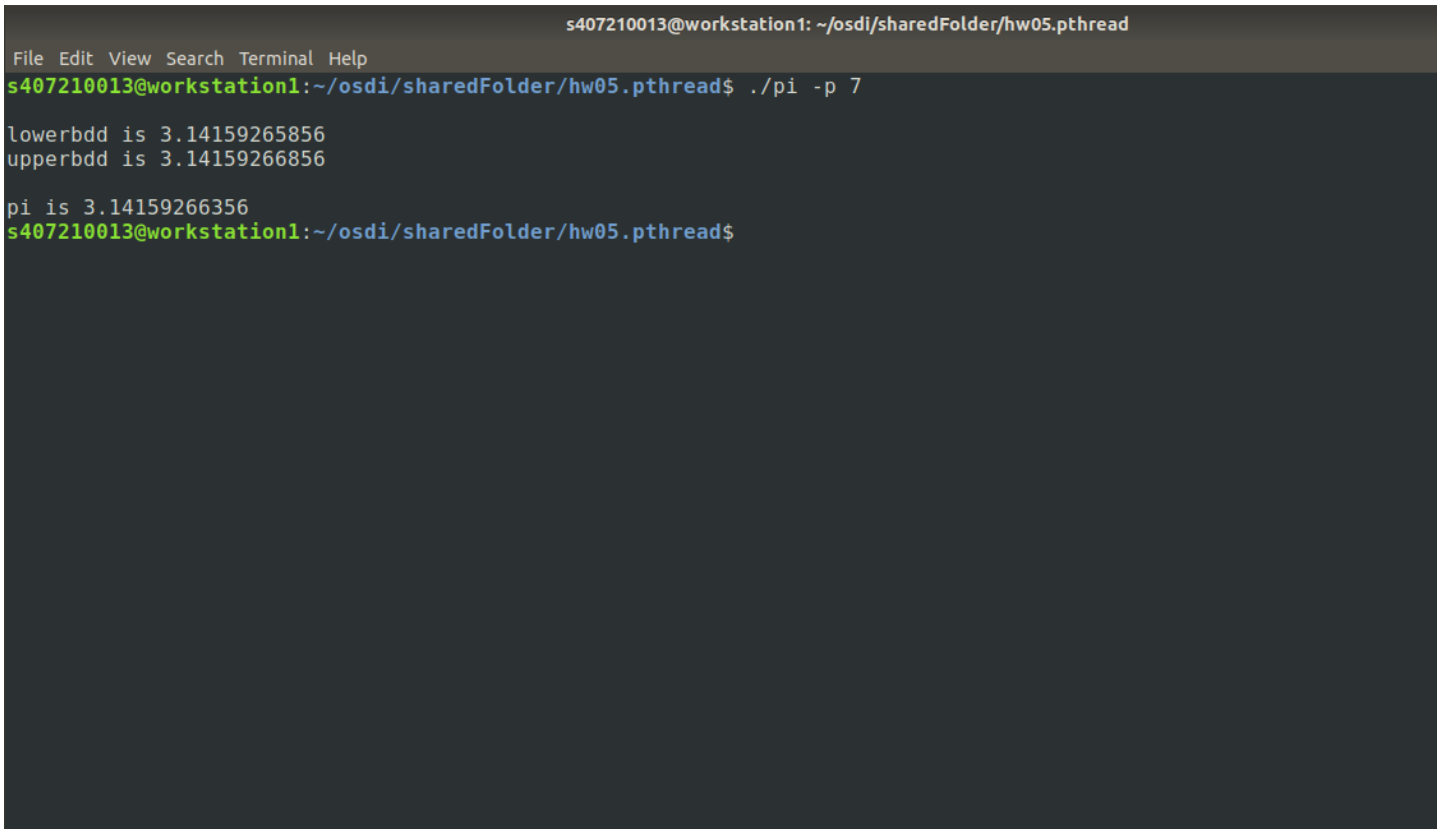
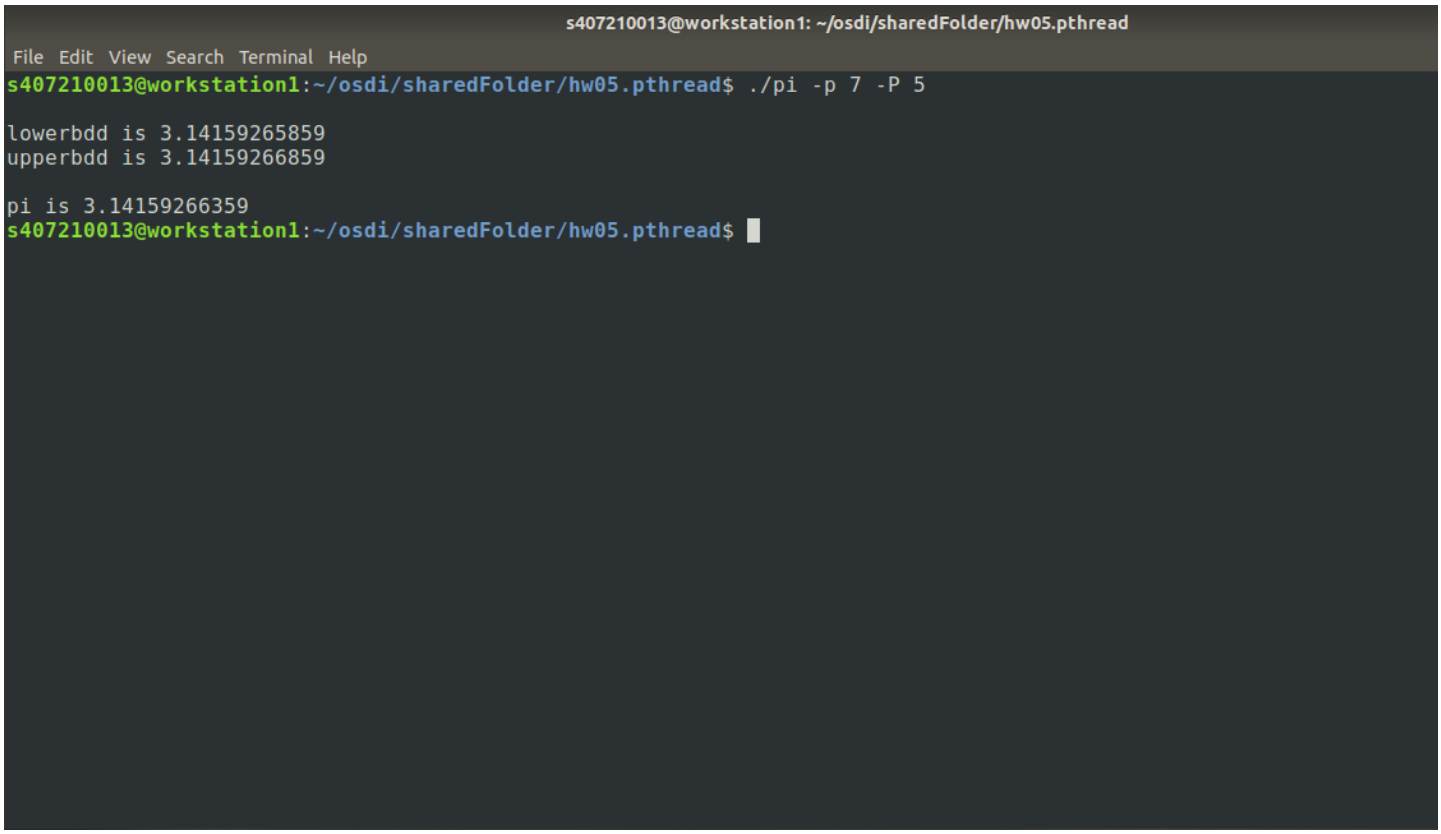
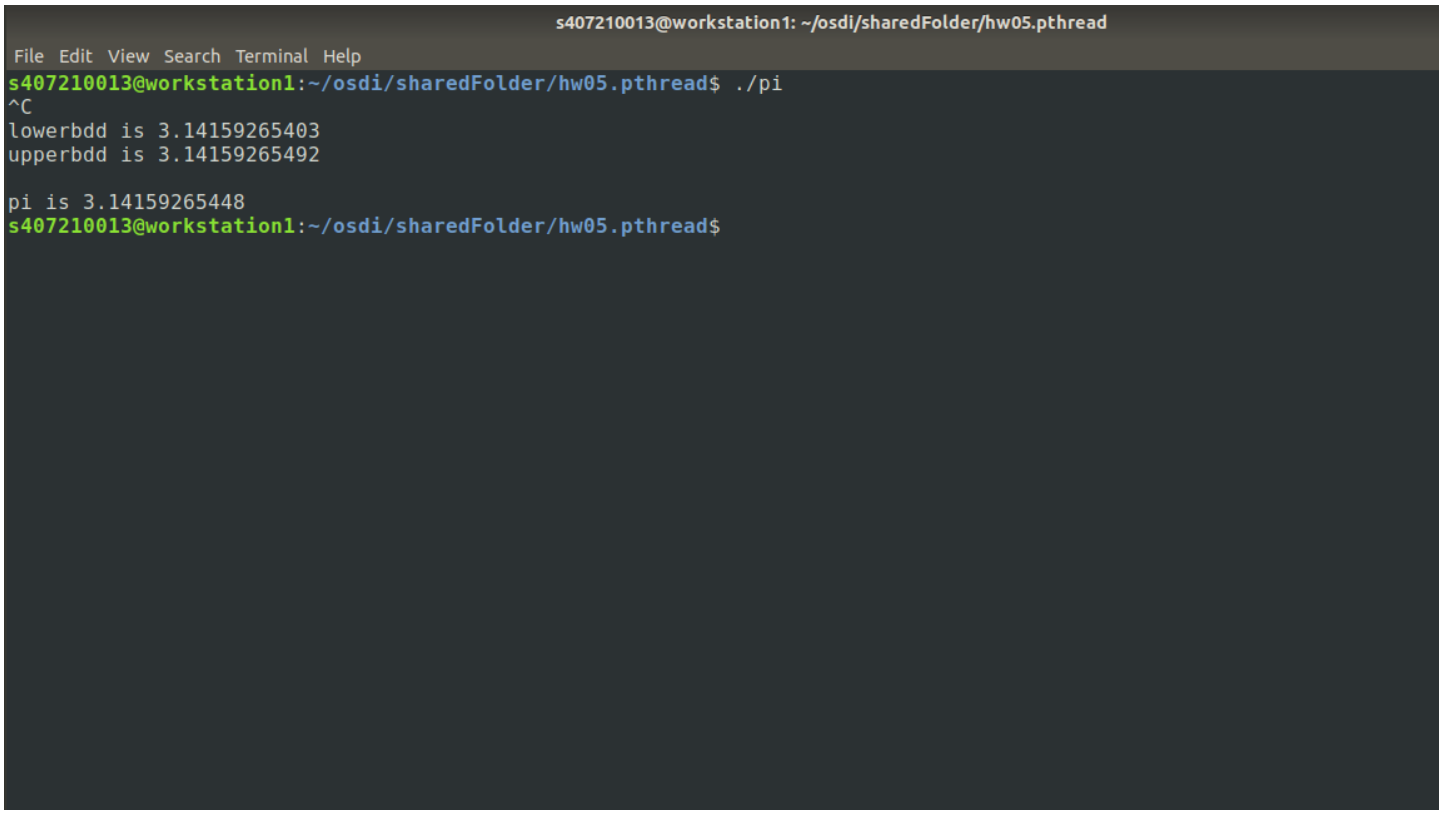
功能一：「pi -p 7」



功能二：「pi -p 7 -P 5」



功能三：「./pi」



主題甲 ：

時間計算 (皆採用 48 核心去做計算) :

Real time : 在 48 核心下需花費的總實際時間。

User time : user mode 處理時總共 CPU 花費的時間。

System time : printf 之類在 kernal mode 所花費的時間。

逼近到小數點第 5 位數

```
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 5

lowerbdd is 3.14159305723
upperbdd is 3.14159403284

pi is 3.14159354504

real    0m0.684s
user    0m2.227s
sys     0m0.991s
```

逼近到小數點第 6 位數

```
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6

lowerbdd is 3.14159270259
upperbdd is 3.14159280259

pi is 3.14159275259

real    0m1.456s
user    0m18.766s
sys     0m1.837s
```

逼近到小數點第 7 位數

```
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 7

lowerbdd is 3.14159265856
upperbdd is 3.14159266856

pi is 3.14159266356

real    0m6.971s
user    3m15.146s
sys     0m2.897s
```

逼近到小數點第 8 位數

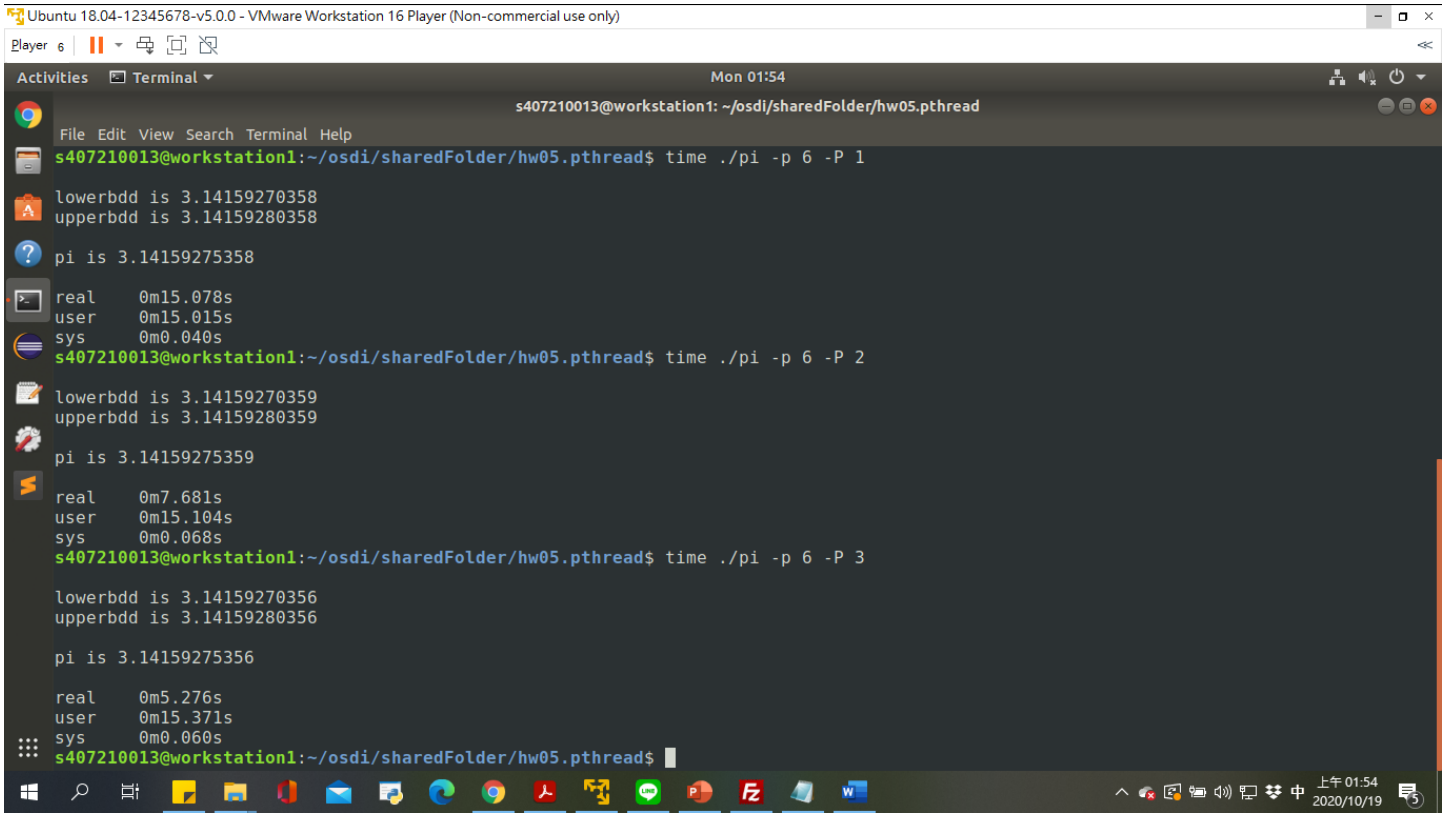
```
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 8

lowerbdd is 3.14159265407
upperbdd is 3.14159265505

pi is 3.14159265456

real    0m54.397s
user    33m55.730s
sys     0m3.619s
```

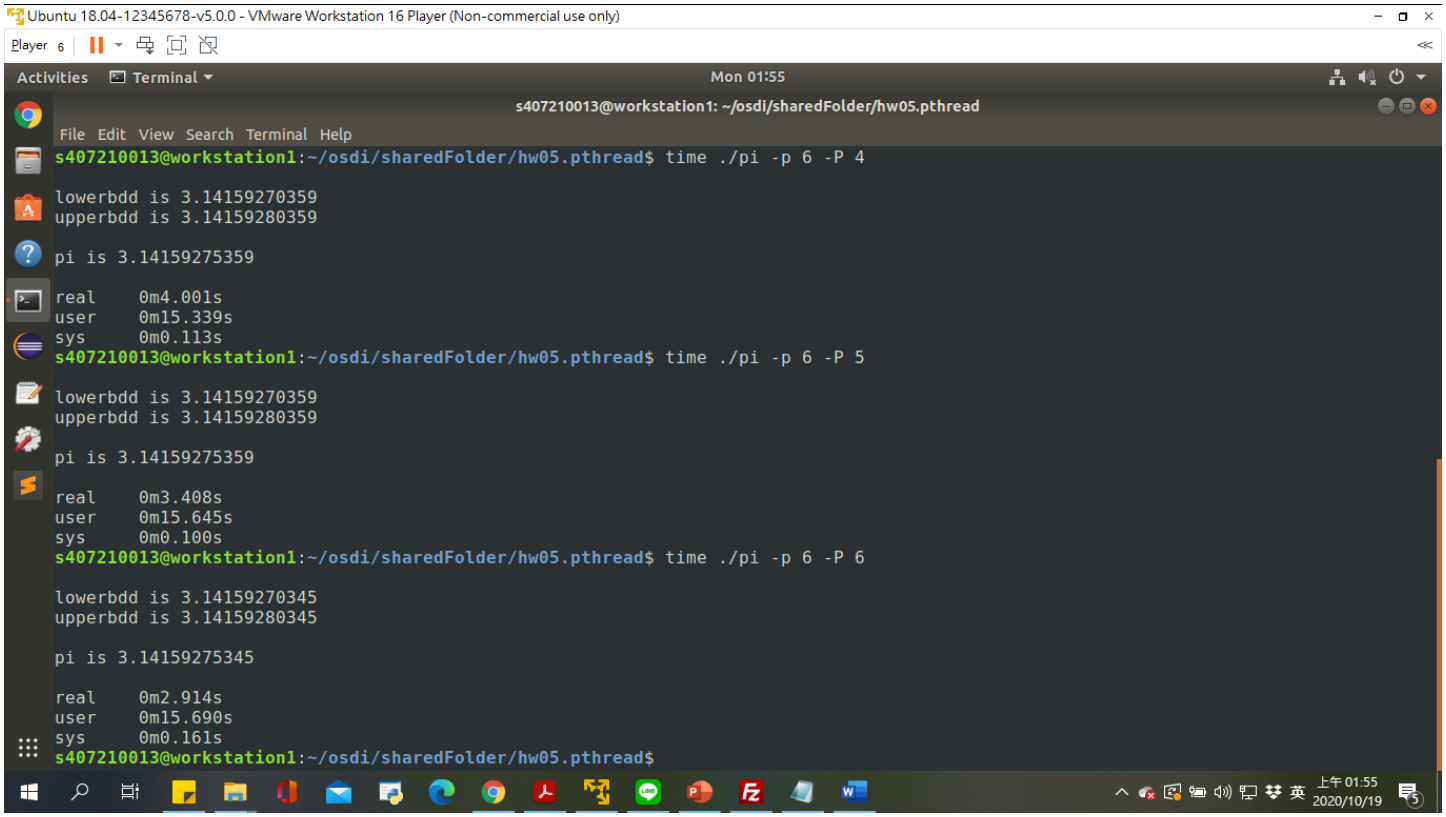
逼近到小數點第 9 位數

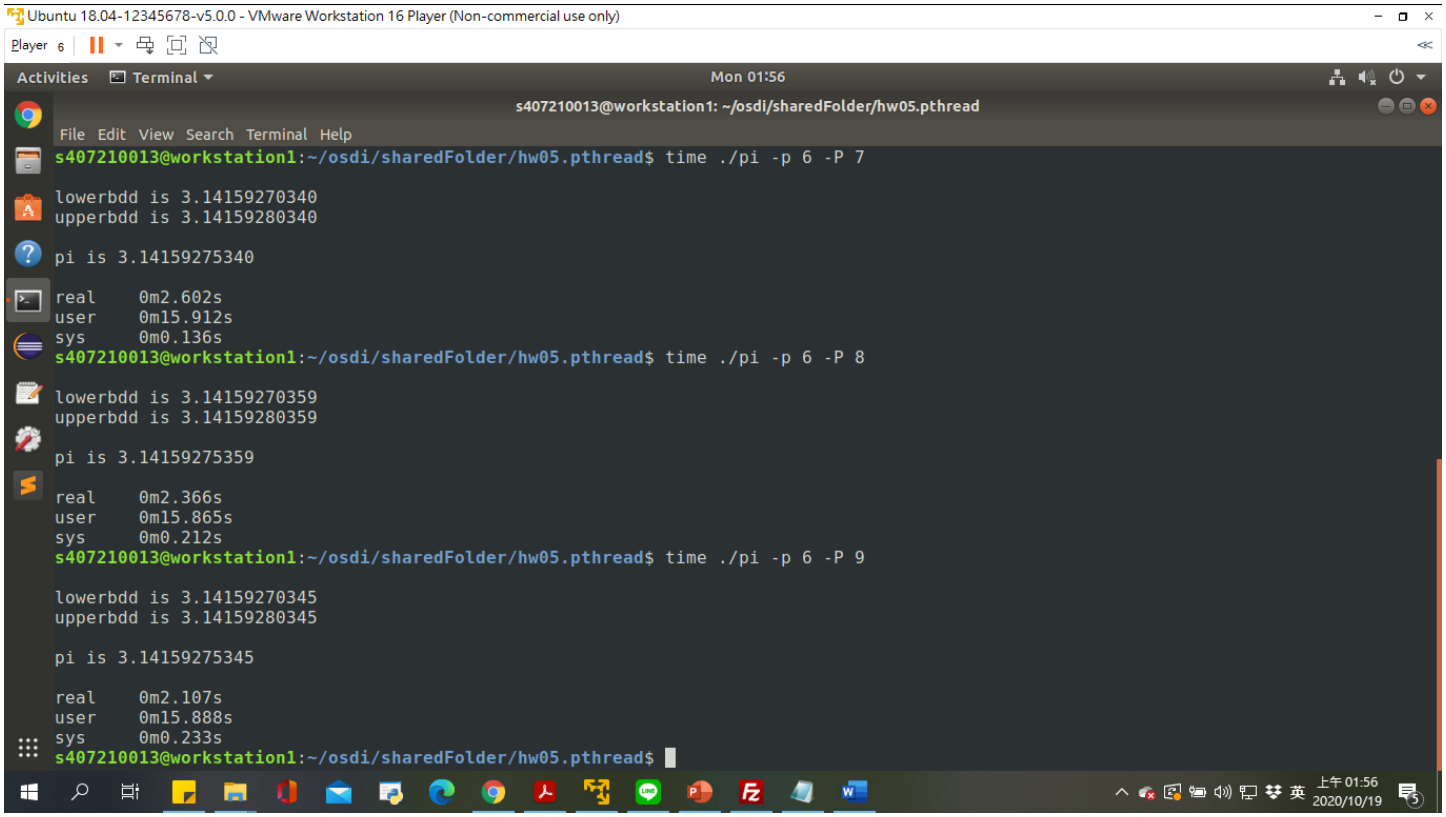
```
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 9

lowerbdd is 3.14159265364
upperbdd is 3.14159265374

pi is 3.14159265369

real    8m9.803s
user    342m59.332s
sys     0m5.688s
```

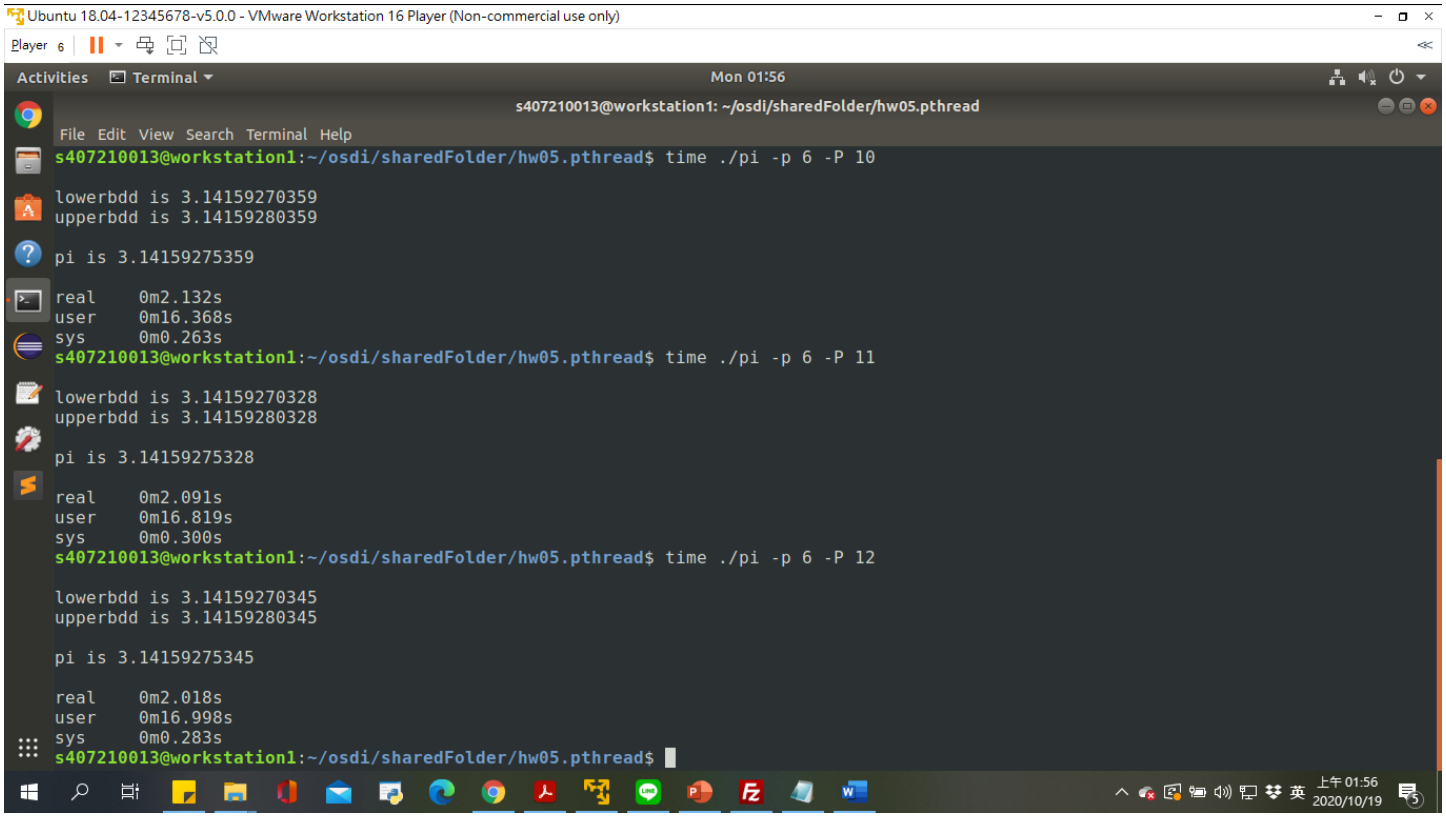
主題乙：

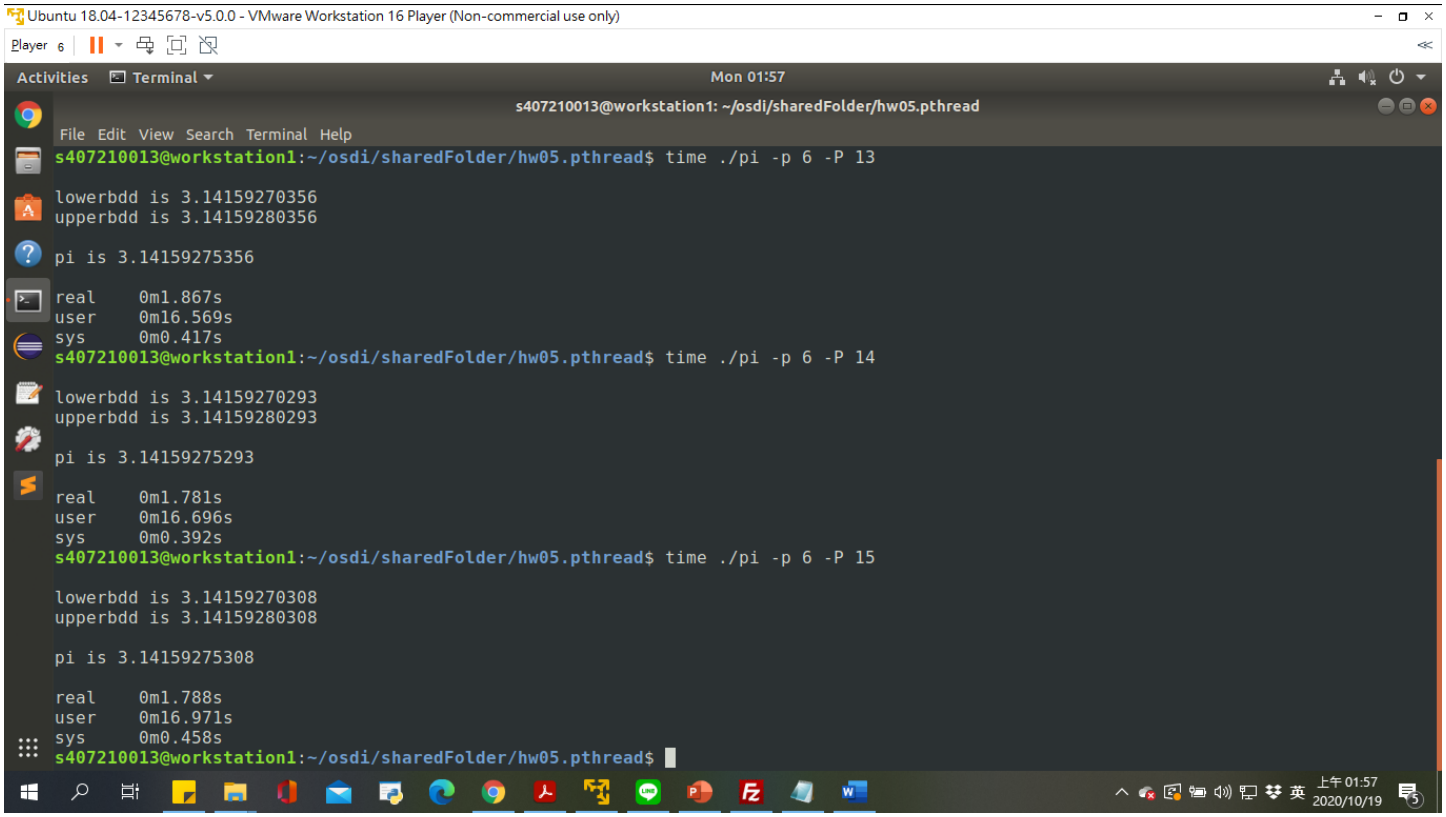
統一選擇逼近到小數點第6位數，探討在同樣的精準度下，觀察核心數與時間的關係。

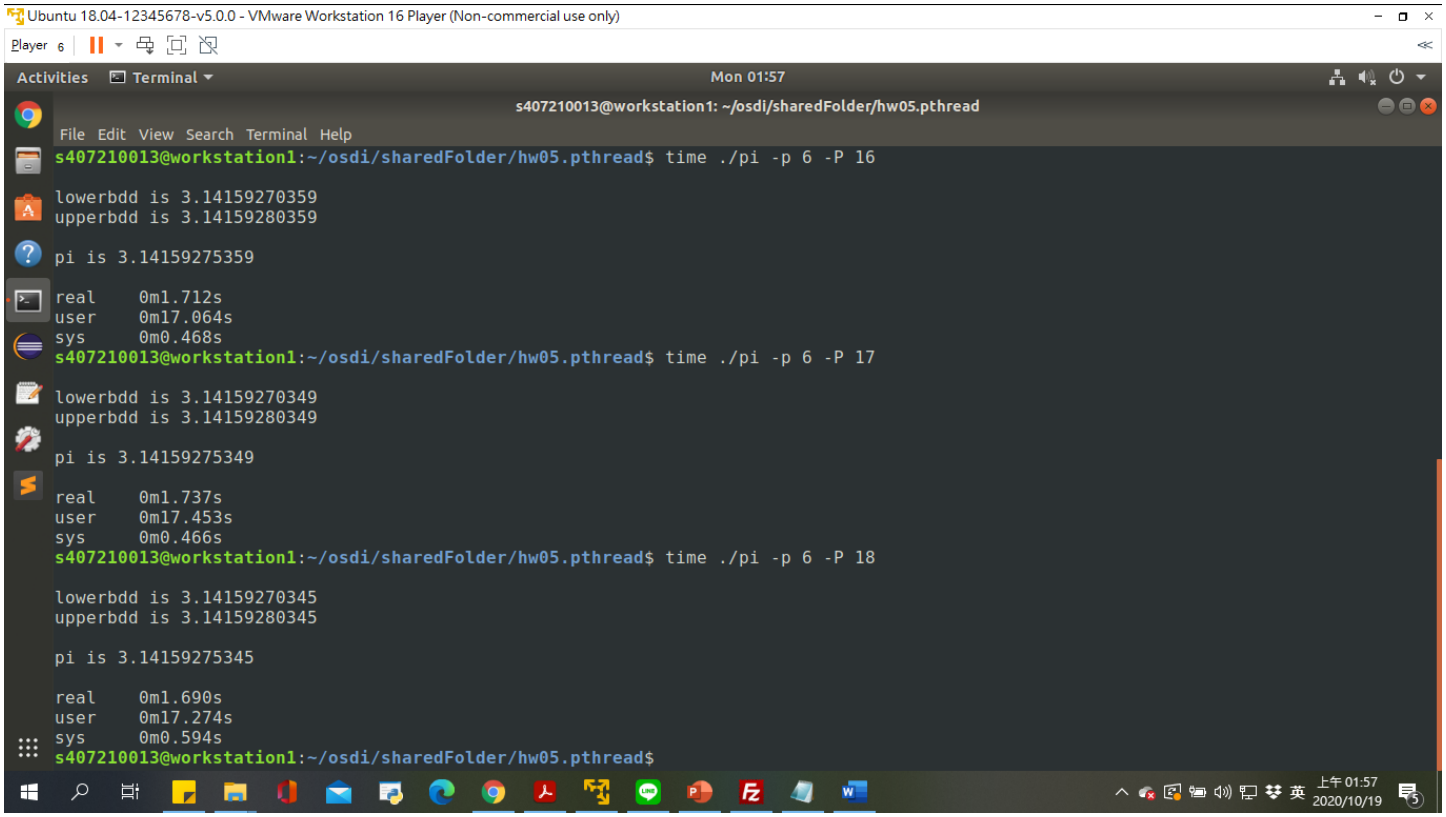

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 01:54
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 1
lowerbdd is 3.14159270358
upperbdd is 3.14159280358
pi is 3.14159275358
real 0m15.078s
user 0m15.015s
sys 0m0.040s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 2
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m7.681s
user 0m15.104s
sys 0m0.068s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 3
lowerbdd is 3.14159270356
upperbdd is 3.14159280356
pi is 3.14159275356
real 0m5.276s
user 0m15.371s
sys 0m0.060s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 01:54
2020/10/19

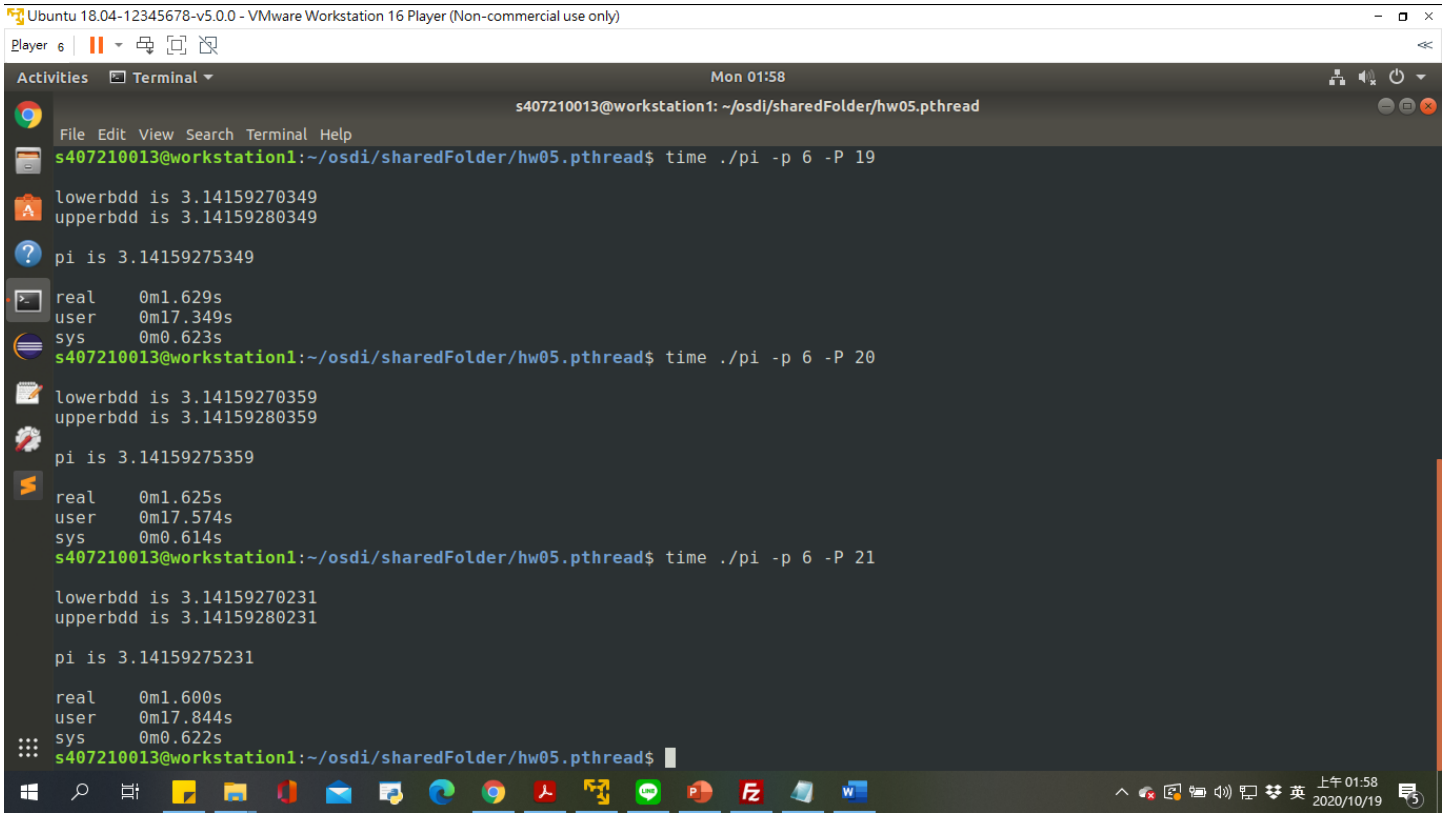

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 01:55
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 4
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m4.001s
user 0m15.339s
sys 0m0.113s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 5
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m3.408s
user 0m15.645s
sys 0m0.100s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 6
lowerbdd is 3.14159270345
upperbdd is 3.14159280345
pi is 3.14159275345
real 0m2.914s
user 0m15.690s
sys 0m0.161s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 01:55
2020/10/19

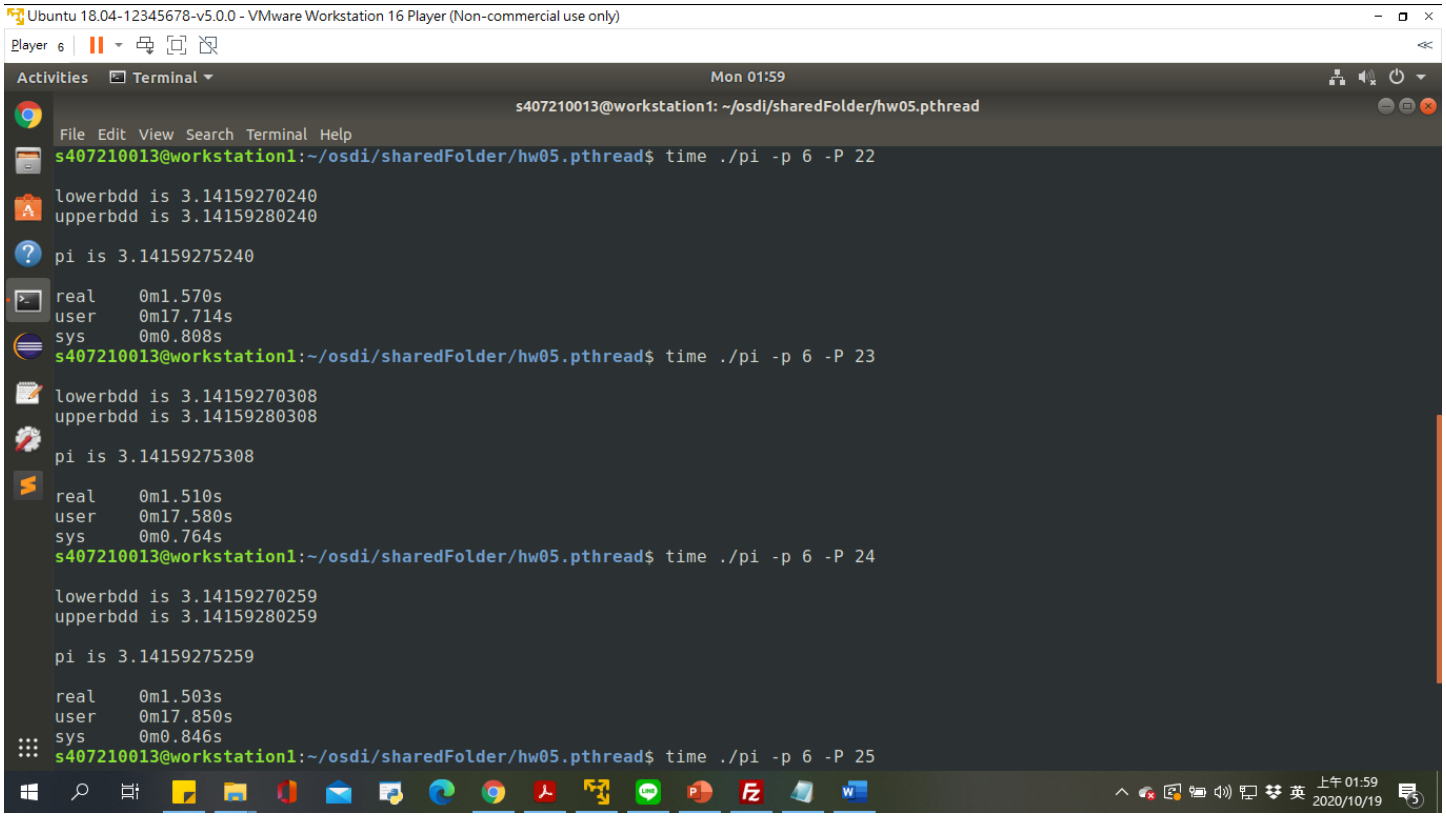

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 01:56
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 7
lowerbdd is 3.14159270340
upperbdd is 3.14159280340
pi is 3.14159275340
real 0m2.602s
user 0m15.912s
sys 0m0.136s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 8
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m2.366s
user 0m15.865s
sys 0m0.212s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 9
lowerbdd is 3.14159270345
upperbdd is 3.14159280345
pi is 3.14159275345
real 0m2.107s
user 0m15.888s
sys 0m0.233s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 01:56
2020/10/19

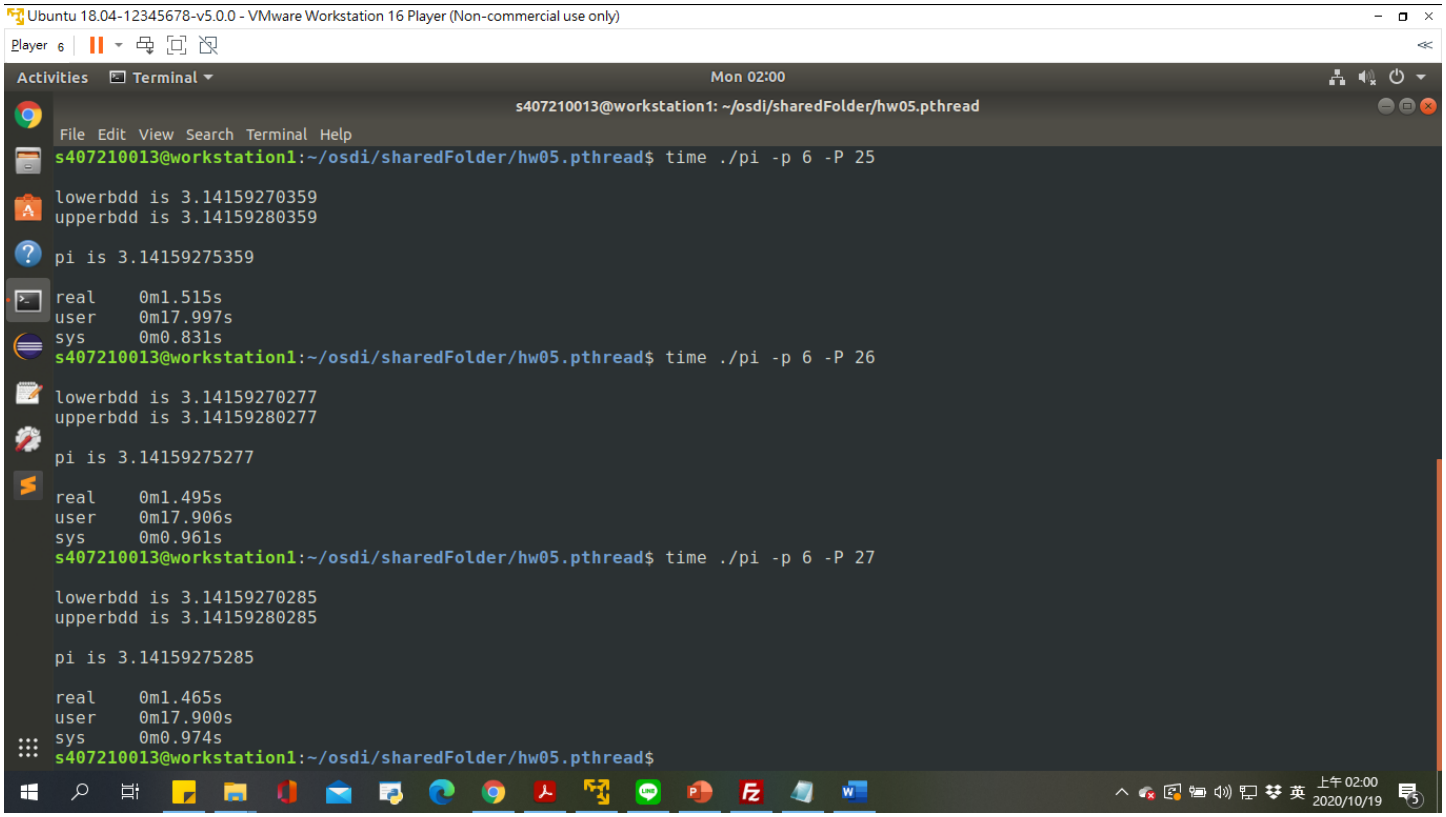

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 01:56
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 10
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m2.132s
user 0m16.368s
sys 0m0.263s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 11
lowerbdd is 3.14159270328
upperbdd is 3.14159280328
pi is 3.14159275328
real 0m2.091s
user 0m16.819s
sys 0m0.300s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 12
lowerbdd is 3.14159270345
upperbdd is 3.14159280345
pi is 3.14159275345
real 0m2.018s
user 0m16.998s
sys 0m0.283s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 01:56
2020/10/19

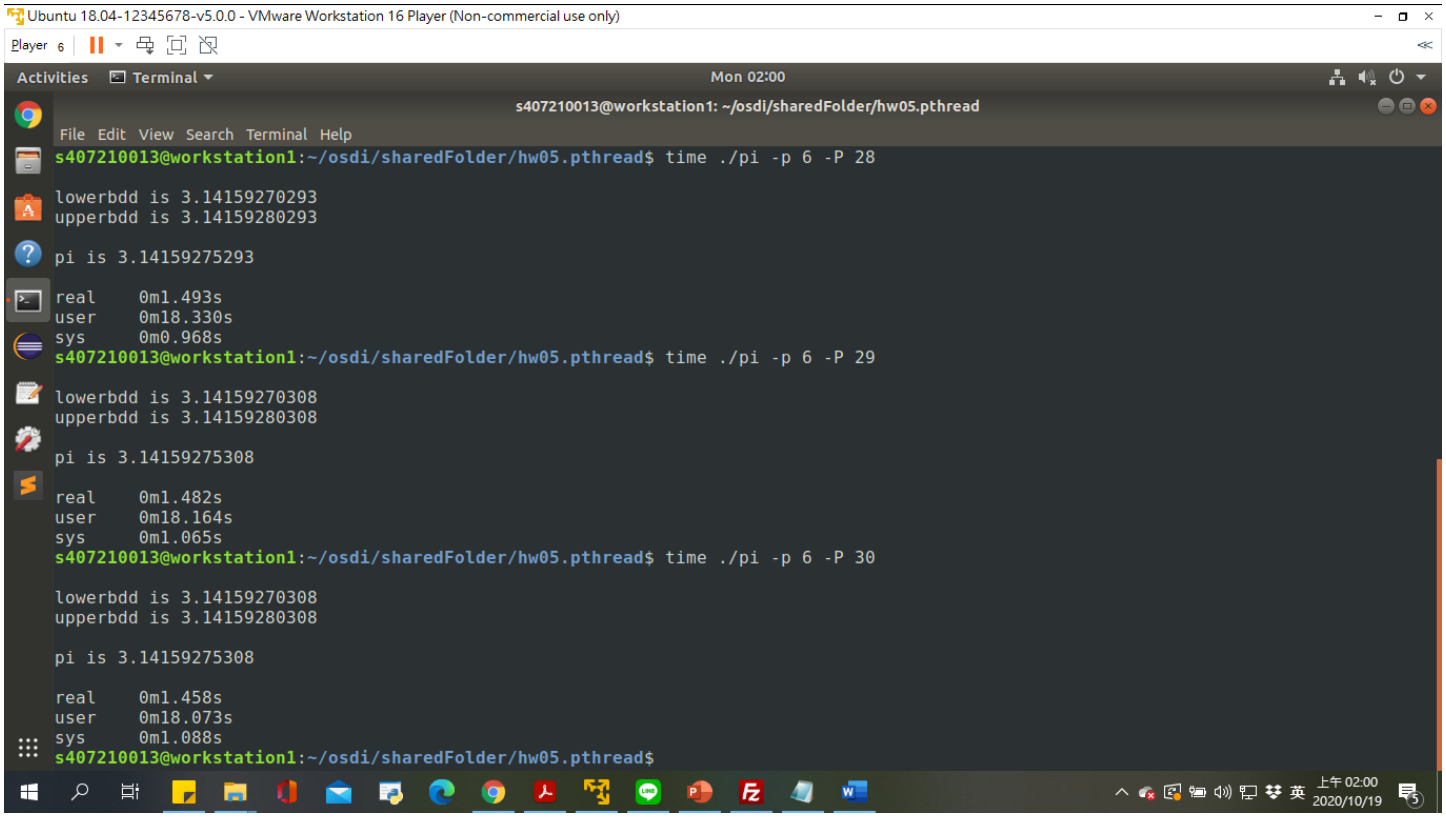

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 01:57
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 13
lowerbdd is 3.14159270356
upperbdd is 3.14159280356
pi is 3.14159275356
real 0m1.867s
user 0m16.569s
sys 0m0.417s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 14
lowerbdd is 3.14159270293
upperbdd is 3.14159280293
pi is 3.14159275293
real 0m1.781s
user 0m16.696s
sys 0m0.392s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 15
lowerbdd is 3.14159270308
upperbdd is 3.14159280308
pi is 3.14159275308
real 0m1.788s
user 0m16.971s
sys 0m0.458s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 01:57
2020/10/19

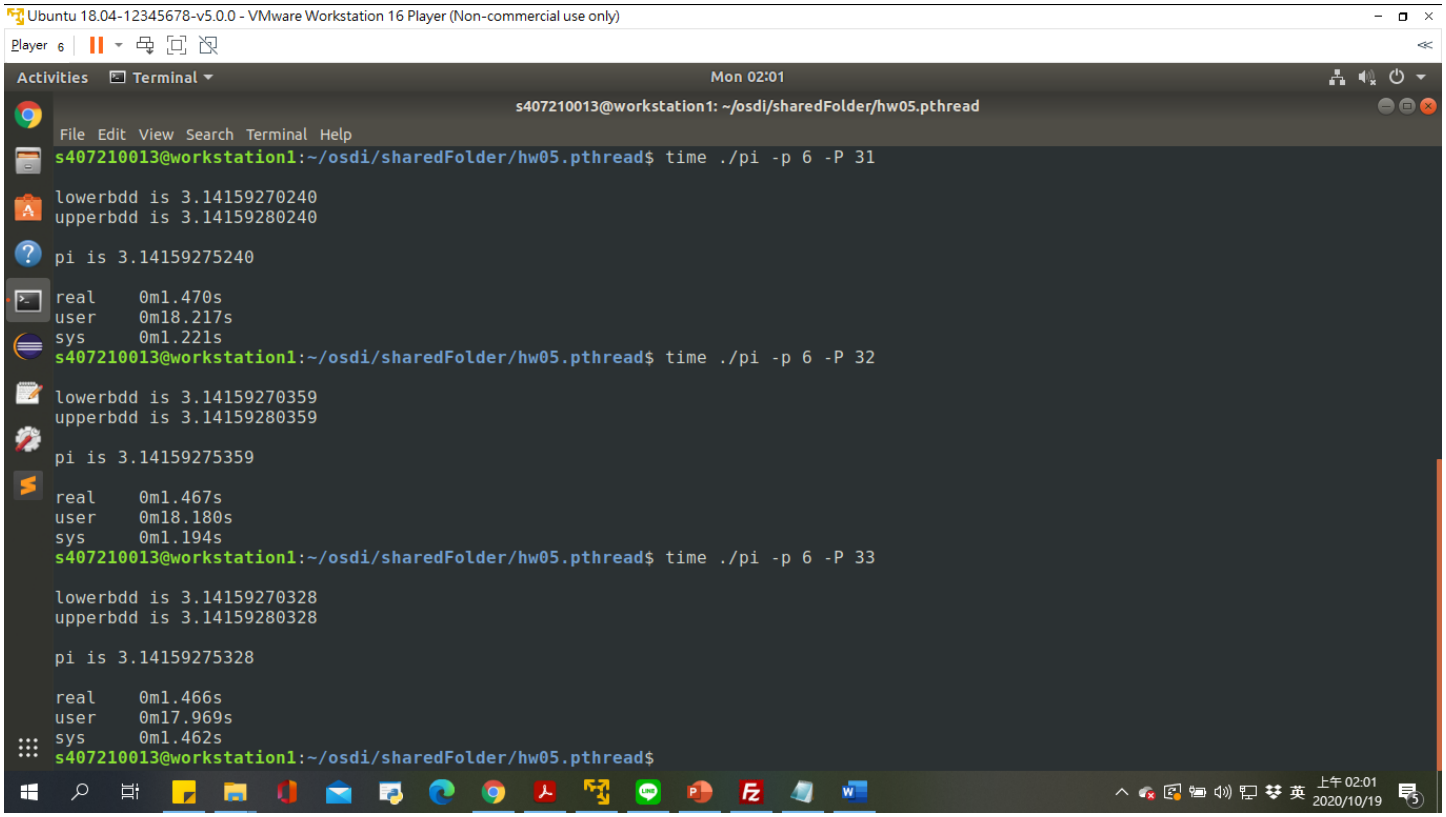

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 01:57
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 16
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m1.712s
user 0m17.064s
sys 0m0.468s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 17
lowerbdd is 3.14159270349
upperbdd is 3.14159280349
pi is 3.14159275349
real 0m1.737s
user 0m17.453s
sys 0m0.466s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 18
lowerbdd is 3.14159270345
upperbdd is 3.14159280345
pi is 3.14159275345
real 0m1.690s
user 0m17.274s
sys 0m0.594s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 01:57
2020/10/19

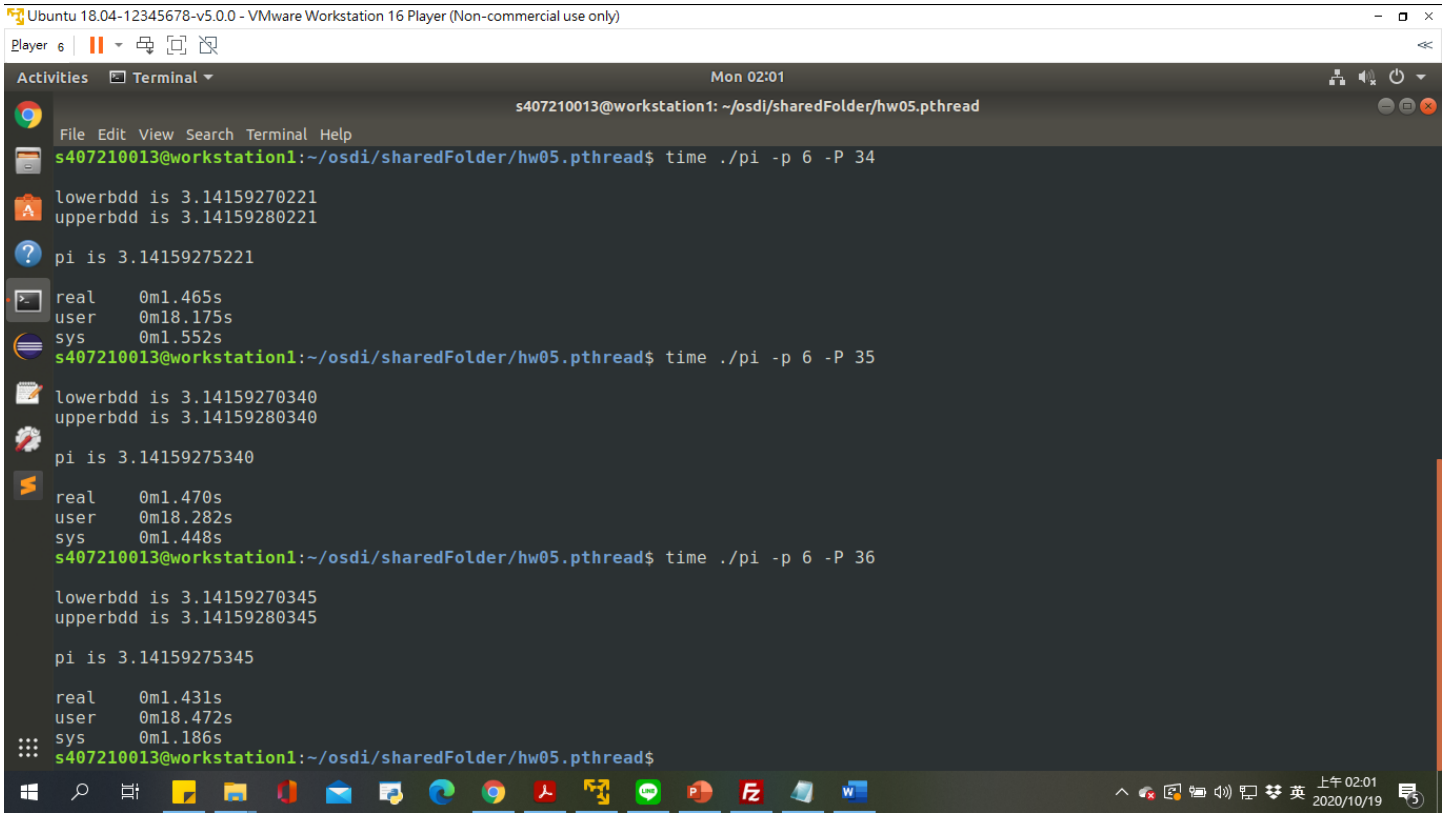

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 01:58
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 19
lowerbdd is 3.14159270349
upperbdd is 3.14159280349
pi is 3.14159275349
real 0m1.629s
user 0m17.349s
sys 0m0.623s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 20
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m1.625s
user 0m17.574s
sys 0m0.614s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 21
lowerbdd is 3.14159270231
upperbdd is 3.14159280231
pi is 3.14159275231
real 0m1.600s
user 0m17.844s
sys 0m0.622s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 01:58
2020/10/19

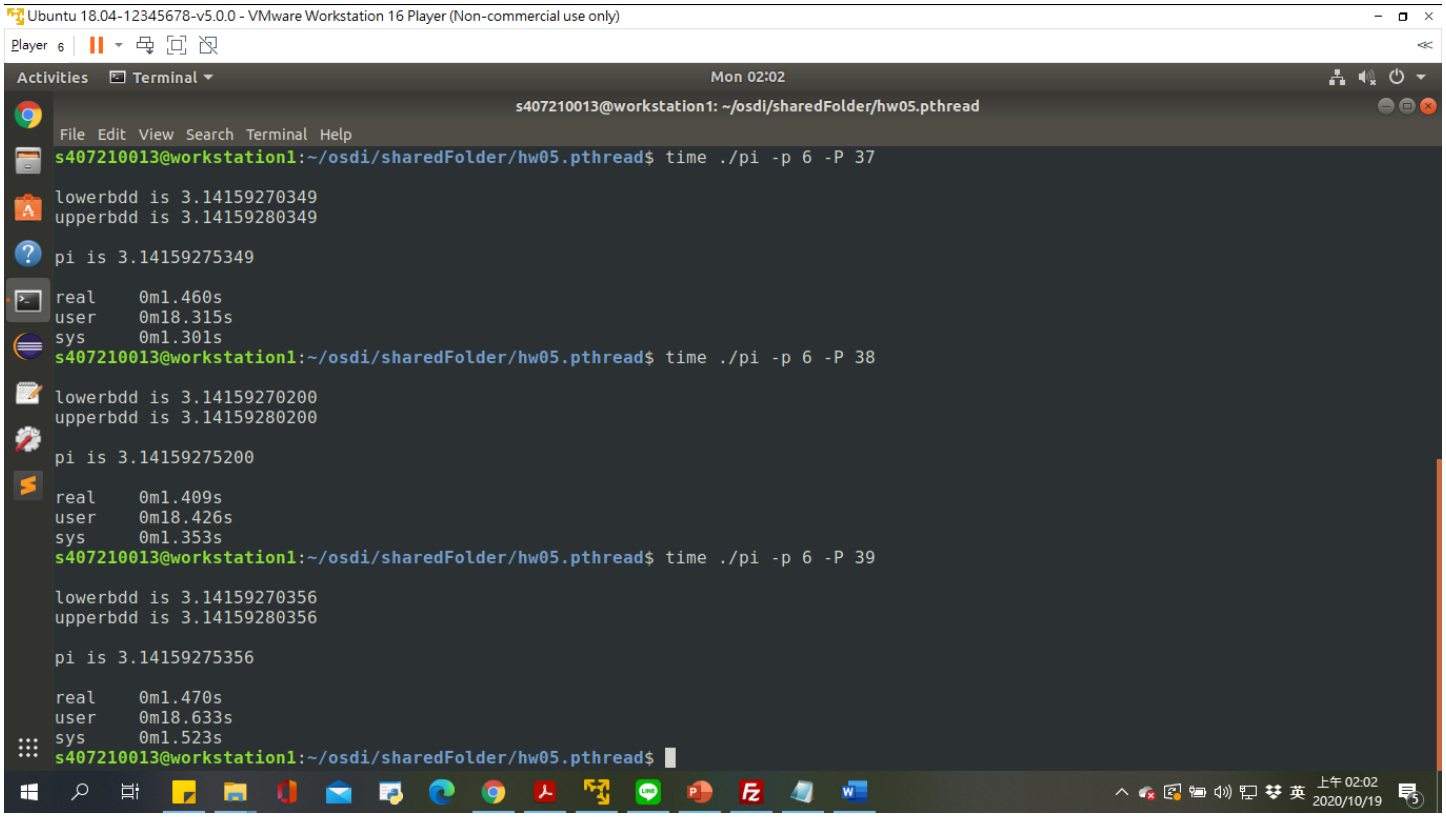

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 01:59
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 22
lowerbdd is 3.14159270240
upperbdd is 3.14159280240
pi is 3.14159275240
real 0m1.570s
user 0m17.714s
sys 0m0.808s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 23
lowerbdd is 3.14159270308
upperbdd is 3.14159280308
pi is 3.14159275308
real 0m1.510s
user 0m17.580s
sys 0m0.764s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 24
lowerbdd is 3.14159270259
upperbdd is 3.14159280259
pi is 3.14159275259
real 0m1.503s
user 0m17.850s
sys 0m0.846s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 25
上午 01:59
2020/10/19

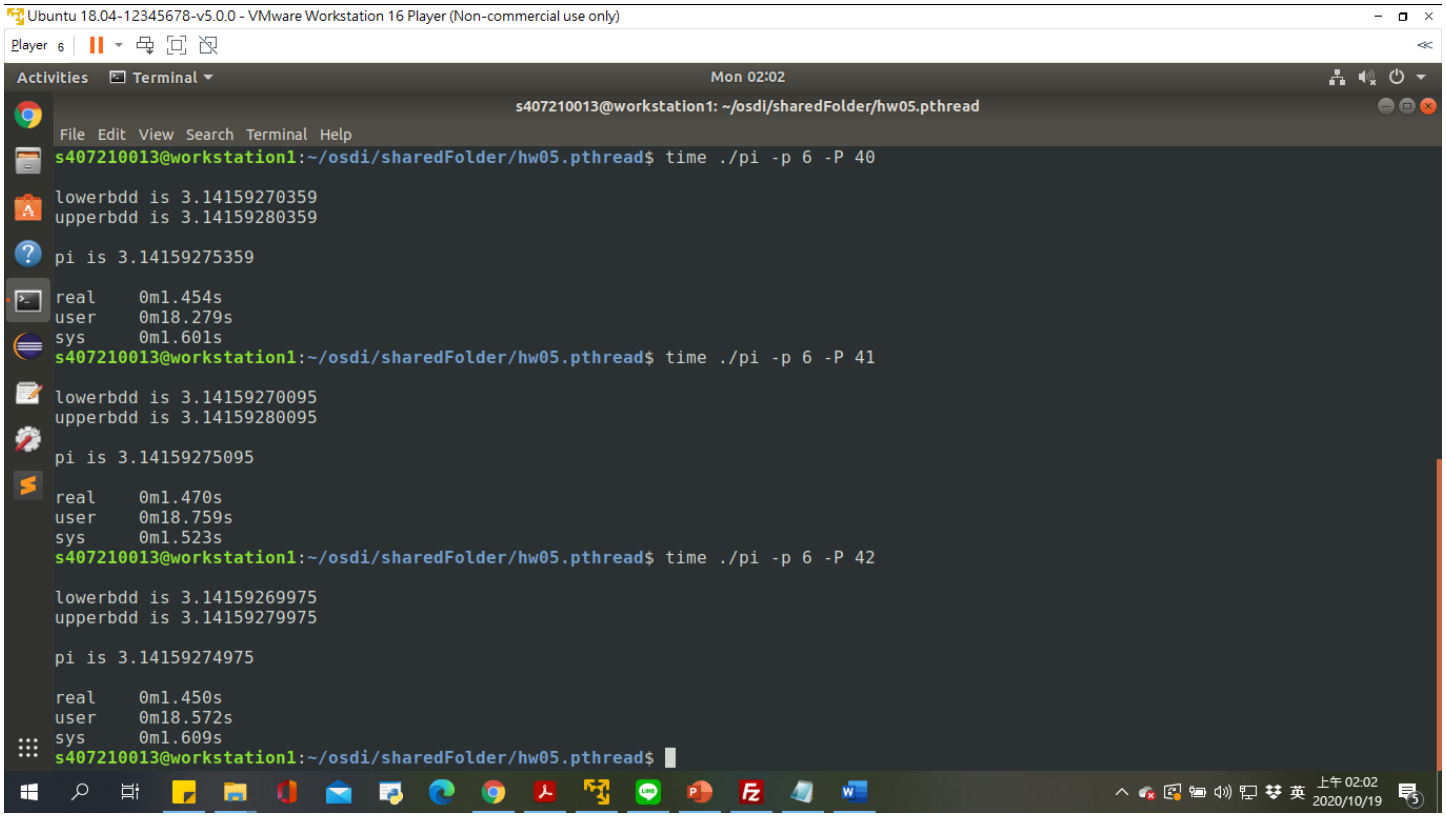

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 02:00
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 25
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m1.515s
user 0m17.997s
sys 0m0.831s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 26
lowerbdd is 3.14159270277
upperbdd is 3.14159280277
pi is 3.14159275277
real 0m1.495s
user 0m17.906s
sys 0m0.961s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 27
lowerbdd is 3.14159270285
upperbdd is 3.14159280285
pi is 3.14159275285
real 0m1.465s
user 0m17.900s
sys 0m0.974s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 02:00
2020/10/19

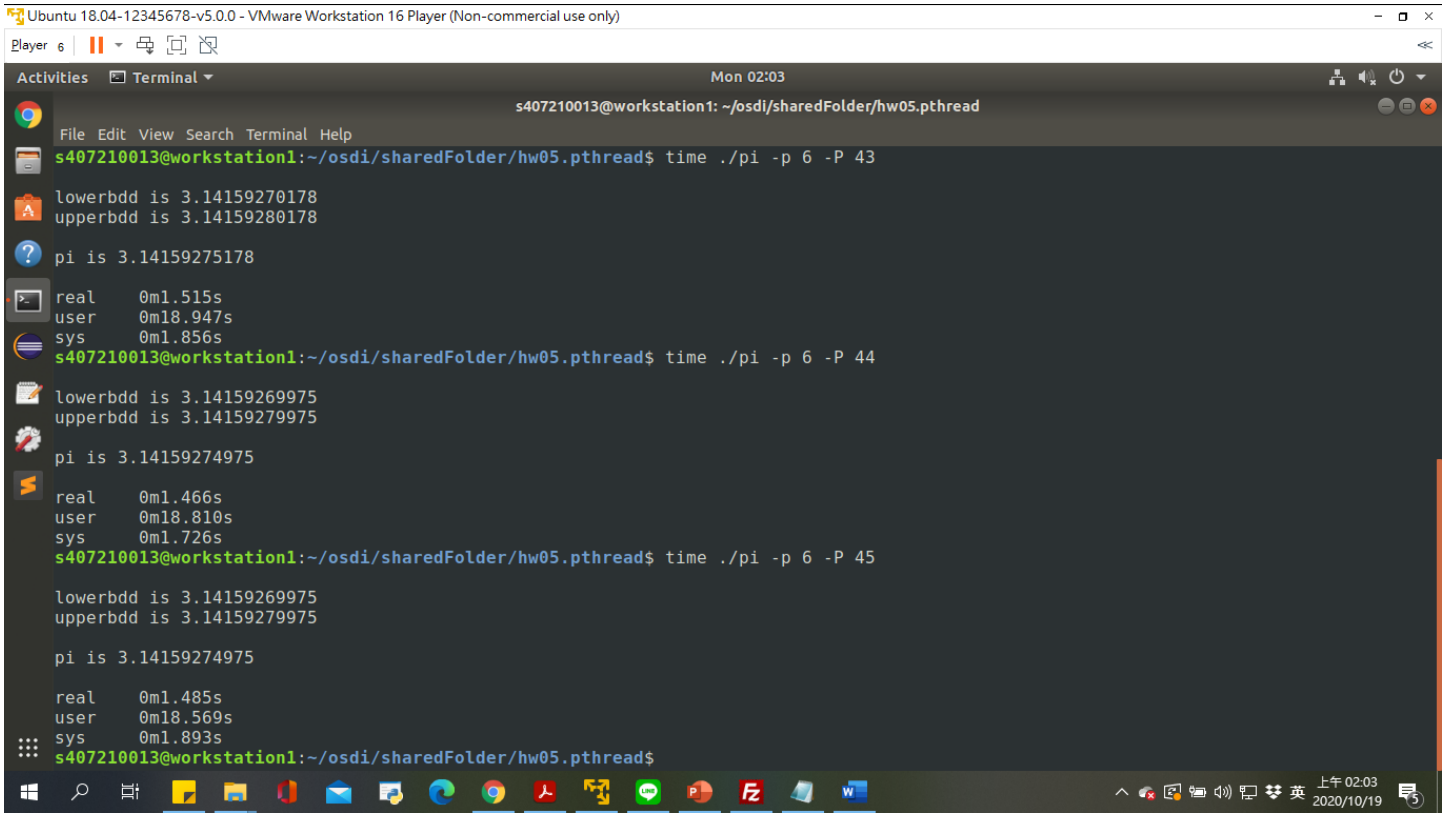

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 02:00
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 28
lowerbdd is 3.14159270293
upperbdd is 3.14159280293
pi is 3.14159275293
real 0m1.493s
user 0m18.330s
sys 0m0.968s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 29
lowerbdd is 3.14159270308
upperbdd is 3.14159280308
pi is 3.14159275308
real 0m1.482s
user 0m18.164s
sys 0m1.065s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 30
lowerbdd is 3.14159270308
upperbdd is 3.14159280308
pi is 3.14159275308
real 0m1.458s
user 0m18.073s
sys 0m1.088s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 02:00
2020/10/19

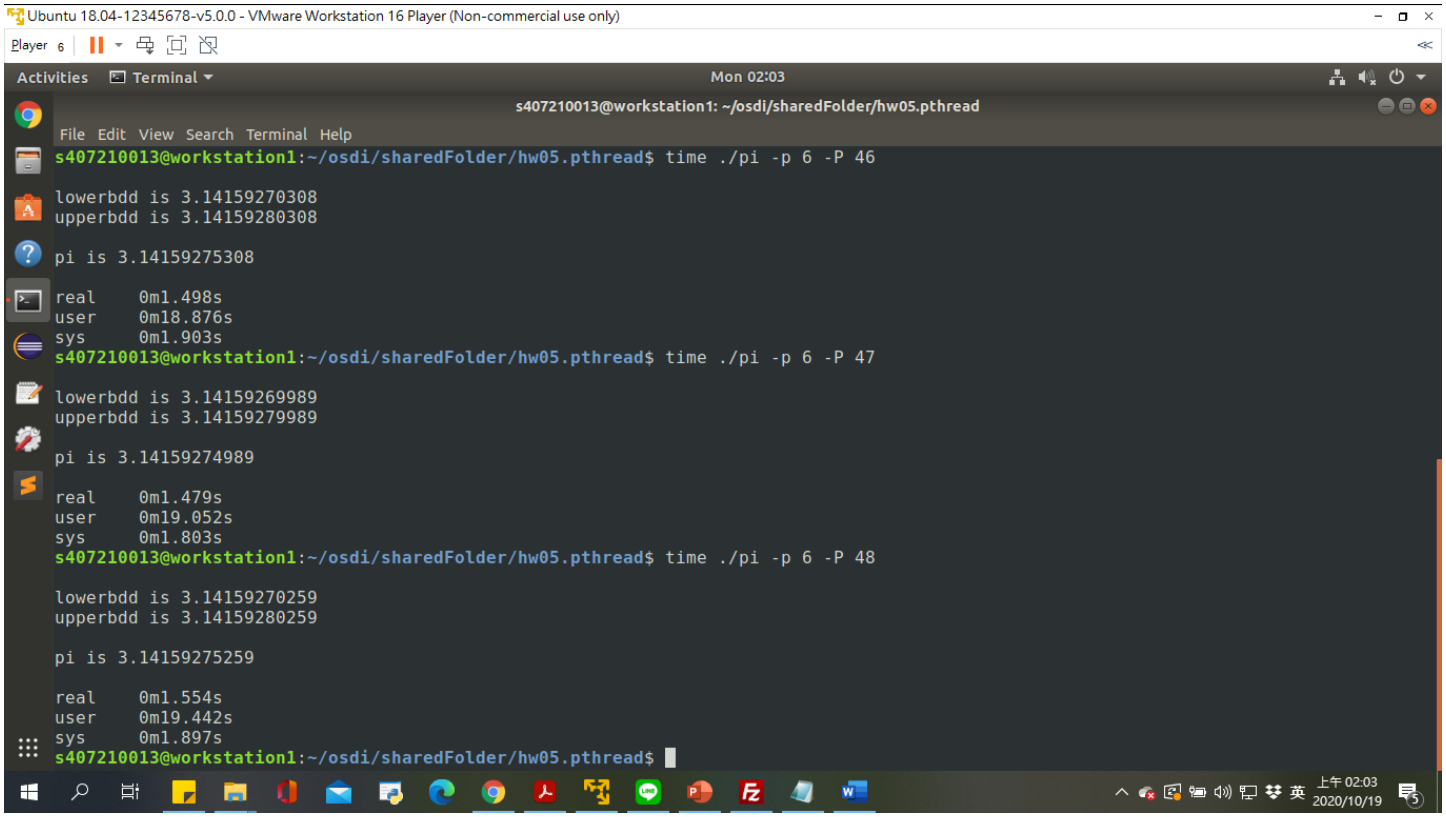

Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 02:01
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 31
lowerbdd is 3.14159270240
upperbdd is 3.14159280240
pi is 3.14159275240
real 0m1.470s
user 0m18.217s
sys 0m1.221s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 32
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m1.467s
user 0m18.180s
sys 0m1.194s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 33
lowerbdd is 3.14159270328
upperbdd is 3.14159280328
pi is 3.14159275328
real 0m1.466s
user 0m17.969s
sys 0m1.462s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 02:01
2020/10/19


Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 02:01
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 34
lowerbdd is 3.14159270221
upperbdd is 3.14159280221
pi is 3.14159275221
real 0m1.465s
user 0m18.175s
sys 0m1.552s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 35
lowerbdd is 3.14159270340
upperbdd is 3.14159280340
pi is 3.14159275340
real 0m1.470s
user 0m18.282s
sys 0m1.448s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 36
lowerbdd is 3.14159270345
upperbdd is 3.14159280345
pi is 3.14159275345
real 0m1.431s
user 0m18.472s
sys 0m1.186s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 02:01
2020/10/19


Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 02:02
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 37
lowerbdd is 3.14159270349
upperbdd is 3.14159280349
pi is 3.14159275349
real 0m1.460s
user 0m18.315s
sys 0m1.301s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 38
lowerbdd is 3.14159270200
upperbdd is 3.14159280200
pi is 3.14159275200
real 0m1.409s
user 0m18.426s
sys 0m1.353s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 39
lowerbdd is 3.14159270356
upperbdd is 3.14159280356
pi is 3.14159275356
real 0m1.470s
user 0m18.633s
sys 0m1.523s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 02:02
2020/10/19


Ubuntu 18.04-12345678-v5.0.0 - VMware Workstation 16 Player (Non-commercial use only)
Player
Activities
Terminal
Mon 02:02
s407210013@workstation1: ~/osdi/sharedFolder/hw05.pthread
File Edit View Search Terminal Help
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 40
lowerbdd is 3.14159270359
upperbdd is 3.14159280359
pi is 3.14159275359
real 0m1.454s
user 0m18.279s
sys 0m1.601s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 41
lowerbdd is 3.14159270095
upperbdd is 3.14159280095
pi is 3.14159275095
real 0m1.470s
user 0m18.759s
sys 0m1.523s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$ time ./pi -p 6 -P 42
lowerbdd is 3.14159269975
upperbdd is 3.14159279975
pi is 3.14159274975
real 0m1.450s
user 0m18.572s
sys 0m1.609s
s407210013@workstation1:~/osdi/sharedFolder/hw05.pthread$
上午 02:02
2020/10/19

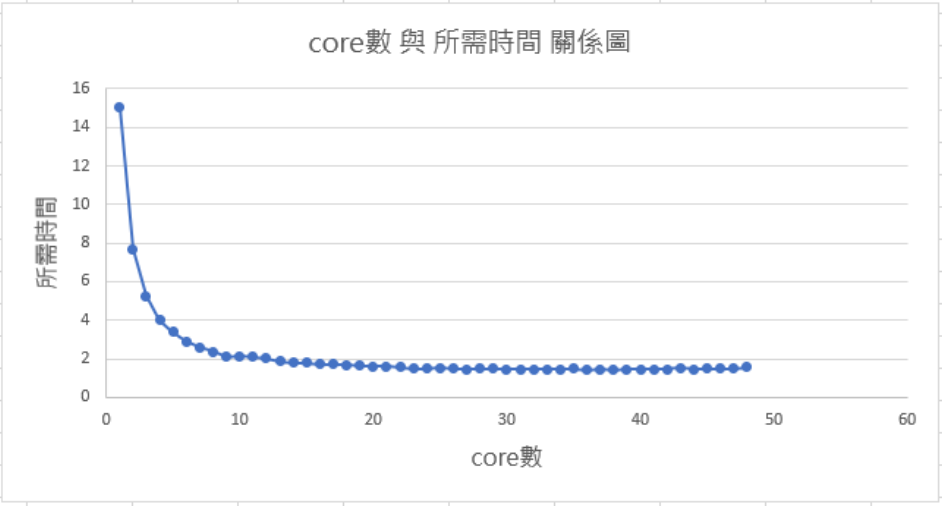




以上為各核心數下統計出來的所需時間。

以下為Core數與所需時間之關係圖，發現可得到非比尋常的線性加速，執行上減少許多花費的時間。

core數	所需時間
1	15.078
2	7.681
3	5.276
4	4.001
5	3.408
6	2.914
7	2.602
8	2.366
9	2.107
10	2.132
11	2.091
12	2.018
13	1.867
14	1.781
15	1.788
16	1.712
17	1.737
18	1.69



主題丙：

對於上界與下界的取法，我們只對下界進行累加，由於上界值與下界值只少了一塊最左邊以圓半徑為長，等分切格的值為寬，所構成之矩形。因此讓下界加上此矩形，便為上界的值，讓時間減少不少。

```
27 //注意，我使用了「volatile」
28 volatile double score[100];
29
30 void thread(void *givenName) {
31     int id = (intptr_t)givenName;
32     double pi = 0.0;
33     double width = (double)1 / loopCount;
34     for(size_t i = loopCount / numCPU * id ; i < loopCount / numCPU * (id + 1) ; i++){
35         double x = (double)i / loopCount;
36         pi = pi + width * sqrt(1 - x * x);
37     }
38     score[id] = pi;
39 }
40
```

```
60     double lowerbdd = 0;
61     double upperbdd = 1;
62     double tol = pow(10 , -(x + 1));
63     int y = 3;
64     while((upperbdd - lowerbdd) >= (tol / 4) && keepRunning){
65         lowerbdd = 0;
66         pthread_t* tid = (pthread_t*)malloc(sizeof(pthread_t) * numCPU);
67         for (long i=0 ; i< numCPU ; i++)
68             pthread_create(&tid[i], NULL, (void *) thread, (void*)i);
69
70         for (int i=0 ; i< numCPU ; i++)
71             pthread_join(tid[i], NULL);
72
73         for (int i = 0; i < numCPU ; i++)
74             lowerbdd += score[i];
75
76         upperbdd = lowerbdd + (double)1 / loopCount;
77         if(loopCount / 10 < pow(10 , y)){
78             loopCount = loopCount + pow(10 , y - 1);
79         }
80         else{
81             loopCount = loopCount + pow(10 , y);
82             y = y + 1;
83         }
84
```