PARALLEL AND DISTRIBUTED COMPUTING LAB

REPORT

NAME: S Shyam Sundaram

REG NO: 19BCE1560

PROGRAMMING ENVIRONMENT: OpenMP

PROBLEM: Scheduling Algorithms with Prime number count and matrix multiplication

DATE: 1s^{t} 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

PRIME NUMBER COUNT

CODE

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

int sieve(int x)
{
   for(int i=2;i*i<=x;++i)
   {
      if(x%i==0)
      return -1;
   }
   return 1;
}

int main()
{
   int N[]={1000,10000,100000,1000000};
   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");


    for(int i=0;i<4;++i)
    {
        printf("-------\nN: %d\n",N[i]);
        for(int t=0;t<10;++t)
        {
            omp_set_num_threads(thread[t]);
            float start=omp_get_wtime();
            int cnt=0;
            int n=N[i];
            #pragma omp parallel for schedule(dynamic,chunk) reduction(+:cnt)
            for(int j=2;j<n;++j)
            {
                if(sieve(j)==1)
                cnt+=1;
            }

            float end=omp_get_wtime();
            float exec=end-start;
            printf("Count: %d Thread count: %d Time taken is: %f\n",cnt,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 prime.c
./a.out
```

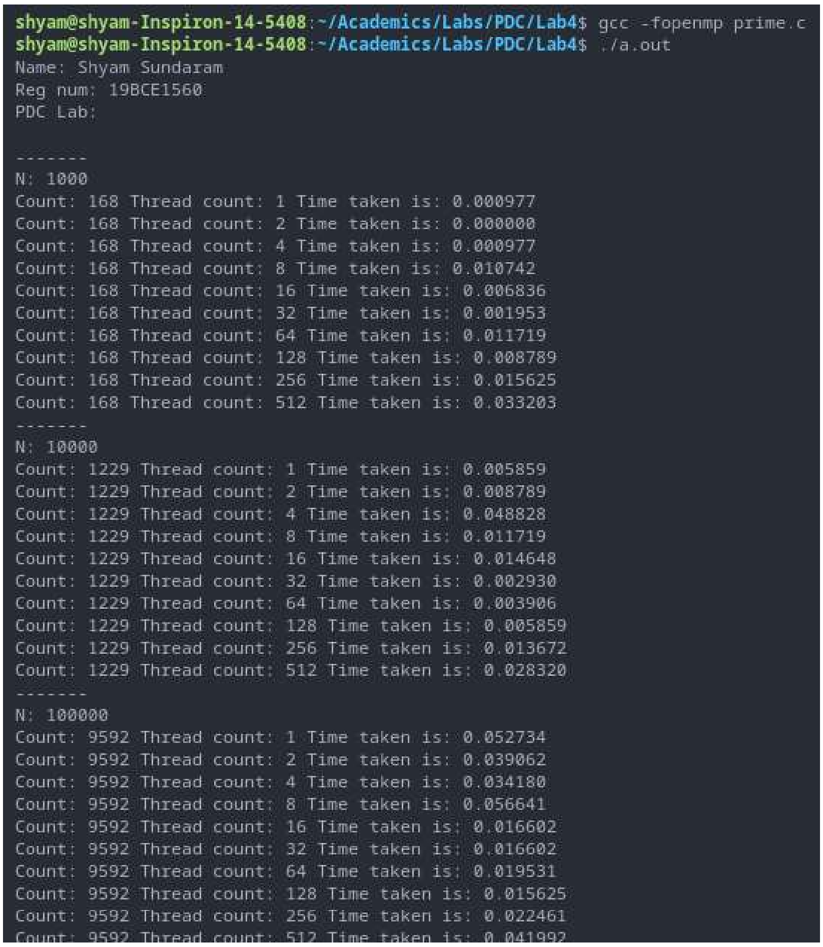
OBSERVATIONS

N	NUMBER OF THREADS	DEFAULT EXECUTION TIME	STATIC EXECUTION TIME	DYNAMIC EXECUTION TIME
10000	1	0.005859	0.005859	0.005859
	2	0.008789	0.019531	0.009766
	4	0.048828	0.057617	0.041016
	8	0.011719	0.058594	0.015625
	16	0.014648	0.026367	0.019531
	32	0.002930	0.003906	0.006836
	64	0.003906	0.005859	0.006836
	128	0.005859	0.011719	0.007812
	256	0.013672	0.017578	0.014648
	512	0.028320	0.028320	0.024414
100000	1	0.052734	0.043945	0.042969
	2	0.039062	0.030273	0.032227
	4	0.034180	0.027344	0.039062
	8	0.056641	0.048828	0.014648
	16	0.016602	0.048828	0.027344
	32	0.016602	0.012695	0.013672
	64	0.019531	0.012695	0.013672
	128	0.015625	0.023438	0.015625
	256	0.022461	0.033203	0.022461
	512	0.041992	0.043945	0.044922
1000000	1	1.002930	0.834961	1.013672
	2	0.528320	0.399414	0.526367
	4	0.322266	0.293945	0.283203
	8	0.260742	0.258789	0.256836
	16	0.215820	0.232422	0.216797
	32	0.201172	0.227539	0.240234
	64	0.200195	0.211914	0.246094
	128	0.226562	0.221680	0.245117
	256	0.262695	0.242188	0.240234
	512	0.254883	0.254883	0.246094

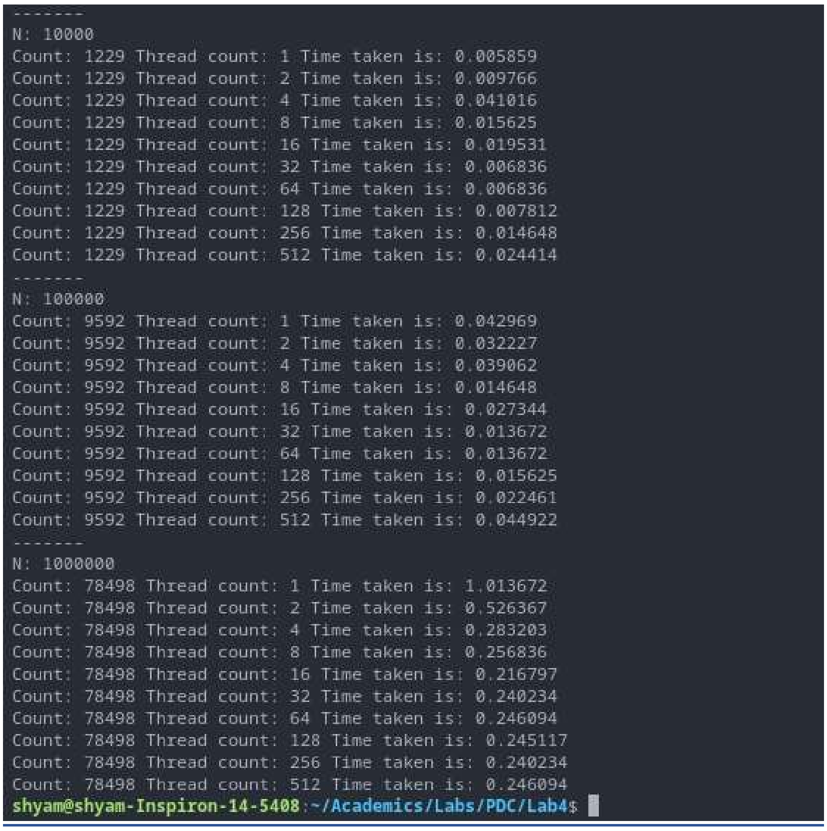
ASSUMPTION

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.

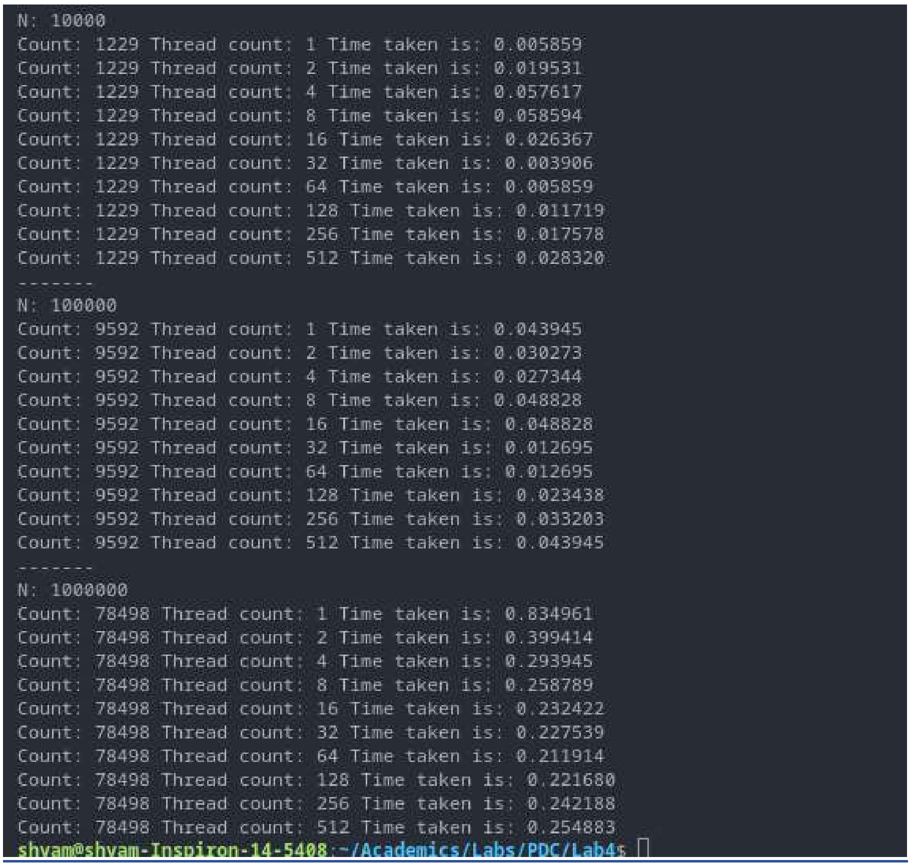
SCREENSHOTS



```
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$ gcc -fopenmp prime.c
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

-------
N: 1000
Count: 168 Thread count: 1 Time taken is: 0.000977
Count: 168 Thread count: 2 Time taken is: 0.000000
Count: 168 Thread count: 4 Time taken is: 0.000977
Count: 168 Thread count: 8 Time taken is: 0.010742
Count: 168 Thread count: 16 Time taken is: 0.006836
Count: 168 Thread count: 32 Time taken is: 0.001953
Count: 168 Thread count: 64 Time taken is: 0.011719
Count: 168 Thread count: 128 Time taken is: 0.008789
Count: 168 Thread count: 256 Time taken is: 0.015625
Count: 168 Thread count: 512 Time taken is: 0.033203
-------
N: 10000
Count: 1229 Thread count: 1 Time taken is: 0.005859
Count: 1229 Thread count: 2 Time taken is: 0.008789
Count: 1229 Thread count: 4 Time taken is: 0.048828
Count: 1229 Thread count: 8 Time taken is: 0.011719
Count: 1229 Thread count: 16 Time taken is: 0.014648
Count: 1229 Thread count: 32 Time taken is: 0.002930
Count: 1229 Thread count: 64 Time taken is: 0.003906
Count: 1229 Thread count: 128 Time taken is: 0.005859
Count: 1229 Thread count: 256 Time taken is: 0.013672
Count: 1229 Thread count: 512 Time taken is: 0.028320
-------
N: 100000
Count: 9592 Thread count: 1 Time taken is: 0.052734
Count: 9592 Thread count: 2 Time taken is: 0.039062
Count: 9592 Thread count: 4 Time taken is: 0.034180
Count: 9592 Thread count: 8 Time taken is: 0.056641
Count: 9592 Thread count: 16 Time taken is: 0.016602
Count: 9592 Thread count: 32 Time taken is: 0.016602
Count: 9592 Thread count: 64 Time taken is: 0.019531
Count: 9592 Thread count: 128 Time taken is: 0.015625
Count: 9592 Thread count: 256 Time taken is: 0.022461
Count: 9592 Thread count: 512 Time taken is: 0.041992
```

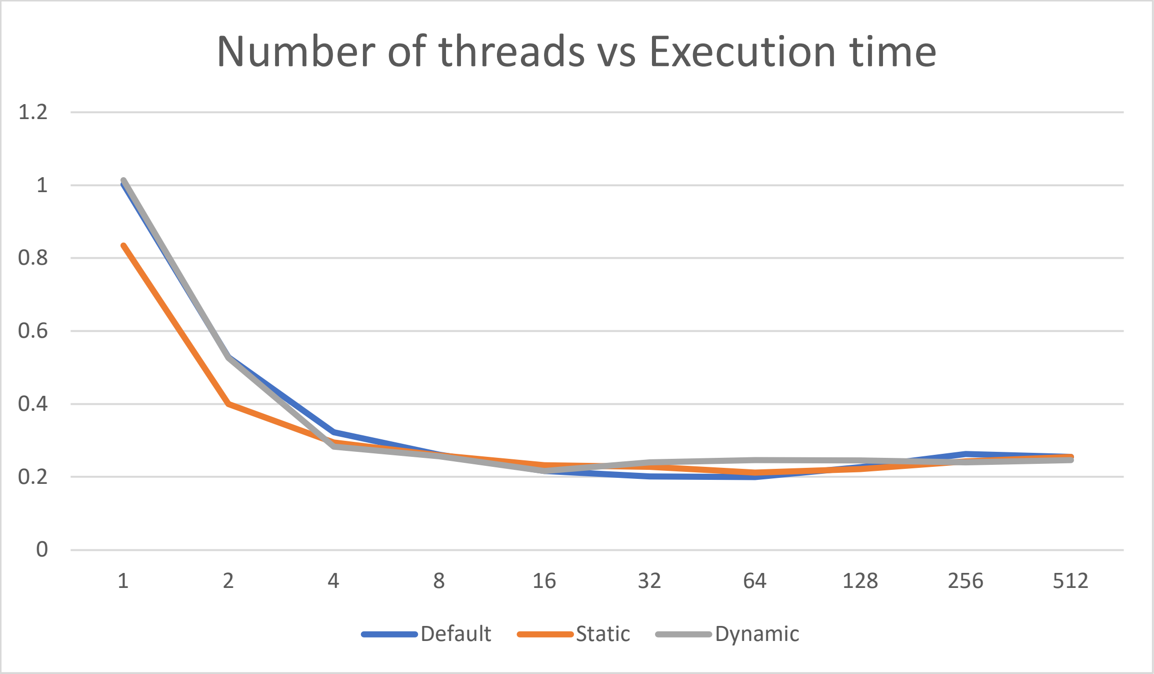


```
-------
N: 10000
Count: 1229 Thread count: 1 Time taken is: 0.005859
Count: 1229 Thread count: 2 Time taken is: 0.009766
Count: 1229 Thread count: 4 Time taken is: 0.041016
Count: 1229 Thread count: 8 Time taken is: 0.015625
Count: 1229 Thread count: 16 Time taken is: 0.019531
Count: 1229 Thread count: 32 Time taken is: 0.006836
Count: 1229 Thread count: 64 Time taken is: 0.006836
Count: 1229 Thread count: 128 Time taken is: 0.007812
Count: 1229 Thread count: 256 Time taken is: 0.014648
Count: 1229 Thread count: 512 Time taken is: 0.024414
-------
N: 100000
Count: 9592 Thread count: 1 Time taken is: 0.042969
Count: 9592 Thread count: 2 Time taken is: 0.032227
Count: 9592 Thread count: 4 Time taken is: 0.039062
Count: 9592 Thread count: 8 Time taken is: 0.014648
Count: 9592 Thread count: 16 Time taken is: 0.027344
Count: 9592 Thread count: 32 Time taken is: 0.013672
Count: 9592 Thread count: 64 Time taken is: 0.013672
Count: 9592 Thread count: 128 Time taken is: 0.015625
Count: 9592 Thread count: 256 Time taken is: 0.022461
Count: 9592 Thread count: 512 Time taken is: 0.044922
-------
N: 1000000
Count: 78498 Thread count: 1 Time taken is: 1.013672
Count: 78498 Thread count: 2 Time taken is: 0.526367
Count: 78498 Thread count: 4 Time taken is: 0.283203
Count: 78498 Thread count: 8 Time taken is: 0.256836
Count: 78498 Thread count: 16 Time taken is: 0.216797
Count: 78498 Thread count: 32 Time taken is: 0.240234
Count: 78498 Thread count: 64 Time taken is: 0.246094
Count: 78498 Thread count: 128 Time taken is: 0.245117
Count: 78498 Thread count: 256 Time taken is: 0.240234
Count: 78498 Thread count: 512 Time taken is: 0.246094
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$ 
```



```
N: 10000
Count: 1229 Thread count: 1 Time taken is: 0.005859
Count: 1229 Thread count: 2 Time taken is: 0.019531
Count: 1229 Thread count: 4 Time taken is: 0.057617
Count: 1229 Thread count: 8 Time taken is: 0.058594
Count: 1229 Thread count: 16 Time taken is: 0.026367
Count: 1229 Thread count: 32 Time taken is: 0.003906
Count: 1229 Thread count: 64 Time taken is: 0.005859
Count: 1229 Thread count: 128 Time taken is: 0.011719
Count: 1229 Thread count: 256 Time taken is: 0.017578
Count: 1229 Thread count: 512 Time taken is: 0.028320
-------
N: 100000
Count: 9592 Thread count: 1 Time taken is: 0.043945
Count: 9592 Thread count: 2 Time taken is: 0.030273
Count: 9592 Thread count: 4 Time taken is: 0.027344
Count: 9592 Thread count: 8 Time taken is: 0.048828
Count: 9592 Thread count: 16 Time taken is: 0.048828
Count: 9592 Thread count: 32 Time taken is: 0.012695
Count: 9592 Thread count: 64 Time taken is: 0.012695
Count: 9592 Thread count: 128 Time taken is: 0.023438
Count: 9592 Thread count: 256 Time taken is: 0.033203
Count: 9592 Thread count: 512 Time taken is: 0.043945
-------
N: 1000000
Count: 78498 Thread count: 1 Time taken is: 0.834961
Count: 78498 Thread count: 2 Time taken is: 0.399414
Count: 78498 Thread count: 4 Time taken is: 0.293945
Count: 78498 Thread count: 8 Time taken is: 0.258789
Count: 78498 Thread count: 16 Time taken is: 0.232422
Count: 78498 Thread count: 32 Time taken is: 0.227539
Count: 78498 Thread count: 64 Time taken is: 0.211914
Count: 78498 Thread count: 128 Time taken is: 0.221680
Count: 78498 Thread count: 256 Time taken is: 0.242188
Count: 78498 Thread count: 512 Time taken is: 0.254883
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$
```

PLOTS



INFERENCE

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

MATRIX MULTIPLICATION

CODE

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

#define R 2500
#define C 250

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[R][C], b[C][C], c[R][C];

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

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

   for(int i=0;i<R;++i)
   for(int j=0;j<C;++j)
   c[i][j]=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 collapse(3) schedule(static,chunk)
      for(i=0;i<R;++i)
        for(j=0;j<C;++j)
          for(k=0;k<C;++k)
            c[i][j]+=a[i][k]*b[k][j];

    }

    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
```

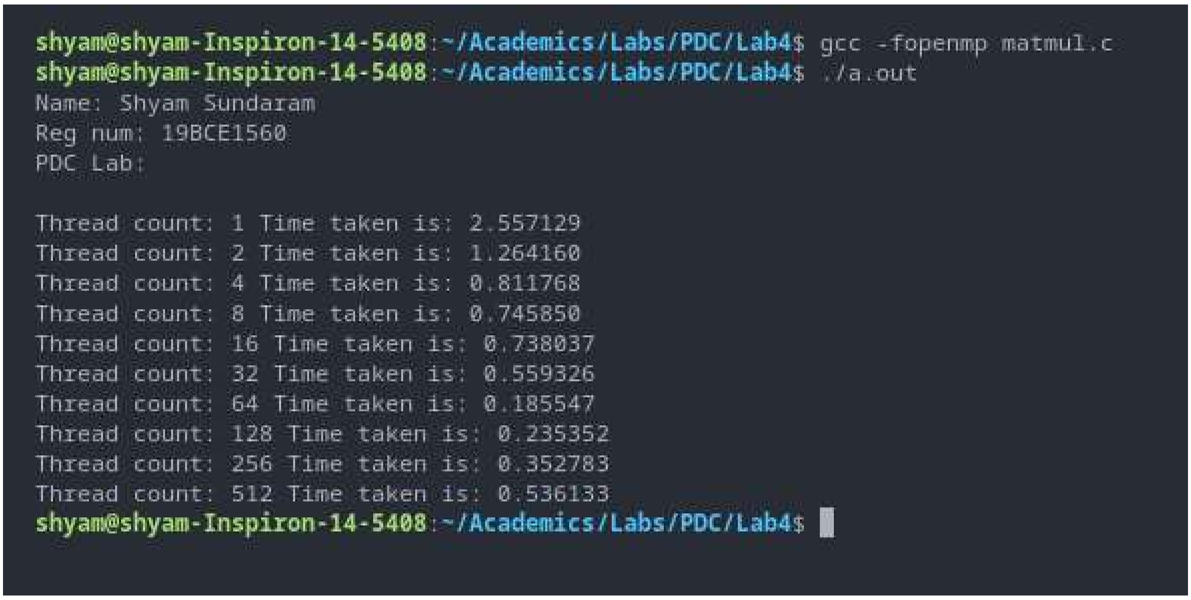
OBSERVATIONS

NUMBER OF THREADS	DEFAULT EXECUTION TIME	STATIC EXECUTION TIME	DYNAMIC EXECUTION TIME
1	2.557129	2.781616	0.828857
2	1.264160	1.394653	0.653564
4	0.811768	1.094727	0.472900
8	0.745850	0.482178	0.395264
16	0.738037	0.166504	0.406250
32	0.559326	0.186768	0.499268
64	0.185547	0.205444	0.432373
128	0.235352	0.249146	0.485107
256	0.352783	0.349365	0.540283
512	0.536133	0.625122	0.655273

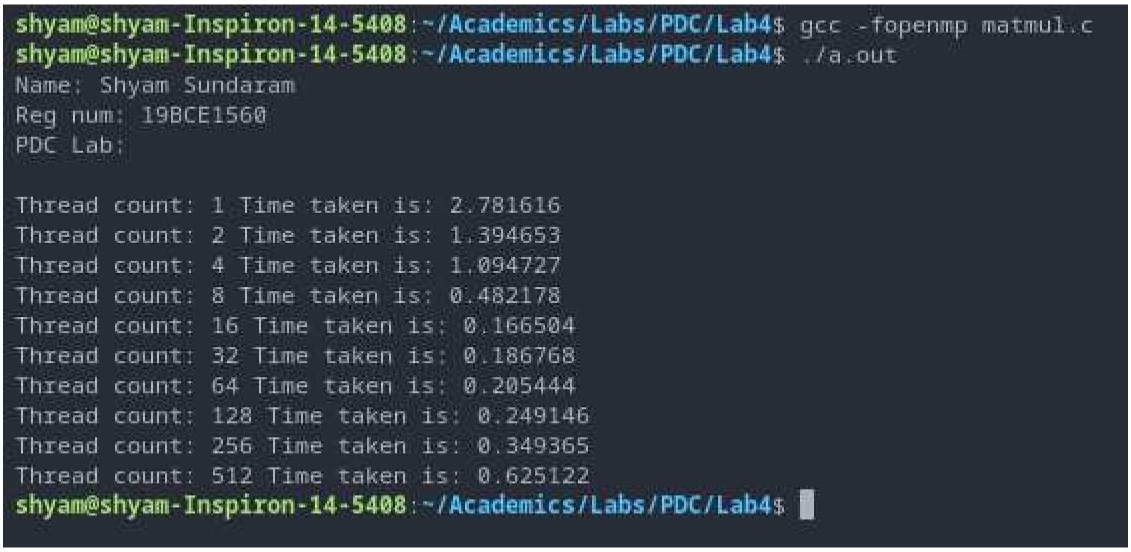
ASSUMPTION

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.

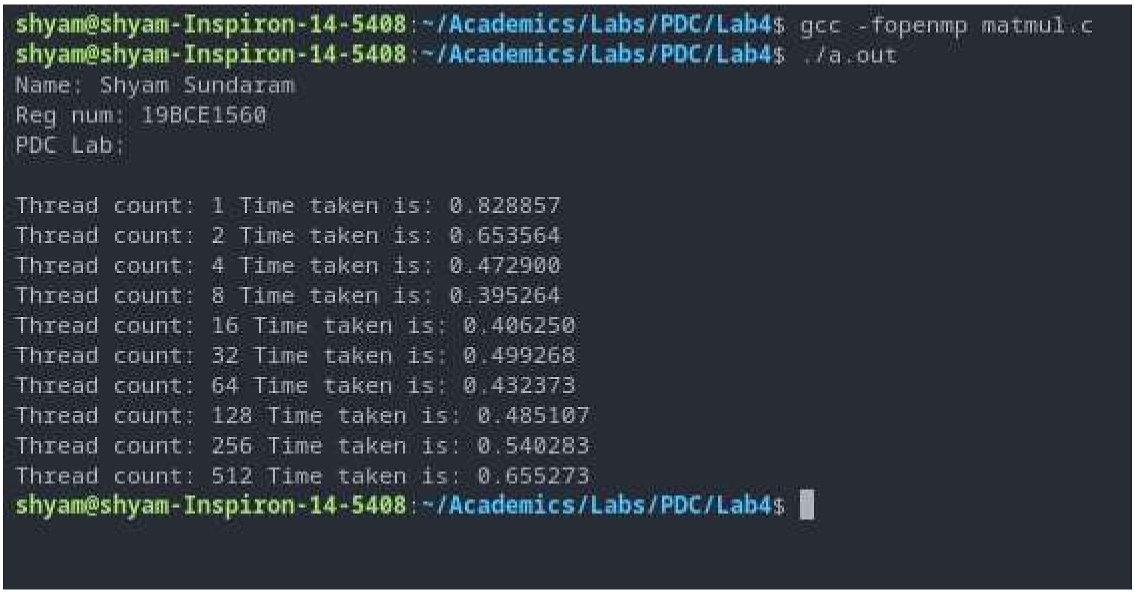
SCREENSHOTS



```
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$ gcc -fopenmp matmul.c
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Thread count: 1 Time taken is: 2.557129
Thread count: 2 Time taken is: 1.264160
Thread count: 4 Time taken is: 0.811768
Thread count: 8 Time taken is: 0.745850
Thread count: 16 Time taken is: 0.738037
Thread count: 32 Time taken is: 0.559326
Thread count: 64 Time taken is: 0.185547
Thread count: 128 Time taken is: 0.235352
Thread count: 256 Time taken is: 0.352783
Thread count: 512 Time taken is: 0.536133
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$
```

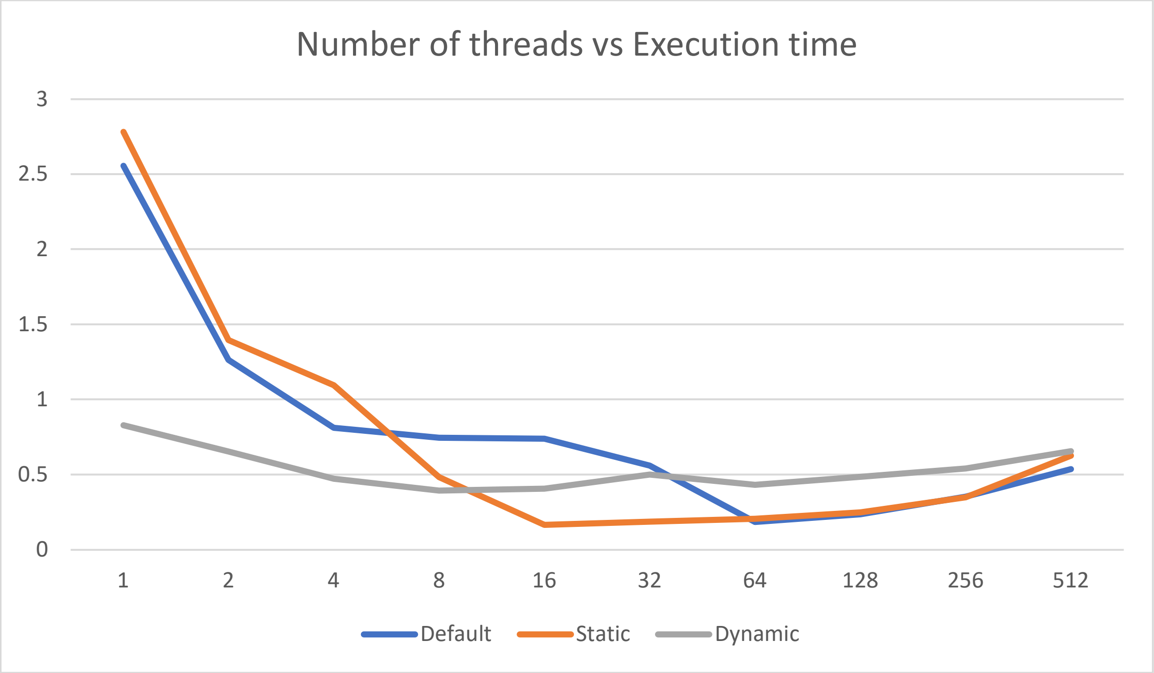


```
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$ gcc -fopenmp matmul.c
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Thread count: 1 Time taken is: 2.781616
Thread count: 2 Time taken is: 1.394653
Thread count: 4 Time taken is: 1.094727
Thread count: 8 Time taken is: 0.482178
Thread count: 16 Time taken is: 0.166504
Thread count: 32 Time taken is: 0.186768
Thread count: 64 Time taken is: 0.205444
Thread count: 128 Time taken is: 0.249146
Thread count: 256 Time taken is: 0.349365
Thread count: 512 Time taken is: 0.625122
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$
```



```
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$ gcc -fopenmp matmul.c
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$ ./a.out
Name: Shyam Sundaram
Reg num: 19BCE1560
PDC Lab:

Thread count: 1 Time taken is: 0.828857
Thread count: 2 Time taken is: 0.653564
Thread count: 4 Time taken is: 0.472900
Thread count: 8 Time taken is: 0.395264
Thread count: 16 Time taken is: 0.406250
Thread count: 32 Time taken is: 0.499268
Thread count: 64 Time taken is: 0.432373
Thread count: 128 Time taken is: 0.485107
Thread count: 256 Time taken is: 0.540283
Thread count: 512 Time taken is: 0.655273
shyam@shyam-Inspiron-14-5408:~/Academics/Labs/PDC/Lab4$
```

PLOTS



INFERENCE

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