作業系統 HW2 報告

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一、前言：

此報告是因應作業 2 簡報中之”Requirement - Multi-threaded Program”第 7 點要求而做成，內容將涵蓋以下：

1. worker threads 的資料分配方式
2. 給定測資的總體時間運算及測定方式說明
3. 總結 2. 中之觀察結果。

二、worker threads 的資料分配方式：

在本次的作業中，我的 worker threads 的本地資料分配方式是用 element dispatch 的方式構成。具體的切割方式如下圖的程式碼：

```
222 /**
223  * this function is used to split the elements of the result function to the local of each threads
224 */
225 void split_matrix(int threads, int r, int c){
226     /*initialization*/
227     locals = (local_matrix *)malloc(sizeof(local_matrix) * threads);
228 
229     int cut = (r * c) / threads, id = 0, counter = 0;
230     for(int i = 0 ; i < r ; i++){
231         for(int j = 0 ; j < c ; j++){
232             if(counter == 0){
233                 locals[id].r_start = i;
234                 locals[id].c_start = j;
235             }
236 
237             counter++;
238 
239             if(counter == cut && id < (threads - 1)){
240                 locals[id].r_end = i;
241                 locals[id++].c_end = j;
242 
243                 counter = 0;
244             }
245         }
246     }
247 
248     locals[id].r_end = r - 1;
249     locals[id].c_end = c - 1;
250 }
```

其中，名為 locals 的陣列是以以下資料型態（以及上圖中之動態分配）所建成：

```
29 /*this data type represents the matrix position that the local of each threads will do the calculation*/
30 typedef struct local_matrix{
31     int r_start; /*local starting row*/
32     int c_start; /*local starting colemn*/
33     int r_end; /*local ending row*/
34     int c_end; /*local ending colemn*/
35 }local_matrix;
36 local_matrix *locals;
```

在 split_matrix 的分配函式中，我會先叫一次輸出矩陣的 row 和 colemn 數字來去做一次巢狀 for，以精確的標定每個 thread 該計算的輸出矩陣起始和終點位置。除此之外，為了能夠控制分配的量，我以 cut 紀錄每個 thread 的大略分配數目，並在巢狀 for 中以 counter 來記錄跑了多少個「位置」數目，且 counter 重置條件為： counter 和 cut 一樣時做結束點輸

入和 counter 重置。

但是，由於我的 cut 是用暴力除法且強制型態轉換的方式，有可能會有餘數的情況沒有記錄到。因此，我設定當 id（在此表示為目前正在記錄的 thread 點，以 0 開始計）是最後一個的時候（也就是 threads - 1），我將其之終點設為輸出矩陣中之最後一個位置－[row - 1, column - 1]，這樣的話就可以把餘數的情況涵蓋在內，不過也當然得會使最後一個 thread 的壓力增加了些。

在此附上針對我這樣分配的各個 thread 中本地矩陣乘法的運算方式：

```
187     int r_start = locals[local_id].r_start;
188     int r_end = locals[local_id].r_end;
189     int c_start = locals[local_id].c_start;
190     int c_end = locals[local_id].c_end;
191 
192     /*matrix multiplication*/
193     int i, j, j_s, j_e, k;
194     for(i = r_start ; i <= r_end ; i++){
195         /*define the current starting and ending colemn (of the out_matrix)*/
196         if(i == r_start){
197             /*the start of j must be c_start*/
198             j_s = c_start;
199             if(r_start == r_end)/*if the r_end is in the same row of r_start*/
200                 j_e = c_end;
201             else
202                 j_e = cout - 1;
203         }else if(i == r_end){
204             /*the last row of this thread*/
205             j_s = 0;
206             j_e = c_end;
207         }else{
208             /*not hitting the end of the row*/
209             j_s = 0;
210             j_e = cout - 1;
211         }
212 
213         for(j = j_s; j <= j_e ; j++){
214             out_matrix[i][j] = 0;
215             for(k = 0 ; k < ca ; k++)
216                 out_matrix[i][j] += (matrixA[i][k] * matrixB[k][j]);
217         }
218     }
```

其中，為了得知此 thread 要用哪個 locals 標記點的 local_id 取得方式為以下：

```
182     /*prevent from the race condition and critical section*/
183     pthread_mutex_lock(&mutex);
184     local_id = proc_id++;
185     pthread_mutex_unlock(&mutex);
```

而 proc_id 被定義為以下形式：

```
18  int proc_id = 0; /*the id for each thread process execute*/
```

三、各個 threads 數對應給定測資的時間分析：

1.) 時間計算方式：

在本次作業的矩陣乘法計算中，我以以下的方式做時間的測定：

```
289     clock_t begin, end;
290     begin = clock();
291     for(i = 0 ; i < threads ; i++)
292         pthread_create(&p[i], NULL, thread_mat_mul, (void*)data);
293     for (i = 0 ; i < threads ; i++)
294         pthread_join(p[i], NULL);
295     end = clock();
296     printf("The execution time of %d threads: %f(s)\n", threads, (double)(end - begin) / CLOCKS_PER_SEC);
```

其中做時間運算的工具是用 C 內部的 time.h 來進行，給 clock()的隨機種子為以下：

```
305         srand((unsigned)time(NULL));
```

2.) 時間測量：

接下來的話將會先放出各個指定 thread 數目的測資結果截圖，之後，再用那些截圖中的時間資料完成圖表的製作，也同時證明說每次運行的結果都是正確的。

a.)Test_case_1：

```
./MT_matrix 1 m1.txt m2.txt
The execution time of 1 threads: 38.130713(s)
PID:16612
    ThreadID:16614 Time:25864(ms) context switch time:180
diff result.txt result1.txt
sudo journalctl --since "5 minutes ago" | grep kernel
```

```
./MT_matrix 2 m1.txt m2.txt
The execution time of 2 threads: 37.549513(s)
PID:17043
    ThreadID:17047 Time:18756(ms) context switch time:71
    ThreadID:17046 Time:18764(ms) context switch time:127
diff result.txt result1.txt
sudo journalctl --since "5 minutes ago" | grep kernel
```

```
./MT_matrix 3 m1.txt m2.txt
The execution time of 3 threads: 36.690304(s)
PID:18342
    ThreadID:18343 Time:11492(ms) context switch time:93
    ThreadID:18345 Time:11580(ms) context switch time:55
    ThreadID:18344 Time:11576(ms) context switch time:141
diff result.txt result1.txt
sudo journalctl --since "5 minutes ago" | grep kernel
```

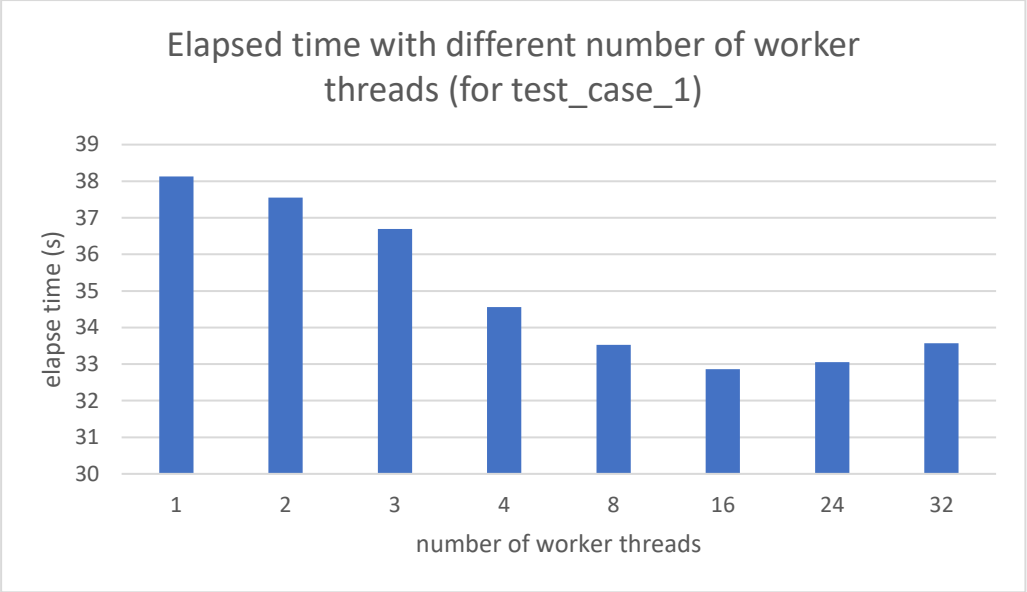
```
./MT_matrix 4 m1.txt m2.txt
The execution time of 4 threads: 34.562768(s)
PID:19618
    ThreadID:19620 Time:8520(ms) context switch time:228
    ThreadID:19619 Time:8596(ms) context switch time:428
    ThreadID:19622 Time:8628(ms) context switch time:73
    ThreadID:19621 Time:8664(ms) context switch time:201
diff result.txt result1.txt
sudo journalctl --since "5 minutes ago" | grep kernel
```

```
./MT_matrix 8 m1.txt m2.txt
The execution time of 8 threads: 33.525668(s)
PID:21283
    ThreadID:21287 Time:4072(ms) context switch time:341
    ThreadID:21288 Time:4156(ms) context switch time:354
    ThreadID:21285 Time:4144(ms) context switch time:453
    ThreadID:21284 Time:4240(ms) context switch time:403
    ThreadID:21291 Time:4152(ms) context switch time:430
    ThreadID:21286 Time:4164(ms) context switch time:373
    ThreadID:21289 Time:4200(ms) context switch time:376
    ThreadID:21290 Time:4220(ms) context switch time:404
diff result.txt result1.txt
sudo journalctl --since "5 minutes ago" | grep kernel
```

```
./MT_matrix 16 m1.txt m2.txt
The execution time of 16 threads: 32.863326(s)
PID:21739
    ThreadID:21740 Time:1980(ms) context switch time:291
    ThreadID:21753 Time:1972(ms) context switch time:284
    ThreadID:21743 Time:2064(ms) context switch time:298
    ThreadID:21746 Time:2044(ms) context switch time:307
    ThreadID:21752 Time:2012(ms) context switch time:295
    ThreadID:21751 Time:2060(ms) context switch time:288
    ThreadID:21749 Time:2024(ms) context switch time:294
    ThreadID:21741 Time:2044(ms) context switch time:299
    ThreadID:21750 Time:2032(ms) context switch time:298
    ThreadID:21744 Time:2076(ms) context switch time:295
    ThreadID:21748 Time:2068(ms) context switch time:337
    ThreadID:21754 Time:2008(ms) context switch time:341
    ThreadID:21755 Time:2116(ms) context switch time:338
    ThreadID:21745 Time:2052(ms) context switch time:328
    ThreadID:21747 Time:2076(ms) context switch time:305
    ThreadID:21742 Time:2068(ms) context switch time:293
diff result.txt result1.txt
```

```
./MT_matrix 24 m1.txt m2.txt
The execution time of 24 threads: 33.050090(s)
PID:23891
    ThreadID:23904 Time:1336(ms) context switch time:235
    ThreadID:23913 Time:1328(ms) context switch time:246
    ThreadID:23910 Time:1400(ms) context switch time:250
    ThreadID:23915 Time:1348(ms) context switch time:231
    ThreadID:23894 Time:1348(ms) context switch time:270
    ThreadID:23902 Time:1324(ms) context switch time:243
    ThreadID:23908 Time:1348(ms) context switch time:262
    ThreadID:23912 Time:1392(ms) context switch time:259
    ThreadID:23893 Time:1340(ms) context switch time:261
    ThreadID:23906 Time:1372(ms) context switch time:258
    ThreadID:23892 Time:1384(ms) context switch time:254
    ThreadID:23903 Time:1364(ms) context switch time:237
    ThreadID:23900 Time:1384(ms) context switch time:237
    ThreadID:23899 Time:1392(ms) context switch time:253
    ThreadID:23897 Time:1360(ms) context switch time:270
    ThreadID:23914 Time:1356(ms) context switch time:239
    ThreadID:23909 Time:1356(ms) context switch time:242
    ThreadID:23907 Time:1384(ms) context switch time:271
    ThreadID:23911 Time:1372(ms) context switch time:257
    ThreadID:23898 Time:1428(ms) context switch time:252
    ThreadID:23901 Time:1352(ms) context switch time:232
    ThreadID:23895 Time:1408(ms) context switch time:257
    ThreadID:23905 Time:1416(ms) context switch time:279
    ThreadID:23896 Time:1380(ms) context switch time:237
diff result.txt result1.txt
sudo journalctl --since "5 minutes ago" | grep kernel
```

```
./MT_matrix 32 m1.txt m2.txt
The execution time of 32 threads: 33.572013(s)
PID:25546
    ThreadID:25549 Time:1092(ms) context switch time:244
    ThreadID:25570 Time:1012(ms) context switch time:243
    ThreadID:25553 Time:1064(ms) context switch time:239
    ThreadID:25552 Time:1036(ms) context switch time:228
    ThreadID:25556 Time:1048(ms) context switch time:224
    ThreadID:25567 Time:1028(ms) context switch time:231
    ThreadID:25566 Time:1000(ms) context switch time:225
    ThreadID:25565 Time:1012(ms) context switch time:221
    ThreadID:25578 Time:1020(ms) context switch time:227
    ThreadID:25557 Time:1028(ms) context switch time:223
    ThreadID:25564 Time:1052(ms) context switch time:230
    ThreadID:25574 Time:1064(ms) context switch time:235
    ThreadID:25550 Time:1080(ms) context switch time:242
    ThreadID:25555 Time:1040(ms) context switch time:226
    ThreadID:25577 Time:1028(ms) context switch time:247
    ThreadID:25561 Time:1044(ms) context switch time:229
    ThreadID:25563 Time:1020(ms) context switch time:223
    ThreadID:25571 Time:1068(ms) context switch time:249
    ThreadID:25560 Time:1028(ms) context switch time:219
    ThreadID:25573 Time:980(ms) context switch time:217
    ThreadID:25548 Time:1080(ms) context switch time:229
    ThreadID:25559 Time:1032(ms) context switch time:233
    ThreadID:25572 Time:1036(ms) context switch time:227
    ThreadID:25547 Time:1020(ms) context switch time:230
    ThreadID:25575 Time:1060(ms) context switch time:231
    ThreadID:25562 Time:1068(ms) context switch time:226
    ThreadID:25576 Time:1048(ms) context switch time:227
    ThreadID:25568 Time:1068(ms) context switch time:227
    ThreadID:25551 Time:1032(ms) context switch time:227
    ThreadID:25554 Time:1044(ms) context switch time:231
    ThreadID:25558 Time:1072(ms) context switch time:223
    ThreadID:25569 Time:1080(ms) context switch time:227
diff result.txt result1.txt
sudo journalctl --since "5 minutes ago" | grep kernel
```



(圖表一)

b.) Test_case_2：

```
./MT_matrix 1 m1.txt m2.txt
The execution time of 1 threads: 312.963263(s)
PID:3850
    ThreadID:3851 Time:202024(ms) context switch time:2182
diff result.txt result2.txt
make unload
```

```
./MT_matrix 2 m1.txt m2.txt
The execution time of 2 threads: 304.027949(s)
PID:4324
    ThreadID:4326 Time:151176(ms) context switch time:1147
    ThreadID:4325 Time:151332(ms) context switch time:296
diff result.txt result2.txt
make unload
```

```
./MT_matrix 3 m1.txt m2.txt
The execution time of 3 threads: 306.032110(s)
PID:4779
    ThreadID:4781 Time:101160(ms) context switch time:1025
    ThreadID:4780 Time:101288(ms) context switch time:753
    ThreadID:4782 Time:102012(ms) context switch time:590
diff result.txt result2.txt
make unload
```

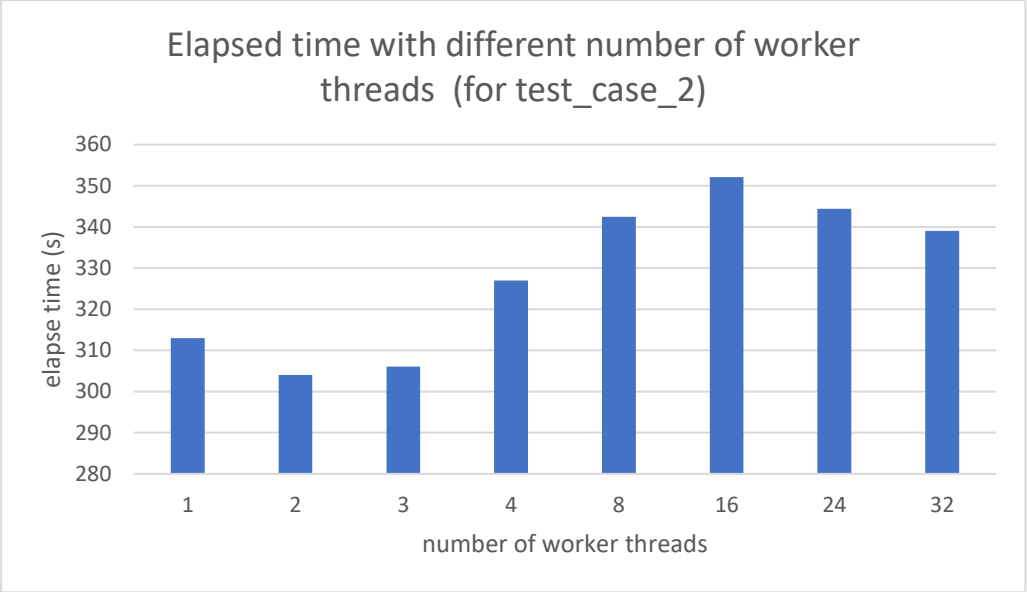
```
./MT_matrix 4 m1.txt m2.txt
The execution time of 4 threads: 327.013625(s)
PID:5631
    ThreadID:5633 Time:80808(ms) context switch time:2426
    ThreadID:5635 Time:80832(ms) context switch time:391
    ThreadID:5634 Time:81468(ms) context switch time:1471
    ThreadID:5632 Time:82128(ms) context switch time:3229
diff result.txt result2.txt
make unload
```

```
./MT_matrix 8 m1.txt m2.txt
The execution time of 8 threads: 342.422343(s)
PID:6083
    ThreadID:6084 Time:42348(ms) context switch time:3759
    ThreadID:6089 Time:42368(ms) context switch time:4602
    ThreadID:6086 Time:42320(ms) context switch time:4585
    ThreadID:6090 Time:42356(ms) context switch time:3773
    ThreadID:6088 Time:42368(ms) context switch time:3664
    ThreadID:6087 Time:42588(ms) context switch time:4018
    ThreadID:6091 Time:42704(ms) context switch time:3667
    ThreadID:6085 Time:42972(ms) context switch time:4023
diff result.txt result2.txt
make unload
```

```
./MT_matrix 16 m1.txt m2.txt
The execution time of 16 threads: 352.077469(s)
PID:6978
    ThreadID:6979 Time:21664(ms) context switch time:3723
    ThreadID:6980 Time:21752(ms) context switch time:3560
    ThreadID:6994 Time:21812(ms) context switch time:3137
    ThreadID:6989 Time:21804(ms) context switch time:3237
    ThreadID:6988 Time:21720(ms) context switch time:3217
    ThreadID:6982 Time:21796(ms) context switch time:3157
    ThreadID:6987 Time:21804(ms) context switch time:3546
    ThreadID:6992 Time:21808(ms) context switch time:3127
    ThreadID:6991 Time:21700(ms) context switch time:3261
    ThreadID:6984 Time:21908(ms) context switch time:3512
    ThreadID:6983 Time:21692(ms) context switch time:3137
    ThreadID:6986 Time:21936(ms) context switch time:3250
    ThreadID:6985 Time:21948(ms) context switch time:3202
    ThreadID:6990 Time:21764(ms) context switch time:3216
    ThreadID:6993 Time:21944(ms) context switch time:3203
    ThreadID:6981 Time:21992(ms) context switch time:3200
diff result.txt result2.txt
make unload
```

```
./MT_matrix 24 m1.txt m2.txt
The execution time of 24 threads: 344.434237(s)
PID:7442
    ThreadID:7455 Time:14072(ms) context switch time:2835
    ThreadID:7456 Time:14148(ms) context switch time:2827
    ThreadID:7463 Time:14024(ms) context switch time:2795
    ThreadID:7469 Time:14160(ms) context switch time:2863
    ThreadID:7450 Time:14220(ms) context switch time:2779
    ThreadID:7449 Time:14204(ms) context switch time:2792
    ThreadID:7454 Time:14144(ms) context switch time:2778
    ThreadID:7462 Time:14104(ms) context switch time:2747
    ThreadID:7452 Time:14440(ms) context switch time:2794
    ThreadID:7472 Time:14276(ms) context switch time:2737
    ThreadID:7471 Time:14236(ms) context switch time:2784
    ThreadID:7460 Time:14132(ms) context switch time:2751
    ThreadID:7467 Time:14364(ms) context switch time:2834
    ThreadID:7465 Time:14156(ms) context switch time:2795
    ThreadID:7458 Time:14188(ms) context switch time:2762
    ThreadID:7466 Time:14268(ms) context switch time:2732
    ThreadID:7461 Time:14248(ms) context switch time:2758
    ThreadID:7464 Time:14180(ms) context switch time:2807
    ThreadID:7459 Time:14172(ms) context switch time:2788
    ThreadID:7468 Time:14236(ms) context switch time:2820
    ThreadID:7453 Time:14320(ms) context switch time:2765
    ThreadID:7451 Time:14280(ms) context switch time:2722
    ThreadID:7470 Time:14264(ms) context switch time:2803
    ThreadID:7457 Time:14244(ms) context switch time:2774
diff result.txt result2.txt
make unload
```

```
./MT_matrix 32 m1.txt m2.txt
The execution time of 32 threads: 339.010256(s)
PID:8064
    ThreadID:8082 Time:10548(ms) context switch time:2350
    ThreadID:8068 Time:10400(ms) context switch time:2379
    ThreadID:8096 Time:10400(ms) context switch time:2394
    ThreadID:8065 Time:10444(ms) context switch time:2381
    ThreadID:8083 Time:10496(ms) context switch time:2410
    ThreadID:8086 Time:10408(ms) context switch time:2452
    ThreadID:8071 Time:10440(ms) context switch time:2396
    ThreadID:8084 Time:10516(ms) context switch time:2449
    ThreadID:8072 Time:10528(ms) context switch time:2554
    ThreadID:8080 Time:10444(ms) context switch time:2469
    ThreadID:8088 Time:10652(ms) context switch time:2442
    ThreadID:8073 Time:10388(ms) context switch time:2457
    ThreadID:8069 Time:10556(ms) context switch time:2401
    ThreadID:8066 Time:10476(ms) context switch time:2480
    ThreadID:8078 Time:10556(ms) context switch time:2490
    ThreadID:8093 Time:10588(ms) context switch time:2348
    ThreadID:8085 Time:10552(ms) context switch time:2474
    ThreadID:8075 Time:10444(ms) context switch time:2388
    ThreadID:8092 Time:10560(ms) context switch time:2468
    ThreadID:8091 Time:10464(ms) context switch time:2393
    ThreadID:8095 Time:10508(ms) context switch time:2356
    ThreadID:8079 Time:10456(ms) context switch time:2372
    ThreadID:8076 Time:10576(ms) context switch time:2373
    ThreadID:8094 Time:10508(ms) context switch time:2365
    ThreadID:8081 Time:10596(ms) context switch time:2344
    ThreadID:8074 Time:10516(ms) context switch time:2405
    ThreadID:8077 Time:10572(ms) context switch time:2344
    ThreadID:8090 Time:10656(ms) context switch time:2416
    ThreadID:8070 Time:10624(ms) context switch time:2423
    ThreadID:8067 Time:10492(ms) context switch time:2430
    ThreadID:8087 Time:10704(ms) context switch time:2450
    ThreadID:8089 Time:10584(ms) context switch time:2436
diff result.txt result2.txt
make unload
```



(圖表二)

c.) Test_case_3：

```
./MT_matrix 1 m1.txt m2.txt
The execution time of 1 threads: 0.076202(s)
PID:8732
    ThreadID:8733 Time:40(ms) context switch time:0
diff result.txt result3.txt
make unload
```

```
./MT_matrix 2 m1.txt m2.txt
The execution time of 2 threads: 0.078838(s)
PID:9165
    ThreadID:9166 Time:40(ms) context switch time:0
    ThreadID:9167 Time:36(ms) context switch time:0
diff result.txt result3.txt
make unload
```

```
./MT_matrix 3 m1.txt m2.txt
The execution time of 3 threads: 0.085041(s)
PID:11241
    ThreadID:11243 Time:28(ms) context switch time:0
    ThreadID:11244 Time:28(ms) context switch time:2
    ThreadID:11242 Time:32(ms) context switch time:0
diff result.txt result3.txt
make unload
```

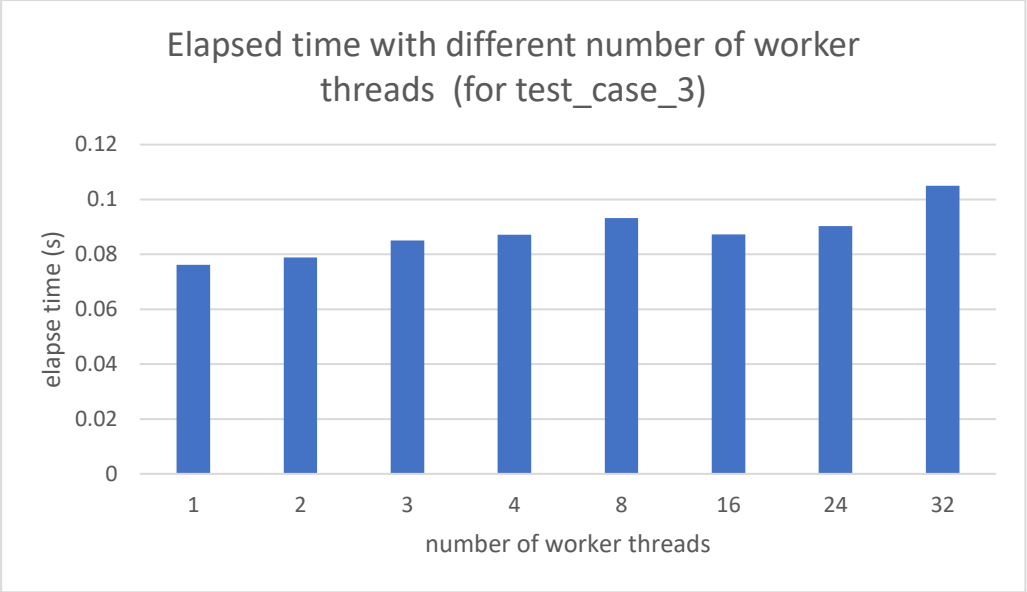
```
./MT_matrix 4 m1.txt m2.txt
The execution time of 4 threads: 0.087111(s)
PID:12482
    ThreadID:12484 Time:20(ms) context switch time:2
    ThreadID:12485 Time:20(ms) context switch time:0
    ThreadID:12486 Time:16(ms) context switch time:1
    ThreadID:12483 Time:24(ms) context switch time:1
diff result.txt result3.txt
make unload
```

```
./MT_matrix 8 m1.txt m2.txt
The execution time of 8 threads: 0.093168(s)
PID:13507
    ThreadID:13510 Time:8(ms) context switch time:0
    ThreadID:13509 Time:12(ms) context switch time:1
    ThreadID:13511 Time:12(ms) context switch time:4
    ThreadID:13508 Time:8(ms) context switch time:2
    ThreadID:13513 Time:12(ms) context switch time:1
    ThreadID:13512 Time:12(ms) context switch time:1
    ThreadID:13514 Time:12(ms) context switch time:5
    ThreadID:13515 Time:12(ms) context switch time:3
diff result.txt result3.txt
make unload
```

```
./MT_matrix 16 m1.txt m2.txt
The execution time of 16 threads: 0.087282(s)
PID:14361
    ThreadID:14362 Time:4(ms) context switch time:1
    ThreadID:14363 Time:0(ms) context switch time:0
    ThreadID:14364 Time:0(ms) context switch time:0
    ThreadID:14377 Time:4(ms) context switch time:1
    ThreadID:14365 Time:4(ms) context switch time:1
    ThreadID:14366 Time:0(ms) context switch time:1
    ThreadID:14376 Time:4(ms) context switch time:2
    ThreadID:14373 Time:8(ms) context switch time:0
    ThreadID:14368 Time:4(ms) context switch time:1
    ThreadID:14375 Time:8(ms) context switch time:4
    ThreadID:14369 Time:4(ms) context switch time:6
    ThreadID:14372 Time:4(ms) context switch time:0
    ThreadID:14367 Time:0(ms) context switch time:3
    ThreadID:14374 Time:8(ms) context switch time:2
    ThreadID:14370 Time:8(ms) context switch time:1
    ThreadID:14371 Time:4(ms) context switch time:1
diff result.txt result3.txt
make unload
```

```
./MT_matrix 24 m1.txt m2.txt
The execution time of 24 threads: 0.090322(s)
PID:16082
    ThreadID:16099 Time:4(ms) context switch time:0
    ThreadID:16085 Time:4(ms) context switch time:1
    ThreadID:16084 Time:4(ms) context switch time:0
    ThreadID:16083 Time:4(ms) context switch time:0
    ThreadID:16088 Time:0(ms) context switch time:1
    ThreadID:16102 Time:4(ms) context switch time:1
    ThreadID:16098 Time:4(ms) context switch time:2
    ThreadID:16103 Time:4(ms) context switch time:1
    ThreadID:16094 Time:0(ms) context switch time:1
    ThreadID:16087 Time:4(ms) context switch time:1
    ThreadID:16089 Time:8(ms) context switch time:4
    ThreadID:16086 Time:0(ms) context switch time:6
    ThreadID:16095 Time:4(ms) context switch time:3
    ThreadID:16100 Time:0(ms) context switch time:2
    ThreadID:16104 Time:4(ms) context switch time:1
    ThreadID:16096 Time:4(ms) context switch time:1
    ThreadID:16093 Time:4(ms) context switch time:6
    ThreadID:16091 Time:4(ms) context switch time:4
    ThreadID:16092 Time:4(ms) context switch time:2
    ThreadID:16105 Time:0(ms) context switch time:1
    ThreadID:16101 Time:4(ms) context switch time:2
    ThreadID:16090 Time:4(ms) context switch time:5
    ThreadID:16097 Time:4(ms) context switch time:3
    ThreadID:16106 Time:8(ms) context switch time:2
diff result.txt result3.txt
make unload
```

```
./MT_matrix 32 m1.txt m2.txt
The execution time of 32 threads: 0.104984(s)
PID:16987
    ThreadID:17013 Time:0(ms) context switch time:0
    ThreadID:16988 Time:0(ms) context switch time:1
    ThreadID:16989 Time:0(ms) context switch time:0
    ThreadID:17014 Time:4(ms) context switch time:1
    ThreadID:17015 Time:0(ms) context switch time:1
    ThreadID:16991 Time:0(ms) context switch time:1
    ThreadID:16994 Time:4(ms) context switch time:3
    ThreadID:16997 Time:0(ms) context switch time:3
    ThreadID:16993 Time:0(ms) context switch time:1
    ThreadID:17008 Time:0(ms) context switch time:0
    ThreadID:16990 Time:0(ms) context switch time:1
    ThreadID:16998 Time:4(ms) context switch time:1
    ThreadID:16999 Time:4(ms) context switch time:1
    ThreadID:17005 Time:4(ms) context switch time:2
    ThreadID:17000 Time:4(ms) context switch time:4
    ThreadID:17006 Time:0(ms) context switch time:1
    ThreadID:17018 Time:0(ms) context switch time:2
    ThreadID:17001 Time:4(ms) context switch time:1
    ThreadID:17002 Time:4(ms) context switch time:2
    ThreadID:16996 Time:4(ms) context switch time:3
    ThreadID:17016 Time:4(ms) context switch time:4
    ThreadID:17017 Time:0(ms) context switch time:4
    ThreadID:17011 Time:0(ms) context switch time:2
    ThreadID:17004 Time:0(ms) context switch time:4
    ThreadID:17009 Time:0(ms) context switch time:2
    ThreadID:17003 Time:4(ms) context switch time:2
    ThreadID:17012 Time:4(ms) context switch time:6
    ThreadID:17010 Time:8(ms) context switch time:3
    ThreadID:17007 Time:8(ms) context switch time:4
    ThreadID:17019 Time:4(ms) context switch time:1
    ThreadID:16995 Time:0(ms) context switch time:4
    ThreadID:16992 Time:0(ms) context switch time:4
diff result.txt result3.txt
make unload
```



(圖表三)

d.) Test_case_4：

```
./MT_matrix 1 m1.txt m2.txt
The execution time of 1 threads: 0.053121(s)
PID:17471
    ThreadID:17472 Time:56(ms) context switch time:0
diff result.txt result4.txt
make unload
```

```
./MT_matrix 2 m1.txt m2.txt
The execution time of 2 threads: 0.053140(s)
PID:18314
    ThreadID:18316 Time:4(ms) context switch time:0
    ThreadID:18315 Time:8(ms) context switch time:1
diff result.txt result4.txt
make unload
```

```
./MT_matrix 3 m1.txt m2.txt
The execution time of 3 threads: 0.053250(s)
PID:19554
    ThreadID:19556 Time:12(ms) context switch time:0
    ThreadID:19555 Time:16(ms) context switch time:1
    ThreadID:19557 Time:16(ms) context switch time:0
diff result.txt result4.txt
make unload
```

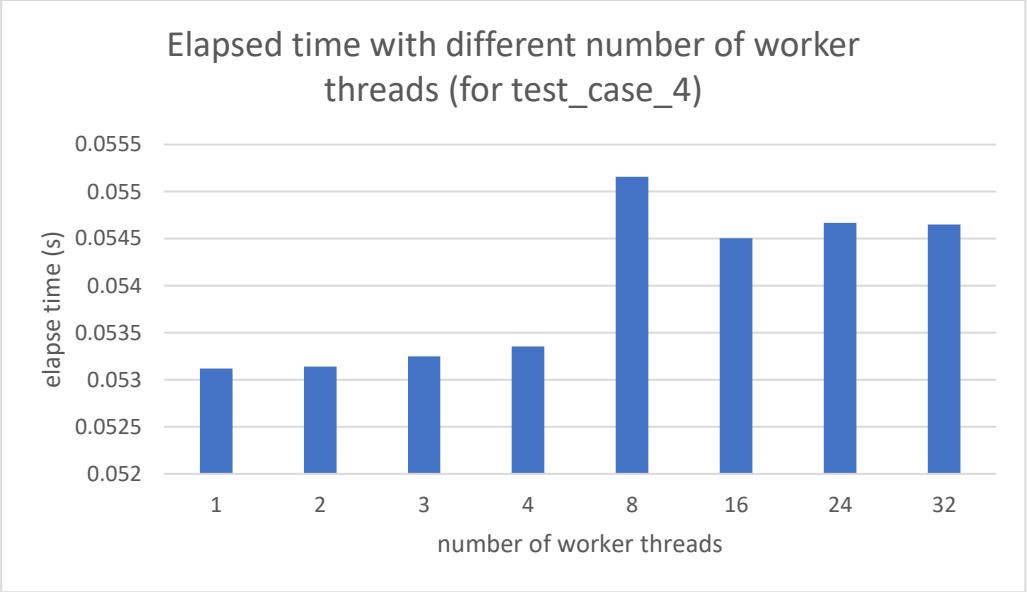
```
./MT_matrix 4 m1.txt m2.txt
The execution time of 4 threads: 0.053353(s)
PID:21204
    ThreadID:21206 Time:12(ms) context switch time:0
    ThreadID:21209 Time:12(ms) context switch time:1
    ThreadID:21207 Time:12(ms) context switch time:1
    ThreadID:21208 Time:12(ms) context switch time:3
diff result.txt result4.txt
make unload
```

```
./MT_matrix 8 m1.txt m2.txt
The execution time of 8 threads: 0.055159(s)
PID:22036
    ThreadID:22038 Time:8(ms) context switch time:0
    ThreadID:22041 Time:8(ms) context switch time:1
    ThreadID:22039 Time:4(ms) context switch time:2
    ThreadID:22044 Time:8(ms) context switch time:1
    ThreadID:22037 Time:8(ms) context switch time:2
    ThreadID:22040 Time:8(ms) context switch time:1
    ThreadID:22043 Time:8(ms) context switch time:3
    ThreadID:22042 Time:4(ms) context switch time:3
diff result.txt result4.txt
make unload
```

```
./MT_matrix 16 m1.txt m2.txt
The execution time of 16 threads: 0.054505(s)
PID:22887
    ThreadID:22890 Time:0(ms) context switch time:1
    ThreadID:22888 Time:4(ms) context switch time:1
    ThreadID:22889 Time:4(ms) context switch time:1
    ThreadID:22903 Time:4(ms) context switch time:2
    ThreadID:22901 Time:4(ms) context switch time:1
    ThreadID:22891 Time:4(ms) context switch time:1
    ThreadID:22894 Time:4(ms) context switch time:1
    ThreadID:22899 Time:0(ms) context switch time:2
    ThreadID:22898 Time:0(ms) context switch time:1
    ThreadID:22896 Time:0(ms) context switch time:1
    ThreadID:22897 Time:0(ms) context switch time:3
    ThreadID:22902 Time:0(ms) context switch time:1
    ThreadID:22892 Time:4(ms) context switch time:4
    ThreadID:22895 Time:4(ms) context switch time:2
    ThreadID:22893 Time:4(ms) context switch time:3
    ThreadID:22900 Time:4(ms) context switch time:2
diff result.txt result4.txt
make unload
```

```
./MT_matrix 24 m1.txt m2.txt
The execution time of 24 threads: 0.054668(s)
PID:23775
    ThreadID:23776 Time:0(ms) context switch time:0
    ThreadID:23777 Time:0(ms) context switch time:1
    ThreadID:23792 Time:0(ms) context switch time:0
    ThreadID:23782 Time:4(ms) context switch time:1
    ThreadID:23789 Time:0(ms) context switch time:1
    ThreadID:23781 Time:0(ms) context switch time:1
    ThreadID:23778 Time:0(ms) context switch time:2
    ThreadID:23784 Time:0(ms) context switch time:2
    ThreadID:23797 Time:0(ms) context switch time:2
    ThreadID:23780 Time:0(ms) context switch time:1
    ThreadID:23783 Time:0(ms) context switch time:1
    ThreadID:23787 Time:0(ms) context switch time:1
    ThreadID:23786 Time:0(ms) context switch time:2
    ThreadID:23791 Time:4(ms) context switch time:1
    ThreadID:23793 Time:4(ms) context switch time:3
    ThreadID:23794 Time:4(ms) context switch time:2
    ThreadID:23779 Time:0(ms) context switch time:2
    ThreadID:23796 Time:4(ms) context switch time:3
    ThreadID:23798 Time:0(ms) context switch time:2
    ThreadID:23790 Time:0(ms) context switch time:2
    ThreadID:23795 Time:0(ms) context switch time:2
    ThreadID:23799 Time:0(ms) context switch time:2
    ThreadID:23785 Time:0(ms) context switch time:4
    ThreadID:23788 Time:4(ms) context switch time:2
diff result.txt result4.txt
make unload
```

```
./MT_matrix 32 m1.txt m2.txt
The execution time of 32 threads: 0.054651(s)
PID:24214
    ThreadID:24216 Time:0(ms) context switch time:0
    ThreadID:24217 Time:0(ms) context switch time:1
    ThreadID:24241 Time:0(ms) context switch time:0
    ThreadID:24215 Time:0(ms) context switch time:2
    ThreadID:24232 Time:0(ms) context switch time:0
    ThreadID:24240 Time:4(ms) context switch time:1
    ThreadID:24243 Time:0(ms) context switch time:0
    ThreadID:24231 Time:0(ms) context switch time:2
    ThreadID:24229 Time:4(ms) context switch time:2
    ThreadID:24221 Time:0(ms) context switch time:1
    ThreadID:24233 Time:0(ms) context switch time:3
    ThreadID:24244 Time:4(ms) context switch time:2
    ThreadID:24230 Time:4(ms) context switch time:4
    ThreadID:24245 Time:4(ms) context switch time:2
    ThreadID:24246 Time:0(ms) context switch time:1
    ThreadID:24237 Time:0(ms) context switch time:2
    ThreadID:24235 Time:0(ms) context switch time:1
    ThreadID:24239 Time:4(ms) context switch time:2
    ThreadID:24228 Time:4(ms) context switch time:1
    ThreadID:24227 Time:0(ms) context switch time:1
    ThreadID:24226 Time:0(ms) context switch time:1
    ThreadID:24222 Time:0(ms) context switch time:1
    ThreadID:24225 Time:0(ms) context switch time:1
    ThreadID:24242 Time:4(ms) context switch time:3
    ThreadID:24218 Time:0(ms) context switch time:4
    ThreadID:24238 Time:0(ms) context switch time:4
    ThreadID:24236 Time:4(ms) context switch time:2
    ThreadID:24224 Time:0(ms) context switch time:4
    ThreadID:24220 Time:0(ms) context switch time:3
    ThreadID:24234 Time:0(ms) context switch time:2
    ThreadID:24219 Time:0(ms) context switch time:4
    ThreadID:24223 Time:4(ms) context switch time:4
diff result.txt result4.txt
make unload
```



（圖表四）

3.) 總結：

根據圖表一到圖表四中，可以發現到，除了圖表三沒那麼明顯以外以外，當 thread 的數目小於 core 的數目（也就是 4 cores）時，通常來說消耗的時間會逐漸變小。不過，圖表三和圖表四中，有上漲一些些而已。前者的現象主要是因為 thread 數變多，且 core 數可以容納下那些 thread 數目，使得這個 multi-thread 專案可以做到類似平行化的 one-to -one 處理，使得運行時間下降；後者的因素應該是來源於 create、join、或 mutex 的關係導致有一些時間偏差。

相反的，當 thread 的數目大於 core 的數目時，消耗的時間會明顯地變大。且在圖表二到圖表四可以觀察到，此情況的時間消耗幾乎是比 thread 的數目小於 core 的數目的情況來的大。會有這種現象我認為是因為 core 的數目明顯的填不下程式創造的 thread 數目，造成說沒有辦法做到 one-to -one 的處理，而變成 many-to -many 的處理方式，使得一些 thread 會和其他的 thread 去疊加運行時間（例如說有些 core 在運行時會變成 concurrency 的方式），造成最終的運行時間不減反增。