1 Basics

We create rdwr.c including functions **block_read** and **block_write**. Both of them have 3 parameters: file_name, block_size, block_count. In block_read, we read buf sized block_size block_count times from the file named file_name. And so on in block_write.

```
block_read(file_name, block_size, block_count);
```

```
block_write(file_name, block_size, block_count);
```

In run.c, we parse the parameters and choose to use block_read or block_write. We record the start time and the end time to get the runtime.

2 Measurement

Firstly, we parse the parameters to get the **file_name** and **block_size**.

Then, we start with **block_count=1**. In each loop, we double **block_count** and run

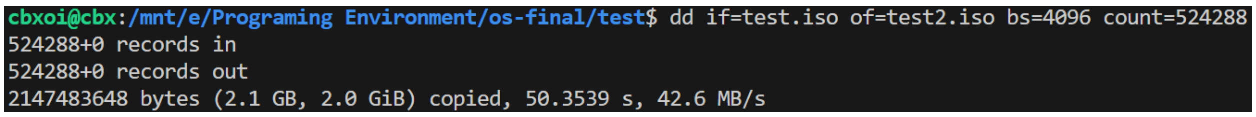
```
block_read(file_name, block_size, block_count);
```

We record the runtime and quit the loop when runtime>5 (second)

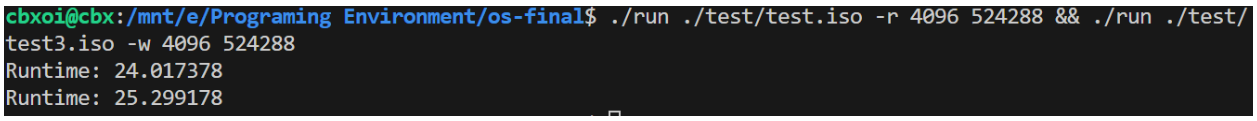
Finally, we print **block_size * block_count** as the file_size

Extra Credit: explore **dd**

We use "dd" to copy 2GB data (block_size 4096) from the iso file and compare its runtime with "run". We find that their runtimes are **almost the same**. "dd" takes 50 seconds and "run" takes 49 seconds total.



```
cbxoi@cbx:/mnt/e/Programing Environment/os-final/test$ dd if=test.iso of=test2.iso bs=4096 count=524288
524288+0 records in
524288+0 records out
2147483648 bytes (2.1 GB, 2.0 GiB) copied, 50.3539 s, 42.6 MB/s
```

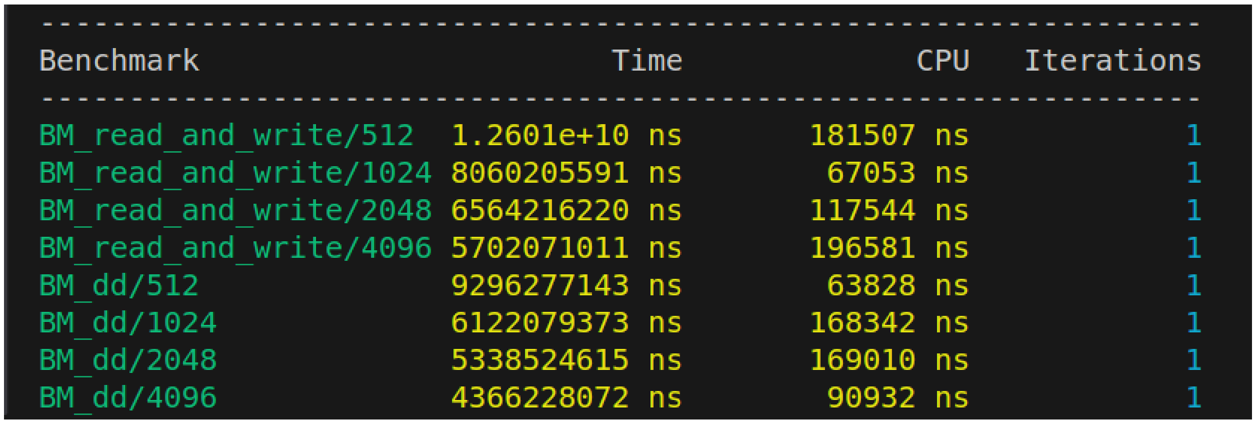


```
cbxoi@cbx:/mnt/e/Programing Environment/os-final$ ./run ./test/test.iso -r 4096 524288 && ./run ./test/
test3.iso -w 4096 524288
Runtime: 24.017378
Runtime: 25.299178
```

Extra credit: learn about Google Benchmark — see if you can use it.

We've tried Google Benchmark on this part. Benchmark is a lightweight library, and it is a bit awkward to use it to calculate a proper file_size. (much simpler just in C code)

However, it is a nice tool to monitor performance. We've included an example below, where we compare dd and our implementation of block_read + block_write. dd is still slightly faster with different block sizes. (the format BM_dd/2048 means that dd is tested using block size of 2048 Bytes)

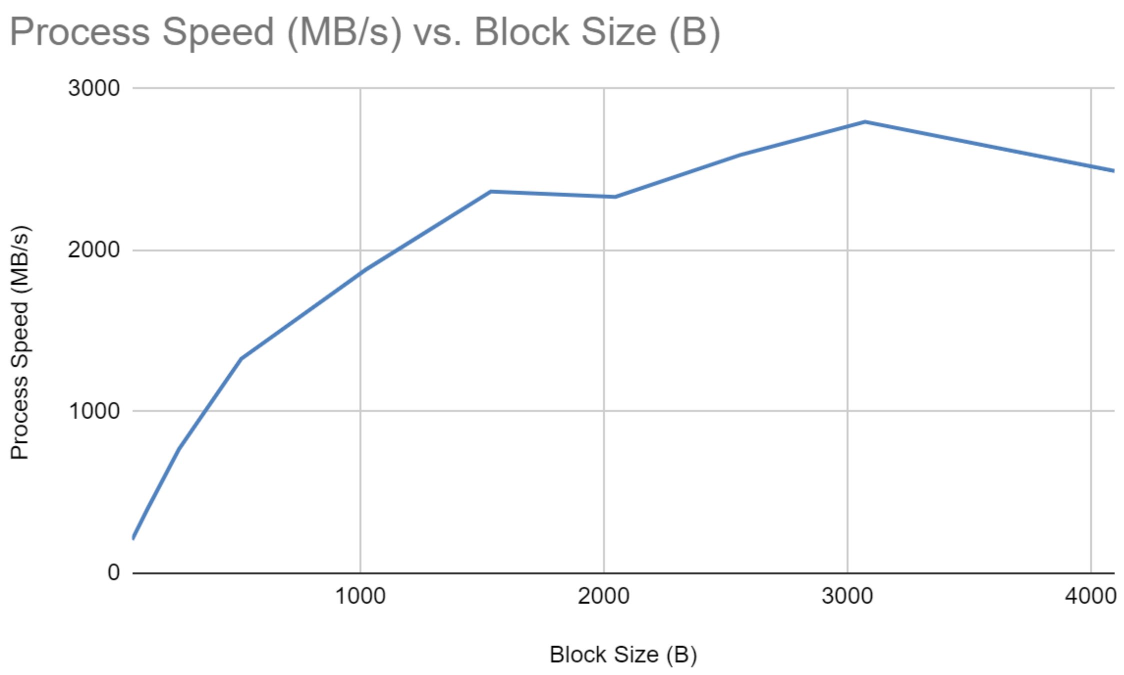


```
------------------------------------------------------------------
Benchmark                          Time             CPU   Iterations
------------------------------------------------------------------
BM_read_and_write/512  1.2601e+10 ns       181507 ns            1
BM_read_and_write/1024 8060205591 ns        67053 ns            1
BM_read_and_write/2048 6564216220 ns       117544 ns            1
BM_read_and_write/4096 5702071011 ns       196581 ns            1
BM_dd/512              9296277143 ns        63828 ns            1
BM_dd/1024             6122079373 ns       168342 ns            1
BM_dd/2048             5338524615 ns       169010 ns            1
BM_dd/4096             4366228072 ns        90932 ns            1
```

3 Raw Performance

- Make a graph that shows its performance as you change the block size.

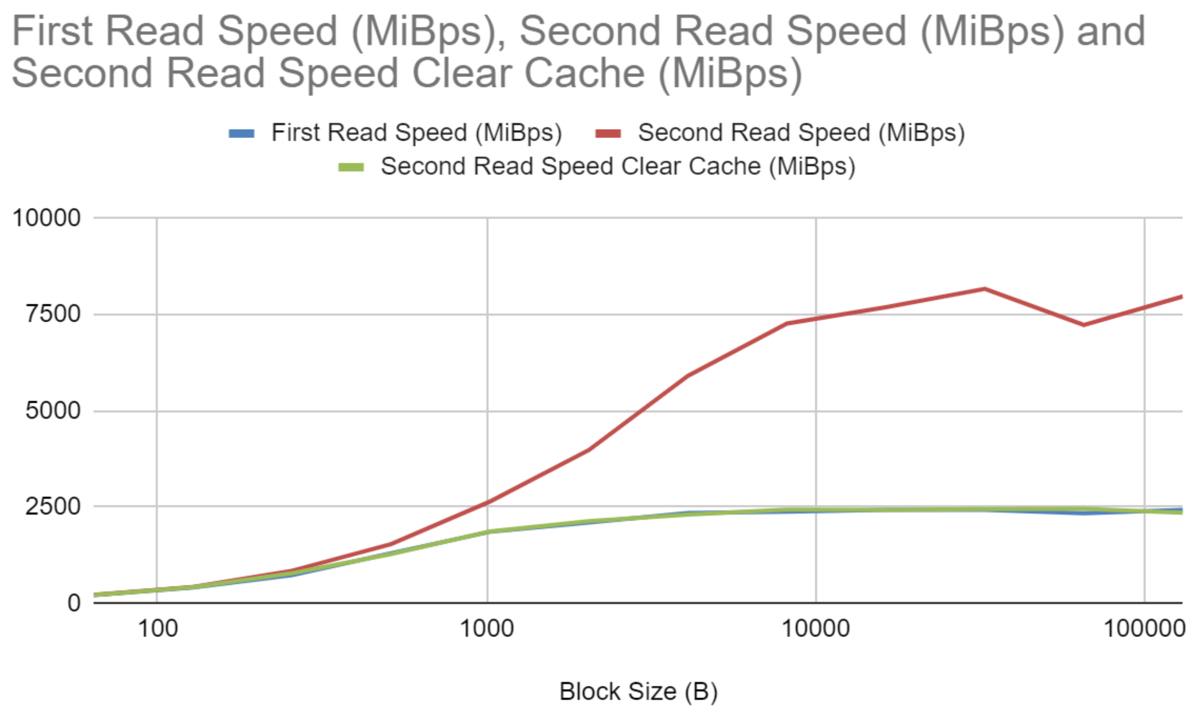
As we can see from the graph, the process speed (performance) increases as the block size increases until reaching around 2.5GB/s. Please also refer to our spreadsheet in data.xlsx.



4 Caching

We read the file once, clear the cache, and then read the file again. Their data has been recorded in data.xlsx. Below is a graph of their speed in different block sizes. (Note that x axis is in log scale)

From this graph, we observed that, second read speed is significantly faster than the first read and second read cache cleared. The difference of speed grows larger and larger as the block size increases, until it becomes stable around block size 8192 Bytes.



Extra Credit: Explain `sudo sh -c "/usr/bin/echo 3 > /proc/sys/vm/drop_caches"`

The following comes from the documentation of Linux:

To free pagecache:

echo 1 > /proc/sys/vm/drop_caches

To free reclaimable slab objects (includes dentries and inodes):

echo 2 > /proc/sys/vm/drop_caches

To free slab objects and pagecache:

echo 3 > /proc/sys/vm/drop_caches

Using 3 remove both the slab objects and pagecache. Slab is a memory management mechanism used in Linux for commonly used objects. Page cache is part of the VM system. It is a cache of pages in RAM.

5 System Calls

Please refers to system_call.c

● Measure performance MiB/s when using block size of 1 byte

3.680185 MiB/s

● Measure performance in B/s. This is how many system calls you can do per second.

3858954 B/s, or 3858954 system calls per second

● Try with other system calls that arguably do even less real work (e.g. **lseek**)

We have compared system calls read and lseek(system_call.c), here's the printing result:

Number of read per second: 3844769.056968

Number of **lseek** per second: 10240425.108437

6 Raw Performance

In this part we use multiple threads.

We use the **block_size 4096**. (Basely)

For the thread numbered i, we open a fd and read the blocks numbered

i, i+num_threads, ... , i+k*num_threads

Use **lseek()** to jump to the right place. After reading, we combine 4 characters into an unsigned int and XOR them.

Finally, we output the total runtime (This runtime includes the time to calculate XOR), the runtime per MB and the result of XOR

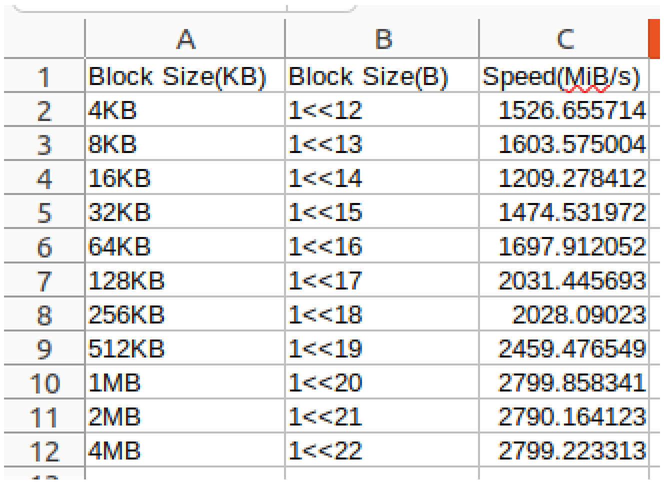
For those files whose size is not a multiple of 4, we add '\0' to its tail when XOR and make sure each byte is included.

Results:

Multiple threads works well. One thread takes approximately 4 times runtime compared to 16 threads.

Find a good enough block size?

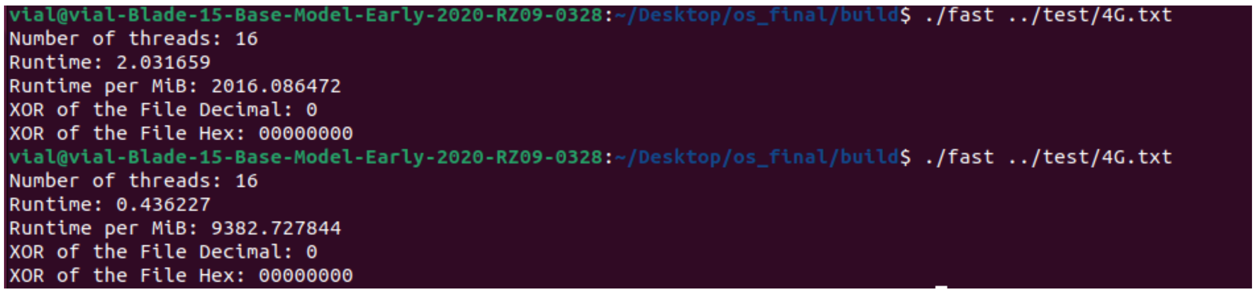
We've explored several block sizes and produced a graph below showing that block size no longer improves speed significantly after around 1MB. Hence, our current program has set the block size to be 1MB.



	A	B	C
1	Block Size(KB)	Block Size(B)	Speed(MiB/s)
2	4KB	1<<12	1526.655714
3	8KB	1<<13	1603.575004
4	16KB	1<<14	1209.278412
5	32KB	1<<15	1474.531972
6	64KB	1<<16	1697.912052
7	128KB	1<<17	2031.445693
8	256KB	1<<18	2028.09023
9	512KB	1<<19	2459.476549
10	1MB	1<<20	2799.858341
11	2MB	1<<21	2790.164123
12	4MB	1<<22	2799.223313

Report both cached and non-cached performance numbers

Below is a comparison of two consecutive call to fast on the same file. Cache improves the program performance a lot from 2016MiB/s to 9382MiB/s.



```
vial@vial-Blade-15-Base-Model-Early-2020-RZ09-0328:~/Desktop/os_final/build$ ./fast ../test/4G.txt
Number of threads: 16
Runtime: 2.031659
Runtime per MiB: 2016.086472
XOR of the File Decimal: 0
XOR of the File Hex: 00000000
vial@vial-Blade-15-Base-Model-Early-2020-RZ09-0328:~/Desktop/os_final/build$ ./fast ../test/4G.txt
Number of threads: 16
Runtime: 0.436227
Runtime per MiB: 9382.727844
XOR of the File Decimal: 0
XOR of the File Hex: 00000000
```

Extra Try:

We try to use **mmap** instead of reading to input the data but we find that it slows down. It almost takes double the time. We guess that under a small **block_size**, mmap takes more time when mapping such a small bunch. The code is in **fast_mmap.c**