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CSC 415 Operating Systems

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File System - Milestone 1

Description:

The purpose of this milestone is to format the volume in order to set up the basic file system on a storage level. This is completed by implementing methods to initialize the volume control block, manage free space, and set up the root directory. When it comes to the Volume Initialization it is important to manipulate everything before it is put onto disk and to ensure it is being loaded into memory. Implementing the structs discussed with our group for the VCB and formatting the volume within fsInit, setting values for the VCB, initializing free space, initializing the root directory, and updating the values within the HexDump by viewing the blocks data using LBAwrite. However in order to initialize the free space along with the root directory these functions must be implemented taking care of their own set of tasks. Thus memory must be allocated for the FAT, initializing all entries of the FAT to be marked as free, and storing the FAT onto the disk immediately after the VCB. Lastly, the Root Directory Initialization must be implemented, calculating the total memory needed based on the size of a directory entry. Setting the first directory entry as the current directory "." and implementing the parent directory as "..", eventually updating the VCB with the starting block number of the root directory.

Approach/What I Did:

- When the Milestone was first assigned, our group began by setting up various meeting dates (4 meetings) in order to consistently discuss the progress we'd make, who were having difficulties with their parts, splitting up the work, and even implementing/analyzing our results.
    - Upon our first meeting, we chose to divide up our work into 4 different parts, the VCB, Root Directories, Freespace, and the writeup.
        - We first began by discussing the structs that each function/file would need to implement, thus we reviewed our first assignment which we got a 6.5/10 for the structure of directory entries.
            - After discussing with each other what was really necessary for our file system while taking the professor's comments into consideration we created our ideal structure for initializing the root directory. Furthermore, we discussed what type of file system we'd want to use if we go with a bitmap structure or implement a FAT system although our group found bitmaps to seem easier, we were all interested in the implementations of a FAT system, and to us, seemed much more efficient and decided on this file system implementation.

- Now that the work was split up and various meeting dates were set, we also at the time were also working on File System Design 1, where we discussed the structs for our VCB and DirEntry all over again. This assignment is what served as a crucial point for starting/implementing milestone 1 into our file system. Although we were still unsure of how to tackle free space, we knew the structures for both the VCB and DirEntry to an extent and simply needed to wait for the professor's feedback.
    - Note once feedback was provided for File System Design 1, our group discussed over Discord what needed to be changed and how to implement the professor's suggestions into the structs of our programs.
        - Our feedback was- "How do you know if the volume needs to be initialized or not? Missing signature. How do you know where your Root directory is located (missing from VCB) Where is the file located? - missing the starting block number for the file in the Dir_entry"
            - We made sure to keep these comments in mind while implementing the root directory and Volume control block. We spent considerable time dissecting the structure and functionalities, such as the initialization of the file system (initFileSystem). We discussed the volume_control_block, understanding its pivotal role in our file system structure. Our in-depth analysis covered memory allocation, error handling, and even the interaction with physical blocks of storage through LBAread and LBAwrite functions. Recognizing the importance of proper memory management, we reviewed the memory allocation for the volume control block.
- By the second meeting, we planned on implementing our program, beginning the actual tasks to completing milestone 1 as we've planned how to approach the overall assignment.
    - We chose to split the parts and complete them separately, however, we made it apparent to communicate with each other when issues arose in code and further made an emphasis on discussing how our programs work over Zoom so that everyone has a decent understanding and can provide input on each other's program.
        - Furthermore, we discussed over Discord the implementation of Freespace, helping each other out when it came to understanding the parameters and the structs along with the multitude of functions the file would contain.
- After working on the Milestone and implementing each other's features, each member had a detailed implementation of their program, and the VCB, Root Initialization, and Freespace files were "completed".
    - Note, although they were completed we hadn't checked if they were on disk properly as we had not yet analyzed the hex dump with each other as we knew

from the professor's insight that our approach of dividing the work like this would lead to multiple linker errors, not being able to call specific functions from various files.
    - During this meeting, we realized the importance of header files and keeping our files organized in order for us to manipulate and discuss our code much more easily.
        - At this point, we all decided to push and pull each other's code so our programs were all up to date with each other, it was here that we analyzed each other's codes and made suggestions on what to fix and what the hex dump should look like.
- We noticed that the VCB was implemented properly in terms of the fields within the hex dump correlated to those initialized within the program, note we reviewed assignment 2 as analyzing the hex dump is crucial, and we needed a refresher on how to take care of this task.
    - We analyzed the VCB and it seemed appropriate, thus we ended the meeting discussing what we knew, what needed to change, and how the next meeting we would try to link everything together.
- Within our final meeting, we began to link the programs together and analyzed the various parts of the hex dump that would hold the free space the root directories, and so on.
    - Within this meeting, we began to make analyses of each part and began to put the write-up together.
        - Although we began our writeup we knew it was overwritten meaning there was too much fluff and didn't directly focus on the tasks at hand we decided to rewrite our writeup to be more broad yet informational in how we tackled our assignment.
            - Note within this linker meeting we ran into multiple errors and needed to review our programs for a couple of hours over Zoom and Discord with screen sharing in order to make our hexdumps work efficiently.
- After attempting to implement all functionalities into the initFileSystem(), we fell short in being unable to properly display freespace data onto the hexdump, however we were able to view the root directory along with the VCB properly.

Issues & Resolutions:

- Issue #1
    - The first issue which we initially ran into were segmentation faults throughout our programs, each member had ran into a segmentation fault atleast once throughout the compilation of milestone 1. With the many amount of files and various

includes there is a large amount of file to focus on thus it becomes difficult to keep track of the where such faults can occur.

- Resolution #1
    - The main way we overcame the consistent issue of segmentation faults was to always double check our program, however since we wanted every member to have an understanding of whats happening in each file, when these errors would occur we'd simply share our files with each other, wherein oftentimes group members were able to spot the error over others. Essentially continuing communication with our team is without a doubt what helped solve this issue.
- Issue #2
    - Although this issue was rather minor we ran into difficulties accessing structs, functions, or variables from each others files. The inability to include c files lead to linking errors when trying to access variables or function calls, specifically when it came to initialize file system.
- Resolution #2
    - Although again it was rather a minor error, it was without a doubt an important step not only for linking but for the proper structure/organization of our files. Creating header files, .h files, allowed it much easier to access functions and these structs across files. Including prototypes along with the many other fields allowed it to be easier to manipulate files and track the various issues that may have been occurring.
- Issue #3
    - One of the most major issues we ran into and are still dealing with to an extent revolves around the locations of various blocks. Within the VCB, values are returned from initalizing the root directory and the free space, wherein these values would then be implemented within the initializeFileSystem function to properly format the disk. However as seen within our analysis we were unable to complete this step when it came to freespace, the expected blocks which we expected values were all null, 00s indicating LBAwrite wasn't properly implemented to the expected blocks.
- Resolution #3
    - Again, although we weren't able to completely solve this issue we know that it arises somewhere between the freespace function and the initialize file system function. The values after using various print statements to debug it weren't alligning properly thus we will continue to find and solve this issue looking over every file and rethinking the way which we approach each function.
- Issue #4

    - Although a minor issue which confused us when it came to analyzing the hex dump, we were unaware of having to delete the SampleVolume when the program's code is changed. Since the hex dump is representative of disk and make
    - run compiles such values to disk, the hex dump remains constant regardless of altering the program's code.
- Resolution #4
    - After viewing the slacked messages along with the email sent by the professor, we noticed that SampleVolume would have to be deleted and everything would need to be made again "make run" as a result of essentially adding new values to the hex dump. This would need to be repeated every time we'd want to fix various values from the hex dump.

Compilation/Build (Make/Make Run):

```
student@student-VirtualBox:~/Desktop/csc415-filesystem-Amandeep-Singh-24$ make
gcc -c -o fsshell.o fsshell.c -g -I.
gcc -c -o fsInit.o fsInit.c -g -I.
gcc -c -o freespace.o freespace.c -g -I.
gcc -c -o directory.o directory.c -g -I.
gcc -o fsshell fsshell.o fsInit.o freespace.o directory.o fsLow.o -g -I. -lm -l readline -l pthread
```

```
student@student-VirtualBox:~/Desktop/csc415-filesystem-Amandeep-Singh-24$ make run
./fsshell SampleVolume 10000000 512
File SampleVolume does not exist, errno = 2
File SampleVolume not good to go, errno = 2
Block size is : 512
Created a volume with 9999872 bytes, broken into 19531 blocks of 512 bytes.
Opened SampleVolume, Volume Size: 9999872;  BlockSize: 512; Return 0
Initializing File System with 19531 blocks with a block size of 512
Writing FreeSpace to disk at block 1
Writing FAT to disk starting at block 2
Allocate freespace 1
|---------------------------------|
|------- Command ------|- Status -|
| ls                   |    OFF   |
| cd                   |    OFF   |
| md                   |    OFF   |
| pwd                  |    OFF   |
| touch                |    OFF   |
| cat                  |    OFF   |
| rm                   |    OFF   |
| cp                   |    OFF   |
```

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Analysis:

VCB Dump:

```
student@student-VirtualBox:~/Desktop/csc415-filesystem-Amandeep-Singh-24$ ./Hexdump/hexdump.linux SampleVolume --start 1 --
count 1
Dumping file SampleVolume, starting at block 1 for 1 block:

000200: 55 AA 00 00 00 00 00 00  4D 79 56 6F 6C 75 6D 65 | U♦......MyVolume
000210: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000220: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000230: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000240: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000250: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000260: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000270: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000280: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000290: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0002A0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0002B0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0002C0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0002D0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0002E0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0002F0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

000300: 00 00 00 00 00 00 00 00  46 41 54 33 32 00 00 00 | ........FAT32...
000310: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000320: 00 00 00 00 00 00 00 00  00 02 00 00 00 00 00 00 | ................
000330: 01 00 00 00 00 00 00 00  14 00 00 00 00 00 00 00 | ................
000340: 15 00 00 00 00 00 00 00  20 00 00 00 00 00 00 00 | ........ .......
000350: 1F 00 00 00 00 00 00 00  2B 4C 00 00 00 00 00 00 | ........+L......
000360: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000370: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000380: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000390: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0003A0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0003B0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0003C0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0003D0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0003E0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0003F0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

student@student-VirtualBox:~/Desktop/csc415-filesystem-Amandeep-Singh-24$
```

```
#define MAX_NAME_LENGTH 256
#define FILE_SYSTEM_TYPE_LENGTH 32
#define Unique_ID 0xAA55
#define CLUSTER_SIZE_IN_BLOCKS 8

// Structure representing the Volume Control Block (VCB) of the file system
struct volume_control_block {
    uint64_t magicNumber;
    char volume_name[MAX_NAME_LENGTH];
    char fileSystemType[FILE_SYSTEM_TYPE_LENGTH];
    uint64_t block_size;
    uint64_t start_block;
    uint64_t table_size;
    uint64_t root_directory_start_block;
    uint64_t first_free_block;
    uint64_t last_allocated_block;
    uint64_t free_block_count;
};
```

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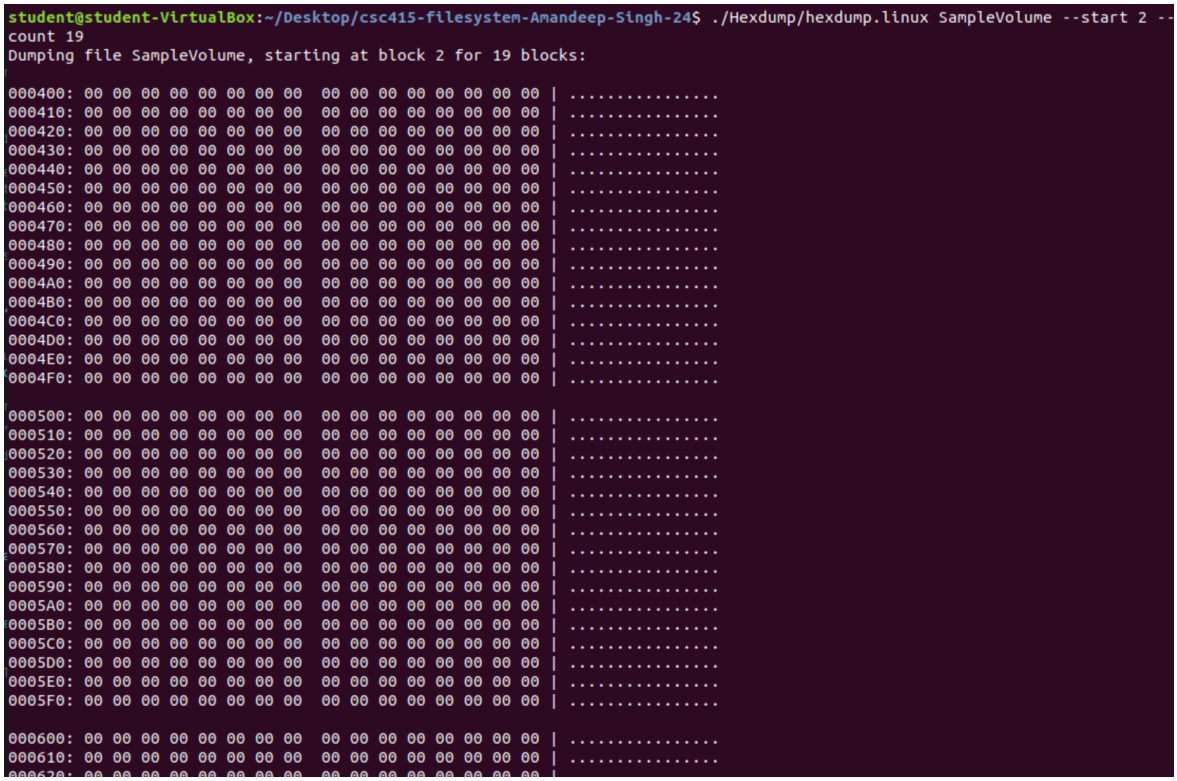
- 55 AA 00 00 00 00 00 00
    - When initializing the VCB we knew we needed a specific signature, a “magic number”, and since our file system is based on a FAT system, we used what we found to be the industry standard of 0xAA55. Note, the declaration of magicNumber is of size uint64_t, which is 8 bytes, thus the address is the whole line. Thus within the VCB we add the unique signature to signify the start of it, thus in little endian notation we see 55AA, which equates to our unique signature.
- 4D 79 56 6F 6C 75 6D 65
    - Next is the volume_name, which is an array of characters which can be up to 256 bytes long. Thus using strcpy, we add volume_name to the VCB and note this is of type char and an array of 256 bytes. Translating the hex values to text, we can see the output in ASCII as “MyVolume” followed by a large buffer of 0’s. This is due to the size of the character array, thus theres a gap of 256 bytes between volume name and fileSystemType.
- 46 41 54 33 32 00 00 00
    - Within the struct after volume_name is the fileSystemType, which is also an array of characters, however, it is limited to 32 bytes. Thus when we strcpy the value “FAT32” to the VCB, we can see the hex be translated to ASCII portraying FAT32, and has a buffer of 0’s after it due to the size of the array, 32 bytes.
- 00 02 00 00 00 00 00 00
    - The next field is block_size, blockSize is already given from the function parameter and is 512 bytes. Thus when adding this to the VCB, we can see the value of 02000 and again the size is 8 bytes, and moreover is represented in little-endian format. Thus these 8 bytes can be adjusted as being 0x0200, which translates to the block size, which again is 512 bytes.
- 01 00 00 00 00 00 00 00
    - Next is the starting block, which simply holds a value of 1. Assuming little-endian format again the hex value of 1 still translates to 1 signifying the beginning of the block.
- 14 00 00 00 00 00 00 00
    - Now table size is evaluated by calculating the number of clusters and since each entry in the fat table is 4 bytes, we multiply it by 4, eventually leading to the value of 20, thus the FAT TABLE has a decimal size of 20. When translating this value into decimal taking it from little-endian this equates to 20, showing that the VCB holds the proper value.
- 15 00 00 00 00 00 00 00
    - The next value is the root_directory_start_block, which occurs after the allocation of the table size. Thus we note, start block of 1, and table_size of 20, thus at location 21, would the root directory start block occur. Thus when translating this hex from little-endian to decimal it contains the value 21, indicating its initialization in the VCB.
- 20 00 00 00 00 00 00 0
    - The value of 20 holds the firsts free block within the VCB dump, after initializing the root dir block, which starts at block 20, and continues for 11 blocks, thus the next block should be available at block 32. Thus when translating this hex 20 to decimal we obtain the decimal number 32 indicating the proper location of the next free block.
- 1F 00 00 00 00 00 00 00
    - The value of 1F indicates the last allocated block, thus within the context of the VCB dump the last allocated block is from the root directory. Again root dir starts at block 20, and lasts 11 blocks long, thus at location 31 is the last allocated block. Thus translating 1F from hex to decimal we

obtain the

value of 32 showing proper implementation into the VCB.

- 2B 4C 00 00 00 00 00 00
    - This value holds the number of free blocks left, and as seen from the hex dump, root directory ends at block 32. Thus we know we have 19531 blocks total, ridding of the initial 32 blocks, translating 2B4C to little endian we obtain the value of 19499. This indicates the proper amount of free blocks left.

Freespace Dump:



```
0005B0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0005C0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0005D0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0005E0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0005F0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

000600: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000610: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000620: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000630: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000640: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000650: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000660: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000670: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000680: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000690: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0006A0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0006B0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0006C0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0006D0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0006E0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0006F0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

000700: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000710: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000720: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000730: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000740: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000750: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000760: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000770: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000780: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000790: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0007A0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0007B0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0007C0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0007D0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0007E0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0007F0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

000800: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000810: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000820: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000830: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
```

```
000800: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000810: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000820: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000830: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000840: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000850: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000860: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000870: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000880: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000890: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0008A0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0008B0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0008C0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0008D0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0008E0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0008F0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

000900: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000910: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000920: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000930: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000940: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000950: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000960: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000970: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000980: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000990: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0009A0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0009B0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0009C0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0009D0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0009E0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
0009F0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

000A00: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000A10: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000A20: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000A30: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000A40: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000A50: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000A60: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000A70: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000A80: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
000A90: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
```

- Within the analysis of our freespace/fat table dump it is apparent that our attempts to write to disk were'nt implemented properly. Although in our program we made attempts within the initFileSystem() function, we were unable to see any values at the blocks which we were expecting. We even went beyond the scope and looked further down the hexdump unable to find any values that should've been written to disk. Thus our analysis upon the dump for this section is invalid.
    - However we can see that all values are initialized to 00s, atleast indicating that the input didn't corrupt/alter the hexdump due to faulty implementation. However again we are missing certain data fields which we expected to see on this hexdump and struggled to implement fully.

Directory Dump:

```
student@student-VirtualBox:~/Desktop/csc415-filesystem-Amandeep-Singh-24$ ./Hexdump/hexdump.linux SampleVolume --start 21 --count 11
Dumping file SampleVolume, starting at block 21 for 11 blocks:

002A00: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002A10: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002A20: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002A30: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002A40: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002A50: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002A60: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002A70: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002A80: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002A90: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002AA0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002AB0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002AC0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002AD0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002AE0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002AF0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

002B00: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002B10: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002B20: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002B30: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002B40: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002B50: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002B60: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
002B70: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
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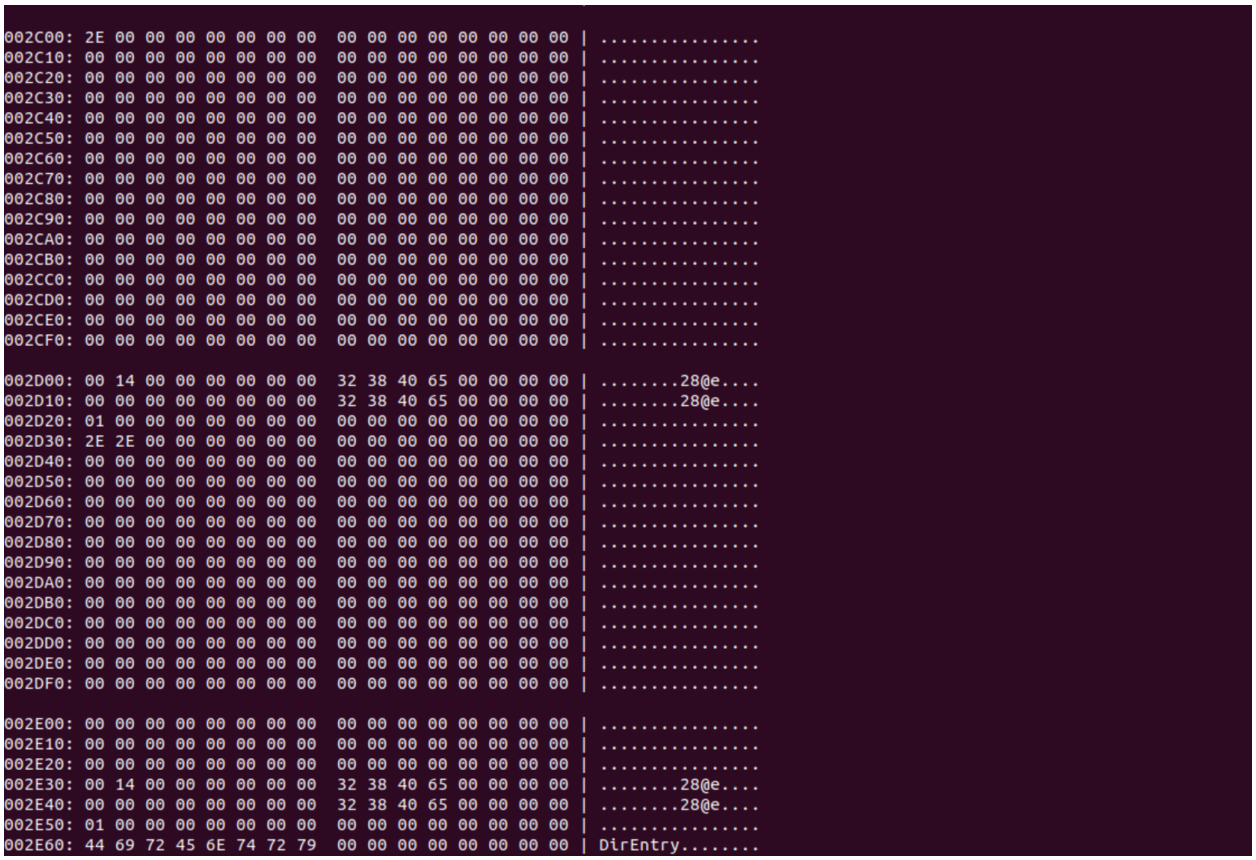
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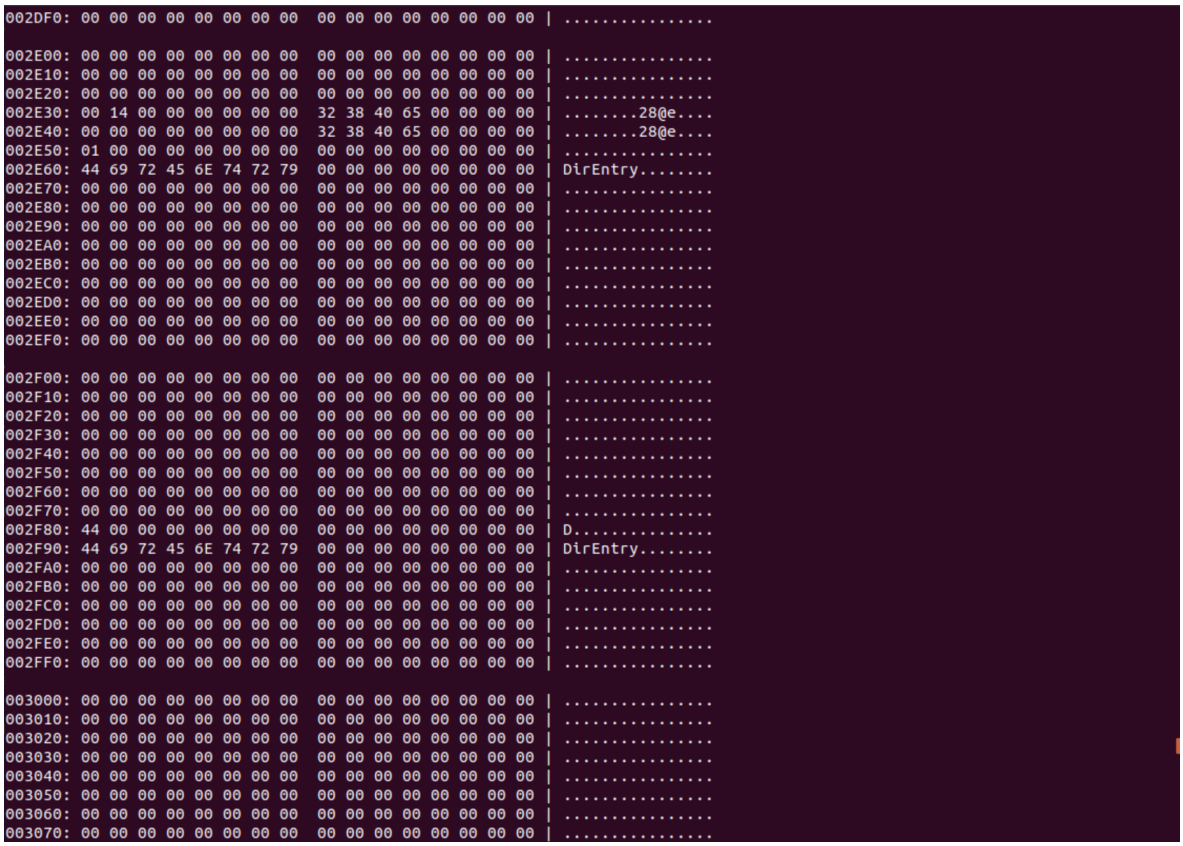
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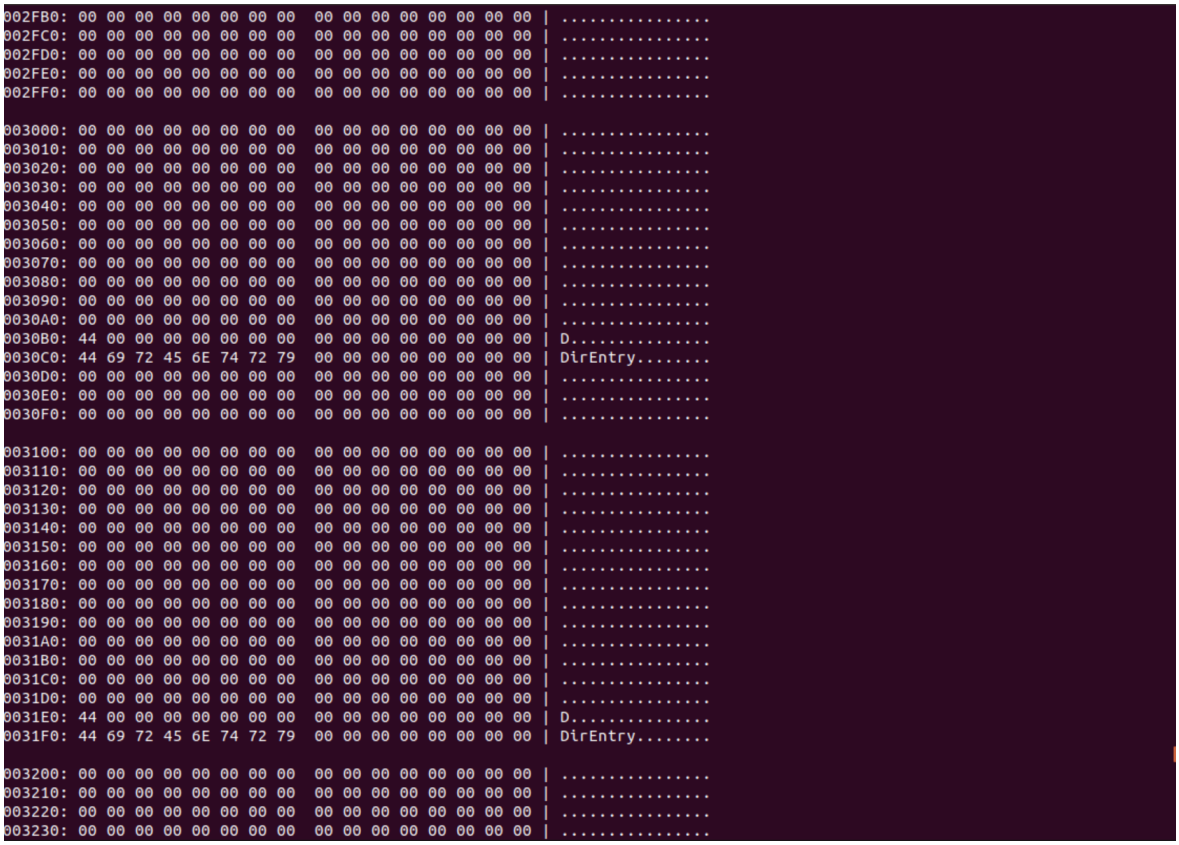
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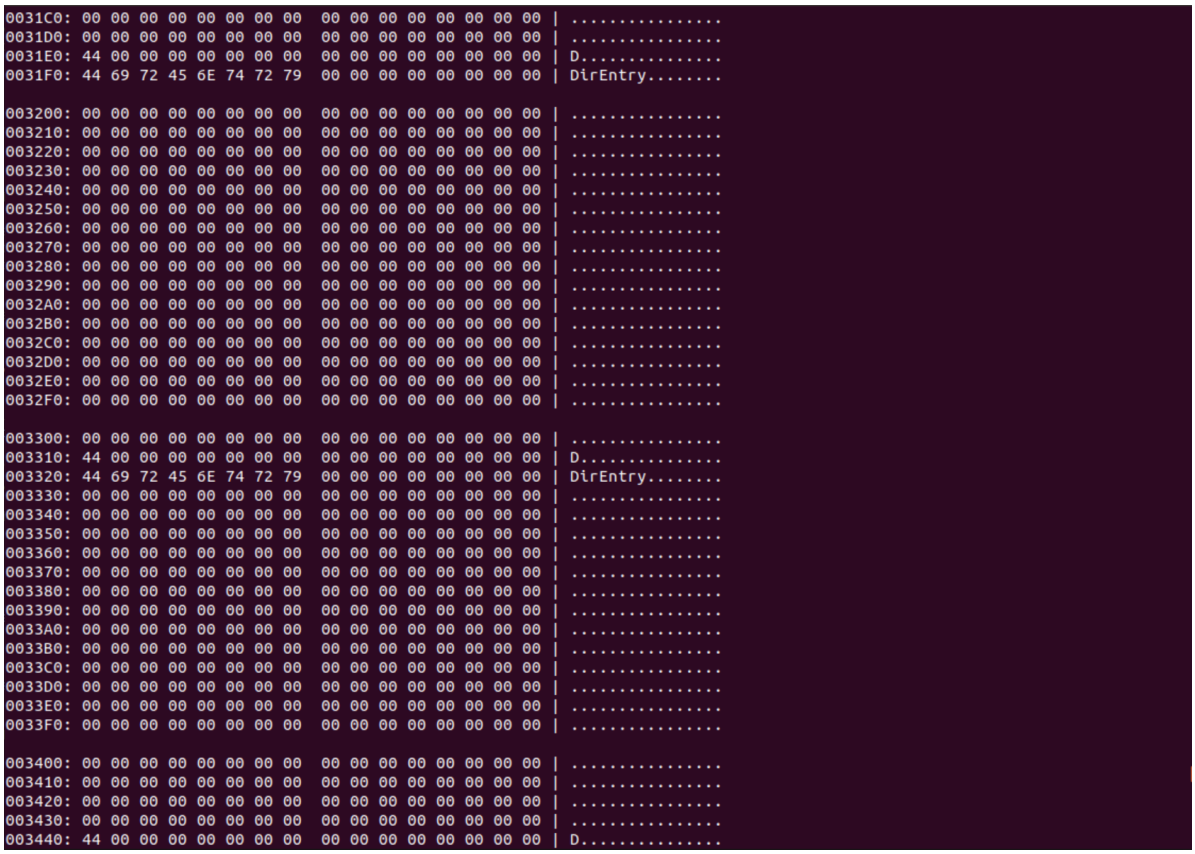
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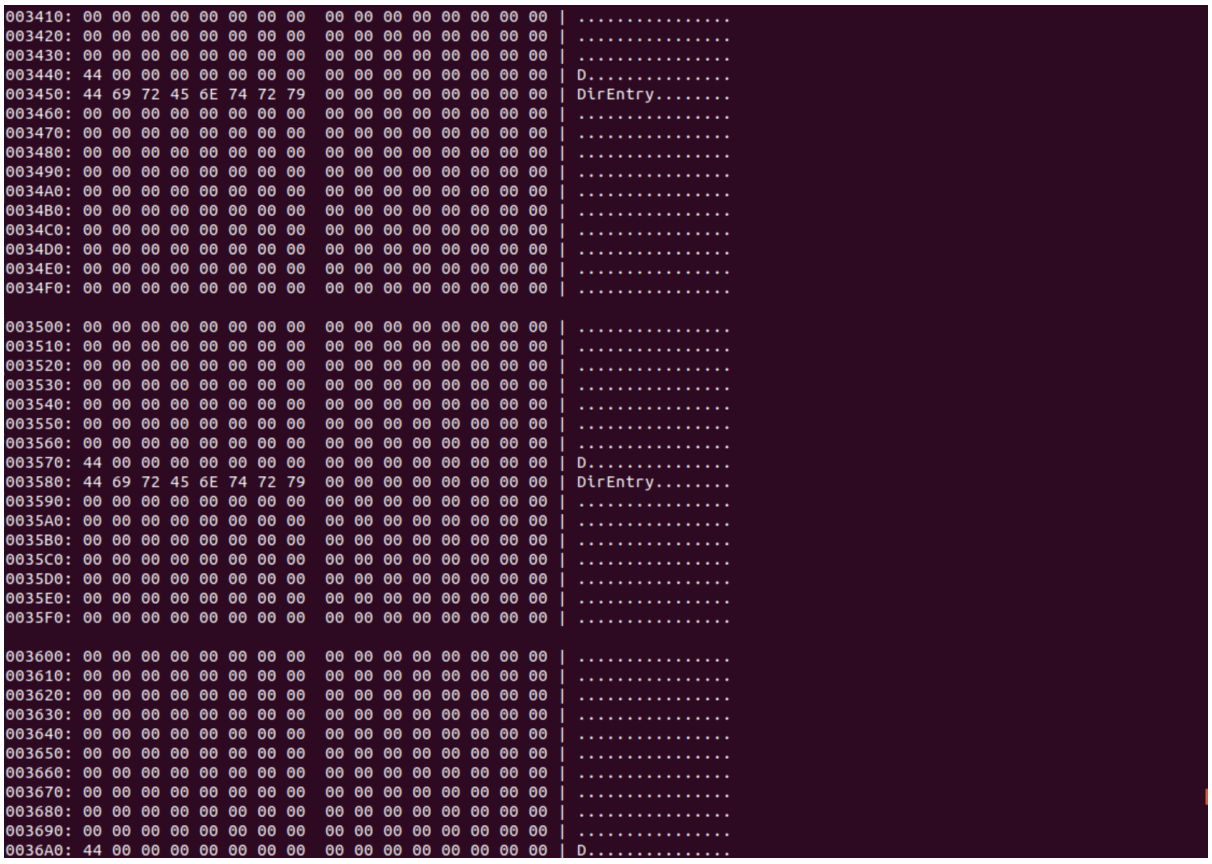
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003BE0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003BF0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

003C00: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003C10: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003C20: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003C30: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003C40: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003C50: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003C60: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003C70: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003C80: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003C90: 44 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | D...............
003CA0: 44 69 72 45 6E 74 72 79  00 00 00 00 00 00 00 00 | DirEntry........
003CB0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003CC0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003CD0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003CE0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003CF0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

003D00: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003D10: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003D20: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003D30: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003D40: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003D50: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003D60: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003D70: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003D80: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003D90: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003DA0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003DB0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003DC0: 44 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | D...............
003DD0: 44 69 72 45 6E 74 72 79  00 00 00 00 00 00 00 00 | DirEntry........
003DE0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003DF0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

003E00: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E10: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E20: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E30: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E40: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
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003E00: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E10: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E20: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E30: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E40: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E50: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E60: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E70: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E80: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003E90: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003EA0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003EB0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003EC0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003ED0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003EE0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003EF0: 44 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | D...............

003F00: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003F10: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003F20: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003F30: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003F40: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003F50: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003F60: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003F70: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003F80: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003F90: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003FA0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003FB0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003FC0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003FD0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003FE0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................
003FF0: 00 00 00 00 00 00 00 00  00 00 00 00 00 00 00 00 | ................

student@student-VirtualBox:~/Desktop/csc415-filesystem-Amandeep-Singh-24$
```

- 2E 00 00 00 00 00 00 00

    - Within the hexdump for the root directory we see the repetition/implementation of the hex value of 2E. This value is crucial to the dump as it indicates the current entry ".", when translating the hex value of 2E to text we obtain the "." value again showing the proper implementation of the directory entry.
- 2E 2E 00 00 00 00 00 00
    - Similar to the implementation of the current directory, 2E 2E is the implementation of the partent directory ".." thus again showing a crucial part of the root directory implementation. Again we know 2E is translated to the "." character thus the repetition of it shows the proper implementation of the parent directory.
- 44 00 00 00 00 00 00 00
    - The repetition of the number 44 is seen in the ASCII translation as the representation of the letter D, representing that it is a directory seen through the isDirectory = *type within our structure. Thus the repetition of the character D indicates that it is within the directory and is a valid directory.
- 44 69 72 45 6E 74 72 79
    - Lastly the value seen above contains the file name of the directory simply called DirEntry, translating the hex to simply text results in the string "DirEntry" showing again that the value is within the appropriate hex as expected. We can see that blocks 20 to 31 contain info about the directory entry again showing the proper implementation in our file system seen through the hexdump.

Descriptions:

VCB structure:

- volume_name[MAX_NAME_LENGTH]:
    - Character array which allows for alphanumeric and special character storage. Having a fixed length of 256 allows for consistent space allocation, preventing buffer overflows
- Block_size:
    - Using a 64-bit unsigned integer allows for a wide range of block sizes from very small to very large, showing its accommodations for different storage and efficiency needs. This specifies the size of each data block in bytes, which is needed to read, write, and allocate on the volume.
- Start_block:
    - Points to the starting block of the FAT table, which is crucial for a FAT-based file system. Using unit64_t ensures the system can address a large number of blocks.
- Table_size:

    - Represents the size of the FAT table n blocks, essential for navigating the FAT structure. Using a 64-bit size ensures the ability to represent large FAT tables, allowing for the implementation of large numbers of files.
- First_free_block:
    - A 64-bit integer ensures efficient space allocation in even vast storage devices by pointing directly to the first unallocated block.
- Free_block_count:
    - Knowing the amount of free blocks left is crucial for understanding the amount of space left for new data, efficiency in allocation, and optimizing performance in where to place new files.
- Last_allocated_block:
    - A 64-bit size ensures that the system remembers the last block allocated even in huge storage devices. Storing the last allocated block, can help in optimizing block allocation and assist in recovery scenarios.

Free space structure:

status:
An 8-bit status flag that's efficient in space and provides quick information on block allocation. It ensures rapid checks during space allocation or retrieval operations.
next:
A 32-bit integer offers an extensive range to point to the next block in a file sequence. This chaining mechanism is core to how FAT systems manage fragmented files.
entries:
A pointer to FAT entries which maps out the storage layout. It's the backbone of the FAT system, linking blocks to form individual files.
size:
Using a 32-bit size ensures the ability to represent a vast number of FAT entries, accommodating large filesystems with numerous files and directories.
SIZE:
A size_t type (often a 64-bit size) provides a broad representation range, ensuring the entire storage's free space can be represented, regardless of the storage's physical size.
startingBlock:
A 32-bit integer ensures efficient space allocation by pointing directly to the first available block, reducing search times in allocation operations.
freeBlocksCount:
A 32-bit count quickly provides the total free blocks, crucial for optimizing space allocation and understanding space availability.

Directory System:

- file_name[MAX_FILE_NAME_LENGTH]:
    - Represents the name of the file or directory, it serves the purpose of being the primary identifier that users and systems use to access or reference a specific file or directory. Using a character array ensures a human-readable name, with a size of 256 ensures consistent storage allocation and easy retrieval.
- File_size:
    - The size of a file in bytes is crucial for understanding the amount of storage a file occupies and is important to read a file's content properly. Using uint64 allows for the representation of very large file sizes, ensuring the file system can handle both small text files and vast multimedia files.
- mtime, atime, ctime:
    - Represents the last modified time of the file or directory, which is important metadata for backup strategies or simply data recency. Using time_t ensures accurate time tracking.
    - Indicates the last accessed time of the file or directory. This is useful for determining the frequency of file usage, and using time_t ensures consistent and accurate time tracking.
    - Denotes the time of file creation and is crucial for understanding the age of data. Using time_t ensures accurate time tracking across different platforms.
- isDirectory:
    - Acts as a flag to determine if the directory entry represents a file or a directory. This is fundamental for file system operations like listing contents or even navigating directories. By using a single char, it is efficient for representing binary states, keeping it simple and efficient.
- Location:
    - A 64-bit integer provides a broad range for pointing to the data's actual start in diverse storage sizes. This is vital for data retrieval and writing.

Table of Components:

Team member	**Worked on**
Amandeep Singh	VCB (fsInit.c & fsInit.h)
Conrad Choi	Freespace.h & Freespace.c
Akshat Sohal	Directory.c & directory.h
Rene Antoun	Writeup

Amandeep Singh, Conrad Choi, Rene Antoun, Akshat Sohal
ID:921287533, 911679059, 922654834, 917815046
Github: Amandeep-Singh-24, ChoiConrad, reneantoun, sohal786

Note:

- When it came to linking the files together all members contributed in attempting to figure out how to initialize the file system. Thus each member played a role in understanding and attempting to troubleshoot errors from other files in order to obtain our hexdump.
    - Through team meetings although not specified, every member had input upon each others part, in order to make it more collaborative creating a teamlike mentality.