Project 3: Design and Implementation of File System Report

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1 Objective

a

Design and implement a basic disk-like secondary storage server.

b

Design and implement a basic file system to act as a client using the disk services provided by the server designed above.

c

Use socket API.

2 Problem Statement

This project will be developed in several steps to help you understand the concepts and encourage good modular development. It is very important that you adhere to the specifications given.

3 Step1:Design a basic disk-storage system

3.1 Design

1. In order to simulate the working process of the disk, we need to declare several **FILE*** variables to operate the disk functions.
2. Second, as we are to get the input from **stdin**, we need to realize a function which provides the **Parse Args** to deal with the input string.
3. Then, we need to realize several functions which simulate the process of disk reading and writing.
4. Last, to simulate the time cost of disk reading and writing, we need to use the **nanosleep** function together with timespec variables to make the program sleep for a while.

3.2 Details

1. We should use the **"w+"** parameter in the **fopen** function to open the file, which means that we can read and write the file and create a new file when no such file exists.
2. We are supposed to use the **strtok** function to parse the input string.

3. Since the **scanf** function will stop reading when it meets the space, we should use the **fgets** function to get the whole line of input. And in function **parseParameter**, if the case is 'W', we should stop using **strtok** since the written content could include space character.

4. In function ReadDisk and WriteDisk, we can use the function **fseek** to locate the position of the file pointer.Also, right after we call this function, it is advised to use the **ferror** and feof function to check the stream state.

4 Demo

4.1 Program

```
cyh627@cyh627-Ubuntu22 ~/S/S/0/C/S/P/step1 (main)> ./disk 5 5 10 disk.log
The disk file disk.log is created
The working log will be put into disk.log
Disk size: 6400
initialize 6400 bytes successfully
>> I
        Cylinder: 5     Sector: 5
>> W 0 0 Alan Turing was an English mathematician, logician, and computer scientist who is widely regarded as the father of theoretical comp
uter science and artificial intelligence. He made important contributions to various areas of mathematics, including number theory and logic
, and his work had a significant impact on the development of modern computing.
YES
>> R 0 0
YES
Alan Turing was an English mathematician, logician, and computer scientist who is widely regarded as the father of theoretical computer scie
nce and artificial intelligence. He made important contributions to various areas of mathematics, including number t
>> W 5 5
Error: wrong W command used...
        W c s data
>> W 5 5 During World War II, Turing played a key role in breaking the German Enigma code, which helped the Allies win the war.
NO
>> R 5 5
NO

>> W 3 4 During World War II, Turing played a key role in breaking the German Enigma code, which helped the Allies win the war.
YES
>> R 3 4
YES
During World War II, Turing played a key role in breaking the German Enigma code, which helped the Allies win the war.
>> E
Goodbye
```

图 1: Disk system

The first writing block call offers a string of 350 characters, so it will be truncated to 256 characters. (using the ipython to show it)

```
In [1]: str = "Alan Turing was an English mathematician, logician, and
   ...:  computer scientist who is widely regarded as the father of th
   ...: eoretical computer science and artificial intelligence. He mad
   ...: e important contributions to various areas of mathematics, inc
   ...: luding number theory and logic, and his work had a significant
   ...:  impact on the development of modern computing."

In [2]: len(str)
Out[2]: 350

In [3]: str2 = "Alan Turing was an English mathematician, logician, an
   ...: d computer scientist who is widely regarded as the father of t
   ...: heoretical computer science and artificial intelligence. He ma
   ...: de important contributions to various areas of mathematics, in
   ...: cluding number t"

In [4]: len(str2)
Out[4]: 256
```

4.2 disk.log

```
cyh627@cyh627-Ubuntu22 ~/S/S/O/C/S/P/step1 (main)> cat disk.log
Alan Turing was an English mathematician, logician, and computer scientist who is widely regarded as the father of theoretica
nce and artificial intelligence. He made important contributions to various areas of mathematics, including number tious area
s, including number theory and logic, and his work had a significant impact on the development of modern computing.
        Write to disk c 0 s 0 write offset: 0
R 0 0
        Read from disk c 0 s 0 read offset: 0
W 5 5
        Write to disk c 5 s 5 Error: wrong W command used...
W c s data
W 5 5 During World War II, Turing played a key role in breaking the German Enigma code, which helped the Allies win the war.
        Write to disk c 5 s 5 R 5 5
        Read from disk c 5 s 5 W 3 4 During World War II, Turing played a key role in breaking the German Enigma code, which
es win the war.
        Write to disk c 3 s 4 write offset: 4864
R 3 4
        Read from disk c 3 s 4 read offset: 4864
E
Goodbye
During World War II, Turing played a key role in breaking the German Enigma code, which helped the Allies win the war.
```

图 2: disk.log

5 Step 2: Design a basic file system

5.1 Design

1. While designing the file system, I think the most important thing is how to design the APIs so the file system functions could work together with the disk functions we have realize in the Part 1.
2. I choose the Inode implementation, like the Unix ext3 and ext4 file system implementation.
3. In my design, the size of the inode structure is the same as the block size, which will make the implementation easier and compatible.
4. In the inode structure, we should declare several necessary variable members, such as filename, file size, time lastly changed, and direct link , second-direct link, etc.
5. Also the disk in this part is just a big char array, but we should take it as a block array.These blocks should be divided into several groups such as inode blocks, data blocks, bitmap block.In reality, there are super blocks and log blocks as well, but they are kind of unnecessary in the part.
6. In the bitmap block, we should use the bitmap to record the status of each block, which means that if the block is occupied, the corresponding bit in the bitmap should be 1, otherwise 0.But it is inefficient to sequentially traverse the bitmap to find the first free block.
7. So I organize the bitmap array into tree array.And this could reduce the time complexity to $O(logn)$.(I was intended to realize a file system that is as close as the reality, so I tried to get some information from the internet about how to traverse the bitmap, and I get very limited information about it, such as Flat Bitmap, Hierarchical Bitmap, Block Group Bitmap.)

5.2 Details

1. First, we should create a root directory while ”f” is called.

2. We should keep record of the current working directory, so we can add the new entry to the current working directory's inode while a new file or directory is created.

3. Some code runs thousands of times, such as find a certain entry in current working directory.So we should change this codes into small functions.

4. While we are to delete a directory, we should delete all the entries in the directory, and then delete the directory itself.This is a recursive process while we are going to delete a directory belonging to the deleted directory.

5. The entries in the directory inode should be filled with the inode number if it points to an entry, otherwise it should be filled with -1;

6. So the entry used in the directory inode turns out to be scattered.We should traverse them one by one to find a free entry slot.

7. But for the file inode, the entries are continuous as the file is continuous, so we can use the file size to calculate the number of entries.

5.3 Demo

```
cyh627@cyh627-Ubuntu22 ~/S/S/O/C/S/P/step2 (main)> ./fs
Welcome to the file system!
disk size: 2560000
Format Done!
/ $ ls
.       0       D       2023-5-16 19:34:6
..      0       D       2023-5-16 19:34:6
YES
/ $ mk file1
YES
/ $ w file1 286 During World War II, Turing played a key role in breaking the German Enigma code, which helped the Allies win the war. He de
signed a machine known as the Bombe that was used to decipher encrypted messages, and his work on codebreaking is widely considered to have
saved countless lives.
YES
/ $ ls
.       0       D       2023-5-16 19:34:6
..      0       D       2023-5-16 19:34:6
file1   286     F       2023-5-16 19:34:15
YES
/ $ cat file1
During World War II, Turing played a key role in breaking the German Enigma code, which helped the Allies win the war. He designed a machine
 known as the Bombe that was used to decipher encrypted messages, and his work on codebreaking is widely considered to have saved countless
lives.
YES
/ $ i file1 286 389 After the war, Turing continued his research in computer science and artificial intelligence. He proposed the concept of
 a universal Turing machine, which is now considered to be a fundamental concept in computer science. He also developed the Turing test, whi
ch is used to determine whether or not a machine can exhibit intelligent behavior that is indistinguishable from that of a human.
YES
/ $ ls
.       0       D       2023-5-16 19:34:6
..      0       D       2023-5-16 19:34:6
file1   675     F       2023-5-16 19:34:15
YES
/ $ cat file1
During World War II, Turing played a key role in breaking the German Enigma code, which helped the Allies win the war. He designed a machine
 known as the Bombe that was used to decipher encrypted messages, and his work on codebreaking is widely considered to have saved countless
lives.After the war, Turing continued his research in computer science and artificial intelligence. He proposed the concept of a universal T
uring machine, which is now considered to be a fundamental concept in computer science. He also developed the Turing test, which is used to
determine whether or not a machine can exhibit intelligent behavior that is indistinguishable from that of a human.
YES
/ $ mkdir dir1
YES
/ $ cd dir1
YES
dir1 $ ls
.       0       D       2023-5-16 19:35:32
..      0       D       2023-5-16 19:34:6
YES
dir1 $ mk file1
YES
dir1 $ w file1 611 Despite his many contributions to computer science and codebreaking, Turing was persecuted for his homosexuality, which w
as illegal in England at the time. He was prosecuted and convicted, and was forced to undergo chemical castration. Tragically, he committed
suicide in 1954 at the age of 41.Today, Turing is widely recognized as one of the most important figures in the history of computer science
and artificial intelligence. His work continues to have a profound impact on the development of new technologies, and he is celebrated as a
pioneer and a hero for his groundbreaking contributions to the field.
YES
dir1 $ ls
.       0       D       2023-5-16 19:35:32
..      0       D       2023-5-16 19:34:6
file1   610     F       2023-5-16 19:37:16
YES
dir1 $ cat file1
Despite his many contributions to computer science and codebreaking, Turing was persecuted for his homosexuality, which was illegal in Engla
nd at the time. He was prosecuted and convicted, and was forced to undergo chemical castration. Tragically, he committed suicide in 1954 at
the age of 41.Today, Turing is widely recognized as one of the most important figures in the history of computer science and artificial inte
lligence. His work continues to have a profound impact on the development of new technologies, and he is celebrated as a pioneer and a hero
for his groundbreaking contributions to the field.
YES
dir1 $ mkdir dir2
YES
dir1 $ cd dir2
YES
dir2 $ cd /
YES
/ $ rmdir dir1
YES
/ $ ls
.       0       D       2023-5-16 19:34:6
..      0       D       2023-5-16 19:34:6
file1   675     F       2023-5-16 19:34:15
YES
/ $ d file1 286 389
YES
/ $ ls
.       0       D       2023-5-16 19:34:6
..      0       D       2023-5-16 19:34:6
file1   286     F       2023-5-16 19:34:15
YES
/ $ cat file1
```

5.4 Important codes

5.4.1 Inode

```
struct Inode{
    char filename[FILENAME_SIZE];
    uint64_t file_size;
    // here are only two types of file: dir 1 and file 0
    uint32_t file_type;
    // need some more design
    uint32_t permission;
    // uint32_t time;
    char Time[32];
    uint64_t block_num;
    uint64_t direct[8];
    uint64_t second_indirect[4];
};
```

Listing 1: inode structure

6 Step 3: Work together

6.1 Design

1. In this part, we are supposed to combine the disk system and file system we realized in the previous two parts and make some modifications.

2. It turns out that it is important to unify interfaces of the disk and file system.While we calculate the physical block num from logical block number, we should not use memcpy, memmove to change the disk.Otherwise, we should use write or read block functions to do that.The abstraction of this layer of encapsulation is very important

6.2 Details

1. It is important to uniform transfer data block size using socket communication.If not, Information processing can occur in asymmetric situations.

2. There exist another small problem we have to pay attention to.That is, if the server close the client's socket, the client program will not exit.This is different from the telnet command.This part we are supposed to realize a client program by ourselves, so we have to care about the case.One solution is that we record the bytes received from the server depending on the return value of recv or read function.The other solution is that we can judge whether the string we get is "Goodbye" or other strings indicating that the process should terminate.

6.3 Demo

6.4 Program

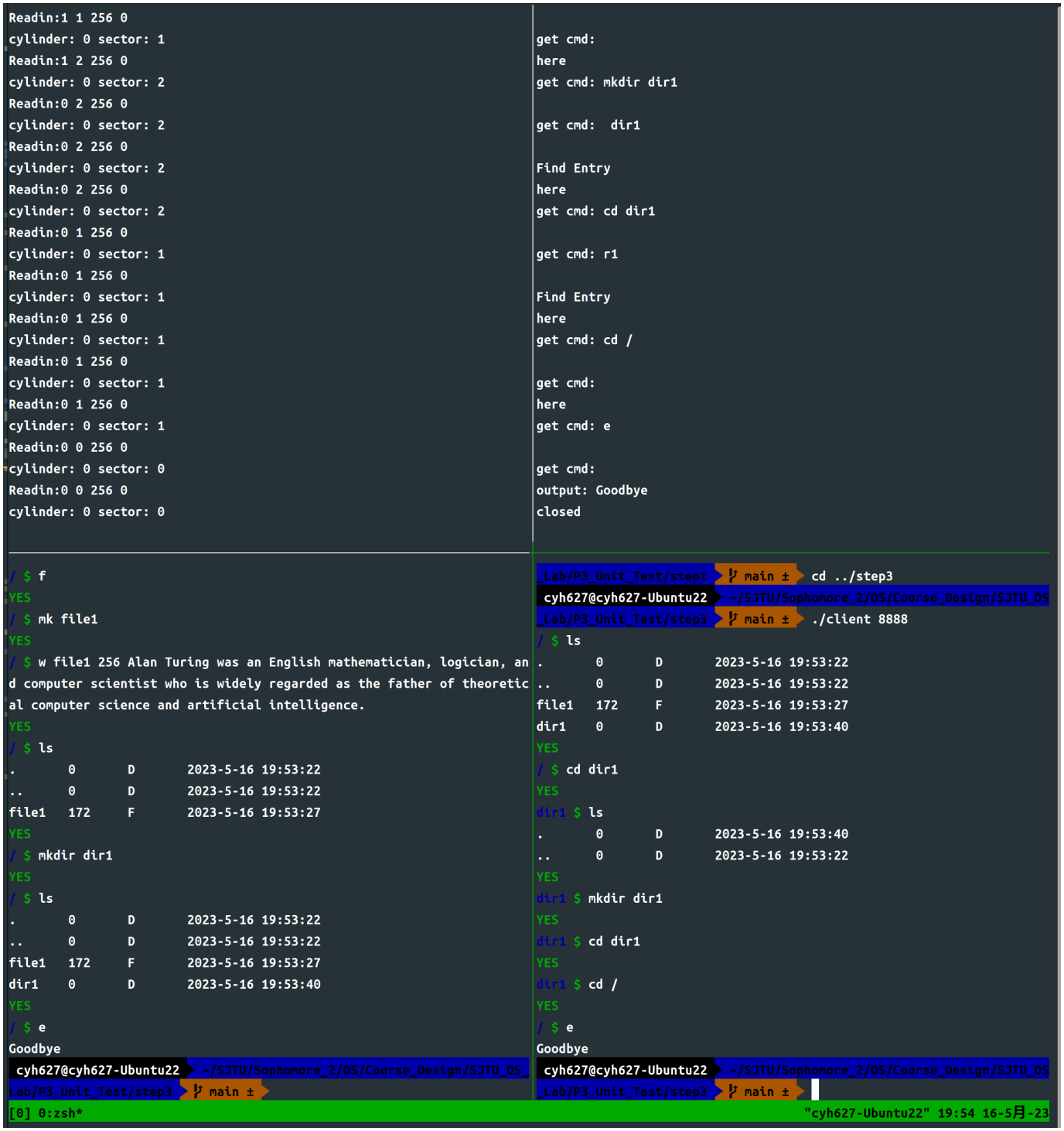

图 4: 从左上至右下依次是 disk server，file server，client1，client2 的运行界面