CSC3150 Assignment 4

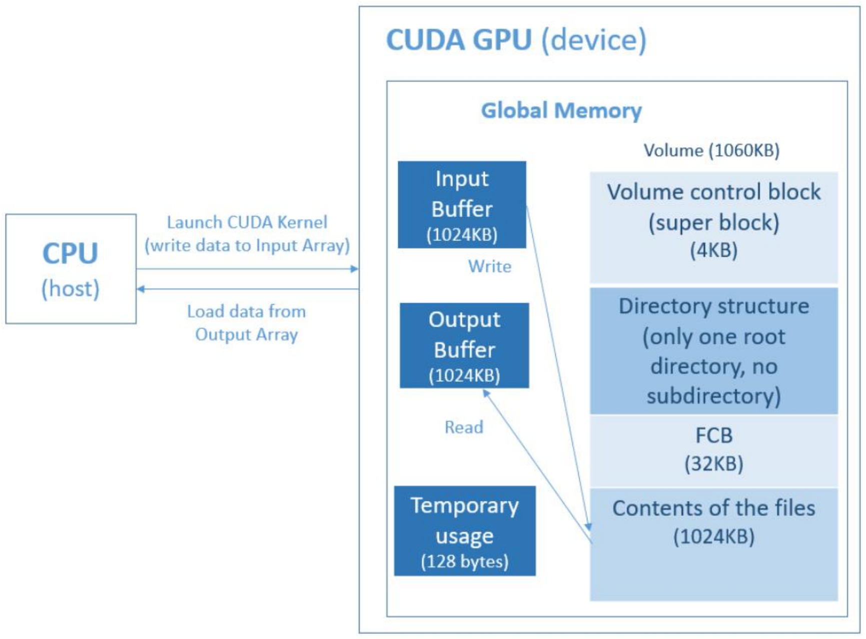
In Assignment 4, you are required to implement a mechanism of file system management via GPU's memory.

Background:

- **File systems** provide efficient and convenient access to the disk by allowing data to be stored, located, and retrieved easily.
- A file system poses two quite different design problems. The first problem is defining how the file system should look to the user. This task involves defining a file with its attributes, the operations allowed on a file, and the directory structure for organizing files.
- The second problem is creating algorithms and data structures to map the logical file system on to the physical secondary-storage devices.
- The file-organization module knows about files and their logical blocks, as well as physical blocks. By knowing the type of file allocation used and the location of the file, the file-organization module can translate logical block address to physical block address for the basic file system to transfer.
- Each file's logical blocks are numbered from 0 (or 1) through N. Since the physical blocks containing the data usually do not match the logical numbers, a translation is required to locate each block.
- The **logical file system** manages **metadata** information.
- **Metadata** includes all of the file-system structure except the actual data (or contents of the files).
- The **file-organization** module also includes the **free-space manager**, which tracks unallocated blocks and provides these blocks to the file-organization module when requested.
- The **logical file system** manages the directory structure to provide the file-organization module with the information the latter needs, given a symbolic file name. It maintains file structure via file-control blocks.
- A **file-control block** (**FCB**) (an inode in UNIX file systems) **contains information about the file**, including ownership, permissions, and location of the file contents.
- Because there have no OS in *GPU* to maintain the mechanism of the **logical file system**, we can try to implement a simple file system in CUDA GPU with single thread, and limit global memory as volume.

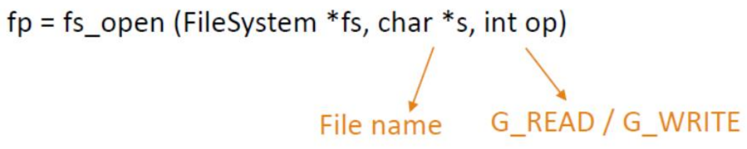
The GPU File System we need to design:

- We take the **global memory as a volume** (logical drive) from a hard disk.
- No directory structure stored in volume, **only one root directory**, no subdirectory in this file system.
- **A set of file operations should be implemented.**
- In this project, **we use only one of GPU memory, the global memory as a volume.** **We don't create the shared memory as physical memory for any data structures stored in**, **like system-wide open file table in memory**.
- In this simple file system, we just directly take the information from a volume (in global memory) by single thread.


CUDA GPU (device)
Global Memory
Volume (1060KB)
Input Buffer (1024KB)
Write
Output Buffer (1024KB)
Read
Temporary usage (128 bytes)
Volume control block (super block) (4KB)
Directory structure (only one root directory, no subdirectory)
FCB (32KB)
Contents of the files (1024KB)
CPU (host)
Launch CUDA Kernel (write data to Input Array)
Load data from Output Array

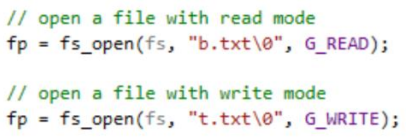
Specification:

- The **size of volume** is **1085440** bytes (1060KB).
- The **size of files** total is **1048576** bytes (1024KB).
- The maximum number of file is 1024.
- The **maximum size of a file** is **1024 bytes** (1KB).
- The **maximum size of a file name** is **20 bytes**.
- File name end with “\0”.
- **FCB size** is **32 bytes**.
- FCB entries is 32KB/ 32 bytes = 1024.
- **Storage block size** is **32 bytes**.
- **fs_open:**
  - Open a file
  - Give a file pointer to find the file’s location.
  - Space in the file system must be found for the file.
  - An entry for the new file must be made in the directory.
  - Also accept access-mode information: read/write
  - When to use write mode, if no such file name can be found, create a new zero byte file.
  - Return a write/read pointer.
  - Function definition:



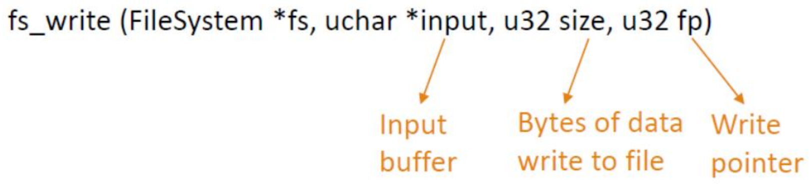
fp = fs_open (FileSystem *fs, char *s, int op)

  - Demo usage:



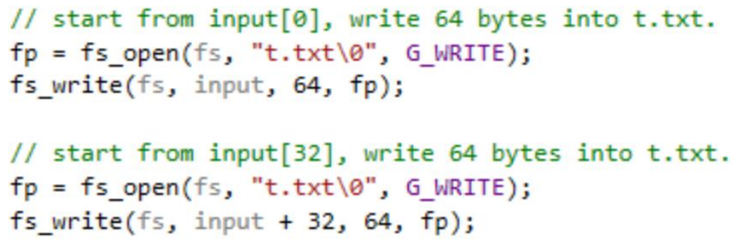
```
// open a file with read mode
fp = fs_open(fs, "b.txt\0", G_READ);

// open a file with write mode
fp = fs_open(fs, "t.txt\0", G_WRITE);
```

- **fs_write:**
  - To write a file.
  - There is a write pointer to identify the location in the file.
  - If the file has existed, cleanup the older contents of the file and write the new contents.
  - Take the **input** buffer to write bytes data to the file.
  - Function definition:



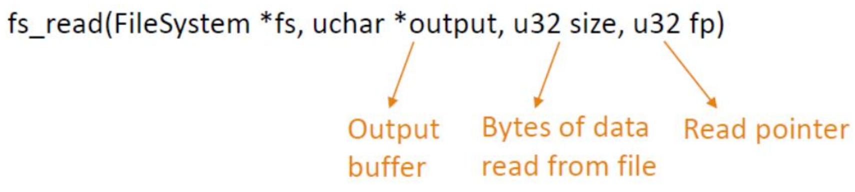
fs_write (FileSystem *fs, uchar *input, u32 size, u32 fp)

  - Demo usage:



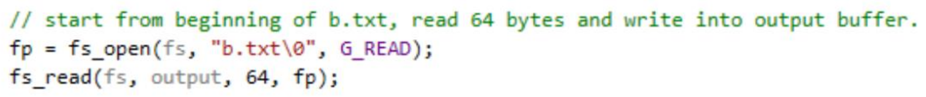
```
// start from input[0], write 64 bytes into t.txt.
fp = fs_open(fs, "t.txt\0", G_WRITE);
fs_write(fs, input, 64, fp);

// start from input[32], write 64 bytes into t.txt.
fp = fs_open(fs, "t.txt\0", G_WRITE);
fs_write(fs, input + 32, 64, fp);
```

- **fs_read:**
  - To read contents from a file.
  - There is a read pointer to identify the location in the file.
  - To read bytes data from the file to the **output** buffer.
  - The offset of the opened file associated with the read pointer is 0 (always read the file from head).
  - Function definition:



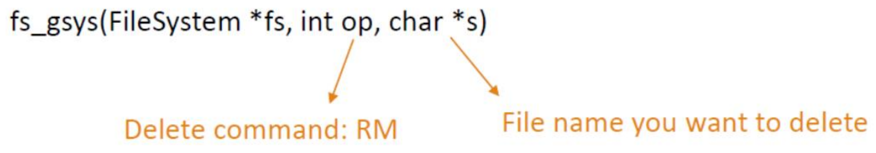
fs_read(FileSystem *fs, uchar *output, u32 size, u32 fp)

  - Demo usage:



```
// start from beginning of b.txt, read 64 bytes and write into output buffer.
fp = fs_open(fs, "b.txt\0", G_READ);
fs_read(fs, output, 64, fp);
```

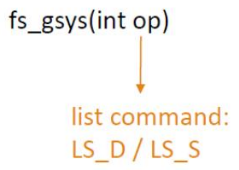
- **fs_gsys (RM):**
  - To delete a file and release the file space.
  - Search the directory for the named file.
  - Implement **gsys()** to pass the **RM** command.
  - Function definition.


fs_gsys(FileSystem *fs, int op, char *s)
Delete command: RM
File name you want to delete

  - Demo usage

```
// remove the file t.txt
fs_gsys(fs, RM, "t.txt\0");
```

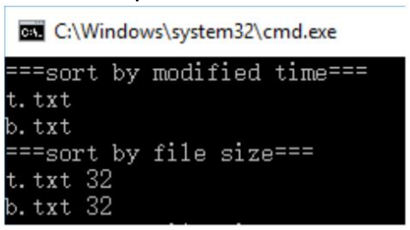
- **fs_gsys (LS_D / LS_S):**
  - List information about files.
  - Implement **gsys()** to pass the **LS_D/LS_S** commands.
  - **LS_D** list all files name in the directory and order by modified time of files.
  - **LS_S** list all files name and size in the directory and order by size.
  - If there are several files with the same size, then first create first print.
  - Function definition



  - Demo usage

```
// list all files in current directy by modifed time
fs_gsys(fs, LS_D);

// list all files in current directy by file size
fs_gsys(fs, LS_S);
```

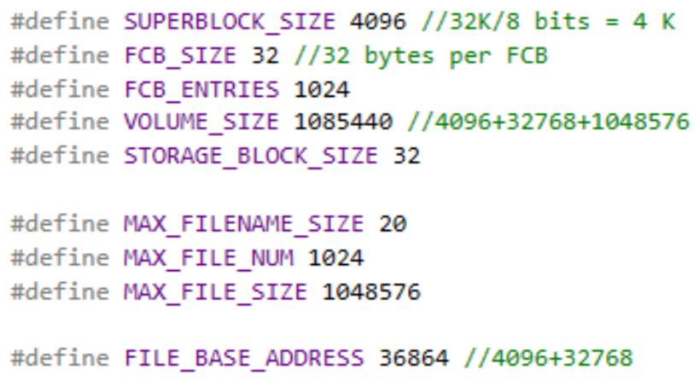
  - Demo output



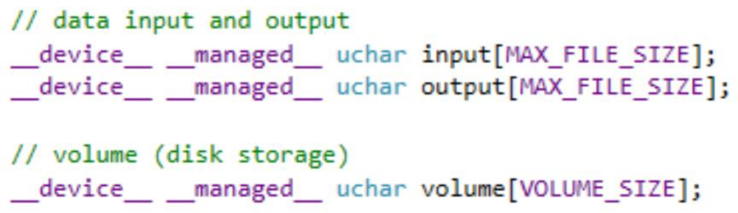
```
===sort by modified time===
t.txt
b.txt
===sort by file size===
t.txt 32
b.txt 32
```

Template structure:

- The storage size of the file system is already pre-defined as:



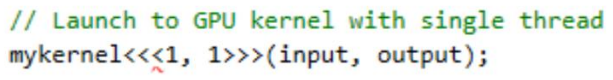
```
#define SUPERBLOCK_SIZE 4096 //32K/8 bits = 4 K
#define FCB_SIZE 32 //32 bytes per FCB
#define FCB_ENTRIES 1024
#define VOLUME_SIZE 1085440 //4096+32768+1048576
#define STORAGE_BLOCK_SIZE 32

#define MAX_FILENAME_SIZE 20
#define MAX_FILE_NUM 1024
#define MAX_FILE_SIZE 1048576

#define FILE_BASE_ADDRESS 36864 //4096+32768
```



```
// data input and output
__device__ __managed__ uchar input[MAX_FILE_SIZE];
__device__ __managed__ uchar output[MAX_FILE_SIZE];

// volume (disk storage)
__device__ __managed__ uchar volume[VOLUME_SIZE];
```

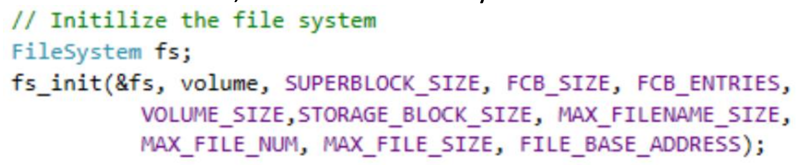
- At first, load the binary file, named **“data.bin”** to **input** buffer (via “load_binarary_file()”) before kernel launch.

- Launch to GPU kernel with single thread.

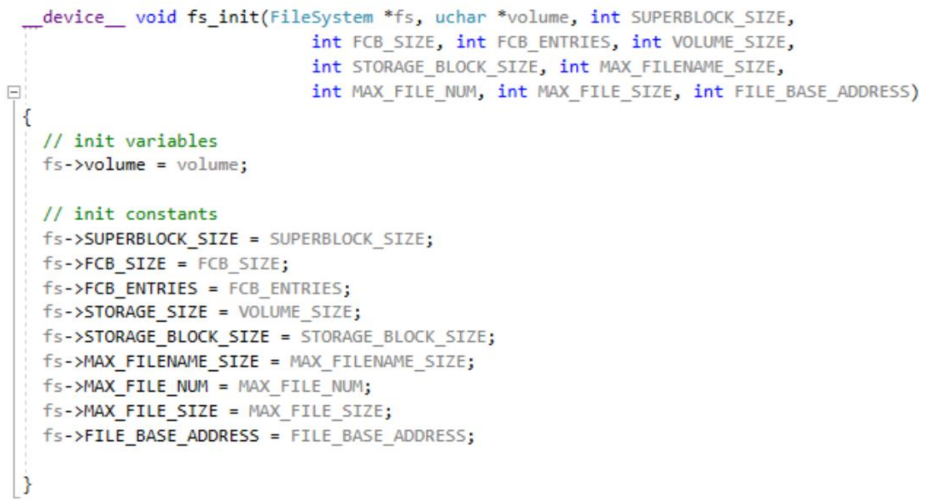


```
// Launch to GPU kernel with single thread
mykernel<<<1, 1>>>(input, output);
```

- In kernel function, initialize the file system we constructed.

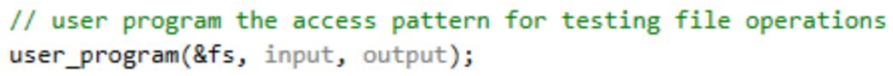


```
// Initilize the file system
FileSystem fs;
fs_init(&fs, volume, SUPERBLOCK_SIZE, FCB_SIZE, FCB_ENTRIES,
        VOLUME_SIZE,STORAGE_BLOCK_SIZE, MAX_FILENAME_SIZE,
        MAX_FILE_NUM, MAX_FILE_SIZE, FILE_BASE_ADDRESS);
```



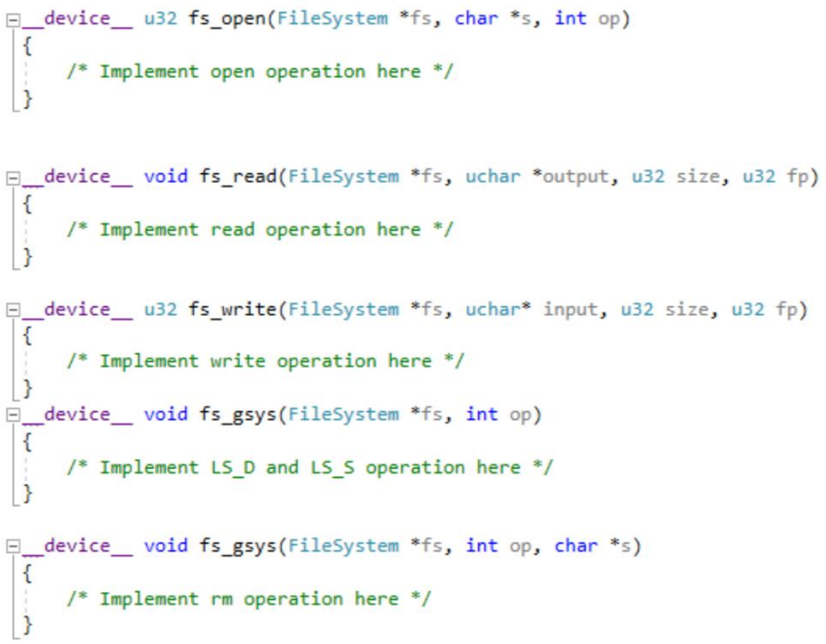
```
__device__ void fs_init(FileSystem *fs, uchar *volume, int SUPERBLOCK_SIZE,
                        int FCB_SIZE, int FCB_ENTRIES, int VOLUME_SIZE,
                        int STORAGE_BLOCK_SIZE, int MAX_FILENAME_SIZE,
                        int MAX_FILE_NUM, int MAX_FILE_SIZE, int FILE_BASE_ADDRESS)
{
  // init variables
  fs->volume = volume;

  // init constants
  fs->SUPERBLOCK_SIZE = SUPERBLOCK_SIZE;
  fs->FCB_SIZE = FCB_SIZE;
  fs->FCB_ENTRIES = FCB_ENTRIES;
  fs->STORAGE_SIZE = VOLUME_SIZE;
  fs->STORAGE_BLOCK_SIZE = STORAGE_BLOCK_SIZE;
  fs->MAX_FILENAME_SIZE = MAX_FILENAME_SIZE;
  fs->MAX_FILE_NUM = MAX_FILE_NUM;
  fs->MAX_FILE_SIZE = MAX_FILE_SIZE;
  fs->FILE_BASE_ADDRESS = FILE_BASE_ADDRESS;

}
```

- In kernel function, invoke user_program to simulate file operations for testing.
  We will replace the user program with different test cases.



```
// user program the access pattern for testing file operations
user_program(&fs, input, output);
```

- You should complete the file operations for fs_open/fs_write/fs_read/fs_gsys(rm)/fs_gsys(ls_d)/fs_gsys(ls_s).



```
__device__ u32 fs_open(FileSystem *fs, char *s, int op)
{
    /* Implement open operation here */
}


__device__ void fs_read(FileSystem *fs, uchar *output, u32 size, u32 fp)
{
    /* Implement read operation here */
}

__device__ u32 fs_write(FileSystem *fs, uchar* input, u32 size, u32 fp)
{
    /* Implement write operation here */
}
__device__ void fs_gsys(FileSystem *fs, int op)
{
    /* Implement LS_D and LS_S operation here */
}

__device__ void fs_gsys(FileSystem *fs, int op, char *s)
{
    /* Implement rm operation here */
}
```

- In CPU(host) main function, the output buffer is copied in device, and it is written into “snapshot.bin” (via write_binarary_file()).

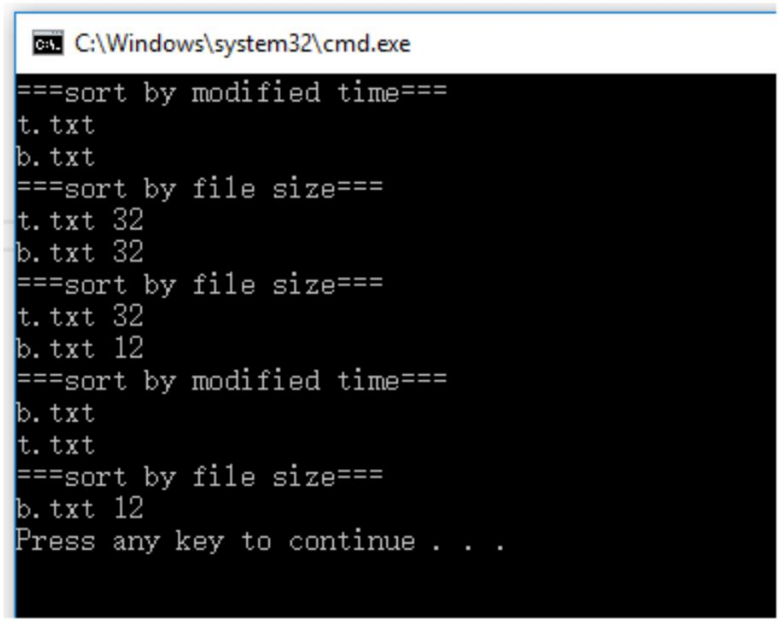
Function Requirements (90 points):

- Implement file volume structure. (10 points)
- Implement free space management. (For example, Bit-Vector / Bit-Map). (10 points)
- Implement contiguous allocation. (10 points)
- Implement fs_open operation (10 points)
- Implement fs_write operation (10 points)
- Implement fs_read operation (10 points)
- Implement fs_gsys(RM) operation (10 points)
- Implement fs_gsys(LS_D) operation (10 points)
- Implement fs_gsys(LS_S) operation (10 points)

Demo Output:

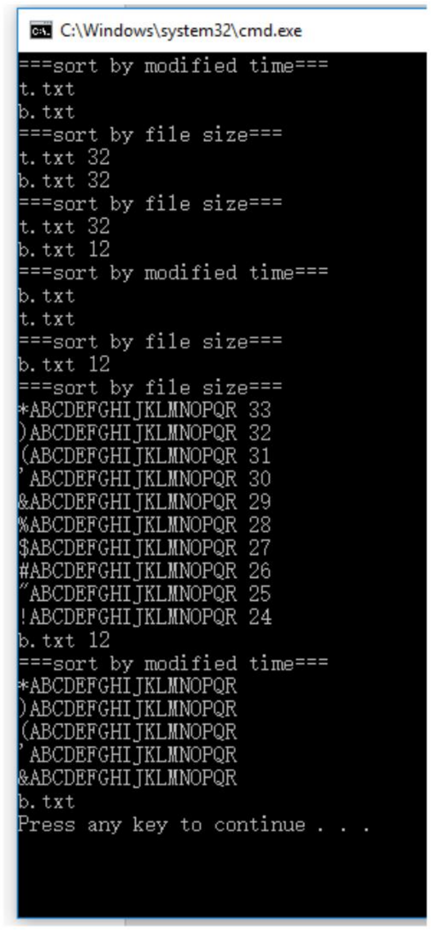
In the “user_program.cu”, we’ve provided three test cases.

- Test Case 1



```
===sort by modified time===
t.txt
b.txt
===sort by file size===
t.txt 32
b.txt 32
===sort by file size===
t.txt 32
b.txt 12
===sort by modified time===
b.txt
t.txt
===sort by file size===
b.txt 12
Press any key to continue . . .
```

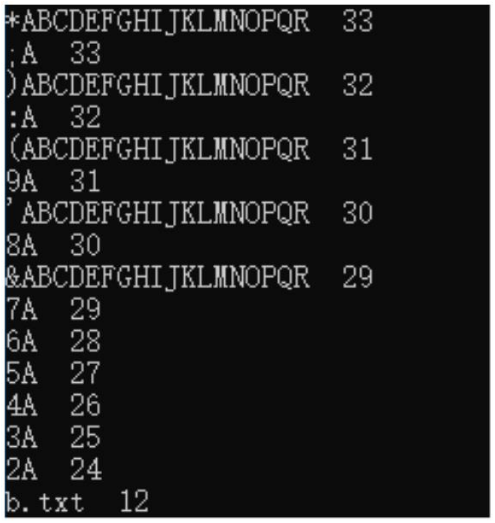
- Test Case 2



C:\Windows\system32\cmd.exe

```
===sort by modified time===
t.txt
b.txt
===sort by file size===
t.txt 32
b.txt 32
===sort by file size===
t.txt 32
b.txt 12
===sort by modified time===
b.txt
t.txt
===sort by file size===
b.txt 12
===sort by file size===
*ABCDEFGHIJKLMNOPQR 33
)ABCDEFGHIJKLMNOPQR 32
(ABCDEFGHIJKLMNOPQR 31
'ABCDEFGHIJKLMNOPQR 30
&ABCDEFGHIJKLMNOPQR 29
%ABCDEFGHIJKLMNOPQR 28
$ABCDEFGHIJKLMNOPQR 27
#ABCDEFGHIJKLMNOPQR 26
"ABCDEFGHIJKLMNOPQR 25
!ABCDEFGHIJKLMNOPQR 24
b.txt 12
===sort by modified time===
*ABCDEFGHIJKLMNOPQR
)ABCDEFGHIJKLMNOPQR
(ABCDEFGHIJKLMNOPQR
'ABCDEFGHIJKLMNOPQR
&ABCDEFGHIJKLMNOPQR
b.txt
Press any key to continue . . .
```

- Test Case 3

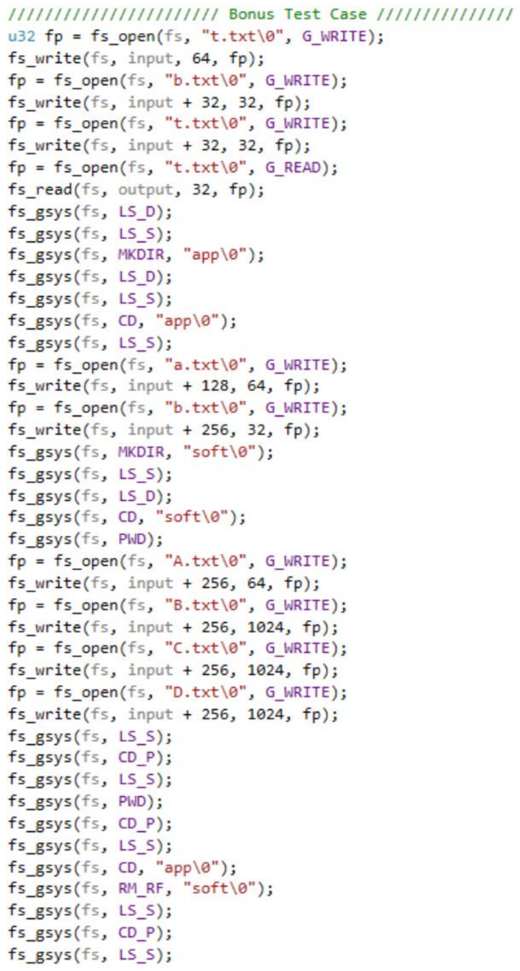


```
*ABCDEFGHIJKLMNOPQR  33
;A  33
)ABCDEFGHIJKLMNOPQR  32
:A  32
(ABCDEFGHIJKLMNOPQR  31
9A  31
'ABCDEFGHIJKLMNOPQR  30
8A  30
&ABCDEFGHIJKLMNOPQR  29
7A  29
6A  28
5A  27
4A  26
3A  25
2A  24
b.txt  12
```

Bonus (15 points)

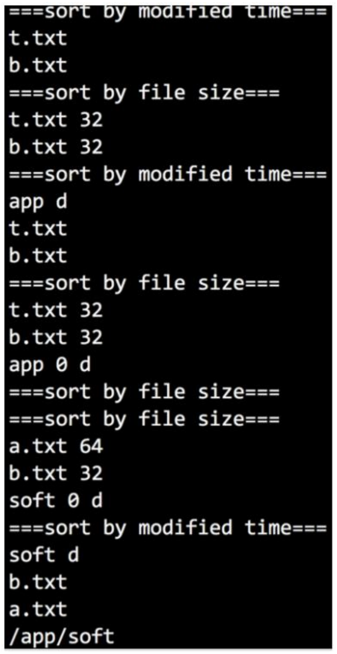
- In basic task, there is only one root directory for the file system. In bonus, you must implement **tree-structured directories**. (3 points)
- A directory (or subdirectory) contains a set of files or subdirectories.
- A directory is simply another file.
- There are at most **50 files** (include subdirectories) in a directory.
- The size of a directory is the **sum of character bytes of all files name** (include subdirectories).
  E.g., the directory root/ have these files:
  “A.txt\0” “b.txt\0” “c.txt\0” “app\0” The
  size of directory root/ is 22 bytes.
- The maximum number of files (include directory) is **1024.**
- The maximum depth of the tree-structured directory is **3**.
- File operations: (12 points)
  - **fs_gsys(fs, MKDIR, “app\0”);**
    Create a directory named ‘app’.
  - **fs_gsys(fs, CD, “app\0”)**;
    Enter app directory (only move to its subdirectory).
  - **fs_gsys(fs, CD_P);**
    Move up to parent directory.
  - **fs_gsys(fs, RM_RF, “app\0”);**
    Remove the app directory and all its subdirectories and files recursively.
    You cannot delete a directory by fs_gsys(fs, RM, “app\0”), cannot remove `app' if it is a directory.
  - **fs, gsys(fs, PWD);**
    Print the path name of current, eg., “/app/soft”
  - **fs_gsys(fs, LS_D / LS_S);**
    Update this file list operation, to list the files as well as directories.
    For a file, list it name (with size) only. For a directory, add an symbol ‘d’ at the end.

- Demo test case:



```
////////////////////// Bonus Test Case //////////////
u32 fp = fs_open(fs, "t.txt\0", G_WRITE);
fs_write(fs, input, 64, fp);
fp = fs_open(fs, "b.txt\0", G_WRITE);
fs_write(fs, input + 32, 32, fp);
fp = fs_open(fs, "t.txt\0", G_WRITE);
fs_write(fs, input + 32, 32, fp);
fp = fs_open(fs, "t.txt\0", G_READ);
fs_read(fs, output, 32, fp);
fs_gsys(fs, LS_D);
fs_gsys(fs, LS_S);
fs_gsys(fs, MKDIR, "app\0");
fs_gsys(fs, LS_D);
fs_gsys(fs, LS_S);
fs_gsys(fs, CD, "app\0");
fs_gsys(fs, LS_S);
fp = fs_open(fs, "a.txt\0", G_WRITE);
fs_write(fs, input + 128, 64, fp);
fp = fs_open(fs, "b.txt\0", G_WRITE);
fs_write(fs, input + 256, 32, fp);
fs_gsys(fs, MKDIR, "soft\0");
fs_gsys(fs, LS_S);
fs_gsys(fs, LS_D);
fs_gsys(fs, CD, "soft\0");
fs_gsys(fs, PWD);
fp = fs_open(fs, "A.txt\0", G_WRITE);
fs_write(fs, input + 256, 64, fp);
fp = fs_open(fs, "B.txt\0", G_WRITE);
fs_write(fs, input + 256, 1024, fp);
fp = fs_open(fs, "C.txt\0", G_WRITE);
fs_write(fs, input + 256, 1024, fp);
fp = fs_open(fs, "D.txt\0", G_WRITE);
fs_write(fs, input + 256, 1024, fp);
fs_gsys(fs, LS_S);
fs_gsys(fs, CD_P);
fs_gsys(fs, LS_S);
fs_gsys(fs, PWD);
fs_gsys(fs, CD_P);
fs_gsys(fs, LS_S);
fs_gsys(fs, CD, "app\0");
fs_gsys(fs, RM_RF, "soft\0");
fs_gsys(fs, LS_S);
fs_gsys(fs, CD_P);
fs_gsys(fs, LS_S);
```

- Demo output:



```
===sort by modified time===
t.txt
b.txt
===sort by file size===
t.txt 32
b.txt 32
===sort by modified time===
app d
t.txt
b.txt
===sort by file size===
t.txt 32
b.txt 32
app 0 d
===sort by file size===
===sort by file size===
a.txt 64
b.txt 32
soft 0 d
===sort by modified time===
soft d
b.txt
a.txt
/app/soft
```

Report (10 points)

Write a report for your assignment, which should include main information as below:

- How did you design your program?
- What problems you met in this assignment and what is your solution?
- The steps to execute your program. • Screenshot of your program output.
- What did you learn from this assignment?

Submission

- Please submit the file as package with directory structure as below:
  - **Assignment_4_Student ID.zip**
    - Source
      - Within the folder 'Source', it should include files below:
        - main.cu
        - file_system.cu
        - file_system.h
        - user_program.cu
        - data.bin
        - snapshot.bin (auto generated after running your program)
        - Makefile or Script
    - Bonus
      - Within the folder 'Bonus', it should include files below:
        - main.cu
        - file_system.cu
        - file_system.h
        - user_program.cu
        - data.bin
        - snapshot.bin (auto generated after running your program)
        - Makefile or Script
    - Report
- Due date: End (23:59) of 24 Nov, 2021

Grading rules

Completion	Marks
Report	10 points
Bonus	15 points
Completed with good quality	80 ~ 90
Completed accurately	80 +
Fully Submitted (compile successfully)	60 +
Partial submitted	0 ~ 60
No submission	0
Late submission	**Not allowed**