National Institute of Technology Karnataka Surathkal,
Mangalore - 575025

DEPARTMENT OF INFORMATION TECHNOLOGY

LAB ASSIGNMENT 5

Submitted for Parallel Computing (IT301) By

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To

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Code link
github

problem - 1

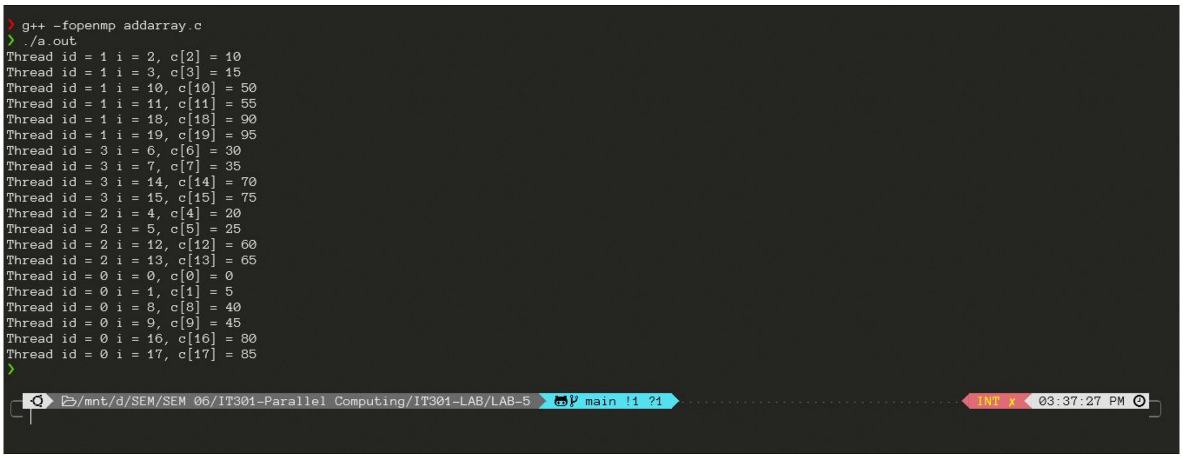
```
#include <stdio.h>
#include <omp.h>
int main()
{
    int i, n, chunk;
    int a[20], b[20], c[20];
    n = 20;
    chunk = 2;
    /*initializing array*/
    for (i = 0; i < n; i++)
    {
        a[i] = i * 2;
        b[i] = i * 3;
    }
#pragma omp parallel for default(shared) private(i)
schedule(static, chunk)
    for (i = 0; i < n; i++)
    {
        c[i] = a[i] + b[i];
        printf("Thread id = %d i = %d, c[%d] = %d\n",
omp_get_thread_num(), i, i, c[i]);
    }
}
```

Output

```
❯ g++ -fopenmp addarray.c
❯ ./a.out
```

Chunk = 2 & threads = 4

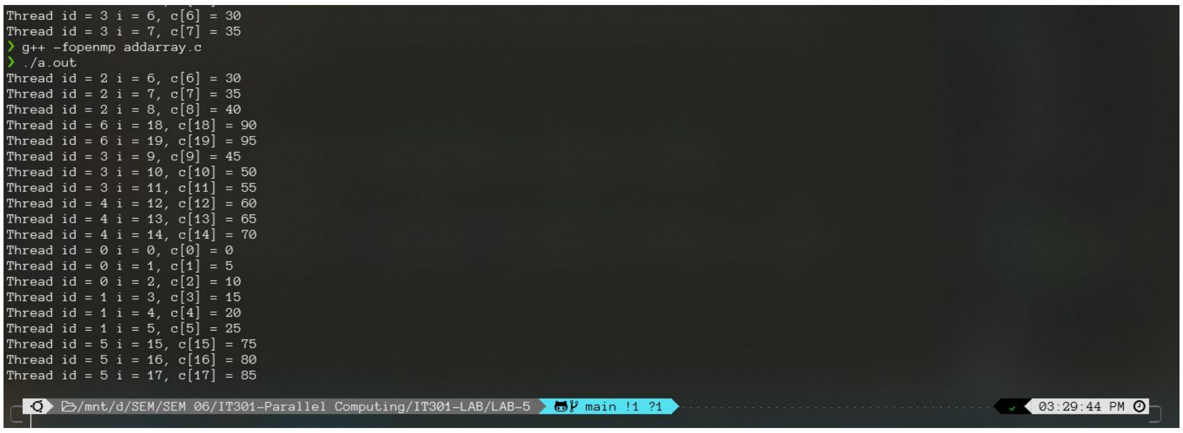
```
Thread id = 1 i = 2, c[2] = 10
Thread id = 1 i = 3, c[3] = 15
Thread id = 1 i = 10, c[10] = 50
Thread id = 1 i = 11, c[11] = 55
Thread id = 1 i = 18, c[18] = 90
Thread id = 1 i = 19, c[19] = 95
Thread id = 3 i = 6, c[6] = 30
Thread id = 3 i = 7, c[7] = 35
Thread id = 3 i = 14, c[14] = 70
Thread id = 3 i = 15, c[15] = 75
Thread id = 2 i = 4, c[4] = 20
Thread id = 2 i = 5, c[5] = 25
Thread id = 2 i = 12, c[12] = 60
Thread id = 2 i = 13, c[13] = 65
Thread id = 0 i = 0, c[0] = 0
Thread id = 0 i = 1, c[1] = 5
Thread id = 0 i = 8, c[8] = 40
Thread id = 0 i = 9, c[9] = 45
Thread id = 0 i = 16, c[16] = 80
Thread id = 0 i = 17, c[17] = 85
```



```
❯ g++ -fopenmp addarray.c
❯ ./a.out
Thread id = 1 i = 2, c[2] = 10
Thread id = 1 i = 3, c[3] = 15
Thread id = 1 i = 10, c[10] = 50
Thread id = 1 i = 11, c[11] = 55
Thread id = 1 i = 18, c[18] = 90
Thread id = 1 i = 19, c[19] = 95
Thread id = 3 i = 6, c[6] = 30
Thread id = 3 i = 7, c[7] = 35
Thread id = 3 i = 14, c[14] = 70
Thread id = 3 i = 15, c[15] = 75
Thread id = 2 i = 4, c[4] = 20
Thread id = 2 i = 5, c[5] = 25
Thread id = 2 i = 12, c[12] = 60
Thread id = 2 i = 13, c[13] = 65
Thread id = 0 i = 0, c[0] = 0
Thread id = 0 i = 1, c[1] = 5
Thread id = 0 i = 8, c[8] = 40
Thread id = 0 i = 9, c[9] = 45
Thread id = 0 i = 16, c[16] = 80
Thread id = 0 i = 17, c[17] = 85
❯

/mnt/d/SEM/SEM 06/IT301-Parallel Computing/IT301-LAB/LAB-5   main !1 ?1   INT x   03:37:27 PM
```

Chunk = 2 & threads = 2

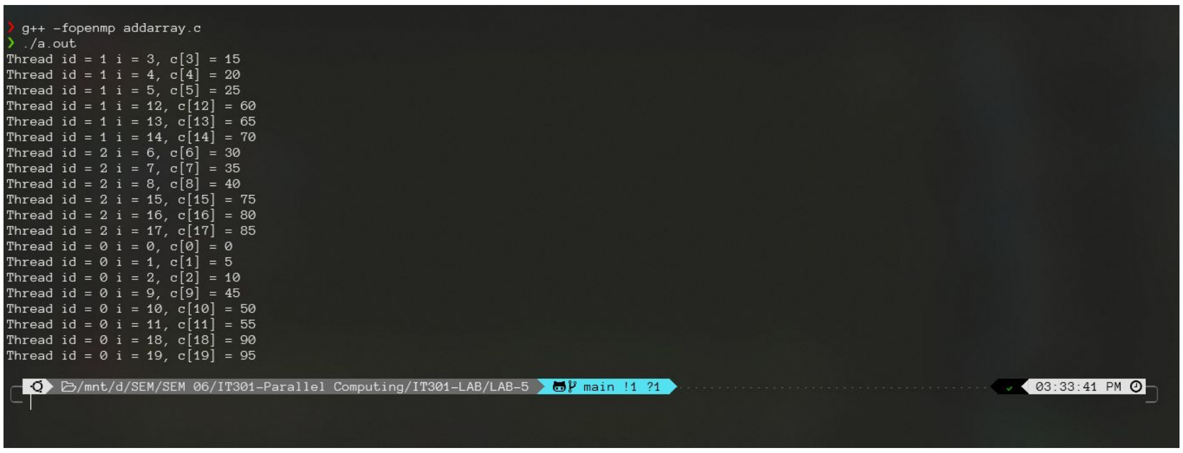
```
❯ g++ -fopenmp addarray.c
❯ ./a.out
Thread id = 0 i = 0, c[0] = 0
Thread id = 0 i = 1, c[1] = 5
Thread id = 0 i = 4, c[4] = 20
Thread id = 0 i = 5, c[5] = 25
Thread id = 0 i = 8, c[8] = 40
Thread id = 0 i = 9, c[9] = 45
Thread id = 0 i = 12, c[12] = 60
Thread id = 0 i = 13, c[13] = 65
Thread id = 0 i = 16, c[16] = 80
Thread id = 0 i = 17, c[17] = 85
Thread id = 1 i = 2, c[2] = 10
Thread id = 1 i = 3, c[3] = 15
Thread id = 1 i = 6, c[6] = 30
Thread id = 1 i = 7, c[7] = 35
Thread id = 1 i = 10, c[10] = 50
Thread id = 1 i = 11, c[11] = 55
Thread id = 1 i = 14, c[14] = 70
Thread id = 1 i = 15, c[15] = 75
Thread id = 1 i = 18, c[18] = 90
Thread id = 1 i = 19, c[19] = 95
```



```
Thread id = 3 i = 6, c[6] = 30
Thread id = 3 i = 7, c[7] = 35
❯ g++ -fopenmp addarray.c
❯ ./a.out
Thread id = 2 i = 6, c[6] = 30
Thread id = 2 i = 7, c[7] = 35
Thread id = 2 i = 8, c[8] = 40
Thread id = 6 i = 18, c[18] = 90
Thread id = 6 i = 19, c[19] = 95
Thread id = 3 i = 9, c[9] = 45
Thread id = 3 i = 10, c[10] = 50
Thread id = 3 i = 11, c[11] = 55
Thread id = 4 i = 12, c[12] = 60
Thread id = 4 i = 13, c[13] = 65
Thread id = 4 i = 14, c[14] = 70
Thread id = 0 i = 0, c[0] = 0
Thread id = 0 i = 1, c[1] = 5
Thread id = 0 i = 2, c[2] = 10
Thread id = 1 i = 3, c[3] = 15
Thread id = 1 i = 4, c[4] = 20
Thread id = 1 i = 5, c[5] = 25
Thread id = 5 i = 15, c[15] = 75
Thread id = 5 i = 16, c[16] = 80
Thread id = 5 i = 17, c[17] = 85
 /mnt/d/SEM/SEM 06/IT301-Parallel Computing/IT301-LAB/LAB-5  main !1 ?1 ........ ✓  03:29:44 PM
```

Chunk = 3 & threads = 3

```
❯ g++ -fopenmp addarray.c
❯ ./a.out
Thread id = 1 i = 3, c[3] = 15
Thread id = 1 i = 4, c[4] = 20
Thread id = 1 i = 5, c[5] = 25
Thread id = 1 i = 12, c[12] = 60
Thread id = 1 i = 13, c[13] = 65
Thread id = 1 i = 14, c[14] = 70
Thread id = 2 i = 6, c[6] = 30
Thread id = 2 i = 7, c[7] = 35
Thread id = 2 i = 8, c[8] = 40
Thread id = 2 i = 15, c[15] = 75
Thread id = 2 i = 16, c[16] = 80
Thread id = 2 i = 17, c[17] = 85
Thread id = 0 i = 0, c[0] = 0
Thread id = 0 i = 1, c[1] = 5
Thread id = 0 i = 2, c[2] = 10
Thread id = 0 i = 9, c[9] = 45
Thread id = 0 i = 10, c[10] = 50
Thread id = 0 i = 11, c[11] = 55
Thread id = 0 i = 18, c[18] = 90
Thread id = 0 i = 19, c[19] = 95
```



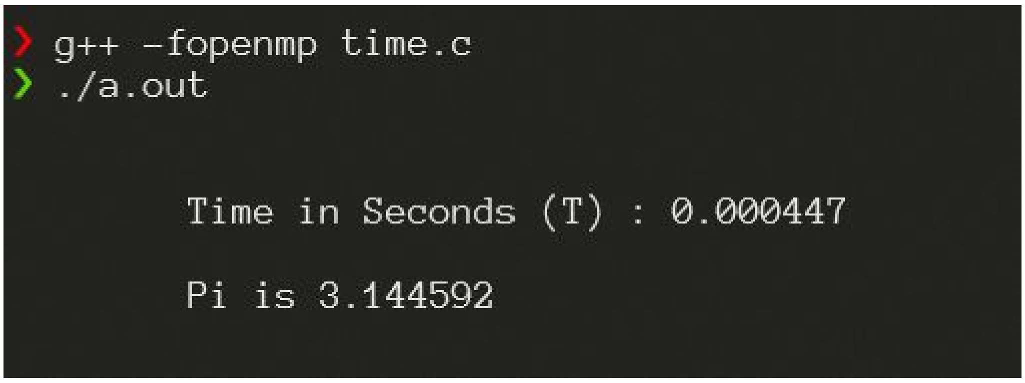
```
❯ g++ -fopenmp addarray.c
❯ ./a.out
Thread id = 1 i = 3, c[3] = 15
Thread id = 1 i = 4, c[4] = 20
Thread id = 1 i = 5, c[5] = 25
Thread id = 1 i = 12, c[12] = 60
Thread id = 1 i = 13, c[13] = 65
Thread id = 1 i = 14, c[14] = 70
Thread id = 2 i = 6, c[6] = 30
Thread id = 2 i = 7, c[7] = 35
Thread id = 2 i = 8, c[8] = 40
Thread id = 2 i = 15, c[15] = 75
Thread id = 2 i = 16, c[16] = 80
Thread id = 2 i = 17, c[17] = 85
Thread id = 0 i = 0, c[0] = 0
Thread id = 0 i = 1, c[1] = 5
Thread id = 0 i = 2, c[2] = 10
Thread id = 0 i = 9, c[9] = 45
Thread id = 0 i = 10, c[10] = 50
Thread id = 0 i = 11, c[11] = 55
Thread id = 0 i = 18, c[18] = 90
Thread id = 0 i = 19, c[19] = 95
 /mnt/d/SEM/SEM 06/IT301-Parallel Computing/IT301-LAB/LAB-5  main !1 ?1 ........ ✓  03:33:41 PM
```

Problem 2: compare sequential and parallel program execution times

```c
#include <stdio.h>
#include <sys/time.h>
#include <omp.h>
#include <stdlib.h>
int main(void)
{
    struct timeval TimeValue_Start;
    struct timezone TimeZone_Start;
    struct timeval TimeValue_Final;
    struct timezone TimeZone_Final;
    long time_start, time_end;
    double time_overhead;
    double pi, x;
    int i, N;
    pi = 0.0;
    N = 1000;
    gettimeofday(&TimeValue_Start, &TimeZone_Start);
#pragma omp parallel for private(x) reduction(+ : pi)
    for (i = 0; i <= N; i++)
    {
        x = (double)i / N;
        pi += 4 / (1 + x * x);
    }
    gettimeofday(&TimeValue_Final, &TimeZone_Final);
    time_start = TimeValue_Start.tv_sec * 1000000 +
TimeValue_Start.tv_usec;
    time_end = TimeValue_Final.tv_sec * 1000000 +
TimeValue_Final.tv_usec;
    time_overhead = (time_end - time_start) / 1000000.0;
    printf("\n\n\tTime in Seconds (T) : %lf\n", time_overhead);
    pi = pi / N;
    printf("\n \tPi is %f\n\n", pi);
}
```

Output

```
❯ g++ -fopenmp time.c
❯ ./a.out
parallel
        Time in Seconds (T) : 0.000447

        Pi is 3.144592
```



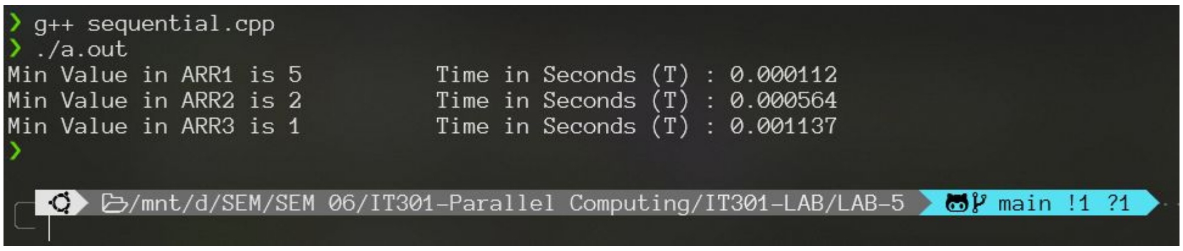
```
❯ g++ -fopenmp time.c
❯ ./a.out


        Time in Seconds (T) : 0.000447

        Pi is 3.144592
```

Problem 3 Write a sequential program to find the smallest element in an array. Convert the same program for parallel execution

```
/* sequential */
#include <iostream>
#include <stdio.h>
#include <climits>
#include <vector>
#include <sys/time.h>

using namespace std;
#define SIZE 20

void get_randome_array(vector<int> &arr) {
    for (int i = 0; i < arr.size(); i++) {
        arr[i] = 1 + (rand() % 100000);
    }
}

int min_value(const vector<int> &arr) {
    int mint = INT_MAX;
    for (auto it: arr) {
        mint = min(mint, it);
    }
    return mint;
}

int main() {
    struct timeval TimeValue_Start;
    struct timezone TimeZone_Start;
    struct timeval TimeValue_Final;
    struct timezone TimeZone_Final;
    long time_start, time_end;
    double time_overhead;
    vector<int> ARR1(10000), ARR2(50000), ARR3(100000);

    gettimeofday(&TimeValue_Start, &TimeZone_Start);
    get_randome_array(ARR1);
    gettimeofday(&TimeValue_Final, &TimeZone_Final);
    time_start = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;
    time_end = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;
    time_overhead = (time_end - time_start) / 1000000.0;
    cout << "Min Value in ARR1 is " << min_value(ARR1) << "\t\tTime in Seconds
(T) : " << time_overhead << endl;

    gettimeofday(&TimeValue_Start, &TimeZone_Start);
    get_randome_array(ARR2);
    gettimeofday(&TimeValue_Final, &TimeZone_Final);
    time_start = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;
    time_end = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;
    time_overhead = (time_end - time_start) / 1000000.0;
    cout << "Min Value in ARR2 is " << min_value(ARR2) << "\t\tTime in Seconds
(T) : " << time_overhead << endl;

    gettimeofday(&TimeValue_Start, &TimeZone_Start);
    get_randome_array(ARR3);
    gettimeofday(&TimeValue_Final, &TimeZone_Final);
    time_start = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;
    time_end = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;
    time_overhead = (time_end - time_start) / 1000000.0;
    cout << "Min Value in ARR3 is " << min_value(ARR3) << "\t\tTime in Seconds
(T) : " << time_overhead << endl;

    return 0;
}
```

Output

```
❯ g++ sequential.cpp
❯ ./a.out
Min Value in ARR1 is 5          Time in Seconds (T) : 0.000112
Min Value in ARR2 is 2          Time in Seconds (T) : 0.000564
Min Value in ARR3 is 1          Time in Seconds (T) : 0.001137
```



```
❯ g++ sequential.cpp
❯ ./a.out
Min Value in ARR1 is 5          Time in Seconds (T) : 0.000112
Min Value in ARR2 is 2          Time in Seconds (T) : 0.000564
Min Value in ARR3 is 1          Time in Seconds (T) : 0.001137
❯
  /mnt/d/SEM/SEM 06/IT301-Parallel Computing/IT301-LAB/LAB-5   main !1 ?1
```

```
/* parallel */
#include <stdio.h>
#include <iostream>
#include <stdlib.h>
#include <omp.h>
#include <sys/time.h>
using namespace std;

int main(void)
{
    struct timeval TimeValue_Start;
    struct timezone TimeZone_Start;
    struct timeval TimeValue_Final;
    struct timezone TimeZone_Final;
    long time_start, time_end;
    double time_overhead;
    int i, a[10000], b[50000], c[100000],sml;
    int tid;
    //initializing array randomly
    for (i = 0; i < 10000; i++)
    {
        a[i] = 1 + (rand() % 100000);
    }
    for (i = 0; i < 50000; i++)
    {
        b[i] = 1 + (rand() % 100000);
    }
    for (i = 0; i < 100000; i++)
    {
        c[i] = 1 + (rand() % 100000);
    }

    gettimeofday(&TimeValue_Start, &TimeZone_Start);
    sml = a[0];
#pragma omp parallel private(tid) num_threads(4)
    {
        tid = omp_get_thread_num();
#pragma omp for private(i) schedule(static, 5)
        for (i = 0; i < 10000; ++i)
        {
            if (sml > a[i])
                sml = a[i];
        }
    }
    gettimeofday(&TimeValue_Final, &TimeZone_Final);
    time_start = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;
    time_end = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;
    time_overhead = (time_end - time_start) / 1000000.0;
    cout << "Min Value in a is " << sml << "\t\tTime in Seconds (T) : " <<
time_overhead << endl;

    gettimeofday(&TimeValue_Start, &TimeZone_Start);
    sml = b[0];
#pragma omp parallel private(tid) num_threads(4)
    {
        tid = omp_get_thread_num();
#pragma omp for private(i) schedule(static, 5)
        for (i = 0; i < 50000; ++i)
        {
            if (sml > b[i])
                sml = b[i];
        }
    }
    gettimeofday(&TimeValue_Final, &TimeZone_Final);
    time_start = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;
    time_end = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;
    time_overhead = (time_end - time_start) / 1000000.0;
    cout << "Min Value in b is " << sml << "\t\tTime in Seconds (T) : " <<
time_overhead << endl;

    gettimeofday(&TimeValue_Start, &TimeZone_Start);
    sml = c[0];
```

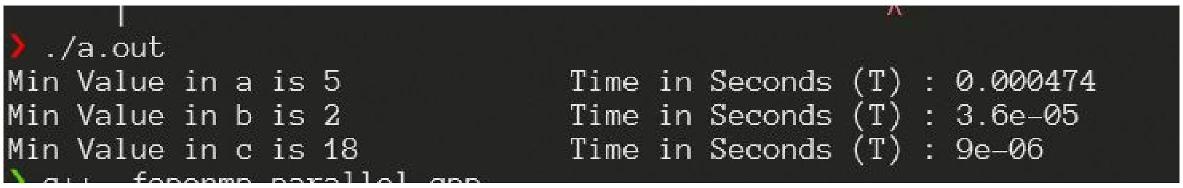
```
#pragma omp parallel private(tid) num_threads(4)
    {
        tid = omp_get_thread_num();
#pragma omp for private(i) schedule(static, 5)
        for (i = 0; i < 10000; ++i)
        {
            if (sml > c[i])
                sml = c[i];
        }
    }
    gettimeofday(&TimeValue_Final, &TimeZone_Final);
    time_start = TimeValue_Start.tv_sec * 1000000 + TimeValue_Start.tv_usec;
    time_end = TimeValue_Final.tv_sec * 1000000 + TimeValue_Final.tv_usec;
    time_overhead = (time_end - time_start) / 1000000.0;
    cout << "Min Value in c is " << sml << "\t\tTime in Seconds (T) : " <<
time_overhead << endl;
}
```

Output

```
❯ g++ -fopenmp parallel.cpp
❯ ./a.out
```

Static, 5

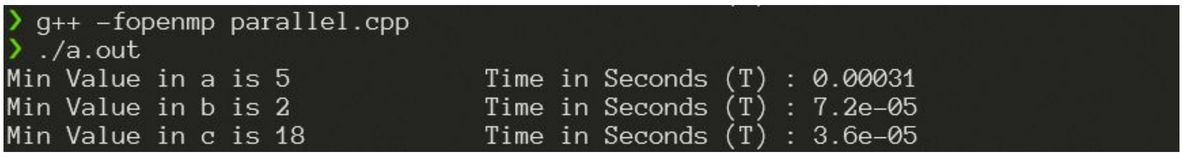
```
Min Value in a is 5             Time in Seconds (T) : 0.000474
Min Value in b is 2             Time in Seconds (T) : 3.6e-05
Min Value in c is 18            Time in Seconds (T) : 9e-06
```



```
❯ ./a.out
Min Value in a is 5             Time in Seconds (T) : 0.000474
Min Value in b is 2             Time in Seconds (T) : 3.6e-05
Min Value in c is 18            Time in Seconds (T) : 9e-06
```

Auto

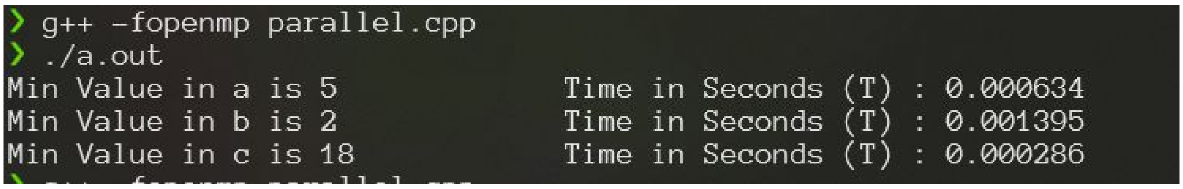
```
Min Value in a is 5             Time in Seconds (T) : 0.00031
Min Value in b is 2             Time in Seconds (T) : 7.2e-05
Min Value in c is 18            Time in Seconds (T) : 3.6e-05
```



```
❯ g++ -fopenmp parallel.cpp
❯ ./a.out
Min Value in a is 5             Time in Seconds (T) : 0.00031
Min Value in b is 2             Time in Seconds (T) : 7.2e-05
Min Value in c is 18            Time in Seconds (T) : 3.6e-05
```

dynamic, 5

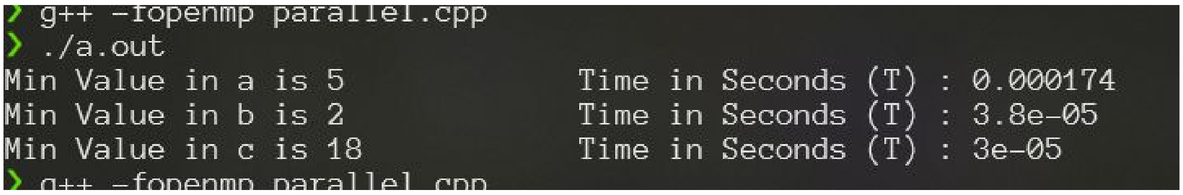
```
Min Value in a is 5             Time in Seconds (T) : 0.000634
Min Value in b is 2             Time in Seconds (T) : 0.001395
Min Value in c is 18            Time in Seconds (T) : 0.000286
```



```
❯ g++ -fopenmp parallel.cpp
❯ ./a.out
Min Value in a is 5          Time in Seconds (T) : 0.000634
Min Value in b is 2          Time in Seconds (T) : 0.001395
Min Value in c is 18         Time in Seconds (T) : 0.000286
```

Guided

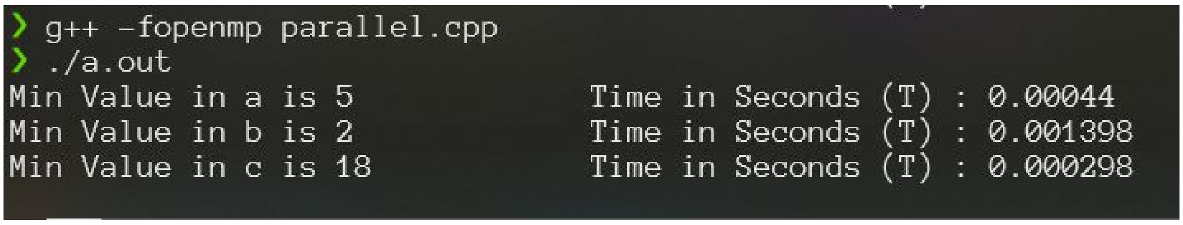
```
Min Value in a is 5          Time in Seconds (T) : 0.000174
Min Value in b is 2          Time in Seconds (T) : 3.8e-05
Min Value in c is 18         Time in Seconds (T) : 3e-05
```



```
❯ g++ -fopenmp parallel.cpp
❯ ./a.out
Min Value in a is 5          Time in Seconds (T) : 0.000174
Min Value in b is 2          Time in Seconds (T) : 3.8e-05
Min Value in c is 18         Time in Seconds (T) : 3e-05
```

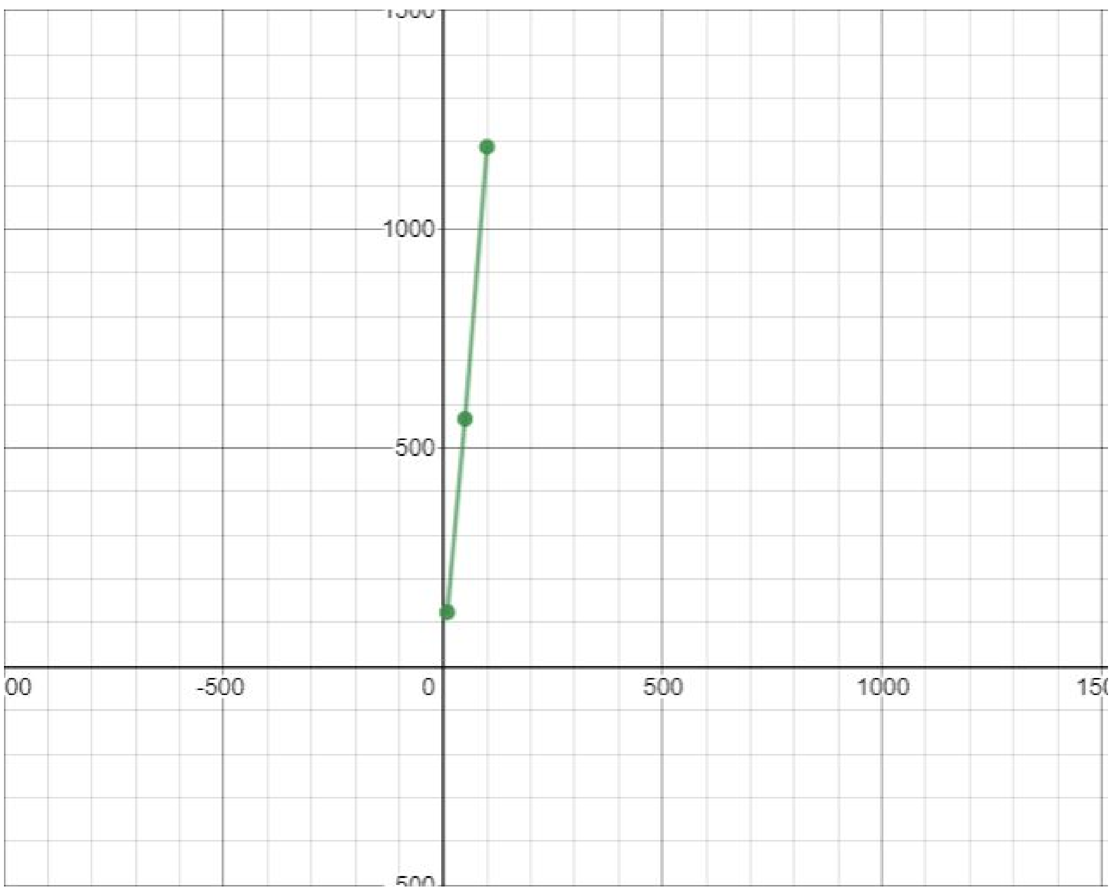
Runtime

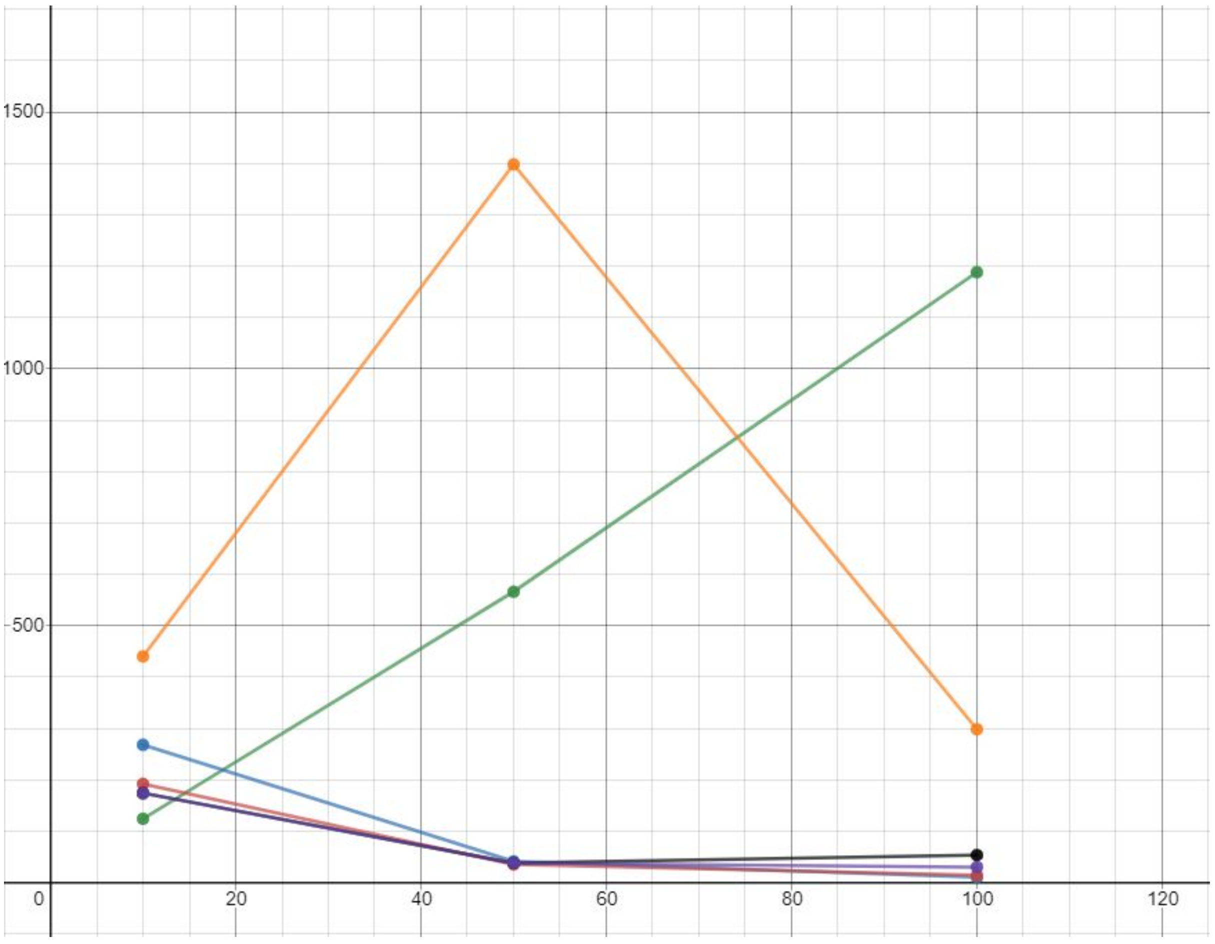
```
Min Value in a is 5          Time in Seconds (T) : 0.00044
Min Value in b is 2          Time in Seconds (T) : 0.001398
Min Value in c is 18         Time in Seconds (T) : 0.000298
```



```
❯ g++ -fopenmp parallel.cpp
❯ ./a.out
Min Value in a is 5          Time in Seconds (T) : 0.00044
Min Value in b is 2          Time in Seconds (T) : 0.001398
Min Value in c is 18         Time in Seconds (T) : 0.000298
```

Schedule	Total execution for number of iterations 10K	Total execution for number of iterations 50K	Total execution for number of iterations 100K
Sequential execution	0.000124	0.000566	0.001188
static	0.000268	0.000041	0.00001
Static, chunksize	0.000192	0.000035	0.000014
Dynamic, chunksize	0.000174	0.000038	0.000053
Guided	0.000174	0.000038	0.00003
runtime	0.00044	0.001398	0.000298


1000
500
-500
0
500
1000


1500
1000
500
0
20
40
60
80
100
120