

Q : You have to explain how you dispatch works to the worker threads.

A : 分三部分解釋

(一) : 分配方法 : by element dispatch

我將最後 result 的矩陣的元素個數平均分給每個 thread ,第一個 thread 會多分到餘數的元素個數。其他就是所有的元素的個數直接除以 thread 的數量。

至於為什麼要用元素個數去分是因為測資 3 與測資 4 的 result 的 row 或 column 有可能為 1。所以我才不選擇將 row 的數量或 column 的數量去分，因為可能還要試試調整。

分給每個 thread 的元素數量，由 displacement 與 counts 去計算每個 thread 要負責算那區塊的元素，而那些區塊的元素起始位址在哪？我矩陣 1、2 與 3 都是用一維陣列做儲存(其實無論 1 維還是 2 維方法都一樣)。

(圖 : displacement 與 counts 的意義)

thread 編號	counts	displacement
thread 1	5	0
thread 2	4	5
thread 3	4	9
thread 4	4	13
thread 5	4	17
thread 6	4	21

0	1	2	3	4
5	6	7	8	9
10	11	12	13	14
15	16	17	18	19
20	21	22	23	24

(二) : 矩陣是哪列哪行做內積

0	1	2	3	4
5	6	7	8	9
10	11	12	13	14
15	16	17	18	19
20	21	22	23	24

×

0	1	2	3	4
5	6	7	8	9
10	11	12	13	14
15	16	17	18	19
20	21	22	23	24

=

0	1	2	3	4
6	7	8	9	10
10	11	12	13	14
15	16	17	18	19
20	21	22	23	24

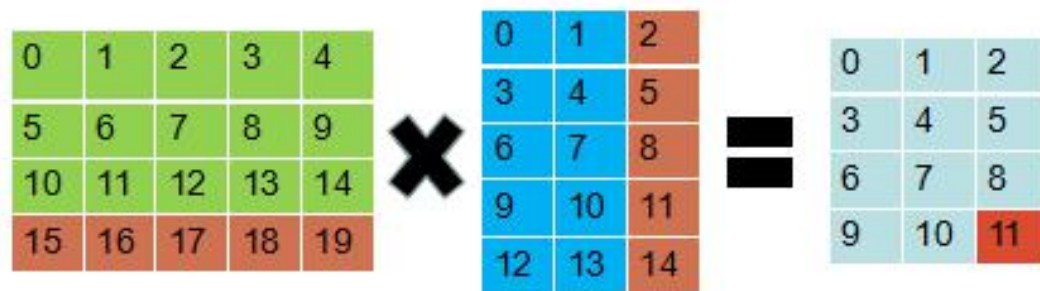
紅色 17 是由這第一個矩陣的第 3(從 0 開始)列 內積 第 2(從 0 開始)行得到的。要如何知道其實由 17 在 result 矩陣的位置(列與行)得到，17 在 result 矩陣的一維陣列的 index 維 17。

$17 / \text{col2}(5) (\text{result 矩陣的列數量}) = 3 (= \text{第 3 列})$ 。

$17 \% \text{col2}(5) (\text{result 矩陣的行數量}) = 2 (= \text{第 2 行})$ 。

因此知道 17 在 result 的第三列第二行。那依照矩陣乘法就是由矩陣 1 的第 3 列內積矩陣 2 的第 2 行 得到。

(三)：內積算法。



內積總共要加總多少個元素相成的數量？ A：矩陣 1 的 col 的數量 或 矩陣 2 的 row 的數量。

至於要內積哪行哪列

```
/*****/
```

11/ (3 = result 矩陣的行數) = 3 (第 3 列)

11% (3 = result 矩陣的行數) = 2 (第 2 行)

所以就是矩陣 1 的第 3 行與矩陣 2 的第 2 行內積。

For(x in 矩陣 1 的 col 的數量){

矩陣 result 的第 11 個元素(index from 0)

元素( 矩陣 1 的 第 3 列 \* 矩陣 1 的 col 的數量 + x ) \*

元素( 矩陣 2 的 第 x 列 \* 矩陣 2 的 col 的數量 + 2)

}

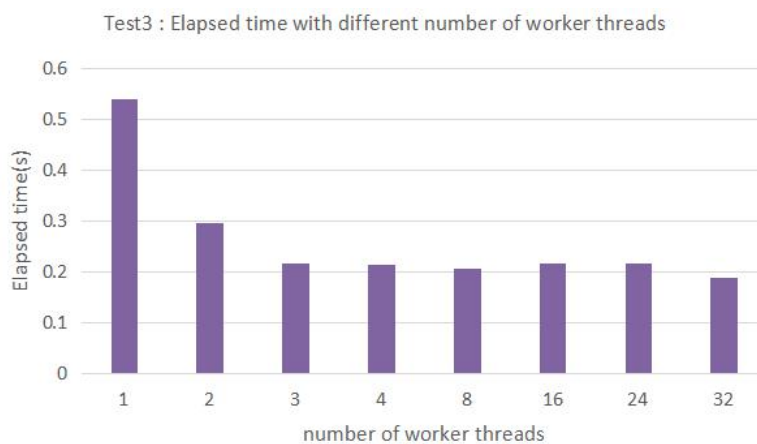
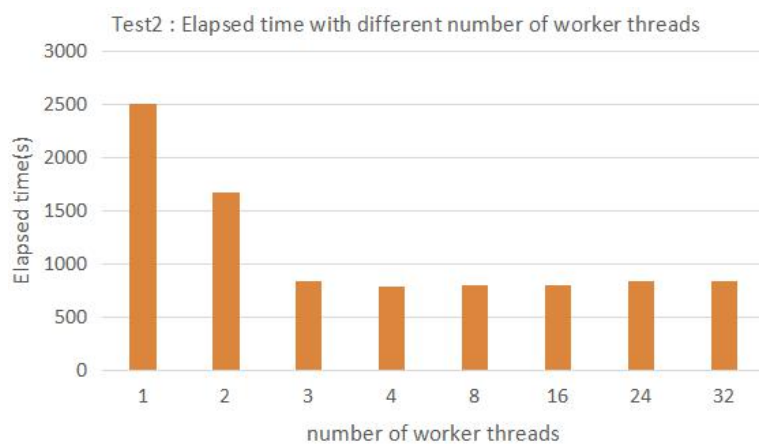
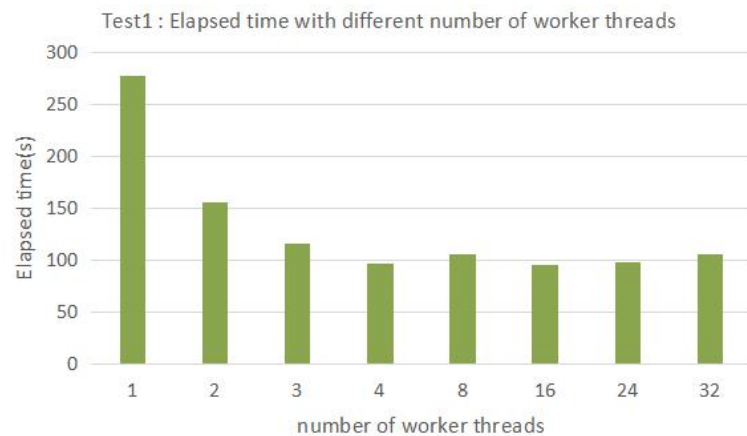
```
/*****/
```

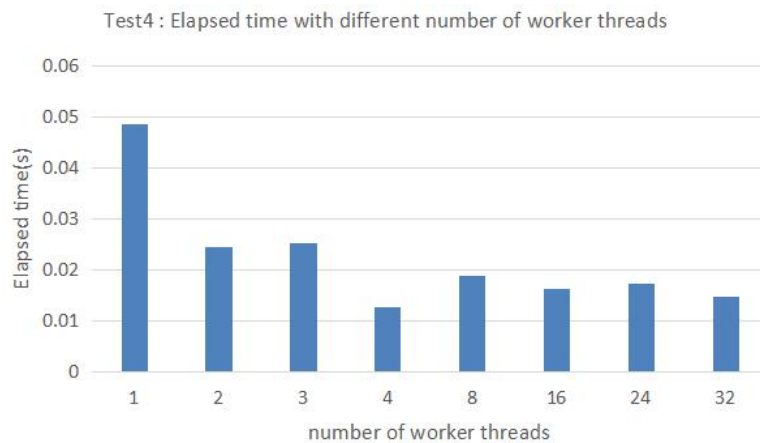
Code

```
result[i] = 0;
int row = i/col2;
int col = i%col2;
for(int k = 0;k < col1;k++){
    result[i] += matrix1[row* col1 + k] * matrix2[k*col2 + col];
}
```

Q : You are given four test cases. For each test case, you have to plot the matrix multiplication execution time with the following worker thread numbers. Worker thread number: 1,2,3,4,8,16,24,32.

You have to summarize the four charts you plot. ( 詳見附錄 )





1. What happen if the number of threads is less than the number of cores.

Why ?

A :

core 的數量小於 thread 的數量時，隨著 thread 增加，elapsed time 減少的幅度的變化量比較大。在 test1 這個減少的幅度還是線性減少的。

因為矩陣計算屬於 CPU bound 的 task 透過 multi thread 主要是提升 CPU 的使用率。對於虛擬機的 4core 來說，其實用 4 個 thread 就可達到很好的效果讓一個 thread 使用 1 個 core。所以我們也看到 4 個 test 執行時間最短的都大概為 4 個 thread。

2. What happen if the number of threads is greater than the number of cores. Why ?

A:

core 的數量大於 thread 的數量時，隨著 thread 的數量增加，elapsed time 並沒有像 thread 的數量小於 number of cores 時有大幅度下降，反而趨近於平緩，甚至有些還一點點增加了。

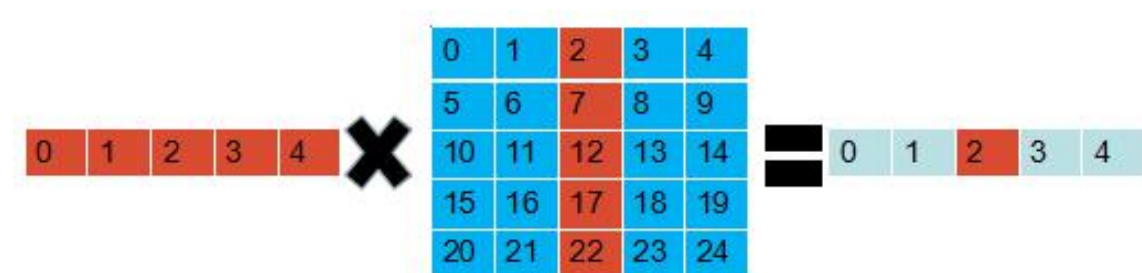
因為當 thread 的數量超過 core 時，每個 thread 在執行部分時間就要將 cpu 的 control 交給其他 thread。而這個交換稱為 context switch。Context switch is not free。必須要花時間儲存 CPU 的狀態，包括暫存器的值得保存與更新新的暫存器的值，Program counter 的切換...等。這些都需要花時間。這樣的 overhead 可能將多平行處理帶來的效益降低，甚至超過，所以才有上述的現象發生。

### 3. Anything else you observe ?

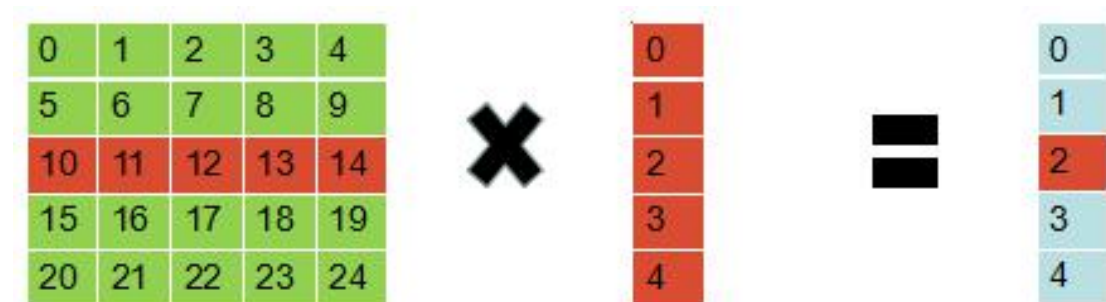
觀察四筆測資元素相對於 cache access 的排列方式

比較 4 筆測資所花的時間，測資 1 因為處理數量( $2048 * 2048$ )遠小於 測資 2 的處理數量( $4096 * 4096$ )。所以用時比較少。而測資 3( $1 * 4096$ ) \* ( $4096 * 4096$ ) 與測資 4( $4096 * 4096$ ) \* ( $4096 * 1$ )。

測資 3 示意：



測資 4 示意：



測資 3 可以看到當計算一個元素時，要存取第二個矩陣的 column 需要跳到下一行。

而相比測資 4 計算一個元素時，因為第二個元素為  $row * 1$ ，所以相當於存取的資料都在 cache 中(只有第一筆資料會 cache miss 其他都會 cache hit)，充分利用 space locality。

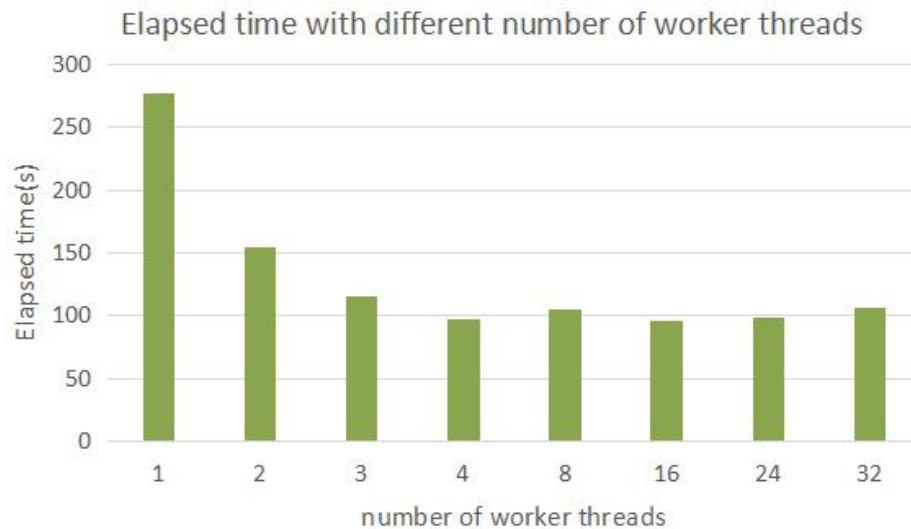
而測資 3(則是當矩陣 2 的行數夠多，每一次存取都會是 cache miss)。

而我們比較兩個測資的時間，也是跟想的一樣。測資 4 花的時間都較測資 3 少。

## 附錄

### Test1

test1									
Elapsed time with	1	2	3	4	8	16	24	32	
different number of	277	155	116	97	105	96	98	106	sec
worker threads									



1 : It took 277.565456 seconds to execute

```
→ HW2test ./MT_matrix 1 m1.txt m2.txt
PID:3423
it took 277.565456 seconds to execute
ProcessID:3423
ThreadID:3424 Time:276236(ms) context switch times:3278
```

2 : It took 155.665888 seconds to execute

```
PID:3962
ThreadID:3963 Time:154772(ms) context switch times:1797
ThreadID:3964 Time:154800(ms) context switch times:1537
it took 155.665888 seconds to execute
```

3. It took 116.951245 seconds to execute

```
→ HW2test ./MT_matrix 3 m1.txt m2.txt
PID:4437
ThreadID:4439 Time:113840(ms) context switch times:6397
ThreadID:4438 Time:113256(ms) context switch times:10545
ThreadID:4440 Time:114204(ms) context switch times:6820
it took 116.951245 seconds to execute
```

4. It took 97.925223 seconds to execute

```
→ HW2test ./MT_matrix 4 m1.txt m2.txt
PID:5423
ThreadID:5425 Time:92268(ms) context switch times:5341
ThreadID:5427 Time:95360(ms) context switch times:2367
ThreadID:5426 Time:95720(ms) context switch times:3819
ThreadID:5424 Time:97028(ms) context switch times:5238P
it took 97.925223 seconds to execute
```



8. It took 105.037331 seconds to execute

```
→ HW2test ./MT_matrix 8 m1.txt m2.txt
PID:5921
  ThreadID:5929 Time:51712(ms) context switch times:4619
  ThreadID:5924 Time:51424(ms) context switch times:4599
  ThreadID:5922 Time:52176(ms) context switch times:4912
  ThreadID:5927 Time:51912(ms) context switch times:4754
  ThreadID:5923 Time:52528(ms) context switch times:5044
  ThreadID:5925 Time:52528(ms) context switch times:6311
  ThreadID:5928 Time:52552(ms) context switch times:6253
  ThreadID:5926 Time:52352(ms) context switch times:5036
it took 105.037331 seconds to execute
```

16. It took 96.929282 seconds to execute

```
→ HW2test ./MT_matrix 16 m1.txt m2.txt
PID:6426
  ThreadID:6431 Time:23192(ms) context switch times:3540
  ThreadID:6428 Time:23920(ms) context switch times:3495
  ThreadID:6442 Time:23572(ms) context switch times:3583
  ThreadID:6440 Time:23500(ms) context switch times:3532
  ThreadID:6434 Time:23560(ms) context switch times:3814
  ThreadID:6427 Time:24016(ms) context switch times:4164
  ThreadID:6441 Time:23660(ms) context switch times:3872
  ThreadID:6433 Time:23536(ms) context switch times:3711
  ThreadID:6432 Time:23696(ms) context switch times:3978
  ThreadID:6430 Time:23888(ms) context switch times:4487
  ThreadID:6429 Time:23852(ms) context switch times:4365
  ThreadID:6439 Time:23712(ms) context switch times:3508
  ThreadID:6435 Time:23548(ms) context switch times:3966
  ThreadID:6436 Time:23904(ms) context switch times:3900
  ThreadID:6437 Time:23812(ms) context switch times:3959
  ThreadID:6438 Time:23828(ms) context switch times:3879
it took 96.929282 seconds to execute
```

24: It took 98.581571 seconds to execute

```
→ HW2test ./MT_matrix 24 m1.txt m2.txt
PID:7615
  ThreadID:7623 Time:16076(ms) context switch times:4201
  ThreadID:7637 Time:16160(ms) context switch times:4230
  ThreadID:7636 Time:16240(ms) context switch times:4172
  ThreadID:7619 Time:16124(ms) context switch times:4098
  ThreadID:7633 Time:16284(ms) context switch times:4133
  ThreadID:7618 Time:16200(ms) context switch times:4173
  ThreadID:7630 Time:16016(ms) context switch times:4082
  ThreadID:7632 Time:16280(ms) context switch times:4181
  ThreadID:7634 Time:16240(ms) context switch times:4093
  ThreadID:7626 Time:16248(ms) context switch times:4154
  ThreadID:7628 Time:16232(ms) context switch times:4165
  ThreadID:7621 Time:16240(ms) context switch times:4153
  ThreadID:7638 Time:16280(ms) context switch times:4171
  ThreadID:7627 Time:16420(ms) context switch times:4232
  ThreadID:7624 Time:16188(ms) context switch times:4240
  ThreadID:7617 Time:16396(ms) context switch times:4269
  ThreadID:7625 Time:16364(ms) context switch times:4160
  ThreadID:7635 Time:16280(ms) context switch times:4143
  ThreadID:7620 Time:16240(ms) context switch times:4155
  ThreadID:7622 Time:16416(ms) context switch times:4247
  ThreadID:7616 Time:16408(ms) context switch times:4191
  ThreadID:7631 Time:16608(ms) context switch times:4243
  ThreadID:7639 Time:16528(ms) context switch times:4345
  ThreadID:7629 Time:16528(ms) context switch times:4133
it took 98.581571 seconds to execute
```

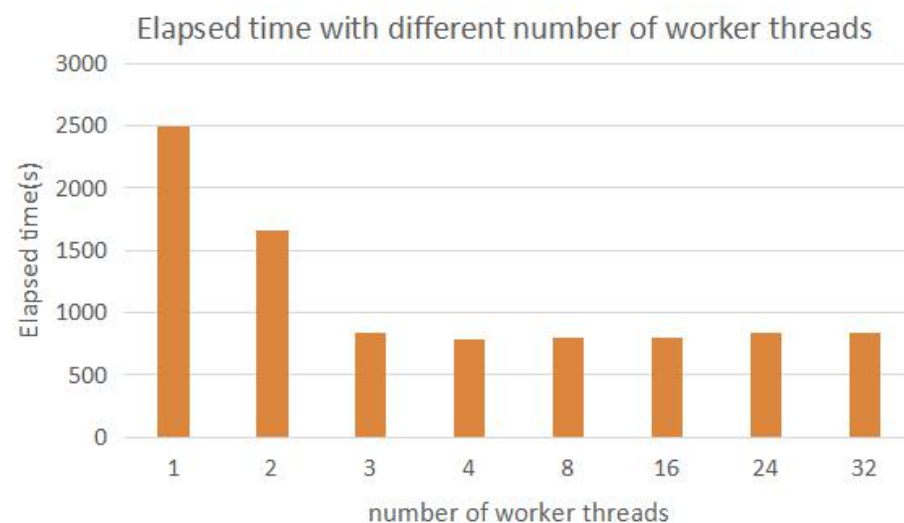


32: It took 106.253660 seconds to execute

```
→ HW2test ./MT_matrix 32 m1.txt m2.txt
PID:6981
  ThreadID:6983 Time:12344(ms) context switch times:4008
  ThreadID:7005 Time:12480(ms) context switch times:3867
  ThreadID:6985 Time:12572(ms) context switch times:4087
  ThreadID:7007 Time:12348(ms) context switch times:4006
  ThreadID:7006 Time:12476(ms) context switch times:3667
  ThreadID:7004 Time:12280(ms) context switch times:3834
  ThreadID:6991 Time:12424(ms) context switch times:3726
  ThreadID:7003 Time:12432(ms) context switch times:3819
  ThreadID:7011 Time:12364(ms) context switch times:3802
  ThreadID:6987 Time:12540(ms) context switch times:3853
  ThreadID:6993 Time:12576(ms) context switch times:3769
  ThreadID:6989 Time:12584(ms) context switch times:3733
  ThreadID:6998 Time:12480(ms) context switch times:3789
  ThreadID:7002 Time:12280(ms) context switch times:3919
  ThreadID:7001 Time:12444(ms) context switch times:3805
  ThreadID:7013 Time:12692(ms) context switch times:3854
  ThreadID:6997 Time:12492(ms) context switch times:3909
  ThreadID:6994 Time:12436(ms) context switch times:3835
  ThreadID:6992 Time:12756(ms) context switch times:4224
  ThreadID:6996 Time:12480(ms) context switch times:3866
  ThreadID:6984 Time:12500(ms) context switch times:3653
  ThreadID:7010 Time:12808(ms) context switch times:3869
  ThreadID:6995 Time:12444(ms) context switch times:3796
  ThreadID:6986 Time:12424(ms) context switch times:3763
  ThreadID:6988 Time:12588(ms) context switch times:3943
  ThreadID:6982 Time:12520(ms) context switch times:3589
  ThreadID:7009 Time:12556(ms) context switch times:3822
  ThreadID:7000 Time:12624(ms) context switch times:3751
  ThreadID:6990 Time:12692(ms) context switch times:3745
  ThreadID:6999 Time:12912(ms) context switch times:3900
  ThreadID:7012 Time:12640(ms) context switch times:3767
  ThreadID:7008 Time:12544(ms) context switch times:3766
it took 106.253660 seconds to execute
```

## Test2

test2									
Elapsed time with	1	2	3	4	8	16	24	32	
different number of	2497	1665	838	781	795	803	835	836	sec
worker threads									





1: It took 2497.434908 seconds to execute

```
→ HW2test ./MT_matrix 1 m1.txt m2.txt
PID:8268
    ThreadID:8270 Time:2480860(ms) context switch times:21808
it took 2497.434908 seconds to execute
```

2. It took 1665.297444 seconds to execute

```
→ HW2test ./MT_matrix 2 m1.txt m2.txt
PID:8870
    ThreadID:8872 Time:1648976(ms) context switch times:12401
    ThreadID:8871 Time:1652468(ms) context switch times:12201
it took 1665.297444 seconds to execute
```

3. It took 838.001101 seconds to execute

```
→ HW2test ./MT_matrix 3 m1.txt m2.txt
PID:3237
    ThreadID:3239 Time:828604(ms) context switch times:14022
    ThreadID:3240 Time:831240(ms) context switch times:14975
    ThreadID:3238 Time:834672(ms) context switch times:11114
it took 838.001101 seconds to execute
```

4. It took 781.397747 seconds to execute

```
→ HW2test ./MT_matrix 4 m1.txt m2.txt
PID:3831
    ThreadID:3834 Time:755528(ms) context switch times:45796
    ThreadID:3832 Time:764744(ms) context switch times:38149
    ThreadID:3835 Time:764932(ms) context switch times:50310
    ThreadID:3833 Time:768628(ms) context switch times:46644
it took 781.397747 seconds to execute
```

8.It took 795.387305 seconds to execute

```
→ HW2test ./MT_matrix 8 m1.txt m2.txt
PID:4413
    ThreadID:4414 Time:389020(ms) context switch times:46215
    ThreadID:4418 Time:390748(ms) context switch times:49692
    ThreadID:4421 Time:392328(ms) context switch times:41352
    ThreadID:4417 Time:389892(ms) context switch times:45986
    ThreadID:4416 Time:392768(ms) context switch times:44317
    ThreadID:4415 Time:392892(ms) context switch times:43732
    ThreadID:4419 Time:393820(ms) context switch times:43332
    ThreadID:4420 Time:394152(ms) context switch times:47355
it took 795.387305 seconds to execute
```

16. It took 803.101699 seconds to execute

```
→ HW2test ./MT_matrix 16 m1.txt m2.txt
PID:5123
    ThreadID:5134 Time:197288(ms) context switch times:30128
    ThreadID:5131 Time:197280(ms) context switch times:31703
    ThreadID:5136 Time:197320(ms) context switch times:31709
    ThreadID:5138 Time:198236(ms) context switch times:32198
    ThreadID:5137 Time:197700(ms) context switch times:32177
    ThreadID:5128 Time:198152(ms) context switch times:32595
    ThreadID:5133 Time:198168(ms) context switch times:30666
    ThreadID:5126 Time:198668(ms) context switch times:32596
    ThreadID:5135 Time:197500(ms) context switch times:30724
    ThreadID:5129 Time:198728(ms) context switch times:33178
    ThreadID:5139 Time:199492(ms) context switch times:32264
    ThreadID:5127 Time:197840(ms) context switch times:31234
    ThreadID:5125 Time:198132(ms) context switch times:32466
    ThreadID:5124 Time:199100(ms) context switch times:31566
    ThreadID:5132 Time:198928(ms) context switch times:32081
    ThreadID:5130 Time:199320(ms) context switch times:32263
it took 803.101699 seconds to execute
```



24. It took 835.876896 seconds to execute

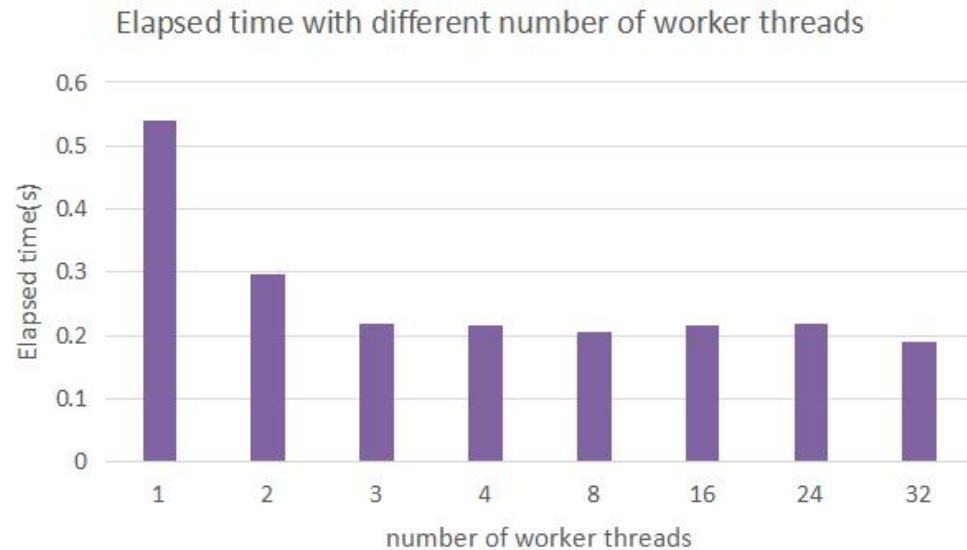
```
→ HW2test ./MT_matrix 24 m1.txt m2.txt
PID:3542
ThreadID:3559 Time:136588(ms) context switch times:35795
ThreadID:3552 Time:136992(ms) context switch times:35922
ThreadID:3549 Time:137628(ms) context switch times:35487
ThreadID:3555 Time:137932(ms) context switch times:35547
ThreadID:3546 Time:138132(ms) context switch times:35072
ThreadID:3558 Time:138192(ms) context switch times:35226
ThreadID:3562 Time:137820(ms) context switch times:35288
ThreadID:3554 Time:137348(ms) context switch times:35696
ThreadID:3564 Time:137964(ms) context switch times:35618
ThreadID:3550 Time:137816(ms) context switch times:35923
ThreadID:3556 Time:137976(ms) context switch times:35709
ThreadID:3565 Time:138476(ms) context switch times:36020
ThreadID:3566 Time:138708(ms) context switch times:35449
ThreadID:3561 Time:138440(ms) context switch times:35894
ThreadID:3557 Time:138252(ms) context switch times:35076
ThreadID:3553 Time:138888(ms) context switch times:35726
ThreadID:3544 Time:139040(ms) context switch times:35940
ThreadID:3547 Time:139308(ms) context switch times:35453
ThreadID:3560 Time:138804(ms) context switch times:35688
ThreadID:3548 Time:139148(ms) context switch times:35470
ThreadID:3551 Time:138984(ms) context switch times:35656
ThreadID:3545 Time:139384(ms) context switch times:35665
ThreadID:3543 Time:139276(ms) context switch times:35449
ThreadID:3563 Time:139364(ms) context switch times:35423
it took 835.876896 seconds to execute
```

32. It took 836.253688 seconds to execute

```
→ HW2test ./MT_matrix 32 m1.txt m2.txt
PID:5849
ThreadID:5854 Time:100776(ms) context switch times:30049
ThreadID:5852 Time:100576(ms) context switch times:29666
ThreadID:5871 Time:101084(ms) context switch times:30094
ThreadID:5876 Time:101408(ms) context switch times:30982
ThreadID:5858 Time:100660(ms) context switch times:29614
ThreadID:5851 Time:100608(ms) context switch times:29627
ThreadID:5873 Time:101144(ms) context switch times:29965
ThreadID:5860 Time:101384(ms) context switch times:29415
ThreadID:5855 Time:101132(ms) context switch times:29580
ThreadID:5864 Time:101496(ms) context switch times:30116
ThreadID:5853 Time:101284(ms) context switch times:29446
ThreadID:5877 Time:101500(ms) context switch times:30309
ThreadID:5868 Time:101636(ms) context switch times:30052
ThreadID:5875 Time:100788(ms) context switch times:29246
ThreadID:5869 Time:101056(ms) context switch times:29893
ThreadID:5880 Time:101540(ms) context switch times:30101
ThreadID:5865 Time:101592(ms) context switch times:30384
ThreadID:5862 Time:101268(ms) context switch times:29776
ThreadID:5866 Time:100916(ms) context switch times:30062
ThreadID:5872 Time:100588(ms) context switch times:29857
ThreadID:5861 Time:101196(ms) context switch times:30562
ThreadID:5850 Time:101516(ms) context switch times:29675
ThreadID:5874 Time:101620(ms) context switch times:29586
ThreadID:5857 Time:101492(ms) context switch times:29338
ThreadID:5856 Time:101632(ms) context switch times:29492
ThreadID:5879 Time:101320(ms) context switch times:29556
ThreadID:5867 Time:102372(ms) context switch times:29530
ThreadID:5881 Time:101028(ms) context switch times:29115
ThreadID:5863 Time:101320(ms) context switch times:30236
ThreadID:5870 Time:101516(ms) context switch times:29382
ThreadID:5878 Time:101344(ms) context switch times:29456
ThreadID:5859 Time:101536(ms) context switch times:29556
it took 836.253688 seconds to execute
```

### Test3

test3									
Elapsed time with different number of worker threads	1	2	3	4	8	16	24	32	
	0.539923	0.297433	0.21815	0.215251	0.205601	0.215919	0.218053	0.189489	sec



1. It took 0.539923 seconds to execute

```
→ HW2test ./MT_matrix 1 m1.txt m2.txt
PID:4657
ThreadID:4658 Time:536(ms) context switch times:20
it took 0.539923 seconds to execute
```

2. It took 0.297433 seconds to execute

```
→ HW2test ./MT_matrix 2 m1.txt m2.txt
PID:5082
ThreadID:5083 Time:288(ms) context switch times:14
ThreadID:5084 Time:292(ms) context switch times:24
it took 0.297433 seconds to execute
```

3. It took 0.218150 seconds to execute

```
→ HW2test ./MT_matrix 3 m1.txt m2.txt
PID:5501
ThreadID:5504 Time:204(ms) context switch times:1
ThreadID:5502 Time:212(ms) context switch times:6
ThreadID:5503 Time:220(ms) context switch times:10
it took 0.218150 seconds to execute
```

4. It took 0.215251 seconds to execute

```
→ HW2test ./MT_matrix 4 m1.txt m2.txt
PID:5924
ThreadID:5926 Time:176(ms) context switch times:3
ThreadID:5928 Time:192(ms) context switch times:2
ThreadID:5927 Time:196(ms) context switch times:3
ThreadID:5925 Time:216(ms) context switch times:19
it took 0.215251 seconds to execute
```



8. It took 0.205601 seconds to execute

```
→ HW2test ./MT_matrix 8 m1.txt m2.txt
PID:6346
  ThreadID:6350 Time:104(ms) context switch times:2
  ThreadID:6347 Time:88(ms) context switch times:7
  ThreadID:6349 Time:92(ms) context switch times:8
  ThreadID:6348 Time:96(ms) context switch times:15
  ThreadID:6352 Time:84(ms) context switch times:8
  ThreadID:6351 Time:76(ms) context switch times:8
  ThreadID:6353 Time:100(ms) context switch times:21
  ThreadID:6354 Time:108(ms) context switch times:27
it took 0.205601 seconds to execute
```

16. It took 0.215919 seconds to execute

```
→ HW2test ./MT_matrix 16 m1.txt m2.txt
PID:6793
  ThreadID:6794 Time:36(ms) context switch times:5
  ThreadID:6797 Time:44(ms) context switch times:17
  ThreadID:6800 Time:44(ms) context switch times:15
  ThreadID:6801 Time:44(ms) context switch times:8
  ThreadID:6796 Time:52(ms) context switch times:10
  ThreadID:6799 Time:52(ms) context switch times:35
  ThreadID:6806 Time:44(ms) context switch times:15
  ThreadID:6808 Time:48(ms) context switch times:16
  ThreadID:6805 Time:44(ms) context switch times:33
  ThreadID:6798 Time:56(ms) context switch times:15
  ThreadID:6807 Time:52(ms) context switch times:28
  ThreadID:6795 Time:68(ms) context switch times:14
  ThreadID:6804 Time:60(ms) context switch times:25
  ThreadID:6803 Time:48(ms) context switch times:30
  ThreadID:6802 Time:48(ms) context switch times:22
  ThreadID:6809 Time:52(ms) context switch times:21
it took 0.215919 seconds to execute
```

24. It took 0.218053 seconds to execute

```
→ HW2test ./MT_matrix 24 m1.txt m2.txt
PID:7490
  ThreadID:7491 Time:28(ms) context switch times:6
  ThreadID:7497 Time:32(ms) context switch times:5
  ThreadID:7495 Time:36(ms) context switch times:6
  ThreadID:7503 Time:44(ms) context switch times:7
  ThreadID:7507 Time:40(ms) context switch times:9
  ThreadID:7493 Time:36(ms) context switch times:9
  ThreadID:7492 Time:32(ms) context switch times:8
  ThreadID:7500 Time:24(ms) context switch times:7
  ThreadID:7501 Time:36(ms) context switch times:7
  ThreadID:7502 Time:36(ms) context switch times:6
  ThreadID:7506 Time:32(ms) context switch times:8
  ThreadID:7494 Time:36(ms) context switch times:11
  ThreadID:7508 Time:36(ms) context switch times:17
  ThreadID:7504 Time:28(ms) context switch times:7
  ThreadID:7509 Time:36(ms) context switch times:7
  ThreadID:7514 Time:32(ms) context switch times:16
  ThreadID:7511 Time:36(ms) context switch times:12
  ThreadID:7512 Time:28(ms) context switch times:31
  ThreadID:7496 Time:32(ms) context switch times:21
  ThreadID:7499 Time:40(ms) context switch times:9
  ThreadID:7510 Time:40(ms) context switch times:19
  ThreadID:7505 Time:24(ms) context switch times:9
  ThreadID:7513 Time:32(ms) context switch times:26
  ThreadID:7498 Time:36(ms) context switch times:40
it took 0.218053 seconds to execute
```



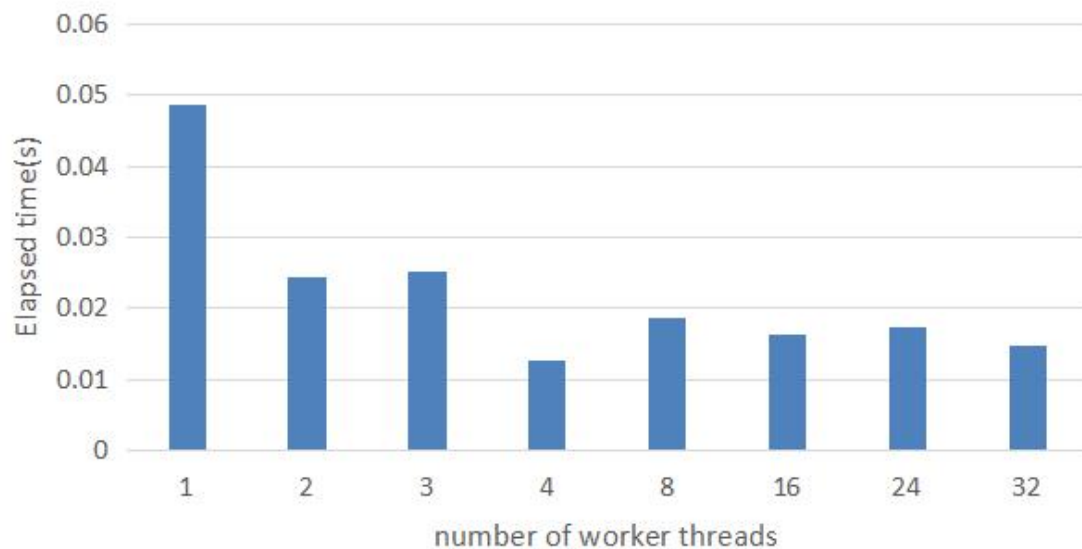
32.It took 0.189489 seconds to execute

```
→ HW2test ./MT_matrix 32 m1.txt m2.txt
PID:8009
ThreadID:8016 Time:16(ms) context switch times:1
ThreadID:8010 Time:16(ms) context switch times:0
ThreadID:8011 Time:20(ms) context switch times:2
ThreadID:8014 Time:12(ms) context switch times:3
ThreadID:8012 Time:16(ms) context switch times:6
ThreadID:8013 Time:16(ms) context switch times:2
ThreadID:8017 Time:24(ms) context switch times:5
ThreadID:8015 Time:24(ms) context switch times:8
ThreadID:8020 Time:28(ms) context switch times:6
ThreadID:8021 Time:20(ms) context switch times:4
ThreadID:8038 Time:16(ms) context switch times:3
ThreadID:8019 Time:20(ms) context switch times:7
ThreadID:8029 Time:28(ms) context switch times:10
ThreadID:8031 Time:16(ms) context switch times:9
ThreadID:8035 Time:20(ms) context switch times:14
ThreadID:8026 Time:16(ms) context switch times:4
ThreadID:8040 Time:24(ms) context switch times:19
ThreadID:8036 Time:20(ms) context switch times:22
ThreadID:8030 Time:28(ms) context switch times:20
ThreadID:8033 Time:24(ms) context switch times:8
ThreadID:8041 Time:24(ms) context switch times:8
ThreadID:8025 Time:24(ms) context switch times:6
ThreadID:8023 Time:28(ms) context switch times:19
ThreadID:8024 Time:20(ms) context switch times:14
ThreadID:8039 Time:20(ms) context switch times:6
ThreadID:8027 Time:36(ms) context switch times:8
ThreadID:8018 Time:20(ms) context switch times:9
ThreadID:8037 Time:28(ms) context switch times:14
ThreadID:8028 Time:24(ms) context switch times:12
ThreadID:8022 Time:16(ms) context switch times:9
ThreadID:8034 Time:24(ms) context switch times:9
ThreadID:8032 Time:32(ms) context switch times:10
it took 0.189489 seconds to execute
```

#### Test4

test4									
Elapsed time with different number of worker threads	1	2	3	4	8	16	24	32	
	0.048583	0.024391	0.025261	0.012646	0.018677	0.016199	0.017302	0.0148	sec

Elapsed time with different number of worker threads



1. It took 0.048583 seconds to execute

```
→ HW2test ./MT_matrix 1 m1.txt m2.txt
PID:9554
    ThreadID:9555 Time:48(ms) context switch times:1
it took 0.048583 seconds to execute
```

2. It took 0.024391 seconds to execute

```
→ HW2test ./MT_matrix 2 m1.txt m2.txt
PID:9977
    ThreadID:9979 Time:24(ms) context switch times:0
    ThreadID:9978 Time:24(ms) context switch times:1
it took 0.024391 seconds to execute
```

3. It took 0.025261 seconds to execute

```
→ HW2test ./MT_matrix 3 m1.txt m2.txt
PID:10428
    ThreadID:10431 Time:16(ms) context switch times:2
    ThreadID:10429 Time:28(ms) context switch times:0
    ThreadID:10430 Time:28(ms) context switch times:3
it took 0.025261 seconds to execute
```

4. It took 0.012646 seconds to execute

```
→ HW2test ./MT_matrix 4 m1.txt m2.txt
PID:10857
    ThreadID:10861 Time:12(ms) context switch times:2
    ThreadID:10859 Time:12(ms) context switch times:0
    ThreadID:10860 Time:12(ms) context switch times:1
    ThreadID:10858 Time:12(ms) context switch times:0
it took 0.012646 seconds to execute
```

8. It took 0.018677 seconds to execute

```
→ HW2test ./MT_matrix 8 m1.txt m2.txt
PID:11284
    ThreadID:11287 Time:4(ms) context switch times:0
    ThreadID:11286 Time:4(ms) context switch times:1
    ThreadID:11285 Time:4(ms) context switch times:0
    ThreadID:11288 Time:8(ms) context switch times:2
    ThreadID:11290 Time:8(ms) context switch times:1
    ThreadID:11292 Time:8(ms) context switch times:3
    ThreadID:11291 Time:4(ms) context switch times:3
    ThreadID:11289 Time:4(ms) context switch times:6
it took 0.018677 seconds to execute
```

16. It took 0.016199 seconds to execute

```
→ HW2test ./MT_matrix 16 m1.txt m2.txt
PID:11731
    ThreadID:11732 Time:4(ms) context switch times:0
    ThreadID:11734 Time:4(ms) context switch times:1
    ThreadID:11733 Time:4(ms) context switch times:0
    ThreadID:11735 Time:4(ms) context switch times:7
    ThreadID:11737 Time:4(ms) context switch times:3
    ThreadID:11740 Time:0(ms) context switch times:0
    ThreadID:11745 Time:4(ms) context switch times:0
    ThreadID:11736 Time:8(ms) context switch times:4
    ThreadID:11743 Time:4(ms) context switch times:3
    ThreadID:11747 Time:0(ms) context switch times:1
    ThreadID:11746 Time:8(ms) context switch times:3
    ThreadID:11742 Time:8(ms) context switch times:2
    ThreadID:11744 Time:0(ms) context switch times:2
    ThreadID:11738 Time:4(ms) context switch times:0
    ThreadID:11739 Time:4(ms) context switch times:2
    ThreadID:11741 Time:4(ms) context switch times:1
it took 0.016199 seconds to execute
```



24. It took 0.017302 seconds to execute

```
→ HW2test ./MT_matrix 24 m1.txt m2.txt
PID:12208
ThreadID:12211 Time:0(ms) context switch times:0
ThreadID:12210 Time:0(ms) context switch times:0
ThreadID:12209 Time:0(ms) context switch times:0
ThreadID:12212 Time:4(ms) context switch times:6
ThreadID:12218 Time:0(ms) context switch times:1
ThreadID:12214 Time:0(ms) context switch times:1
ThreadID:12215 Time:4(ms) context switch times:0
ThreadID:12216 Time:4(ms) context switch times:2
ThreadID:12213 Time:4(ms) context switch times:7
ThreadID:12217 Time:0(ms) context switch times:3
ThreadID:12223 Time:0(ms) context switch times:4
ThreadID:12232 Time:0(ms) context switch times:1
ThreadID:12220 Time:4(ms) context switch times:1
ThreadID:12219 Time:4(ms) context switch times:2
ThreadID:12227 Time:0(ms) context switch times:2
ThreadID:12222 Time:0(ms) context switch times:7
ThreadID:12230 Time:0(ms) context switch times:1
ThreadID:12231 Time:4(ms) context switch times:2
ThreadID:12226 Time:0(ms) context switch times:3
ThreadID:12224 Time:4(ms) context switch times:2
ThreadID:12221 Time:0(ms) context switch times:2
ThreadID:12229 Time:4(ms) context switch times:2
ThreadID:12228 Time:0(ms) context switch times:6
ThreadID:12225 Time:4(ms) context switch times:5
it took 0.017302 seconds to execute
```

32.It took 0.014800 seconds to execute

```
→ HW2test ./MT_matrix 32 m1.txt m2.txt
PID:12718
ThreadID:12720 Time:4(ms) context switch times:0
ThreadID:12719 Time:4(ms) context switch times:0
ThreadID:12721 Time:4(ms) context switch times:1
ThreadID:12749 Time:0(ms) context switch times:2
ThreadID:12744 Time:4(ms) context switch times:0
ThreadID:12750 Time:4(ms) context switch times:0
ThreadID:12733 Time:0(ms) context switch times:1
ThreadID:12735 Time:0(ms) context switch times:0
ThreadID:12745 Time:0(ms) context switch times:2
ThreadID:12732 Time:0(ms) context switch times:2
ThreadID:12734 Time:0(ms) context switch times:1
ThreadID:12746 Time:0(ms) context switch times:2
ThreadID:12731 Time:4(ms) context switch times:1
ThreadID:12727 Time:0(ms) context switch times:1
ThreadID:12736 Time:0(ms) context switch times:0
ThreadID:12723 Time:0(ms) context switch times:0
ThreadID:12737 Time:4(ms) context switch times:0
ThreadID:12742 Time:0(ms) context switch times:6
ThreadID:12748 Time:0(ms) context switch times:0
ThreadID:12729 Time:4(ms) context switch times:0
ThreadID:12724 Time:4(ms) context switch times:6
ThreadID:12747 Time:0(ms) context switch times:6
ThreadID:12743 Time:0(ms) context switch times:1
ThreadID:12730 Time:0(ms) context switch times:0
ThreadID:12740 Time:4(ms) context switch times:1
ThreadID:12739 Time:0(ms) context switch times:3
ThreadID:12738 Time:0(ms) context switch times:3
ThreadID:12741 Time:0(ms) context switch times:5
ThreadID:12728 Time:4(ms) context switch times:4
ThreadID:12725 Time:0(ms) context switch times:0
ThreadID:12722 Time:0(ms) context switch times:1
ThreadID:12726 Time:4(ms) context switch times:7
it took 0.014800 seconds to execute
```