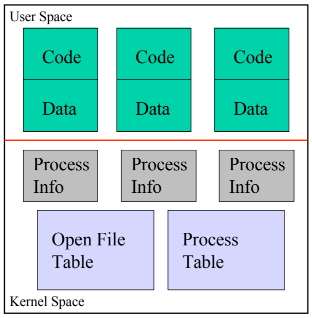
Lecture 3

Processes and Filters

Kernel Data Structures

- Information about each process.
- **Process table**: contains an entry for every process in the system.
- **Open-file table**: contains at least one entry for every open file in the system.



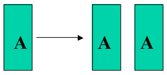
Unix Processes

Process: An entity of execution

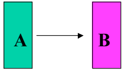
- *Definitions*
  - **program**: collection of bytes stored in a file that can be run
  - **image**: computer execution environment of program
  - **process**: execution of an image
- Unix can execute many processes simultaneously.

Process Creation

- Interesting trait of UNIX
- **fork** system call clones the current process



- **exec** system call replaces current process



- A **fork** is typically followed by an **exec**

Process Setup

- All of the per process information is copied with the **fork** operation
  - Working directory
  - Open files
- *Copy-on-write* makes this efficient
- Before **exec**, these values can be modified

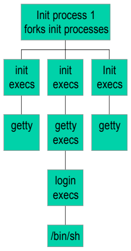
fork and exec

- Example: the shell

```
while(1) {
  display_prompt();
  read_input(cmd, params);
  pid = fork();                /* create child */
  if (pid != 0)
    waitpid(-1, &stat, 0);     /* parent waits */
  else
    execve(cmd, params, 0);    /* child execs */
}
```

Unix process genealogy

Process generation



Background Jobs

- By default, executing a command in the shell will wait for it to exit before printing out the next prompt
- Trailing a command with & allows the shell and command to run simultaneously

```
$ /bin/sleep 10 &
[1] 3424
$
```

Program Arguments

- When a process is started, it is sent a list of strings
  - **`argv`**, **`argc`**
- The process can use this list however it wants to

Ending a process

- When a process ends, there is a return code associated with the process
- This is a positive integer
  - 0 means success
  - >0 represent various kinds of failure, up to process

Process Information Maintained

- Working directory
- File descriptor table
- Process id
  - number used to identify process
- Process group id
  - number used to identify set of processes
- Parent process id
  - process id of the process that created the process

Process Information Maintained

- Umask
  - Default file permissions for new file

We haven't talked about these yet:

- Effective user and group id
  - The user and group this process is running with permissions as
- Real user and group id
  - The user and group that invoked the process
- Environment variables

Setuid and Setgid Mechanisms

- The kernel can set the effective user and group ids of a process to something different than the real user and group
  - Files executed with a setuid or setgid flag set cause the these values to change
- Make it possible to do privileged tasks:
  - Change your password
- Open up a can of worms for security if buggy

Environment of a Process

- A set of name-value pairs associated with a process
- Keys and values are strings
- Passed to children processes
- Cannot be passed back up
- Common examples:
  - **PATH**: Where to search for programs
  - **TERM**: Terminal type

The PATH environment variable

- Colon-separated list of directories.
- Non-absolute pathnames of executables are only executed if found in the list.
  - Searched left to right
- Example:

```
$ myprogram
sh: myprogram not found
$ PATH=/bin:/usr/bin:/home/kornj/bin
$ myprogram
hello!
```

Having . In Your Path

```
$ ls
foo
$ foo
sh: foo: not found
```

```
$ ./foo
Hello, foo.
```

- What **not** to do:

```
$ PATH=.:/bin
$ ls
foo
$ cd /usr/badguy
$ ls
Congratulations, your files have been removed
and you have just sent email to Prof. Korn
challenging him to a fight.
```

Shell Variables

- Shells have several mechanisms for creating variables. A variable is a name representing a string value. Example: **PATH**
  - Shell variables can save time and reduce typing errors
- Allow you to store and manipulate information
  - Eg: `ls $DIR > $FILE`
- Two types: **local** and **environmental**
  - *local* are set by the user or by the shell itself
  - *environmental* come from the operating system and are passed to children

Variables (con't)

- Syntax varies by shell

```
– varname=value         # sh, ksh
– set varname = value   # csh
```

- To access the value: **`$varname`**

- Turn local variable into environment:

```
– export varname        # sh, ksh
– setenv varname value  # csh
```

Environmental Variables

NAME	MEANING
$HOME	Absolute pathname of your home directory
$PATH	A list of directories to search for
$MAIL	Absolute pathname to mailbox
$USER	Your user id
$SHELL	Absolute pathname of login shell
$TERM	Type of your terminal
$PS1	Prompt

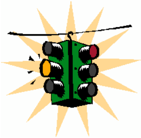
Inter-process Communication

Ways in which processes communicate:

- Passing arguments, environment
- Read/write regular files
- Exit values
- **Signals**
- **Pipes**

Signals

- **Signal**: A message a process can send to a process or process group, if it has appropriate permissions.
- Message type represented by a symbolic name
- For each signal, the **receiving process** can**:**
  - Explicitly ignore signal
  - Specify action to be taken upron receipt (**signal handler**)
  - Otherwise, default action takes place (usually process is killed)
- Common signals:
  - SIGKILL, SIGTERM, SIGINT
  - SIGSTOP, SIGCONT
  - SIGSEGV, SIGBUS



An Example of Signals

- When a child exists, it sends a **SIGCHLD** signal to its parent.
- If a parent wants to wait for a child to exit, it tells the system it wants to catch the **SIGCHLD** signal
- When a parent does not issue a **wait**, ignores the **SIGCHLD** signal

Process Subsystem utilities

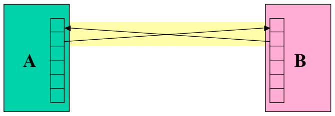
ps	monitors status of processes
kill	send a signal to a pid
wait	parent process wait for one of its children to terminate
nohup	makes a command immune to the hangup and terminate signal
sleep	sleep in seconds
nice	run processes at low priority

Pipes

One of the cornerstones of UNIX

Pipes

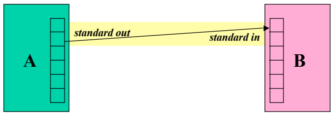
- General idea: The input of one program is the output of the other, and vice versa



- Both programs run at the same time

Pipes (2)

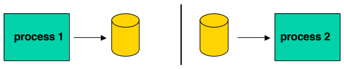
- Often, only one end of the pipe is used



- Could this be done with files?

File Approach

- Run first program, save output into file
- Run second program, using file as input



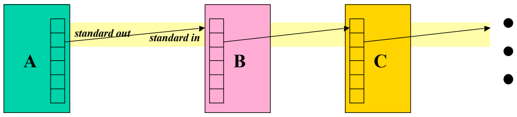
- Unnecessary use of the disk
  - Slower
  - Can take up a lot of space
- Makes no use of multi-tasking

More about pipes

- What if a process tries to read data but nothing is available?
  - UNIX puts the reader to sleep until data available
- What if a process can't keep up reading from the process that's writing?
  - UNIX keeps a buffer of unread data
    - This is referred to as the *pipe size.*
  - If the pipe fills up, UNIX puts the writer to sleep until the reader frees up space (by doing a read)
- Multiple readers and writers possible with pipes.

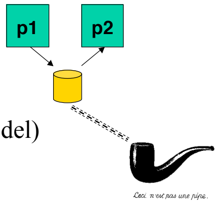
More about Pipes

- Pipes are often chained together
  - Called *filters*



Interprocess Communication For Unrelated Processes

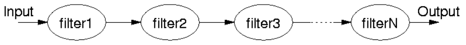
- FIFO (*named pipes*)
  - A special file that when opened represents pipe
- System V IPC
  - message queues
  - semaphores
  - shared memory
- Sockets (client/server model)



Pipelines

- Output of one program becomes input to another
  - Uses concept of UNIX **pipes**
- Example: `$ who | wc -l`
  - counts the number of users logged in
- Pipelines can be long

```
filter1 | filter2 | filter3 | ... | filterN
```



What's the difference?

Both of these commands send input to ***command*** from a file instead of the terminal:

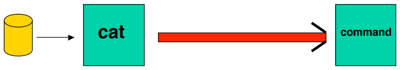
```
$ cat file | command
```

vs.

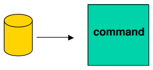
```
$ command < file
```

An Extra Process

```
$ cat file | command
```



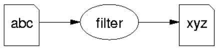
```
$ command < file
```



Introduction to Filters

- A class of Unix tools called ***filters***.
  - Utilities that read from standard input, transform the file, and write to standard out
- Using filters can be thought of as *data oriented programming*.
  - Each step of the computation transforms data *stream*.

```
filter < abc > xyz
```



Examples of Filters

- **Sort**
  - Input: lines from a file
  - Output: lines from the file sorted
- **Grep**
  - Input: lines from a file
  - Output: lines that match the argument
- **Awk**
  - Programmable filter

cat: The simplest filter

- The `cat` command copies its input to output unchanged (*identity filter*). When supplied a list of file names, it con**cat**enates them onto stdout.
- Some options:
  - **-n** **n**umber output lines (starting from 1)
  - **-v** display control-characters in **v**isible form (e.g. ^C)

```
cat file*
ls | cat -n
```

head

- Display the first few lines of a specified file
- Syntax: *head [-n] [filename...]*
  - *-n* - number of lines to display, default is 10
  - *filename...* - list of filenames to display
- When more than one filename is specified, the start of each files listing displays
  `==>filename<==`

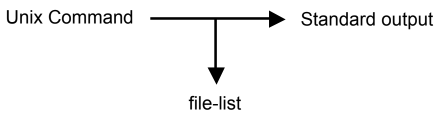
tail

- Displays the last part of a file
- Syntax: *tail* +|-*number [lbc] [f] [filename]*
  or: *tail* +|-*number [l] [rf] [filename]*
  - *+number* - begins copying at distance *number* from beginning of file, if *number* isn't given, defaults to 10
  - *-number* - begins from end of file
  - *l,b,c* - *number* is in units of lines/block/characters
  - *r* - print in reverse order (lines only)
  - *f* - if input is not a pipe, do not terminate after end of file has been copied but loop. This is useful to monitor a file being written by another process

head and tail examples

```
head /etc/passwd
head *.c
tail +20 /etc/passwd
ls -lt | tail -3
head -100 /etc/passwd | tail -5
tail -f /usr/local/httpd/access_log
```

tee



- Copy standard input to standard output and one or more files
  - Captures intermediate results from a filter in the pipeline

tee con't

- Syntax: *tee [-ai] file-list*
  - *-a* - append to output file rather than overwrite, default is to overwrite (replace) the output file
  - *-i* - ignore interrupts
  - *file-list* - one or more file names for capturing output
- Examples

```
ls | head -10 | tee first_10 | tail -5
who | tee user_list | wc
```

Unix Text Files: Delimited Data

Tab Separated

```
John      99
Anne      75
Andrew    50
Tim       95
Arun      33
Sowmya    76
```

Pipe-separated

```
COMP1011|2252424|Abbot, Andrew John |3727|1|M
COMP2011|2211222|Abdurjh, Saeed |3640|2|M
COMP1011|2250631|Accent, Aac-Ek-Murhg |3640|1|M
COMP1021|2250127|Addison, Blair |3971|1|F
COMP4012|2190705|Allen, David Peter |3645|4|M
COMP4910|2190705|Allen, David Pater |3645|4|M
```

Colon-separated

```
root:ZHolHAHZw8As2:0:0:root:/root:/bin/ksh
jas:nJz3ru5a/44Ko:100:100:John Shepherd:/home/jas:/bin/ksh
cs1021:iZ3sO9005eZY6:101:101:COMP1021:/home/cs1021:/bin/bash
cs2041:rX9KwSSPqkLyA:102:102:COMP2041:/home/cs2041:/bin/csh
cs3311:mLRiCIvmtI9O2:103:103:COMP3311:/home/cs3311:/bin/sh
```

cut: select columns

- The `cut` command prints selected parts of input lines.
  - can select columns (assumes tab-separated input)
  - can select a range of character positions
- Some options:
  - _ `-f` *listOfCols***:** print only the specified columns (tab-separated) on output
  - _ `-c` *listOfPos***:** print only chars in the specified positions
  - _ `-d` *c***:** use character *c* as the column separator
- Lists are specified as ranges (e.g. `1-5`) or comma-separated (e.g. `2,4,5`).

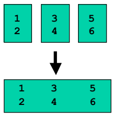
cut examples

```
cut -f 1 < data
cut -f 1-3 < data
cut -f 1,4 < data
cut -f 4- < data
cut -d'|' -f 1-3 < data
cut -c 1-4 < data
```

Unfortunately, there's no way to refer to "last column" without counting the columns.

paste: join columns

- The `paste` command displays several text files "in parallel" on output.
- If the inputs are files **a**, **b**, **c**
  - the first line of output is composed of the first lines of **a**, **b**, **c**
  - the second line of output is composed of the second lines of **a**, **b**, **c**



- Lines from each file are separated by a tab character.
- If files are different lengths, output has all lines from longest file, with empty strings for missing lines.

paste example

```
cut -f 1 < data > data1
cut -f 2 < data > data2
cut -f 3 < data > data3
paste data1 data3 data2 > newdata
```

sort: Sort lines of a file

- The `sort` command copies input to output but ensures that the output is arranged in ascending order of lines.
  - By default, sorting is based on ASCII comparisons of the whole line.
- Other features of `sort`:
  - understands text data that occurs in columns. (can also sort on a column other than the first)
  - can distinguish numbers and sort appropriately
  - can sort files "in place" as well as behaving like a filter
  - capable of sorting *very large* files

sort: Options

- Syntax: *sort [-dftnr] [-o filename] [filename(s)]*
  - *-d* Dictionary order, only letters, digits, and whitespace are significant in determining sort order
  - *-f* Ignore case (fold into lower case)
  - *-t* Specify delimiter
  - *-n* Numeric order, sort by arithmetic value instead of first digit
  - *-r* Sort in reverse order
  - *-o filename* - write output to filename, filename can be the same as one of the input files
- Lots of more options…

sort: Specifying fields

- Delimiter : `-t`*d*
- Old way:
  - `+`*f*`[.`*c*`][`*options*`] [-`*f*`[.`*c*`][`*options*`]`
    - `+2.1 -3 +0 -2 +3n`
  - Exclusive
  - Start from 0 (unlike cut, which starts at 1)
- New way:
  - `-k `*f*`[.`*c*`][`*options*`][,`*f*`[.`*c*`][`*options*`]]`
    - `-k2.1 -k0,1 -k3n`
  - Inclusive
  - Start from 1

sort Examples

```
sort +2nr < data
sort -k2nr data

sort -t: +4 /etc/passwd

sort -o mydata mydata
```

uniq: list UNIQue items

- Remove or report adjacent duplicate lines
- Syntax: *uniq [-cdu] [input-file] [output-file]*

  `-c` Supersede the -u and -d options and generate an output report with each line preceded by an occurrence count

  `-d` Write only the duplicated lines

  `-u` Write only those lines which are not duplicated

  – The default output is the union (combination) of *-d* and *-u*

wc: Counting results

- The word count utility, **wc**, counts the number of lines, characters or words
- Options:

  `-l` Count lines

  `-w` Count words

  `-c` Count characters
- Default: count lines, words and chars

wc and uniq Examples

```
who | sort | uniq -d

wc my_essay

who | wc

sort file | uniq | wc -l

sort file | uniq -d | wc -l

sort file | uniq -u | wc -l
```

tr: TRanslate Characters

- Copies standard input to standard output with substitution or deletion of selected characters
- Syntax: *tr [-cds] [string1] [string2]*
  - `-d` delete all input characters contained in *string1*
  - `-c` complements the characters in *string1* with respect to the entire ASCII character set
  - `-s` squeeze all strings of repeated output characters in the last operand to single characters

tr (continued)

- *tr* reads from standard input.
  - Any character that does not match a character in *string1* is passed to *standard output* unchanged
  - Any character that does match a character in *string1* is translated into the corresponding character in *string2* and then passed to *standard output*
- Examples

– *tr s z*	replaces all instances of *s* with z
– *tr so zx*	replaces all instances of *s* with *z* and *o* with *x*
– *tr a-z A-Z*	replaces all lower case characters with upper case characters
– *tr –d a-c*	deletes all a-c characters

tr uses

- Change delimiter

```
tr ‘|’ ‘:’
```

- Rewrite numbers

```
tr ,. .,
```

- Import DOS files

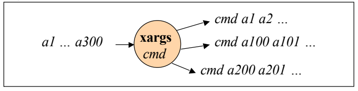
```
tr –d ’\r’ < dos_file
```

- Find printable ASCII in a binary file

```
tr –cd ’\na-zA-Z0-9 ’ < binary_file
```

xargs

- Unix limits the size of arguments and environment that can be passed down to child
- What happens when we have a list of 10,000 files to send to a command?
- **xargs** solves this problem
  - Reads arguments as standard input
  - Sends them to commands that take file lists
  - May invoke program several times depending on size of arguments



find utility and xargs

- `find . -type f -print | xargs wc -l`
  - `-type f` for files
  - `-print` to print them out
  - **xargs** invokes **wc** 1 or more times

-
  ```
  wc -l a b c d e f g
  wc -l h i j k l m n o
  ...
  ```
- Compare to: `find . -type f –exec wc -l {} \;`

Next Time

- Regular Expressions
  - Allow you to search for text in files
  - **grep** command
- We will soon learn how to write *scripts* that use these utilities in interesting ways.