P3 - File Systems

COP4600

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Paths

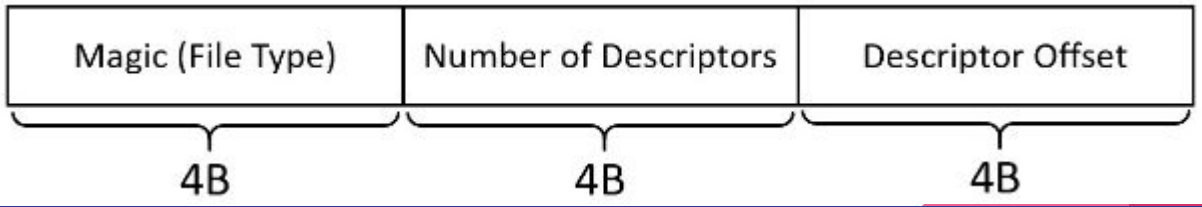
- Most library functions will take in an std::string representing a path to a file in the filesystem. Paths can represent either regular content files, or directories.
- Paths will always begin with a “/” character, representing the root directory. When you ssh into reptilian, your terminal spawns in /home/reptilian.
- In this project, paths to content can look like:
  - /E1M0/01.txt
- While paths to directories can look like either:
  - /F/F1
  - /F/F1/
- The extra “/” at the end of a path to a directory is valid and should be considered.

The .WAD file format - Overview

- In this project you will be provided with files of filetype .WAD, and you will need to read in and modify their contents. Your library will contain the bulk of your code, and the filesystem daemon will be a relatively short program that leverages the library you create.
- There are 3 main sections to a .WAD file, in order:
- A **header**, which will contain information about where to begin reading the descriptor list.
- File **lump data**, which contains the actual content for a given file.
- The **descriptor list**, which contains the relevant information about directory structure, filenames, file sizes, and file content locations.

The .WAD file format - Header

- The header will always be exactly 12 bytes:
  - 4 bytes for the file magic, a 4 character ASCII string
  - 4 byte numerical value for the amount of descriptors in the descriptor list
  - 4 byte numerical value stating the location of the descriptor list in the file
- Each of these 3 values you take in should be stored as class member variables.
- The file magic will not change, but the number of descriptors and descriptor offset will, once directories and files are added.
- If they change, you will need to update the member variables, as well as writing the new changes into the file.

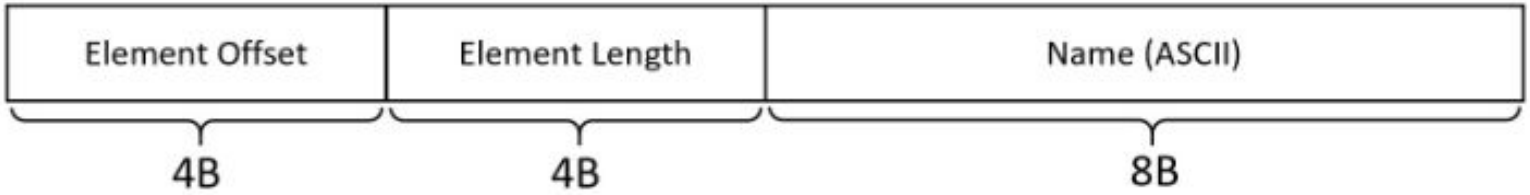


The .WAD file format - Lump Data

- Located in the middle of the file, and will vary in size and length.
- Contains the contents of files.
- Location to a file's lump data will be provided by the file's descriptor, as well as how many bytes starting at that location belong to that file.
- Should not be read into memory until it is necessary.
- You can safely ignore all the lump data in **loadWad**, until accessing the data is necessary in **writeToFile** and **getContents.**

The .WAD file format - Descriptor List

- A list of several descriptors describing files and directories. Can be thought of as the “File Control Block” for the .WAD file filesystem.
- Will always be 16 bytes total:
  - 4 bytes for the ‘Element Offset’, which is the location of the lump data for this file.
  - 4 bytes for the ‘Element Length’, which is the size of the file.
  - 8 bytes for the name of the file, including file extension. The means the max length a filename can be is 8 characters.
    - For ex: **file.txt** is valid, but **files.txt** is not, since it won’t fit into 8 bytes.



Directory Marker Types - Map Markers

- In this project there will be 2 types of directories you will be working with, denoted by marker elements in the descriptor list.
- Type 1: Map Directories
  - Map directories will always have a name in the “E#M#” format, where “#” is any number from 0 to 9.
  - The next 10 descriptors following a map marker will always be content files, whose parent directory is the map marker.
  - Files will never be have the “E#M#” name format, to prevent confusion.

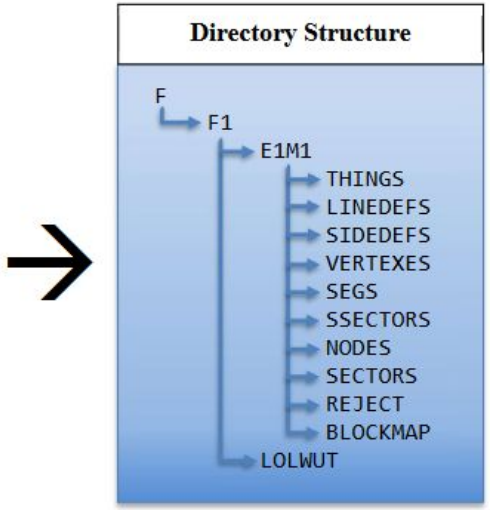
Directory Marker Types - Namespace Markers

- Type 2: Namespace Directories
  - The beginning of a namespace directory is denoted by a descriptor whose name has suffix “_START”.
  - Since “_START” is 6 characters, and we can only fit up to 8 characters in a descriptor filename, the maximum length a namespace directory can be named is 2 characters.
  - Ex: “F1_START” or “F_START”
  - The end of a namespace directory is denoted by a descriptor whose name has suffix “_END”.
  - All descriptors between the “_START” and “_END” of a namespace directory are treated as children of that directory.
  - These are the kind of directories you will be creating in **createDirectory**.

Example Directory Structure

- The first hurdle to overcome in this project is how to organize your filesystem in memory.
- You must traverse the flattened tree that is your descriptor list, and convert it into an *actual* tree.
- This required a depth-first search algorithm that can keep track of directory nesting (usually a stack, though recursion also works.)
- You should be storing this information in an n-ary tree of some kind of struct, where each struct contains the filename, offset, length, and a way to store other files if a given descriptor is a directory.
- You are also regularly provided strings to filepaths, and you need to use those paths to look up information about a file/directory.
- Sounds like a good candidate for a key-value system…

Offset	Length	Name
0	0	F_START
0	0	F1_START
67500	0	E1M1
67500	1380	THINGS
68880	6650	LINEDEFS
75532	19440	SIDEDEFS
94972	1868	VERTEXES
96840	8784	SEGS
105624	948	SSECTORS
106572	6608	NODES
113180	2210	SECTORS
115392	904	REJECT
116296	6922	BLOCKMAP
42	9001	LOLWUT
0	0	F1_END
0	0	F_END



```
public static Wad* loadWad(const string &path)
```

- Invokes the constructor by creating a Wad object with new, then returns the pointer to it.

```
private Wad(const string &path)
```

- Private constructor, takes in path to a .WAD file from your **real** filesystem.
- Should initialize an fstream object and store it as a member variable, and use it to read the header data, and construct your tree from the descriptor list. No need to read in lump data at this point.

```
public bool isContent(const string &path)
```

- Takes in path to a file in your WAD filesystem.
- Will return true if it is a valid path to an existing content file.
- Will return false if it is a valid path to a directory, or if the path is invalid (nonexistent)

```
public bool isDirectory(const string &path)
```

- Similar to above, but will return true for valid directories, and false for content files/nonexistent paths.

```
public int getSize(const string &path)
```

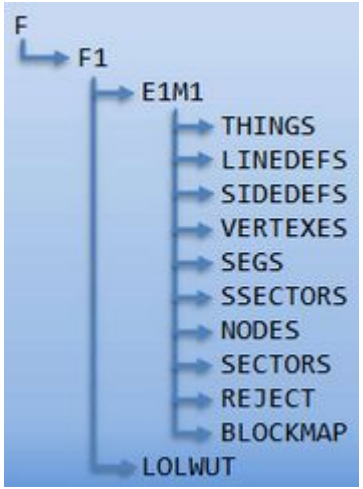
- Returns the size of the file at path. If path is points to a directory or is invalid, returns -1.

```
public int getContents(const string &path, char *buffer, int length, int offset = 0)
```

- Given a valid path to an existing content file, it will read length amount of bytes from the file's lump data, starting at offset. Returns amount of bytes successfully copied. Returns -1 if path is directory/invalid.
- Example: Let's say we have a valid path to a text file, "/F/F2/file.txt".
  Let's say this file has a size of 5 bytes, and contains data "hello".
- Case 1: length = 5, offset blank (defaults to 0): All 5 bytes, "hello", gets copied into buffer. We return 5.
- Case 2: length = 4, offset blank. 4 bytes, "hell", gets copied into buffer. We return 4.
- Case 3: length = 4, offset = 1. 4 bytes, starting at offset 1, "ello", gets copied into buffer, return 4.
- Case 5: length = 6, offset blank.
  Length exceeds size of file, so we only copy **what we can**.
  We copy 5 bytes, "hello", into buffer. Return 5.
- Case 6: length = 8, offset = 2
  Length exceeds size of file, and we must read from offset 2.
  We can only copy "llo", 3 bytes. Return 3.
- Case 7: length = 5, offset = 6
  Offset goes beyond end of file, we cannot copy any bytes.
  Not an error, but no bytes are copied. We return 0.

```
public int getDirectory(const string &path, vector<string> *directory)
```

- Takes in path to a directory, and pushes back the names of all the directory's children into the passed in vector.
- Returns the amount of children copied into vector.
- Example 1: On the image on the right, directory "/F/F1" has two children: E1M1, and LOLWUT.
    - You would add those names into the vector of strings, and return 2.
- Example 2: Path = "/", the root directory. The root directory has 1 child, "F".
    - Add "F" to the vector of strings and return 1.
- Example 3: Path = "/F/F1/E1M1/". E1M1 has 10 children.
    - Add names of all 10 children to vector, return 10.



```
public void createDirectory(const string &path)
```

- Takes in a path to a directory that does not yet exist, and must be created. It will be a namespace directory, meaning you will need to add a start and end descriptor, and the filename must be at most 2 characters.
- New directories can only be created in namespace directories. Map directories cannot have files or directories added to them.
- First, separate out the filename from the path, and ensure that the path before the filename is a valid, existing directory.
- Ex: “/F/F1/F2”. “F2” is the name of the new directory to be created. “/F/F1” is its parent directory.
- The two new descriptors must be added to the very end of the parent directory, before the parent directory’s “_END” descriptor.
- You will have to create 32 bytes worth of space (16 for each new descriptor) by shifting the rest of the descriptor list forward, so that you can fit the two new descriptors into the list.
- Update your data structures, and remember to add 2 to the number of descriptors in the header!
- Example: **createDirectory(“/F/F1/F2”)** will result in the new descriptor list on the right.

Offset	Length	Name
0	0	F_START
0	0	F1_START
67500	0	E1M1
67500	1380	THINGS
68880	6650	LINEDEFS
75532	19440	SIDEDEFS
94972	1868	VERTEXES
96840	8784	SEGS
105624	948	SSECTORS
106572	6608	NODES
113180	2210	SECTORS
115392	904	REJECT
116296	6922	BLOCKMAP
42	9001	LOLWUT
0	0	F2_START
0	0	F2_END
0	0	F1_END
0	0	F_END

```
public void createFile(const string &path)
```

- Takes in a path to a file that does not yet exist, and must be created.
- Same rules apply, files can only be created inside namespace directories.
- Ex: “/F/F1/F2/file.txt”. “file.txt” is the name of the new file to be created. “/F/F1/F2/” is its parent directory.
- Take caution to ensure that the filename does not contain illegal sequences for files, like “_START/_END” or “E#M#”.
- The offset and length of the file can be set to 0 initially, before it has been written to.
- Example:
  createDirectory(“/F/F1/F2”);
  createFile(“F/F1/F2/file.txt”);
- The above two calls will result in the descriptor list on the right.

Offset	Length	Name
0	0	F_START
0	0	F1_START
67500	0	E1M1
67500	1380	THINGS
68880	6650	LINEDEFS
75532	19440	SIDEDEFS
94972	1868	VERTEXES
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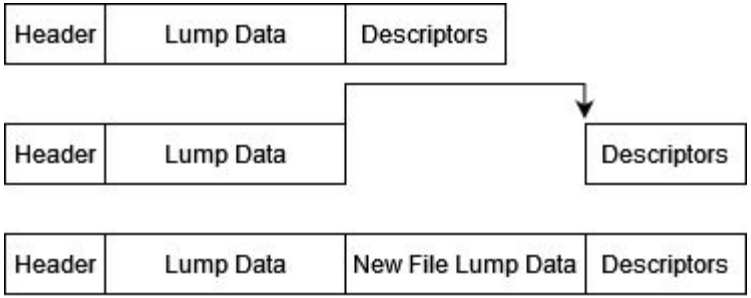
106572	6608	NODES
113180	2210	SECTORS
115392	904	REJECT
116296	6922	BLOCKMAP
42	9001	LOLWUT
0	0	F2_START
0	0	file.txt
0	0	F2_END
0	0	F1_END
0	0	F_END

```
public int writeToFile(const string &path, const char *buffer, int length, int offset = 0)
```

- Takes in a path to an existing, empty file. Returns -1 if path is a directory or invalid. Returns 0 if non-empty file.
- Reads length amount of bytes from buffer, and writes them into the lump data of the file starting at offset.
- You will need to create space in the lump data in the middle of the file to be able to write the file contents.
- The way to do so would be to propagate the entire descriptor list forward by length bytes, creating a space for you to write your new file contents.



- Remember to update the file's length and offset in both your data structure and in the descriptor, as well as updating the header to represent the new position of the descriptor list.

Sidenotes for Library…

- In both **createFile** and **createDirectory**, you will need to search through the descriptor list to find the place to add the new descriptors.
- Separating out a path “/F/F1/F2/file.txt” into tokens like “F”,”F1”, and “F2” may be useful to you, as well a helper function that searches the descriptor list.
- Another possible helper function to consider would be one that can propagate the .WAD file forward by a certain amount of bytes, since you will have to create space for the descriptors in **createFile** and **createDirectoy**, and you will need to create space in the lump data before the descriptor list in **writeToFile.**

Fuse Daemon

- The fuse daemon is a secondary program you will be writing for this project that will leverage your library to be able to mount your .WAD file and traverse it as if it were a real place in your filesystem!
- This will be significantly shorter than your library, probably around 80-200 lines where your library might be 600+. It is recommended that you **heavily** rely on the **linked resources** in the pdf, since those will be able to guide you on a lot of the fuse specific syntax.
- Fuse functions via the use of ‘callback’ functions, which replace normal filesystem syscalls with the functions you implement.
- You will be writing 6 fuse callback functions, excluding main:
  get_attr, **mknod, mkdir**, **read**, **write**, and **readdir.**
- Each function has a use case covered by library functions you have already written, meaning that you should be able to leverage your library extensively here to do all the heavy lifting for you. Generally, you will notice they have very similar parameters to the library functions as well.

Report/Screencast

- **Library:**
  - Go over all functions implemented, and explain how the .WAD filesystem is implemented in memory.
  - Be brief for **getSize**, **isContent** and **isDirectory**, and go into a bit more depth for **loadWad**, **getContents/Directory**, **createFile/Directory**, and **writeToFile**.
- **Daemon:**
  - Go over all required callback functions, explaining how they leverage your library. This generally won't be too complex, since most of them just call a lib function to perform its task.
  - Explain how fuse_main is initialized, and how you parsed command line arguments and initialized your Wad object.
- **Screencast:**
  - As always, treat your report as a loose script for your screencast. Show all code, walk through all functions.
  - Demonstrate your daemon functionality by mounting a .WAD file and performing read/write operations.
  - Demoing your daemon is sufficient to prove library functionality, but if you are submitting without your daemon, show your library score on the test suite.

So… how do I start?

- Start early! We are nearing the end of the course and finding time to complete the project in the last couple of weeks will prove difficult, and office hours will flood.
- Code your library! Specifically, focus on the read-only functions, and return -1 for all the write functions until you have all the read functionality down. The important thing is to be able to build the data structure that stores your file system, and getting **loadWad** and **getDirectory** working first.
- Test with wad_dump.cpp before you test with the provided test suite. Examine wad_dump.cpp and libtests.cpp so that you know what behavior is expected.
- Get all library functionality working perfectly before you move on to the daemon. If you pass 35 tests on the test suite, you're good to start. Not knowing whether a bug resides in your daemon or library will make debugging extremely difficult.
- Post in teams, pass by office hours, and ask for help very frequently.
- Watch the discussions! Please! The slides are visually helpful, but so far the students that have found the most success have taken the time to watch the discussions in detail.