Report

Prime Numbers

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Abstract

The purpose of this document is to compare the differences between sequential and concurrent code. The only difference between the two is the use of OpenMP in the concurrent code. This allows the code to run on multiple threads.

Pseudo Code

```
Bool isPrime(int n)
        If n <= 1 return false
        If n <= 3 return true

        If n%2 = 0 or n%3 = 0 return false

        For i = 5; i*i<=n; i=i+6
                If n%i = 0 or n%i+2 == 0 return false
        Return true

Int countPrimes(int p)
        C = 0
        If isPrime(p)
                C++
        Return c

Public void twinPrime(int range, int threads)
        Int count = 0
        Int countTwin = 0;

        #pragma omp parallel for num_threads(threads) reduction(+: count, countTwin)
        For int i = 0; i < range; i++
                If isPrime(i) && isPrime(i+2)
                        countTwin++
                        Print i and i + 2
                Count += countPrimes(i)
        Print countTwin
        Print count

Int main(int argc, char* argv)
Int num = atoi(argv[1])
Int threads = atoi(argv[2])

twinPrime(num, threads)
Return 0
```

Sequential

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    2m44.284s
user    2m44.227s
sys     0m0.033s
```

Absolute Time Sequential:
Run 1: 2m44.284s
Run 2: 2m43.956s
Run 3: 2m44.125s
Avg. : 2m44.122s = 164.122

Parallel 1 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    2m43.917s
user    2m43.931s
sys     0m0.016s
```

Run 1: 2m43.945s
Run 2: 2m 48.525s
Run 3: 2m 43.781s
Avg. : 2m 45.417s = 165.417

Parallel 2 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    1m43.653s
user    2m43.973s
sys     0m0.000s
```

Run 1 : 1m43.653s
Run 2 : 1m43.385s
Run 3 : 1m43.588s
Avg. : 1m43.542s = 103.542s

Absolute Speed up:
164.122 / 103.542 = ~1.585

Relative Speed up:
165.417 / 103.542 = ~1.598

Parallel 3 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real     1m13.953s
user     2m45.830s
sys      0m0.056s
```

Run 1 : 1m13.953s
Run 2 : 1m13.855s
Run 3 : 1m14.443s
Avg. : 1m14.428s = 74.428s

Absolute Speed up:
164.122 / 74.428 = ~2.205

Relative Speed up:
165.417 / 74.428 = ~2.223

Parallel 4 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real     0m57.986s
user     2m51.883s
sys      0m0.025s
```

Run 1 : 0m57.986s
Run 2 : 0m58.731s
Run 3 : 0m56.970s
Avg. : 0m57.897s

Absolute Speed up:

164.122 / 57.897 = ~2.835

Relative Speed up:

165.417 / 87.897 = ~2.857

Parallel 5 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    0m47.351s
user    2m52.977s
sys     0m0.029s
```

Run 1 : 0m47.351s

Run 2 : 0m50.718s

Run 3 : 0m47.851s

Avg. : 0m48.640

Absolute Speed up:

164.122 / 48.640 = ~3.374

Relative Speed up:

165.417 / 48.640 = ~3.401

Parallel 6 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    0m42.482s
user    3m8.966s
sys     0m0.110s
```

Run 1 : 0m42.482s

Run 2 : 0m42.823s

Run 3 : 0m42.588s

Avg. : 0m42.631

Absolute Speed up:

164.122 / 42.631 = ~3.850

Relative Speed up:

165.417 / 42.631 = ~3.880

Concurrent 7 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    0m40.595s
user    3m18.994s
sys     0m0.104s
```

Run 1 : 0m40.595s
Run 2 : 0m40.780s
Run 3 : 0m39.961s
Avg. : 0m40.445

Absolute Speed up:
164.122 / 40.445 = ~4.058

Relative Speed up:
165.417 / 40.445 = ~4.090

Concurrent 8 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    0m37.403s
user    3m17.565s
sys     0m0.128s
```

Run 1 : 0m37.403s
Run 2 : 0m40.816s
Run 3 : 0m39.994s
Avg. : 0m39.404

Absolute Speed up:
164.122 / 39.404 = ~4.165

Relative Speed up:
165.417 / 39.404 = ~4.198

Concurrent 16 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    0m35.992s
user    3m23.361s
sys     0m0.181s
```

Run 1 : 0m35.992s
Run 2 : 0m34.982s
Run 3 : 0m34.946s
Avg. : 0m35.307

Absolute Speed up:
164.122 / 35.307 = ~4.648

Relative Speed up:
165.417 / 35.307 = ~4.485

Concurrent 32 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    0m34.778s
user    3m26.713s
sys     0m0.155s
```

Run 1 : 0m34.778s
Run 2 : 0m35.596s
Run 3 : 0m35.215s
Avg. : 0m35.196

Absolute Speed up:
164.122 / 35.196= ~4.663

Relative Speed up:
165.417 / 35.196 = ~4.610

Concurrent 64 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    0m35.152s
user    3m30.082s
sys     0m0.160s
```

Run 1 : 0m35.152s
Run 2 :0m34.929s
Run 3 : 0m35.075s
Avg. : 0m35.052

Absolute Speed up:
164.122 / 35.052 = ~4.682

Relative Speed up:
165.417 / 35.052 = ~4.719

Concurrent 128 Core

```
Number of twin primes between 1 and 100000000 is 440312
Number of Primes: 5761455
real    0m35.776s
user    3m33.883s
sys     0m0.184s
```

Run 1 : 0m35.776s
Run 2 : 0m34.898s
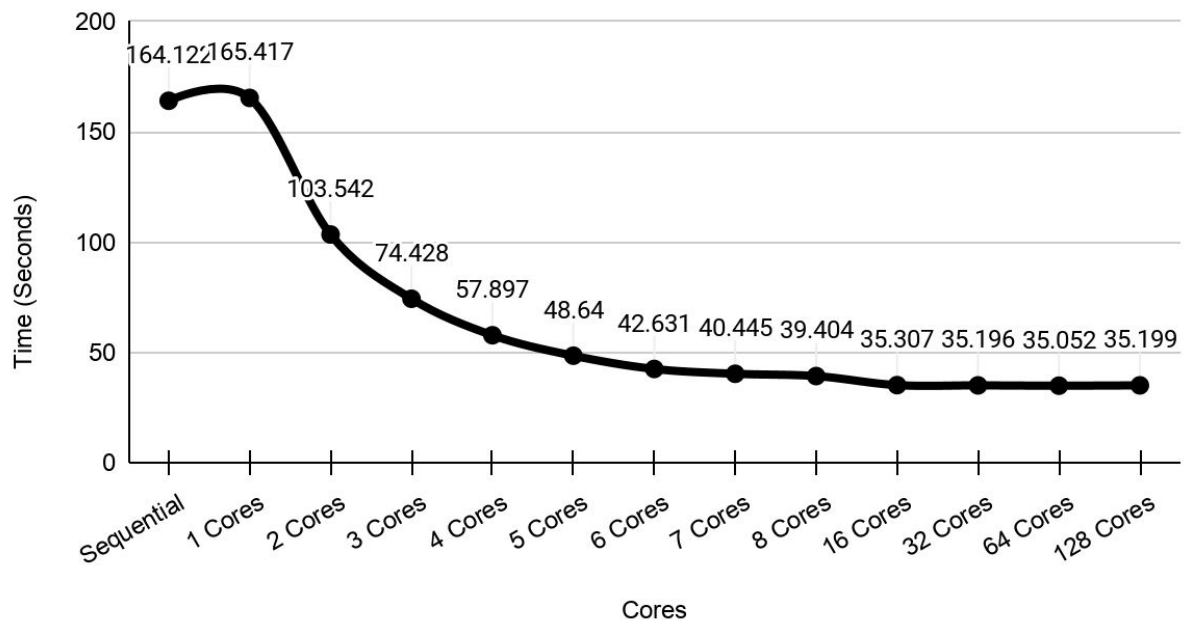Run 3 : 0m34.924s
Avg. : 0m35.199

Absolute Speed up:
164.122 / 35.199 = ~4.663

Relative Speed up:
165.417 / 35.199 = ~4.699

Time vs Cores

Time vs Cores chart. Time (Seconds) vs Cores. Values: Sequential 164.122, 1 Cores 165.417, 2 Cores 103.542, 3 Cores 74.428, 4 Cores 57.897, 5 Cores 48.64, 6 Cores 42.631, 7 Cores 40.445, 8 Cores 39.404, 16 Cores 35.307, 32 Cores 35.196, 64 Cores 35.052, 128 Cores 35.199

Scalability

To determine scalability of the code, the number was chosen to run in sequential and parallel code with each iteration the number is doubled until scalability can be assessed. Parallel code was run with 16 cores.

Sequential

N = 400, 000

```
Number of twin primes between 1 and 400000 is 3804
Number of Primes: 33860
real    0m0.064s
user    0m0.064s
sys     0m0.000s
```

N = 800, 000

```
Number of twin primes between 1 and 800000 is 6766
Number of Primes: 63951
real    0m0.168s
user    0m0.167s
sys     0m0.000s
```

N = 1, 600, 000

```
Number of twin primes between 1 and 1600000 is 12260
Number of Primes: 121127
real    0m0.442s
user    0m0.441s
sys     0m0.000s
```

N = 3, 200, 000

```
Number of twin primes between 1 and 3200000 is 22137
Number of Primes: 230209
real    0m1.175s
user    0m1.175s
sys     0m0.000s
```

N = 6, 400, 000

```
Number of twin primes between 1 and 6400000 is 40092
Number of Primes: 438410
real    0m3.155s
user    0m3.155s
sys     0m0.000s
```

N = 12, 800, 000

```
Number of twin primes between 1 and 12800000 is 72946
Number of Primes: 837099
real    0m8.518s
user    0m8.512s
sys     0m0.006s
```

N = 25, 600, 000

```
Number of twin primes between 1 and 25600000 is 133180
Number of Primes: 1601049
real    0m22.978s
user    0m22.978s
sys     0m0.000s
```

Parallel

N = 400, 000

```
Number of twin primes between 1 and 400000 is 3804
Number of Primes: 33860
real    0m0.018s
user    0m0.071s
sys     0m0.000s
```

N = 800, 000

```
Number of twin primes between 1 and 800000 is 6766
Number of Primes: 63951
real    0m0.064s
user    0m0.244s
sys     0m0.008s
```

N = 1, 600, 000

```
Number of twin primes between 1 and 1200000 is 9599
Number of Primes: 92938
real    0m0.083s
user    0m0.351s
sys     0m0.013s
```

N = 3, 200, 000

```
Number of twin primes between 1 and 3200000 is 22137
Number of Primes: 230209
real    0m0.270s
user    0m1.383s
sys     0m0.008s
```
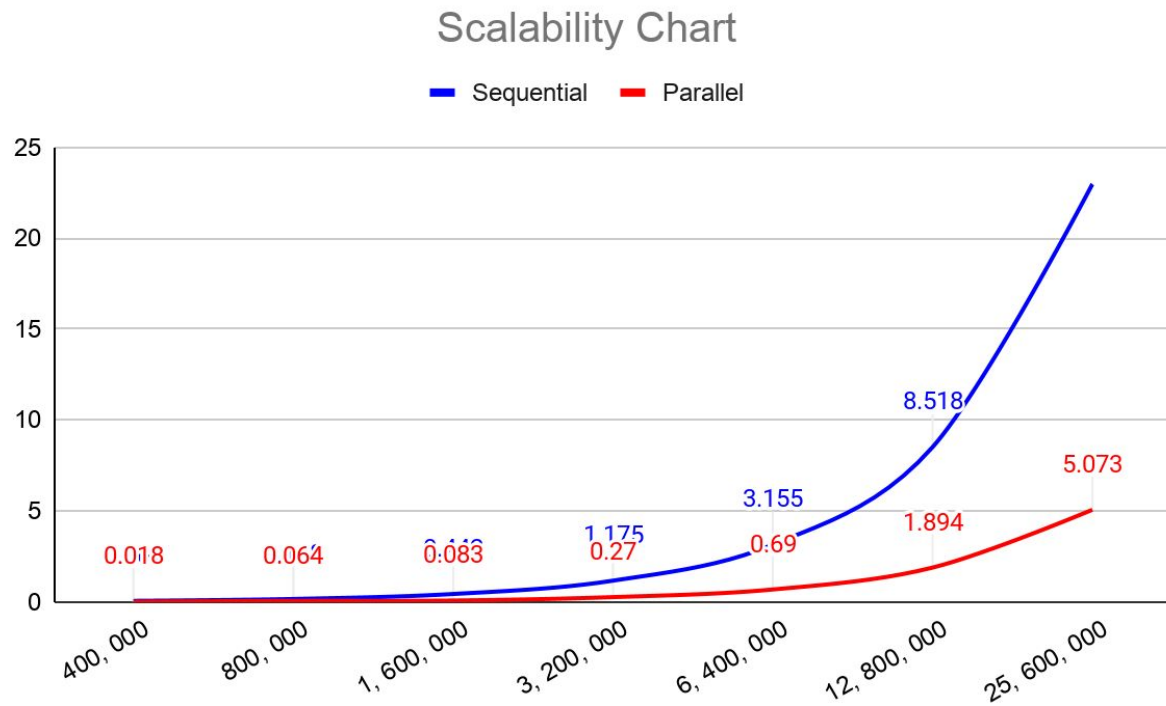
N = 6, 400, 000

```
Number of twin primes between 1 and 6400000 is 40092
Number of Primes: 438410
real    0m0.690s
user    0m3.781s
sys     0m0.004s
```

N = 12, 800, 000

```
Number of twin primes between 1 and 12800000 is 72946
Number of Primes: 837099
real    0m1.894s
user    0m10.369s
sys     0m0.004s
```

N = 25, 600, 000

```
Number of twin primes between 1 and 25600000 is 133180
Number of Primes: 1601049
real    0m5.073s
user    0m28.844s
sys     0m0.053s
```

Scalability Chart

— Sequential   — Parallel

```
25 ┤
   │
20 ┤
   │
15 ┤
   │                                              8.518
10 ┤                                                      5.073
   │                                    3.155
5  ┤                          1.175        1.894
   │ 0.018   0.064   0.083    0.27  0.69
0  ┤
   └────────────────────────────────────────────────────────
   400,000  800,000  1,600,000  3,200,000  6,400,000  12,800,000  25,600,000
```

Conclusion

Sequential program does not differ much from a parallel program that is run on 1 core as the times are very close. After a certain point it did not matter if a code was run with double the amount of cores as the results were within 1 second of each other.

The difference in speed can be seen on the scalability graph. Sequential programs run time has more than doubled each time the range was doubled.