Unix File Structure

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Adapted from slides by Jon Herlocker, OSU

One more `cat` demo

```
% echo "FISH"
FISH
% echo "FISH" > net.txt
% cat net.txt
FISH
% echo "CRAB" > net.txt
% cat net.txt
CRAB
% echo "BARNACLE" >> net.txt
% cat net.txt
CRAB
BARNACLE
```

Files!

- If everything is a file, how does the file structure work?

Files!

- Files are “hard links” to “inodes”.
- Inodes:
  - Contain all meta-information (size, permissions, etc)
  - Contain a "reference count“:
    - How many hard links to the inode
  - Contain pointers to actual file data
  - Are identified by a unique number:
    - inode number

Hard Links

- An entry in a file system “directory” that points to an inode
- Connects a text file name to an inode on disk

Directories!

- You can create or remove directories
  - mkdir, rmdir
- Or read the contents of a directory (in C)
  - opendir(), closedir(), readdir(), rewinddir()
- .
- ..

What’s in a directory file?

```
% ls -pla
drwxr-xr-x  2 brewsteb upg22026   512 Jun 22 16:44 ./
drwxr-xr-x  8 brewsteb ftp       1024 Jun 22 15:46 ../
-rw-r--r--  1 brewsteb upg22026  1027 Jun 22 15:47 cursesDemo.c
-rw-r--r--  1 brewsteb upg22026 42558 Jun 22 15:55 Curses.pdf
-rw-r--r--  1 brewsteb upg22026  4208 Jun 22 16:24 index.html
-rw-r--r--  1 brewsteb upg22026 61554 Jun 22 15:46 IntroToUnixShell.html
-rw-r--r--  1 brewsteb upg22026    38 Jun 22 15:46 OnE1FAQ.txt
-rw-------  1 brewsteb upg22026   467 Jun 22 15:46 OnE1_sol.txt
-rw-r--r--  1 brewsteb upg22026   288 Jun 22 15:46 OnE1.txt
-rw-r--r--  1 brewsteb upg22026    38 Jun 22 15:55 Prog1FAQ.txt
-rw-r--r--  1 brewsteb upg22026  8098 Jun 22 15:46 Prog1.html
-rw-r--r--  1 brewsteb upg22026  7114 Jun 22 15:46 Prog1.test
-rw-r--r--  1 brewsteb upg22026    38 Jun 22 15:46 Prog2FAQ.txt
-rw-r--r--  1 brewsteb upg22026  4517 Jun 22 16:14 Prog2.html
```

Permissions
hard link count
owner
group
size (bytes)
last modified
name

What’s in a directory file?

```
% vi .

" Press ? for keyboard shortcuts
" Sorted by name (.bak,~,.o,.h,.info,.swp,.obj at end of list)
"= /nfs/rack/u2/b/brewsteb/public_html/CS311/
../
Curses.pdf
IntroToUnixShell.html
OnE1.txt
OnE1FAQ.txt
OnE1_sol.txt
Prog1.html
Prog1.test
Prog1FAQ.txt
Prog2.html
Prog2FAQ.txt
cursesDemo.c
index.html
```

Some C code showing that directories can be “read” like a file

```
DIR *directory;
struct dirent *dir_entry;

directory = opendir(argv[1]);

if (directory == NULL)
{
   fprintf(stderr, "Could not open directory %s\n",
  argv[1]);
   perror(argv[0]);
   exit(1);
}

while (dir_entry = readdir(directory))
{
   if (dir_entry->d_ino != 0)
           printf("%s\n", dir_entry->d_name);
}

closedir(directory);
```

Note the dangerous single equals

Creating Links

- When you create a file (using `open`), an inode is allocated and a hard link is automatically created
- However, you can create multiple hard links to the same inode
  - So a file can appear in multiple directories at the same time!
  - The same file can also appear under different names
    - even in the same directory
- To create a link, use the `ln` or `link` commands

Removing Files

- Removing is approximately unlinking everything
  - The inode is garbage collected when ref count == 0
- One way to "remove" a file:
  - `unlink(file_name)`
  - can't unlink directories
- Another way to "remove" a file
  - `remove(file_name)`
  - unlike `unlink`, remove will delete empty directories
  - if file, `remove` is identical to `unlink`
  - if directory, `remove` is identical to `rmdir`

Symbolic Link

- A symbolic link is like a Windows shortcut - It’s not actually a file, it refers to the file.
- If you delete a file, any symbolic links to it become unusable, whereas a hard link to a file means that the file is not yet deleted.
- You can link to directories, or to files on another computer
  - Which you can’t do with a hard link

Symbolic Link Example

```
flip% ssh babylon.eecs.oregonstate.edu -l brewsteb
```

- I’m on babylon, and I want access to my EECS files (which aren’t mapped, unlike flip and eos-class)

```
babylon% ln -s /nfs/rack/u2/b/brewsteb eecsLink
babylon% cd eecsLink
```

- I am now in my EECS filesystem using babylon!

Another Link Example

```
% touch temp
% ls -pla temp*
-rw-------  1 brewsteb upg22026     13 Jun 29 14:49 temp
% ln temp temp2
% ls -pla temp*
-rw-------  2 brewsteb upg22026     13 Jun 29 14:49 temp
-rw-------  2 brewsteb upg22026     13 Jun 29 14:49 temp2
% echo “Hello World!” >> temp
% cat temp
Hello World!
% cat temp2
Hello World!
% rm -f temp
% ls -pla temp*
-rw-------  1 brewsteb upg22026     13 Jun 29 14:49 temp2
```

Permissions

- Files in UNIX have access permissions for three designations of people:
  - **u**ser (the owner of the file)
  - **g**roup
  - all **o**thers

- Three kinds of access permissions for each:
  - **r**ead
  - **w**rite
  - e**x**ecute

Read Permissions

- File
  - The file’s contents can be read
- Directory
  - The directory’s contents can be read (ie, a listing of the files in the directory can be returned)

Write Permissions

- File
  - The file can be written to (ie, the contents of the file can be changed)
- Directory
  - Files can be added/removed/renamed/etc. to/in the directory

Execute Permissions

- File
  - The file appears in directories
  - The file can be executed (program, shell script)

- Directory
  - The directory can be cd’d to
  - The contents can be listed
  - The directory appears in its parents directory listing

chmod

- You can change the permissions on a file by using the `chmod` (**ch**ange **mod**e) command

Man page deficiency – no chmod examples!

- Here is a sample file listing (generated by `ls -pla`) of a file and dir:

```
-rw-r--r--  1 brewsteb upg22026  4517 Jun 22 16:14 Prog2.html
drwx--x--x  2 brewsteb upg22026   512 Jun 22 17:48 tempDir/
```

user

group

others

chmod

- Why does everything in UNIX have to be so hard?
  - r = 4
  - w = 2
  - x = 1

```
-rw-r--r--  1 brewsteb upg22026  4517 Jun 22 16:14 Prog2.html
drwxr-xr-x  2 brewsteb upg22026   512 Jun 22 17:48 tempDir/
```

4 + 2 + 1 = 7

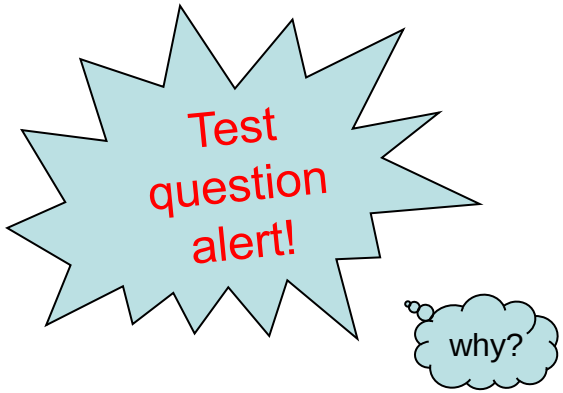
4 + 0 + 1 = 5

```
% chmod 644 Prog2.html
% chmod 755 tempDir
```

<- Standard rights for a publicly viewable file

<- Standard rights for a publicly viewable directory

chmod



- There IS an easier way:

```
----------  1 brewsteb upg22026  4517 Jun 22 16:14 Prog2.html

% chmod u+rwx Prog2.html

-rwx------  1 brewsteb upg22026  4517 Jun 22 16:14 Prog2.html

% chmod g+rx,o+rwx Prog2.html

-rwxr-xrwx  1 brewsteb upg22026  4517 Jun 22 16:14 Prog2.html

% chmod o-w Prog2.html

-rwxr-xr-x  1 brewsteb upg22026  4517 Jun 22 16:14 Prog2.html
```

`umask`

- The *creation mask* setting defines the default attributes for new files.
- You can set this mask with `umask`
- If no argument is included, *umask* displays the current setting

http://unix.t-a-y-l-o-r.com/UAumask.html

`umask`

- Since this is a mask…

```
umask 022
```

- …would give the owner full privileges, while the group and all others would not have write privileges
- This is the complement of what we saw with `chmod`

http://unix.t-a-y-l-o-r.com/UAumask.html

umask

```
% umask
77
% umask 077
% umask
77
% umask 707
% umask
707
```

Which groups?

```
flip 134 CS311% id
uid=22026(brewsteb) gid=6009(upg22026)
  groups=6009(upg22026),12028(transfer)
```

- These groups are the same groups referred to when using the `chmod` command

du

- Returns the total in kilobytes of the specified directory

```
% du
1479      .
```

df

- Displays unused space:

```
%df
Filesystem           1K-blocks      Used Available Use% Mounted on
/dev/sda8              1035660    462276    520776  48% /
/dev/sda1               101086     16797     79070  18% /boot
none                   2045244         0   2045244   0% /dev/shm
/dev/sda7              1035660     34112    948940   4% /private
/dev/sda9             17346660    585992  15879508   4% /scratch
/dev/sda5              4127076     41108   3876324   2% /tmp
/dev/sda2              5162828   3934176    966392  81% /usr
/dev/sda3              4127108    337768   3579692   9% /var
guille.eecs.oregonstate.edu:/a2
                     154893632  71398656  81946048  47% /nfs/guille/a2
stak.ENGR.ORST.EDU:/a1
                     252994240  84486624 165977664  34% /nfs/stak/a1
stak.ENGR.ORST.EDU:/u14
                     206524224  67558688 136900288  34% /nfs/stak/u14
rack.engr.oregonstate.edu:/u2
                     139490368  48546656  89548800  36% /nfs/rack/u2
```

Standard Directories

- Root dir:
  - `/`
- Home dir:
  - `~`
- Bad idea:
  - `rm -rf /*`