26764  12m  24m S  0.3  2.5   0:12.68 kscd
 3810 jdoe      16   0  2892  916 1620 R  0.3  0.2   0:00.06 top
```

- You can change the sorting order by typing M: Memory usage, P: %CPU, T: Time.
- You can kill a task by typing k and the process id.

Killing processes (1)

- kill <pids>

Sends an abort signal to the given processes. Lets processes save data and exit by themselves. Should be used first.

Example:

kill 3039 3134 3190 3416

- kill -9 <pids>

Sends an immediate termination signal. The system itself terminates the processes. Useful when a process is really stuck (doesn't answer to kill -1).

- kill -9 -1

Kills all the processes of the current user. -1: means all processes.

Killing processes (2)

- killall [-<signal>] <command>

Kills all the jobs running <command>. Example:

killall bash

- xkill

Lets you kill a graphical application by clicking on it!

Very quick! Convenient when you don't know the application command name.

Recovering from stuck graphics

- If your graphical session is stuck and you can no longer type in your terminals, don't reboot!
- It is very likely that your system is still fine. Try to access a text console by pressing the [Ctrl][Alt][F1] keys
(or [F2],[F3] for more text consoles)
- In the text console, you can try to kill the guilty application.
- Once this is done, you can go back to the graphic session by pressing [Ctrl][Alt][F5] or [Ctrl][Alt][F7] (depending on your distribution)
- If you can't identify the stuck program, you can also kill all your processes: kill -9 -1
You are then brought back to the login screen.

Sequential commands

- Can type the next command in your terminal even when the current one is not over.
- Can separate commands with the ; symbol:
echo “I love thee”; sleep 10; echo “ not”
- Conditionals: use || (or) or && (and):
more God || echo “Sorry, God doesn't exist”
Runs echo only if the first command fails

ls ~sd6 && cat ~sd6/* > ~sydney/recipes.txt
Only cats the directory contents if the ls command succeeds (means read access).

Quoting (1)

Double (") quotes can be used to prevent the shell from interpreting spaces as argument separators, as well as to prevent file name pattern expansion.

```
> echo "Hello World"
  Hello World
> echo "You are logged as $USER"
  You are logged as bgates
> echo *.log
  find_prince_charming.log cosmetic_buys.log
> echo "*.log"
  *.log
```


Quoting (2)

Single quotes bring a similar functionality, but what is between quotes is never substituted

```
> echo 'You are logged as $USER'
  You are logged as $USER
```

Back quotes (`) can be used to call a command within another

```
> cd /lib/modules/`uname -r`; pwd
  /lib/modules/2.6.9-1.6_FC2
```

Back quotes can be used within double quotes

```
> echo "You are using Linux `uname -r`"
  You are using Linux 2.6.9-1.6_FC2
```


Measuring elapsed time

- time find_expensive_housing --near
<...command output...>
real 0m2.304s (actual elapsed time)
user 0m0.449s (CPU time running program code)
sys 0m0.106s (CPU time running system calls)

real = user + sys + *waiting*
waiting = I/O waiting time + idle time (running other tasks)

Environment variables

- Shells let the user define *variables*.
They can be reused in shell commands.
Convention: lower case names
- You can also define *environment variables*: variables that are also visible within scripts or executables called from the shell.
Convention: upper case names.
- env
Lists all defined environment variables and their value.

Shell variables examples

Shell variables (bash)

- projdir=/home/marshall/coolstuff
ls -la $projdir; cd $projdir

Environment variables (bash)

- cd $HOME
- export DEBUG=1
./find_extraterrestrial_life
(displays debug information if DEBUG is set)

Main standard environment variables

Used by lots of applications!

- LD_LIBRARY_PATH
Shared library search path
- DISPLAY
Screen id to display X (graphical) applications on.
- EDITOR
Default editor (vi, emacs...)
- HOME
Current user home directory
- HOSTNAME
Name of the local machine
- MANPATH
Manual page search path
- PATH
Command search path
- PRINTER
Default printer name
- SHELL
Current shell name
- TERM
Current terminal type
- USER
Current user name

PATH environment variables

- PATH
Specifies the shell search order for commands

/home/acox/bin:/usr/local/bin:/usr/kerberos/bin:/usr/bin:/bin:/usr/X11R6/bin:/bin:/usr/bin

- LD_LIBRARY_PATH
Specifies the shared library (binary code libraries shared by applications, like the C library) search order for ld

/usr/local/lib:/usr/lib:/lib:/usr/X11R6/lib

- MANPATH
Specifies the search order for manual pages

/usr/local/man:/usr/share/man

PATH usage warning

It is strongly recommended not to have the “.” directory in your PATH environment variable, in particular not at the beginning:

- A cracker could place a malicious ls file in your directories. It would get executed when you run ls in this directory and could do naughty things to your data.
- If you have an executable file called test in a directory, this will override the default test program and some scripts will stop working properly.
- Each time you cd to a new directory, the shell will waste time updating its list of available commands.

Call your local commands as follows: ./test

Alias

Shells let you define command *aliases*: shortcuts for commands you use very frequently.

Examples

- alias ls='ls -la'
Useful to always run commands with default arguments.
- alias rm='rm -i'
Useful to make rm always ask for confirmation.
- alias frd='find_rambaldi_device --asap --risky'
Useful to replace very long and frequent commands.
- alias cia='. /home/sydney/env/cia.sh'
Useful to set an environment in a quick way
(. is a shell command to execute the content of a shell script).

The which command

Before you run a command, which tells you where it is found

- bash> which ls
alias ls='ls --color=tty'
/bin/ls
- tcsh> which ls
ls: aliased to ls --color=tty
- bash> which alias
/usr/bin/which: no alias in
(/usr/local/bin:/usr/bin:/bin:/usr/X11R6/bin)
- tcsh> which alias
alias: shell built-in command.

~/.bashrc file

- ~/.bashrc

Shell script read each time a bash shell is started

- You can use this file to define
- Your default environment variables (PATH, EDITOR...).
- Your aliases.
- Your prompt (see the bash manual for details).
- A greeting message.

Command editing

- You can use the left and right arrow keys to move the cursor in the current command.
- You can use [Ctrl][a] to go to the beginning of the line, and [Ctrl][e] to go to the end.
- You can use the up and down arrows to select earlier commands.
- You can use [Ctrl][r] to search inside the history of previous commands.

Command history (1)

- history

Displays the latest commands that you ran and their number.
You can copy and paste command strings.

- You can recall the latest command:

!!

- You can recall a command by its number

!1003

- You can recall the latest command matching a starting string:

!cat

Command history (2)

- You can make substitutions on the latest command:

^more^less

- You can run another command with the same arguments:

more !*

The Unix and GNU / Linux command line

Miscellaneous
Text editors

Text editors

Graphical text editors
Fine for most needs

- nedit
- Emacs, Xemacs
- Kate, Gedit

Text-only text editors
Often needed for sysadmins and great for power users

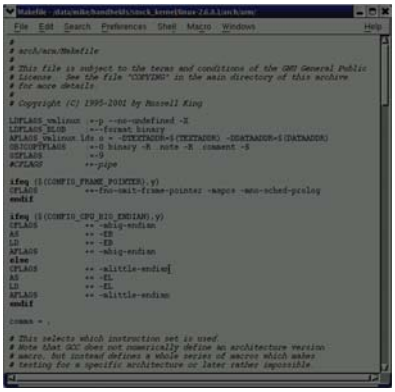
- vi, vim
- nano

The nedit text editor

http://www.nedit.org/

- Best text editor for non vi or emacs experts
- Feature highlights:
- Very easy text selection and moving
- Syntax highlighting for most languages and formats. Can be tailored for your own log files, to highlight particular errors and warnings.
- Easy to customize through menus
- Not installed by default by all distributions

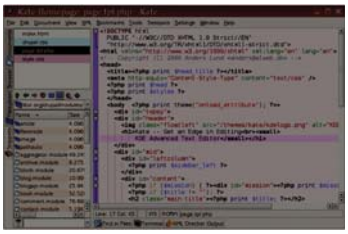
nedit screenshot



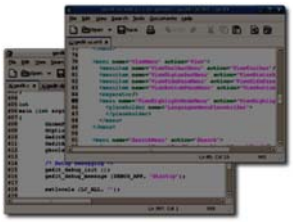
Emacs / Xemacs

- Emacs and Xemacs are pretty similar (up to your preference)
- Extremely powerful text editor features
- Great for power users
- Less ergonomic than nedit
- Non standard shortcuts
- Much more than a text editor (games, e-mail, shell, browser).
- Some power commands have to be learnt.

Kate and gedit



- Kate is a powerful text editor dedicated to programming activities, for KDE
- http://kate.kde.org



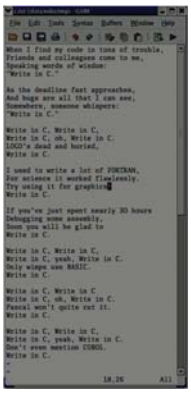
- Gedit is a text editor for the Gnome environment
- http://projects.gnome.org/gedit/

vi

Text-mode text editor available in all Unix systems. Created before computers with mice appeared.

- Difficult to learn for beginners used to graphical text editors.
- Very productive for power users.
- Often can't be replaced to edit files in system administration or in Embedded Systems, when you just have a text console.

vim - vi improved



- vi implementation now found in most GNU / Linux host systems
- Implements lots of features available in modern editors: syntax highlighting, command history, help, unlimited undo and much much more.
- Cool feature example: can directly open compressed text files.
- Comes with a GTK graphical interface (gvim)
- Unfortunately, not free software (because of a small restriction in freedom to make changes)

vi basic commands

Though vi is extremely powerful, its main 30 commands are easy to learn and are sufficient for 99% of everyone's needs!

You can also take the quick tutorial by running vimtutor.

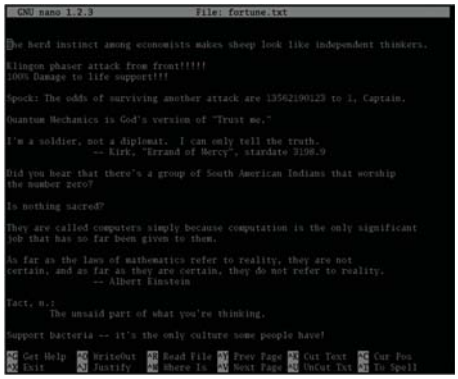
Get our vi memento sheet if you didn't get it with this course:
http://free-electrons.com/docs/command-line

GNU nano

http://www.nano-editor.org/

- Another small text-only, mouse free text editor.
- An enhanced Pico clone (non free editor in Pine)
- Friendly and easier to learn for beginners thanks to on screen command summaries.
- Available in binary packages for several platforms.
- An alternative to vi in embedded systems.
However, not available as a busybox built-in.

GNU nano screenshot



The Unix and GNU / Linux command line

Miscellaneous
Compressing and archiving

Measuring disk usage

Caution: different from file size!

- du -h <file> (disk usage)

-h: returns size on disk of the given file, in human readable format: K (kilobytes), M (megabytes) or G (gigabytes), .
Without -h, du returns the raw number of disk blocks used by the file (hard to read).
Note that the -h option only exists in GNU du.

- du -sh <dir>

-s: returns the sum of disk usage of all the files in the given directory.

Measuring disk space

- df -h <dir>

Returns disk usage and free space for the filesystem containing the given directory.
Similarly, the -h option only exists in GNU df.

- Example:

```
> df -h .
Filesystem            Size  Used Avail Use% Mounted on
/dev/hda5             9.2G  7.1G  1.8G  81% /
```

- df -h

Returns disk space information for all filesystems available in the system. When errors happen, useful to look for full filesystems.

Compressing and decompressing

Very useful for shrinking huge files and saving space

- g[un]zip <file>

GNU zip compression utility. Creates .gz files.
Ordinary performance (similar to Zip).

- b[un]zip2 <file>

More recent and effective compression utility.
Creates .bz2 files. Usually 20-25% better than gzip.

- [un]lzma <file>

Much better compression ratio than bzip2 (up to 10 to 20%).
Compatible command line options.

Archiving (1)

Useful to backup or release a set of files within 1 file

- tar: originally “tape archive”
- Creating an archive:

tar cvf <archive> <files or directories>
c: create
v: verbose. Useful to follow archiving progress.
f: file. Archive created in file (tape used otherwise).

- Example:

tar cvf /backup/home.tar /home
bzip2 /backup/home.tar

Archiving (2)

- Viewing the contents of an archive or integrity check:

tar tvf <archive>
t: test

- Extracting all the files from an archive:

tar xvf <archive>

- Extracting just a few files from an archive:

tar xvf <archive> <files or directories>
Files or directories are given with paths relative to the archive root directory.

Extra options in GNU tar

tar = gtar = GNU tar on GNU / Linux
Can compress and uncompress archives on the fly.
Useful to avoid creating huge intermediate files
Much simpler to do than with tar and bzip2!

- j option: [un]compresses on the fly with bzip2
- z option: [un]compresses on the fly with gzip
- --lzma option: [un]compresses on the fly with lzma
- Examples (which one will you remember?)

- gtar jcvf bills_bugs.tar.bz2 bills_bugs
- tar cvf - bills_bugs | bzip2 > bills_bugs.tar.bz2

Checking file integrity

Very low cost solution to check file integrity

- md5sum FC3-i386-disk*.iso > MD5SUM

Computes a MD5 (Message Digest Algorithm 5) 128 bit checksum of the given files. Usually redirected to a file.

- Example output:

db8c7254beeb4f6b891d1ed3f689b412 FC3-i386-disc1.iso
2c11674cf429fe570445afd9d5ff564e FC3-i386-disc2.iso
f88f6ab5947ca41f3cf31db04487279b FC3-i386-disc3.iso
6331c00aa3e8c088cc365eeb7ef230ea FC3-i386-disc4.iso

- md5sum -c MD5SUM

Checks the integrity of the files in MD5SUM by comparing their actual MD5 checksum with their original one.

The Unix and GNU / Linux command line

Miscellaneous
Printing

Unix printing

- Multi-user, multi-job, multi-client, multi-printer
In Unix / Linux, printing commands don't really print. They send jobs to printing queues, possibly on the local machine, on network printing servers or on network printers.
- Printer independent system:
Print servers only accept jobs in PostScript or text. Printer drivers on the server take care of the conversion to each printers own format.

- Robust system:
Reboot a system, it will continue to print pending jobs.

Printing commands

- Useful environment variable: PRINTER
Sets the default printer on the system. Example:
`export PRINTER=lp`
- lpr [-P<queue>] <files>
Sends the given files to the specified printing queue
The files must be in text or PostScript format. Otherwise, you only print garbage.
- a2ps [-P<queue>] <files>
“Any to PostScript” converts many formats to PostScript and send the output to the specified queue. Useful features: several pages / sheet, page numbering, info frame...

Print job control

- lpq [-P<queue>]
Lists all the print jobs in the given or default queue.

```
lp is not ready
Rank    Owner   Job     File(s)                 Total Size
1st     asloane 84      nsa_windows_backdoors.ps        60416 bytes
2nd     amoore  85      gw_bush_iraq_mistakes.ps        65024000 bytes
```

- cancel <job#> [<queue>]
Removes the given job number from the default queue.

Using PostScript and PDF files

Viewing a PostScript file

- PostScript viewers exist, but their quality is pretty poor.
- Better convert to PDF with ps2pdf:
`ps2pdf decss_algorithm.ps`
`xpdf decss_algorithm.pdf &`

Printing a PDF file

- You don't need to open a PDF reader!
- Better convert to PostScript with pdf2ps:
`pdf2ps rambaldi_artifacts_for_dummies.pdf`
`lpr rambaldi_artifacts_for_dummies.ps`

The Unix and GNU / Linux command line

Miscellaneous
Synchronizing files

Smart directory copy with rsync

rsync (remote sync) has been designed to keep in sync directories on 2 machines with a low bandwidth connection.

- Only copies files that have changed. Files with the same size are compared by checksums.
- Only transfers the blocks that differ within a file!
- Can compress the transferred blocks
- Preserves symbolic links and file permissions: also very useful for copies on the same machine.
- Can work through ssh (secure remote shell). Very useful to update the contents of a website, for example.

rsync examples (1)

- rsync -a /home/arvin/sd6_agents/ /home/sydney/misc/
  - -a: archive mode. Equivalent to -rlptgoD... easy way to tell you want recursion and want to preserve almost everything.
- rsync -Pav --delete /home/steve/ideas/ /home/bill/my_ideas/
  - -P: --partial (keep partially transferred files) and --progress (show progress during transfer)
  - --delete: delete files in the target which don't exist in the source.

Caution: directory names should end with / . Otherwise, you get a my_ideas/ideas/ directory at the destination.

rsync examples (2)

- Copying to a remote machine

  rsync -Pav /home/bill/legal/arguments/ \
  bill@www.sco.com:/home/legal/arguments/

  User bill will be prompted for a password.
- Copying from a remote machine through ssh

  rsync -Pav -e ssh homer@tank.duff.com:/prod/beer/ \
  fridge/homer/beer/

  User homer will be prompted for his ssh key password.

The Unix and GNU / Linux command line

Miscellaneous
Comparing files and directories

Comparing files and directories

- diff file1 file2

Reports the differences between 2 files, or nothing if the files are identical.

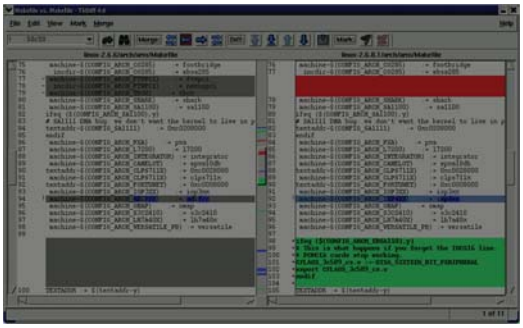
- diff -r dir1/ dir2/

Reports all the differences between files with the same name in the 2 directories.

- These differences can be saved in a file using the redirection, and then later re-applied using the patch command.
- To investigate differences in detail, better use graphical tools!

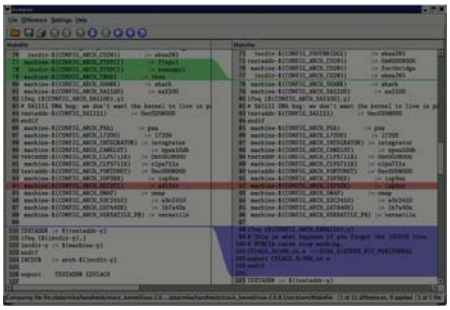
tkdiff

http://tkdiff.sourceforge.net/
Useful tool to compare files and merge differences



kompare

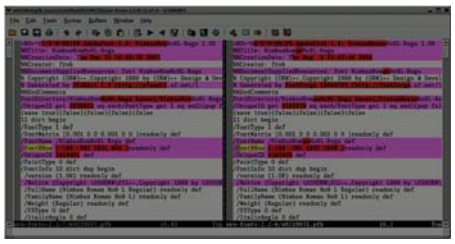
Another nice tool to compare files and merge differences
Part of the kdesdk package (Fedora Core)



gvimdiff

Another nice tool to view differences in files

Available in most distributions with gvim
Apparently not using diff.
No issue with files with binary sections!



The Unix and GNU / Linux command line

Miscellaneous
Looking for files

The find command

Better explained by a few examples!

- find . -name “*.pdf”
  Lists all the *.pdf files in the current (.) directory or subdirectories. You need the double quotes to prevent the shell from expanding the * character.
- find docs -name "*.pdf" -exec xpdf {} ';'
  Finds all the *.pdf files in the docs directory and displays one after the other.
- Many more possibilities available! However, the above 2 examples cover most needs.

The locate command

Much faster regular expression search alternative to find

- locate keys
  Lists all the files on your system with keys in their name.
- locate “*.pdf”
  Lists all the *.pdf files available on the whole machine
- locate “/home/fridge/*beer*”
  Lists all the *beer* files in the given directory (absolute path)
- locate is much faster because it indexes all files in a dedicated database, which is updated on a regular basis.
- find is better to search through recently created files.

The Unix and GNU / Linux command line

Miscellaneous
Various commands

Getting information about users

- who
  Lists all the users logged on the system.
- whoami
  Tells what user I am logged as.
- groups
  Tells which groups I belong to.
- groups <user>
  Tells which groups <user> belongs to.
- finger <user>
  Tells more details (real name, etc) about <user>
  Disabled in some systems (security reasons).

Changing users

You do not have to log out to log on another user account!

- su hyde
  (Rare) Change to the hyde account, but keeping the environment variable settings of the original user.
- su - jekyll
  (More frequent) Log on the jekyll account, with exactly the same settings as this new user.
- su -
  When no argument is given, it means the root user.

The wget command

Instead of downloading files from your browser, just copy and paste their URL and download them with wget!

wget main features

- http and ftp support
- Can resume interrupted downloads
- Can download entire sites or at least check for bad links
- Very useful in scripts or when no graphics are available (system administration, embedded systems)
- Proxy support (http_proxy and ftp_proxy env. variables)

wget examples

- wget -c \ http://microsoft.com/customers/dogs/winxp4dogs.zip
  Continues an interrupted download.
- wget -m http://lwn.net/
  Mirrors a site.
- wget -r -np http://www.xml.com/ldd/chapter/book/
  Recursively downloads an on-line book for off-line access.
  -np: "no-parent". Only follows links in the current directory.

Misc commands (1)

- sleep 60
  Waits for 60 seconds
  (doesn't consume system resources).
- wc report.txt (word count)
  438 2115 18302 report.txt
  Counts the number of lines, words and characters in a file or in standard input.

Misc commands (2)

- bc ("basic calculator?")
  bc is a handy but full-featured calculator. Even includes a programming language! Use the -l option to have floating point support.
- date
  Returns the current date. Useful in scripts to record when commands started or completed.

Checksum commands

- *A checksum or hash sum is a fixed-size datum computed from an arbitrary block of digital data for the purpose of detecting accidental errors that may have been introduced during its transmissions or storage.*
  http://en.wikipedia.org/wiki/Checksum
- The MD5 hash algorithm is implemented in the md5sum command
  ```
  $ md5sum patch-2.6.24.7.bz2
  0c1c5d6d8cd82e18d62406d2f34d1d38  patch-2.6.24.7.bz2
  ```
- The SHA algorithm is implemented in the shaXsum (sha1sum, sha256sum, etc.)
- The integrity of several files can be verified against a file listing the checksums using the -c option.

System administration

See our presentation about system administration basics:

- Network setup
- Creating and mounting filesystems
- Accessing administrator (root) priviledges
- Package management

Also available on http://free-electrons.com/docs/command-line

The Unix and GNU / Linux command line

Application development

Compiling simple applications

- The compiler used for all Linux systems is GCC
http://gcc.gnu.org
- To compile a single-file application, developed in C :
gcc -o test test.c
- Will generate a test binary, from the test.c source file
- For C++ :
g++ -o test test.cc
- The -Wall option enables more warnings
- To compile sources files to object files and link the application :
gcc -c test1.c
gcc -c test2.c
gcc -o test test1.o test2.o
- gcc automatically calls the linker ld

Using libraries (1)

- On any Linux system, a C library is available and offers a large set of APIs for application development.
- See http://www.gnu.org/software/libc/manual/
- Outside of the C library, thousands of other libraries are available for graphic programming, multimedia, networking, scientific computations, and moroe.
- Most libraries are already available as packages in your distribution, in general in two packages
- **libfoo** is the package containing the library itself. This package is required to **execute** already compiled applications, but not sufficient to build new applications
- **libfoo-dev** is the package containing the headers and other configurations files and tools needed to **build** new applications relying on libfoo.

Using libraries (2)

- In your source code, include the proper header files of the library
- Usually #include <foo.h> or #include <foo/foo.h>
- These headers are present in /usr/include/
- Refer to the documentation of the library for details, available in /usr/share/doc/<package>/, on the Web... or in the header files !
- To compile your application with the library, the easiest solution is to use pkg-config, which is supported by most libraries today :
gcc -o test test.c $(pkg-config --cflags –libs)
- By default, the application are dynamically linked with the libraries
- The libraries must be present in /lib/ for the application to work
- Use the ldd command to see which libraries are needed by an application

Make and Makefiles

- The compilation process can be automated using the make tool.
- make reads a file called Makefile from the current directory, and executes the rules described in this file
- Every rule is has a target name, a colon, and a list of dependencies, and the list of commands to generate the target from the dependencies

```
target: dep1 dep2
        command1
        command2
        command3
```

- When simply running make, the default target that is generated is “all”. A target is only re-generated if dependencies have changed.
- See http://www.gnu.org/software/make/manual/

Simple Makefile example

```
CFLAGS = -Wall

all: test

test: t1.o t2.o
	gcc -o $@ $^ $(CFLAGS)

clean:
	$(RM) -f test

install:
	$(CP) test /usr/bin
```

Variables can be defined and later expaneded with $(VARNAME)

The default target “all” simply depends on the “test” target.

The “test” target depends on t1.o and t2.o. Once these files are generated, the gcc command is executed.
$@ is the target name
$^is the name of all dependencies.
The .o files are generated using implicit dependencies, known by make.

These targets are executed by running “make clean” and “make install”

Build systems

- Makefiles are nice, but they don't easily allow easy adaptation to the different build environment and different build options
- More elaborated build systems have been developed
- Autotools (automake, autoconf), based on Makefiles and shell scripts. Even though they are old and a little bit difficult to understand, they are the most popular build system for free software packages.
- CMake, a newer, cleaner build system
- Sconcs and Waf, other build systems based on Python
- The typical steps to compile a autotools based package are
./configure
make
sudo make install

Debugging

- The official debugger that comes with the GNU development tools is gdb.
- See http://sourceware.org/gdb/download/onlinedocs/gdb.html
- An application must be compiled with the -g option to be properly debugged. This option adds debugging information to the application binary
gcc -o test test.c -g
- The application can then be run inside the gdb debugger :
gdb test
- Or the debugger can be attached to the application while it is running :
gdb test -p PID
- Where PID is the process ID of the running application

Using gdb

- **gdb** is a text-based debugger, with a command-line interface like a shell, providing dedicated commands. Some of the important commands are :
- break (b) to set a breakpoint in the code. Can be used with a function name or a location in the source code, or an absolute memory address.
- print (p) to print the value of a variable. Used with a variable name, even if it's a complex one (which involves dereferencing structures, for example)
- c to continue the execution until the next breakpoint.
- next (n) to execute only the next line of code (step *over* any function call) and step (s) to execute only the next line of code (step *into* any function call)
- backtrace (bt) to display the function call stack

gdb sample session

```
thomas@surf:/tmp$ gcc -o test test.c -g
thomas@surf:/tmp$ gdb test
GNU gdb 6.8-debian
[...]
(gdb) break foo
Breakpoint 1 at 0x80483c7: file test.c, line 5.
(gdb) run
Starting program: /tmp/test2

Breakpoint 1, foo (a=2, b=3) at test.c:5
5               return a + b;
(gdb) p a
$1 = 2
(gdb) p b
$2 = 3
(gdb) c
Continuing.
foo=5

Program exited normally.
```

ddd, the graphical gdb

- There are several graphical front-ends to gdb. A popular one is **ddd**.
- Allows to navigate in the source code while debugging
- Allows to set break points, inspect and change variable value directly by looking at the source code
- http://www.gnu.org/software/ddd/