

Introduction to the Linux OS

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Overview and Organization

Introduction to the Operation system Linux, focus on the command line, scripting, basic services and tools used in (not only) physics: tasks automation in data processing and modeling

Organization

- Graded Assessment (KZ): attendance to the lectures, worked out homeworks

Literature

- C. Herborth: Unix a Linux - Názorný průvodce, Computer Press, Praha, 2006
- D. J. Barrett: Linux - Kapesní přehled, Computer Press, Praha, 2006
- M. Sobell: Mistrovství v RedHat a Fedora Linux, Computer Press, Praha, 2006
- M. Sobell: Linux - praktický průvodce, Computer Press, Praha, 2002
- E. Siever: Linux v kostce, Computer Press, Praha, 1999
- **Number of online sources...**

Study materials and homeworks

- <http://kfa.mff.cuni.cz/linux>



- 1 UNIX systems, history, installation, basic applications
- 2 Structure of the Linux OS, file systems, hierarchy of the file system
- 3 Command line, shells, remote access (ssh, ftp)
- 4 Processes and their administration, basic system commands, packages, printing
- 5 Users, file and directory permissions
- 6 Work with files and directories, file compression, links, partition
- 7 Text-file processing commands, redirection, pipeline
- 8 Regular expressions
- 9 Command line based text editors
- 10 User and system variables, output processing
- 11 Scripts: basic construction, conditionals, loops, functions, automation
- 12 Networking, server-client services: http, (s)ftp, scp, ssh, sshfs, nfs
- 13 Programming in Linux (examples of Fortran, C/C++, Python), version control systems, documents in Latex

Shell Variables

Variables

BASH variables

You can use variables as in any programming languages. There are no data types. A variable in bash can contain a number, a character, a string of characters. You have no need to declare a variable, just assigning a value to its reference will create it.

- Creation and assigning a variable

```
STR="Hello World!"  
echo ${STR} # to refer to variable value, use $  
MYVAR=1000000  
echo ${MYVAR} MYVAR # this prints '1000000 MYVAR'
```

- There are system variables that control the behavior of the system/shell/GUI:
- The command **set** will list all the system/shell variables (and functions - see later)
- E.g. \$HOME - the HOME directory, \$LANGUAGE - the system language, \$PS1 - the look of the prompt
- E.g. \$PATH - the list of paths, where BASH looks for binary files
- User can define his own system variables by setting them in .bashrc (in your home directory)
- use **export MYVAR="value"** in order the variable behaves as global
- A variable can be in three states: defined with a value (MYVAR=value), defined with NULL value (MYVAR=) and unset. To unset a variable, use **unset MYVAR**.
- You can define new variables with existing ones:
NEWVAR=\${OLDVAR1}\${OLDVAR2} (this example merges two strings)

- Bash enables numerous operations on variable value and gathering information on the variable (besides "asking" for its value)

```
#{MYVAR} # the length of variable value
{!prefix*} # prints all variables with their names starting with "prefix"
{MYVAR#pattern} # removes the match for pattern from the beginnig of MYVAR value
{MYVAR/pattern} # same as above but from the end of value
${MYVAR/pattern/string} # replaces pattern in MYVAR with string
${MYVAR^^} and ${MYVAR,,} # makes variables characters upper/lower case
```

- In the above examples, variables are "expanded" to a new value, which can be written out (with echo) or just saved to different variable(s).
- In the followig example, we rename all jpg files in a directory to JPG

```
for f in *.jpg; do # we will learn later
  echo "Renaming $f ..."
  mv $f ${f/.jpg/.JPG}
done
```

For a full list of variable expansion possibilities, see https://www.gnu.org/software/bash/manual/html_node/Shell-Parameter-Expansion.html

Variables

Command output substitution in a variable

- The output of any command can be assigned to a variable as value in two syntactical way:

```
MYVAR=$( mycommand ) # preferred
MYVAR=' mycommand ' # not preferred
# the first way enables nesting:
MYVAR=$( mycommand $( anothercommand ) ) # mycommand takes the output of another command as argument
```

- `eval` - is a built-in Linux command which is used to execute arguments as a shell command. It combines arguments into a single string and uses it as an input to the shell and execute the commands.

```
MYVAR="ls -l /mydir"
eval $MYVAR
MYVAR='$'
MYVAR2=value
eval echo ${MYVAR}MYVAR2
```

- Use variable as a (part of) name for another variable.

```
MYVAR_A="123"
i=A
echo ${MYVAR_$i}
eval MYVAR_$i="456"
echo $MYVAR_A
```

- Bash supports 1-dimensional arrays with arbitrary integer indexing

```
MYARR= ( 1 2 a b ahøj abc) # definition of an array, in this case indexing is starting from zero
echo ${MYARR[0]} -> 1 etc.
MYARR[100] = value # we can define/add arbitrary index
MYARR=( [7]=a [10]=b [100]=c) # possibility of defining arbitrary index
MYARR+=(newelement1 newelement2) # extension of array
```

- Different information can be retrieved of arrays, including its length, list of elements, list of indexes

```
echo ${MYARR[*]} # prints all the elements
... ${#MYARR[*]} # number of elements
... ${!MYARR[*]} # the list of indexes
```


Scripts

Sequence of commands to be processed.

- Allows functions, loops, conditions, call external commands
- Two ways how to run a script:
 - `./script.sh`: starts a new shell and runs the script in it (script file must be executable:
`chmod +x ./script.sh`)
 - `source ./script.sh` (or also `. ./script.sh`: runs the commands from the script one by one in the current shell → i.e. as if one would write them manually in the current terminal)
 - `*.sh` used for *bash*-compatible scripts
 - `*.csh` used for *csh*-compatible scripts
- `#` are used for comments
- Special header "comment": `#!/usr/bin/zsh` instructs the script to be run by the *zsh* shell. Not only for shells, but also for interpreters like *python*
- `exit [number]` to quit script [and possibly return a *return code*]
 - Not needed at the very end of a script, it will end by itself
- `set -x` command inside a script instruct to show the commands being run by the script (i.e. for debugging)

Special characters (reminder)

- `'` (single quotes) do not interpret special chars, while `"` (double quotes) do
 - e.g. `echo '$i'` vs. `echo "$i"`
- ``` (single backquotes) to insert output of command between the quotes
 - But better use `$(command)` instead
- `;` (semicolon) allows to put more commands on single line
 - e.g. `echo "ahoj" ; echo "abc"`
- `&` at the end of line to run program in the background, while continuing in the script
- `\` (backslash) cancels meaning of a special character
 - e.g. `echo "\$i"`
 - e.g. not to interpret space (`./script.sh ahoj\ abc = ./script.sh "ahoj abc"`)
 - e.g. to allow quotes inside quotes (`echo "var = \"ahoj\""`)
 - at the end of line means wrapping - the line continues and the next line. Otherwise end-of-line is interpreted as delimiter of next command (equivalent of `;`)

```
echo \  
"ahoj"
```

```
for myfile in filename1 \  
             filename2 \  
             filename3 \  
do  
  echo $myfile  
done
```

Script special variables

Input arguments

The arguments passed with script are accessible via special variables

- `./script.sh arg1 arg2 arg3 ...`

```
$1, $2, $3, ...   Individual arguments on command line (positional parameters)
$#               Number of command-line arguments
$*               All arguments on command line (" $1 $2 ...")
$@               All arguments on command line, individually quoted (" $1" " $2" ...)
$0               Command name
```

- Use `shift` command to "destroy" the first argument and shift the list of arguments to left, i.e. `$1` becomes what was `$2`, `$2` what was `$3` etc., while original content of `$1` is lost

Control of run commands in script (as well as in shell)

```
 $?           Return value (exit code) of the last preceding command
 $!           Process ID number (PID, see 'ps auxf' of the last preceding command)
 $$           Process ID number of the current process (the shell running the script)
```

Quick check of input variables content (script: `$var` replace by `$1`)

```
 ${var:-value}  Use var if set; otherwise, use value
 ${var:=value}  Use var if set; otherwise, use value and assign value to var
 ${var:?value}   Use var if set; otherwise, print value and exit
 ${var:+value}  Use value if var is set; otherwise, use nothing
```

Test expressions

`test` **EXPRESSION**: compare values, check file types, same as [**EXPRESSION**]

[**EXPRESSION**]: more versatile version of []

(()): arithmetic tests (e.g. comparison of numbers)

- Return code `$?` is 0 if true, 1 if false

```
( EXPRESSION )           EXPRESSION is true
! EXPRESSION            EXPRESSION is false
EXPRESSION1 -a EXPRESSION2  both EXPRESSION1 and EXPRESSION2 are true
EXPRESSION1 -o EXPRESSION2  either EXPRESSION1 or EXPRESSION2 is true
-n STRING                the length of STRING is nonzero (also without -n)
-z STRING                the length of STRING is zero
STRING1 = STRING2        the strings are equal
STRING1 != STRING2       the strings are not equal
INTEGER1 -eq INTEGER2     INTEGER1 is equal to INTEGER2
INTEGER1 -ge INTEGER2     INTEGER1 is greater than or equal to INTEGER2
INTEGER1 -gt INTEGER2     INTEGER1 is greater than INTEGER2
INTEGER1 -le INTEGER2     INTEGER1 is less than or equal to INTEGER2
INTEGER1 -lt INTEGER2     INTEGER1 is less than INTEGER2
INTEGER1 -ne INTEGER2     INTEGER1 is not equal to INTEGER2
```

```
FILE1 -nt FILE2          FILE1 is newer (modification date) than FILE2
FILE1 -ot FILE2          FILE1 is older than FILE2
-d FILE                  FILE exists and is a directory
-e FILE                  FILE exists
-f FILE                  FILE exists and is a regular file
-L FILE                  FILE exists and is a symbolic link
-r FILE                  FILE exists and read permission is granted
-w FILE                  FILE exists and write permission is granted
-x FILE                  FILE exists and execute (or search) permission is granted
-s FILE                  FILE exists and has a size greater than zero
```

and other file flags (ownership, types)

- Arguments in **EXPRESSION** typically contain output of commands

```
test $(cat /etc/passwd | cut -d: -f1 | wc -l) -gt 100
test 'cat /etc/passwd | cut -d: -f1 | wc -l' -gt 100
```

- Be careful to treat cases when arguments in expression can contain spaces, better always use `"` for string arguments (works for integers too though), especially when argument is an output of command with not-well predictable result ! (e.g. filenames can contain spaces...)

```
i="ahoj abc"
test $i = "ahoj abc"      # results in: bash: [: too many arguments
test "$i" = "ahoj abc"   # OK
```

`[]` vs `[[]]`: Using the `[[...]]` test construct, rather than `[...]` can prevent many logic errors in scripts. For example, the `&&`, `||`, `<`, and `>` operators work within a `[[]]` test, despite giving an error within a `[]` construct. Arithmetic evaluation of octal or hexadecimal constants takes place automatically within a `[[...]]` construct.

```
[[ -L $file && -f $file ]] works in [[ ]]  
[ -L "$file" ] && [ -f "$file" ]  
[[ a < b ]]: lexicographical comparison  
[ a \< b ]: Same as above. \ required or else does redirection like for any other command.  
[[ a = a && b = b ]]: true, logical and  
[ a = a && b = b ]: syntax error, && parsed as an AND command separator cmd1 && cmd2  
[[ ( a = a || a = b ) && a = b ]] vs. [ ( a = a ) ]: syntax error, ( ) is interpreted as a subshell
```

`((EXPRESSION))`

```
(( 5 > 4 ))  
(( 5 == 5 ))  
(( t = 40 < 45?7:11 )) # C-style ternary operator.  
echo "If 40 < 45, then t = 7, else t = 11."
```

Use result of `test`

- Notation using square brackets `[EXPRESSION]`

```
if [ EXPRESSION ]
then
  command1
elif [ EXPRESSION ]
then
  command2
else
  command3
fi
```

```
if [ EXPRESSION ] ; then
  command1
elif [ EXPRESSION ] ; then
  command2
else
  command3
fi
```

- Short one-command condition using `&&` and/or `||`:

```
[ EXPRESSION ] && command1 || command2
```

- is equivalent to:

```
if [ EXPRESSION ] ; then command1 ; else command2 ; fi
```


Equivalent of `if/then/elif/elif/.../else/fi` statements chain

- Can use shell pattern matching (e.g. `*`)
- Use `|` for OR of matches
- On match the sequence of commands is run till `;;`
- `*`) typically used for safety `else` with an error message that there was no match

```
case $varname in
  pattern1)
    command1
    ;;
  pattern2|pattern3|pattern4)
    command2
    ;;
  *)
    command_error_no_match
esac
```

Loops - while/until/do/done

Keep looping (un)till EXPRESSION is valid

- Assuming the arguments in the EXPRESSION are changing during the sequence of commands in the loop, thus allowing the loop to stop at some point
- Can immediately stop the loop with **break** command
- Can immediately jump to next iteration with **continue** command

While

Stop looping if EXPRESSION becomes false

```
while [ EXPRESSION ]
do
  commands
  if [ ... ] ; then break ; fi      # alternative way to stop the loop
done
```

Until

Stop looping when EXPRESSION becomes true

```
until [ EXPRESSION ]
do
  commands
  if [ ... ] ; then break ; fi      # alternative way to stop the loop
done
```

For cycle

Loop over predefined list of items

- The list of items to cycle over is space-separated
- Can immediately stop the loop with **break** command
- Can immediately jump to next iteration with **continue** command
- **seq 1 100** to generate list of indexes from 1 to 100

```
for var_i in item1 item2 item3
do
    commands
    if [ ... ] ; then break ; fi      # possible way to stop the loop prematurely
done
```

Space separation in list

- Potentially dangerous when list contains items with space, e.g. weird filenames
- For files use **find** command instead of **for** cycle
- Or replace spaces by a defined string and inside the loop revert this replacement:

```
# Would not work for files with space
for i in $(ls -l) ; do
    echo $i
done

# Works:
for ii in $(ls -l | sed 's, __mezera__,g') ; do
    i=$(echo $ii | sed 's, __mezera__, ,g')
    echo $i
done
# Works
find . -maxdepth 1 -name '*' -exec echo {} \;
# Works
find . -maxdepth 1 -name 'a*' | while read i ; do echo $i ; done
```

Loop over predefined list of items - cont'd

- The list of items to cycle over can be defined alternatively like:

```
for i in {1..5};do echo $i ;done
# from BASH v4.0+, {START..END..INCREMENT} syntax
for in {0..10..2};do echo $i ;done
# control the width of the loop item:
for i in {001..500};do echo $i ;done
# or combining with other character and multiple ranges
for i in a{001..500} {700..999};do echo $i ;done

## The C-style Bash for loop
for (( initializer; condition; step ))
for (( c=1; c<=5; c++ ));do echo $c ;done
```

Similar behaviour as in other programming languages

- Mostly to help organization/readability of the code
- Accept parameters, treated in similar way as input parameters of scripts (i.e. \$1, \$2, etc.)
- Output transferred via `echo` command or e.g. my modifying a "global" variable

```
x=0

myfunc() {
  for i in $@ ; do
    echo $i
  done
  x=1
}

echo $x
myfunc a bb cc 123
echo $x
x=0
str='myfunc dd ee' # x is not changed, myfunc is run in separate shell !
echo $str
echo $x
```

Use of `getopt` command

- Colon `:` after option letter specifies that the option is expecting an argument

```
while getopts 'ha:' OPTION; do
  case "$OPTION" in
    h)
      echo "Option h (does not expect argument)"
      ;;
    a)
      echo "Option a with value \"${OPTARG}\""
      ;;
    ?)
      echo "script usage: $(basename $0) [-h] [-a somevalue]" >&2
      exit 1
      ;;
    esac
  done
  shift "$(($OPTIND -1))"

  echo "Remaining input arguments: $@"
```

- Exercise 1: How to compare floating-point numbers ? Hint `bc -l`, `python -c ...`
`exit`, `print`
- Exercise 2: Loop through all links in current directory (and sub-directories), check the file really exists (link is valid)
- Exercise 3: Store script input parameters into variables array. Iteratively destroy input parameters one by one and print the remaining on the screen (try all `for`, `while` and `until` loops)

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- Exercise 3: Store script input parameters into variables array. Iteratively destroy input parameters one by one and print the remaining on the screen (try all `for`, `while` and `until` loops)
- Exercise 4: For cycle to generate N random numbers (N=1000 if no argument passed to the script) and print the highest value. Hint: `$RANDOM`.
- Exercise 5: Select random 500 lines from `mcData.txt` (make sure the lines do not repeat)
- Exercise 6: Loop through archives `backup*`, search for files named `Invariant_masses.txt`, join their content with `mcData.txt` and remove duplicated lines
- Exercise 7: Batch analysis: script triggering a computation jobs
 - Job = generate 100 random numbers with given seed in `rnd.txt`, sleep 1 sec between the generation
 - Run max. 5 jobs in parallel
 - Allow the script to run more than once without breaking the rule above
 - Hint: use flag-files or `ps axuf` to find out which jobs are running, which are finished

Scripts running after logout

nohup

- Most simple way to keep process running after logout (or killing mother terminal)
- Syntax: `nohup command arguments`
- Output goes to `nohup.out` file

screen

- More complex system, behaving as a virtual terminal, allowing to:
 - Detach and re-attach to running session
 - After re-attaching one can see the output of the session
 - Works better on remote machines with complex authentication
 - Can name sessions
 - `screen` allows to send command to a running detached session
- `screen` to start a session
 - `CTRL-a d` to detach from session
 - `screen -list` to list sessions (either attached or detached)
 - `screen -r` to attach to a sessions

tmux

- Similar functionality to `screen`, but more actively developed
- `tmux` to start a session
 - `CTRL-b d` to detach from sessions
 - `tmux ls` to list sessions
 - `tmux attach` to attach

CRON system:

- `/etc/crontab`: basic file to run tasks per hour/day/week/month
- `/etc/cron.hourly`
- `/etc/cron.daily`
- `/etc/cron.weekly`
- `/etc/cron.monthly`
- `/etc/cron.d`: more complicated rules

```
# /etc/cron.d/renew_prak0x: crontab entries for reweal of the prak0x user home directories
# Execute only during the period of the exercises (01.Oct - 20.Jan)
# TODO ?: Add entry in between day in case of 2 excercises per single day

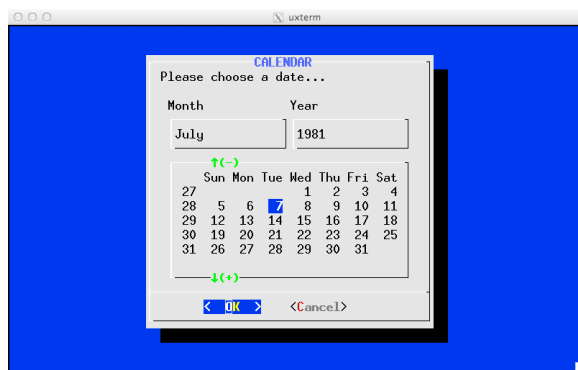
SHELL=/bin/bash

# m h dom mon dow user  command
32 01 * OCT,NOV,DEC,JAN SUN root /home/prak_template/bin/reboot.cron.sh
# NO!!! (studenti by po rebooutu nenasli sva data !)
#@reboot root /home/prak_template/bin/renew_prak0x.cron.sh
12 03 * OCT,NOV,DEC * root /home/prak_template/bin/renew_prak0x.cron.sh
12 03 1-20 JAN * root /home/prak_template/bin/renew_prak0x.cron.sh
```

Graphical interface to scripts

Programs to easily create simple graphics interfaces:

- Calendar
- File selection
- Forms
- Messages
- Lists
- Progress bars
- Text entry



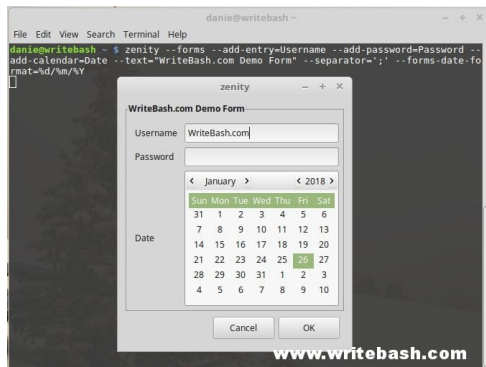
dialog

- Terminal-based graphics
- See number of examples in </usr/share/doc/dialog/examples>

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dialog

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zenity / gdialog

- Graphical windows (GTK)
- See examples at <https://help.gnome.org/users/zenity/3.32/>