bw HPC – C5

Advanced Bash Scripting

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How to read the following slides

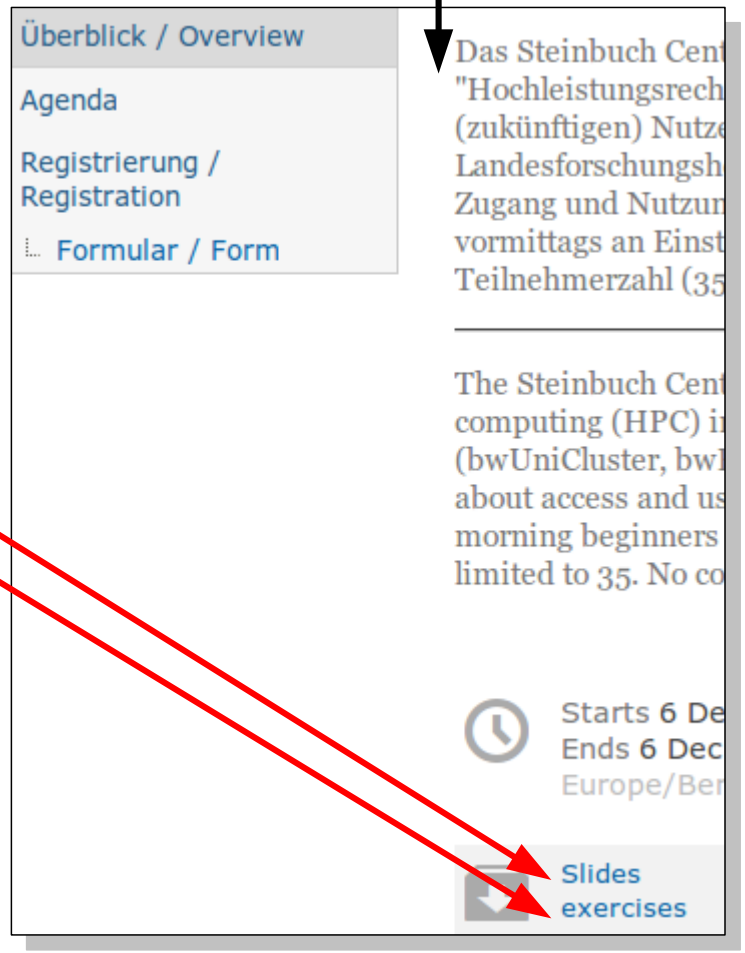
Abbreviation/Colour code	Full meaning
`$ command -opt value`	*$* = prompt of the interactive shell The full prompt may look like: `user@machine:path $` The command has been entered in the interactive shell session
`<integer>` `<string>`	<> = Placeholder for integer, string etc
`foo, bar`	Metasyntactic variables
`${WORKSHOP}`	`/pfs/data1/software_uc1/bwhpc/kit/workshop/2018-04-12`

Sources of this slides?

- http://tldp.org/HOWTO/Bash-Prog-Intro-HOWTO.html (intro)
- http://tldp.org/LDP/abs/html (advanced)
- ***$* man bash**

Where to get the slides and exercises?

- http://indico.scc.kit.edu/indico/e/bwhpc_course_2018-04-12 or uc1:/pfs/data1/software_uc1/bwhpc/kit/workshop/2018-04-12
  - Slides
  - Exercises



Why (not) Bash?!

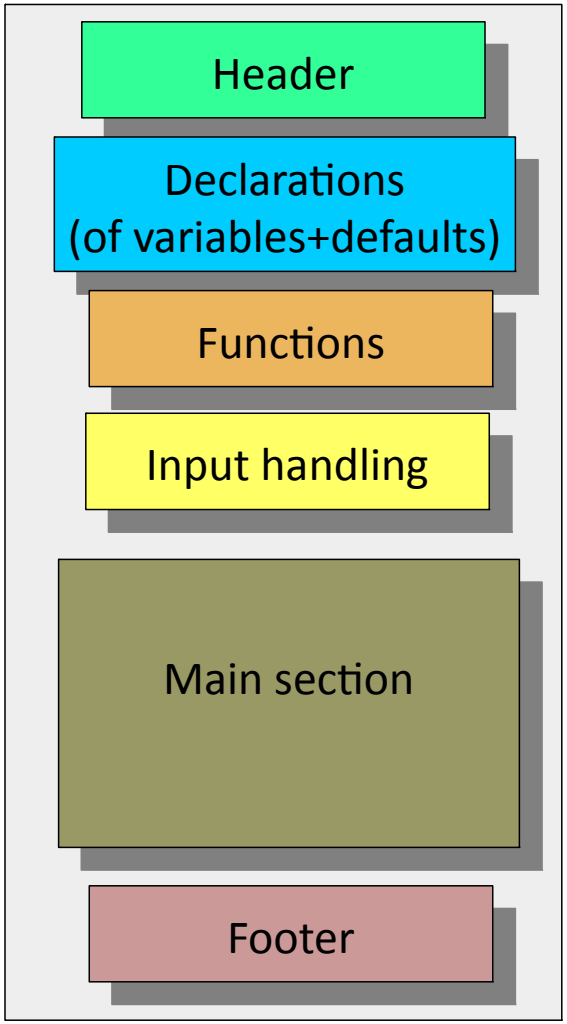
- Great at:
  - managing batch jobs
  - managing external programs
  - invoking entire UNIX command stack & many builtins
- Powerful scripting language
- Portable and version-stable
- Bash almost everywhere installed

- Less useful when:
  - Resource-intensive tasks (e.g. sorting, recursion, hashing)
  - Heavy-duty math operations
  - Extensive file operations
  - Need for native support of multi-dimensional arrays

Goal

- Be descriptive!
  - Comment your code
    - e.g. via headers sections of script and functions.
  - Decipherable names for variables and functions
- Organise and structure!
  - Break complex scripts into simpler blocks

    e.g. use functions
  - Use exit codes
  - Use standardized parameter flags for script invocation.



Header & Line format

- Sha-Bang = '#!'
  → at head of file = 1. line only!

```
#!/bin/bash
```

  - Options: e.g. debugging shell):

```
#!/bin/bash -x
```

  - #!/bin/sh → invokes default shell interpreter → mostly Bash
  - If path of bash shell varies:

```
#!/usr/bin/env bash
```

- Line ends with no special character!
  - But multiple statements in one line to be separated by:

`;` Semicolon

```
echo hello; echo World; echo bye
```

- Group commands
  - In current shell:

```
{ cmd1; cmd2; }
```

  - In subshell:

```
(cmd1; cmd2)
```

Bash Output

- **echo**

  a) trails every output with a „newline“

```
$ echo hello; echo World
hello
World
```

  b) prevent newline:

```
$ echo -n hello; echo World
helloWorld
```

  c) parsing „escape sequences“

```
$ echo -e "hello\nWorld"
hello
World
```

- **printf** = „enhanced“ echo
  - by default no „newline“ trailing
  - formated output

```
$ printf hello; printf World
helloWorld$
```

```
$ printf "%-9.9s: %03d\n" "Integer" "5"
Integer  : 005
```

Special bash characters (1)

Chars with meta-meaning

Comments

- at beginning
- at the end
- exception: escaping, quotes, substitution

```
# This line is not executed
```

```
echo 'something' # Comment starts here
```

**** Escape = Quoting mechanism for single characters

```
echo \#
```

' Full Quotes = Preserves all special characters within

```
echo '#'
```

" Partial Quotes = Preserves some of the special characters, but not ${var}

```
var=42
echo "\${var} = ${var}"; echo '\${var} = ${var}'
```

Special bash characters (2)

Chars with meta-meaning

`$(  )` Command subsitution

old version: `` ` ` `` (backticks) → do not use anymore

```
$ echo "today = $(date)"
today = Wed Oct 11 02:03:40 CEST 2017
```

`(  )` Group commands in a subshell

```
$ (ls -l; date)
```

`((  ))` Double-parentheses construct

→ arithmetic expansion and evaluation

```
$ echo $((1 + 3))
4
```

$ prefixing of (( )) to return the value it holds

`[  ]` Test builtin (cf. slide 24)

or

Array element (cf. slide 11)

Globbing

- = filename expansion

  → recognices and expands „wildcards“
- but this is **not** a Regular Expression interpretion (for such use awk/sed)

- wildcards:

  `*` = any multiple characters

  `?` = any single character

  `[]` = to list specific character

  e.g. list all files starting with a or b

```
$ ls [a,b]*
```

  `^` = to negate the wildcard match

  e.g. list all files not starting with a

```
$ ls [^a]*
```

Variables (1)

- Substitution:
  - No spaces before and after '='
  - Brace protect your variables!

    → check difference:
  - Values can be generated by commands

```
var1=abcdef
```

```
var2=01_${var1}_gh
        vs
var3=01_$var1_gh
```

```
$ echo ${var2}
01_abcdef_gh
$ echo ${var3}
01_
```

```
var4=$(date)
```

- Bash variables are untyped

  → essentially strings,

  → depending on content arithmetics permitted

```
$ a=41; echo $((a+1))
42
```

```
$ a=BB; echo $((a+1))
1
```

→ string has an integer value of 0

- declare/typeset (bash builtin)
  - set variable to integer, readonly, **array** etc.

```
$ declare -r a=1
$ let a+=1
bash: a: readonly variable
```

```
$ declare -a arr=( '1 2' 3)
$ echo ${arr[0]}
1 2
```

← space is separator

Variables (2)

- declare – *cont.*
  - Arrays: e.g. store file content in array:

a) 1 element per string

```
a=( $(< file) )
```

=

```
a=( $(cat file) )
```

b) 1 element for whole file

```
a=( "$(< file)" )
```

c) 1 element per line

```
while read -r line; do
   a+=( "${line}" )
done < file
```

- Usage only without **$** prefix when declare, assign, export, unset

```
declare -i a=41
export a
echo ${a}
unset a
echo ${a}
```

Manipulation of Variables (1)

Syntax	Does?	Examples
`${#var}`	String length	`$ A='abcdef_abcd'; echo ${#A}` `11`
`${var:pos:len}`	Substring extraction:	
	a) via Parameterisation	`$ POS=3; echo ${A:${POS}:2}` `de`
	b) Indexing from right	`$ echo ${A:(-2)}` `cd`
`${var#sstr}`	Strip shortest match of $sstr from front of $var	`$ sstr=a*b; echo ${A#${sstr}}` `cdef_abcd`
`${var%sstr}`	Strip shortest match of $sstr from back of $var	`$ sstr=c*d; echo ${A%${sstr}}` `abcdef_ab`
`${var/sstr/repl}`	Replace first match of $sstr with $repl	`$ sstr=ab; rp=AB; echo ${A/${sstr}/${rp}}` `ABcdef_abcd`
`${var//sstr/repl}`	Replace all matches of $sstr with $repl	`$ echo ${A//${sstr}/$rp}` `ABcdef_ABcd`
`${var/#sstr/repl}`	If $sstr matches frond end, replace by $repl	`$ sstr=a; rp=z_; echo ${A/#${sstr}/${rp}}` `z_bcdef_abcd`
`${var/%sstr/repl}`	If $sstr matches back end, replace by $repl	`$ sstr=d; rp=_z; echo ${A/%${sstr}/${rp}}` `abcdef_abc_z`

Manipulation of Arrays

Syntax	Does?	Examples
`${#array[@]}`	Number of elements	`$ dt=( $(date) ); echo ${#dt[@]}` `6`
`${array[@]:p1:p2}`	Print elements from no. **p1** to **p2**:	`$ echo ${dt[@]:1:2}` `Feb 25`
`${array[@]#sstr}`	Strip shortest match of $sstr from front of all elements of Array	`$ sstr=W*d; echo ${dt[@]#${sstr}}` `Feb 25 10:18:22 CET 2015`

- Adding elements to an array:

  a) at the end:

```
$ dt+=( "AD" )
$ echo ${dt[@]}
Wed Feb 25 17:18:22 CET 2015 AD
```

  b) in-between

```
$ dt=( ${dt[@]:0:2} ':-)' ${dt[@]:2}} )
$ echo ${dt[@]}
Wed Feb 25 :-) 17:18:22 CET 2015
```

Exercise 1: Variables and Arrays (5min)

- Write a bash script that:
  - Defines a readonly output file name based on:
    - `$LOGNAME`
    - Arbitrary string generate in subshell via: `(mktemp -u XXXX)`
    - First 2 characters of the current month using bash array

Exercise 1: Variables and Arrays - Solution

- Write a bash script that:
  - Defines a readonly output file name based on:
    - `$LOGNAME`
    - Arbitrary string generate in subshell via: `(mktemp -u XXXX)`
    - First 2 characters of the current month using bash array

`${WORKSHOP}/solutions/01/exercise_1.sh`

```
#!/bin/bash

# in case language is en_us.utf8, month is 2.element in "date"
tmp=($(date))
month=${tmp[1]:0:2}

declare -r outputfile="${LOGNAME}_$(mktemp -u XXXX)_${month}.log"
echo ${outputfile}

# Try changing output file
outputfile="new"
```

Output & Input Redirection (1)

Syntax	Does?	Examples
`exe > log`	Standard output (stdout) of application exe is (over)written to file log	`$ date > log; cat log`
`exe >> log`	Standard output (stdout) of application exe is append to file log	`$ date >> log; cat log`
`exe 2> err`	Standard output (stderr) of application exe is (over)written to file err	`$ date 2> err; cat err`
`exe 2>> log`	Standard output (stderr) of application exe is append to file log	`$ date 2>> err; cat err`
`exe >> log 2>&1`	Redirects stderr to stdout	`$ date >> log 2>&1`
`exe1 | exe2`	Passes stdout of exe1 to standard input (stdin) of exe2 of next command	`# Print stdout & stderr to screen and then append both to file` `$ date 2>&1 | tee -a log`
`exe < inp`	Accept stdin from file inp	`$ wc -l < file`

Output & Input Redirection (2)

- Take care of order when using redirecting
  - e.g:

```
(ls -yz; date) >> log 2>&1
```

→ Stdout (date) redirected to file
→ Stderr (invalid option of ls) redirected to file pointed to by stdout

```
(ls -yz; date) 2>&1 >> log2
```

→ Stderr (invalid option of ls) redirected to stdout (channel), but not written file
→ Stdout (date) redirected to file

- Suppressing stderr

```
ls -yz >> log 2>/dev/null
```

Usage? Keep variable empty when error occurs,

→ e.g. list of files with extension log

```
list_logs="$(ls *.log 2>/dev/null)"
```

Output & Input Redirection (3)

- Redirection of „all“ output in shell script to one user file

  → generalise = define variable

```
#!/bin/bash

log="blah.log"
err="blah.err"

echo "value 1" >> ${log} 2>> ${err}
command >> ${log} 2>> ${err}
```

  → or use exec

```
#!/bin/bash

exec > "blah.log" 2> "blah.err"

echo "value 1"
command
```

→ all stdout and stderr after 'exec'
will be written to blah.log and blah.err resp.

Output & Input Redirection (4)

- Reading input e.g. file line by line

${WORKSHOP}/exercises/01/01_read_input.sh

```
#!/bin/bash

declare -i i=1
while read -r line ; do
   echo "line ${i}: ${line}"
   let i+=1
done < 01_input_file
```

- Reading output of other commands line by line, e.g. ls -l

${WORKSHOP}/exercises/01/02_read_input.sh

```
#!/bin/bash

declare -i i=1
while read -r line ; do
   echo "line ${i}: ${line}"
   let i+=1
done < <(ls -l *)
```

Process substition:
form of redirection; input/output of process = temp file

Manipulation of Variables (2)

- Example:

${WORKSHOP}/exercises/01/03_var_manipulation.sh

```
#!/bin/bash

## Purpose: Define automatic output names for executables

exe="03_binary.x"

## Assume: $exe contains extension .x or .exe etc
sstr=".*"
log="${exe%${sstr}}.log"  ## replace extension with .log
err="${exe%${sstr}}.err"  ## replace extension with .err

## Define command: echo and run
echo "${exe} >> ${log} 2>> ${err}"
${exe} >> ${log} 2>> ${err}
```

Expansion of Variables

Syntax	Does?	Examples
`${var-${def}}`	If $var not set, set value of $def	`$ unset var; def=new; echo ${var-${def}}` `new`
`${var:-${def}}`	If $var not set or *is empty*, set value of $def	`$ var=''; def=new; echo ${var:-${def}}` `new`
		`# Output name for interactive and MOAB` `jobID=${MOAB_JOBID:-${BASHPID}}`

`${var:?${err}}`	If $var not set or *is empty*, print $err and abort script with exit status of 1	`$ var=''; err='ERROR - var not set'`
		`$ echo ${var:?${err}}`
		`bash: var: ERROR - var not set`

Exit & Exit Status

- Exit terminates a script
- Every command returns an exit status
  - successfull = 0
  - non-successfull > 0 (max 255)
- **$?** = the exit status of last command executed (of a pipe)

```
ls -xy 2>/dev/null; echo $?
2
```

- Special meanings (avoid in user-specified definitions):
  - 1 = Catchall for general errors
  - 2 = Misuse of shell builtins
  - 126 = Command invoked cannot execute (e.g. /dev/null)
  - 127 = "command not found"
  - 128 + n = Fatal error signal "n" (e.g. kill -9 of cmd in shell returns 137)

(Conditional) Tests

```
if condition1 ; then
   do_if_cond1_true/0
elif condition2 ; then
   do_if_cond2_true/0
else
   do_the_default
fi
```

condition	Does?	Examples
`(( ))`	Arithmetic evaluation	`$ if (( 2 > 0 )) ; then echo yes ; fi` `yes`

`[ ]`	Part of (file) test builtin, arithmetic evaluation only with `-gt`, `-ge`, `-eq`, `-lt`, `-le`, `-ne`	`$ if [ 2 -gt 0 ] ; then echo yes ; fi`
		`yes`
		`$ # existance of file`
		`$ if [ -e "file" ] ; then echo yes ; fi`

`[[ ]]`	Extented test builtin; allows usage of `&&`, `||`, `<`, `>`	`$ a=8; b=9`
		`$ if [[ ${a} < ${b} ]]; then echo $? ; fi`
		`0`

Typical File Tests

- (not) exists:
```
if [ ! -e "file" ] ; then echo "file does not exist" ; fi
```
- file is not zero:
```
[ -s "file" ] && (echo "file greater than zero")
```
- file is directory:
```
[ -d "file" ] && (echo "This is a directory")
```

- readable:
- writeable:
- executable:

```
[ -r "file" ]

[ -w "file" ]

[ -x "file" ]
```

- newer that file2:
```
[ "file" -nt "file2" ]
```

- Pitfalls when using variables:

wrong:
```
$ unset file_var; if [ -e ${file_var} ] ; then echo "yes" ; fi
yes
```

right:
```
$ unset file_var; if [ -e "${file_var}" ] ; then echo "yes" ; fi
```

for Loops

```
for arg in list
   do
    command
done
```

- Iterates command(s) until all arguments of *list* are passed
- *list* may contain globbing wildcards

- Example 1

```
#!/bin/bash

## Example 1: Loop over generated integer sequence
counter=1
for i in {1..10} ; do
   echo "loop no. ${counter}: ${i}"
   let counter+=1
done
```

- Example 2

```
## Example 2: Loop over space separated list of strings
list="file_1,file_2,file_3"
for x in ${list//,/" "} ; do
   echo ${x}
done
```

while Loops

```
while condition
   do
    command
done
```

- Iterates command(s) as long as *condition* is true (or exit status 0)
- Allows indefinite loops

- Example

```
#!/bin/bash

## Purpose: Loop until max is reached
max=10
i=1
while (( ${max} >= ${i} )) ; do
   echo "${i}"
   let i+=1
done
```

Positional parameters (1)

= Arguments passed to the script from the command line

Special variable	Meaning, notes
`$0`	Name of script itself
`$1, $2, $3`	First, second, and third argument
`${10}`	10th argument, but: `$10 = $1 + 0`
`$#`	Number of arguments
`$*`	List of all arguments as one single string
`$@`	List of all arguments, each argument separately quoted

Example:

Show differences between ${*} and ${@}

```
echo "Number PPs: ${#}"

i=1
for PP in "${@}" ; do
   printf "%3.3s.PP: %s\n" "${i}" "${PP}"
   let i+=1
done

i=1
for PP in "${*}" ; do
   printf "%3.3s.PP: %s\n" "${i}" "${PP}"
   let i+=1
done
```

${WORKSHOP}/exercises/01/04_special_var.sh

Positional parameters (2)

= Arguments passed to the script from the command line

Special variable	Meaning, notes
`$0`	Name of script itself
`$1, $2, $3`	First, second, and third argument
`${10}`	10th argument, but: `$10 = $1 + 0`
`$#`	Number of arguments
`$*`	List of all arguments as one single string
`$@`	List of all arguments, each argument separately quoted

Shifting positions:

shift Drops $1 → shifts $2 to $1 → $3 to $2 and so → $# is reduced by 1

Conditional evaluation - case

```
case variable in
   condition1)
      do_if_cond1_true/0
      ;;
   *)
      do_the_default
      ;;
esac
```

- analog to switch in C/C++
- to simplify multiple if/then/else
- each condition block ends with double semicolon
- If a condition tests true:
  - a) commands in that block are executed
  - b) case block terminates

${WORKSHOP}/exercises/01/05_case.sh

```
#!/bin/bash

## Purpose: Color output red or blue
e0="\033[0m";eR="\033[31;1m";eB="\033[34;1m"
case ${1} in
  red)
    echo -e "${eR}This line is red${e0}"
    ;;
  blue)
    echo -e "${eB}This line is blue${e0}"
    ;;
  *)
    echo -e "Line wo color" ;;
esac
```

Excerise 2 (10-15 min)

- Write Script that processes options:

  `-h`

  `-i <integer>`

  without shell build getopts combining „positional parameter“, „shift“, „tests“, „case“ and „while“

`Template: ${WORKSHOP}/exercises/01/06_proc_input.sh`

`→ Replace everything betw ... and ... by code`

```
#!/bin/bash

while ...test total num_positional parameter (PP) greater zero... ; do
   case "PP1" in
      ## script option: -h
      ...PP is option1...) ...echo something...
      ;;
      ...PP is option2...) ...echo PP2...
                           ...do PP shift...
      ;;
   esac
   ...do PP shift...
done
```

Excerise 1: Solution
Processing Input without *getopts*

- Combining: Positional parameter + shift + tests + case + while

${WORKSHOP}/solutions/01/06_proc_input.sh

```
#!/bin/bash

## Purpose: Processing positional parameters

while (( ${#} > 0 )) ; do
   case "${1}" in

      ## script option: -h
      -h) echo "${1}: This option is for HELP"  ;;

      ## script option: -i + argument
      -i) echo "${1}: This option contains the argument ${2}"
          shift ;;

      ## default
       *) echo "${1}: This is non-defined PP"   ;;
   esac
   ## Shifting positional parameter one to the left: $1 <-- $2 <-- $3
   shift
done
```

Lifetime of Variables (1)

- Script execution:
  - assigned variables only known during runtime
  - assigned variables not known in „slave“ scripts until „exported“
  - Example:

${WORKSHOP}/exercises/01/07_master_parse_var.sh
${WORKSHOP}/exercises/01/08_slave_get_var.sh

```
#!/bin/bash

## Purpose: Demonstrate parsing of assigned variables

var1="Non-exported value of var1"
export var2="Exported value of var2"
slave_sh="./08_slave_get_var.sh"

## check if $slave_sh is executable for user
echo "${0}: \$var1 = $var1"
echo "${0}: \$var2 = $var2"
if [ -x "${slave_sh}" ] ; then
   "${slave_sh}"
fi
```

- But: export of variables in script to interactive shell session only via:

`$ source script.sh` (compare ~/.bashrc)

Lifetime of Variables (2)

- Environmental variables

  a) can be read in e.g. `my_workDIR=${PWD}`

  b) during script changed, example:

```
...
## Purpose: Demonstrating effects on environmental variables

## Changing it during runtime
export HOME="new_home_dir"
echo "${0}: \${HOME} = ${HOME}"
...
```

${WORKSHOP}/exercises/01/09_env_var.sh

```
$ echo ${HOME}; ./06_env_var.sh; echo ${HOME}
/home/kit/scc/ab1234
./env_var.sh: ${HOME} = new_home_dir
/home/kit/scc/ab1234
```

awk & sed: Command substitution

- **awk**

  → full-featured text processing language with a syntax reminiscent of C

  → use for complicated arithmetics or text or *regular expression* processing

  - Examples:

    a) logarithm of variable:

    ```
    a=10; echo ${a} | awk '{print log($1)}'
    ```

    b) first column reformated:

    ```
    awk '{printf "%20.20s\n",$1}' file
    ```

  - One-liners: http://www.pement.org/awk/awk1line.txt

- **sed**

  → non-interactive stream editor

  → use for deleting blank or commented lines etc

  - Example: delete all blank lines of a file:

    ```
    sed '/^$/d' file
    ```

  - One-liners: http://sed.sourceforge.net/sed1line.txt

Functions (1)

```
function my_name ()
{
    commands
}
```

- Stores a series of commands for ***later*** or ***repeative*** execution
- Functions are called by writing the name
- **Like scripts:** functions handle positional parameters
- Example:

${WORKSHOP}/exercises/01/10_fct.sh

```
#!/bin/bash

## Purpose: Demonstrating features of functions

## Add to printf command the date string
function my_printf ()
{
   printf "${0}: $(date): ${@}"
}

my_printf "Hello World\n"
```

Functions (2)

- **`local`** variables: values do not exist outside function, example:

```
#!/bin/bash
## Purpose: Demonstrating features of functions

var1="global value"

## Function: assign to global var1 temporarily a local value
function locally_mod_var ()
{
   local var1=${1}
   if [ -z "${var1}" ] ; then
      return 1
   fi
   echo "fct: local \${var1} = ${var1}"
   var1="new value in fct"
   echo "fct: local \${var1} = ${var1}"
}

echo "main: global \${var1} = ${var1}"
locally_mod_var "${var1}"
echo "main: global \${var1} = ${var1}"
```

${WORKSHOP}/exercises/01/11_fct.sh

- **`return`**: Terminates a function, optionally takes integer = „exit status of the function“

Trap

- Catch abort signals, e.g.
  - SIGHUP = Hangup
  - SIGINT = Interrupt (Ctrl + C)
  - SIGTERM = Termination signal (kill -15)

  and do something (e.g. cleanup) before abort

- Example:

${WORKSHOP}/exercises/01/12_trap.sh

```
#!/bin/bash

cleanup(){
   echo "Cleanup before interrupt and exit"
   exit 0
}

## Trap interrupt with funtion cleanup
trap "cleanup" SIGINT

## Loop forever doing not really anything
while true ; do
   sleep 10
done
```

Thank you for your attention!