Linux, command line & MetaCentrum

Use of Linux command line not only for MetaCentrum of CESNET

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Outline I

Outline II

What it is UNIX, Linux and GNU... I

- UNIX
  - Originally developed in Bell labs of AT&T in 1696, written in C, since then huge radiation, hybridization, HGT, ...
  - Trademark — only systems passing certain conditions (paid certification) can be called "UNIX" — Solaris, HP-UX, AIX, ... — commercial systems for big servers
  - main principles: simple, multitasking, hierarchical, network, for more users (takes cares about permissions etc.), configuration written in plain text files, important relationships among applications (generally one application = one task — they are chained), work primarily with text, has kernel and API (interface to communicate with the rest of the system)
  - unix-line (UN*X) — systems compatible with UNIX (Linux, BSD and its variants, Mac OS X, ...)
    - Mainly open-source (UNIX is commonly commercial — source code is not available, but specification is)

What it is UNIX, Linux and GNU... II

- Nowadays prevailing over "old" UNIX systems, used in many devices from tiny embedded toys to huge data centres
- Try to provide same service as paid systems, but (mostly) for free

- Many courts about copyrights, parts of code, patents, ... — USA allow software patents, EU not — GNU, Linux, BSD, ... try to ensure to have only code not ocvered by any licence — to avoid possible courts

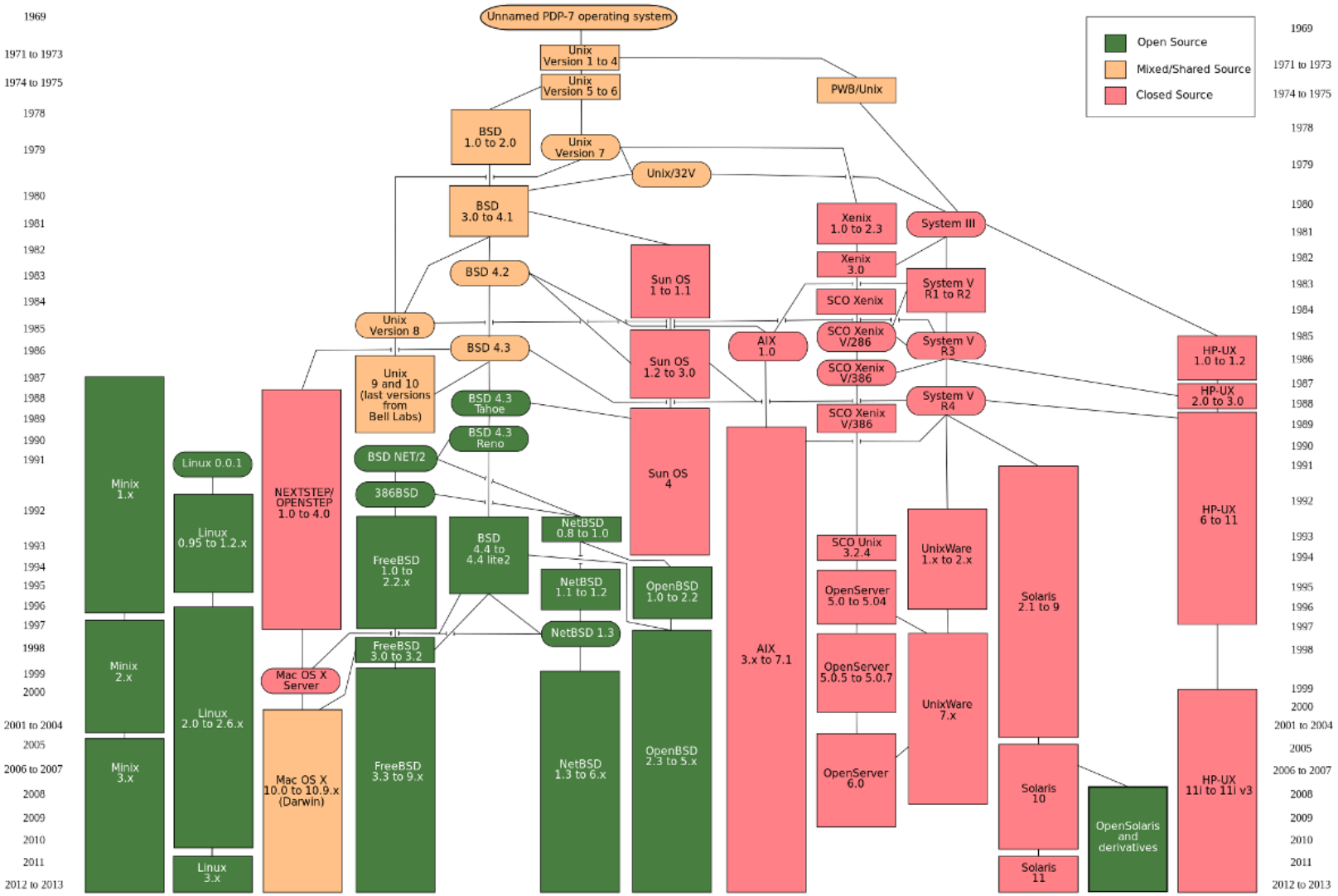
- GNU
  - "GNU's Not Unix!" — but they are compatible
  - Since 1984 Richard Stallman (founder of Free Software Foundation) tried to make new kernel (Hurd — not finished yet...)
  - Generally set of basic system tools — working with many kernels (Linux BSD*, Mac's Darwin, ...), also present in many commercial paid UNIX systems
  - Source code is free — anyone can study it (Security!), report bugs, contribute, modify, share it, ...

What it is UNIX, Linux and GNU... III

- GNU General Public License (GPL) — free spirit of open-source — licence, idea, how to share software

- Linux
  - First version of kernel written by Linus Torvalds in Helsinki in 1991
  - Kernel was in principle inspired by various UNIX systems and using GNU tools for work
  - Quickly became popular — anyone can take it and use for any needs
  - Used in small embedded (commonly network) devices, mobile devices (book readers, Android, ...), personal computers, servers (from home level to biggest data centres), ...
  - Nowadays powering most of the Internet
  - Anyone can contribute — not only code, also documentation, design, translations, ...

Extremely simplified UNIX phylogeny



Cathedral vs. market place

What is principal difference between free open-source and commercial software

- Commercial software is like a cathedral
  - Pay big money and get it in the state which the architect like
  - User can not modify it (or it is terribly expensive)
  - Might be you don't need everything — but still paying whole set
- Free open-source software (FOSS) is like a market place
  - Find there many producers of same tools — pick up those you like — freedom of choice
  - Take exactly the tools you need — any combination is possible
  - Much cheaper to shop there
- Both have pros and cons — depends what you wish...

Free and open-source software I

- Free like freedom of speech, not like free beer!
- Not every OSS (generally less strict conditions) has to be **F**OSS (you can do with it (almost) whatever you like) — source code might be available under some circumstance (only to look), but modification and/or reuse of the code prohibited (and then it is not **free**)
- Open-source — source code can be seen by the holder of the licence — many variants what he can do with the code then
- GNU GPL ("copyleft") — probably most common OSS licence, strict, viral — derived code has to keep the licence — surprisingly not fully "free" as it doesn't allow changes of licence
- LGPL — Lesser GPL — more permissive
- BSD license — permissive — allow derived code to became closed-source (commonly used by Apple Mac OS X, Safari browser, ...)

Free and open-source software II

- Apache licence, Mozilla licence, ...— many variants... for specific use in particular software
- Creative Commons (CC) — software licences above not suitable for multimedia, text, etc. — CC has many options (including denial of reuse of the product), see https://creativecommons.org/
- And many more...
- Orientation might be tricky, but practical output for users is more or less same — the software can be independently checked for bugs, backdoors, malware, can be improved and under some circumstances, new software can be derived, and usually, it is available for free
- Aim is to "liberate" software to keep open sharing of ideas, mutual improve and security control — although the point is clear, there are debates how to reach it...

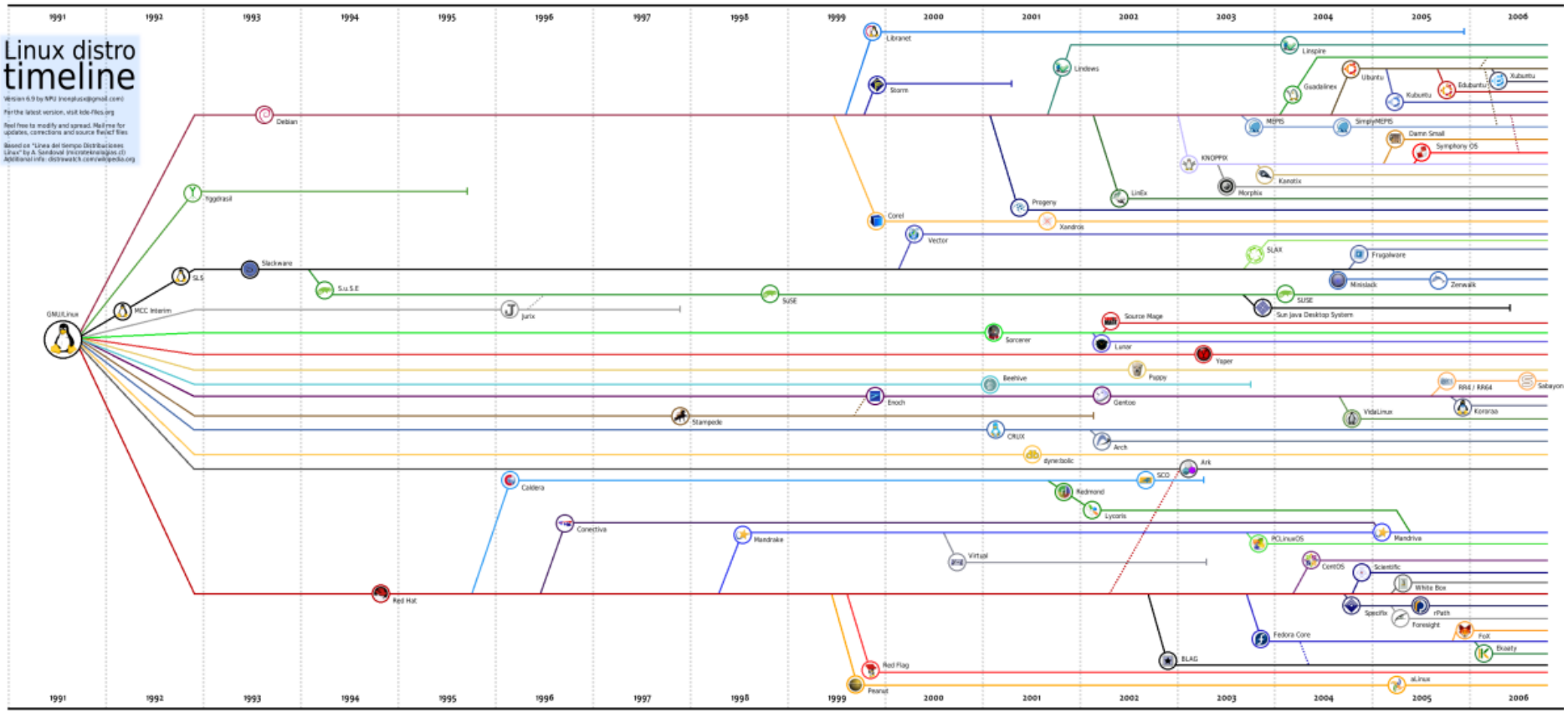
How to make money with free open-source software?

- Traditional model — user rents right ("buys a licence") to use the software (and sometimes for support — usually for extra money)
- Common mistake — software is not "bought" — only licence is rented
- Software as service
  - (F)OSS is available for free — user can use it as it is or buy a support — help
  - No vendor lock-in — user has the code, so he can modify the software himself, change solution, ...
  - Cheap for user as well as company — company specialized for one task, let's say server database, doesn't have to take care about the rest of the system — someone else does; user pays only what he needs
  - Our faculty is using Plone system for web pages — anyone can use it for free, someone (like we) found company to help, and if we'd decided, we could keep Plone and maintain it ourselves or find another company to help us with it

What it is a "Linux"

- Operating system respecting principles of UNIX
- Components
  - Linux kernel — basic part of the system responsible for hardware and very basic low-level running of the system
  - GNU core utilities — basic applications
  - Graphical user environment (GUI) — many choices
  - Many other applications — according to use — whatever imaginable
- Linux distribution?
  - Somehow assemble Linux kernel, basic tools and some applications
  - Optionally add some patches and extra tools and gadgets
  - Make your own design! (very important)
  - If lazy, remake existing distribution ;-)
  - Still surprised there are hundreds of them?
  - It is like Lego — pieces are more or less same across distributions, but result is very variable
  - From "general" for daily use (pick up whatever you like) to very specialized — special hardware devices, network services, rescue, ...

Extremely simplified adaptive radiation of Linux distributions



See also https://en.wikipedia.org/wiki/List_of_Linux_distributions and http://distrowatch.com/ (currently lists 260 distributions)

Most common Linux distributions

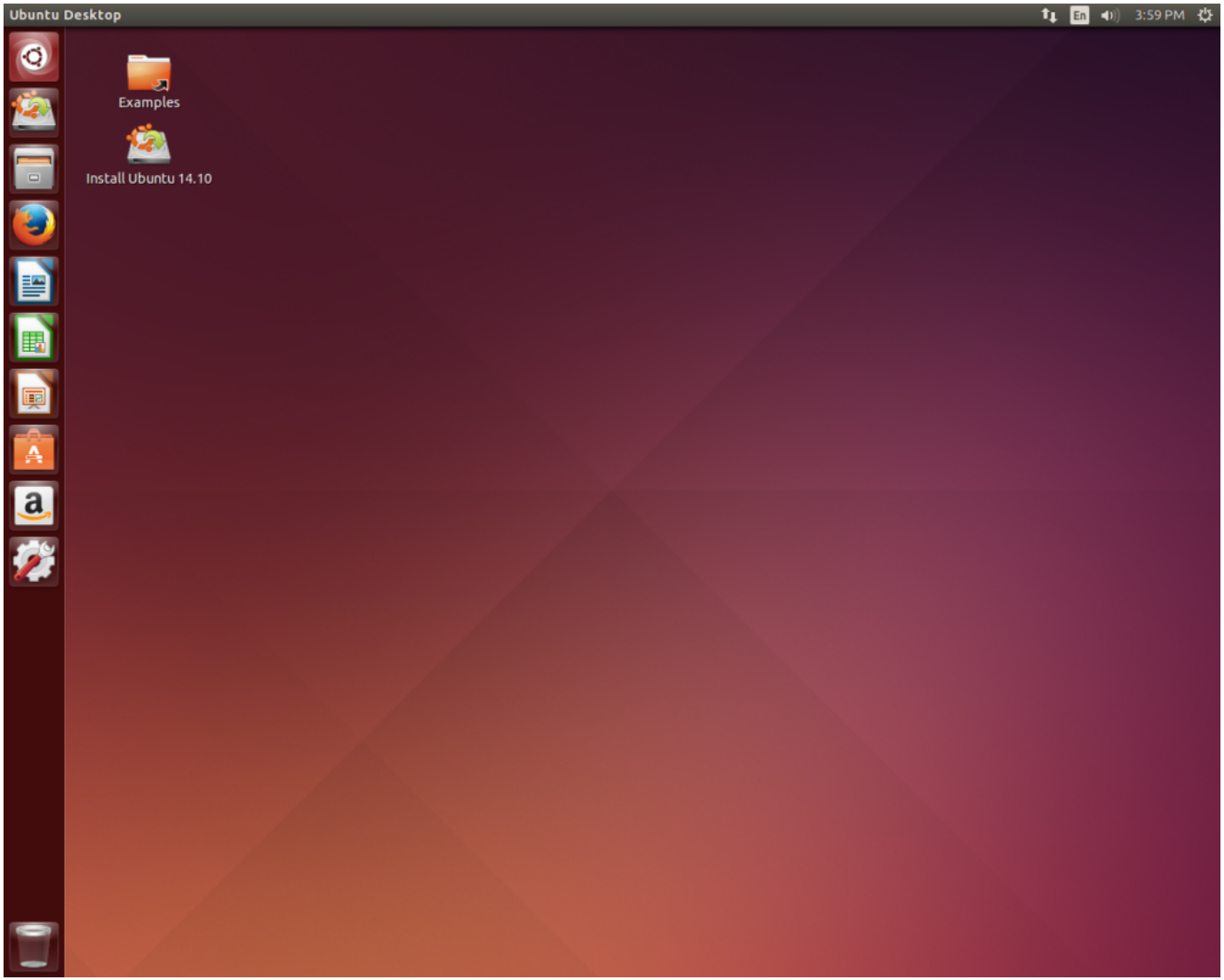
- Debian based
  - Debian — one of oldest and most common, especially on servers
  - Ubuntu (nowadays probably the most popular on PCs and notebooks) and derivatives — Kubuntu, Xubuntu, Lubuntu, ... (according to GUI used)
  - Mint — Based on Ubuntu as well as Debian, very user-friendly
  - Kali, KNOPPIX, ...
- Red Hat based
  - Red Hat — probably the most common commercial
  - Fedora — "playground" for Red Hat — very experimental
  - Centos — Clone of Red Hat
  - openSUSE — SUSE is second largest Linux company, openSUSE is community distribution (free)
  - Mageia, PCLinuxOS, ...
- Android
- For experienced users: Arch, Slackware, Gentoo, ...

Graphical User Interfaces

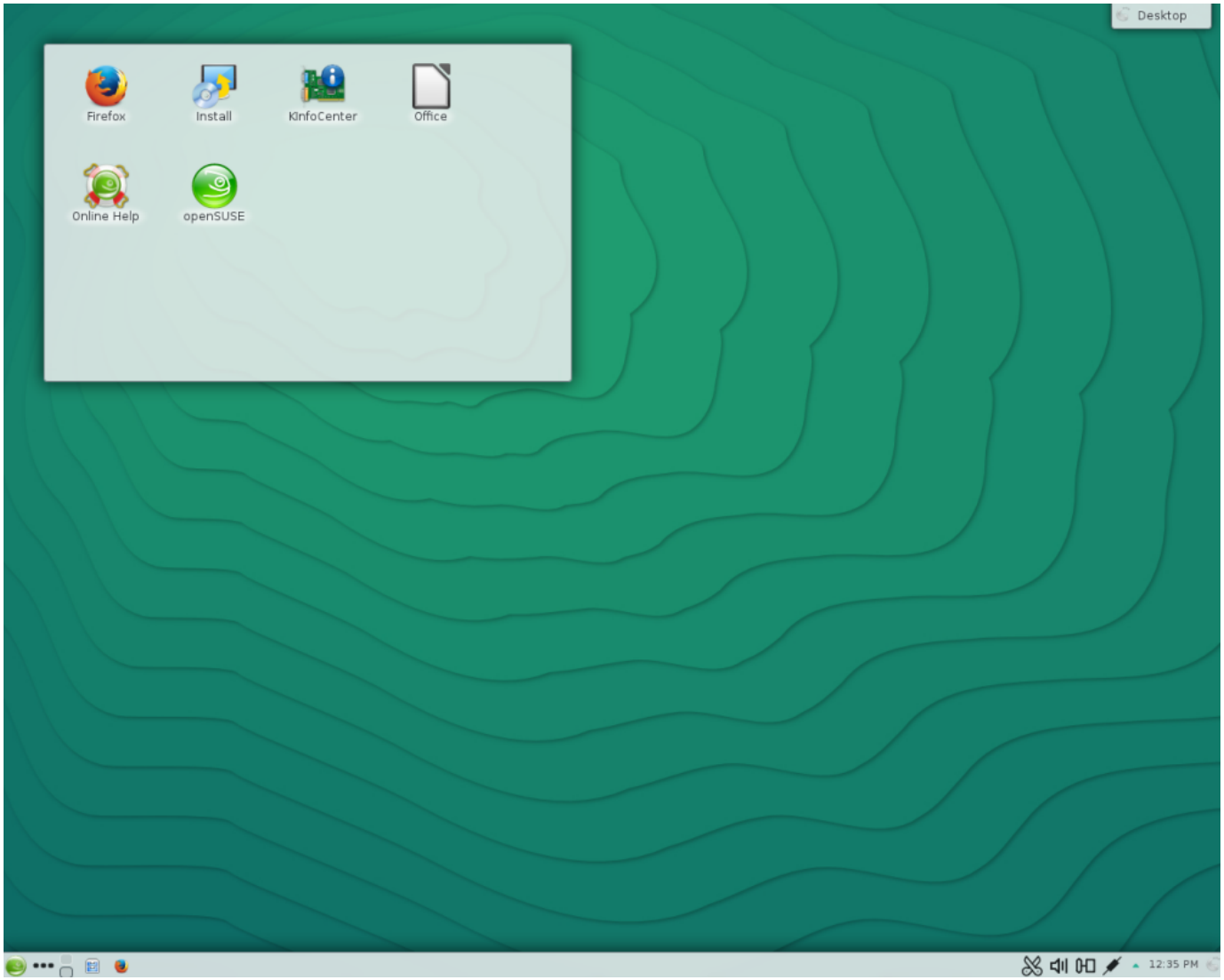
More like “Mac-style”, “Windows-style” or something else? Feature rich or minimalistic?

- Most of GUIs are available for most of common distributions — one is picked as default and “only” colour style is different
- Unity — developed by Ubuntu, relatively specific (not common outside Ubuntu), “Mac-style”
- KDE — one of the most common, feature extremely rich, basically “Windows-like” (can be changed)
- GNOME — one of the most common, relatively simplistic interface, but still feature rich, “Mac-like”
- XFCE — lightweight version of older GNOME — for older computers or users not willing to be disturbed by graphical effects, basically “Mac-like” looking, but panels can be moved to “Windows style”
- Cinnamon — remake of GNOME to look more like Windows...
- And much more...
- Choose that you like — doesn’t matter much which one...

Ubuntu with Unity



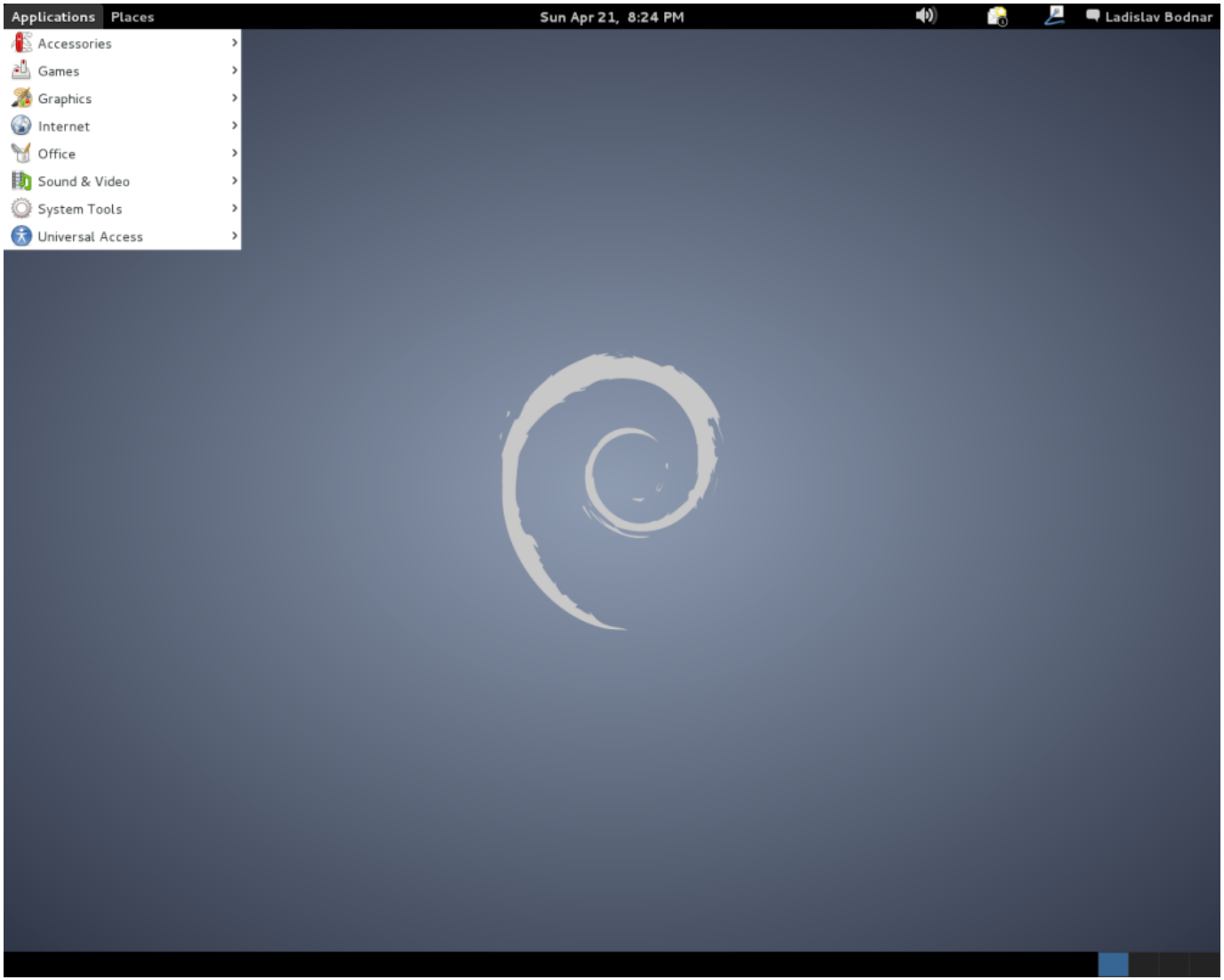
openSUSE with KDE — Kubuntu is same, but blue...



Fedora with GNOME

Linux Mint with Cinnamon

Debian with XFCE — Xubuntu has more “modern” design



How to try it?

- Install it on some computer together with or instead of Windows
  - If you can use whole disk, just boot from CD/USB and click “Next”...
  - If you don’t have whole disk, you need at least one (commonly more) disk partition(s) — if you don’t know how to manage them, ask someone skilled...
- Live CD/USB
  - The most easy — burn ISO image of CD from web of almost any Linux distribution or use for example UNetbootin to prepare bootable flash
  - You only have to need how to boot from CD/USB (usually press ESC, DEL, F2, F10, F12, ... when starting computer — varies according to manufacturer)
- Virtualisation
  - Requires powerful computer (preferable Intel i5 or i7 and over 4 GB of RAM)
  - Install virtual machine (probably the most easy is VirtualBox) — allows install and run another operating system inside host as an ordinary application

The Linux diversity...

- Try several distributions and just choose one you like...
- Unless selection among the most common, it doesn't matter much which one you pick up
- Which design do you like?
- Which distribution is your friend or colleague using?
- You can change GUI without change of distribution
- Applications are still same — no difference in Firefox across distributions — keep your settings when changing distribution
- Everyone using Android is using Linux ;-)
- Special use — FreeNAS for home as well as bussiness file server, Parted Magic and/or SystemRescueCD to repair broken system (disk failure) and save data, ...

Differences among (common) Linux distributions

- Design and colours ;-)
- Default GUI
- Applications available right after installation
- Default settings (not much)
- Package management — especially in command line
- Management of system services (how to start/stop certain server service like database or web)
- Sometimes in location of some configuration files (for system services)
- Kernel is almost same, applications are used in same way
- Command line is almost same across Linux, and almost same as in other UNIX

Lets go through the theory of UNIX operating systems and how to use them...

1. We start with some theory and broader context
2. We will see differences among operating systems commonly making issues
3. We will learn basic commands to use in almost any UNIX command line
   - We will work on Linux, but other systems are very similar, regarding command line
   - We won't distinguish among various types of UNIX/UN*X
4. We will learn some basic manipulation with text
5. We will write some easy scripts
6. And more...

Short overview of hard disk layout

- Physical disk (piece of hardware) has at least 1 partition — division seen in Windows as “disks” (C, D, ...) and mounted directory in UNIX
- MBR — older description of disk division, up to 4 primary partitions (OS typically requires at leas one to run), one can be extended and contain more partitions, disks up to 2 TB
- GPT — newer, no relevant limits, requires UEFI (replacement of BIOS, newer computers)
- If unsure what to do, high probability to break it...
- Blank new partition has to be formatted to desired file system according to use and target operating system
- Linux distributions have easy graphical tools to manage disk partitions
- Always have backup before such management!

Put together more disks

- RAID — Redundant Array of Inexpensive/Independent Disks
- RAID 0 — stripping, no redundancy, no security, speed up (two or more disks joined into one, files divided among disks)
- RAID 1 — mirroring — even number of disks of same size — resulting capacity is half, very fast, secure
- RAID 5 — at least three disks, one is used for parity control, little bit slower
- Combinations (RAID 10, ...)
- LVM — Logical Volume Management — built over several partitions/disks — seen by OS as one continuous space, can be dynamically managed
- Functionality of RAID and LVM (and more) is more or less covered by XFS and Btrfs (next slide)

File systems

FS name	Name length	Characters in file name	Path length	File size	Partition size	Systems
FAT32	255	Unicode	No limit	4 GB	2 TB	Any
NTFS	255	Variable	Variable	16 TB	16 EB	Windows, read-write in UN*X
HFS+	255	Unicode	?	8 EB	8 EB	Mac OS
ext4	255	Any, not /	No limit	16 TB	1 EB	UN*X
XFS	255	Any	No limit	9 EB	9 EB	UN*X
Btrfs	255	Any	?	16 EB	16 EB	UN*X

- FAT32 (including extensions) is old-fashioned and not reliable FS
- NTFS doesn't support UNIX permissions, so it can't be used as system partition in Linux
- ext4, XFS and Btrfs are not accessible in Windows
- XFS and Btrfs are the most advanced FS in common use

Creation and control of FS

- To manage disk partitioning use `fdisk /dev/sdX` (doesn't support GPT very well yet) or `gdisk /dev/sdX`
- When hard drive is partitioned, partitions must be formatted
- Commands `mkfs.*` create various FS, common syntax is `mkfs.XXX -parameters /dev/sdXY`, where sdXY is particular disk partition
- Parameters can set label and various settings of behaviour of the disk partition, check `man mkfs.XXX`
- To check FS for errors use `fsck.XXX /dev/sdXY` (according to respective FS)
- `tune2fs -parameters /dev/sdXY` can set various parameters to influence behaviour of disk partition
- `hdparm -parameters /dev/sdX` can set advanced hardware parameters of hard drive
- The most convenient is using graphical tools available in all distributions...

File names

- Linux allow any character in file name, except slash (/), so including anything on keyboard as well as line break (!). Be conservative...

```
mkdir My New Directory # Produces THREE directories (mkdir creates
                       # directories; spaces separate parameters)
                       # Solutions:
mkdir "My New Directory" # (you can use simple quotes '...' as well) or
mkdir My\ New\ Directory # \ escapes following character
rmdir My\ New\ Directory # Same problem and solution when removing it
touch \* # Creates new empty file named just *
rm * # What would be removed? :-)
rm \* # This works...
```

- File names starting by dot (.) are hidden by default (typically user settings and application data in user home)

```
touch .hiddenfile # Let's make empty text file hidden by default
ls # We will not see it
ls -a # We will see it
```

Directory structure in Linux I

- Similar in another UN*X systems
- Top directory "/" — "root"
- Everything else (including disks and network shares) are mounted in subdirectories (/...)
- /bin — very basic command line utilities
- /boot — bootloader responsible for start of system
- /dev — devices — disks, CD, RAM, USB devices, ...
- /etc — system configuration in plain text files — edit them to change settings (read documentation and comments there)
- /home — users' homes
- /lib, /lib64 — basic system libraries
- /lost+found — feature of FS, after crash and recovery of FS, restored files are there

Directory structure in Linux II

- /media — attached disks (USB flash, ...) usually appear there (might be in /var/run/media) — subdirectories are automatically created when device is plugged and disappears when unplugged
- /mnt — usually manually mounted file systems (but can it can be mounted elsewhere)
- /opt – optional, usually locally compiled software
- /proc — dynamic information about system processes
- /root — root's (admin's) home
- /sbin — basic system utilities
- /selinux — SELinux is security framework
- /srv — FTP and www server data (can be in /var/srv)
- /sys — basic system

Directory structure in Linux III

- /tmp — temporary files — users have private dynamically created spaces there
- /usr — binaries (executable applications) and libraries of installed applications
- /var — data of most of applications and services, including e.g. database data, system logs, ...
- /windows — if on dualboot, Windows disks are commonly mounted here
- Can be altered, modified
- Usually, work only in your home, anywhere else modify files only if you are absolutely sure what you are doing
- Normal user doesn't have permission to modify files outside his directory (with exception of plugged removable media)
- Try `man hier` for details

Configuration in /etc (examples)

- Configuration of system services (servers, ...) and behaviour
  - Apache web server, database, FTP server, networking, basic system settings, ...
- cron* — cron automatically repeatedly runs tasks
- fstab — description of mounted FS
- group — list of users and groups
- passwd — basic settings of for users (home directory, default shell, ...)
- resolv.conf — DNS settings (part of basic networking)
- shadow — users passwords in encrypted format
- skel — basic directories and configuration for new users
- Much more...

Types of files

- Regular file — ordinary file, marked by `-`
- Directory — in UNIX special type of file, marked by `d`
- Symbolic link (symlink, "soft link") — points to another place, marked by `l`, slide 57
- Hard link — just another name for existing file, no special symbol, slide 57
- Block and character device — in `/dev`, representations of devices (hard disks, terminals, ...), marked by `b` or `c` respectively
- Named pipe — pipe can be saved (by `mkfifo`), looks like a file, more at slide 63
- Socket — for communication among processes, also bidirectional, available on network

Login to remote server

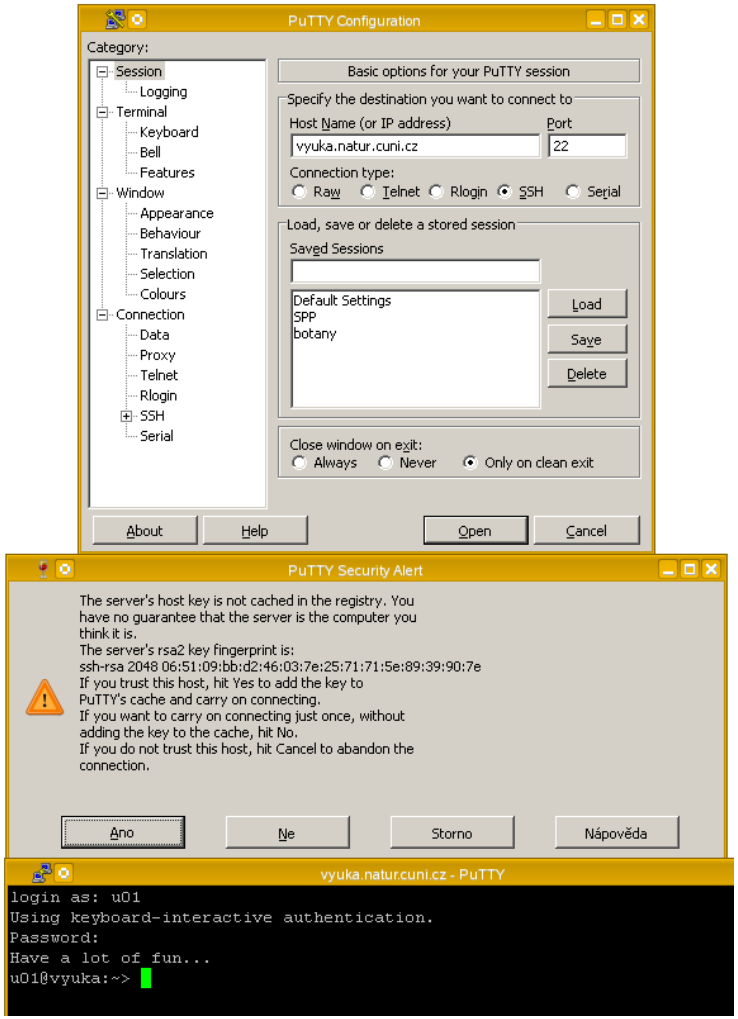
SSH — secure shell — encrypted connection

```
ssh remoteUser@remote.server.cz
# When logging first time, check
# and confirm fingerprint key
yes # And press Enter
# Type remote user's password
# (nothing is shown when typing)
# Confirm by Enter
```

Our toy server: user names from u01 to u25, password `user`

```
ssh uXY@vyuka.natur.cuni.cz
```

If fingerprint key changes, ssh complains a lot — possible man in the middle attack



File permissions

- Combination of permissions to read/write/execute for user(owner)/group/others

Permission	**Number**	**Directory**	**File**
r	4	Read content	Read content
w	2	Write into it	Write into it
x	1	Enter it	Launch application

- rwxr-wr-- — 3 characters for permissions for owner of the file/directory, group he is belonging to, and other users ("d" on beginning marks directories, "l" links, "+" ACL, slide 39)
- 764 — same as above — numbers for each role are summed — first one is for owner, second for group and last for others

Permission examples

```
ls -l
# Only owner can read and write the file; 600
-rw-------   1 vojta users   38211 20. led 09.23 .bash_history
# Owner can write read and write the file, others read; 644
-rw-r--r--   1 vojta users    2707 29. lis 16.21 .bashrc
# Owner can enter, read and write directory, others can read
# and enter it; 755
drwxr-xr-x  41 vojta users    4096 27. pro 09.55 bin
# Only owner can read, write and enter the directory,
# others nothing; 700
drwx------  58 vojta users    4096 17. pro 15.45 .config
# Link, everyone can do everything; 777
lrwxrwxrwx   1 vojta users      37 20. led 09.33 .lyxpipe.in ->
  /tmp/kde-vojta/kilemj7d3E/.lyxpipe.in
# Executable (application) - everyone can launch it, but only
# owner can write into the file; 755
-rwxr-xr-x   1 vojta users    2187 27. lis 13.10 strap.sh*
```

Permission to “write” also means permission to **delete** it.

Check and modify permissions

```
ls -l # Long list - file names and attributes
ls -a # All, including hidden files (starting with dot)
ls -F # Add on the end of name "/" for directories and "*"
      # for executable
ls -h # Human readable size units (use with -l or -s)
ls --color ## Coloured output
ls -laFh --color # Combine any parameters you like
chmod u/g/o/a+/-r/w/x FILE # For respective user/group/others/all
                           # adds/removes permission to
                           # read/write/execute
chmod XYZ FILE # Instead of XYZ use number code of permission
chmod -R # Recursive (including subdirectories)
chmod +x script.sh # Make script.sh executable for everyone
chmod o-r mydir # Remove read permission from others on mydir
chmod 600 FILE1 FILE2 # Make both files readable and
                      # writeable only by their owner
chmod 000 FILE # No one can do anything - owner or root must add
               # some permissions before any manipulation...
chmod 777 * # All permissions for everyone for all files
```

Extending permissions — ACL

Access control list

- By default, it is not possible to give specific permission to the user who is not owner, nor member of group owing the file
- In ext4 FS it has to be turned on manually (usually it is by default), it is part of XFS and Btrfs
- Command `getfacl` lists those extra permissions
- When in use, "basic" tools listing permissions (e.g. `ls -l`, ACL in use is marked by "+" on the beginning of the line) sometimes do not show correct result
- Command `setfacl` sets it

```
1 getfacl FILE # get ACL for FILE
2 setfacl -m u/g:USER/GROUP:r/w/x FILE # Add for USER/GROUP r/w/x right
3 setfacl -R # Recursive
4 setfacl -b # Remove all ACL
```

Set default permissions for new files

- `umask` sets implicit permissions for newly created files for user
- syntax is similar to `chmod`, but reverse (i.e. 027 keeps all rights for owner, for group only reading and nothing for others)
- `umask 027` (or other number) is typically set in `~/.bashrc`
- Typically used in network environment
- Set with care — new permissions will have plenty of consequences (different are typically needed for web pages, private files, shared files etc.)
- `umask` work recursively for all new files in user home directory — it is not possible to set new implicit rules for particular directory

Other permissions

- sticky bit — new directory/file in shared directory (where everyone can write) will be deletable only by owner (typically in `/tmp`)

```
chmod +t somedirectory
ls -la /
drwxrwxrwt 22 root root 800 21. led 18.20 tmp # "t" marks it
```

- setgid — application can have root permission even it was launched by normal user

```
chmod u+s someapplication
ls -al /bin/passwd
-rwsr-xr-x 1 root shadow 51200 25. zář 08.38 /usr/bin/passwd # Note "s"
```

- `chattr` — change of advanced attributes on Linux FS
- Usually, there is no need to modify them

```
chattr -RVf -+=aAcCdDeijsStTu files
man chattr # See explanation of attributes
lsattr # List extended attributes
```

Owner and group

- Every file has a owner and group — for finer setting of rights
- Group can have just one member — the user
- System usually shows names of groups and users, but important are IDs: GID and UID
- Commands chown requires root privileges
- Commands chgrp commonly requires root privileges — user has to be member of particular group to be able to change ownership to it
- Information about users and groups and their IDs are in /etc/group and /etc/passwd

```
1 ls -l # Shows also owner and group
2 id # Display UID and GIDs of current user
3 chown newowner:newgroup files # Change owner and group
4 chown -R newowner files # Recursively (-R) change owner
5 chgrp -R newgroup files # Recursively (-R) change group
```

Root vs. "normal" user

- Root is administrator — more than God — can do anything
- Other users have limited permissions
  - System users providing particular service (web server, database, networking service) are as restricted as possible to do the task — security
  - "Human" users don't have access to system files (at least not for modification), homes of users are separated

Gain root rights:

```
1 su # Requires root password (stay in current directory)
2 su - # Requires root password (go to /root)
3 su -c "some command" # Launch one command with root permissions
4 su USER # Became USER (his password is required)
5 sudo -i # For trusted users, became root (asks for user's password)
6         # User has to be listed in /etc/sudoers
7         # Can be restricted for particular commands
8 sudo somecommand # Launch somecommand with root's privileges
```

Text and text — differences among operating systems

- Windows and UNIX have different internal symbol for end of line (new line) — EOL
  - UNIX: LF ("\n")
  - Windows/DOS: CR+LF ("\r\n")
  - Older Mac: CR ("\r") (Mac up to 9 wasn't UN*X, since OS X is)
- Good text editor can open correctly any EOL, but for example execution of script written in Windows will probably fail on Linux
- Different systems use different encoding
  - UNIX: mainly UTF-8 (unicode, universal)
  - Windows: win-cp-125X (variants according to region)
  - Older UNIX: ISO-8859-X (variants according to region)
  - Other much less common types
- Text editors can usually open any encoding, but autodetection commonly fails — set it manually

Converting the text

Prevent bad display and weird errors when launching scripts

Mac OS X mostly uses same encoding and EOL as Linux (and rest of UNIX world), so there are no problems with compatibility

```
unix2dos textfile # Convert text file from UNIX to Windows EOL
unix2mac textfile # Convert text file from UNIX to old Mac EOL
dos2unix textfile # Convert text file from Windows to UNIX EOL
mac2unix textfile # Convert text file from old Mac to UNIX EOL
unix2dos --help # More information about usage, include encodings
iconv -f ISO-8859-2 -t UTF-8 infile.txt > outfile.txt
  # Converts encoding of input file (ISO-8859-2) to outfile in UTF-8
iconv -l # List of available encodings to convert
iconv --help # More information about usage
recode CP1250..UTF-8 textfile # Convert encoding from CP-1250 to UTF-8
recode ../CR-LF textfile # Convert EOL from UNIX to Windows
recode -l # List of available encodings to convert
recode --help # More information about usage
```

Launching of bash script written on Windows on Linux will probably fail (because of different EOL)

Importance of good text editor

Can your text editor...?

- Show syntax highlight
- Show line numbers
- Show space between brackets
- Open any encoding and EOL type
- Fold source code
- Show line breaks
- Mark lines
- Open multiple files
- Advanced search and replace
- Use regular expressions
- Make projects
- Add notes
- Use command line
- Debug source code

- Kate
- KWrite
- Vim
- GNU Emacs
- Geany
- Bluefish
- Gedit
- SciTE
- Ste
- Tea
- Nano
- And more...

Friendly interactive shell

- Many names, many ways how to get it, still the same thing
- Fish — the command line interface
- Terminal
  - Originally machine used for connection to remote server
  - System uses old fashioned terminal for inner purposes
    - From GUI available using Ctrl+Alt+F1 to F12
    - Changing terminals using Alt+F1 to F12
    - Return back to GUI using Alt+F7
    - Some are used for log outputs etc.
  - Nowadays used “indirectly” with special applications (“emulators”)
- Terminal emulator
  - Application used to get the “terminal” and work in command line
  - Every GUI has some — Konsole, Yakuake, XTerm, Gnome Terminal, Guake, ...
  - Commonly allow appearance customisation — font, colours, background, style of notifications, ...
  - Launch as many copies as you need (some allow tabs for easier work)

BASH and others

- Shell (sh) — feature rich scripting programming language — general specification, several variants
- So called POSIX shell — Portable Operating System Interface — transferable among hardware platforms (and UNIX variants)
- Interpreter of our commands inserted into command line
- BASH — Bourne again shell
  - Probably the most common shell, based on original sh, respecting original specification, adding new features
  - We will use it
- Other variants: csh (syntax influenced by C), ksh (younger, backward compatible with bash), zsh (extended bash), ash (mainly in BSD)
- There are subtle differences in syntax and features
- Language suitable for easy scripting and system tasks, not for “big” programming, neither for graphical applications

Nice BASH features for easier work

- Arrows up and down list in the history of commands
- List whole history by command `history`
- Ctrl+R — reverse search in history — type to search last command containing typed characters
- TAB — list command and files starting by typed characters
- Home/End — go to beginning/end of the line
- Ctrl+L — clears screen (like `clear` command)
- Ctrl+Shift+C/V — copy/paste the text
- Ctrl+C — cancel running task
- Ctrl+D — log out (like commands `exit` or `logout`)
- Ctrl+U — move text before cursor into clipboard
- Ctrl+K — move text after cursor into clipboard
- Ctrl+left/right arrow — skip words
- And more...

Variables

- Variables contain various information (where to look for the executable programs, name of the computer, user settings, ...)
- Can be local (within a script for some temporal purpose) or global — available for all processes
- Commonly written in CAPITALS (just a costume)
- Popular and useful variables
  - HOME — location of user's home directory
  - HOSTNAME — network name of the computer
  - LANG — language settings, encoding, similarly variables LC_*
  - PATH — paths where to look for applications — all applications have to be in PATH or called directly
  - SHELL — shell in use (bash or something else)
  - USER — user name
  - And many more, commonly specific for particular server

Work with variables

```
printenv # Get all exported variables and their values
export -p # Get all exported variables and their values
echo $VARIABLENAME # Get value of particular variable
echo $PATH # Get path where to look for applications
export VARIABLE=variablevalue # Set new variable and its value
                              # Or replace existing variable by new value
export EDITOR=/usr/bin/vim # Set new default text editor
export PATH=$PATH:~/bin # Extend PATH -- add /home/$USER/bin
                        # Take existing PATH and add new values
                        # separated by ":"
export GREP_OPTIONS='--color=auto' # Coloured grep
unset VARIABLENAME # Drop variable and its value
```

- Exported variables will be lost when logging off
- To make variables permanent, add `export` commands into `~/.profile` or `~/.bash_profile`, or `~/.bashrc` (according to shell and its settings)
- "~" means home directory

Reading variables from command line

```
read X # We will read new variable from input (no need to use "$" here)
10 # Type any value and press Enter
echo $X # Get value of the variable
10 # It works
unset X # Destroy this variable
# Following two commands are very similar and can lead to same result
X=`command` # Set as variable output of command
X=$(cat somefile) # Read into variable from file
echo $X # X will contain content of somefile
```

- This is especially useful in scripting to read input from users or from another commands

Expressions

```
1  # Many operands have special meaning in BASH - must be escaped
2  echo `expr 1 '<' 2` # Is 1 smaller than 2? TRUE
3  echo `expr 1 '>' 2` # Is 2 smaller than 1? FALSE
4  echo `expr 5 '%' 2` # What remains after aritmetic division
5  echo `expr 1 '&' 0` # If both arguments non-empty and not 0, then 1
6  x=`expr 1 '+' 6` # Result will be in $x
7  echo $x
8  x=1 # Set x to 1
9  y=$x+1 # Will this add 1? Why not?
10 echo $y # See result
11 y=`expr $x + 1` # This will work - note ` and space around +
12 echo $y # Result
13 echo `expr length "MetaCentrum and Linux"` # Get length of chain
14 echo `expr substr "MetaCentrum and Linux" 12 10` # Length of subchain
15 # Does 1st chain contain 2nd chain? Get position of first hit
16 echo `expr index "GNU Linux" "Linux"` # If no overlap, return value is 0
```

- expr works with various operands (see man expr)

Aliases and BASH settings — became lazy

Alias is short cut — instead of very long command write short alias

```
1  # Define new alias
2  alias ll="ls -l"
3  # Since now, instead of "ls -l" we can use just "ll"
4  # To make the change above permanent, write it into ~/.profile or
5  # ~/.bash_profile or ~/.bashrc and the launch
6  source ~/.bashrc # to reload BASH settings
7  # or "source" the file you modified
8  # Popular aliases
9  alias ls="ls --color=auto" # Make output of ls coloured
10 alias l="ls -la" # Long list (add details) with hidden files
11 # Popular settings in ~/.bashrc (influencing bash, not other shells)
12 test -s ~/.alias && . ~/.alias || true # Check for extra alias file
13 eval "`dircolors -b`" # More colours for outputs
14 HISTCONTROL='ignoreboth' # Ignore repeated entries in bash history
15 HISTFILESIZE='100000' # Length of bash history
```

Brace expansion and quotes

```
1 echo a{p,c,d,b}e # ape ace ade abe - all combinations
2 echo {a,b,c}{d,e,f} # ad ae af bd be bf cd ce cf - all combinations
3 ls *.{jpg,jpeg,png} # expansion to *.jpg *.jpeg *.png, same as
4 ls *.jpg *.jpeg *.png
```

- Text in single quotes ('...') preserves the literal value of each character within the quotes
- Textin double quotes ("...") preserves the literal value of all characters within the quotes, with the exception of dollar ($), back tick (`) and back slash (\)
- A double quote may be quoted within double quotes by preceding it with a backslash
- Text between back ticks (`...`) will be evaluated and then used as command or argument

Exemplar quotes and more

```
1  a=abcdef # Set new variable
2  echo $a # See variable's content
3  abcdef
4  echo '$a' # Single quotes preserve literal value
5  $a
6  echo "$a" # Double quotes preserve literal value, except $, `, \
7  abcdef
8  echo `$a` # Text between back ticks is evaluated and launched
9  abcdef: command not found
10 workdir=`pwd` && echo $workdir # Common use of `...` and $
11 echo "Hi, dear $USER" # Compare this and following command...
12 echo 'Hi, dear $USER'
```

- $ marks variables
- \ escapes following character — it will not have its special meaning (space to separate arguments, ...)
- * replaces any characters (`ls a*` lists all files starting with "a")
- ? replaces one single character

Links

- Soft links — like links on the web — short-cut to another place: `ln -s source target`
  - When we delete link, nothing happens, when target, non-working link remains

```
ls -l bin/cinema5
lrwxrwxrwx 1 vojta users 42 5. dub 2014 cinema5 -> # "l" marks link
  /home/vojta/bin/cinema5-0.2.1-beta/cinema5* # "->" points to target
```

- Hard links — only second name for file already presented on the disk (available only for files): `ln source target`

```
ln .bashrc .bashrcX
ls -l .bash* # Numbers in first column show links pointing to it
             # For directories - number of items, for files = 1
-rw------- 1 vojta users 27298 21. led 16.43 .bash_history # One link
-rw-r--r-- 2 vojta users  2707 29. lis 16.21 .bashrc # Same data as below
-rw-r--r-- 2 vojta users  2707 29. lis 16.21 .bashrcX # Two links
```

Screen

Split terminal or keep task running after logging off

- When you log off or network connection is broken, running tasks for particular terminal usually crash
- Sometimes number of connections is limited
- `screen` is solution — virtual terminals
- Launch `screen` to start new screen terminal, read some info, confirm by Space key or Enter
- To detach from the screen press `Ctrl+A, D` — screen is still running in background — you can even log off
- To return back to running screen use `screen -r` — if only one screen is running, you get back to it
- If more screens are running, use `screen -r 1234` (the number is seen from `screen -r`)
- To cancel running screen press `Ctrl+D` (or type `exit` or `logout`)

Automated launching of tasks

- at can run command at certain time (atd daemon must be running)

```
systemctl status/start/stop atd.service # Check/start/stop if atd runs
at HHMM # Run commands at certain time check "man at" for time settings
at> command1 # Add as many commands as you wish (separate by Enter)
# When done, press Ctrl+D to cancel giving commands to at
at HHMM <<< 'cat somescript.sh' # Run script at certain time
```

- cron runs tasks repeatedly (cron daemon must be running)

```
systemctl status/start/stop cron.service # Check/start/stop if cron runs
crontab -l # List cron tasks
crontab -e # Edit cron tasks (launches editor according to the variable):
# Minute, Hour, Day in month, Month, Day in week, Command (absolute path)
# 0-59    0-23  1-31          1-12   0-6 starting with Sunday (WTF?)
  *       *     *             *      *            /usr/bin/command
  10      22    1             *      *       # 1st day in month, 23:11
  0       */3   *             *      *       # Every 3 hours
# root can copy scripts into directories /etc/cron.*/
```

Chaining commands

- & — command will be launched in background, terminal is available for next typing: `firefox &`
- && — second command is launched only when first command exits without error (exits with 0 status): `mkdir NewDir && cd NewDir`
- ; — second command is launched regardless exit status of the first one: `kshfskcbd; hostname`
- {...} — commands within curl brackets are launched as one block
- || — second command is launched when first command fails (has non zero exit status):
  `cd newdir || { mkdir newdir && cd newdir; }`
- Behaviour in shells other than bash might be little bit different
- | — pipe — redirects standard output of one command into standard input of second command: `ps aux | sort`

Standard input and output and redirects

- Standard input (`stdin`) is standard place where software takes input (keyboard and terminal) and writes results to standard output (`stdout`) — typically monitor
- Standard error output (`stderr`) is target of error messages — typically also monitor (but can be log file or so)
- `>` — redirects output into new place (file, device, another command)

```
1 cat /etc/group # Print whole file /etc/group
2 grep users /etc/group > users # Extract from /etc/group lines containing
3                               # "users" and write output into new file
4 cat users # See result
```

- `>>` — adds output to the end of the file ("`>`" rewrites target file)

```
1 grep root /etc/group >> users # Add new information into existing file
2 cat users # See result
```

Redirects of standard input and output

```
1 # Write directory content into text file
2 # If file directory_listing.txt exists, will be overwritten
3 ls -la > directory_listing.txt
4 # If file directory_listing.txt exists, new content will be added to
5 # the end
6 ls -la >> directory_listing.txt
```

Redirects and pipes

```
# Add error output to the end of standard output file
command >> outputfile 2>&1
# Add error output to the error log text file
command >> outputfile 2>error.log
```

- /dev/null — "black hole" — discards everything (don't care about errors?): `command 2> /dev/null`
- /dev/stdin — standard input (in case application reads files, not from standard input): `echo "Žluťoučký kůň" | iconv -f utf-8 -t cp1250 /dev/stdin`
- /dev/stdout — standard output (we wish to see errors which would be discarded otherwise): `command 2> /dev/stdout`
- /dev/stderr — standard error output (right place to send errors to): `echo "error" > /dev/stderr`

Which system are we using?

```
uname -a # Information about Linux kernel (version, ...)
lsb_release -a # Information about Linux distribution release
lscpu # Information about CPU
cat /proc/cpuinfo # Raw list of information about CPU
lsusb # List of devices on USB
lspci # List of PCI devices (graphic card, network card, ...)
lshw # Complete list of hardware
lshw -C memory # Information about RAM
hwinfo # Complete list of hardware
hwinfo --network # Information about network devices
free -h # Available memory (RAM) and swap, -h for nice units
df -h # Free space on disk partitions, -h for nice units
lsmod # List loaded kernel modules
uptime # How long is the system running, number of users, average load
date # Date and time - plenty of options for formatting
mount # Information about mounted file systems
```

Processes — Every running program has its own process

```
1  htop # Nice listing of processes (better version of top), quit using "q"
2  pgrep application # Return PID (process ID) of application
3  ps # processes related to actual terminal
4  ps x # All user's processes
5  ps aux # All processes
6  # kill (terminate) process by name or process ID (PID)
7  ps aux | grep geany # Find which PID has application to terminate
8  # This is the application - its PID we need
9  vojta 14639 9.3 0.8 2828512 134816 ?   Sl 16:12 0:01 /usr/bin/geany
10 # This is previous "ps aux | grep geany" command (last column)
11 vojta 14769 0.0 0.0   9440  1628 pts/0 S+ 16:12 0:00 grep geany
12 kill -SIGTERM 14639 # SIGTERM is "nice" termination, SIGKILL "brutal"
13 killall -SIGTERM geany # Select by name (more processes with same name)
14 # nice - how much resources will task use: from -20 (high priority - not
15 # "nice" process) to +19 (low priority - very "nice" process), default 0
16 nice -n 7 hard_task.sh # set priority 7 for newly launched task
17 renice 15 16302 # Change priority of PID 16302 to 15
18 sudo renice 15 16302 -u USER # Change priority of USER's process
```

Managing system services

- Different among distributions — several main methods
- Most common is SystemD, less common older init scripts and RC scripts
- Used to manage services like webserver, database, ...
- Read documentation for your distribution!
- All actions require root authentication

```
# SystemD - huge amount of possibilities
systemctl enable/disable/status/start/stop servicename # TAB helps
# RC scripts
rcservicename status/start/stop # TAB helps to select service
# Init scripts
/etc/init.d/servicename status/start/stop # TAB helps to select service
```

Users

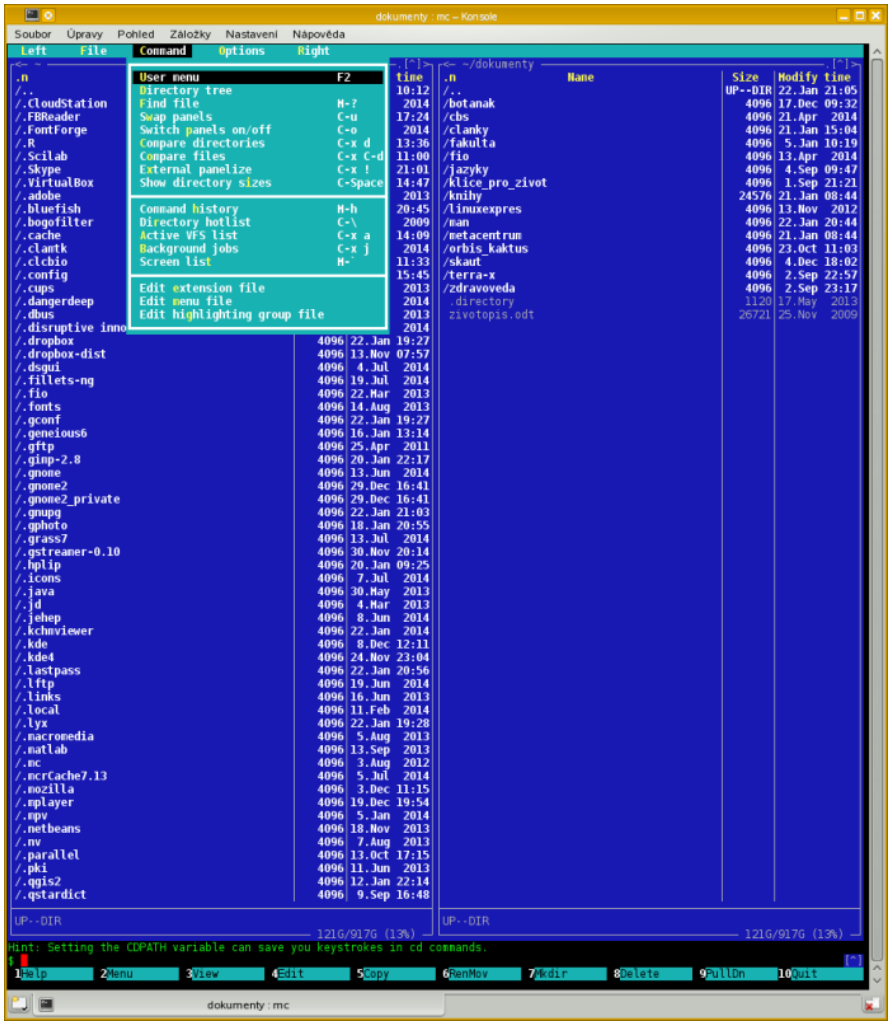
```
1  whoami # What is my user name
2  id # Information about current user (user ID and group IDs)
3  who # Who is logged in
4  w # Who is logged in, more information
5  users # Plain list of currently logged users
6  finger # Information about users on current terminals
7  passwd # Change password
8  passwd USER # Change USER's password
9  groups # List your groups
10 # Following commands to manage users and groups do not have to work
11 # on all systems - depends on authentication methods used
12 useradd newuser # Add new user
13 usermod --help # Modify user, see possible modifications
14 userdel user # Delete user
15 groupadd newgroup # Add new group
16 groupmod --help # Modify group, see possible modifications
17 groupdel group # Delete group
```

Directories

```
pwd # Print working directory - where we are right now
cd # Change directory (just "cd" or "cd ~" goes to home directory)
cd .. # One directory up; cd ../..; cd ../../another/directory/
cd relative/path/from/current/position # Go to selected directory
cd /absolute/path/from/root # Absolute path stars by "/"
tree # Tree like hierarchy of files and directories
tree -d # List only directories; see tree --help
tree -L 2 # Only up to second level; combine: tree -d -L 3
du -sh # Disk usage by current directory, -s for sum, -h for nice units
mkdir # Make directory
rmdir # Remove empty directory
ls # List directory content
   # Try parameters -l, -a, -1, -F, -h (with -l or -s), --help
rm -r # Recursive delete - remove also non-empty directories
mv from to # Move files/directories (also for renaming)
cp from to # Copy, -r (recursive, including subdirectories)
           # -a (keeps all attributes), -v (verbose)
file somefile # Information about questioned file (what it is, ...)
xdg-open somefile # Open file by graphical application as in GUI
```

Midnight Commander

- `mc` to launch MC
- Move, copy, delete, files/directories, connect to SSH/(S)FTP, ...
- Can be used with mouse
- Edit text files (F4)
- F2 for quick menu
- F9 for top menu with many possibilities
- And much more...
- Not possible to live without it :-)



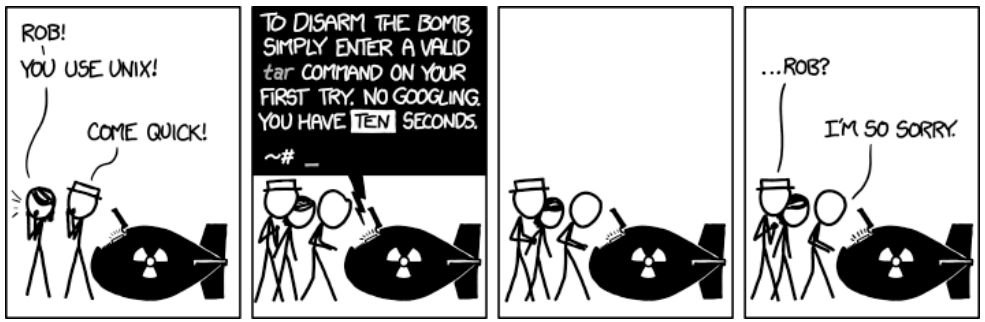
Compressing files into archives

Archive	**Compressing command**
*.tar	tar cvf archive.tar file1 file2
.tar.gz/.tgz	tar czvf archive.tar.gz/.tgz file1 file2
.tar.bz/.tbz/*.tar.bz2	tar cjvf archive.tar.bz/.tbz/.tar.bz2 file1 file2
*.tar.xz	tar cvf - file1 file2 | lzma > archive.tar.xz
*.gz	gzip file
*.bz2	bzip2 file
*.xz	lzma file
*.zip	zip -r archive.zip file1 file2
*.rar	rar a archive.rar file1 file2

- `gzip`, `bzip2` and `lzma` are able to pack only one file — use them together with `tar` to pack multiple files
- `gzip`, `bzip2` and `lzma` when used **without** `tar` move file into archive
- `lzma` has excellent compression, but sometimes it is very slow

Compressing and decompressing archives

Archive	**Decompressing command**
*.tar	tar xvf archive.tar
.tar.gz/.tgz	tar xzvf archive.tar.gz/.tgz
.tar.bz/.tbz/*.tar.bz2	tar xjvf archive.tar.bz/.tbz/.tar.bz2
*.tar.xz	lzcat archive.tar.xz | tar xvf -
*.gz	gunzip archive.gz
*.bz2	bunzip2 archive.bz2
*.xz	unlzma archive.xz
*.zip	unzip archive.zip
*.rar	unrar x archive.rar



Looking for files

```
1  locate somename # Searches for files/directories in local database
2  updatedb # Must be regularly launched to get "locate" to work
3  which # Full path to application (shell command)
4  whereis # Path to source code, executables and man pages for the command
5  # Test if executable command exists (good for scripts)
6  # If "Application" is missing, script ends with error
7  command -v Application >/dev/null 2>&1 || { echo >&2 "Application is
8    required but not installed. Aborting." }
9  command -v find # Behaves like which, but reliable in scripts
10 type Application >/dev/null 2>&1 || { echo >&2 "Application is
11   required but not installed. Aborting."; }
12 hash Application 2>/dev/null || { echo >&2 "Application is required
13   but not installed. Aborting."; }
14 exit 1; # It can be added before the end of the bracket to send
15         # term signal 1 - for better handling of various errors
```

Find

```
find # The most powerful searching tool, many parameters (man find):
find <where> -type d/f -name XXX -print
find photos/ -name *.jpg -exec mogrify -resize 1000x1000 '{}' \;
```

- First `find`'s parameter is location, to search — absolute or relative, "." means current directory (the only compulsory parameter)
- `-type` for only directories or only files (without this parameter, files as well as directories are looked for)
- `-name` supports wildcarts (`*`, `?` and `[...]`)
- `-print` is default action — prints list of results
- `-exec` runs some command with results (e.g. find all images and resize them)
  - All following arguments are argument of the command until ";" is encountered
  - `{}` is replaced by the current file name being processed
  - Those constructs might require protection by escape ("\") or quotes not to be expanded by shell

Launching commands and scripts

- Parameters of commands are separated by space and preceded by one or two minus(es)
- Parameter `-h` or `--help` usually gives help for particular command
- Getting help with `man` command
  - `man somecommand`
  - Arrows to list up and down, `q` to quit
  - Type `/` and type text and hit Enter to search — next hit by `n`, quit search by Esc (twice)
  - Command `info` more advanced — type `?` for help
- Parameters can be combined, order doesn't matter (same variants: `ls -la`; `ls -al`; `ls -a -l`; `ls -l -a`)
- "Long" parameters (`--XXX`) must stay separated
- Commands must be in PATH — actual directory isn't in PATH
  - If the script is is current directory, use `./script.sh` or full path
- Custom scripts must have execute permission (`chmod +x script.sh`)

Package management

- Package — an application or its part (documentation, plugins, translations, ...)
- Packages are available in repositories on the internet
  - System has list of applications available
  - Updates, bug fixes are installed for all applications using one interface (GUI or command line) — very reliable
  - Packages are digitally signed — security
  - User can set custom repositories to get new packages
- The most different task among distributions
- Packages have dependencies — required shared libraries and so on — use package manager and try to avoid downloading packages from the internet
- Read manual for your distribution!

Package management in command line in openSUSE and Debian/Ubuntu

Root password is required: use `sudo` ... or `su -`

Task	**openSUSE**	**Debian/Ubuntu**
Package name	*.rpm	*.deb
Install	zypper in *package*	apt-get install *package*
Remove	zypper rm *package*	apt-get remove *package*
Refresh repositories	zypper ref	apt-get update
Update	zypper up	apt-get update
Upgrade	zypper dup	apt-get dist-upgrade
Search	zypper se *term*	apt-cache search *term*
Clear packages	rpmorphan	apt-get autoremove
Interactive manager	yast sw_single	aptitude
Add repository	zypper ar *repository*	nano /etc/apt/sources.list
Remove repository	zypper rm *repository*	nano /etc/apt/sources.list

Basics of compilation

- Some software is distributed only as source code written in languages like C or C++ — user has to compile it to get binary executable
- Compilation creates binary specific for particular operating system and hardware platform — can be tuned for optimal performance
- Interpreted languages like Bash, Perl, Python or Java don't have to be compiled (but it is possible) — they need their interpreter to run, relative easily portable among hardware platforms and OS
- Applications requiring compilation usually have good instructions

```
1 # General schema:
2 configure # Many possible parameters, settings for compilation
3           # Not required in every time
4 make # Basic building command, sometimes only this is required
5 make install # Final creation of binary, sometimes required
```

- If you don't have to do it, don't do it. Solving problems can be complicated — contact someone skilled or author of the application...

Compilation of RAxML

Available from https://github.com/stamatak/standard-RAxML (cite Stamakis 2014).

```
# Create working directory
mkdir raxml
# Go there
cd raxml/
# Get source code from GitHub (svn downloads only changed files)
svn co https://github.com/stamatak/standard-RAxML/tags/v8.1.16
# Go to newly created directory
cd v8.1.16/
ls # List files
# No need of Windows version - delete it
rm -rf Windows*
# Compile standard version (other versions are available for better CPU)
make -f Makefile.gcc
# Remove unneeded files
rm *.o
# Launch it - see RAxML help
./raxmlHPC -h
```

Launching Java applications

- Java is probably the most portable language working on any operating system — the only condition is to install Java virtual machine
- Let's download FigTree from http://tree.bio.ed.ac.uk/download.php?id=90&num=3

```
# Go to directory where you downloaded it
cd directory/with/downloaded/figtree
# Uncompress downloaded archive
tar -zxvf FigTree_v1.4.2.tgz
# Go to created directory
cd FigTree_v1.4.2/
# List files, also in subdirectories
ls *
# Launch it (command java launches *.jar files)
java -jar lib/figtree.jar
# Limit its memory usage to 512 MB
java -Xmx512m -jar lib/figtree.jar
```

Network connection

```
ssh -vvv remoteuser@remote.server.cz # When there are problems with SSH
  # "v" for verbosity - more "v", more information - helps debugging
  # -X enables X11 forwarding - allows use of graphical applications
  # X11 forwarding must be allowed on the server, check it there by
cat /etc/ssh/sshd_config | grep X11 # Reading might be disabled
# Copy files (-r for recursive) over SSH from local computer to
# remote server or vice versa (just flip arguments)
scp -r localfiles remoteuser@remote.server.cz:/remote/path/
rsync -arv somefiles otherlocation # All parameters, recursive, verbose
```

- `rsync` has huge amount of possibilities (see `man rsync`)
- It transmits only changes — very efficient
- Suitable for local as well as network backup
- Network address for rsync is written in same way as for `scp`
- `--delete` deletes in target location files which are not in source location any more

Basic network information and testing

```
hostnmae # Get name of the computer
ping web.natur.cuni.cz # Ping host. Is it alive? Cancel by Ctrl+C
traceroute www.metacentrum.cz # Get route to the host
mtr hostname # Combines ping and traceroute, quit with "q"
ip a s # Information about all network devices (MAC, IP address, ...)
ifconfig -a # Older version of above command
nc -vz web.natur.cuni.cz 22 # Does SSH work on the host?
   # verbose (-v), scan (-z), host, port number (22 for SSH, can be any)
man nc # See for more information; "nc" is alias for "netcat"
netstat -atn # Information about all network connections
        # -a for all connections, -t for TCP/IP, -n for IP addresses
nmap -r someserver # Scan someserver for opened ports
                   # If using at faculty, firewall disconnects you!
nmap botany.natur.cuni.cz --script ssh-hostkey # See SSH key
wget http://some.address.cz/internet # Download file(s) from Internet
wget --help # -r for recursive download (whole web), -k to convert links
```

Parallelization with GNU Parallel

- GNU Parallel can distribute task among CPU threads of one computer, or even among different computers in network
- To distribute tasks (manage parallelization) takes some effort — it is not effective for short/small tasks
- Important operands (for more see `man parallel`)
  - `{}` — input line — whole line read from input source (typically standard input)
  - `{.}` — input line without extension
  - `{/}` — basename of input line — only file name (without path)
  - `{//}` — dirname from input line (filename is removed)
  - `{/.}` — basename of input line without extension
  - `:::` — use arguments from command line instead of stdin (::: is placed after the command and before the argument)
  - `::::` — read from argument files
  - `-j` — number of jobs — if not provide, `parallel` will use all available CPU threads

GNU Parallel examples I

```
# Convert all images from JPG to PNG
ls -1 *.jpg | parallel --bar convert '{}' '{.}.png'
# Resize all images ("\" marks that command continue on next line)
find . -name '*.jpg' -print | parallel convert -resize 1000x1000 \
  -quality 75 '{}' '{.}-small.jpg' # or
parallel convert -resize 1000x1000 '{}' '{.}-small.jpg' ::: *.jpg
# Find WORD in huge text file (named "longfile" here) - this works
# but it is not possible to get line number (file is red in blocks)
parallel --pipe --block 10M -- grep --color=always WORD < longfile
# Same as above but add line numbers according to original file
nl longfile | parallel -k --pipe --block 20M -- grep WORD
# When needed to get phrase or regular expression (use parameter
# "-q" for escaping of shell special characters or extra quotes):
# "--" stops reading parameters for parallel
nl longfile | parallel -qk --pipe --block 20M -- grep "WORD TEXT" # or
nl longfile | parallel -k --pipe --block 20M -- grep '"WORD TEXT"'
```

GNU Parallel examples II

```
# Run in parallel commands from command list file (list of commands)
parallel < command_list # or
parallel :::: command_list
# Add same text to the end of multiple files
ls -1 *.txt | parallel 'cat block_to_be_added.txt >> {}'
# Replace particular text in multiple files with sed and GNU Parallel
ls -1 *.txt | parallel 'sed -i "s/XXX/YYY/g" {}'
# Launch MrBayes for multiple nexus files and create log file with
# starting and ending date and time
ls -1 *.nexus | parallel 'echo Start > {}.log && date >> {}.log && \
  mrbayes {} | tee -a {}.log && echo End: >> {}.log && date >> {}.log'
# tee (-a for append to existing file) records output of MrBayes and
# records it into a log file. General usage:
tee record.txt | command # tee will record output of command
# If software reads commands from user, we can reuse record next time:
command < record.txt # Empy lines are interpreted as Enter key
                     # Each line is used whenever command waits for new
                     # input (instead of user typing, record.txt is used)
```

Removable media

```
eject # Open CD/DVD drive
# Mounting and unmounting of devices require root privileges
mount # Which FS (disk partitions) are mounted
# mount usually recognize FS of mounted device, if not, us -t FStype
mount /dev/sdXY /mount/directory # Mount disk sdXY to /mount/directory
umount /dev/sdXY # Unmount disk sdXY
umount /mount/directory # Unmount disk from /mount/directory
dmesg | grep sd | tail # Get information about recently plugged media
mkdir /mnt/iso # Directory must exist prior mounting into it
mount -t iso9660 -o loop soubor.iso /mnt/iso # See CD/DVD image content
  # Mount CD/DVD ISO image file into directory /mnt/iso
```

Other commands

```
touch filename # Creates empty text file
echo # Write empty line of text
echo $USER # Write value of variable $USER
echo "Some text" # Write text in quotes
# dd produces physical copy of whole device - including empty space
dd if=/dev/sdXY of=image.iso # Backups disk sdXY to imago.iso
dd if=image.iso of=/dev/sdXY # Used to write image of Linux live
                             # media to USB flash disk
apropos keyword # Searches for command descriptions containing keyword
dmesg # Recent entries in main system log - filter with grep, tail, ...
lnav # Comfortably browse recent logs, quit by "q"
```

Read text file

```
cat # Read or join files (-n adds line numbers, -v prints non-printable
    # characters like EOL)
cat textfile # Print content of text file
cat textfile1 >> textfile2 # Add textfile1 to the end of textfile2
nl textfile # Like cat -n, prints textfile with line numbers
tac textfile # Like cat, but prints lines in reverse order
more textfile # When textfile is long, prints screen by screen (space
              # for next screen, q to quit)
less textfile # Better version of more - you can scroll up and down by
              # PgUp, PgDown, arrows, searching by / (type searched
              # string, hit Enter, n for next, twice Esc to quit),
              # q to quit viewing
most textfile # Better version of less
fmt textfile # Basic formatting of text - joining of commented lines,
             # line breaks to break too long lines, ...
fmt textfile > formatted_file # Save output of fmt into new file
wc textfile # lines, words and bytes in text file
wc -l for only lines, -m for characters, -w for words
```

Get part of text file

```
1  head -n N textfile # Print first N lines from textfile
2  tail -n N textfile # Print last N lines from textfile
3  head -n-N textfile # Print textfile without last N lines
4  tail -n+N textfile # Print textfile from Nth line to the end
5  # Split text file on selected pattern - creates new files xxXY
6  csplit textfile '/pattern/' '{*}' # pattern itself is inside '/___/'
7  # Pattern can be regular expression - set it carefully
8  # {*} says to repeat operation as many times as possible
9  grep -parameters pattern textfile # Write lines containing pattern
10 grep user /etc/passwd # Write all lines in passwd containing user
11 cat /etc/passwd | grep user # Same as above
12 grep -v user /etc/passwd # Write all lines in passwd NOT containing user
13 grep -c user /etc/passwd # get number of lines in passwd containing user
14 grep -i USER /etc/passwd # -i isn't case sensitive
15 grep -q ... # quiet - no output - good for testing in scripts
16 grep -ls user /etc/* # -l prints files with pattern, -s suppresses errors
17 grep "longer text" textfile # Extract whole phrase
```

Grep supports regular expressions, slide 96.

Get a column — cut, awk

```
cut column OR delimiter+field textfile
cut -c1 /etc/group # Get first character
cut -c1-5 /etc/group # Get character 1-5
cut -c4- /etc/group # Get character 4 and more
cut -c2,5,7 /etc/group # Get characters 2, 5 and 7
cut -d':' -f1 /etc/group # Select 1st field separated by ":"
cut -d':' -f2-4 /etc/group # Select fields 2-4 separated by ":"
cut -d':' -f1,3 /etc/group # Select fields 1 and 3 separated by ":"
awk 'regexp { commands parameters }' file
awk '{print $NF}' textfile # Select last column (separated by tab)
awk '{print $2}' textfile # Select 2nd column (separated by tab)
awk '{print $3, $2}' textfile # Print columns 3 and 2 (in this order)
ls -l | awk '/^d/ { print $8 "\t" $3 }' # Separate columns by TAB
            # /^d/ for lines starting with "d" (only directories)
```

For regular expressions, see slide 96.

Sorting

```
sort textfile # Sort a text file
sort -d textfile # Take into account only spaces and alphanumerical
                 # characters (ignore any other characters)
sort -r textfile # Reverse order
sort -f textfile # Ignore character case (not case sensitive)
sort -m textfile1 textfile2 # Merge already sorted text files
sort -u textfile # Print only first of multiple entries
sort -b textfile # Ignore leading blanks (space on beginning of line)
# Sorting is influenced by locale setting (e.g. Czech ``ch'')
# To force use of English locale use
LC_ALL=C sort ... # Set for this command language variable to English
uniq textfile # Filters following identical lines - only unique
              # are printed (to get unique lines from whole file,
              # sort it first)
uniq -c textfile # Add number of occurrences before each line
uniq -d textfile # Print only repeated lines
uniq -i textfile # Ignore case (not case sensitive)
uniq -s N textfile # Skip first N characters
uniq -u textfile # Print only not-repeated lines
```

Replacements — tr

```
# tr replaces or deletes characters from standard input and writes
# result to standard output - use pipes and/or redirects:
cat inputtextfile | tr " " "\t" > outputtextfile # Replace space by TAB
                                                 # in inputtextfile and
                                                 # save result as
                                                 # outputtextfile
tr -d "text" # Delete "text" from each line
tr "[A-Z]" "[a-z]" < inputtextfile > outputtextfile # Replace capital
                                                    # letters by small
# Alternative (easier reading) of previous command:
cat inputtextfile | tr "[A-Z]" "[a-z]" > outputtextfile
# Alternative solution using sed (next slide)
cat inputtextfile | sed 's/[A-Z]/\L&/g' > outputtextfile # Vice versa:
cat inputtextfile | sed 's/[a-z]/\U&/g' > outputtextfile
tr --help # See possible replacement patterns
```

Replacements — sed

```
sed 's/FindToReplace/Replace/modificator' textfile > newtextfile
sed 's/find/replace/g' textfile # Search and replace all occurrences
                                # (thanks to "g") of "find" by "replace"
# Replace "g" by number to replace number of occurrences
# To work only on particular line, place number or range (e.g. 2,6)
# right before "s" (sed '1,7s/...')
sed 's/find/replace/g' somedirectory/* # Work on all files in directory
cat textfile | sed 's/find/replace/g' > newtextfile
  # Read textfile by cat, pass it to sed and write output into new file
sed -i ... # Modify processed file - otherwise output is displayed but
           # not saved (can be for example piped into text file or so)
# Groups to remember work in same way in sed, grep as well as vim
\(ToRemember\) # Remember expression in brackets
\Number # Use remembered expression (numbered from one)
ls -l | sed 's/\(users\)/\1RULEZZZ/g' # Take output of ls -l and replace
                                      # "users" by "usersRULEZZZ"
ls -l | sed 's/\([0-9]\{3,8\}\)/size:\t\1/g' # Add "size:TAB" before
                  # file size column (we suppose it has 3-8 digits)
```

sed suports regular expressions, see slide 96 (same as in grep and vim).

Comparisons

```
join textfile1 textfile2 # Compare two sorted text files and write
                         # shared lines (duplicitous lines
                         # are shown just once)
comm textfile1 textfile2 # Compare two sorted columns. Output
  # 1st column - lines only in textfile1
  # 2nd column - lines only in textfile2
  # 3rd column - lines in both files
comm -2 textfile1 textfile2 # Don't show 2nd column (similarly -1, -3)
diff textfile1 textfile2 # Show differences between text files
  # First number shows line(s) in 1st file, then if add/delete/change
  # and last number shows line(s) in the second file, <> show direction
diff -e textfile1 textfile2 # More simple output
diff -c textfile1 textfile2 # Show context (lines around change)
diff -u textfile1 textfile2 # Better version of previous, the most common
colordiff # Same usage and parameters as previous, coloured output
diff -u textfile1 textfile2 | view - # Launches vim (exit by :q! Enter)
vimdiff # Can show more colours, launches vim (exit by :q! Enter)
```

Editors

- `nano`, `pico` and `mc` are very simple, just for very basic text editing in command line or until you learn `vim` (graphical version is **gVim**) or `emacs` (graphical version is also available, just search for **Emacs** in your distribution software manager)
- You can work most of the time in graphical editors (slide 46)
- Emacs and Vim are extremely rich, but having completely different approach — when you get use to one, you can't use the another

```
1 nano textfile # Basic simple text editor
2 pico textfile # Clone of nano, same basic thing
3 mc # Use its internal editor, just very basic
4 emacs textfile # Extremely feature rich (including file browser
5                # and many tools), Exit by Ctrl+X and Ctrl+C
6 vim textfile # Probably the most common, as rich as Emacs
7 vimtutor # Launch tutorial to learn Vim (in various languages)
```

Vim

- Modes of `vim`:
  1. "Normal" — nothing is displayed in bottom left corner, every key has some meaning (`dd` to cut current line, `r` to replace character below cursor,`v` for selection of text, `y` to copy, `x` to cut, `p` to paste, `i` or `Insert` key to enter insert mode, `:` to enter command mode, number to get to line of particular line number, `u` to undo last change(s), ...)
  2. Insert — in bottom left corner "-- INSERT --" is displayed — the most familiar mode — normal typing etc., exit to normal mode by `Esc` key
  3. Command — in bottom left corner ":" is displayed — awaits commands, e.g. `w` to write file, `q` to quit, `q!` to quit and discard changes, `%s/...` to search and replace as in `sed`, `syntax on/off` to turn syntax highlight on/off, `/` to search, ...Exit to command mode by `Backspace` key (delete ":").
- For more information see http://www.vim.org/ and http://vim.wikia.com/wiki/Vim_Tips_Wiki
- In Czech http://www.nti.tul.cz/~satrapa/docs/vim/

Regular expressions I

- . — any single character
- * — any number of characters/occurrences of pattern (including 0)
- [...] — any one character in the brackets
- [^...] — reverse case — all characters except newline and those listed in brackets
- ^ — first character of reg exp — beginning of the line
- $ — last character of reg exp — end of the line
- \{n,m\} — range of occurrences of single character
- \{n\} — exactly *n* occurrences
- \{n,\} — at least *n* occurrences
- \ — escape following special character
- + — one or more occurrences of the preceding reg exp

Regular expressions II

- ? — zero or one occurrences of the preceding reg exp
- | — either the preceding or following reg exp can be matched (alternation)
- \(...\) — group reg exp (numbered, starting with 1) — can be called by \n, where n is number of the group (starting with 1)
- \< \> — word boundary
- [[:alnum:]] — alphanumerical characters (includes whitespace), same like [a-zA-Z0-9]
- [[:alpha:]] — alphabetic characters, like [a-zA-Z]
- [[:blank:]] — space and TAB
- [[:cntrl:]] — control characters
- [[:digit:]] — numeric characters, like [0-9]
- [[:graph:]] — printable and visible (non-space) characters

Regular expressions III

- [[:lower:]] — lowercase characters, like [a-z]
- [[:print:]] — printable characters (includes whitespace)
- [[:punct:]] — punctuation characters
- [[:space:]] — whitespace characters
- [[:upper:]] — uppercase characters, like [A-Z]
- [[:xdigit:]] — hexadecimal digits
- ^$ — blank line
- ^.*$ — entire line whatever it is
- * — one or more spaces (there is space before asterisk)
- & — content of pattern that was matched
- Implementation in `vim`, `sed`, `grep`, `awk` and `perl` and among various UNIX systems is almost same, but not identical...

Regular expressions IV

- **grep**, **sed** and **vim** require escaping of +, ?, {, }, (and) — **egrep** (extended version, launched as `grep -E ...` or `egrep ...`) and **perl** not
- Read http://www.regular-expressions.info/, in Czech http://www.nti.tul.cz/~satrapa/docs/regvyr/, http://www.root.cz/serialy/regularni-vyrazy/ and http://www.regularnivyrazy.info/, and manuals for Grep, Vim, Sed, Awk, Perl, ...

Basic script

- Every script begins with `#!/bin/bash` (or alternative for another shells, Perl, ...)
- Add any commands you like...
- Every script should end with `exit` (but it is not necessary)
- After writing the script, add execution permission (`chmod o+x noninteractive.sh` or `chmod +x noninteractive.sh`)
- The most simple script:

```
1 #!/bin/bash
2 # Simple non-interactive script - no communication with user
3 # only list of commands
4 echo "Hi, $USER, today is `date` and your PATH is $PATH."
5 echo
6 exit
```

Script reading two variables

```
#!/bin/bash
# Arguments are read from command line as parameters of the script
# Order has to be kept (well, not in this case, but generally yes)
echo "Sum of two numbers $1 and $2 is `expr $1 + $2` ."
# "$#" is available every time and contains number of parameters
# (variables) given to the script
echo "Number of parameters is $# ."
# "$*" is available every time and contains all supplied parameters
echo "Those parameters were supplied: $*."
echo
exit
```

When done, do:

```
chmod +x interactive1.sh
./interactive1.sh 8 9 # Or select any other two numbers
```

There is no checking of input values, nothing advanced, ...

Variables will be interactively by user

```
#!/bin/bash
# Arguments are read from user input (script asks for them)
echo "Please, input first value to sum and press Enter"
read V1
echo "Please, input second value to sum and press Enter"
read V2
echo "Sum of two numbers $V1 and $V2 is `expr $V1 + $V2` ."
echo
exit
```

When done, do:

```
chmod +x interactive2.sh
./interactive1.sh # Values will be provided when script asks
```

There is no checking of input values, nothing advanced, ...

Provide named parameters

```
#!/bin/bash
# Script has only one parameter ($1) provided as its parameter
case "$1" in # evaluating provided parameter and behaving accordingly
  -d|--disk)
    echo "Your disk usage is:"
    df -h
    ;;
  -u|--uptime)
    echo "Your computer is running:"
    uptime
    ;;
  # This should be every time last possibility - any other input
  *) # User is then notified he entered nonsense and gets some help
    echo "Wrong option!
      Usage: -d or --disk for available disk space or
      -u or --uptime for computer uptime"
     ;;
esac
exit
```

Notes to previous script

- First make `interactive3.sh` executable and launch it via e.g. `./interactive3.sh -d` or `./interactive3.sh --uptime` or so
- Function `case` has basic checking of input available — as last parameter use "`*)`" — any other input except those defined will produce some warning message or so
- In same way can be added more parameters (by multiple use of `case`), but order of parameters must be kept and all parameters are compulsory
- Having variable number of parameters, possibility to use only some of them and variable order is more complicated and it usually requires `case` in `while` loop and reading variable into an array

Provide parameters, verify them and behave accordingly I

```
#!/bin/bash
NUMBER='^[0-9]+$'
if [ "$#" -ne "3" ]; then
    echo "Error! Requiring 3 parameters! Received $#.
    Usage number1 -plus/-minus/-product/-quotient number2
    Use -plus for sum, -minus for difference, -product
    for multiplication or -quotient for quotient."
    exit 1
  fi
if [[ ! $1 =~ $NUMBER ]]; then
    echo "Parameter 1 is not an integer!"
    exit 1
  fi
if [[ ! $3 =~ $NUMBER ]]; then
    echo "Parameter 3 is not an integer!"
    exit 1
  fi
```

Continues on next slide...

Provide parameters, verify them and behave accordingly II

Remaining part from previous slide...

```
case $2 in
  -plus) expr $1 '+' $3;;
  -minus) expr $1 '-' $3;;
  -product) expr $1 '*' $3;;
  -quotient) expr $1 '/' $3;;
  *) echo "Wrong option!
    Usage number1 -plus/-minus/-product/-quotient number2
    Use -plus for sum, -minus for difference,
    -product for multiplication or -quotient
    for quotient.";;
esac
exit
```

`chmod +x interactive4.sh && ./interactive4.sh 7 -plus 5` (for example)

If branching

```
1  # Basic variant - commands are done only if condition is met
2  if expression; then
3      commands
4    fi
5  # Two branches - when condition is met and when not
6  if expression; then
7      commands1
8    else
9      commands2
10   fi
11 # Join together two (or more) if branches
12 if expression1; then
13     commands1
14   elif expression2
15     then
16       commands2
17     else
18       commands3
19     fi
```

Evaluation of conditions I

- "[...]" (always keep space around it — inside) is function to evaluate expressions (alternatively use command `test`)
  - `if [ "$VAR" -eq 25 ]` or `test $VAR -eq 25`
  - `if [ "$VAR" == "value" ]; …`
    - Escaping variables and values by double quotes ("...") is recommended (to be sure), but not strictly required all the time
  - `if [ ! -f regularfile ]; …` — reverted condition
  - Single-bracket conditions — file, string, or arithmetic conditions
  - Double-bracket syntax — enhanced
    - `if [[ "$stringvar" == *[sS]tring* ]]; then` — regular expressions
    - Word splitting is prevented — $stringvar can contain spaces
    - Expanding file names — `if [[ -a *.sh ]]` (variant with only one bracket doesn't when there are multiple sh files)
    - Allows more detailed test, e.g. `if [[ $num -eq 3 && "$stringvar" == XXX ]] …`

Evaluation of conditions II

- -eq — Equal to
- -lt — Less than
- -gt — Greater than
- -ge — Greater than or Equal to
- -le — Less than or Equal to
- -f $file — True if $file exists and is a regular file
- -r $file — True if $file exists and is readable
- -w $file — True if $file exists and is writable
- -x $file — True if $file exists and is executable
- -d $file — True if $file exists and is a directory
- -s $file — True if $file exists and has a size greater than zero
- -n str — True if string str is not a null string

Evaluation of conditions III

- -z str — True if string str is a null string
- str1 == str2 — True if both strings are equal
- str — True if string str is assigned a value and is not null
- str1 != str2 — True if both strings are unequal
- -s $file — True if $file exists and has a size greater than zero
- -a — Performs the AND function
- -o — Performs the OR function

For, while and until cycles

```
1  # One line for cycle for resizing of images
2  for file in *.jpg; do convert $file -resize 100x100 thumbs-$file; done
3  # More commands in a block
4  for file in `ls -1 *.jpg`; do
5    echo "Processing file $file"
6    convert $file -resize 100x100 thumbs-$file
7    echo thumbs-$file created
8    done
9  # while cycle is evaluating expression and if it is equal to 0
10 # the cycle body is launched, repeatedly while the condition is met
11 while expression
12   do
13     commands
14   done
15 # Like while cycle, but until expression is not equal to zero
16 until expression; do
17   commands
18   done
```

CESNET and MetaCentrum I

- CESNET is organisation of Czech universities, Academy of Science and other organisations taking care about Czech backbone Internet, one of world leading institutions of this type
- CESNET provides various services
  - Massive computations — MetaCentrum
  - Practically unlimited data storage
  - FileSender to be able to send up to 500 GB file
  - ownCloud to backup and/or sync data across devices (capacity is 100 GB)
  - And more...
- Without registration
  - ownClou https://owncloud.cesnet.cz/
  - FileSender https://filesender.cesnet.cz/
  - Go to web and log in with your institutional password (currently this is not available for Institute of Botany)

CESNET and MetaCentrum II

- Requiring registration (and approval)
  - To use MetaCentrum fill registration form http://metavo.metacentrum.cz/en/application/form
  - To use data storage fill registration form https://einfra.cesnet.cz/perun-registrar-fed/?vo=storage&locale=en
  - Users from Institute of Botany (not having access to EduID) have to register first at HostelID http://hostel.eduid.cz/en/index.html
- Information about data storage https://du.cesnet.cz/en/start (contains detailed instructions about usage)
- Information about MetaCentrum http://www.metacentrum.cz/en/ (most of practical information for users are at wiki https://wiki.metacentrum.cz/w/index.php?&setlang=en)

MetaCentrum

- Also available is Galaxy https://galaxy.metacentrum.cz/galaxy/ — web based bioinformatic framework (more information at wiki)
- Current state and usage as available at http://metavo.metacentrum.cz/en/
- Manage your user account at http://metavo.metacentrum.cz/en/myaccount/index.html
- Personal view on actual resources and running tasks is at http://metavo.metacentrum.cz/pbsmon2/person
- List of available applications https://wiki.metacentrum.cz/wiki/Kategorie:Applications
- It has 7 frontends where users log and thousands of computers doing the calculations — they are not accessed directly, most of computers are running Debian GNU/Linux

MetaCentrum usage

- User can transfer data on one of frontends by `scp` or for example WinSCP
- Same credentials are used for all frontends, for SSH login as well as file transmissions

```
1 # Login to selected server (tarkil is located in Prague)
2 ssh -X USER@tarkil.cesnet.cz
3 # Continue as in any other command line...
```

- In home directory on the server prepare all needed data and non-interactive script (interactive are more complicated) which will do the calculations
- Tasks are not launched immediately, but using `qsub` — task is submitted into queue and system decides when it will be launched

Basic skeleton of script running tasks I

```
1  #!/bin/bash
2  # Modify the script according to your needs!
3  # Set data directories
4  WORKDIR="bayes_batch"
5  DATADIR="/storage/praha1/home/$LOGNAME"
6  # So there is directory /storage/praha1/home/gunnera/bayes_batch
7  # containing all the data needed for calculations
8  # Clean-up of SCRATCH (it is temporal directory created by server) -
9  # the commands will be launched on the end when the job is done
10 trap 'clean_scratch' TERM EXIT
11 trap 'cp -ar $SCRATCHDIR $DATADIR/ && clean_scratch' TERM
12 # Prepare the task - copy all needed files from working directory
13 # into particular computer which will finally do the calculations
14 cp -ar $DATADIR/$WORKDIR/* $SCRATCHDIR/  || exit 1
15 # Change working directory - script goes to the directory where
16 # calculations are done
17 cd $SCRATCHDIR/ || exit 2 # If it fails, exit script
```

Ends on following slide

Basic skeleton of script running tasks II

Begins on previous slide

```
# Prepare calculations - load required application modules
# See https://wiki.metacentrum.cz/wiki/Kategorie:Applications
# Every application module is loaded by "modile add XXX"
. /packages/run/modules-2.0/init/sh
module add parallel # In this case GNU Parallel and MrBayes
module add mrbayes-3.2.2
# Launch the analysis - calculate MrBayes for multiple files
ls -1 *.nexus | parallel -j 8 'mb {} | tee -a {}.log'
# Copy results back to home directory
cp -ar $SCRATCHDIR $DATADIR/$WORKDIR || export CLEAN_SCRATCH=false
# This is all needed, the script is ready to be launched...
```

Don't forget to make `metacentrum.sh` executable and modify it according to your needs... If the script was written on Windows, convert EOL and possibly encoding as well...

Launching of tasks

- See https://wiki.metacentrum.cz/wiki/Running_jobs_in_scheduler
- Personal view http://metavo.metacentrum.cz/pbsmon2/person has nice overview of available resources and tasks and allows comfortable construction of submission command

```
# We will tun up to 5 days, require 4 GB of RAM, 5 GB of disk space, one
# physical computer with 8 CPU threads and we get all information mails
qsub -l walltime=5d -l mem=4gb -l scratch=5gb -l nodes=1:ppn=8 -m abe \
  bayes_batch.sh
# Check how the task is running (above web) and
qstat | grep USERNAME
qstat -u USERNAME
qstat 123456789 # The ID of task is available from commands above or mail
qstat -f 123456789
# Terminate scheduled or running task
qdel 123456789
# List available resources
qfree
```

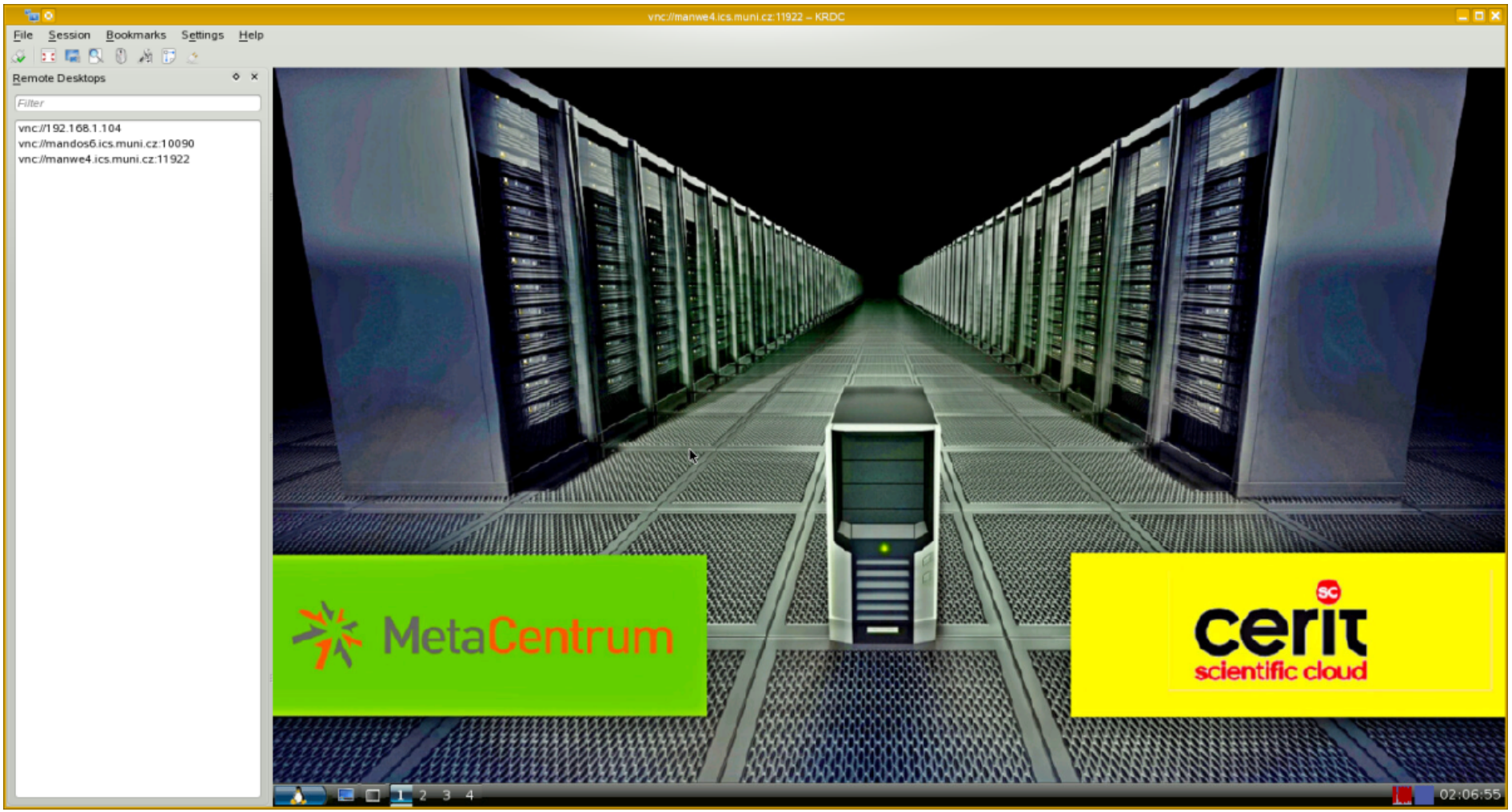
Graphical interactive task

- See information at https://wiki.metacentrum.cz/wiki/Remote_desktop

```
# Again launch qsub according to actual needs
qsub -I -l walltime=2h -l nodes=1:ppn=1 -l mem=2gb
# After we get the interactive task, we are on new server
screen # Secure we can log off in the meantime
module add gui # We need to add GUI module
gui start # Start GUI (see above link for details)
gui info -p # Print information about running VNC sessions
            # Including address, port and password
```

- Launch your favourite VNC client (KRDC, TightVNC, ...) and use credentials from above output to connect

Running VNC


vnc://manwe4.ics.muni.cz:11922 – KRDC
File Session Bookmarks Settings Help
Remote Desktops
Filter
vnc://192.168.1.104
vnc://mandos6.ics.muni.cz:10090
vnc://manwe4.ics.muni.cz:11922
MetaCentrum
cerit
scientific cloud
02:06:55

The end

Our course is over...

...I hope it was helpful for You...

...any feedback is welcomed...

...happy Linux hacking...

...any final questions?

Typesetting using XeLaTeX on openSUSE GNU/Linux