Introduction to UNIX

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- General introduction
- History, principles
- File system, organization, tools
- Processes, life cycle, communication
- Shell: conception, commands
- Text processing (ed, grep, sed, vi, awk)

Literature

- L.Forst: Shell v příkladech aneb aby váš UNIX skvěle shell; Matfyzpress 2010
  `www.yq.cz/SvP`
- The Single UNIX® Specification, Version 3 (POSIX), The Open Group Base Specifications Issue 7, IEEE Std 1003.1-2008
  `www.opengroup.org/onlinepubs/9699919799`
- manual pages

Literature (basic)

- G. Todino, J. Strang, J. Peek: Learning the UNIX Operating System; O'Reilly & Associates 2002; ISBN 0-596-00261-0
- A. Robbins: UNIX in a nutshell; O'Reilly & Associates 2006; ISBN 978-0-596-10029-2
- L. Lamb: Learning the vi Editor; O'Reilly & Associates 1990; ISBN 0-937175-67-6

Literature (programming)

- C. Newham, B. Rosenblatt: Learning the bash Shell; O'Reilly & Associates 2005; ISBN 0-596-00965-8
- D. Dougherty: sed & awk; O'Reilly & Associates 1997; ISBN 978-1-565-92225-9
- A. Robbins, N. Beebe: Classic Shell Scripting; O'Reilly & Associates Inc., 2005; ISBN 978-0-596-00595-5
- C. Albing, J. Vossen, C. Newham: bash Cookbook; O'Reilly & Associates Inc., 2007; ISBN 978-0-596-52678-8
- E. Quigley: UNIX Shells by Example; Pearson Education Inc. (Prentice-Hall), 2005; ISBN 0-13-147572-X
- S. Kochan, P. Wood: Unix Shell Programming; SAMS, 2003; ISBN 0-672-32390-3

Literature (principles)

- M.J.Bach: The Design of the UNIX Operating System; Prentice-Hall 1986
- E. Raymond: The Art of UNIX Programming; Addison Wesley; 2004; ISBN 0131429019

Conventions

- Fixed part of command (non-proportional font)
  - used as it is written:
    `man` [**`-k`**] [*section*] *topic*
- Variable part of command (italics)
  - requested text (word, number etc.) is used:
    `man` [**`-k`**] [*section*] *topic*
- Optional part of command:
  `man` [**`-k`**] [*section*] *topic*
- Selection from more alternatives:
  {**`BEGIN`** | **`END`** | **`/`***regexp***`/`** | *cond* | } **{** *cmds* **}**

UNIX History

- 1925 - **Bell Laboratories** - communication research
- the 60s - with General Electric and MIT: OS **Multics** (MULTIplexed Information and Computing System)
- 1969 - Bell Labs leaves project, **Ken Thompson** writes assembler, basic OS and file system for PDP-7
- 1970 - Multi-cs => **Uni-x** (**Brian Kernighan**?)
- 1971 - Thompson requests a new machine PDP-11 for further development - denied
- Thompson fakes work on project of automated office system - a machine granted => text processing tools
- 1973 - UNIX rewritten in C language made for this purpose by **Dennisem Ritchiem**

UNIX Divergence

- mid of the 70s - releasing UNIX to universities: namely University of California **Berkeley**
- 1979 - in Berkeley UNIX rewritten for 32bit VAX as **BSD Unix** (Berkeley System Distribution) version 3.0; today version 4.4
- Bell Labs migrate under **AT&T** and development goes on: version **III** to **V.4** - so called **SVR4**
- UNIX release for commerce: Microsoft and SCO develop for Intel **XENIX**
- established UNIX International, OSF (Open Software Foundation), X/OPEN,...

UNIX Variants

- SUN: **Sun OS, Solaris**
- Silicon Graphics: **Irix**
- DEC: **Ultrix**, **Digital Unix**
- IBM: **AIX**
- HP: **HP-UX**
- Siemens Nixdorf: **SINIX**
- Novell: **UNIXware**
- SCO: **SCO** Unix

- FreeBSD, NetBSD, OpenBSD,...
- Linux

UNIX Standards

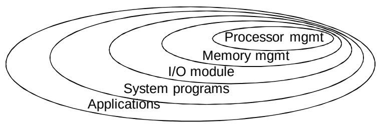
- SVID (System V Interface Definition)
  - "The Purple Book", issued by AT&T for the first time in 1985 as a standard, conformance with which was required for branding a system "UNIX"
- POSIX (Portable Operating System based on UNIX)
  - series of standards by IEEE marked P1003.xx, gradually overtaken by international top standard organisation ISO
- XPG (X/Open Portability Guide)
  - recommendation of X/Open consortium, founded by main workstation producers in 1984
- Single UNIX Specification
  - standard of Open Group organisation, founded in 1996 by joining of X/Open and OSF
  - Version 2 (**UNIX98**), Version 3
  - conformance is now required for branding a system "UNIX"

UNIX Characteristics

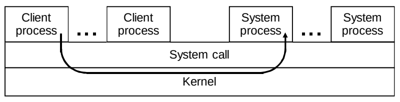
- inspired but not burdened by the past
- noncommercial environment
- open operating system
- file system
- users, groups
- processes, communication
- command interpreter, GUI
- utilities, C language
- portability, flexibility
- networking support
- public domain SW (e.g. GNU)
- command **`man`**

OS Models

Classic OS



UNIX



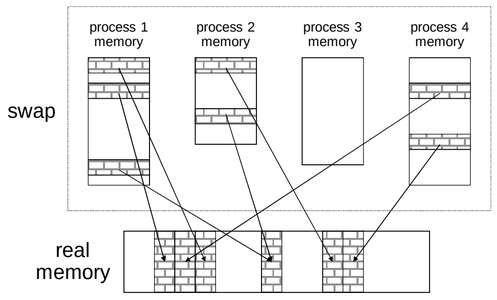
OS kernel functions

- Job execution control (creation, termination, suspending, communication, peripherals,...)
- File system management (disc organisation, file creation and removal, protection, consistency keeping,...)
- Memory management (allocation, releasing, protection, holding of temporarily unused memory - *swapping* or *paging*,...)
- Process scheduling for CPU time sharing (scheduling algorithm, time slices management, priorities,...)

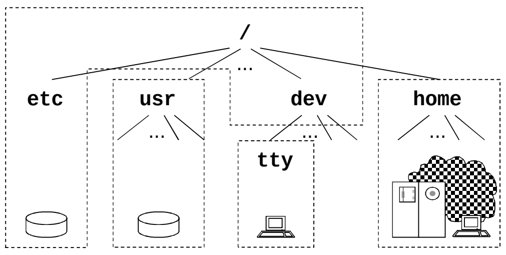
HW requirements

- Possibility to run in two modes:
  - user mode: limited access to memory, instructions etc.
  - kernel mode: unlimited privileged mode
- Hierarchical handling of interrupts
  - external: hardware (disc, peripherals, ...)
  - internal: CPU conditions (e.g. addressing error, division by zero, ...)
  - software: special instruction
- Memory management for virtual memory usage

Virtual memory



Integrated hierarchical file system



Directory tree

• **`/bin`**	- essential system commands
• **`/dev`**	- special files (*devices*)
• **`/etc`**	- configuration files
• **`/lib`**	- essential system libraries
• **`/tmp`**	- public directory for temporary files
• **`/usr/include`**	- C language headers
• **`/usr/man`**	- manual pages *
• **`/usr/spool`**	- *spool* (printing, email,...) *
• **`/usr/local`**	- local installations *
• **`/home`**	- root of home directories *

* may vary on some systems

Process, communication

- Process
  - general idea: running user or system program
  - created by duplication of parent process
  - process list: command **`ps`**
- Communication
  - when started, parent prepares data for son; no way to share data vice versa
  - pipe - data flow from a producer to a consumer: **`ls | more`**
  - advanced tools (e.g. shared memory)

Command Interpreter (*shell*)

- essential program for UNIX operating
- independent system component: more shells exist
- command format:

  command -options operands e.g. `ls -l /etc`

- metacharacters, e.g.:

  ```
  ls *.c > "output *.c"
  ```

- commands:
  - internal: e.g. **`echo`**, **`cd`**, **`pwd`**
  - external: files in file system (path to search: **`PATH`**)

Shell language

- shell interprets own programming language
  - control flow statement (e.g. **`for`**, **`if`**)
  - variables

    ```
    PATH=/bin:/usr/bin:$HOME/bin
    ```

- language controls text substitutions (*text processor*)
- programming directly on the command line
- shell-script - file with stored shell program

  ```
  sh test.sh; ./test.sh
  ```

`man` command

- Call:

  `man` [**`-k`**] [*section*] *topic*

- Manual pages sections:

  1 - general user commands
  2 - kernel functions (*syscalls*)
  3 - library (C language) functions
  4 - devices and device drivers
  5 - formats of (configuration) files
  6 - trivial application programs
  7 - miscellaneous
  8 - administrator commands and programs

List of users (**`/etc/passwd`**)

```
forst:DxyAF1eG:1004:11:Libor Forst:/u/forst:/bin/sh
```

Field semantics:

- user login name
- encoded password (today e.g. in **`/etc/shadow`**...)
- user number (*UID*); superuser (*root*) has UID 0
- number (*GID*) of user's primary group
- full name (optionally with comment)
- home directory
- login-shell

List of groups (**`/etc/group`**)

```
users::11:operator,novak
```

Field semantics:

- group name
- *unused*
- group number (*GID*)
- group members

Users having a group as their primary group are members of the group, too.

User session

After logging into system (locally or remotely - e.g. via **`ssh`**, **`putty.exe`**) user's *login-shell* is started.
Thereby, the user *session* is started.

• closing session:	**`logout`**
• closing shell:	**`exit`**
• user (login-shell) change:	**`login`** *user*
• another user shell start:	**`su`** [**`-`**] [*user*]
• user identity display:	**`id`**, **`whoami`**, **`who am i`**
• information about system:	**`uname`** [**`-amnrsv`**]
• list of logged-in users:	**`who`**, **`w`**
• session log listing:	**`last`**

Inter-user communication

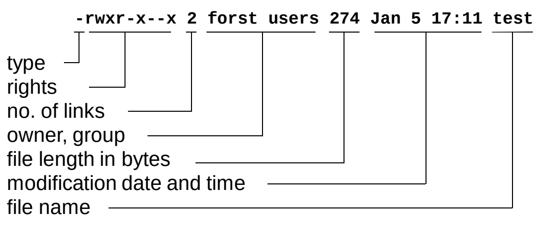
- on-line (messages):
  - sending: **`write`** *user*
  - receipt perm./denial: **`mesg`** [**y** | **n**]
- on-line (dialogue):
  - command: **`talk`** *user*[*@host*]
- off-line: e-mail
  - reading: **`mail`**
  - sending: **`mail`** [**-v**] [**-s***subject*] *email...*
  - receipt message: **`biff`** [**y** | **n**]
  - mail forwarding: **`$HOME/.forward`**

```
forst@ms.mff.cuni.cz
"| /usr/local/bin/filter"
```

File system

- hierarchical system
- unified approach to directories, devices etc.
- disc partitioning, remote disc mounting
- consistency, synchronization (**`sync`**, **`fsck`**)
- protection (access rights)
- naming rules (length, charset, case sensitivity, hidden files)
- paths (absolute, relative, `.` and `..`)
- text files format (**`<LF>`**)

`ls` command



```
-rwxr-x--x 2 forst users 274 Jan 5 17:11 test
```

options: long output (**`l`**), single column (**`1`**), include hidden files (**`aA`**), sort by time (**`t`**), reverse sort (**`r`**), flag file type (**`F`**), traverse recursively (**`R`**), don't follow directories (**`d`**), follow links (**`L`**)

File types

- File types in **`ls`** command output:

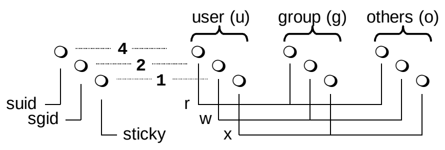
-	regular file - sequence of bytes
d	directory - set of binary records describing files and subdirectories
b	block device
c	character (raw) device
l	symbolic link
p	named pipe
s	socket

- Type recognition: **`file`** command

Access rights (file modes)

- ownership categories: user (**u**), group (**g**), others (**o**); exactly user's most special category is significant
- three permissions: read (**r**), write (**w**), execute file and work with directory (**x**)
- setUID, setGID (**s**) for executable files: run under owner (user and/or group) identity
- setGID for directory: new files will have directory's group owner (default on many systems)
- sticky bit (**t**) for directories: only file owners and root can remove and rename files (e.g. `/tmp`)

File mode change



- access rights change (only owner and root):
  `chmod` [**`-R`**] **`751`** *file...*
  `chmod` [**`-R`**] **`og-w,+x`** *file...*
- owner change (only root): **`chown`**
- group owner change (only group member): **`chgrp`**
- default file mode mask: **`umask`** [*masked_bits*]
- shell with new default group: **`newgrp`** *group*

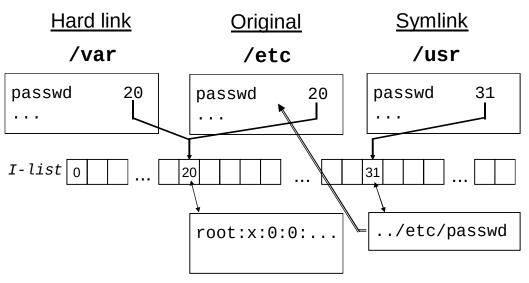
Disc organisation

- Physical: *sector*, *track*, *cylinder*, *surface*
- Logical: *partition* (correspond to block/raw device)
  - display filesystems: **`df`** command
  - configuration file **`/etc/fstab`**
- System-level: *filesystem*
  - boot block
  - superblock(s)
  - i-list (list of i-nodes)
  - data blocks
- Filesystem image kept in memory (**`sync`**, **`fsck`**)

Index node (i-node)

- Every file in filesystem has exactly one index node structure containing:
  - number of links
  - user and group owner (ID)
  - permissions
  - file type
  - file size
  - time of
    - last file modification
    - last access to file
    - last i-node modification
  - data block references
- List files including i-node numbers: **`ls –i`**
- List i-node content (not in SUSv3): **`stat`**

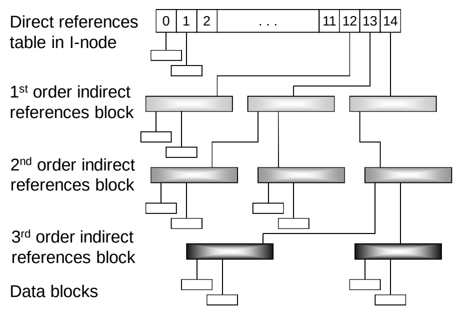
Links



`ln /etc/passwd passwd`

`ln -s ../etc/passwd passwd`
(loop: `Too many symlinks`)

Data block addressing


Direct references table in I-node
0
1
2
. . .
11
12
13
14
1st order indirect references block
2nd order indirect references block
3rd order indirect references block
Data blocks

General commands

- copy file: **`cp`** `[-pR]`
- move (or just rename) file: **`mv`**
- remove file: **`rm`** `[-rfi]`
- change date + time: **`touch`** [{ `-t`*time* | `-r`*file* }]
- change current directory: **`cd`**
- print working directory path: **`pwd`** `[-P]`
- make directory: **`mkdir`** `[-p]` [`-m`*mode*]
- remove directory: **`rmdir`**

- no undelete command!

File content output

- output (concatenate) files: **`cat`** [*files*]
- output per pages: **`more`**, **`pg`**, **`less`**
- file beginning output: **`head`** [**`-n`** *n*] [*files*]
- file end output: **`tail`** [{**`-n`**|**`-c`**} [**`+`**]*n*] [**`-f`**] [*files*]
- file output for printer: **`pr`**
- file output with numbering lines: **`nl`**
- count bytes, words and/or lines: **`wc`** [**`-cwl`**]
- duplication to output and file: **`tee`** [**`-a`**] *file*

- binary file output: **`od`** [**`-t`***fmt*] [**`-j`***off*] [**`-N`***len*]
- extract strings: **`strings`**

`more` command

- Call:
  `more` [`-`*n*] { `+`*line* | `+/`*regexp* | } [*files*]
- Commands (* - multiplication prefix *k* accepted):
  - space, `d` ... next page, next half of page (*)
  - Enter ... next line (* - *k* will set a default)
  - `s`, `f`, `b` ... skip *k* lines, pages, pages backward (*)
  - `/`*regexp*, `n` ... search for *k*-th string occurrence (*)
  - `'` ... return to search beginning
  - `!`*cmd*, `v` ... start shell, editor
  - `=`, `h` ... file position output, display help
  - `:n`, `:p` ... skip to next/previous file

Printing

	SUSv3	System V	BSD
• print:	`lp` [*file*]	`lp` [*file*]	`lpr` [*file*]
	`-d` *printer*	`-P` *printer*	`-d` *printer*
• show printer status:		`lpstat` *job*	`lpq` *job*
			`-d` *printer*
• cancel printing job:		`cancel` *job*	`lprm` *job*
			`-d` *printer*

- “printers” description: `/etc/printcap`
- default printer: `PRINTER` variable
- spool location: `/var/spool/*`
- print formatting: `pr`, `mpage`

Text processing

- files and/or directories comparison:
  `diff` [`-bBi`] { `-e` | `-C`*n* | `-rqs` } *file1 file2*
  `comm` [`-123`] *file1 file2* *(have to be sorted)*
- cutting parts of lines (cannot change order of parts):
  `cut` [`-s`] { `-c`*list* | `-f`*list* `-d`*char* } [*files*]
- pasting “columns” of files; pasting all lines of one file:
  `paste` [[`-s`] `-d`*chars*] [*files*]
- splitting file per lines or blocks:
  `split` [{ `-l`*lines* | `-b`*bytes*[{`k`|`m`}] }] [*file* [*name*]]
- character conversion:
  `tr` [`-cds`] *table1* [*table2*] př.: `tr 'A-Z\n' 'a-z:'`

`sort` command

- Call:
  `sort` [`-s`] [`-k`*beg*[`,`*end*][*mod*]] [`-t`*d*] [`-ucm`] [*files*]
- Sorts files to output, or to a file (`-o` *file*)
- Key fields definition:
  - *beg* ... first character position, *end* ... last char pos
  - format: *field*[`.`*char*] ... numbered from 1
- Modifiers: `b` (w/o blanks), `f` (ignorecase),
  `n` (numbers), `r` (reverse)
- Options: `t` (field separator, default: sequence of spaces),
  `u` (exclude equal keys), `m` (merge only),
  `c` (check only), `s` (stable - not in SUSv3)
- Beware of local settings (`LC_ALL=C`)
- Similar command: `uniq` (does not sort, can count)

`find` command

- Call: `find` *path... condition... action*
- Conditions:
  - `name`, `path`, `size`, `type`, `links`, `inum`, `fstype`
  - `user`, `group`, `perm`
  - `atime`, `ctime`, `mtime`, `newer`
  - depth within the tree
  - negation (`!`), `-o`, `-a`, parentheses
  - numerical values: *n*, `+`*n*, `-`*n*; filenames: wildcard patterns
- Actions:
  - `print` (usually default)
  - `exec`; filename subst.: `{}`, end of params: semicolon
- Example:
  `find / -name *core -atime +7 -exec rm {} ";"`
- Searching for executable files: `which`, `whereis`

`dd` command

- Provides data copying and conversions
- Name and parameter syntax derived IBM 360 system JCL statement DD (Data Definition)
- Parameters:
  - `if=`*file* - input (default: standard input)
  - `of=`*file* - output (default: standard output)
  - `bs=`*expr* - block size (*n*[`k`][`x`*n*[`k`]]...)
  - `count=`*n* - number of blocks
  - `skip=`*n* - seek from the file beginning
  - `conv=`*c*[`,`*c*]... - conversion(s)
- Conversion ASCII/EBCDIC, fixed line length/LF
- Example:
  `dd if=myfile bs=8 count=1`

`join` command

- Provides database *join* operation - file merge based on parity of key within records
- Options:
  - **`t`** *c* - field separator [sequence of whitespace]
  - {**1**|**2**} *f* - key field number in file 1 or 2 respectively [1]
  - **`a`** *n* - take also unpaired lines from file *n*
  - **`v`** *n* - take only unpaired lines from file *n*
  - **`e`** *str* - substitution for empty fields []
  - **`o`** *list* - output format [key and then all fields in a row]
- Output format syntax:
  - list of field descriptions separated by commas, spaces, or written in more parameters
  - field description: *`n.f`* or **`0`** (join field)
- Illustration example: `ls -l | tr -s ' ' : | join -1 3 -t : -o1.9,2.3 - /etc/passwd`

`xargs` command

- call: **`xargs`** *command*
  - calls *command*, standard input content is used for command parameters
  - e.g.: `xargs rm < files_to_delete`
- call: **`xargs`** {**`-L`***lcnt* | **`-n`***wcnt* } *command*
  - repeats *command* for every *lcnt* lines or *wcnt* words from standard input; particular portion of input is used for command parameters
- call: **`xargs -I`***fn command*
  - repeats *command* for every input line replacing every occurence of symbol defined as *fn* by line text
  - e.g.: `ls *.c | xargs -I{} cp -p {} {}.bak`

Archiving

- directory archiving: **`tar`** {**`c`** | **`t`** | **`x`**} [**`f`** *file*] [*files*]
  - e.g.: **`tar cf - . | ssh host tar xf -`**
  - SW package distribution
- in SUS replaced by **`pax`** command
- file compression
  - historical standard (**`.Z`**): **`compress`**
  - GNU (**`.gz`**): **`gzip`**, **`gunzip`**
- system backup: **`backup`**, **`dump`**, **`restore`**
- remote backup: **`rdump`**, **`rrestore`**

Line-oriented editors

ed - editor available often even in diagnosis mode
- edits <u>file copy</u>, result has to be written back
- commands are taken <u>from standard input</u>
- batch editing (**ed**-scripts)

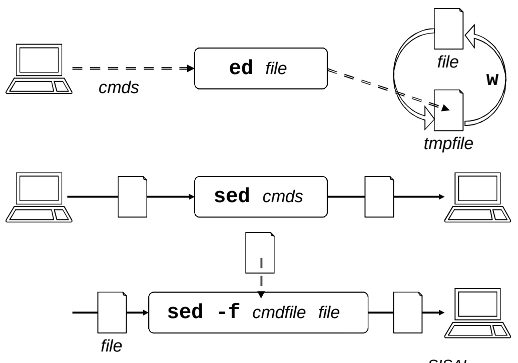
- call: **ed** *file*

sed - stream editor
- edits <u>standard input</u>, result to <u>standard output</u>
- editor commands are given as <u>call parameter</u>

- call: **sed** *commands* [*file ...*]

- example: `hostname | sed 's/\..*//'`

Workflow of **ed** and **sed**



Command format, line address (**ed**)

- Command syntax:
  [*address*[**,***address*]]*cmd*[*parameters*]
- In every moment, one line holds <u>current line</u> status
  (last line touched by last command; last line of file on start)
- Line address formats and semantics:

`.`	current line (usual default)
±[*n*]	line relative to current line
n	line with absolute number *n* (numbered from 1)
`$`	the last line of the file
`/`*pat***`/`**	following line containing pattern
`?`*pat***`?`**	previous line containing pattern
`'`*x*	line marked by mark (letter) *x*
adr±[*n*]	line relative to line addressed by *adr*

Basic regular expressions (**ed**, **sed**, **vi**)

Way how to define strings in many utilities. Metachars:

- **`.`** … any character
- **`[`***list***`]`**, **`[^`***list***`]`** … any char from the list, or list complement
  e.g.: `[a-zA-Z0-9_]`, `[^ ]`, `[]^-]`
- **`[[:`***class***`:]]`** … any character from the class
  e.g.: `[[:alnum:]]`, `[[:xdigit:]]`
- **`^`**, **`$`** … start, or end of line (used on start or end of regexp)
- `\`*c* … metachar used as regular char (e.g.: `\.` means dot)
- *exp***`*`** … any number of occurence of the last subexpression
  e.g.: `a*`, `[0-9][0-9]*`
- *exp***`\{`***n***`\}`**, *exp***`\{`***m***`,`**[*n*]**`\}`** … repeating *n* times, *m-n* times
- **`\(`**, **`\)`**, `\`*n* … grouping of subexpression, backreference
  e.g.: `\(ab\)*`, `A\(.\)\1A`

Positional commands of **ed**

Commands having current line as default address,
commands marked by * cannot have block address:

print, num, list	… print, numbered, incl. control chars
delete	… removing lines
append*, change, insert*	… inserting lines (end: a single dot)

e.g.:
```
0a
new line 1
new line 2
.
```

move, to	… moving, copying lines

e.g.: `/begin/,/end/ t $`

mark* (**k***x*)	… setting a mark *x* (letter)
join	… joining lines (deletes LF, def. +1)
substitute	… string replacement

substitute command (**ed**)

Syntax:
`s/`*pattern***`/`***replacement***`/`**{**g**|*n*}

Character after command name defines string delimiter
e.g.: `s/\/$//` or `s=/$==`

Pattern: regexp, replacement: text with metacharacters:

- \n … backreference (slow!)
  e.g.: `s/\(.*\) \(.*\)/\2 \1/`
- **&** … whole original text matching pattern
  e.g.: `s/.*/(&)/`

Global substitution starts search of next pattern occurence after the last character it has already modified:
e.g.: `s=/\./=/=g` ... does not replace „`/././`“

A star “eats” the longest string that matches:
e.g.: `s/\(.*\)-/\1/` ... removes the <u>last</u> hyphen

Global commands of **ed**

Commands having “entire file” as default address:

global, invert (**v**)	… command execution on selected lines

`g/`*pattern***`/`***cmd* [**`\<LF>`***cmd*]

write (**w** [*file*])	… saving (under original name)

(when address part used, only these lines are saved!)

W *file*	… appending to file
w!*cmd*	… writing to command pipe

Commands having “the last line of the file” as default address:

read (**r** [*file*])	… inserting text of another file
=	… displaying line number

Non-positional commands of **ed**

Commands without address part:

undo	… undoing last change
edit (**e** [*file*])	… (re-)opening file
file (**f** *file*)	… changing file name
quit	… ending editor
help	… explanation of the last error

Examples of **global** command usage

- **`g/integer/s//longint/g`**
  changes all integers to long ones

-
  ```
  g/procedure/i\
  { begin of procedure }\
  .
  ```
  inserts a comment line before every procedure

-
  ```
  g/^Chapter/ . W index\
  /./ W index
  ```
  writes chapter index
- **`g/^/ m 0`**
  rewrites file “crablike”

`grep` command

- Name origin: **`g/`***`re`***`/p`**
- Variants:
  - **`egrep`** (**`-E`**, *extended* regular expressions)
  - **`fgrep`** (**`-F`**, *fixed* string only)
- Options:
  `-c`(*count*), **`-l`**(*listfiles*), **`-n`**(*number*), **`-q`**(*quiet*)
  `-i`(*ignorecase*) , **`-x`**(*exact*), **`-v`**(*invert*)
  `-e` *expression*, **`-f`** *filename*
- Extensions:
  `-w`(*word*) , **`-H`**(*head*)
  `-`*n* ... print *n* lines surrounding matching ones
- Quick implementation of regular expressions!

sed filter

- stream editor
- edits input (usually another program output)
- modified lines (and/or printed ones) writes to output
- call:
  `sed` [**`-n`**] { [**`-e`**] *cmd* | **`-f`** *script* } [*file*]
- commands similar to **`ed`** ones
- separated by semicolon or end-of-line
- executed in given order
- cannot end with a space

Command format, line address (**sed**)

- Command syntax:
  [*address*[**`,`***address*]]*cmd*[*parameters*]
- No current line exists, commands with empty address part are applied to every line
- Line address formats and semantics:

n	line with absolute number *n* (numbered from 1)
`$`	the last line of the file
`/`*pat*`/`	every line matching pattern

- Address space complement: *address* **`!`** *command*...
- Compound statement: *address* **`{`**
  commands...
  `}`
- Comment: **`#`** *comment*...

Commands of **sed** (I)

- the same commands as in **`ed`**:
  - **`p`**, **`d`**, **`s`**, **`w`**, **`q`**
  - **`a`**, **`c`**, **`i`**
    command itself and all lines but the last ended by "`\`":

```
sed '3a\
fourth\
fifth'
```

- new parameters of **`substitute`** command
  - **`p`** ... line is printed after editing
  - **`w`** *file* ... line is written to a file after editing
- character conversion
  - **`y/`***intable***`/`***outtable***`/`**
    function similar to the **`tr`** command

Commands of **sed** (II)

- control flow
  - **`n`**(ext) … closing work with line, reading next one
  - **`:`***label* … label definition
  - **`b`**(ranch)[*label*] … jump to a label (to the end of cmds)
  - **`t`**(est) [*label*] … conditional jump
    (jump if some substitution was made since last reading-in of a line, or `test` command execution)
    Example:

```
:loop
s:/\./:/:g
t loop
```

    ... removes all "`/./`" sequences from a path

Commands of **sed** (III)

- more lines in *pattern space* (separator: **`\n`**)
  - **`N`**(ext) … appending next line from input
  - **`P`**(rint) … printing first line from pattern space
  - **`D`**(elete) … removing first line from pattern space

  Example:

```
:loop
/foo([^)]*$/{
  N
  b loop
}
/foo(/s/);/, true);/
```

  ... adds a new parameter to function calls

Commands of **sed** (IV)

- work with *hold space*
  - **h**, **H**(old) … copying (appending) to hold space
  - **g**, **G**(et) … copying (appending) to pattern space
  - **x**(change) … exchanging of content of both spaces

  Example:
```
/procedure/h
/^end/ {
  p
  g
  s/procedure/{ end of/;s/ *(.*/ }/
}
```
  ... adds comments with name behind procedures

sed command examples (I)

- **`sed  /record/,/end/d  program.pas`**
  prints program without record definitions
- **`sed '/procedure/i\`**
  `{ begin of procedure }' program.pas`
  inserts a comment line before every procedure
- **`sed '1p;$p' program.pas`**
  prints file with duplicated first and last line
- **`sed -n '4,6!p' program.pas`**
  prints file without lines #4 to #6

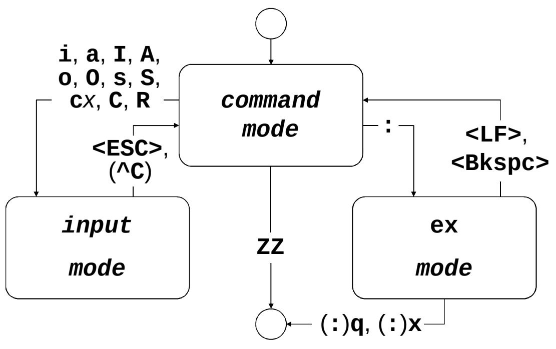
sed command examples (II)

- **`sed 's/:.*//;s/$/./' /etc/passwd`**
  result: `forst.`
- **`ls *.c | sed 's/\(.*\).c/cp -p & \1.bak/'`**
  result: `cp -p test.c test.bak`
- **`echo ab | sed 's/a/b/;s/b/a/'`**
  result: ab
  correct: **`y/ab/ba/`**
  or: **`s/a/\`**
  `/g;s/b/a/g;s/\n/b/g`
- **`sed 's/.*:\(.*\) \(.*\):.*/\2 \1/' /etc/passwd`**
  result: `Cooper:/home/spock Sheldon`
  correct: **`s/.*:\(.*\) \([^:]*\):.*/\2 \1/`**

vi editor

- visual editor
- genesis: **ed** ⇨ **ex** ⇨ **vi**
- fullscreen editor
- available on every UNIX
- wide spectrum of commands
- small number of necessary commands
- editing on temporary copy of file
- call:
  vi [**-rR**] {**+**[*line*] | **+/***pattern* } [*files*]

Modes of **vi**



Essential commands of **vi**

- **vi** *file* … editor call
- **i** … text inserting mode
- *text being inserted*
- **<ESC>** … finishing input mode
- **h**, **j**, **k**, **l** … cursor movements
- **/***pattern* … string pattern searching
- **x**, **dd** … deleting a char, a line
- **A** … appending to the end of line
- **J** … joining lines
- **ZZ**, **:x** … closing editor
- **:q!** … cancelling editor

Movement commands (I)

Commands may be prefixed by repeating factor *k*

- `h` (`<BKSPC>`), `j`, `k`, `l` (`<SPACE>`) … *k* places (⇦, ⇩, ⇧, ⇨)
- `w`, `b`, `e`, `W`, `B`, `E` … *k* words (forward, backward, to the end of word, ignoring punctuation)
- `(`, `)`, `{`, `[[` … to next (prev.) sentence, paragraph, section
- `+` (`<LF>`), `-` … to the beginning of next (prev.) line
- `$`, `0`, `^` … to the end, beg., first nonspace char on the line
- `f`*x*, `F`*x*, `t`*x*, `T`*x*, `;`, `,` … char *x* on line (forward, backward), char before/after *x*, repeat, repeat in opposite direction
- `/`*regexp*, `?`*regexp*, `/`, `?`, `n`, `N` … search string, forward, repeat pattern, repeat search, repeat in opposite direction
- `^F`, `^B`, `^D`, `^U` … page forward, backward, half a page

Movement commands (II)

Commands may be prefixed by absolute value *k*:

- *k*`|` … *k*-th position on the line
- [*k*]`H` … move to *k*-th line on the screen [1]
- [*k*]`L` … move to *k*-th line from the end of screen [1]
- `M` … move to mid-line on the screen
- [*k*]`G` … move to *k*-th line of the file [last]

Mark *x* (letter) handling:

- `‘`*x* … move to position marked by mark *x*
- `‘‘` … move to last position marked
- `'`*x* … move to beginning of the line marked by mark *x*
- `''` … move to beginning of the last marked

(mark is being placed by `m`*x* command)

Insertion, modification

Commands may be prefixed by repeating factor *k*

- `i`, `a`, `I`, `A` … inserting before (behind) cursor, line
- `o`, `O` … opening new line above (below) current one
- `~` … changing case of letter under cursor *
- `r`*x* … replacing character under cursor by character *x* *
- `R` … replacing text (move to input mode in replace mode)
- `c`*m* … changing text from cursor up to position defined by any movement command *m*
- `cc`, `C` … changing whole line, changing to end of line
- `s`, `S` … removing char (line) and enter input mode

Commands marked * do not switch to input mode.

Removal, work with buffers

Commands may be prefixed by repeating factor *k*

- `x`, `X` ... deleting character under (before) cursor
- `d`*m* … deleting text from cursor up to position defined by any movement command *m*
- `dd`, `D` … deleting whole line, deleting to end of line

Deleted text is stored into numbered buffer.

- `p`, `P` … pasting buffer behind (before) cursor (or line)
- `"`*n*`p`, `"`*n*`P` … pasting *n*-th last buffer
- `"`*x*`p`, `"`*x*`P` … pasting buffer named *x* (lowercase letter)

Copying text into (named) buffer:

- [`"`*x*]`y`*m* … copying text up to position defined by *m*
- [`"`*x*]`yy`, [`"`*x*]`Y` … copying whole line

Miscellaneous commands (`vi`)

- `.` … repeating last modification command
- `u` … undoing last modification command
- `U` … restoring last changed line to original state
- `J` … joining line with next one
- `%` … move to pair `)`, `]` or `}` (not `>`)
- `^L` … redraw screen
- `z<LF>`, `z.`, `z-` … scroll, current line will be placed on the top (middle, bottom) of the screen
- `^E`, `^Y` … scroll by one line
- `^G` … current file and line info displaying
- `!`*m cmd*, `!!`*cmd* … extracting block of text, using it as input for *cmd* and storing output back to the text
- `<`*m*, `>`*m* … indenting
- `@`*x* … executing commands stored in buffer *x*
- `^W`, `^V` … (in input mode) deleting word, inserting control char

`ex` - command extensions (I)

- addresses may be separated by semicolon - the first line will become current instead of the last one
- extension of `substitute` command
  - `c` parameter … replacing with confirming (`y<LF>`)
  - `~` metachar in regexp … previous regexp
  - `\<` and `\>` sequences in regexp … beg. and end of word
  - `\u`, `\l`, `\U` and `\L` sequences in replacement ... lettercase changing (whole word)
- new commands
  - `co` (copying, an alias of `t` command)
  - `j`[`!`] … joining lines; after `.` adds two spaces, after `)` none, one otherwise (`!` ... means no spaces)
  - `ya`[*x*], `pu`[*x*] … work with (named) buffers

ex - command extensions (II)

- **sh**, **!***cmd* … shell run, command run
- **so** … executing ex source code
- **w!**, **w>>** … writing to read-only file, appending to file
- **x**, **wq** … storing file and exiting editor
- **q!** … quitting editor without storing changes
- **n**[**!**] … editing next file from list (without storing changes) Named buffers, the last regexp and editing command remain available.
- **e**[**!**] [*file*] … editing another file (**%** substitutes current file name, **#** the last used file name)
- **ab** *word string*, **una** … abbreviation
- **map**[**!**] {*char* | **#***n*} *string*, **unm** … character or function key mapping (for input mode); control chars entered using **^V**

vi editor settings

Options setting: **set**, list of all options: **set all**

- **autoindent**, **ai** ... new lines autoindentation [**noai**]
- **directory=***dir*, **dir** ... working directory [**=/tmp**]
- **ignorecase**, **ic** ... ignorecase search [**noic**]
- **number**, **nu** ... displaying line numbers [**nonu**]
- **shell=***path*, **sh** ... path to shell [**=/bin/sh**]
- **showmatch**, **sm** ... pair characters matching [**nosm**]
- **tabstop=***n*, **ts** ... tab size [**=8**]
- **wrapscan**, **ws** ... search over end of file [**ws**]
- **wrapmargin=***n*, **wm** ... right margin for wrapping [**=0**]

Default setting for **ex** and **vi**

Before editor start, commands for default setting are executed; order of execution:

- the **EXINIT** variable
- script **.exrc** in home directory
- script **.exrc** in current directory

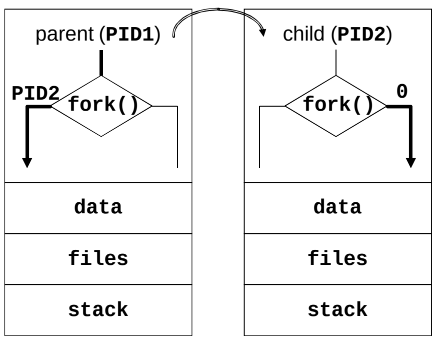
  if option **exrc** is set (unset by default)

Commands are written like in **ex** (without colon).

Process

- running program ... (at least one) process
- process scheduling - priority
- list: **ps** command
- PID
- parent process ⇨ child process
- context of process
  - memory, files, environment variables,...
- communication
  - signals, pipes, sockets, shared memory,...
- return code (0..255)
- foreground/background run, daemon

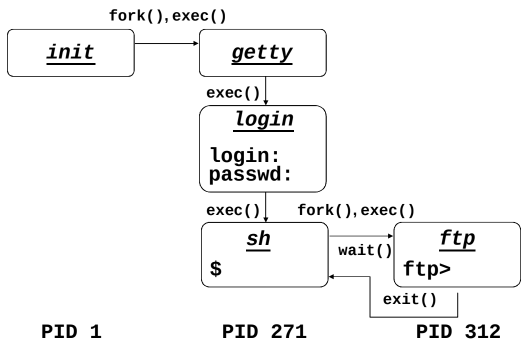
Process creation



Process control functions

- **fork()** … creates copy of parent process; "Cannot fork" error must be handled
- **exec()** … overlaps the address space of the process by given program
- **wait()** … (parent process) waits for end of child processes
- **exit()** … terminates process and passes return code to parent process

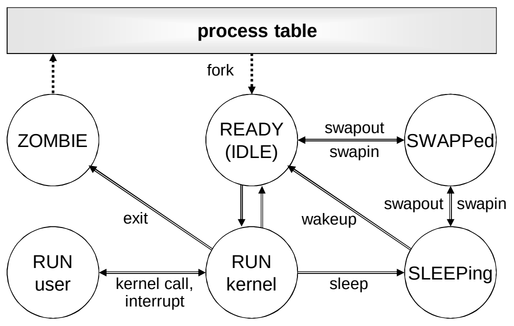
User session



Process context

- From user's point of view
  - program code, data, stack
  - open files
  - system (*environment*) variables
- From system point of view
  - general registers, program counter, processor status register, stack pointer, floating point registers, memory mapping registers...
  - memory allocated for process in user mode
  - kernel memory bound to process (e.g. process kernel stack)

Process states



Process priority

- One of the factors used by process scheduler
- Positive number (the higher one, the "nicer" process)
- Child process inherits parent's priority
- It is possible to change priority when process started
  `nice -n` *incr cmd*
- Increment used to be allowed within -20 to +20
- Only root can use negative values
- Running process priority change
  `renice -n` *incr PID...*

ps command

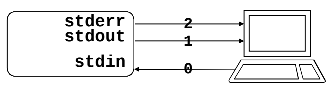
- **`PID`**, **`TTY`**, **`STAT`**, **`TIME`** a **`COMMAND`** of own processes

	System V	BSD	POSIX
• process selection:	**`-e`** (every)	**`-a`** (all users) **`-x`** (no tty)	**`-A`** (All)
	`-p` *PIDs* **`-t`** *ttys* **`-U`** *users* **`-G`** *grps*		
• output content:	**`-l`** (long), ...	**`-l`** (long), ...	
	`-o`*key*, ... (only given columns)		
	`-O`*key*, ... (columns added)		
• sorting: *(PD program **`top`**)*		**`-r`** (cpu) **`-m`** (mem)	

Process and I/O

- access to input and output file through so called *file-descriptors*

0	-	standard input (**`stdin`**)
1	-	standard output (**`stdout`**)
2	-	standard error output (**`stderr`**)
…	-	further files being opened



Inter-process communications

- sending signals
  - asynchronous control
  - information of type: event *N* occurred
- input/output through pipes
- System V IPC
  - semaphores
  - sending messages
  - shared memory
- BSD Sockets
  - sending messages, establishing streams
  - inside a system (files of **`s`** type), or between a client and a server via network

Signal handling

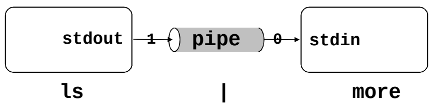
- signal sending:
  - command: **`kill`** [**`-`***signal*] *PID*
  - function: **`kill`**
- signal trapping:
  - command: **`trap`** [*command*] *signal ...*
  - function: **`signal`**, **`sigaction`**
  - standard handlers: **`SIG_IGN`**, **`SIG_DFL`**, **`SIG_ERR`**
  - non-maskable signals: **`KILL`**, **`STOP`**
- list of signals: **`kill -l`**

Important signals

`HUP`(**`1`**)		program restart
`INT`(**`2`**), **`QUIT`**(**`3`**)		user interrupt (**`^C`**, **`^\`**)
`ILL`(**`4`**)		bad instruction
`ABRT`(**`6`**)		**`abort`** function call
`FPE`(**`8`**)		error in arithmetic
`KILL`(**`9`**)	(non-maskable)	process termination
`SEGV`(**`11`**)		addressing exception
`SYS`(**`12`**)		bad system call
`ALRM`(**`14`**)		timer interrupt
`TERM`(**`15`**)	(maskable)	process termination (**`kill`**)
`STOP`(**`17`**), **`TSTP`**(**`18`**), **`CONT`**(**`19`**)		process stopping/resuming
`CHLD`(**`20`**)		child exiting
`USR1`(**`30`**), **`USR2`**(**`31`**)		user signals

Pipes

- in shell - binding input and output of two processes



- in program:
  - pipe executing a command: **`popen`**, **`pclose`**
  - pipe between (parent and) children: **`pipe`**
- permanent (named) pipes
  - included to filesystem (**`p`** type)
  - created by **`mknod`** function, or **`mkfifo`** command

System V IPC

- Every medium has unique ID
- Semaphores:
  - generalization of *P* and *V* operations [Dijkstra, Dekker]
  - *dead-lock* protection, process termination
  - functions: **`semget`**, **`semop`**, **`semctl`**
- Sending messages:
  - system creates communication channel
  - functions: **`msgget`**, **`msgsnd`**, **`msgrcv`**, **`msgctl`**
- Shared memory:
  - system adds requested area to process memory table
  - functions: **`shmget`**, **`shmat`**, **`shmdt`**, **`shmctl`**

BSD Sockets

Socket - end of channel for client-server communication
System functions:

- `socket` creates file descriptor according to
  - domain (*address family*): **`AF_UNIX`**, **`AF_ INET`**
  - type: virtual circuit (*stream*), *datagram*

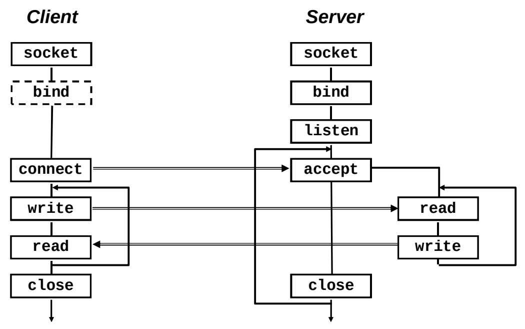
- `bind` assigns own address:
  - UNIX: name in filesystem (**`s`** type)
  - INET: IP address + port

- `listen` starts listening (e.g. sets queue length)

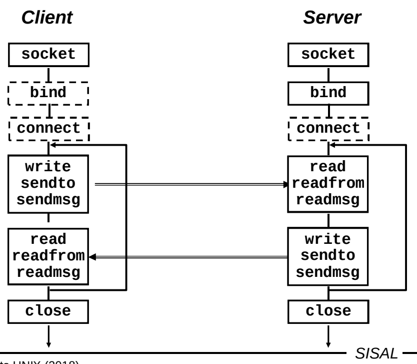
- `accept` (server) accepts request to channel from client

- `connect` (client) tries to make a connection to server

TCP application model



UDP application model



Start of network daemons

- **direct start**
  - within starting scripts
  - intensively used services, with complicated startup
- **indirect start** (on demand)
  - by **`inetd`** daemon
  - configuration in **`/etc/inetd.conf`**:

```
bootps dgram  udp wait   root   /etc/bootpd bootpd
tftp   dgram  udp wait   nobody /etc/tftpd  tftpd /tftpboot
whois  stream tcp nowait nobody /etc/whoisd whoisd
```

  - reconfiguration: **`kill -HUP`** *PID*
  - server communicates through file descriptors 0/1

Terminal

- user exploits system services by means of *terminal* - either real or *pseudoterminal*
- properties in **`/etc/termcap`** or **`/etc/terminfo`**
- terminal type in **`TERM`** variable
- terminal (re)initialization by **`tset`** command
- properties change by **`stty`** command
  (e.g. **`stty erase`** *char*)
- access to own terminal through **`/dev/tty`**

Control characters

- some are configurable, others depend on shell
  ⇨ terminal and **`TERM`** accordance required
- usual default control sequences:

Ctrl+H	-	backspace
Ctrl+S	-	output stop
Ctrl+Q	-	output continuation
Ctrl+C	-	process termination (**`SIGINT`**)
Ctrl+\	-	termination with dump (**`SIGQUIT`**)
Ctrl+D	-	end of input
Ctrl+Z	-	process suspension (**`SIGTSTP`**) continuation: **`fg`** or **`bg`**

Shell

- basic program for communication with UNIX
- independent system component
  - Bourne shell, C shell, Korn shell
- reads lines and executes commands
  - own commands
  - programs stored in file system
- text preprocessor
  - meta-characters
  - variables
- program language & its interpreter
  - scripts

Basic built-in commands of shell

: [*arg...*]	- null command
echo [**-n**] *text*	- text output (with/without newline)
printf *fmt arg...*	- formatted text output
pwd	- current directory path output
cd [*dir*]	- current dir change (shell property)
exit [*rc*]	- shell exit (with return code)
set {**+**|**-**}*opt...*	- shell options setting
ulimit [*limit*]	- work with user limits setting
umask [*mask*]	- work with new file mode mask

Formatting directives of `printf`

- General form: **%**[*flags*][*width*][.*prec*]*type*
  - **%c** ... print one char
  - **%s** ... print string
  - **%u**, **%d**, **%o**, **%x** ... print integer (unsign., dec., oct., hex.)
  - **%e**, **%f**, **%g** ... print real number
  - **%%** ... print percent sign
- Modifiers:
  - **%**[**-**] *width* [**.***len*] **s** ... left alignment, maximum length
  - **%**[**+**][**0**]*width fmt-spec* ... sign enforced, leading zeroes
  - **%***width* [**.***precision*] *fmt-spec* ... real number precision
- Almost the same directives used in command in **awk** and function in C language

Meta-characters

- characters with a special meaning (e.g. *****, **>**)
- special meaning may be suppressed ("quoted") by
  - prefixing the char by "\" (so called *escape-sequence*)
  - enclosing to single quotes (suppresses all metachars)
  - enclosing to double quotes (keeps meaning of **$**, **`**, **"**, ****)
- suppressed also:
  <LF> ... do not execute command, just continue
  space ... take several words as a single parameter
- take care namely in complex command parameters (e.g. `sed 's/ [0-9]*/ #/' ...`)

- comment: ... *#comment*

Shell patterns

Word with shell pattern meta-characters is replaced by list of all filenames matching the pattern.

*****	- matches any string of characters
?	- matches any single character
[a-f0-9]	- matches any character from the list
[!a-z]	- matches any character not on the list

Whitespaces have to be escaped by ****.
Chars **!**, **]**, **-** can be used same way like in regexps.

Expansion done by shell !
Expansion does not include leading dot in filenames, does not cross directory border.

Shell variables

*name***=***value*	- assigning a value
*name***=***value cmd*	- setting just for *cmd* execution
$*name*, **${***name***}**	- value expansion (substitution)
${#*name***}**	- substitution for value length

Identifier - alphanumeric characters, case sensitive.
Variables have only text value.
Substitution of unset variable - empty string.
Output of variable value: **set**, **echo "$***name***"**
Local and *environment* variables.
Child process (subshell, pipe) inherits only *exported* variables (by **export** *variable*).
Child cannot change variables of its parent!

Environment variables

IFS	- Internal Field Separator, default: IFS=<space><tab><LF>
PS1, **PS2**	- prompt, continuation prompt
PATH	- path: list of dirs with executable files (current dir not included by default!)
CDPATH	- path for **cd** command
TERM	- terminal type
SHELL	- running shell
LOGNAME	- logged user name
HOME	- user home directory
MAIL	- user's incoming mailbox file

Conditional variables substitution

syntax	result if *name* variable is	
	defined	undefined
${*name***:-***value***}**	**$***name*	*value*
${*name***:=***value***}**	**$***name*	*value* +assigning *name***=***value*
${*name***:+***value***}**	*value*	""
${*name***:?***value***}**	**$***name*	"" +**echo** *value* and **exit**

Command files - scripts

- "direct" call (rights **+rx**):
  script params
- call by shell (rights **+r**):
  sh [*options*] *script params*
- code sourcing (runs in the same shell process, not as a new process):
  . *script*
- the first line may define interpreter and options:
  #!*abs_path_to_interpreter* [*options*]
- login startup scripts (sourced):
  /etc/profile, **.profile**

Positional and special parameters

$*n*	- *n*-th parameter (of script), *n* <= 9
$#	- number of parameters (of script)
$0	- script name
shift [*n*]	- shift positional parameters (`$2` ⇒ `$1`)
set [**--**] *text*	- reset positional parameters
e.g.: `set a + b`	⇒ $1=a, $2=+, $3=b, $#=3
`IFS=:; set $PATH`	⇒ $1=/bin, ...
$*	- all positional parameters as text
$@	- all params, but **"$@"** is **"$1" "$2"**...
$?	- return code of last command
$$	- current shell PID
$!	- last background process PID

Command input redirection

syntax	redirects command input ...
cmd **<** *file*	... from *file*
cmd **<<** *str*	... from shell input (shell script text); input processed like text in double quotes e.g.: `ed xxx << END` `${line_number}d` ← *here document* `END`

cmd **<<** `\`*str*	ditto, processed like text in single quotes
	e.g.: `ed xxx << \END`
	`1,$d`
	`END`

cmd **<<-** *str*	ditto, text may be indented (by tabs)
	e.g.: `ed xxx <<- END`
	`        1,$d`
	`END`

Command output redirection

syntax	redirects ...
cmd **>** *file*	standard output to *file*
cmd **2>** *file*	standard error output to *file* e.g.: `rm xxx 2> /dev/null`
cmd **>>** *file*	standard output to end of *file*
cmd **2>>** *file*	standard error output to end of *file*
cmd **2>&1**	standard error output to standard output, attention to redirection order: - `grep xxx file > $log 2>&1` both outputs go to `$log` file - `grep xxx file 2>&1 > $log` output goes to `$log`, error to output

Command lists

- *cmd1* **|** [<LF>] *cmd2*
  - pipe between commands
    e.g.: `ls -l *.c | wc -l`
- *cmd1***;** *cmd2*
  - sequence of commands
- *cmd1* **||** [<LF>] *cmd2*, *cmd1* **&&** [<LF>] *cmd2*
  - conditional sequence of commands
    e.g.: `rm aa && echo File aa removed`
- **{** *cmd1***;** *cmd2***;}**
  - compound statement
- **(***cmd1***;** *cmd2***)**
  - run command(s) in subshell
    e.g.: `(cd wrk; rm *)`

read command

- Command **read** *var* reads line from input to variable
- Command sets return code (success may be tested)
- In case of more parameters it assigns one-by-one fields from input line to variables (rest of line to the last one); field separators defined in **IFS**; subsequent whitespace separators grouped; *as-is* reading can be forced by **IFS=''**
- Character \ in input is interpreted as quoting (escapes field separator, but <LF>, too!); may be suppressed by **-r** option
- When called from prompt it reads from terminal, can be redirected (**read** *var* **<** *file*), as well as terminal read can be enforced (**read** *var* **</dev/tty**)

read command examples

- `echo -n "Enter number: "; read x`
  ... reads answer
- `IFS=: read user x x x name x < /etc/passwd`
  ... reads login and full name of (1st) user

-
  ```
  LHOST=ss1000.ms.mff.cuni.cz
  echo $LHOST | cut -f1 -d. | read SHOST
  ```
  ... does nothing (SHOST set in child process)

-
  ```
  echo $LHOST | cut -f1 -d. > /tmp/x.$$
  read SHOST < /tmp/x.$$
  rm /tmp/x.$$
  ```

Command output substitution

...`` `cmd` ``... - inserting output of *cmd* call into line text

- př.:
  ```
  SHOST=`echo $LHOST | cut -f1 -d.`
          ⇓
  SHOST=ss1000
  ```
- command runs in a subprocess of the same shell
- the last LF is removed
- attention to nested call
  - inner back quotes (and slashes) have to be “quoted”
  - solution: storing to temporary variables
  - since **ksh** added new syntax ...**$(***cmd***)**...
- e.g.:
  ```
  rm `cat files`
  vi `grep –l '^\\.\\\\"' man8/*.8`
  ```

Control structures

```
if cmd
then  cmds
[elif  cmd
 then  cmds]
[else  cmds]
fi
```

```
case  word  in
pat1 | pat2 )
   cmds;;
*)
   cmds;;
esac
```

```
{while|until} cmd
do
  cmds
done
```

```
for  var  [ in  text ]
do
  cmds
done
```

test command

- call: **test** *condition* or **[** *condition* **]**
- when true exits with return code **0**
- attention to unset variables, spaces etc.:
  - right: **[-n = "$x"]**
  - wrong: **[-n = $x]**, **[-n="$x"]**
- logical operations (with unconditional evaluating):
  - conjunction: *cond1* **-a** *cond2*
  - disjunction: *cond1* **-o** *cond2*
  - negation: **!** *cond*
  - subexpression: **(** *cond* **)**

    attention - quoting in shell needed

test command operators

-e *file*	- *file* exists
-f *file*	- *file* is regular file
-d *file*	- *file* is directory
-L *file*	- *file* is symbolic link
-r *file*	- current user has **r** access right to *file*
-w *file*	- current user has **w** access right to *file*
-x *file*	- current user has **x** access right to *file*
-s *file*	- *file* exists and is not empty
-z *string*	- *string* is empty
-n *string*	- *string* is not empty
str1 = *str2*	- string equality (really equality: **$x = a*** !)
str1 **!=** *str2*	- string inequality
int1 **-eq** *int2*	- number equality (**-ne**, **-lt**, **-le**, **-gt**, **-ge**)

`expr` command

- call: **`expr`** *opndA op opndB ...*
- outputs text result and exits with return code
- logical operators: **`=`**, **`<`**, **`>`**, **`<=`**, **`>=`**, **`!=`**
- arithmetic operators: **`+`**, **`-`**, **`*`**, **`/`**, **`%`**
- string operators (in SUS only "**`:`**"):
  - *string* **`:`** *regexp* (anchor to beginning by default!)
  - **`match`** *string regexp*
  - **`substr`** *string pos len*
  - **`length`** *string*
  - **`index`** *string chars*
- attention to meta characters
- newer shells have arithmetic directly: **`$((`**...**`))`**

Control structures - **`if`**

Example:
```
if [ -d tmp ]; then
   echo directory exists
elif mkdir tmp; then
   echo directory created
else
   echo cannot create directory
fi
```

Comments:
- A pipe can be used as the tested command.
- Command result may be negated: `if !` *cmd*
- If the command produces output, it has to be handled:
  `if echo "$x" | grep ... > /dev/null`

Control structures - **`case`**

Example:
```
case $1 in
-h | -\? ) echo "Usage: ..."; exit;;
'' | *[!0-9]* )
   echo "No number entered"; exit;;
* ) NUMBER=$1;;
esac
```

Comments:
- Labels are formed by *wildcards*, however without the special meaning of dot and slash (no expansion made).
- Label order is important (sometimes it may be used to compensate missing negation or regexps).
- Variables (even tested ones) may be used in labels.

Control structures - **`while`**, **`until`**

Example:
```
while read line; do
   case $line in
   \#* ) continue;;
   *   ) $line;;
   esac
done < script
```

Example:
```
i=1; until mkdir /tmp/$i; do
   i=`expr $i + 1`
done
```

Example:
```
while [ $# -gt 0 ]; do
   case $1 in
   -n  ) N=$2; shift 2;;
   -n* ) N=`echo $1 | cut -c3-`; shift;;
   *   ) break;;
   esac
done
```

Control structures - **`for`**

Example:
```
list=MFF,FF,FaF,FTVS
for file in *; do
   case ,$list, in
   *,$file,* ) cp $file ${file}_bak;;
   esac
done
```

Comments:
- Loop from 1 to *n* (`seq` is not in SUS):
  ```
  for i in `seq 1 $n`; do
  i=1; while [ $i -le $n ]; do i=`expr $i + 1`
  i=:; while [ ${#i} -le $n ]; do i=:$i
  ```
- The `for` loop is not suitable for file reading:
  ```
  for line in `cat file`
  ```

Example: input file reading

-
  ```
  n=0
  while read x < file; do
     n=`expr $n + 1`
  done
  ```
  ... reads infinitely first line

-
  ```
  n=0
  cat file | while read x; do
     n=`expr $n + 1`
  done
  ```
  ... the **n** variable is set only in child

-
  ```
  n=0
  while read x; do # < file
     n=`expr $n + 1`
  done < file
  ```

Example: pipe output reading

```
• n=0; find ... | ( while read x; do
      n=`expr $n + 1`
    done
    echo Found $n files
  )
• ... | while read x; do
      printf "Delete $x? (y/[n]) "
      read z
      case $z in
      '' | n* | N* ) continue;;
      esac
      rm $x; n=`expr $n + 1`
    done
```

... the **z** variable is read also from the file

- `read z < /dev/tty`
- `{ ... read z <&3 ... } 3<&0`

Functions

Function *name* definition:

name`(){`
  statements
`}`

- runs in the same process
- variables are global, function can change them!
- call + parameters same as other commands call
- parameters are accessed via **`$#`**, **`$1`** etc.
  (positional parameters are local, no change of caller ones!)
- function exits with return code of last command,
  can be changed using command **`return`** *val*
- priority: functions, built-in commands, external programs
  built-in commands can be forced by **`command`** *cmd*
- functions are not inherited into subshells

Line processing steps

Line is parsed from left to right in following steps:

1. breaking up to atoms (words) by operators
2. control structures and operators detection
3. redirection operators detection
   and variables definition
4. variables and command substitution

5*. breaking substitution result by chars in **`$IFS`**

6*. shell patterns expansion

7. quote removal

*Steps 5 and 6 are not executed when setting variables.

Re-parsing of input line

`eval` *arg* - re-parsing and executing line made by concatenating all the arguments with spaces

- example: `read login x uid x < /etc/passwd`
  `eval UID$uid=$login`
  ⇓
  `UID0=root`
  - using indirect variables (array compensation)
- example: `eval echo \$$#`
  - using value of the last parameter

Process control

cmd **`&`** - execution in background
`wait` - waiting for background process exiting

... since **`csh`** more sophisticated management (**`jobs`**,...)

`exec` *cmd* - call of `exec()` with *cmd* command
(shell changes to given program)

... since **`ksh`**, **`exec`** can be used for current shell file descriptors redirection (e.g.: **`exec 3<&0`**)

Signal handling in shell

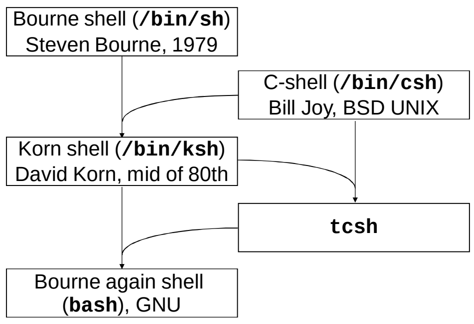
- Handler setting: **`trap`** [*cmd*] *sig...*
  - *sig*: number/name of signal or `0`/`EXIT`
  - *cmd:* handler (executed within current process)
- Child process cannot handle signals masked off by parent.
- Masking signals off: **`trap ""`** *sig...*
- Default handler resetting: **`trap`** *sig...*

Shell options

Sheel options can be set
- on command line when starting shell
- on the first line of script
- by **`set`** command

Most important options:
`-a` ... all variables are exported
`-C` ... do not overwrite existing files with redirection
`-e` ... stop shell when error occurs
`-f` ... disable shell pattern expansion
`-n` ... read commands but do not execute them
`-u` ... expanding unset variable is error
`-v` ... shell input lines are written to standard error
`-x` ... executed cmds are written prior execution

Shell evolution



C-shell

Basic differences:
- **`.login`**, **`.cshrc`** … startup script
- **`set`** *var*=*str*, **`env`**, **`setenv`**, **`@`** *var expr* … variables
- **`foreach`**, C-like expressions and commands
- **`>&`**, **`>>&`**, **`|&`** … standard error output redirection
- **`$<`** … direct input from terminal

Features adopted (and modified) by successors:
- ~[*user*] … home directory
- **`<ESC>`** … filename completion
- **`history`**, **`!`**[[**`-`**]*n*], **`!`**[[**`?`**]*str*] … command history
- **`alias`** *name str* … command aliasing
- **`pushd`**, **`popd`** … directory stack for **`cd`** command

Korn shell

- **`cd`** *old new*, **`cd -`** … path change, undo **`cd`**
- **`VISUAL`**, **`set -o`** *ed* … history with line editing
- **`\`** resp. **`<Esc><Esc>`** … filename completion
- **`FPATH`** … path for functions
- **`*()`**, **`+()`**, **`?()`**, **`@()`**, **`!()`** … regexp-like shell patterns
- **`${`***var***`#`***pat***`}`**, **`${##}`**, **`${%}`**, **`${%%}`** … **`$`***var* trimmed by min.(max.) string matching pattern from start (end)
- **`[[]]`** … internal **`test`** (**`<`**, **`>`**, **`-nt`**, **`-ot`**, **`-O`**, **`-G`**)
- **`let`** *var*=*exp*, **`(())`**… arithmetic
- **`${`***v***`[`***e***`]}`**, **`${#`***v***`[*]}`**, *v***`[`***e***`]=`***s*, **`set -A`** *v str* … arrays
- **`select`**, **`getopts`**, **`typeset`**

Options parsing (`getopts`)

```
while getopts :x:y NAME; do
    case $NAME in
    x )  opt_x=$OPTARG;;
    y )  opt_y=1;;
    \? ) echo "Unknown option $OPTARG";;
    : )  echo "Missing value of $OPTARG";;
    esac
done
shift `expr $OPTIND - 1`
```

Time handling utilities

- running command with time keeping:
  `time` *command*
- process suspending:
  `sleep` *seconds*
- output of current (or another*) date and time:
  `date` [**+***format*]

  Format (same as C **`strftime()`**): text with **`%`**-directives
  - **`aAbB`** ... short/long day/month name
  - **`dmyYHMS`** ... (numeric) date and time
  - **`uUVjC`** ... nr. of week-day, week, year-day, century
  - **`cxX`** ... “normal” date and time format
  - **`s`** ... seconds since “epoch” (1.1.1970) *

Synchronization

- If two processes share some resource, it is necessary to avoid concurrent approach to *critical sections* by a lock.
- File based synchronization: program tests the *lock* file; if it exists, resource is locked, process waits in loop (`sleep` !) and when the lock file disappears, the program creates new one by itself.
- Testing and re-locking must be *uninterruptible* operation from the operation system view, e.g. `mkdir`, or redirection (>) when `-C` is set.
- After leaving the critical section, the file must be removed; it is necessary to handle all exceptional cases (`trap` !). For the case of post-mortem check, the lock should be marked by PID.

Batch processing

- Running a command with **`HUP`** and **`QUIT`** signals blocked and output sent to **`$HOME/nohup.out`**

  nohup *command*
- Running a command at given time (user must be allowed to use it in files **`at.allow`** or **`at.deny`**, command output is mailed to user):

  `at` {**`-t`** *mmddHHMM* | *time* [**+***incr*] } *command*

  The command can list (**`-l`**) and remove (**`-r`**) jobs.
- Scheduled regular running by **`cron`** daemon:

  `crontab` [**`-l`**]

  Record example:

```
0 1 * * 1-2,5 /usr/sbin/backup
```

awk filter

- Aho, Weinberger, Kernighan
- language similar to C, differences:
  - LF has significant meaning
  - easier working with strings
  - interpreted language
- dialects: **awk**, **nawk**, **gawk**
- call:

  awk [*opt*] {**`-f`** *script* | *pgm*} {*params* | *file* | **`-`**}...
- filter parses records (lines) of given input files and executes awk-script commands on them
- example: `ls -l |`

```
  awk '/^-/ { s += $5 } END { print s }'
```

Patterns and actions (**awk**)

- Program (awk-script) is a series of branches in form

  pattern **{** *action* **}**
- Pattern types:

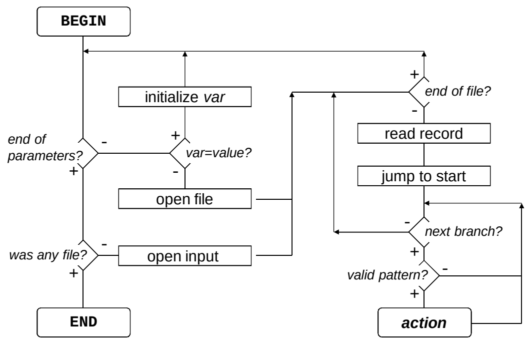
`BEGIN`	executed once, at the beginning of work
`END`	executed once, at the end of work
`/`*regexp***`/`**	executed on every matching record
expression	executed when condition is true
*pat1***`,`***pat2*	executed since the time *pat1* is valid, until *pat2* is valid

- Default pattern: execute action on every record
- Default action: print record

awk program example

```
BEGIN   { procs=0; lines=0 }
/procedure/ { procs++; print;
          lines=1; level=0; next }
! lines { next }
        { lines++ }
/begin/ { level++ }
/end/   { level-- }
/end/ && ! level {
        print "Lines:", lines; lines=0 }
END     { print "Procedures: " procs }
```

awk control flow diagram



Extended regular expressions (**awk**)

Added (changed) meta characters
- *exp*`+`, *exp*`?` … repeating (>0, <=1)
- *exp1*`|`*exp2*`|`*exp3* … alternatives
- `(`, `)` … subexpression grouping

Meaning clarification
- `^`, `$` … beginning and end of tested string

Missing meta characters (comparing to basic regexps)
- `\<`, `\>`, `\{`, `\}`, `\(`, `\)`, `\`*n*

Regexp must be written as a <u>literal</u> (it is not possible to match with literal stored in variable)!

Records (**awk**)

- By default, a line is the record
- Record separator is stored in the **`RS`** variable and can be changed to another char: **`RS="`***char***`"`**
  - e.g. for HTML: **`RS="<"`**
- Special separator - empty line: **`RS=""`**
- Separator change has effect to next record parsing
- Ordinal number of record: **`NR`** variable
- Output record separator (string, written at the end of **`print`** command work): **`ORS=`***string*

Record fields (**awk**)

- Input record is parsed and broken into fields
- Number of fields: **`NF`** variable
- Individual fields accessible via “variable” **`$`***number*
- Number can be written as expression, e.g. **`$(NF-1)`**
- Attention to difference between **`NF`** and **`$NF`** !
- Entire record can be referenced as **`$0`**
- Record fields can be altered, however, the exact form of the original record is lost (separators disappear)!

Field separator (**awk**)

- Field separator is stored in **`FS`** variable
- Can be set up from command line by **`-F`***sep* option
- Separator can have following forms:
  - space, then any whitespaces sequence breaks field
  - non space char, then any char occurrence breaks field
  - (**`nawk`**) regexp, e.g. a line a==b
    - has three fields, if **`FS="="`**
    - has two fields, if **`FS="=="`** or **`FS="=+"`**
- Separator change has effect to next record *
- Parameter separator of **`print`** command: **`OFS=`***string*

Basic syntax rules of **awk**

- The **`awk`** language is **<u>line oriented</u>**
- Commands are separated by semicolon or LF, entire command must be (usually) on a single line
- Line continuation is marked by backslash at the end of previous line
- Exceptions:
  - after condition of **`if`** and **`while`** commands
  - after commas, opening braces (“**`{`**”)
  - after **`&&`** and **`||`** operators
- Comment: any text beginning by “**`#`**” up to end of line

Constants, variables (**awk**)

- <u>Constants</u>
  - common arithmetic constants
  - strings are delimited by double quotes
  - *escape* sequences: **`\b`**, **`\f`**, **`\n`**, **`\r`**, **`\t`**, **`\`***ooo*, **`\x`***xx*
- <u>Variables</u>
  - have only text values
  - text is converted to number in arithmetic context
  - are initialized
  - associative arrays (string is index): *var***`[`***item***`]`**
  - (**`nawk`**) special *member* operator: *item* **`in`** *var*

Expressions (**awk**)

- arithmetic operators:
  - common C-operators: **+**, **-**, *****, **/**, **%** (modulo)
  - power: **^**
  - assignment operators, in(de)crement: **=**, **+=**, ... , **++**, **--**
- concatenation operator: space (!)
  - e.g.: `"File: " FILENAME " opened"`
- relational and logical operators (result is **1**/**0**):
  - common C-operators: **<**, **>**, **<=**, **>=**, **==**, **!=**, **!**, **||**, **&&**
  - operator *match* (with regular expression written as literal, not as variable) and its negation: **~**, **!~** e.g. test, whether 2nd field starts by dot: `$2 ~ /^\./`
- (**nawk**) conditional expression: *cond* **?** *then* **:** *else*

Basic commands (**awk**)

- **{***cmd1***;***cmd2***}** ... compound statement
- **if(***cond***)***cmd* [**;else** *cmd*] ... conditional statement
- **while(***cond***)***cmd* ... loop statement
- **do** *cmd***;while(***cond***)**... loop statement
- **for(***init***;***cond***;***step***)***cmd* ... loop statement (*step* expression evaluated after each iteration)
- **for(***var* **in** *array***)***cmd* ... loop statement (repeating loop body for each index, in random order!)
- **break**, **continue** ... exit loop, next loop iteration
- **next** ... end of current record processing
- **exit** ... end of program (jump to END branch)

Output commands (**awk**)

- **print**
  printing whole record ended by **ORS** (LF by default)
- **print** *str1***,** *str2***,** ...
  printing strings separated by **OFS** (“ ”) ended by **ORS**
- **printf** *fmt***,** *par1***,** *par2***,** ...
  formatted printing
- **print,printf >** *filename*
  output to file (maximum 10 opened files !)
- **print,printf >>** *filename*
  output to end of file
  Example:
```
printf "%s::%d:\n",
           grp, gid >> "/etc/group"
```

Library functions (**awk**)

- mathematical functions: **int**, **exp**, **log**, **sqrt**
- (**nawk**): **sin**, **cos**, **atan2**, **rand**, **srand**
- string functions:
  - **index(***s***,***t***)** ... returns position of *t* in *s* or **0**
  - **length(***s***)** ... returns length of string *s*
  - **split(***s***,***var***,***sep***)** ... splits *s* to words by *sep* separator and assigns them to *var* array items; returns number of items; example: `split("194.50.16.1",ip,".")`
  - **sprintf(***fmt***,**...**)** ... returns formatted text as string
  - **substr(***s***,***pos*[**,***len*]**)** ... returns substring starting at *pos*
- (**nawk**): **match**, **close**, **sub**, **gsub**
- (**gawk**): **tolower**, **toupper**, **strftime**

Own functions (**nawk**)

- **function** *name***(***parameter-list***){**
  statements
  }
- **return** *expression*

- functions defined among branches
- order is not significant
- own function “library” : **awk -f** *lib* **-f** *script* ...
- variables are global, parameters local
- called within expressions
- not all parameters need to be entered

awk program configuration

- Input parameters via **echo** and standard input:
  e.g.:
```
echo $LOW $HIGH | awk '
   NR == 1 { low=$1; high=$2;
      FS=":"; next }
   ...' - /etc/passwd
```
- Shell variables substitution:
  e.g.: `awk /"$RE"/`
- Initialization of variables from command line:
  e.g.: `awk var=value1 file1 var=value2 file2`
- Environment variables (**nawk**): **ENVIRON** array
  e.g.: `file = ENVIRON["HOME"] "/log"`

Built-in variables (**awk**, **nawk**)

- **RS**, **ORS**, **NR**, **FS**, **OFS**, **NF**
- **FILENAME** - currently processed file name
  example: `FILENAME == "-" { ... }`

- **FNR** - ordinal number of record in current file
- **ARGC**, **ARGV** - number of parameters, values array
  - semantics like in C language
  - awk-script and options are not included

  example: `{ ARGV[ARGC++] = "file" }`
- **SUBSEP** - dimension separator in array index
- **RLENGTH** - length of string matched by **match()**

Communication with system in **awk**

- environment variable change: impossible !
```
– PATH='awk '{print path}''
– eval 'awk '{printf "PATH=%s;HOME=%s", p, h}''
– awk '{print path; print home}' | {
        read PATH; read HOME; ...
    }
– { read PATH; read HOME; } << EOF
  `awk '{print path; print home}'`
  EOF
```
- system command call (**nawk**): **system(***command***)**
  - example: `system( "rm " filename )`
  - function returns command return code, not output !
  - command runs in subshell !

getline command, pipe (**nawk**)

- **getline** [*var*] [**<**{**"-"** | *filename*}]
  reading new record from current input, from standard input, or from other file to fields **$0**, **$1**, ... or to *var* variable
  e.g.: `getline < "/etc/hosts"`
- *command* **| getline**
  command (*pipe*) output reading
  e.g.: `"pwd" | getline dir`
- **print |** *command*
  printing to pipe
  e.g.: `printf "Job %d ended", id | "mail " adm`

  Maximum number of open pipes: 1 !

C language - files

***.c**, ***.cpp**	source files
***.h**	header files
***.o**	compiled (*object*) modules
a.out	default name of compiler result
/usr/include	system header files root
/lib/lib*.a, **.so**	system libraries

C language - compiler

Call: **cc** [*options*] *file...*

Important options:

-o*filename*	output file name
-c	compile only (do not link)
-E	preprocess only (do not compile)
-O*level*	optimization level
-g*level*	debugging level
-D*macro*	define preprocessor macro
-U*macro*	undefine preprocessor macro
-I*path*	path to **#include** (header) files
-l*lib*	use linkage library **lib***lib***.a**
-L*path*	path to linkage libraries (**-l***lib*)

Predefined macros

Besides standard ones (**__DATE__**, **__FILE__**, **__LINE__**, **__cplusplus**, etc.), following macros are defined in UNIX:

unix	always defined in UNIX
mips, **i386**,...	hardware architecture
__osf__,...	operating system clone
SunOS	operating system version
_POSIX_SOURCE, **_XOPEN_SOURCE**, **_ANSI_C_SOURCE**	compiling according to particular standard

Macro definitions output: **cc -dM -E** *file*

make program

- command generator
- SW project management
- example (file **Makefile**):

```
program: main.o util.o
    cc -o program main.o util.o
main.o: main.c program.h
    cc -c main.c
util.o: util.c program.h
    cc -c util.c
```

- compiling and linking proper modules:
  make [program]

Input file syntax (**make**)

- target dependency: *targets* **:** [*files*]
- executed commands: **<Tab>***command*
- comment: *#comment*
- line continuation: *line-beginning*****
  line-continuation

Macros (**make**)

- macro definition:
  name **=** *string*
- undefined macros are empty
- order is not significant
- cannot redefine
- command line definition:
  make *target name***=***string*
- macro usage:
  $*name*, **${***name***}** or **(***name***)**
- environment variables are macros

System administration

- Basic tasks:
  - installation (OS, SW packages)
  - configuration (filesystems, users, services, ...)
  - system backup
  - system monitoring (`syslog`, `cron`,...)
- In general, the tasks on various UNIX systems are similar, however, special admin tools vary quite a lot, even in case of the same vendor.

Start of system

- First, **init** process is started, it then controls system operation.
- BSD systems startup:
  - script **/etc/rc** („run control“)
  - scripts called from **/etc/rc** (e.g. **/etc/rc.local**)
  - configuration **/etc/rc.conf**
- System V startup:
  - script start is driven by run level and configuration file **/etc/inittab**
  - scripts are collected to directories **/etc/rc#.d**
- Current system usually uses some combination

Runlevels, **inittab**

- Selected on boot, or by **init** *level* call
- In details, they can slightly differ, however usually
  - 0 ... means system stopping
  - 1 ... means single-user mode
  - 3 ... means full user mode
- Configuration file **inittab**:

```
l3:3:wait:/sbin/rc default
```

Startup scripts

- Classic system:
  - for runlevel **`#`** in **`/etc/rc#.d`**
  - names: **`S`*`##service`*** and **`K`*`##service`***
  - order given by number
  - script calls another script from **`/etc/init.d`** with parameter **`start`** or **`stop`** respectively
- Current systems typically use some variation; starting order is deduced by system itself due to dependency definitions in the scripts

The End