CSC3150 Assignment 4

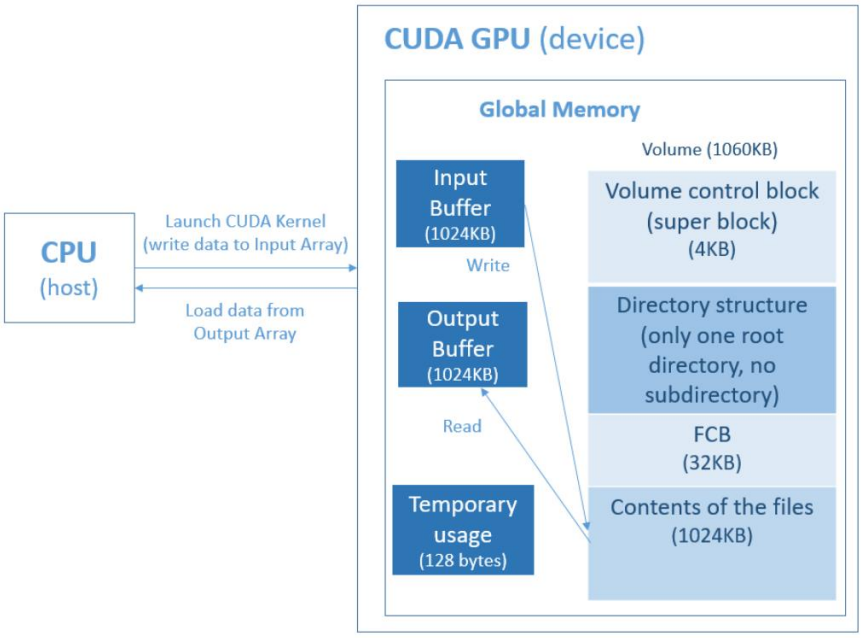
In Assignment 4, you are required to implement a mechanism of file system management via GPU's memory.

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.



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)
                              File name    G_READ / G_WRITE
```

  - 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)
```

Input buffer — Bytes of data write to file — Write pointer

  - 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:

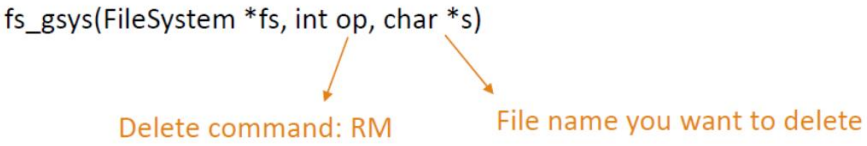
```
fs_read(FileSystem *fs, uchar *output, u32 size, u32 fp)
```

Output buffer — Bytes of data read from file — Read pointer

  - 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);
```

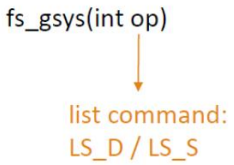
- **fs_gsys (RM):**
  - To delete a file and release the file space.
  - Search the directory for the named file.
  - Implement **gsys()** to pass the **RM** command.
  - Function definition.



  - 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

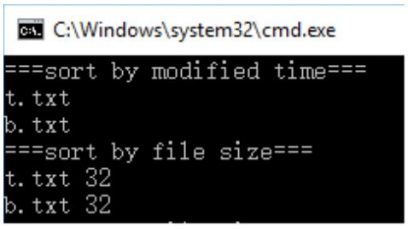


  - Demo usage

```
// 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



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()).

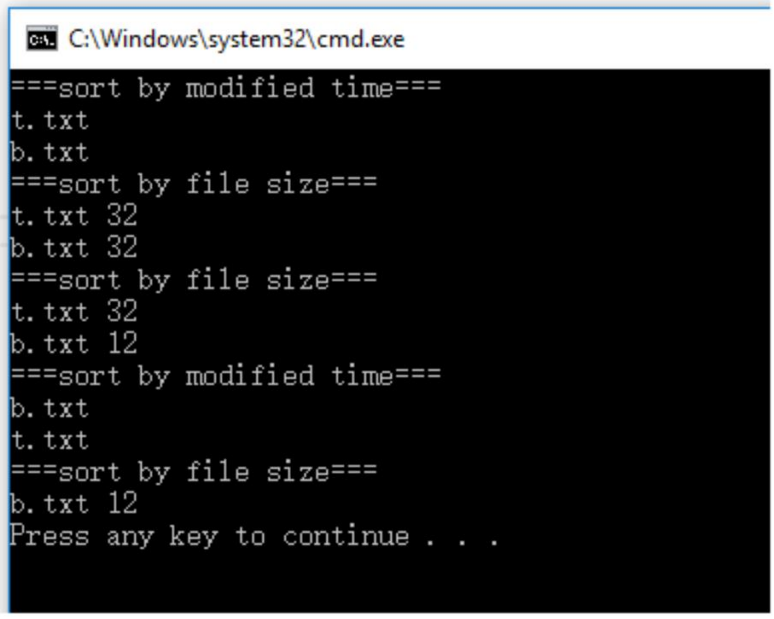
Function Requirements (90 points):

- 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:

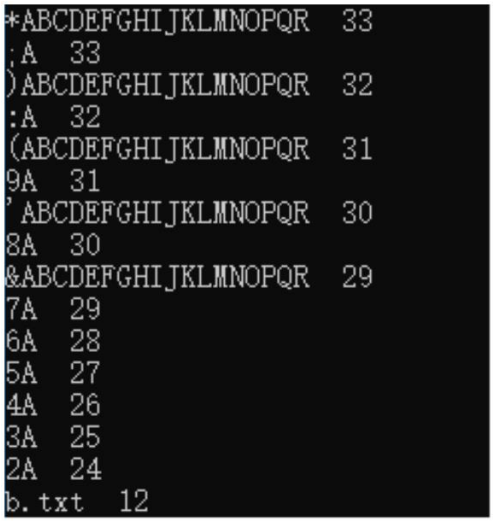
In the “user_program.cu”, we’ve provided three test cases.

- Test Case 1



- Test Case 2

- Test Case 3



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**