Programming in Shell 1

Introduction to Unix/Unix-like operating systems

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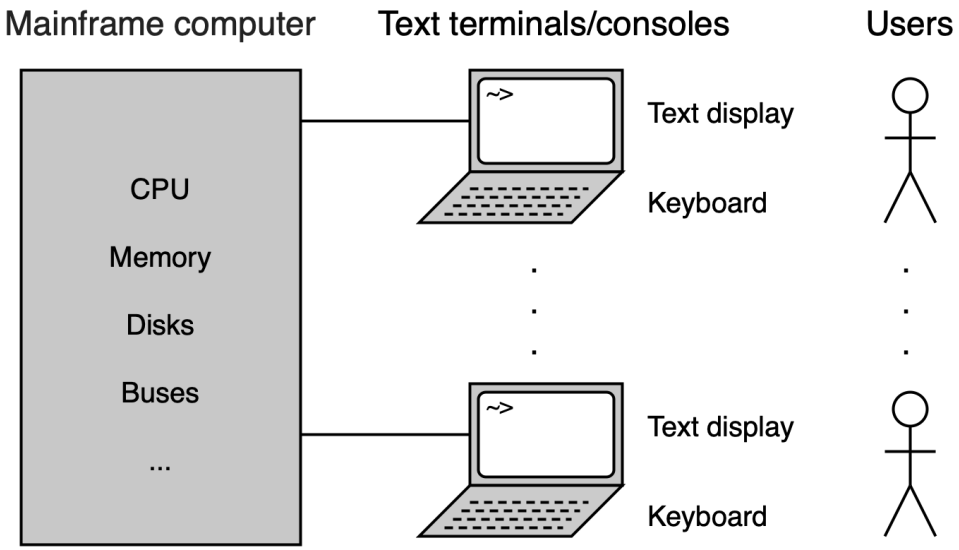
Content

Unix – history

1969

- First implementation.
- AT&T's Bell Labs (Kenneth Thompson and Dennis Ritchie).



- "Simple hardware"
  - Central processing unit (CPU) can only process one instruction stream at a time.
  - Only command line interface (CLI).
  - No network interface, no remote devices (flash disks,...), ...

Unix – history

1972

- New programming language C.
- AT&T's Bell Labs (Dennis Ritchie).

1973

- Unix was rewritten in C ⇒ portability.
- Unix was licensed to educational institutions.

1977

- Berkeley Software Distribution (BSD) ⇒ new features were added.

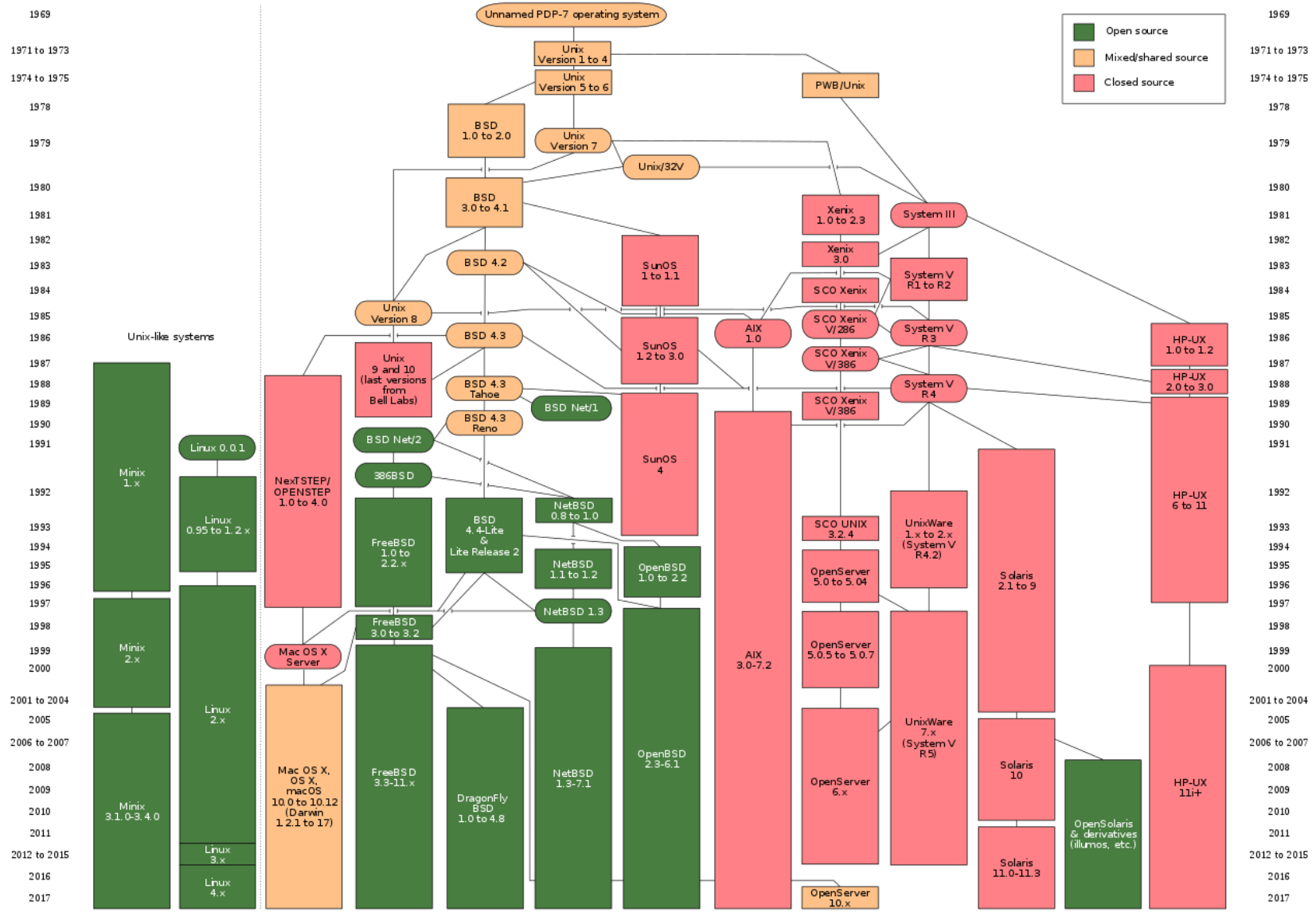
1983

- System V Release 4 was commercially the most successful version.
- GNU project
  - Fee UNIX-like operating system (not finished),
  - GNU tools.

1991

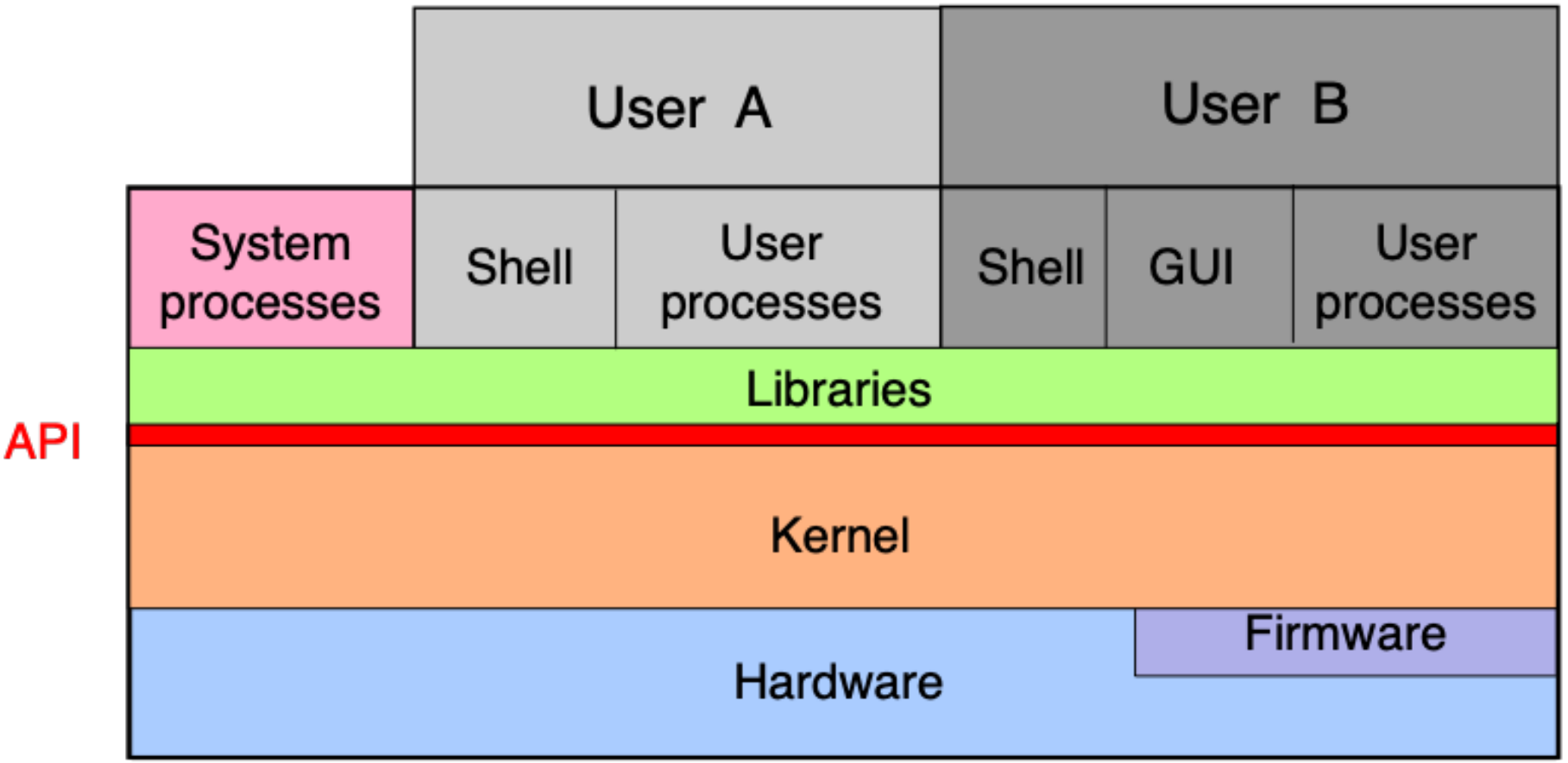
- Linux (Linus Torvalds).

Unix – history



- Source: Wikipedia

Unix – architecture



Unix – architecture

- **Hardware (HW)**
  - Physical resources: CPU, RAM, bus, disk, network card, ...
  - Firmware (software for hardware testing, kernel loading,...): BIOS, ...
- **Operating system (OS)**
  - Kernel and drivers (basic part of OS)
    - Logical resources: users, processes, files, permissions, ...
    - Resource management
    - Application program interface
- **Processes**
  - Abstraction of the running program/application
  - OS processes
    - Graphical user interface (GUI): GNOME, KDE,...
    - Command-line interface (CLI): shell
    - Command line tools (commands) and other applications
  - Other suppliers' processes: web browser, graphic editor, design tools, ...
- **Users/user account**
  - Abstraction of physical user for which some attributes are defined
    - User name + password
    - User ID, member of some groups, home directory, login shell, ...

Unix-like operating systems

- **GNU/Linux**
  - Linux kernel
  - GNU tools and other tools
  - Distributions: OpenSUSE, Red Hat, Debian, ...

```
$> ps -ef
UID          PID    PPID  C STIME TTY          TIME CMD
gdm         2308    2307  0 17:43 ?        00:00:00 (sd-pam)
honza       7239    6782  0 17:56 pts/0    00:00:00 ps -ef
```

- **Oracle Solaris**
  - SunOS kernel + tools (UNIX System V Release 4 + BSD)
  - GNU tools can be added (gfind, gsed, gawk, ...)

```
$> ps -ef
     UID   PID  PPID   C    STIME TTY          TIME CMD
    root     0     0   0   Sep 05 ?           0:17 sched
trdlicka 10887  9934   0 17:45:10 pts/27      0:00 ps -ef
```

- **macOS**
  - macOS kernel + tools (BSD)
  - GNU tools can be added by Homebrew

```
$> ps -ef
  UID   PID  PPID   C STIME   TTY           TIME CMD
    0     1     0   0  9:37AM ??         1:09.65 /sbin/launchd
  501   784   783   0 10:07AM ttys001    0:00.30 -bash
```

Unix – features

- **Multiuser OS**
  - Multiple users can use Unix at the same time.
- **Processes**
  - All non-kernel software is organised into separate, kernel-managed processes.
- **Multitasking OS (time-sharing)**
  - Multiple processes can run at the same time.
- **Filesystem**
  - Files are stored on disk in a hierarchical file system, with a single top location throughout the system (root, or "/").
- **Command line interface (CLI)**
  - Text-based user interface (UI) used to view and manage computer files.
  - CLI is implemented by shell.
- **Input/output redirection**
  - Output from a file or command can be sent (redirected) as input to another file or command.
- **Special files as abstractions of devices and other objects**
  - Files in the directory `/dev` represent logical/physical devices.

Unix – features

- **Built-in documentation**
  - Manual pages available thought command `man`.
  - Info about shell builtin commands available thought command `help`.
  - TextInfo (the GNU Documentation System) available thought command `info`.
- **Portability**
  - 90% of kernel is written in C.
- **Built-in networking**
  - TCP/IP, Network filesystem (NFS), Remote Procedure Call (RPC),...
- **Graphic user interface (GUI)**
  - GUI is separated from the Unix kernel and consists of two parts
    - X Window System: interface between kernel and graphic application.
    - Window managers: define the "look and feel" of an X-based GUI (window frames, buttons, ...).
- **Multithreading**
  - Multiple threads (instruction streams) can be executed concurrently.

Shell

- **Features**
  - Interface between user and kernel.
  - Command interpreter.
- **Shell implementations** (according to control language syntax)
  - Bourne shell
    - Pascal-like syntax,
    - Bourne shell (sh), Korn shell (ksh), Bourne again shell (bash), ...
  - C shell
    - C-like syntax
    - C shell (csh), Toronto C shell (tcsh), ...
- **In this course, we will focus on the group of Bourne shells.**

Shell

- **Environment settings**
  - We can define variables that control system and application behavior.
  - The variables are local $\Rightarrow$ each user has its own environment.
  - Can be saved in a configuration file (local to each user)
    $\Rightarrow$ environment is remembered.

- Example
  - The system time is absolute (GMT).
  - User can define the value of TZ (TimeZone) variable, eg. CET (Central European Time) and all displayed time data will be recalculated.
  - When working on a remote server, the user can see the time data (system time, file times,...) in their local time depending on how the TZ variable is set.

Example

Central European Time Zone

```
$>  export TZ=CET                          # we define timezone
                                           # (see /usr/share/zoneinfo)

$> date                                    # command date
Tue Sep 24 13:43:58 CEST 2019

$> ls -l /etc/passwd                       # command ls
-rw-r--r-- 1 root root 2058 Sep 23 22:31 /etc/passwd
```

Japan Time Zone

```
$>  export TZ=Japan

$> date
Tue Sep 24 20:43:58 JST 2019

honza@suse100:~> ls -l /etc/passwd
-rw-r--r-- 1 root root 2058 Sep 24 05:31 /etc/passwd
```

Shell – features

- **Interactive mode**
  1. The command is defined from the keyboard (default standard input).
  2. Command line analysis (find command, meta-character substitution,...).
  3. Execution of a command (binary program or script).

- **Batch mode**
  - Shell reads commands from a file, called a script.
  - It gradually executes (interprets) these commands.
  - Script = Unixu commands + control structures (eg. conditional statements, loops,...).

- From the shell point of view, there is no difference between interactive and batch mode.

Shell – command line syntax

Variables

- <prompt> <variable_name>=<value>
- <prompt>
  - Prompt is printed by shell.
  - Value of prompt is defined by the shell variable PS1.
- <variable_name>
  - Variable name is identifier.
  - No spaces around symbol =.
  - Shell assigns the value to the variable.
- <value>
  - By default it is string.
  - If it contains spaces, it must be enclosed in quotation marks.

Example

```
$> A="abc    123"
$> echo "$A"
abc    123
```

Shell – command line syntax

Simple commands

- <prompt> <command_name> <options> <arguments>
- <command_name>
  - It defines which program will be executed (which).
  - It can be only name or path to the file (relative/absolute).
- <options>
  - They can modify the behaviour of command (how).
- <arguments>
  - They specify the data to be processed (what).
- Command name, options and arguments are available
  - in script by variables $#, $0, $1, $2, ...
  - in C program by variables argc , argv[0], arg[1], ...

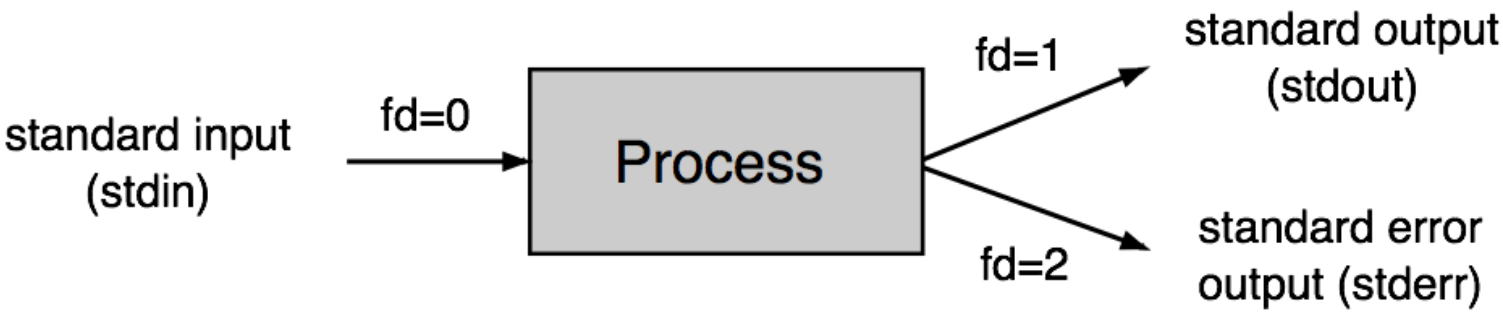
Example

```
$> ls
Desktop  Documents  Downloads  Music  Pictures

$> ls -l /etc/passwd
-rw-r--r-- 1 root root 2058 Sep 23 22:31 /etc/passwd
```

Filters

- Most of the commands are filters, so that they communicate with the environment through input and output streams.
- Streams are numbered using file descriptors (fd).
- Processes access files using file descriptors.
- Each process has the following descriptors open by default
  - 0 – standard input (keyboard by default)
  - 1 – standard output (terminal by default)
  - 2 – standard error output (terminal by default)



- The default assignment can be redirected.
- The commands can be use in pipes, where the output of one command is redirected like input of next one.

Command execution

- The commands are executed by the shell.
- The command can be a binary program or a script.
- Command can be executed in several different ways
  - **Forground execution:** the command is executed and the shell awaits its completion.

```
$> cmd
```

  - **Background execution:** the shell does not wait for the command completion and communicates immediately with the user.

```
$> cmd &
```

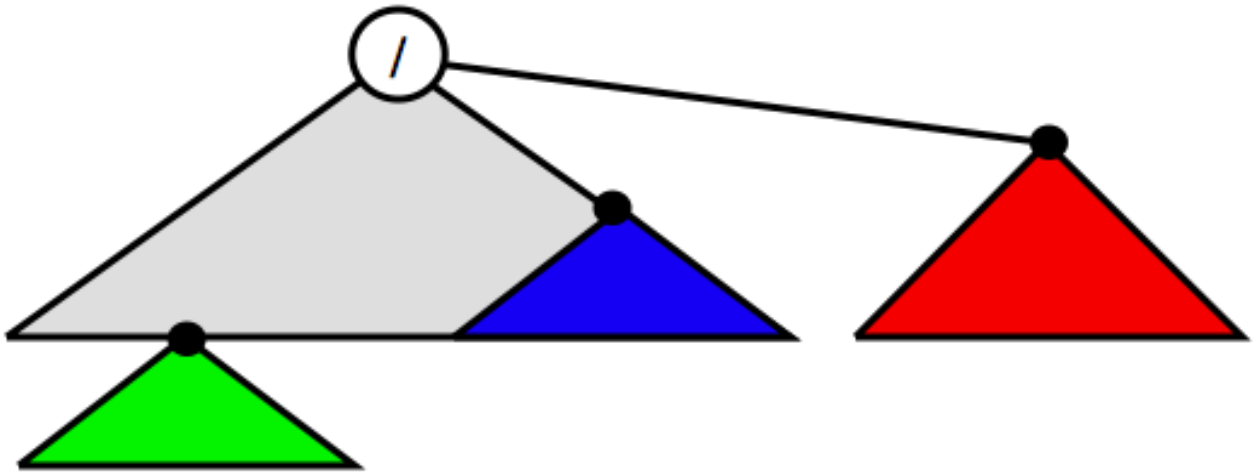
  - **Sequential execution of multiple commands:** the shell executes the first command, the next one after its termination, etc.

```
$> cmd1 ;  cmd2 ; cmd3
```

  - **Pipe of multiple commands:** the commands are executed in parallel, stdout of the first command is redirected to stdin of the second command etc.

```
$> cmd1 | cmd2 | cmd3
```

Filesystem



- Data (files) are organised as a directory tree.
- Directories can contain files or subdirectories (in Unix, directory is represented as "special" file).
- Root directory is represented by symbol /.
- Parts of the tree can be mapped to different devices (disk, DVD, remote FS, ...).
- The mapping is transparent to the user.

Directories

- It creates a tree structure that allows hierarchical storage of information.

- **Absolute (complete) path**
  - It always starts in the root directory /.
  - Contains a sequence of all directories (separated by /) between / and the destination file

    `/home/stud/smith`

- **Working (current) directory**
  - Can be displayed by command `pwd`.
  - Its value is stored in the shell variable `PWD`.
  - It changes with the command `cd new_working_directory`.
  - It is represented by the absolute path.

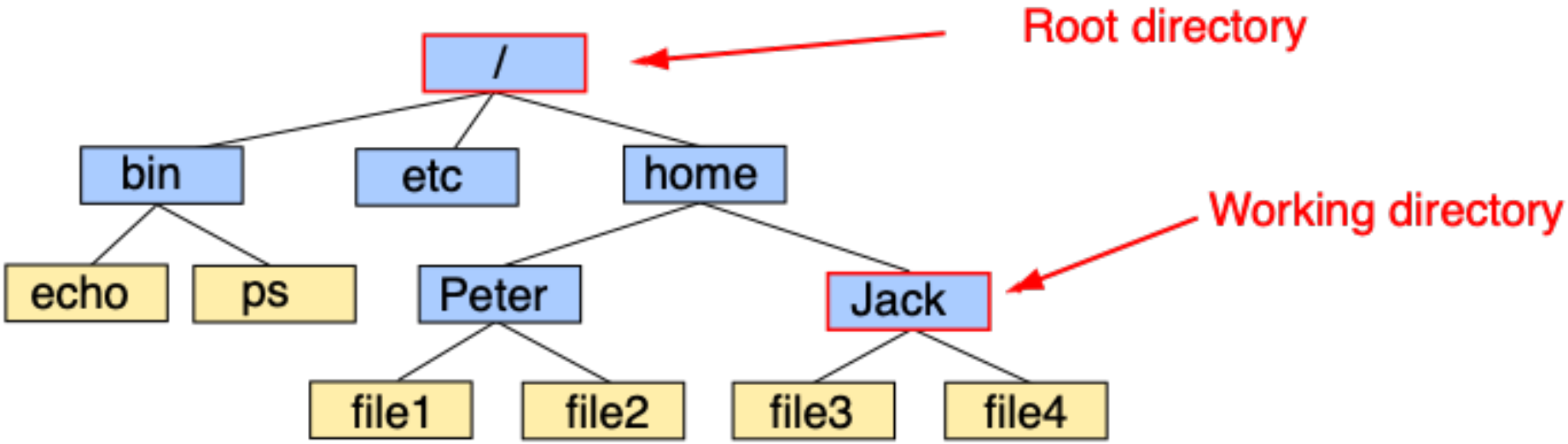
Directories

- **Relative path**
  - It always starts in the working (current) `$PWD` directory.
  - Contains a sequence of subdirectories between `$PWD` and the target file.

```
PWD=/home/stud/smith
../../../etc
```

- **Home directory**
  - Defined for each user.
  - After login, the working directory is set to home directory.
  - Its value is stored in the shell variable `HOME`.
  - The user is usually the owner and has the right to write.

Directories – example



`/home/Peter/file1`	absolute path to the file `file1`
`./../Peter/file1`	relative path to the file `file1`
`../Peter/file1`	relative path to the file `file1`
`/home/Jack/file4`	absolute path to the file `file4`
`./file4`	relative path to the file `file4`
`file4`	relative path to the file `file4`

Examples – commands

- **Redirection of input/output**

```
$> date > d.txt                    # output of command date
                                   # is redirected to file d.txt
```

```
$> getent passwd | grep "Peter" > p.txt
                                   # info about users with name Peter
                                   # will be save in the file p.txt
```

- **Everything is clear? Is it too simple?**

Examples

- **Little bit more complicated example?**

```
$> echo PID FD EXEC FILENAME; PID=$(pgrep ''); pfiles $PID | awk
'BEGIN␣{␣fd=-1;␣}␣␣/^[0-9]/␣{␣if␣(fd>=0)␣{␣print␣pid,␣fd,␣exec;
fd=-1;␣};␣pid=substr($1,0,length($1)-1);␣exec=$2;␣}␣/^␣*[0-9]*:
/␣{␣if␣(fd>=0)␣{␣print␣pid,␣fd,␣exec;␣fd=-1;␣};␣if
($2=="S_IFREG")␣{␣fd=substr($1,0,length($1)-1);␣}␣}␣/^␣*\//
{␣fd=-1;␣}' | while read pid fd exec; do echo $pid $fd $exec
$(echo 0t$pid ::pid2proc \| ::fd $fd \| ::print file_t f_vnode
\| ::vnode2path | mdb -k 2>/dev/null); done
```