Experiment Report

— Matrix Multiplication

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1 Introduction

Given two matrices A and B, where A is a matrix with M rows and K columns and matrix B contains K rows and N columns, the matrix product of A and B is matrix C, where C contains M rows and N columns. The entry in matrix C for row i column j(C_{ij}) is the sum of the products of the elements for row i in matrix A and column j in matrix B. In this project, the multiplication can be implemented by both single-thread and multi-thread programming. Comparing the running time, we can have a more specific understanding about multi-thread programming.

2 Running environment

$\longrightarrow$ Ubuntu 16.04

3 Experimental procedure

3.1 Single-thread programming

The implementation of matrix multiplication by single-thread programming is quite easy. All we need to do is calculating each element in matrix C separately. The time complexity is $O(n^3)$. The core of the source code is shown below:

```
for(row = 0; row < M; ++row){
    for(column = 0; column < N; ++column){
        multi(row, column);
    }
}
```

3.2 Multi-thread programming

3.2.1 Each element in a worker thread

The method that textbook shows is to calculate each element C_{ij} in a separated worker thread. This will involve creating M $\times$ N worker threads. We use Pthread to do this task. A thread is created by *pthread_create()*. The arguments are pointed to the function to be executed in each thread and the parameters needed in that function. We define the matrices A, B and C as global variables, so the parameters passed to each thread is the value of row i and column j. So we need a data structure to pass the parameters.

```
typedef struct{
    int row;
    int column;
} matrixWorkInfo;
```

After the multiplication, we use *pthread_join()* to join each thread into the main one.

```
void peer_multi(matrixWorkInfo *workInfo){
    int row = workInfo->row;
    int column = workInfo->column;
    int position;
    C[row][column] = 0;
    for (position = 0; position < K; ++position) {
        C[row][column] = C[row][column] + (A[row][
            position] * B[position][column]);
    }
    free(workInfo);
}

for (row = 0; row < M; ++row){
    for (column = 0; column < N; ++column){
        id = N * row + column;
        workInfo = (matrixWorkInfo *)malloc(sizeof(
            matrixWorkInfo));
        workInfo->row = row;
        workInfo->column = column;
        pthread_create(&(peer[id]), NULL,(void *)
            peer_multi, (void *)workInfo);
    }
}

for (i = 0; i < (M * N); ++i){
    pthread_join(peer[i], NULL);
```

```
}
```

3.2.2 Each row in a worker thread

But as the scale of the matrix gets larger, the number of thread is growing fast, too. For example, the multiplication of two 1000 $\times$ 1000 matrices will create 1,000,000 threads, which memory cannot afford. So We can calculate each row of matrix C in a separated worker thread.

```
void peer_multi(int *arg){
    int row = *arg;
    int column, position;
    for (column = 0; column < N; ++column) {
        C[row][column] = 0;
        for (position = 0; position < K; ++position) {
            C[row][column] = C[row][column] + (A[row][
                position] * B[position][column]);
        }
    }
}

for (row = 0; row < M; ++row){
    id = row;
    int *arg = (int *)malloc(sizeof(int));
    *arg = row;
    pthread_create(&(peer[id]), NULL, (void *)
        peer_multi, arg);
}
for (i = 0; i < M; ++i){
    pthread_join(peer[i], NULL);
}
```

3.3 Note

3.3.1 Time calculation

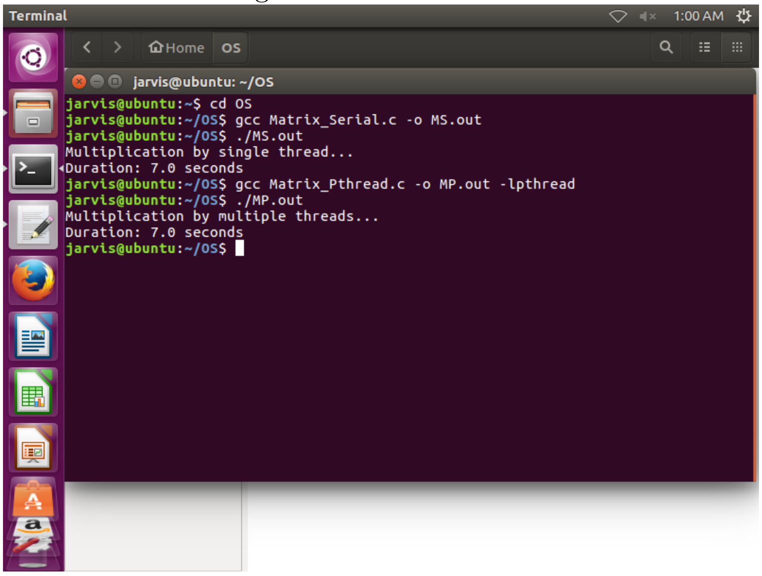
We use *time* function to calculate the executing time instead of *clock()*, because the later one is calculating the CPU executing clocks, which will be wrong when there is multi-thread programming.

```
time_t start, finish;
double duration;
start = time(NULL);
\\calculation
finish = time(NULL);
```

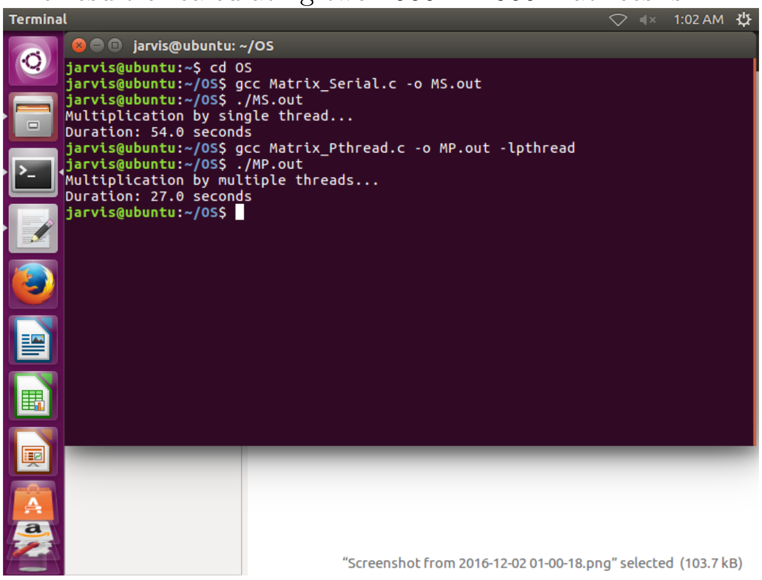
```
duration = (double)(finish - start);
```

4 Conclusion and Discussion

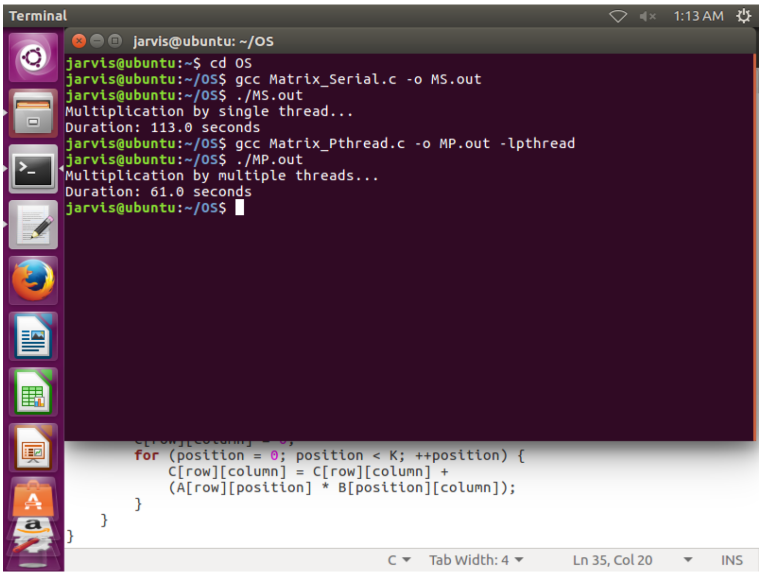
The result of calculating two 1000×1000 matrices is:



The result of calculating two 1500×1500 matrices is:



The result of calculating two 2000×2000 matrices is:



It's easy to see that when calculating 1000×1000 matrix multiplication, the executing time is approximately the same. But as the scale of matrices gets larger, the priority of multi-thread programming becomes more obvious.