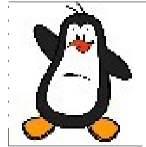


Lecture # 2.5
Programming the Terminal Devices

Course: **Advanced Operating System**

Instructor: Arif Butt

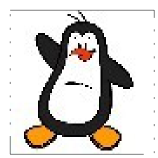
Punjab University College of Information Technology (PUCIT)
University of the Punjab

Source Code files available at: **`https://bitbucket.org/arifpucit/spvl-repo/src`**
Lecture Slides available at: **`http://arifbutt.me`**

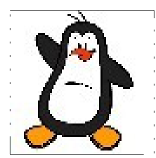
Agenda

- In UNIX every thing is a file
- Similarities and differences between regular & device Files
- Reading/Writing on some one's terminal
- Modes of terminal driver
- Attributes of terminal driver
- Modifying terminal attributes using `stty(1)`
- Where terminal attributes are saved?
- Modifying terminal attributes using
  - `system()` library call
  - `tcgetattr()` and `tcsetattr()` library calls
  - `ioctl()` system call

Review OS with LinuxVideo Lec#25 on Device files
Review OS with LinuxVideo Lec#26 on Terminal attributes

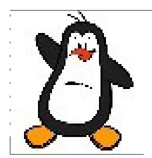


In UNIX
Everything is a File



File Types in UNIX based Systems

- Regular files **`(-)`**
- Directories **`(d)`**
- Symbolic Links **`(l)`**
- Character special files **`(c)`**
- Block special files **`(b)`**
- Named pipes **`(p)`**
- Sockets **`(s)`**



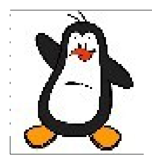
Device Files

Character Special Files (c)

These files represents hardware devices that reads or writes a serial stream of data bytes. Devices connected via serial/parallel ports fall in this category. Examples of such devices are terminal devices, sound cards, and tape drives

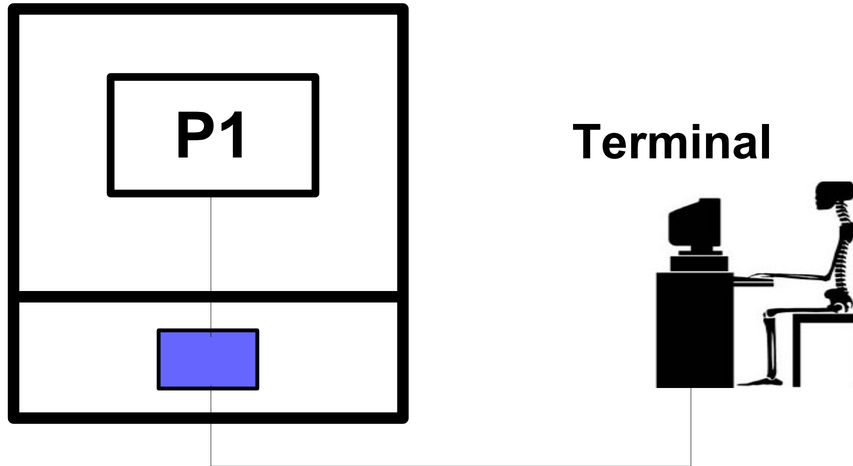
Block special files (b)

These files represents hardware devices that reads or writes data in fixed size blocks. Unlike serial devices they provide random access to data stored on the device. Examples of such devices are HDD, SSD, and cdrom

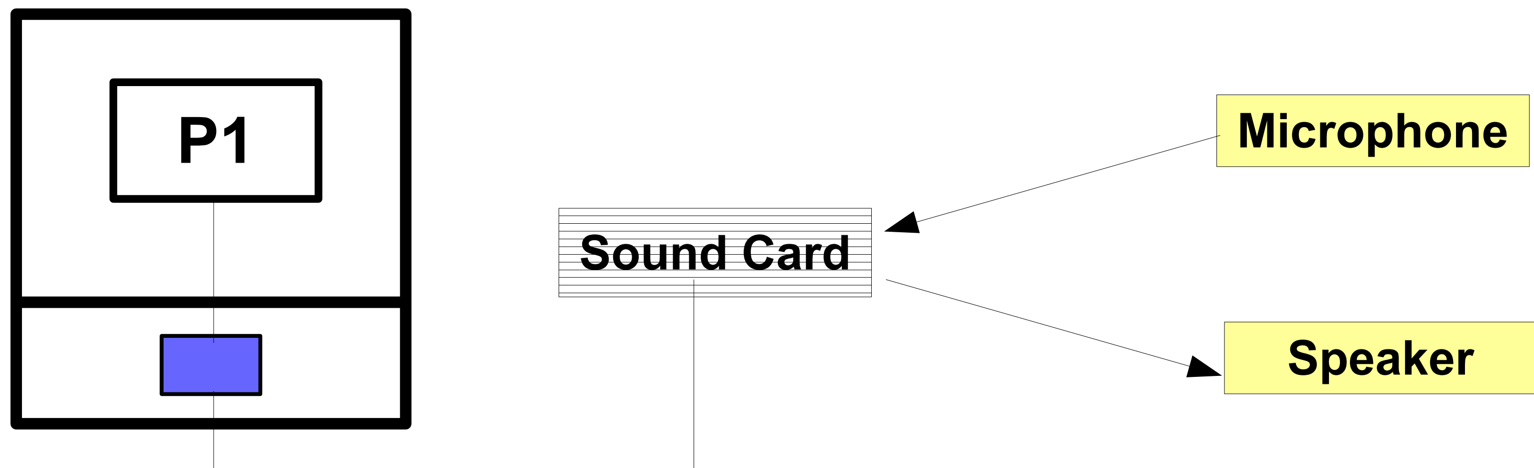


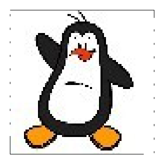
Similarities Between Devices & Regular Files

For a process, a terminal is a source/destination of data

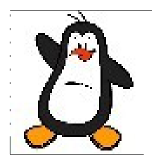


For a process, a sound card is a source/destination of data





Overview of Device Files



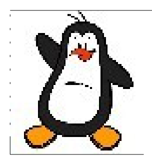
Differences Between Device & Regular Files

- A regular file is a container, while a device file is a connection
- The inode block of a regular file contains pointer that points to its data blocks, while the inode block of a device file contains pointer that points to a function inside the kernel called the device driver
- When you see the long listing, a regular file shows its size while a device file displays the major and minor number of the device driver at the place of size when you see its long listing

Device Numbers:

Linux identify devices using a 16 bit number divided into two parts

- **Major number** (8 bits) that identifies the driver program
- **Minor number** (8 bits) that is used by the driver program to identify the instance



The /dev/ Directory

- Describe the contents of /dev/ directory and show the difference between a device file and a regular file:

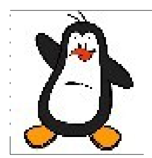
```
$ ls -lis /dev
$ ls -l /dev/ | grep sda
$ ls -l /dev/ | grep tty | less
```

- Create your own character and block special files:

```
$ sudo mknod-m 0666 mychfile c 555 1
$ sudo mknod -m 0666 myblk b 444 1
```

- Discuss the /dev/pts/ directory:

```
$ echo “hello” 1> /dev/pts/3
$ cp armyfriends.txt /dev/pts/5
```



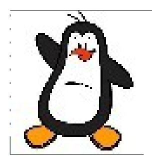
The /dev/null and /dev/zero Files

These are character special files. Any write in these files is discarded. Any read in /dev/null return an EOF. Any read in /dev/zero return an infinite trail of '\0' bytes:

```
$ dd if=/dev/null of=./mynull count=2 bs=1024
$ dd if=/dev/zero of=./myzero count=2 bs=1024
```

Usage:

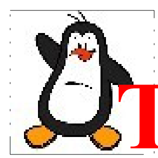
- Whenever you are not interested in the o/p or error of your program, you can redirect it to these files
- Whenever you want to read an empty file and check the behavior of your program, you read the /dev/null file
- Whenever you want to create file of very large size containing zeros, you use dd command and read the /dev/zero file



The /dev/full File

- This is also a character special file. Any write in this file return ENOSPC error, so it can be used to test how a program handles disk-full errors. Any read from /dev/zero return an infinite trail of '\0' characters (just like the /dev/zero file). It has a major device number of 1 and minor device number of 7. If it does not exist on your machine you can create it using following command:

```
$ sudo mknod -m 666 /dev/full c 1 7
$ sudo chown root:root /dev/full
$ cat 0< /etc/passwd 1> /dev/full
cat: write error: No space left on device
```



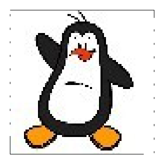
The /dev/random and /dev/urandom Files

The character special files /dev/random and /dev/urandom provide an interface to the kernel's random number generator. Any read from these files return an infinite trail of random bytes using a pseudorandom number generator:

```
$ cat /dev/urandom
$ od /dev/urandom
$ dd if=/dev/urandom of=./temp count=1 bs=100
```

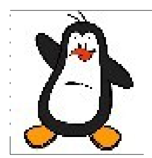
Any write in these file(s) will update the entropy pool with the data written. This entropy pool is used to create the random numbers. The random number generator gathers environmental noise from device drivers and other sources into this entropy pool

The /dev/random interface is considered a legacy interface, and /dev/urandom is preferred, with the exception of applications which require randomness during early boot time



Proof of concepts
On Linux Terminal

`/dev/, mknod(1)`



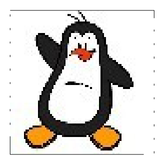
Modes of Terminal Driver

Canonical Mode:

- Input is made available line by line, and the line goes to the process only after the user presses the Enter key (mean while it is buffered inside the `tty` driver program)
- Line editing is enabled

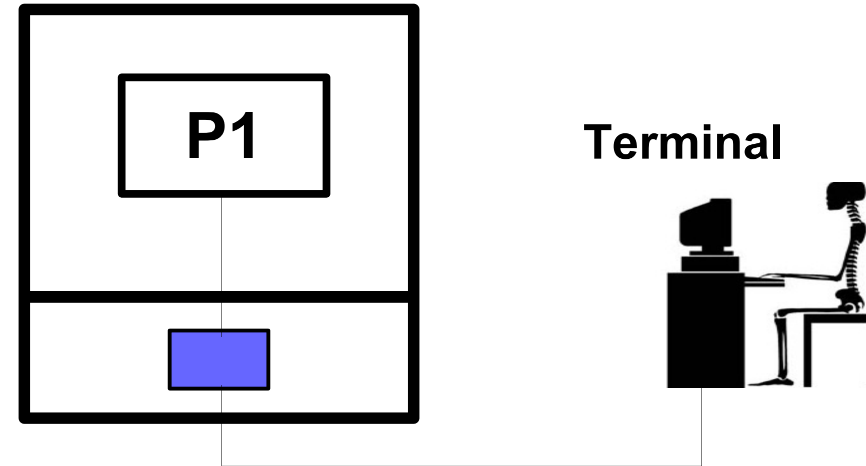
Non-Canonical Mode:

- Input is made available immediately as a key is pressed, without the need to press the Enter key (no buffering is done by the driver program)
- Line editing is disabled

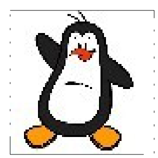


Attributes of Terminal Driver

Actions performed by `tty` driver on the data passing through it can be grouped into four main categories:



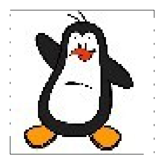
- **Input Processing:** Processing performed by `tty` driver on the characters received via key board, before sending them to the process. Example: `icrnl`
- **Output Processing:** Processing performed by `tty` driver on the characters received from process, before sending them to the display unit. Example: `onlcr`
- **Control Processing:** How characters are represented? Example: `cs8`
- **Local Processing:** What the driver do while the characters are inside the driver? Example: `icanon, echo`



Attributes of Terminal Drivers

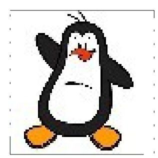
100$ Question

How can we examine and modify the value of Terminal Attributes?



Accessing & Modifying Terminal Attributes using

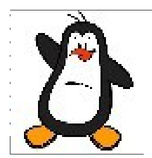
stty(1), mywrite.c, mycat.c



Programming the Terminal Driver

There are three ways you can get/set the attributes of terminal driver inside your C program:

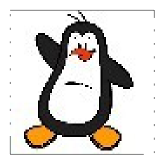
- Use `system()` library call
- Use `tcgetattr()` and `tcsetattr()` library calls
- Use `ioctl()` system call



`system()` Library Call

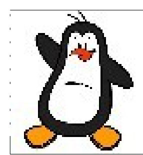
```
int system(const char* command);
```

- It executes a command specified in **`cmd`** by calling **`/bin/bash -c`** command and returns after the command has been completed
- Return -1 on error and the return status of the cmd other wise
- Main cost of **`system()`** is inefficiency. Executing a command using `system()` requires the creation of at least two processes
  - One for the shell
  - Other for the command(s) it executes



Accessing & Modifying Terminal Attributes using `system()`

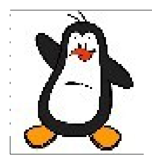
`password_simple.c, password_system.c`



Use `tcgetattr()` and `tcsetattr()` Library Calls

```
int tcgetattr(int fd, struct termios* info);
int tcsetattr(int fd,int when,struct termios* info)
```

- The **`tcgetattr()`** copies current settings from `tty` driver associated to the open file `fd` into the struct pointed by `info`. Returns 0 on success and -1 on error
- The **`tcsetattr()`** sets the `tty` driver associated to the open file `fd` with the settings given in the struct pointed by `info`. The `when` argument tells when to update the driver settings. The `when` argument can take following values:
  - TCSANOW: update driver settings immediately
  - TCSADRAIN: wait until all o/p already queued in the driver has been transmitted to the terminal and then update the driver
  - TCSAFLUSH: wait for o/p queue to be emptied + flush all queued i/p data and then update the driver



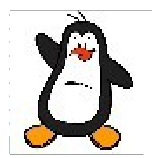
Structure termios

The termio structure is defined in /usr/include/asm-generic/termios.h file. Some important members of the termio structure that of our interest right now are shown below:

```
struct termios{
   tcflag_t  c_iflag;  //contains flags related to input processing
   tcflag_t  c_oflag;  //contains flags related to output processing
   tcflag_t  c_cflag;//contains flags related to control processing
   tcflag_t  c_lflag;//contains flags relating to local processing
   . . .
   . . .
   };
```

Individual Bits of termios Flags

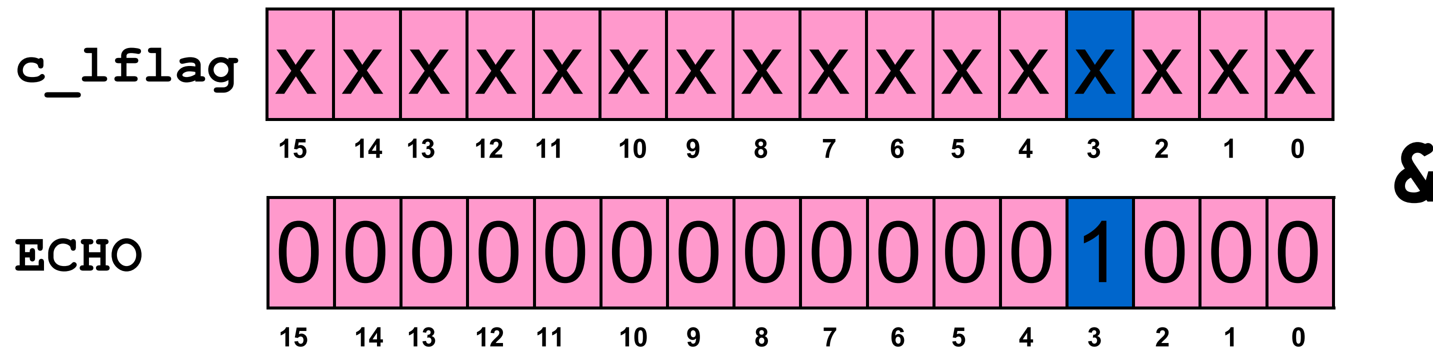
Flag	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
c_iflag	---	IUTF8	IMAXBEL	IXOFF	IXANY	IXON	IUCLC	ICRNL	IGNCR	INLCR	ISTRIP	INPCK	PARMRK	IGNPAR	BRKINT	IGNBRK
c_oflag	---	---	FFDLY	VTDLY	BSDLY	TABDLY	CRDLY	NLDLY	OFDEL	OFILL	ONLRET	ONOCR	OCRNL	ONLCR	OLCUC	OPOST
c_cflag	---	---	---	CRTSCTS	CMSPAR	CIBAUD	LOBLK	CLOCL	HUPCL	PARODD	PARENB	CREAD	CSTOPB	CSIZE	CBAUDEX	CBAUD
c_lflag	IEXTEN	PENDIN	TOSTOP	NOFLSH	FLUSHO	DEFECHO	ECHOKE	ECHOPRT	ECHOCTL	ECHONL	ECHOK	ECHOE	ECHO	XCASE	ICANON	ISIG



Testing status of echo Flag

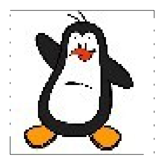
Code snippet to test the `echo` flag in the `c_lflag` member of `termios` structure:

```
struct termios info;
tcgetattr(0, &info);
if((info.c_lflag & ECHO) == 0)
   printf("echo is off, since its bit is 0");
else
   printf("echo is on, since its bit is 1");
```




```
$ gcc echostate.c
$ ./a.out
$ stty -echo; ./a.out
```

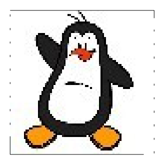
```
$ gcc icanonstate.c
$ ./a.out
$ stty -icanon; ./a.out
```



Changing Attributes of Terminal Driver

Three steps to change the attributes of a terminal driver:

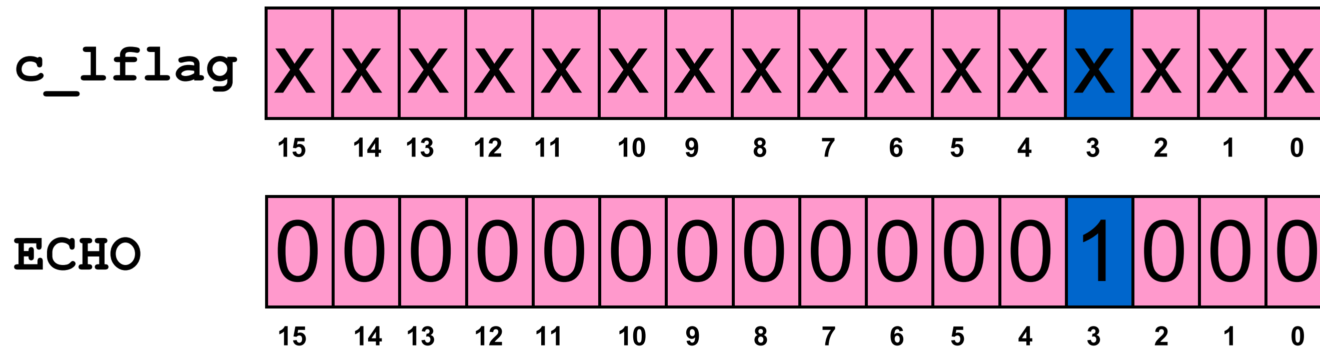
- Get the attributes from the driver
- Modify the attribute(s) you need to change
- Send these revised attributes back to the driver

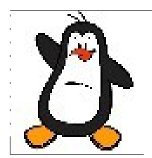


Making the echo Flag ON

Code snippet to turn ON the echo flag in the `c_lflag` member of `termios` structure:

```
struct termios info;
tcgetattr(0, &info);
info.c_lflag = info.c_lflag | ECHO;
tcsetattr(0, TCSANOW, &info);
```

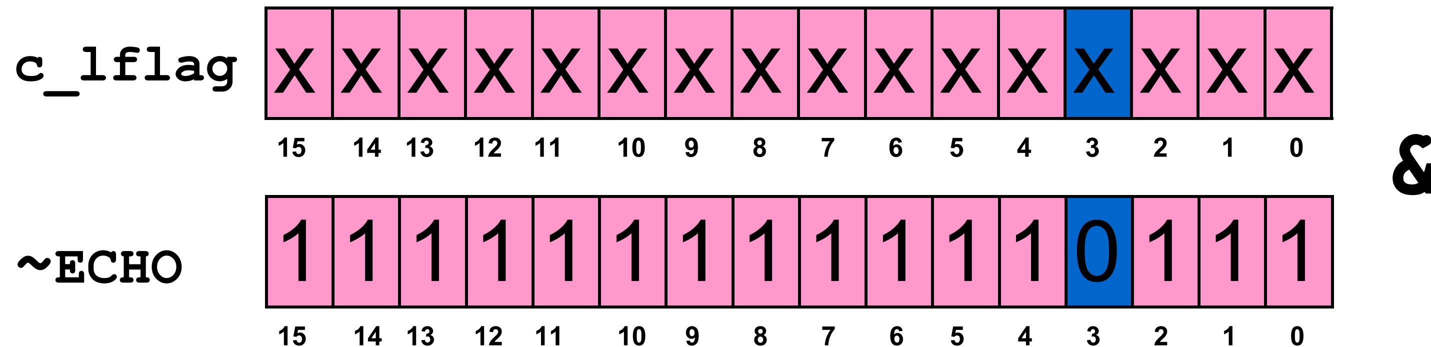


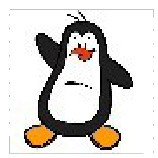


Making the echo Flag OFF

Code snippet to turn OFF the echo flag in the `c_lflag` member of `termios` structure:

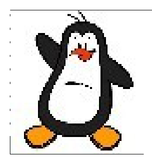
```
struct termios info;
tcgetattr(0, &info);
info.c_lflag = info.c_lflag & ~ECHO;
tcsetattr(0, TCSANOW, &info);
```





Accessing & Modifying Terminal Attributes using `tcgetattr() & tcsetattr()`

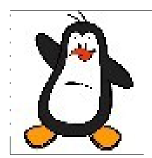
`password_tcget.c`



ioctl() System call

```
int ioctl(int fd, int request[,arg,...]);
```

- We have seen the use of `fcntl()` system call to get/set the attributes of a disk file. To get/set the attributes of device files we can use the `ioctl()` system call. Each type of device has its own set of properties and `ioctl` operations
- The first argument `fd` specifies an open file descriptor that refers to a device
- The second argument `request` specifies the control function to be performed based upon the device being addressed. Defined in `/usr/include/asm-generic/ioctls.h`
- Remaining optional arguments are request specific, defined in `/usr/include/x86_64-linux-gnu/bits/ioctl-types.h`



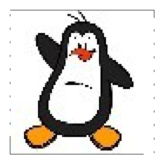
Changing echo Flag Bit Using `ioctl()`

Code snippet to turn ON the echo flag in the `c_lflag` member of `termios` structure using `ioclt()`:

```
struct termios info;
ioctl(0,TCGETS, &info);
info.c_lflag = info.c_lflag | ECHO;
ioctl(0, TCSETS, &info);
```

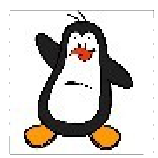
Code snippet to turn OFF the echo flag in the `c_lflag` member of `termios` structure using `ioclt()`:

```
struct termios info;
ioctl(0,TCGETS, &info);
info.c_lflag = info.c_lflag & ~ECHO;
ioctl(0, TCSETS, &info);
```



Accessing & Modifying Terminal Attributes using `ioctl()`

`password_ioctl.c`

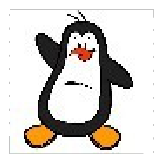


Getting the Screen Size Using `ioctl()`

A video terminal screen, has size measured in rows and columns or pixels. The following code snippet displays the dimensions of the screen using `ioctl()` call (`winsize_ioctl.c`):

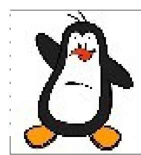
```
struct winsize wbuf;

ioctl(0, TIOCGWINSZ, &wbuf);

printf("%d rows x %d cols \n", wbuf.ws_row,wbuf.ws_col)
```

- Along with many other constants the second argument `TIOCGWINSZ` is defined in `/usr/include/asm-generic/ioctls.h`
- The `winsize` structure is defined in `/usr/include/x86_64-linux-gnu/bits/ioctl-types.h`

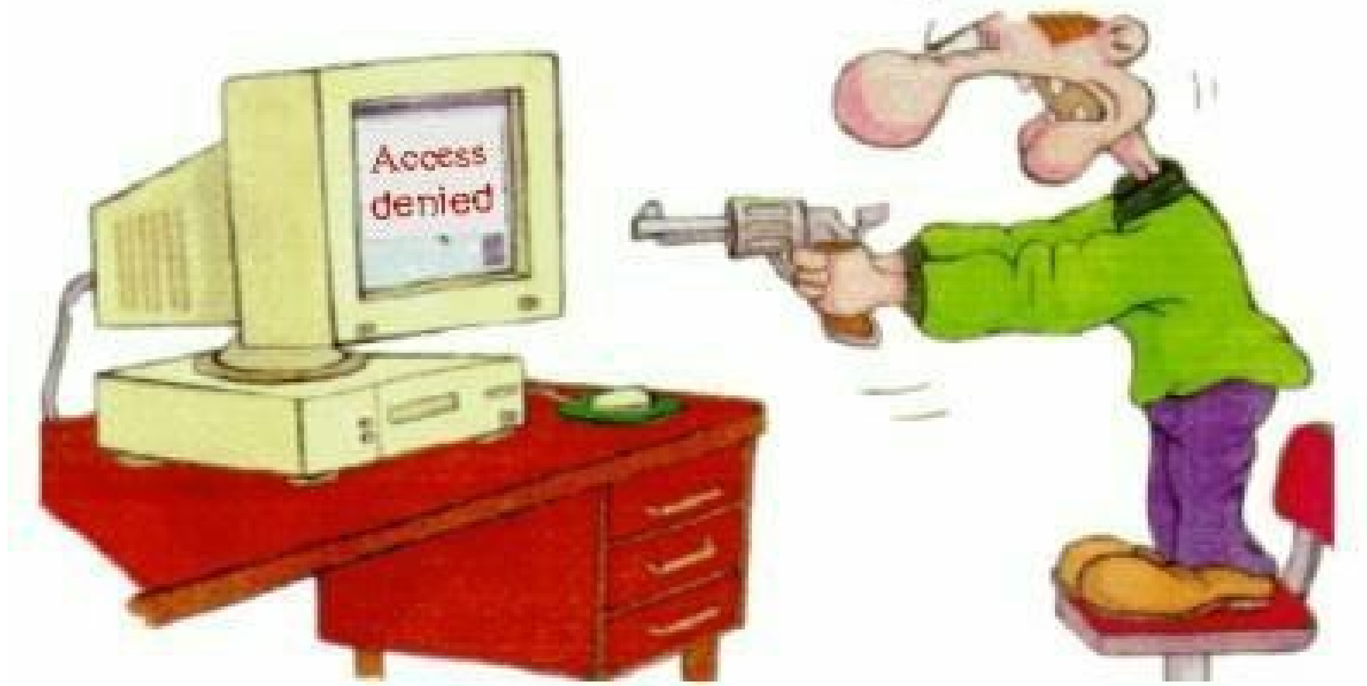


`mystty.c`

Try writing your own `stty` program, that mimic the behavior of `stty` command as close as possible



Things To Do



If you have problems visit me in counseling hours. . . .