ASSIGNMENT 1- SEQUENTIAL SEARCHING AND PARALLEL SEARCHING USING OPENMP REPORT

CSC4005 High Performance Computing

Abstract

I doing some coding and some tests to research and solve some problems with openMP . The openMP API is very useful for parallel application.

1.introduction

OpenMP API have been developed to support parallel application. It provides parallel application programmer with a model for parallel programming that is portable across architecture from different ventors , and it has been widely accepted as a set of Compiler Directives for multiprocessor programming of shared memory parallel systems . OpenMP supported programming languages include C, C++, and Fortran; and OpenMp-enabled compilers include Sun Compiler, GNU Compiler, and Intel Compiler. OpenMp provides a high-level abstract description of parallel algorithms. The programmer specifies the intent by adding a dedicated pragma to the source code, so that the compiler can automatically parallelize the program and add synchronization mutex where necessary. And communication. When we choose to ignore these pragmas, or if the compiler does not support OpenMp, the program can degenerate into the usual program (usually serial), the code will still work.

In this assignment, I focus on the basic use of openMP, and discuss the performance about using openMP to a straightforward pattern matching algorithm with diffident threads. In detail, understand how straightforward pattern matching algorithm works. Generate the test cases, and coding the searching sequential.c into an OpenMP program,also need find the bug and do some optimizations on code to improve the performance.

2.1 Part A - Sequential Searching

About straightforward pattern matching algorithm:

The name of the straightforward pattern matching algorithm is very cool, but the efficiency is not very good, which is a simple, rude way to search.

About the Worst case of straightforward pattern matching algorithm: the time complexity of straightforward pattern matching is O(mn) ,which also have not a preprocessing stage.So that In the worst case, the straightforward pattern matching algorithm looks for a length of M in a text of length N and requires ~NM character comparisons, until it found the pattern on text at last M.

Therefore, I figured out a way to solve this, for example if the pattern is [aaab] , then the text is [aaaaaaaaaaaab], the algorithm will do full pattern length 4 times searches from each letter, and totally do (14-4)*4 times searches until the pattern found at the end.

About the code:

Time function:

In some testcases, elapsed wall clock time is “0.000000” because the value returned from the time() function which in the original code couldn’t have a high accurate to the 0.000000 . After tried a few different timing function and finally a high precision time function - gettimeofday() has been choose to be used on this code because the time it returns accurate to microseconds which meet the requirement perfectly. What’s more it’s also in the time.h, so that we can introduce it easily without add new head files.

Snippet of code:

[Length of Pattern and text choose] part:'

Totally 20 patterns and texts which will result in the worst case performance and note the CPU execution time for different length(text)*length(pattern).
For the selection of pattern and text length. In the first four testcases I design the pattern length is 2 ,4, 5 ,10(the pattern is "ab","aaab","aaaab","aaaaaaaaab") and the text length is simply the 100/[pattern Length], as there is a rule that the product length(text)*length(pattern) should be approximately equal to 10^2, 10^4, 10^6, 10^8 and 10^10. So, each 4 test cases is a stage. Pattern Length will multiply by 100 in next stage, length is always following the formula: [text length] = product / [pattern Length].
There is another benefit of the design is that the totally file size is very small, less than 100 MB whatever.

And the Snippet of code as below:

```
long textLength;
long patternLength;// 2 4 5 10

if(testNumber>=0 && testNumber<4){
        if(testNumber%4==0)//0
                patternLength = 2;
        if(testNumber%4==1)//1
                patternLength = 4;
        if(testNumber%4==2)//2
                patternLength = 5;
        if(testNumber%4==3)//3
                patternLength = 10;
        textLength = 100/patternLength;

}
if(testNumber>=4 && testNumber<8){
        if(testNumber%4==0)//4
                patternLength = 20;
        if(testNumber%4==1)//5
                patternLength = 40;
        if(testNumber%4==2)//6
                patternLength = 50;
        if(testNumber%4==3)//7
                patternLength = 100;
        textLength = 10000/patternLength;

}
if(testNumber>=8 && testNumber<12){
        if(testNumber%4==0)//8
                patternLength = 200;
        if(testNumber%4==1)//9
                patternLength = 400;
        if(testNumber%4==2)//10
                patternLength = 500;
        if(testNumber%4==3)//11
                patternLength = 1000;
        textLength = 1000000/patternLength;
}
```

Folder creation part, generate text and pattern, and write them to each document:

About the text and pattern generation, I used 2 for loop to create them respective:

Put ‘a’ to index (0~arrayLength-2), then put b to index arrayLength-1

And use open() function and write() function to create text file and write the array of text and pattern to the corresponding file.

And the Snippet of code as below:

```
char textName[1000];
sprintf(textName,"inputs/test%d/text.txt",testNumber);
int handle_text;
char *text = (char*)malloc(textLength * sizeof(char));
handle_text = open(textName,O_CREAT|O_RDWR,0777);
if(handle_text ==-1){
        printf("errno=%d\n",errno);
        printf("couldn't create text for test%d\n",testNumber);
}
int ch = 'a';
int i;
for(i=0;i<textLength-1;i++)
        text[i] = ch;
text[textLength-1] = 'b';
write(handle_text,text,textLength);
free(text);


char patternName[1000];
sprintf(patternName,"inputs/test%d/pattern.txt",testNumber);
int handle_pattern;
char pattern[patternLength];
handle_pattern = open(patternName,O_CREAT|O_RDWR,0777);
if(handle_pattern ==-1){
        printf("errno=%d\n",errno);
        printf("couldn't create pattern for test%d\n",testNumber);
}

pattern[patternLength-1] = 'b';
for(i=patternLength-2;i>=0;i--)
        pattern[i] = 'a';
write(handle_pattern,pattern,patternLength);
if(handle_text!=-1 && handle_pattern!=-1)
        printf("create text and pattern for test%d successfully\n",testNumber);
```

Results(output):

Read test number 0

Text length = 50

Pattern length = 2

Pattern found at position 48

comparisons = 98

Test 0 elapsed wall clock time = 0.000005

Test 0 elapsed CPU time = 0.000000

Read test number 1

Text length = 25

Pattern length = 4

Pattern found at position 21

comparisons = 88

Test 1 elapsed wall clock time = 0.000005

Test 1 elapsed CPU time = 0.000000

Read test number 2

Text length = 20

Pattern length = 5

Pattern found at position 15

comparisons = 80

Test 2 elapsed wall clock time = 0.000004

Test 2 elapsed CPU time = 0.000000

Read test number 3

Text length = 10

Pattern length = 10

Pattern found at position 0

comparisons = 10

Test 3 elapsed wall clock time = 0.000004

Test 3 elapsed CPU time = 0.000000

Read test number 4

Text length = 500

Pattern length = 20

Pattern found at position 480

comparisons = 9620

Test 4 elapsed wall clock time = 0.000033

Test 4 elapsed CPU time = 0.000000

Read test number 5

Text length = 250

Pattern length = 40

Pattern found at position 210

comparisons = 8440

Test 5 elapsed wall clock time = 0.000029

Test 5 elapsed CPU time = 0.000000

Read test number 6

Text length = 200

Pattern length = 50

Pattern found at position 150

comparisons = 7550

Test 6 elapsed wall clock time = 0.000026

Test 6 elapsed CPU time = 0.000000

Read test number 7

Text length = 100

Pattern length = 100

Pattern found at position 0

comparisons = 100

Test 7 elapsed wall clock time = 0.000005

Test 7 elapsed CPU time = 0.000000

Read test number 8

Text length = 5000

Pattern length = 200

Pattern found at position 4800

comparisons = 960200

Test 8 elapsed wall clock time = 0.002755

Test 8 elapsed CPU time = 0.000000

Read test number 9

Text length = 2500

Pattern length = 400

Pattern found at position 2100

comparisons = 840400

Test 9 elapsed wall clock time = 0.002289

Test 9 elapsed CPU time = 0.000000

Read test number 10

Text length = 2000

Pattern length = 500

Pattern found at position 1500

comparisons = 750500

Test 10 elapsed wall clock time = 0.002062

Test 10 elapsed CPU time = 0.000000

Read test number 11

Text length = 1000

Pattern length = 1000

Pattern found at position 0

comparisons = 1000

Test 11 elapsed wall clock time = 0.000008

Test 11 elapsed CPU time = 0.000000

Read test number 12

Text length = 50000

Pattern length = 2000

Pattern found at position 48000

comparisons = 96002000

Test 12 elapsed wall clock time = 0.261211

Test 12 elapsed CPU time = 0.260000

Read test number 13

Text length = 25000

Pattern length = 4000

Pattern found at position 21000

comparisons = 84004000

Test 13 elapsed wall clock time = 0.228414

Test 13 elapsed CPU time = 0.230000

Read test number 14

Text length = 20000

Pattern length = 5000

Pattern found at position 15000

comparisons = 75005000

Test 14 elapsed wall clock time = 0.210776

Test 14 elapsed CPU time = 0.200000

Read test number 15

Text length = 10000

Pattern length = 10000

Pattern found at position 0

comparisons = 10000

Test 15 elapsed wall clock time = 0.000032

Test 15 elapsed CPU time = 0.000000

Read test number 16

Text length = 500000

Pattern length = 20000

Pattern found at position 480000

comparisons = 9600020000

Test 16 elapsed wall clock time = 25.954374

Test 16 elapsed CPU time = 25.900000

Read test number 17

Text length = 250000

Pattern length = 40000

Pattern found at position 210000

comparisons = 8400040000

Test 17 elapsed wall clock time = 22.770283

Test 17 elapsed CPU time = 22.709999

Read test number 18

Text length = 200000

Pattern length = 50000

Pattern found at position 150000

comparisons = 7500050000

Test 18 elapsed wall clock time = 20.294216

Test 18 elapsed CPU time = 20.190001

Read test number 19

Text length = 100000

Pattern length = 100000

Pattern found at position 0

comparisons = 100000

Test 19 elapsed wall clock time = 0.000276

Test 19 elapsed CPU time = 0.000000

Points selection:

Results(graphs):

2.2 Part B - Parallel Searching using OpenMP

the data below will be used as a reference point(sequential) for test0,1,2 :

[40120405@login1(kelvin) assignment-1b]$ $time ./searching_sequential

Read test number 0

Text length = 2000000

Pattern length = 2000

Pattern found at position 1998000

comparisons = 3996002000

Test 0 elapsed wall clock time = 11

Test 0 elapsed CPU time = 10.680000

Read test number 1

Text length = 10000000

Pattern length = 1000

Pattern found at position 1001

comparisons = 1002000

Test 1 elapsed wall clock time = 0

Test 1 elapsed CPU time = 0.000000

Read test number 2

Text length = 10000000

Pattern length = 1000

Pattern found at position 5001001

comparisons = 5001002000

Test 2 elapsed wall clock time = 14

Test 2 elapsed CPU time = 13.380000

Test0:

3.result：

When using openMP instead of sequential:

3a. Table of elapsed times and numbers of comparisons for 3 diffident scheduling strategies:

Static:

threads	elapsed wall clock time	# comparisons
1	14	3996002000
2	17	2030548914
4	15	1096949133
8	14	710435625
16	14	502073365
32	13	306680491
64	13	213813455

Dynamic:

threads	elapsed wall clock time	# comparisons
1	15	3996002000
2	11	2001120988
4	12	881603152
8	15	616882128
16	13	490186714
32	16	303730807
64	13	251423397

Guided:

threads	elapsed wall clock time	# comparisons
1	14	3996002000
2	12	2068039267
4	15	1009143678
8	17	589765247
16	16	481164226
32	16	297276873
64	17	176220192

3b.

Static:

parallel speedup(1) = 14/14=1

parallel speedup(2) = 14/17=0.824

parallel speedup(4) = 14/15=0.933

parallel speedup(8) = 14/14=1

parallel speedup(16) = 14/14=1

parallel speedup(32) = 14/13=1.077

parallel speedup(64) = 14/13=1.077

dynamic:

parallel speedup(1) = 15/15=1

parallel speedup(2) = 15/11=1.364

parallel speedup(4) = 15/12=1.25

parallel speedup(8)=15/15=1

parallel speedup(16)=15/13=1.154

parallel speedup(32)=15/16=0.938

parallel speedup(64)=15/13=1.154

guided:

parallel speedup(1) = 14/14=1

parallel speedup(2) = 14/12=1.167

parallel speedup(4) = 14/15=0.933

parallel speedup(8)= 14/17=0.824

parallel speedup(16)=14/16=0.875

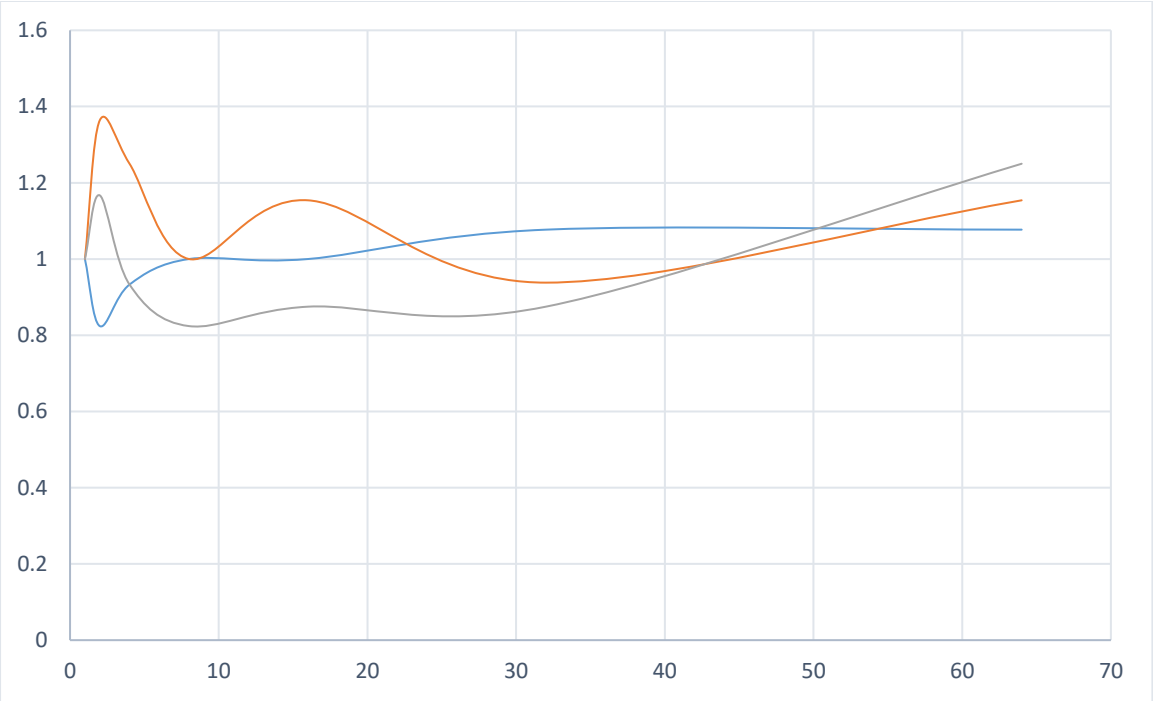
parallel speedup(32)=14/16=0.875

parallel speedup(64)=14/17=0.824

graph of the parallel speedup vs the number of threads:

x: the number of threads

y: the parallel speedup(blue:static,red:dynamic,gray:guided)



3c.

Static:

parallel efficiency (1) = 1/1=1

parallel efficiency (2) = 0.824/2=0.412

parallel efficiency (4) = 0.933/4=0.233

parallel efficiency (8) = 1/8=0.125

parallel efficiency (16) = 1/16=0.062

parallel efficiency (32) = 1.077/32=0.034

parallel efficiency (64) = 1.077/64=0.017

dynamic:

parallel efficiency (1) = 1/1=1

parallel efficiency (2) = 1.364/2 = 0.682

parallel efficiency (4) = 1.25/4= 0.3125

parallel efficiency (8) = 1/8=0.125

parallel efficiency (16) = 1.154/16=0.072

parallel efficiency (32) = 0.938/32=0.029

parallel efficiency (64) = 1.154/64=0.018

guided:

parallel efficiency (1) = 1/1=1

parallel efficiency (2) = 1.167/2=0.584

parallel efficiency (4) = 0.933/4=0.233

parallel efficiency (8) = 0.824/8=0.103

parallel efficiency (16) = 0.875/16=0.054

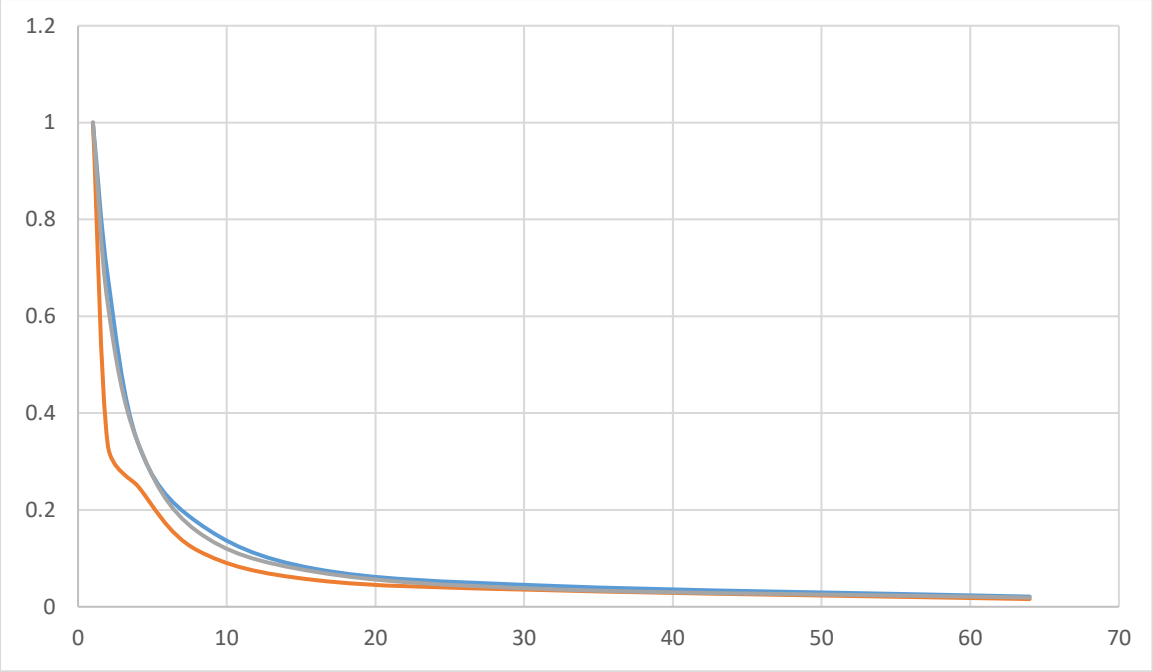
parallel efficiency (32) = 0.875/32=0.027

parallel efficiency (64) = 0.824/64=0.013

graph of the parallel efficiency vs the number of threads:

x: number of threads:

y: parallel efficiency (blue: static,red:dynamic,gray:guided)



Conclusion: According to the 2 graphs of PS vs P and PE vs P, there is no too much diffidence regarding to 3 scheduling strategies, and the performance of static schedule is slightly better than other 2's. However, while the threads increase, the parallel efficiency is decline, the relationship of them is nearly y = 1/x.

Test1:

2.

Result of using searching OMP 0.c on the test case 1 using two threads:

using 2 threads:

Text length = 10000000

Pattern length = 1000

Pattern found at position 1001

comparisons = 5154093467

using 2 threads: on test0 elapsed wall clock time = 29

using 2 threads: elapsed CPU time = 54.869999

3.

After observe the result, the wall clock time is nearly 30s, which is much longer than running on test case 0. The number of comparisons is also much longer. That's because in test case 1, the pattern is in the front part of text. If it's in the sequential program, the pattern would be found very quickly then the program quit. But on openMP there is no exit function to break the loop, it must run through all the letters in the text even if the pattern has been found, that's where the "bug" is.

4.

Combined with the reason of the performance problem, I simply add a conditional statement:

```
for(i=0;i<=lastI;i++){
        if(position != -1)// pattern has been found
                continue;


        k=i;
        j=0;
```

Which means when pattern has been found, the position of the pattern will assign to the variable [position], after condition checking, the program passed at loop start. so the program will not do any search after pattern has been found. The performance is very good:

```
using 2 threads:
Text length = 10000000
Pattern length = 1000
Pattern found at position 1001
# comparisons = 1091672
using 2 threads: on test0 elapsed wall clock time = 0
using 2 threads: elapsed CPU time = 0.040000

using 4 threads:
Text length = 10000000
Pattern length = 1000
Pattern found at position 1001
# comparisons = 2658883
using 4 threads: on test0 elapsed wall clock time = 0
using 4 threads: elapsed CPU time = 0.860000

using 8 threads:
Text length = 10000000
Pattern length = 1000
Pattern found at position 1001
# comparisons = 6219281
using 8 threads: on test0 elapsed wall clock time = 1
using 8 threads: elapsed CPU time = 2.360000
```

Test2

3.Conclusion

This is a very good assignment which helps us totally understand the basic knowledge about openMP. Thorough doing the assignment, I consider that there still be a lot of points need me to master, especially the 3 scheduling strategies and how to boosting the performance of a parallel program. To this end, my next step is to learn other unknown information about parallel computing for building high efficiency programs in future.