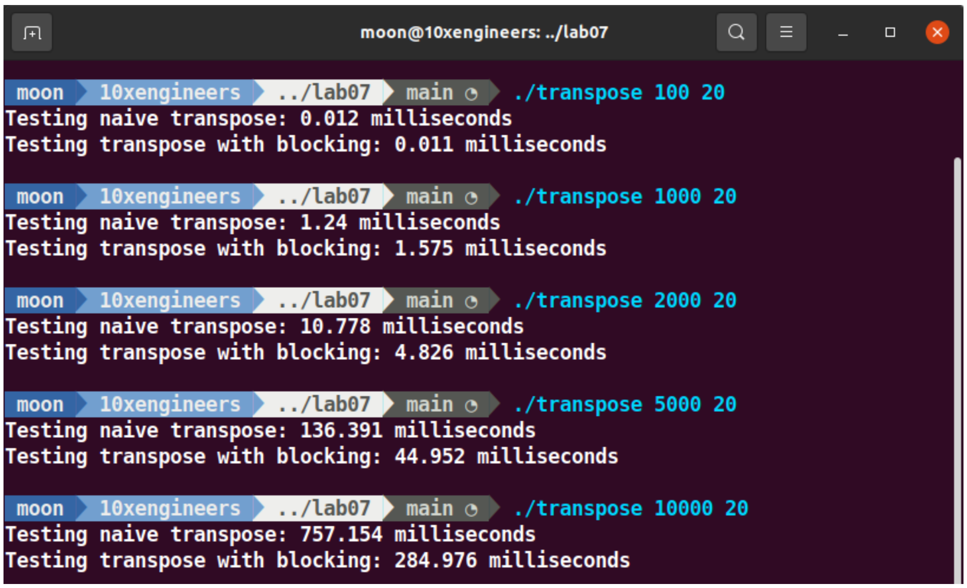
Task 4

Part 1 - Changing Array Sizes

Question 1: At what point does cache blocked version of transpose become faster than the non-cache blocked version?

Cache blocked version become faster than non-cache blocked version when n=2000 i.e. the size of array is 2000x2000



Question 2: Why does cache blocking require the matrix to be a certain size before it outperforms the non-cache blocked code?

When we use cache blocking, we divide the matrix into smaller blocks. But cache blocking also adds some extra work. We need to manage these blocks, which means there is additional overhead there. Because we had to keep track of which blocks are being processed and the movement of data in and out of cache.

With cache blocking, there is a higher chance that the data we need for the current block is not already in the cache, so it may result in more cache misses. Therefore, for smaller matrix sizes, the benefits of cache blocking, such as improved cache utilization, may not outweigh the overhead and increased cache misses.

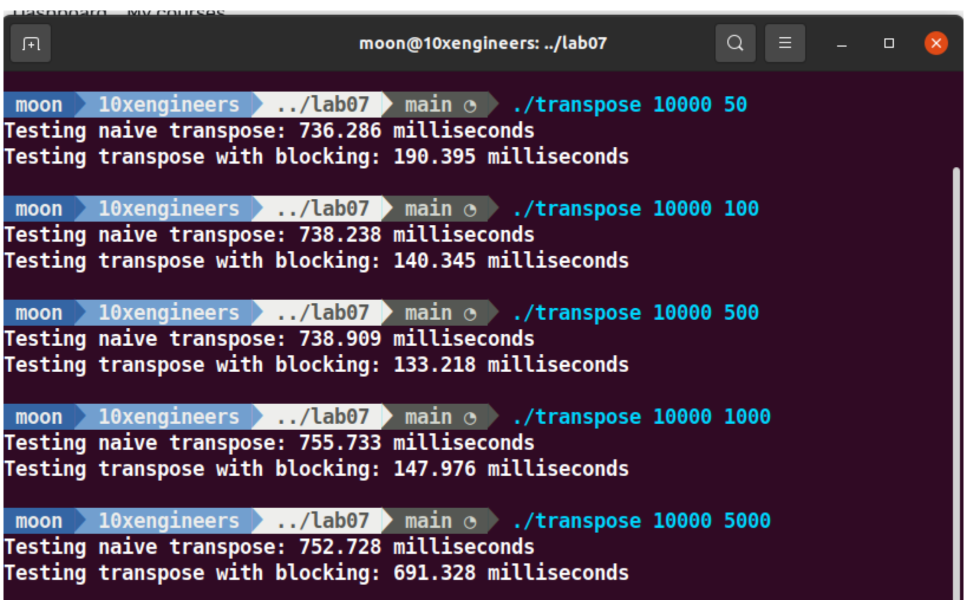
Part 2 - Changing Block Size

Question 3: How does performance change as blocksize increases? Why is this the case?

The performance improves initially and then started decreasing.

The reason for the initial performance improvement with larger blocksize is related to cache utilization. With a larger block size, a higher number of matrix elements are processed together, which improves data locality and reduces cache misses. The cache can hold more elements from the same block, and the reuse of these elements within the block leads to better cache performance.

However, when the block size becomes too large, such as when it is set to 1000 or 5000, the performance starts to decrease. This happens because as the block size increases, the number of blocks or chunks decreases, and each block becomes larger. This larger block may exceed the cache capacity, resulting in more frequent cache evictions and increased cache misses. Consequently, the performance suffers due to the increased main memory accesses.



```
moon@10xengineers: ../lab07

moon 10xengineers ../lab07 main ./transpose 10000 50
Testing naive transpose: 736.286 milliseconds
Testing transpose with blocking: 190.395 milliseconds

moon 10xengineers ../lab07 main ./transpose 10000 100
Testing naive transpose: 738.238 milliseconds
Testing transpose with blocking: 140.345 milliseconds

moon 10xengineers ../lab07 main ./transpose 10000 500
Testing naive transpose: 738.909 milliseconds
Testing transpose with blocking: 133.218 milliseconds

moon 10xengineers ../lab07 main ./transpose 10000 1000
Testing naive transpose: 755.733 milliseconds
Testing transpose with blocking: 147.976 milliseconds

moon 10xengineers ../lab07 main ./transpose 10000 5000
Testing naive transpose: 752.728 milliseconds
Testing transpose with blocking: 691.328 milliseconds
```

Code for the implemented transpose_blocking is:

```
void transpose_blocking(int n, int blocksize, int *dst, int *src) {
    // YOUR CODE HERE
    int chunk_count = n / blocksize;
    // normal case
    // i: iterates over the chunk in rows
    // j: iterates over the chunk in columns
    // x: iterates over the elements within each row chunk
    // y: iterates over the elements within each column chunk
    for (int i = 0; i < chunk_count; i++) {
        for (int j = 0; j < chunk_count; j++) {
            for (int x = 0; x < blocksize; x++) {
                for (int y = 0; y < blocksize; y++) {
                    dst[y + j * blocksize + (x + i * blocksize) * n] = src[x + i * blocksize + (y + j * blocksize) * n];
                }
            }
        }
    }

    // If n is not a multiple of blocksize, handle the edge case
    int normalsize = chunk_count * blocksize;
    for (int k = 0; k < n; k++) {
        for (int z = normalsize; z < n; z++) {
            dst[z + k * n] = src[k + z * n];
            dst[k + z * n] = src[z + k * n];
        }
    }
}
```