

# CS 1550 – Project 4: File Systems

Groups Picked By: Tuesday, March 27, 2012, 11:59pm

Directories Due: Sunday, April 1, 2012, 11:59pm

Completed Due: Sunday, April 15, 2012, 11:59pm

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## Description

FUSE (<http://fuse.sourceforge.net/>) is a Linux kernel extension that allows for a user space program to provide the implementations for the various file-related syscalls. We will be using FUSE to create our own file system, managed via two files that represent our disk device. Through FUSE and our implementation, it will be possible to interact with our newly created file system using standard UNIX/Linux programs in a transparent way.

From a user interface perspective, our file system will be a two level directory system, with the following restrictions/simplifications:

1. The root directory “\” will only contain other subdirectories, and no regular files
2. The subdirectories will only contain regular files, and no subdirectories of their own
3. All files will be full access (i.e., `chmod 0666`), with permissions to be mainly ignored
4. Many file attributes such as creation and modification times will not be accurately stored
5. Files cannot truncated

From an implementation perspective, the file system will keep data on “disk” via a contiguous allocation strategy, outlined below.

## Installation of FUSE

FUSE consists of two major components: A kernel module that has already been installed, and a set of libraries and example programs that you need to install.

First, copy the source code to your `/u/OSLab/USERNAME` directory

```
cd /u/OSLab/USERNAME
cp /u/OSLab/original/fuse-2.7.0.tar.gz .
tar xvfz fuse-2.7.0.tar.gz
cd fuse-2.7.0
```

Now, we do the normal configure, compile, install procedure on UNIX, but omit the install step since that needs to be done as a superuser and has already been done.

```
./configure  
make
```

(The third step would be `make install`, but if you try it, you will be met with many access denied errors.)

## First FUSE Example

Let us now walk through one of the examples. Enter the following:

```
cd /u/OSLab/USERNAME/  
cd fuse-2.7.0/examples  
mkdir testmount  
ls -al testmount  
./hello testmount  
ls -al testmount
```

You should see 3 entries: `.`, `..`, and `hello`. We just created this directory, and thus it was empty, so where did `hello` come from? Obviously the `hello` application we just ran could have created it, but what it actually did was lie to the operating system when the OS asked for the contents of that directory. So let's see what happens when we try to display the contents of the file.

```
cat testmount/hello
```

You should get the familiar hello world quotation. If we `cat` a file that doesn't really exist, how do we get meaningful output? The answer comes from the fact that the `hello` application also gets notified of the attempt to read and open the fictional file "hello" and thus can return the data as if it was really there.

Examine the contents of `hello.c` in your favorite text editor, and look at the implementations of `readdir` and `read` to see that it is just returning hard coded data back to the system.

The final thing we always need to do is to unmount the file system we just used when we are done or need to make changes to the program. Do so by:

```
fusermount -u testmount
```

## FUSE High-level Description

The `hello` application we ran in the above example is a particular FUSE file system provided as a sample to demonstrate a few of the main ideas behind FUSE. The first thing we did was to create an empty directory to serve as a mount point. A mount point is a location in the UNIX hierarchical file system where a new device or file system is located. As an analogy, in Windows, "My Computer" is the mount point for your hard disks and CD-ROMs, and if you insert a USB drive or MP3 player, it will show up there as well. In UNIX, we can have mount points at any location in the file system tree.

Running the `hello` application and passing it the location of where we want the new file system mounted initiates FUSE and tells the kernel that any file operations that occur under our now mounted directory will be handled via FUSE and the `hello` application. When we are done using this file system, we simply tell the OS

that it no longer is mounted by issuing the above `fusermount -u` command. At that point the OS goes back to managing that directory by itself.

## What You Need to Do

Your job is to create the `cs1550` file system as a FUSE application that provides the interface described in the first section. A code skeleton has been provided under the examples directory as `cs1550.c`. It is automatically built when you type `make` in the examples directory.

The `cs1550` file system should be implemented using a pair of files, managed by the real file system in the directory that contains the `cs1550` application. The first file should keep track of the directories, and the second should be the disk. We will consider the disk to have 512 byte blocks.

## Directories

Directories should be recorded in a hidden file named `.directories` that contains a list of `cs1550_directory_entry` structures. There is no limit on how many directories we can have.

```
struct cs1550_directory_entry
{
    char dname[MAX_FILENAME + 1];    //the directory name (plus space for a nul)
    int nFiles;                      //How many files are in this directory.
                                    //Needs to be less than MAX_FILES_IN_DIR

    struct cs1550_file_directory
    {
        char fname[MAX_FILENAME + 1]; //filename (plus space for nul)
        char fext[MAX_EXTENSION + 1]; //extension (plus space for nul)
        size_t fsize;                 //file size
        long nStartBlock;              //where the first block is on disk
    } files[MAX_FILES_IN_DIR];        //There is an array of these
};
```

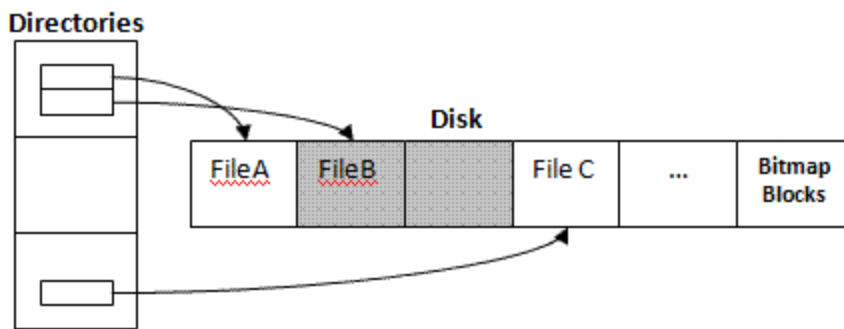
Each directory entry will contain an 8-character maximum directory name, and then have a list of files that are in the directory. Since each directory entry can only take up a single disk block, we are limited to a fixed number of files per directory.

Each file entry in the directory has a filename in 8.3 format. We also need to record the total size of the file, and the location of the file's first block on disk.

## Files

Files will be stored in a virtual disk that is implemented as a single, pre-sized file called `.disk` with 512 byte data blocks of the format:

```
struct cs1550_disk_block
{
    //All the space in the block can be used for actual data
    //storage.
    char data[MAX_DATA_IN_BLOCK];
};
```



This is how the resulting system is logically structured.

## Disk Management

In order to manage the free or empty space, you will need to create a bookkeeping block on the disk that records what blocks have been previously allocated or not. Use a bitmap as we have discussed in class.

To create a 5MB disk image, execute the following:

```
dd bs=1K count=5K if=/dev/zero of=.disk
```

This will create a file initialized to contain all zeros, named `.disk`. You only need to do this once, or every time you want to completely destroy the disk. (This is our “format” command.)

## Syscalls

To be able to have a simple functioning file system, we need to handle a minimum set of operations on files and directories. The functions are listed here in the order that I suggest you implement them in. The last two do not need implemented beyond what the skeleton code has already.

The syscalls need to return success or failure. Success is indicated by 0 and appropriate errors by the negation of the error code, as listed on the corresponding function’s man page.

`cs1550_getattr`

<b>Description:</b>	This function should look up the input path to determine if it is a directory or a file. If it is a directory, return the appropriate permissions. If it is a file, return the appropriate permissions as well as the actual size. This size must be accurate since it is used to determine EOF and thus read may not be called.
<b>UNIX Equivalent:</b>	<code>man -s 2 stat</code>
<b>Return values:</b>	0 on success, with a correctly set structure -ENOENT if the file is not found

<b>Description:</b>	This function should look up the input path, ensuring that it is a directory, and then list the contents.  To list the contents, you need to use the <code>filler()</code> function. For example: <code>filler(buf, ".", NULL, 0);</code> adds the
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cs1550\_readdir

	current directory to the listing generated by <code>ls -a</code>  In general, you will only need to change the second parameter to be the name of the file or directory you want to add to the listing.
<b>UNIX Equivalent:</b>	<code>man -s 2 readdir</code>  However it's not exactly equivalent
<b>Return values:</b>	0 on success - ENOENT if the directory is not valid or found

cs1550\_mkdir

<b>Description:</b>	This function should add the new directory to the root level, and should update the <code>.directories</code> file appropriately.
<b>UNIX Equivalent:</b>	<code>man -s 2 mkdir</code>
<b>Return values:</b>	0 on success - ENAMETOOLONG if the name is beyond 8 chars - EPERM if the directory is not under the root dir only - EEXIST if the directory already exists

cs1550\_rmdir

<b>Description:</b>	Deletes an empty directory
<b>UNIX Equivalent:</b>	<code>man -s 2 rmdir</code>
<b>Return values:</b>	0 read on success - ENOTEMPTY if the directory is not empty - ENOENT if the directory is not found - ENOTDIR if the path is not a directory

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**Above this line are the directory calls required for the first due date**

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cs1550\_mknod

<b>Description:</b>	This function should add a new file to a subdirectory, and should update the <code>.directories</code> file appropriately with the modified directory entry structure.
<b>UNIX Equivalent:</b>	<code>man -s 2 mknod</code>
<b>Return values:</b>	0 on success - ENAMETOOLONG if the name is beyond 8.3 chars - EPERM if the file is trying to be created in the root dir - EEXIST if the file already exists

cs1550\_write

<b>Description:</b>	This function should write the data in <code>buf</code> into the file denoted by <code>path</code> , starting at <code>offset</code> .
<b>UNIX Equivalent:</b>	<code>man -s 2 write</code>

<b>Return values:</b>	size on success - EFBIG if the offset is beyond the file size (but handle appends)
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cs1550\_read

<b>Description:</b>	This function should read the data in the file denoted by path into buf, starting at offset.
<b>UNIX Equivalent:</b>	man -s 2 read
<b>Return values:</b>	size read on success - EISDIR if the path is a directory

cs1550\_unlink

<b>Description:</b>	Delete a file
<b>UNIX Equivalent:</b>	man -s 2 unlink
<b>Return values:</b>	0 read on success - EISDIR if the path is a directory - ENOENT if the file is not found

cs1550\_truncate

This function should not be modified.

cs1550\_open

This function should not be modified, as you get the full path every time any of the other functions are called.

cs1550\_flush

This function should not be modified.

## Building and Testing

The cs1550.c file is included as part of the Makefile in the examples directory, so building your changes is as simple as typing make.

One suggestion for testing is to launch a FUSE application with the -d option (./cs1550 -d testmount). This will keep the program in the foreground, and it will print out every message that the application receives, and interpret the return values that you're getting back. Just open a second terminal window and try your testing procedures. Note if you do a **CTRL+C** in this window, you may not need to unmount the file system, but on crashes (transport errors) you definitely need to.

Your first steps will involve simply testing with ls and mkdir. When that works, try using echo and redirection to write to a file. cat will read from a file, and you will eventually even be able to launch pico on a file.

Remember that you may want to delete your .directories or .disk files if they become corrupted. You can use the commands od -x to see the contents in hex of either file, or the command strings to grab human readable text out of a binary file.

## Notes and Hints

- The root directory is equivalent to your mount point. The FUSE application does not see the directory

tree outside of this position. All paths are translated automatically for you.

- `sscanf(path, "%[^/]/%[^.].%s", directory, filename, extension);` or you can use `strtok()`
- Your application is part of userspace, and as such you are free to use whatever C Standard Libraries you wish, including the file handling ones.
- Remember to always close your disk and directory files after you open them in a function. Since the program doesn't terminate until you unmount the file system, if you've opened a file for writing and not closed it, no other function can open that file simultaneously.
- Remember to open your files for binary access.
- Without the `-d` option, FUSE will be launched without knowledge of the directory you started it in, and thus won't be able to find your `.disk` and `.directories` files, if they are referenced via a relative path. This is ok, or you can hardcode the full path to the files when you open them. We will grade with the `-d` option enabled.

## Group Work

For this assignment you may work in pairs. You and your partner must send me an email with the other's name by the stated time (on the first page). Once chosen, you are required to remain working with that person and submit one combined project for the directories portion. If there are irreconcilable differences, groups can be disbanded after the first deadline with permission from me. You may choose to work alone from the beginning, but real life involves teamwork, so I highly suggest partnering with someone.

## File Backups

One of the major contributions the university provides for the AFS file system is nightly backups. However, the `/u/OSLab/` partition is **not** part of AFS space. Thus, any files you modify under your personal directory in `/u/OSLab/` are not backed up. If there is a catastrophic disk failure, all of your work will be irrecoverably lost. As such, it is my recommendation that you:

**Backup all the files you change under `/u/OSLab` to your `~/private/` directory frequently!**

Loss of work not backed up is not grounds for an extension. **YOU HAVE BEEN WARNED.**

## Grading

20% of the grade will be based upon the directory portion of the project that is due by the first due date.

## Requirements and Submission

There are two submission dates.

For the directories portion, you need to submit:

- Your well-commented `cs1550.c` program's source

Make a `tar.gz` file as in the first assignment, named `USERNAMES-project4-dir.tar.gz`

Copy it to `~jrmst106/submit/1550` by the deadline for credit.

For the complete project, you need to submit:

- Your well-commented `cs1550.c` program's source

Make a `tar.gz` file as in the first assignment, named `USERNAMES-project4-complete.tar.gz`

Copy it to `~jrmst106/submit/1550` by the deadline for credit.