CS6

Practical System Skills

Fall 2019 edition

Leonhard Spiegelberg
lspiegel@cs.brown.edu

Errata

Lecture01: Slide 35

Welcome to different standards…

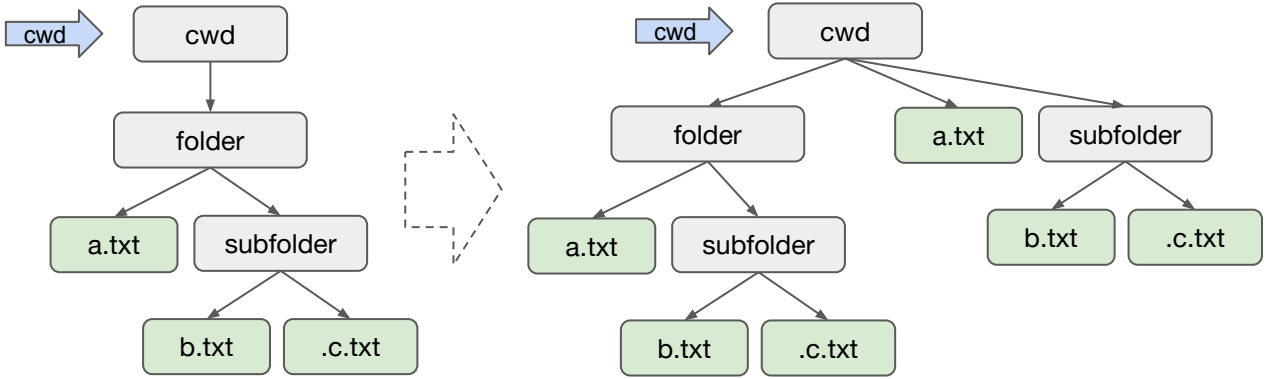
*NIX is not *NIX...

Mac OS X: `ls -G` displays colors

GNU/Linux: `ls --color`

Lecture 02: (Slide 20) GNU/Linux vs. BSD

```
cp -R folder/ .
```



Mac OS X/BSD: ⇒ the trailing / in cp is accounted for

GNU/Linux: ⇒ the trailing / in cp is not accounted for,
however to get BSD behavior use `cp -R folder/* .`

Recap

05.07 Recap - File permissions

Unix has file permission to retrict access

Permissions can be changed using chmod
⇒ symbolic mode
⇒ numeric mode

Octal	Binary	String	Description
0	000	---	no permissions
1	001	--x	execute only
2	010	-w-	write only
3	011	-wx	write and execute
4	100	r--	read only
5	101	r-x	read and execute
6	110	rw-	read and write
7	111	rwx	read, write and execute

`chmod u=rw,g=rx,o= file.txt` ⇒ `chmod 650 file.txt`

05.07 Recap - Streams & Pipes

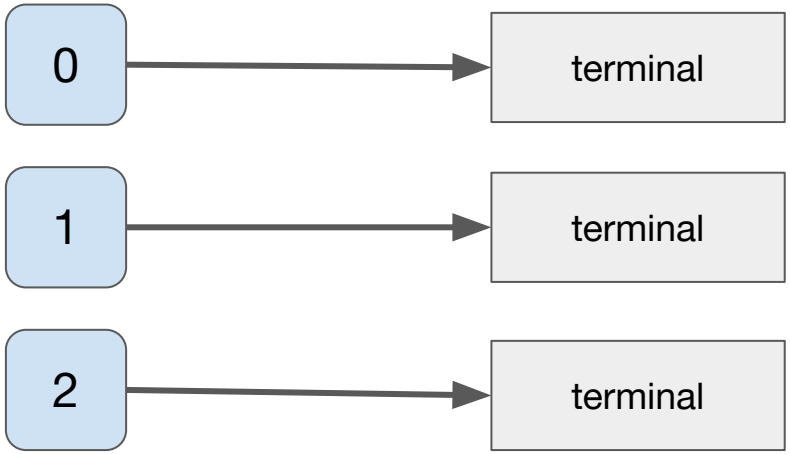
standard streams: 0 = stdin, 1 = stdout, 2 = stderr

⇒ can connect streams of commands via pipe operator |

⇒ >, <, >>, << to redirect streams to/from files

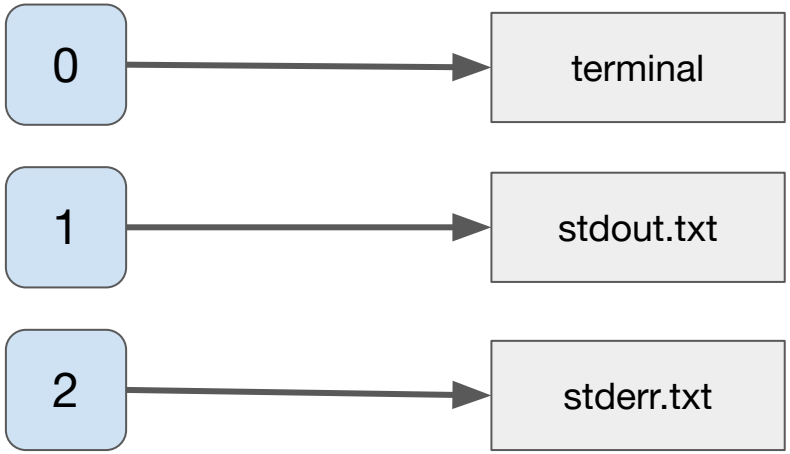
More on stream redirection

05.08 Redirecting streams



When the shell is started, it sets up the 3 standard file descriptors (0=stdin, 1=stdout, 2=stderr) and redirects them to the terminal

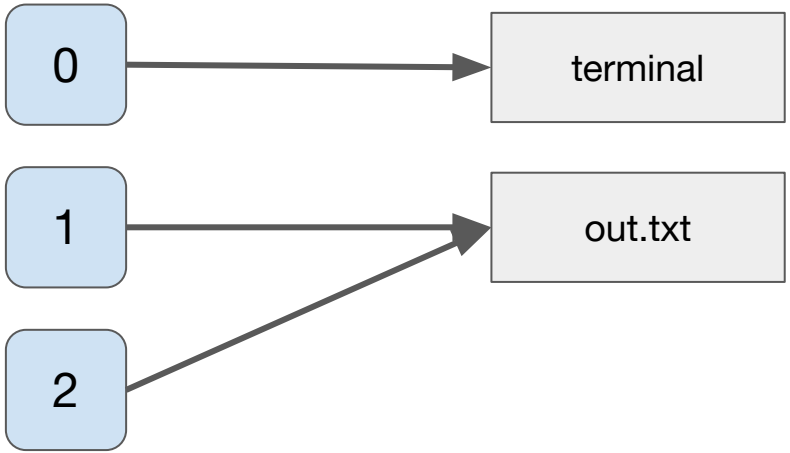
05.08 Redirecting streams




```
cmd > stdout.txt 2> stderr.txt
```

1> (or >) to redirect stdout, 2> to redirect stderr

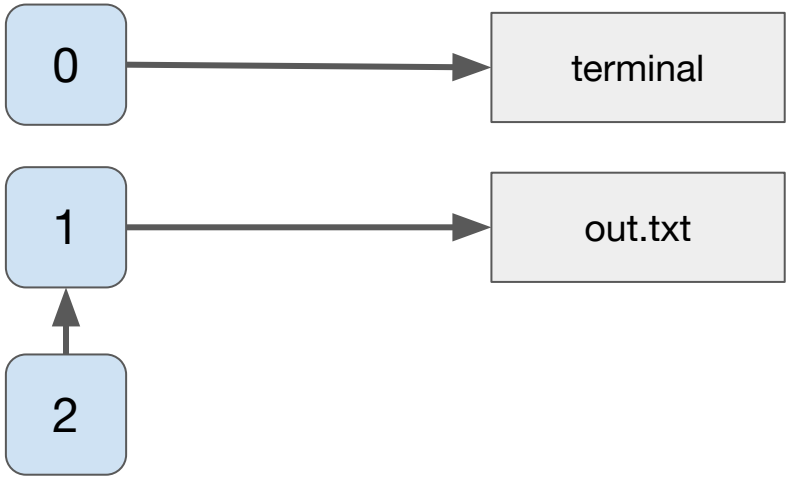
05.08 Redirecting streams




```
cmd &> out.txt
```

`&> out.txt` to redirect both stdout and stderr to out.txt

05.08 Redirecting streams to file descriptors



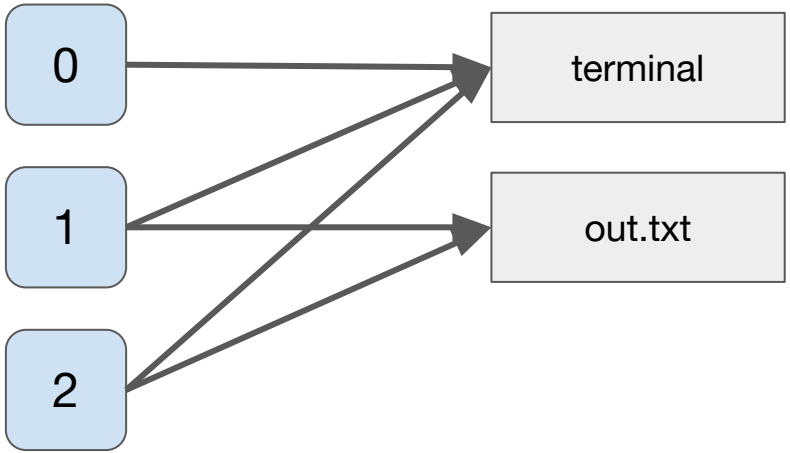

```
cmd > out.txt 2>&1
```

Note the order here! First, redirect stdout to the file out.txt. Then redirect stderr to stdout. If 2>&1 > out.txt was used, stderr would print to the terminal!

`&n` references file descriptor `n`.

⇒ can use this to redirect stderr to stdout!

05.08 Redirecting streams | tee



Why is this useful?
⇒ You can log a command and see its output while it's running.

```
cmd 2>&1 | tee out.txt
```

Can we redirect streams to both the terminal and a file?

⇒ `tee file` *reads from stdin and writes to* `stdout` ***and*** `file`

⇒ use `tee -a file` to append to `file`

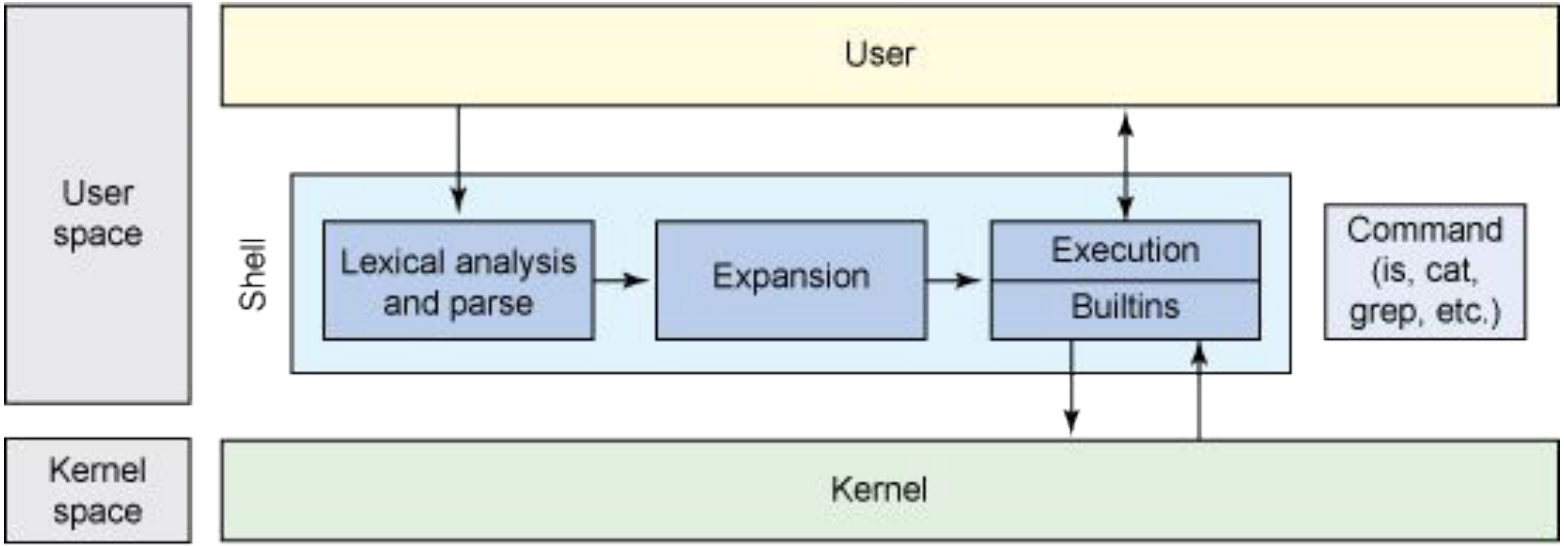
06 Scripting

CS6 Practical System Skills

Fall 2019

Leonhard Spiegelberg *lspiegel@cs.brown.edu*

06.01 Shells


User space
User
Shell
Lexical analysis and parse
Expansion
Execution
Builtins
Command (is, cat, grep, etc.)
Kernel space
Kernel

06.01 Shells

On *NIX systems, there are multiple shells available

shell = CLI to the operating system

⇒ pick your favourite shell
⇒ each has a different syntax
and unique features
⇒ In **CS6** we'll learn bash

sh	Bourne shell	1977
ksh	Korn shell	1983
csh	C shell	1978
tcsh	Tenex C shell	1983
bash	**Bourne again shell**	**1989**
zsh	Z shell	1990
fish	friendly interactive shell	2005

more on the history of shells: https://developer.ibm.com/tutorials/l-linux-shells/

06.02 BASH, the bourne again shell

⇒ widely deployed, de facto standard to write scripts

⇒ documentation under `man bash`

⇒ typically stored under `/bin/bash` or `/usr/bin/bash`

06.02 Why scripting?

Shell scripts allow to create new commands & save us a lot of time

⇒ automate daily tasks

⇒ system administration can be also automated
(e.g., installation of dependencies,
technical users, configuration)

⇒ often they are required to deploy services
(wrapper scripts, startup scripts)

06.03 Writing scripts - the basics

⇒ scripts are text files, simply create and edit them using e.g. vim

⇒ typical extension for shell scripts: `.sh`

⇒ to execute a script `script.sh`, set read&execute permissions (i.e. >= 500) and run it via an interpreter (i.e. a shell), e.g. `bash script.sh`

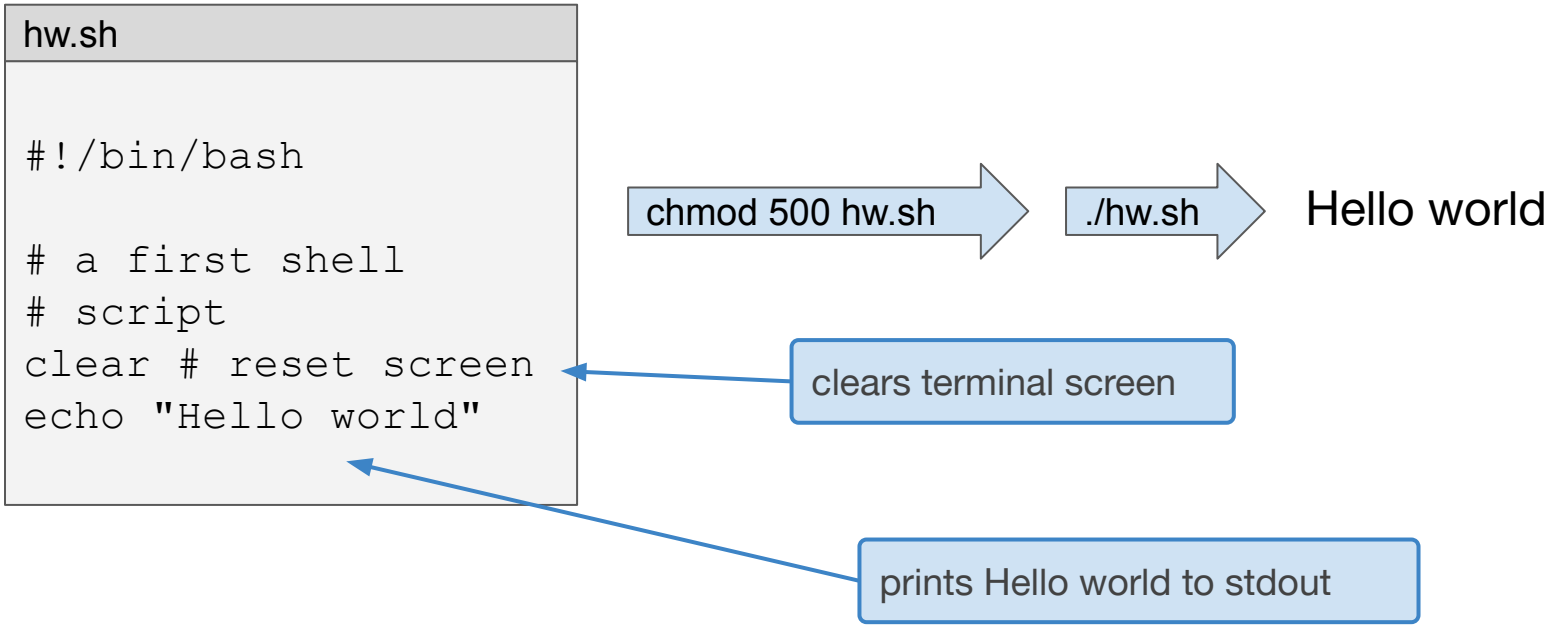
⇒ Alternative: you can add a shebang (or bang) line to script.sh, and execute it then like an executable via `./script.sh`

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

If the first line of script.sh is formatted as `#!<interpreter>` `./script.sh` will be the same as `<interpreter> script.sh`

06.03 Writing scripts - the basics

⇒ everything after # is treated as a comment

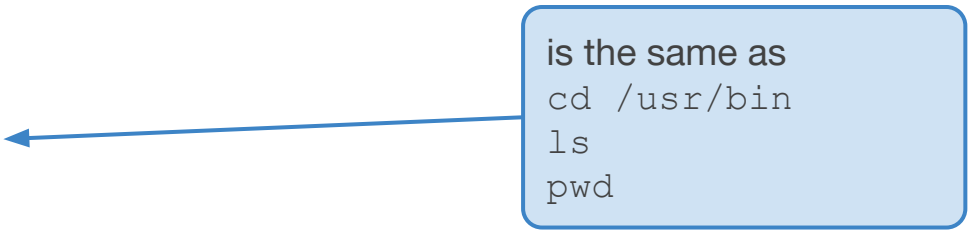


06.03 Multiple commands in one line

⇒ multiple statements/commands can be written in one line by separating them using ;

Example:

```
cd /usr/bin;ls;pwd
```



06.03 source

⇒ with the `source` command a script may be executed within the current shell.

⇒ helpful, if you want to "save" multiple commands in a file and execute them.

06.04 Variables

Define variables using

```
VARIABLE=value
```

⇒ variable names must consist of alphanumeric character or underscores (_) only

⇒ variable names are case sensitive

⇒ you can define a NULL variable (i.e., no value), using `VARIABLE=`

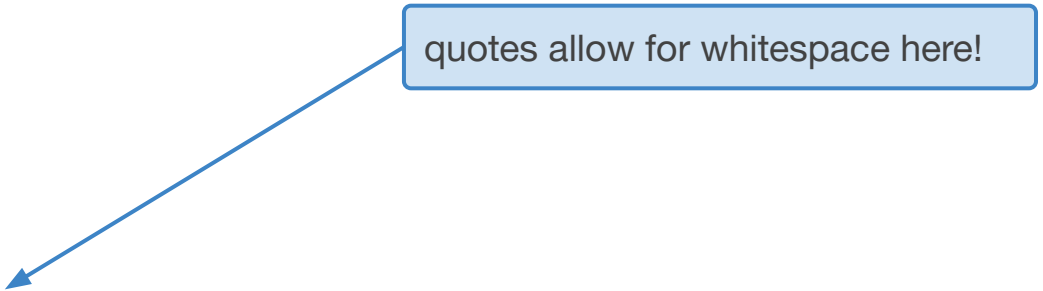
⇒ many people use a capital letter naming convention for bash variables

06.04 Variables

To print or access the value of a variable, use $

Examples:

```
DEST=/home/tux

cd $DEST

MESSAGE="hello world"

echo $MESSAGE
```



06.04 Variables and environments

⇒ when variables are defined using `VARIABLE=value`, they are added to the local environment of the executing process

⇒ E.g., if we type `VARIABLE=value` directly in the shell, then `VARIABLE` is added to the local environment of the shell

⇒ If we write `VARIABLE=value` in a script, it is added to the local environment of the script during execution

06.04 Shell variables and environment variables

⇒ when a script is invoked, bash will export its global environment to the script.

⇒ to add a variable to the global environment, use

`export VARIABLE`

or `export VARIABLE=value`

⇒ bash defines a set of predefined variables, called shell variables which are always exported.

⇒ to list the global environment, run `printenv`

06.04 Shell variables

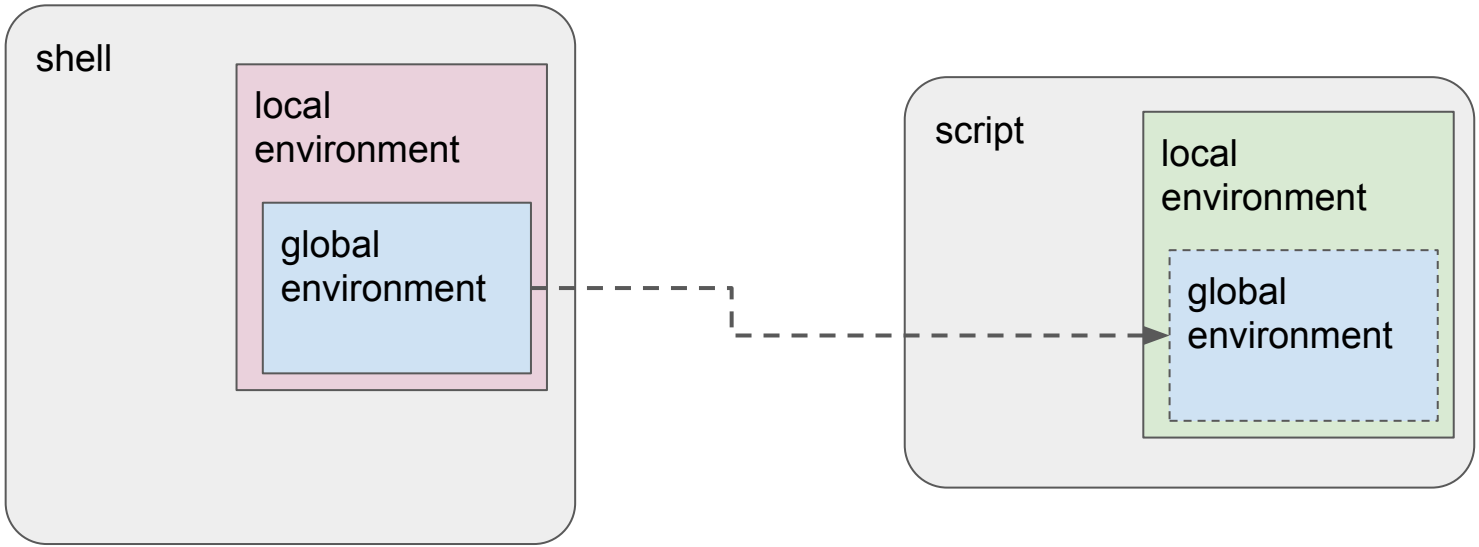
Some useful shell variables (many more are available):

`HOME`	the path of the home directory
`USER`	name of the user
`SHELL`	path to the shell
`PWD`	current working directory

⇒ e.g. `cd $HOME` will go to the home directory

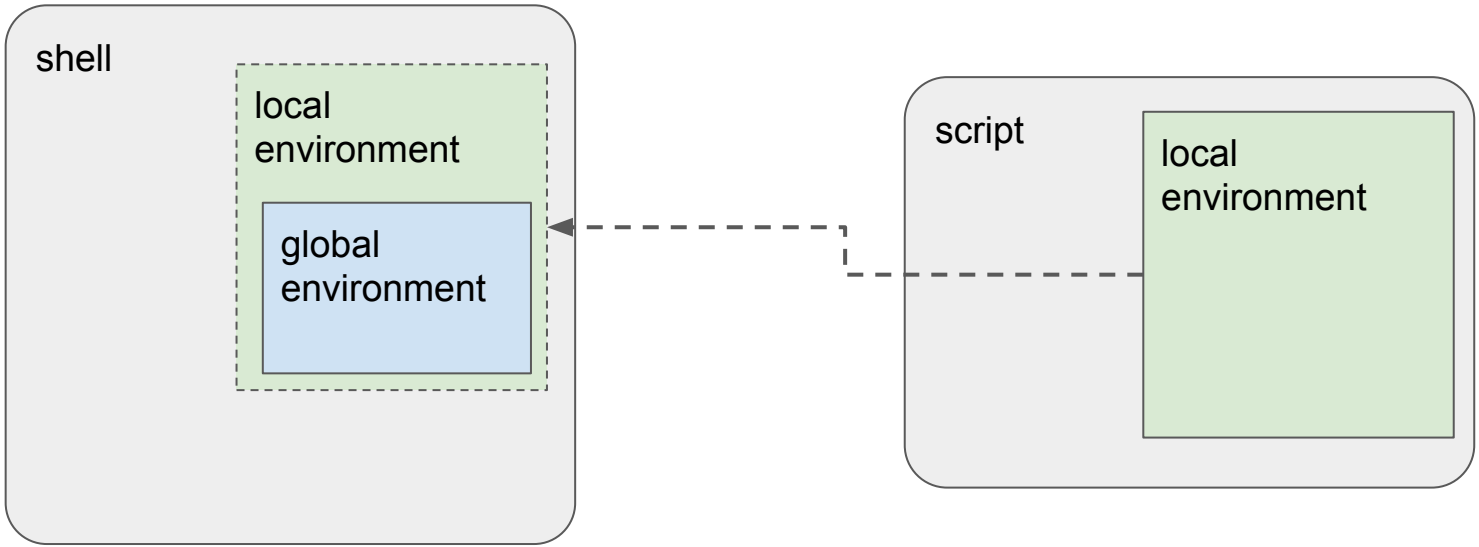
06.04 Exporting variables

```
export var
```



06.04 Importing variables

```
source script
```



Allows to override any variables (incl. the shell ones)! Don't blindly source a script!

06.04 In a nutshell: source vs. export

⇒ with `export VARIABLE=value` you can
pass a variable to a script.

⇒ with `source script.sh` you can
add variables to the shell's environment.

Operations on variables

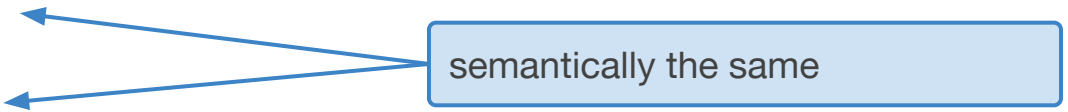
06.05 Integer operations

⇒ basic arithmetic operations may be executed using

`let expression`

or `((expression))`

or `$((expression))`



⇒ `let expression` and `((expression))` evaluate the provided expression using bash's rules regarding arithmetic evaluation.

06.05 Integer operations

⇒ `$((expression))` evaluates the expression and performs then substitution of the result, i.e. returns the result.

⇒ use arithmetic evaluation **for integers only!**

(no floating point support in bash)

06.05 Arithmetic evaluation - operators

- +	unary plus/minus
**	exponentiation
* / %	multiplication, division, remainder(modulo)
+ -	(binary) addition, subtraction
~ & ^ |	bitwise negation, AND, exclusive OR and OR
<< >>	left/right bitwise shifts
!	logical negation
<= => < >	comparison operators
== !=	equality / inequality
&& ||	logical AND, logical OR

06.05 Arithmetic evaluation

`var++` `var--`	variable post-increment or post-decrement
`++var` `--var`	variable pre-increment and pre-decrement
`= *= /= %= += -= <<= >>= &= ^- |=`	assignment operators
`exprA?exprB:exprC`	conditional operator (i.e. if exprA then return exprB else return exprC)
`expr1, expr2`	list operator (more next lecture)

⇒ can use parentheses, precedence like in C

06.05 Arithmetic evaluation - example

```
x=42
echo $x #=> 42

let x=x+42
echo $x #=> 84

#use " to allow for whitespace
let "x = x - 4"
echo $x #=> 80

((x--))
echo $x #=> 79

# can use whitespace within (( )) here
(( x *= 7 )) #=> 553
echo $x

let "a=3"
let "b = 4"

let "c = a**2 + b **2"
echo $c

# clamp to [10, ...)
# use $(( )) to get the result
echo $(( c > 10 ? c : 10 )) #=> 25
```

Note: within `(( ))` or `let` or `$(( ))`, the variables are referenced using their name `var`, not by `$var`.

`let expression` ⇒ executes expression, but returns no result

`(( expression ))` ⇒ executes expression, but returns no result

`$(( expression ))` ⇒ executes expression and returns result

06.06 String operations

⇒ we can use variables as part of strings, e.g.

`cd $HOME/.local/bin` will change the directory to `/home/tux/.local/bin` if `HOME=/home/tux`

Problems:

What is `$avariableinasentence`?

How can we define a variable with content `$HOME`?

What about whitespace/tokenization?

06.06 Quoting

double quotes `"..."` ⇒ perform string interpolation

single quotes `'...'` ⇒ treat characters within literally

backticks `` `...` `` ⇒ treat … as command and return its stdout

⇒ all details available under `man bash`

06.06 Quoting - single quotes: ' .... '

⇒ single quotes treat each character within them as literal value.

⇒ However, ' can't be contained within ' '

Examples:

```
echo '$variables are not substituted'

echo 'All sorts of things are ignored in single quotes, like $ & * ; |.'

MESSAGE='hello world!'

echo $MESSAGE
```

06.06 Quoting - single quotes '...'

⇒ I.e. single quotes preserve ALL chars except '

⇒ can use this for multiline strings, e.g.

```
sealion@server:~$ echo 'hello
> world'
hello
world
```

06.07 Quoting - double quotes

⇒ double quotes " " preserve literal value (incl. newline!) of characters within them, except for `$`, `` ` ``, `\` and `!`. They can be escaped using \, i.e. \$ \` \!

⇒ `$` performs parameter/variable expansion

⇒ `` ` `` performs command substitution

⇒ `\` is the escape character

⇒ `!` performs history expansion

06.07 Quoting - double quotes

Examples:

```
MESSAGE="hello world"

echo $MESSAGE

echo "message is: $MESSAGE"

echo "message is: ${MESSAGE}\!"

cache_dir=./cache/

echo "images will be saved to ${cache_dir}images"

echo "images will be saved to $cache_dirimages"
```

with { } the variable cache_dir is expanded

bash tries to get the value of cache_dirimages.
⇒ variable does not exists, hence result here will be
images will be saved to

06.08 The $ character

⇒ `$` performs parameter expansion, command substitution or arithmetic expansion

⇒ `${parameter}` is substituted by the value of parameter
(if parameter exists, else the empty string)

⇒ `$(command)` executes command in a subshell
and returns its stdout

⇒ `$` can do a lot more, cf. `man bash`

06.08 Backticks

`` `cmd` `` is a shortcut for `$(cmd)`

Examples:

```
echo "ls returns `ls`"

echo "ls returns $(ls)"

echo "the current user is $(whoami) (should be ${USER})"
```

06.08 Combining the different quote types

⇒ we can combine the different quote types

Examples:

```
echo 'To escape '"'"' simply surround it with "'
```

```
echo 'result of ls without newlines is: '`ls`
```

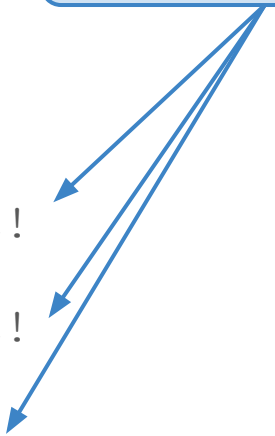
06.09 A note on whitespace and quotes

⇒ quoting just allows us to write special chars,
but the values are still passed as words

Example:

```
PARAMS="file.txt dest"

cp $PARAMS        # <= expands to cp dest src!

cp "$PARAMS"      # <= expands to cp dest\ src!

cp "${PARAMS}"    # <= expands to cp dest\ src!

cp '$PARAMS'      # <= expands to cp \$PARAMS
```

these commands will raise an error to stderr: cp: missing destination file operand after ...



06.09 Quoting is just a way to specify strings!

Another example:

```
PARAMS="word1 word2"

echo PARAMS   # <= output will be PARAMS

echo $PARAMS  # <= output will be the word1 word2
```

Passing input

06.09 Passing input to scripts

We can pass data in different ways to a script:

1.) as parameters
2.) via stdin
3.) via (exported) environment variables
4.) via an interactive prompt

06.09 Passing parameters

```
./script.sh param1 param2 param3 … param20
```

⇒ access the nth parameter via `${n}` in a script.

⇒ `$0` (short for `${0}`) holds the command name (here `./script.sh`)

=> `$1` is param1

=> `${20}` is param20

=> `${100}` is NULL/empty string (not set)

06.09 stdout, stderr, stdin revisited

⇒ within scripts it may be sometimes useful to access stdout, stderr, stdin as files

⇒ bash creates 3 special files for the 3 streams to which a command may write to or read from:

stdout	`/dev/stdout`
stderr	`/dev/stderr`
stdin	`/dev/stdin`

Example: `echo 'Hello world' > /dev/stdout`

06.09 stdin

can use either cat for this and access stdin indirectly

```
STDIN=$(cat)
```

or use the special file

```
/dev/stdin
```

stdin.sh

```
#!/bin/bash
STDIN=$(cat)
echo "stdin via cat: $STDIN"
STDIN=`head -n 1 /dev/stdin`
echo "header: $STDIN"
```

execute this script via
./stdin.sh < file.txt

06.09 Environment variables

⇒ you can access variables that have been exported in the parent shell, via $VARIABLE

Example:

info.sh

```
#!/bin/bash

echo "$USER started
this script via
$SHELL"
```

06.09 Interactive prompt

⇒ use `read -p PROMPT VARIABLE` to display `PROMPT`, wait for user to type input and save it to `VARIABLE`.

Example:

prompt.sh

```
#!/bin/bash

echo "what is your favourite animal?"
read -p '> ' ANSWER
echo "It's a ${ANSWER}, so cool!"
```

There are multiple ways to customize the prompt, e.g. for passwords (-s) etc.
⇒ check man bash

06.09 Interactive prompt - multiple variables

⇒ `read -p PROMPT VAR1 VAR2 VAR3` will issue a prompt, perform word splitting on the received input and fill in the variables.

Example:

prompt_multiword.sh

```
#!/bin/bash

echo "Please write a sentence"
read -p '> ' WORD1 WORD2 WORD3
echo 'First word: '"$WORD1"'
Second word: '"$WORD2"'
Third word: '"$WORD3"
```


So long, and thanks for all the fish.

Next Lecture:

⇒ more advanced variable/parameter expansions

⇒ control structures

- conditional statements (if)

- loops (while/for)

⇒ arrays & dictionaries

Homework 2 out today!

⇒ get started early!

⇒ the first scripting homework

⇒ if you're stuck, get help

⇒ man bash is your friend.

End of lecture.

Next class: Thu, 4pm-5:20pm @ CIT 477