PARALLEL AND DISTRIBUTED COMPUTING LAB

REPORT

NAME: S Shyam Sundaram

REG NO: 19BCE1560

PROGRAMMING ENVIRONMENT: OpenMP

PROBLEM: Summation of numbers with and without reduction and row major matrix multiplication

DATE: 22nd September, 2021

HARDWARE CONFIGURATION:

CPU NAME	:	Intel core i5 – 1035G1 @ 1.00 Ghz
Number of Sockets:	:	1
Cores per Socket	:	4
Threads per core	:	1
L1 Cache size	:	320KB
L2 Cache size	:	2MB
L3 Cache size (Shared):		6MB
RAM	:	8 GB

SUM OF N NUMBERS WITHOUT REDUCTION

CODE

```
#include<stdio.h>
#include<stdlib.h>
#include<omp.h>

#define N 100000000
int main()
{
   int chunk =20;
   int thread[]={1,2,4,8,16,32,64,128,256,512};

   printf("Name: Shyam Sundaram\nReg num: 19BCE1560\nPDC Lab:\n\n");


   printf("Size of array: %d----------\n",s);

   for(int t=0;t<10;++t)
   {
      omp_set_num_threads(thread[t]);
```

```
        long *sum=(long*)malloc(thread[t]*sizeof(long));
        for(int i=0;i<thread[t];++i)
        sum[i]=0;
        long s=0;
        int i;
        float start=omp_get_wtime();
        #pragma omp parallel for schedule(static,chunk) shared(sum) private(i)
        for(i=0;i<N;++i)
        sum[omp_get_thread_num()]+=i;

        for(int i=0;i<thread[t];++i)
        s+=sum[i];
        float end=omp_get_wtime();
        float exec=end-start;

        printf("Thread count: %d Time taken is: %f\n",thread[t],exec);
        free(sum);
    }
    return 0;
}
```

NOTE: For dynamic, replace schedule clause (in orange) argument to ‘dynamic’ from ‘static’. For default, remove schedule clause.

COMPILATION AND EXECUTION

```
gcc -fopenmp sum.c
./a.out
```

OBSERVATIONS

N	NUMBER OF THREADS	DEFAULT EXECUTION TIME	STATIC EXECUTION TIME	DYNAMIC EXECUTION TIME
100000	1	0.014465	0.014801	0.012512
	2	0.014648	0.017029	0.015503
	4	0.008362	0.011505	0.010315
	8	0.018433	0.023468	0.044312
	16	0.018311	0.017303	0.026428
	32	0.008423	0.009186	0.011475
	64	0.008301	0.007599	0.010803
	128	0.009583	0.010040	0.013550
	256	0.014771	0.015625	0.021118
	512	0.022095	0.029694	0.026733
10000000	1	0.108337	0.102722	0.127991
	2	0.130615	0.118286	0.195923
	4	0.107605	0.090332	0.129211
	8	0.101440	0.101868	0.132507
	16	0.116272	0.105286	0.152222
	32	0.066345	0.068176	0.093811
	64	0.043274	0.047119	0.064331
	128	0.039856	0.039734	0.061279
	256	0.040710	0.040833	0.088501
	512	0.035828	0.045166	0.070068
100000000	1	1.059448	0.988892	1.229126
	2	1.137085	1.033936	2.045776
	4	1.004272	0.706543	1.280640
	8	0.944580	0.187744	1.284546
	16	0.237305	0.237793	0.493774
	32	0.121826	0.129395	0.189331
	64	0.084229	0.089478	0.115845
	128	0.076050	0.074585	0.105957
	256	0.069214	0.067383	0.149048
	512	0.064575	0.067505	0.103149

ASSUMPTION

As the number of threads increase, the work done by each thread is reduced, thus we see an overall decline in the execution time for all three types of scheduling (up to a point in some cases).

SCREENSHOTS

```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ gcc -fopenmp sum.c
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Size of array: 1000000------------
Thread count: 1 Time taken is: 0.012512
Thread count: 2 Time taken is: 0.015503
Thread count: 4 Time taken is: 0.010315
Thread count: 8 Time taken is: 0.044312
Thread count: 16 Time taken is: 0.026428
Thread count: 32 Time taken is: 0.011475
Thread count: 64 Time taken is: 0.010803
Thread count: 128 Time taken is: 0.013550
Thread count: 256 Time taken is: 0.021118
Thread count: 512 Time taken is: 0.026733
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$
```

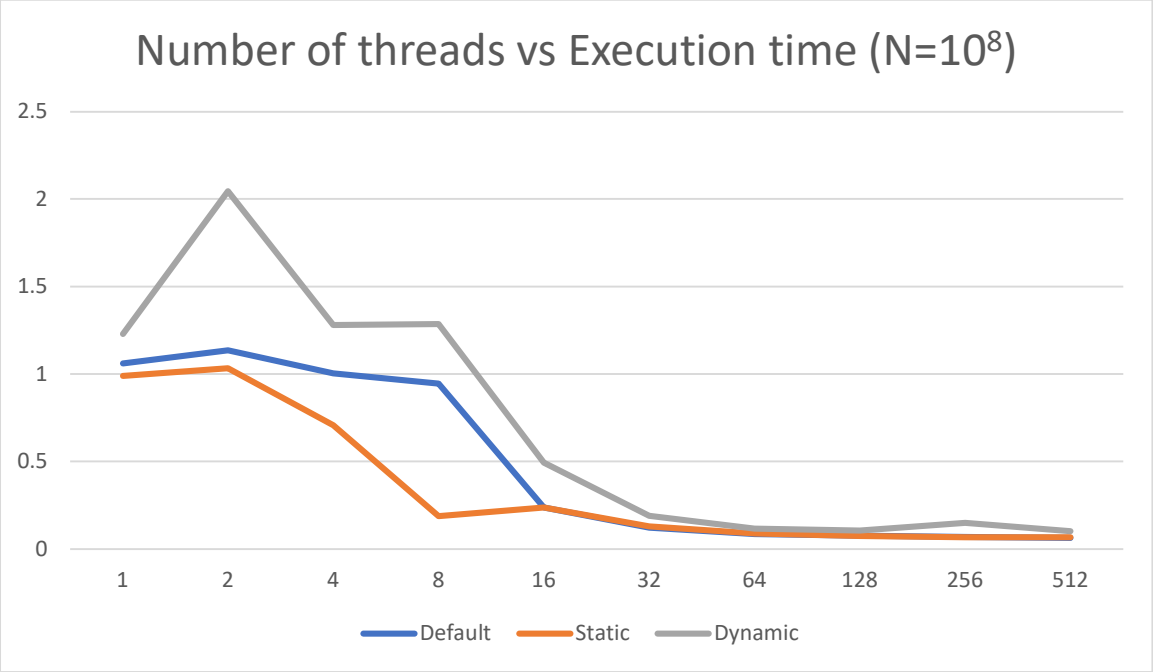
```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ gcc -fopenmp sum.c
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Size of array: 10000000------------
Thread count: 1 Time taken is: 0.102722
Thread count: 2 Time taken is: 0.118286
Thread count: 4 Time taken is: 0.090332
Thread count: 8 Time taken is: 0.101868
Thread count: 16 Time taken is: 0.105286
Thread count: 32 Time taken is: 0.068176
Thread count: 64 Time taken is: 0.047119
Thread count: 128 Time taken is: 0.039734
Thread count: 256 Time taken is: 0.040833
Thread count: 512 Time taken is: 0.045166
```

```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ gcc -fopenmp sum.c
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Size of array: 100000000------------
Thread count: 1 Time taken is: 0.988892
Thread count: 2 Time taken is: 1.033936
Thread count: 4 Time taken is: 0.706543
Thread count: 8 Time taken is: 0.187744
Thread count: 16 Time taken is: 0.237793
Thread count: 32 Time taken is: 0.129395
Thread count: 64 Time taken is: 0.089478
Thread count: 128 Time taken is: 0.074585
Thread count: 256 Time taken is: 0.067383
Thread count: 512 Time taken is: 0.067505
```

PLOT



INFERENCE

As more threads are allocated, the workload is distributed according to the respective scheduling algorithms, thus the overall execution time decreases.

SUM OF N NUMBERS WITH REDUCTION

CODE

```
#include <stdio.h>
#include <stdlib.h>
#include <omp.h>

#define N 10000000

int main()
{
   int chunk =10;
   int thread[]={1,2,4,8,16,32,64,128,256,512};

   printf("Name: Shyam Sundaram\nReg num: 19BCE1560\nPDC Lab:\n\n");

   int s=N;
   printf("Size of array: %d----------\n",s);
```

```
    for(int t=0;t<10;++t)
    {
        omp_set_num_threads(thread[t]);
        int sum=0;

        int i;

        float start=omp_get_wtime();
        #pragma omp parallel for schedule(dynamic,chunk) private(i) reduction(+:sum)
        for(i=0;i<N;++i)
            sum+=i;

        float end=omp_get_wtime();
        float exec=end-start;
        printf("Thread count: %d Time taken is: %f\n",thread[t],exec);

    }
    return 0;
}
```

NOTE: For dynamic, replace schedule clause (in orange) argument to ‘dynamic’ from ‘static’. For default, remove schedule clause.

COMPILATION AND EXECUTION

```
gcc -fopenmp sumred.c
./a.out
```

OBSERVATIONS

N	NUMBER OF THREADS	DEFAULT EXECUTION TIME	STATIC EXECUTION TIME	DYNAMIC EXECUTION TIME
1000000	1	0.006958	0.011108	0.014526
	2	0.003418	0.005615	0.016113
	4	0.001831	0.002930	0.011475
	8	0.010742	0.014282	0.046631
	16	0.010254	0.004150	0.016479
	32	0.001099	0.003906	0.018188
	64	0.001221	0.004761	0.012451
	128	0.002197	0.008057	0.018555
	256	0.003052	0.013672	0.021362
	512	0.005615	0.024658	0.033447
10000000	1	0.120605	0.110962	0.140991
	2	0.062622	0.057373	0.153809
	4	0.031738	0.027954	0.120239
	8	0.046631	0.044434	0.092896
	16	0.039551	0.031250	0.094482
	32	0.025024	0.023071	0.147339
	64	0.025024	0.024292	0.095825
	128	0.024780	0.024658	0.098999
	256	0.029907	0.033447	0.109863
	512	0.037354	0.035889	0.118896

ASSUMPTION

As the number of threads increase, the work done by each thread is reduced, thus we see an overall decline in the execution time for all three types of scheduling (up to a point in some cases).

SCREENSHOTS

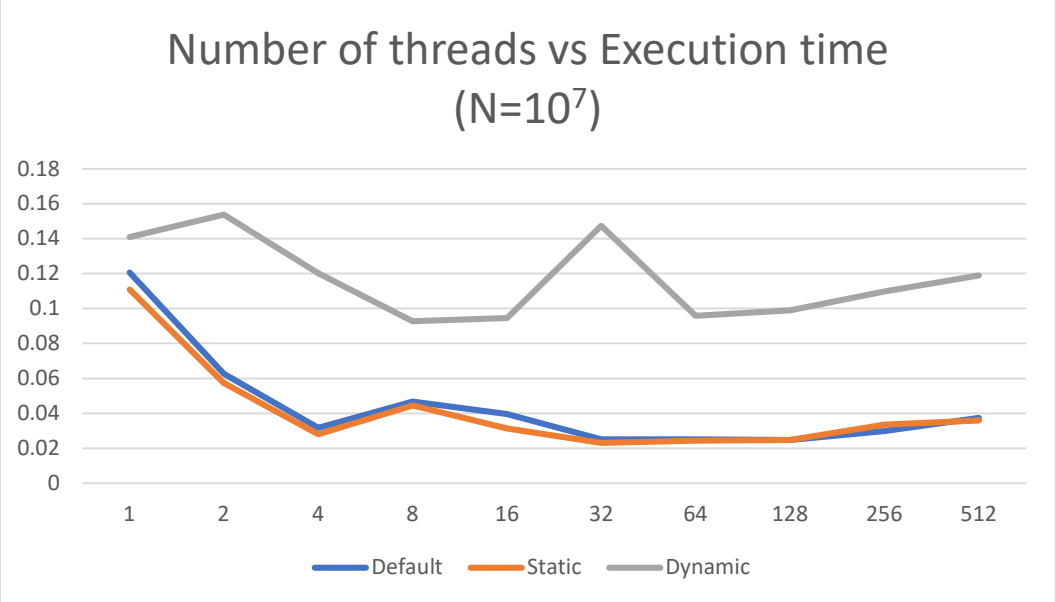
```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ gcc -fopenmp sumred.c
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Size of array: 1000000------------
Thread count: 1 Time taken is: 0.012573
Thread count: 2 Time taken is: 0.006104
Thread count: 4 Time taken is: 0.003418
Thread count: 8 Time taken is: 0.003784
Thread count: 16 Time taken is: 0.011719
Thread count: 32 Time taken is: 0.003662
Thread count: 64 Time taken is: 0.006226
Thread count: 128 Time taken is: 0.007690
Thread count: 256 Time taken is: 0.017212
Thread count: 512 Time taken is: 0.026001
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$
```

```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ gcc -fopenmp sumred.c
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Size of array: 10000000------------
Thread count: 1 Time taken is: 0.110962
Thread count: 2 Time taken is: 0.057373
Thread count: 4 Time taken is: 0.027954
Thread count: 8 Time taken is: 0.044434
Thread count: 16 Time taken is: 0.031250
Thread count: 32 Time taken is: 0.023071
Thread count: 64 Time taken is: 0.024292
Thread count: 128 Time taken is: 0.024658
Thread count: 256 Time taken is: 0.033447
Thread count: 512 Time taken is: 0.035889
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$
```

PLOT



INFERENCE

As more threads are allocated, the workload is distributed according to the respective scheduling algorithms, thus the overall execution time decreases.

ROW MAJOR MATRIX MULTIPLICATION

CODE

```
#include<stdio.h>
#include<stdlib.h>
#include<omp.h>

#define M 2500
#define N 250
#define L 300

int main()
{
   int chunk = 10;
   int thread[]={1,2,4,8,16,32,64,128,256,512};

   printf("Name: Shyam Sundaram\nReg num: 19BCE1560\nPDC Lab:\n\n");

   float a[M*L],b[L*N],c[M*N];

   for(int i=0;i<M;++i)
   for(int j=0;j<L;++j)
   a[j+i*L]=10*j+i;

   for(int i=0;i<L;++i)
   for(int j=0;j<N;++j)
   b[j+i*N]=10*j+i;

   for(int i=0;i<M;++i)
   for(int j=0;j<N;++j)
   c[j+i*N]=0;

   for(int t=0;t<10;++t)
   {
      omp_set_num_threads(thread[t]);
      float start=omp_get_wtime();
      int chunk=10;
      int i,j,k;
```

```
    #pragma omp parallel private(i,j,k) shared(a,b) reduction(+:c)
    {
      #pragma omp for schedule(dynamic,chunk) collapse(3)
      for(i=0;i<M;++i)
      {
        for(j=0;j<N;++j)
        {
          for(k=0;k<L;++k)
          {
            c[j+i*N]+=a[k+i*L]*b[j+k*N];
          }
        }
      }
    }

    float end=omp_get_wtime();
    float exec=end-start;
    printf("Thread count: %d Time taken is: %f\n",thread[t],exec);
  }

  return 0;
}
```

NOTE: For Static, replace schedule clause (in orange) argument from 'dynamic' to 'static'. For default, remove schedule clause.

COMPILATION AND EXECUTION

```
gcc -fopenmp matmul.c
./a.out
```

OBSERVATIONS

NUMBER OF THREADS	DEFAULT EXECUTION TIME	STATIC EXECUTION TIME	DYNAMIC EXECUTION TIME
1	2.965149	3.125854	3.932495
2	1.499512	1.551147	0.694580
4	0.798767	0.840210	0.556641
8	0.743347	0.825928	0.403564
16	0.806763	0.893799	0.422852
32	0.812683	0.492432	0.562988
64	0.784302	0.213135	0.446167
128	0.269714	0.281494	0.521118
256	0.395447	0.428101	0.675415
512	0.637573	0.773926	0.898926

ASSUMPTION

As the number of threads increase, the work done by each thread is reduced, thus we see an overall decline in the execution time for all three types of scheduling.

SCREENSHOTS

```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ gcc -fopenmp matmul.c
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Thread count: 1 Time taken is: 2.965149
Thread count: 2 Time taken is: 1.499512
Thread count: 4 Time taken is: 0.798767
Thread count: 8 Time taken is: 0.743347
Thread count: 16 Time taken is: 0.806763
Thread count: 32 Time taken is: 0.812683
Thread count: 64 Time taken is: 0.784302
Thread count: 128 Time taken is: 0.269714
Thread count: 256 Time taken is: 0.395447
Thread count: 512 Time taken is: 0.637573
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$
```

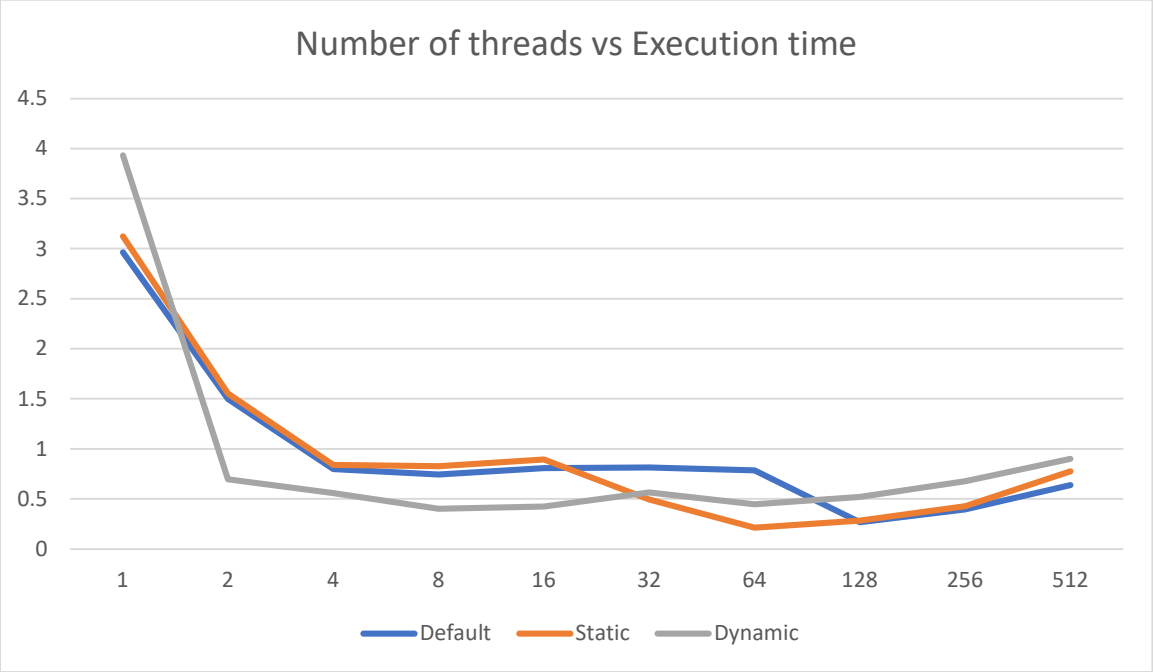
```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ gcc -fopenmp matmul.c
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Thread count: 1 Time taken is: 3.932495
Thread count: 2 Time taken is: 0.694580
Thread count: 4 Time taken is: 0.556641
Thread count: 8 Time taken is: 0.403564
Thread count: 16 Time taken is: 0.422852
Thread count: 32 Time taken is: 0.562988
Thread count: 64 Time taken is: 0.446167
Thread count: 128 Time taken is: 0.521118
Thread count: 256 Time taken is: 0.675415
Thread count: 512 Time taken is: 0.898926
```

```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ gcc -fopenmp matmul.c
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Thread count: 1 Time taken is: 3.125854
Thread count: 2 Time taken is: 1.551147
Thread count: 4 Time taken is: 0.840210
Thread count: 8 Time taken is: 0.825928
Thread count: 16 Time taken is: 0.893799
Thread count: 32 Time taken is: 0.492432
Thread count: 64 Time taken is: 0.213135
Thread count: 128 Time taken is: 0.281494
Thread count: 256 Time taken is: 0.428101
Thread count: 512 Time taken is: 0.773926
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab5$
```

PLOTS



INFERENCE

As more threads are allocated, the workload is distributed according to the respective scheduling algorithms, thus the overall execution time decreases.