PARALLEL AND DISTRIBUTED COMPUTING LAB

REPORT

NAME: S Shyam Sundaram

REG NO: 19BCE1560

PROGRAMMING ENVIRONMENT: OpenMP

PROBLEM: Finding the prefix sum and calculating pi (with and without reduction) with guided scheduling

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

PREFIX SUM

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};

   long *x=(long*)malloc(N*sizeof(long));
   for(int i=0;i<N;++i)
   {
      x[i]=i;
   }

   for(int t=0;t<10;++t)
```

```
    {
        omp_set_num_threads(thread[t]);

        long *y=(long*)malloc(N*sizeof(long));
        long *z=(long*)malloc(N*sizeof(long));
        #pragma omp parallel for
        for(int i=0;i<N;++i)
        y[i]=x[i];

        float start=omp_get_wtime();
        int d=1;
        while(d<N)
        {
            int i;
            #pragma omp parallel for schedule(guided)
            for(i=d;i<N;++i)
            z[i]=y[i-d];

            #pragma omp parallel for schedule(guided)
            for(i=d;i<N;++i)
            y[i]+=z[i];

            d*=2;
        }
        float end=omp_get_wtime();
        float exec=end-start;
        printf("Thread count: %d Time taken is: %f\n",thread[t],exec);
        // for(int i=0;i<N;++i)
        // printf("%ld ",y[i]);
        free(y);
        free(z);
    }
    free(x);
}
```

COMPILATION AND EXECUTION

```
gcc -fopenmp prefixsum2.c
./a.out
```

OBSERVATIONS

N	NUMBER OF THREADS	GUIDED SCHEDULING EXECUTION TIME
10000000	1	5.608856
	2	0.855698
	4	0.704330
	8	0.584625
	16	0.588684
	32	0.586212
	64	0.590820
	128	0.589951
	256	0.622177
	512	0.663330
100000000	1	40.406250
	2	12.852386
	4	6.379395
	8	6.572662
	16	6.568298
	32	6.539917
	64	6.551178
	128	6.557220
	256	6.590454
	512	6.658295

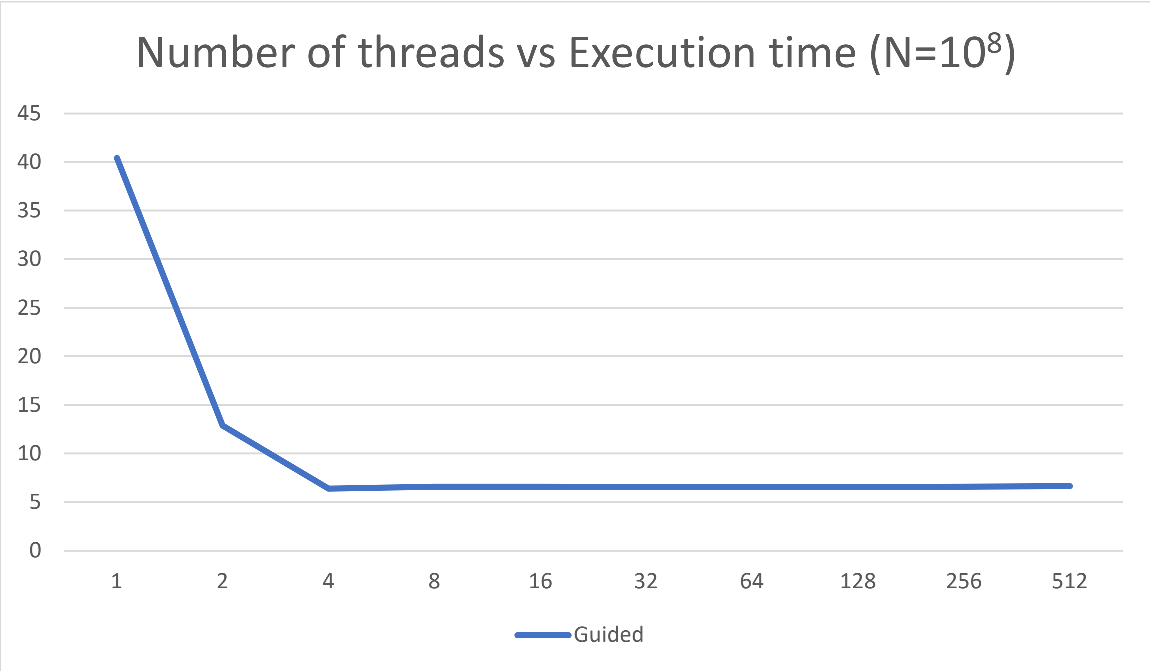
ASSUMPTION

As the number of threads increase, the work done by each thread is reduced, thus we see an overall decline in the execution (up to a point in some cases). Guided scheduling behaves similarly to dynamic scheduling but seems to handle load imbalance better.

SCREENSHOTS

```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$ gcc -fopenmp prefixsum2.c
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$ ./a.out
Thread count: 1 Time taken is: 40.406250
Thread count: 2 Time taken is: 12.852386
Thread count: 4 Time taken is: 6.379395
Thread count: 8 Time taken is: 6.572662
Thread count: 16 Time taken is: 6.568298
Thread count: 32 Time taken is: 6.539917
Thread count: 64 Time taken is: 6.551178
Thread count: 128 Time taken is: 6.557220
Thread count: 256 Time taken is: 6.590454
Thread count: 512 Time taken is: 6.658295
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$
```

PLOT



INFERENCE

As more threads are allocated, the workload is distributed, thus the overall execution time decreases. Guided scheduling also handles load imbalance better by starting with a larger chunk size and decreasing it as time goes on.

CALCULATING PI WITH CRITICAL CONSTRUCT

CODE

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

#define terms 10000000

int main()
{

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


   for(int t=0;t<10;++t)
   {
      omp_set_num_threads(thread[t]);
      int i=3;
      double sum=4;
      double ps;
      float start=omp_get_wtime();
      #pragma omp parallel for schedule(guided,chunk) private(i,ps) shared(sum)
      for(i=3;i<2*terms;i+=2)
      {
         ps=((pow(-1,i/2)*4)/i);

         #pragma omp critical
         sum=sum+ps;
      }
      printf("sum= %f ",sum);
      float end=omp_get_wtime();
      float exec=end-start;
      printf("Thread count: %d Time taken is: %f\n",thread[t],exec);
   }
   return 0;
}
```

COMPILATION AND EXECUTION

gcc -fopenmp picritic.c -lm
./a.out

OBSERVATIONS

N	NUMBER OF THREADS	GUIDED SCHEDULING EXECUTION TIME
1000000	1	0.097900
	2	0.204346
	4	0.583252
	8	0.963867
	16	0.932251
	32	0.936401
	64	0.961792
	128	0.972412
	256	0.498901
	512	0.188843
10000000	1	0.969238
	2	2.975098
	4	1.883789
	8	1.958496
	16	1.828613
	32	1.869629
	64	1.947266
	128	1.984131
	256	1.992676
	512	1.992188

ASSUMPTION

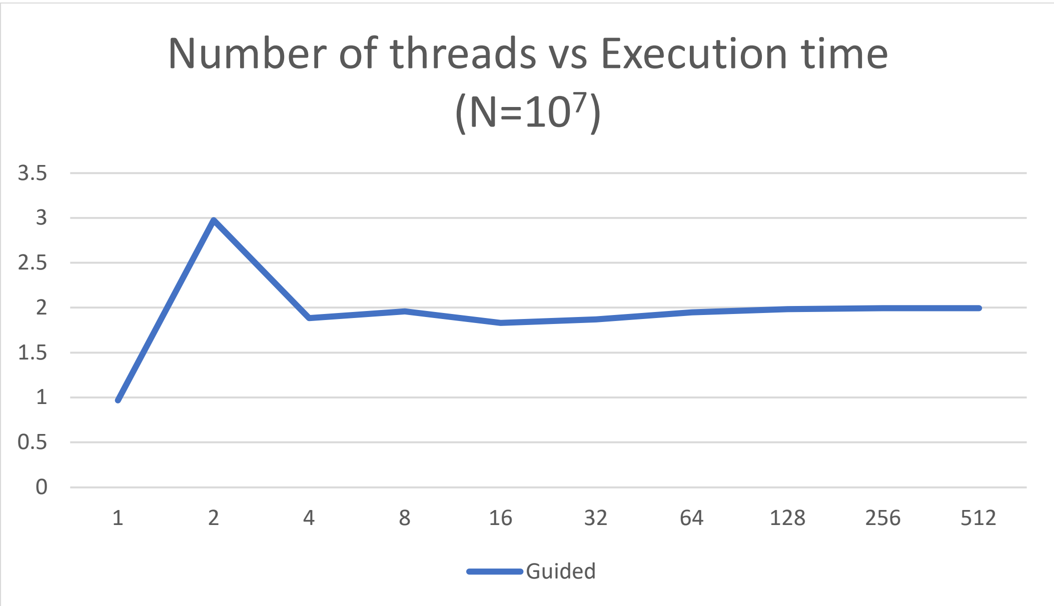
As the number of threads increase, the work done by each thread is reduced, thus we see an overall decline in the execution (up to a point in some cases). Guided scheduling behaves similarly to dynamic scheduling but seems to handle load imbalance better.

SCREENSHOTS

```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$ gcc -fopenmp picritic.c -lm
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$ ./a.out
sum= 3.141592 Thread count: 1 Time taken is: 0.097900
sum= 3.141592 Thread count: 2 Time taken is: 0.204346
sum= 3.141592 Thread count: 4 Time taken is: 0.583252
sum= 3.141592 Thread count: 8 Time taken is: 0.963867
sum= 3.141592 Thread count: 16 Time taken is: 0.932251
sum= 3.141592 Thread count: 32 Time taken is: 0.936401
sum= 3.141592 Thread count: 64 Time taken is: 0.961792
sum= 3.141592 Thread count: 128 Time taken is: 0.972412
sum= 3.141592 Thread count: 256 Time taken is: 0.498901
sum= 3.141592 Thread count: 512 Time taken is: 0.188843
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$
```

```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$ gcc -fopenmp picritic.c -lm
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$ ./a.out
sum= 3.141593 Thread count: 1 Time taken is: 0.969238
sum= 3.141593 Thread count: 2 Time taken is: 2.975098
sum= 3.141593 Thread count: 4 Time taken is: 1.883789
sum= 3.141593 Thread count: 8 Time taken is: 1.958496
sum= 3.141593 Thread count: 16 Time taken is: 1.828613
sum= 3.141593 Thread count: 32 Time taken is: 1.869629
sum= 3.141593 Thread count: 64 Time taken is: 1.947266
sum= 3.141593 Thread count: 128 Time taken is: 1.984131
sum= 3.141593 Thread count: 256 Time taken is: 1.992676
sum= 3.141593 Thread count: 512 Time taken is: 1.992188
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$
```

PLOT



INFERENCE

As more threads are allocated, the workload is distributed, thus the overall execution time decreases. Guided scheduling also handles load imbalance better by starting with a larger chunk size and decreasing it as time goes on. The critical construct ensures that only one thread updates sum at a time.

CALCULATING PI WITH SINGLE CONSTRUCT

CODE

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

#define terms 10000000

int main()
{

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

  for(int t=0;t<10;++t)
  {
    omp_set_num_threads(thread[t]);
    int i=3;
    double *sum=malloc(sizeof(double)*thread[t]);
    for(int k=0;k<thread[t];++k)
    sum[k]=0;
    double pi=4;
    double ps;
    float start=omp_get_wtime();
    #pragma omp parallel private(i,ps) shared(sum)
    {

      #pragma omp for schedule(guided,chunk)
      for(i=3;i<2*terms;i+=2)
      {
        ps=((pow(-1,i/2)*4)/i);
        sum[omp_get_thread_num()]+=ps;
      }

      #pragma omp single
      {
        for(int k=0;k<thread[t];++k)
        pi+=sum[k];
      }
    }
    printf("sum= %f ",pi);
    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;
}
```

COMPILATION AND EXECUTION

```
gcc -fopenmp pisingle.c -lm
./a.out
```

OBSERVATIONS

N	NUMBER OF THREADS	GUIDED SCHEDULING EXECUTION TIME
1000000	1	0.090088
	2	0.088135
	4	0.052734
	8	0.046387
	16	0.060059
	32	0.033691
	64	0.034180
	128	0.034912
	256	0.039795
	512	0.048340
10000000	1	0.886230
	2	0.898926
	4	0.464844
	8	0.423828
	16	0.416992
	32	0.302734
	64	0.249023
	128	0.215332
	256	0.206543
	512	0.218262

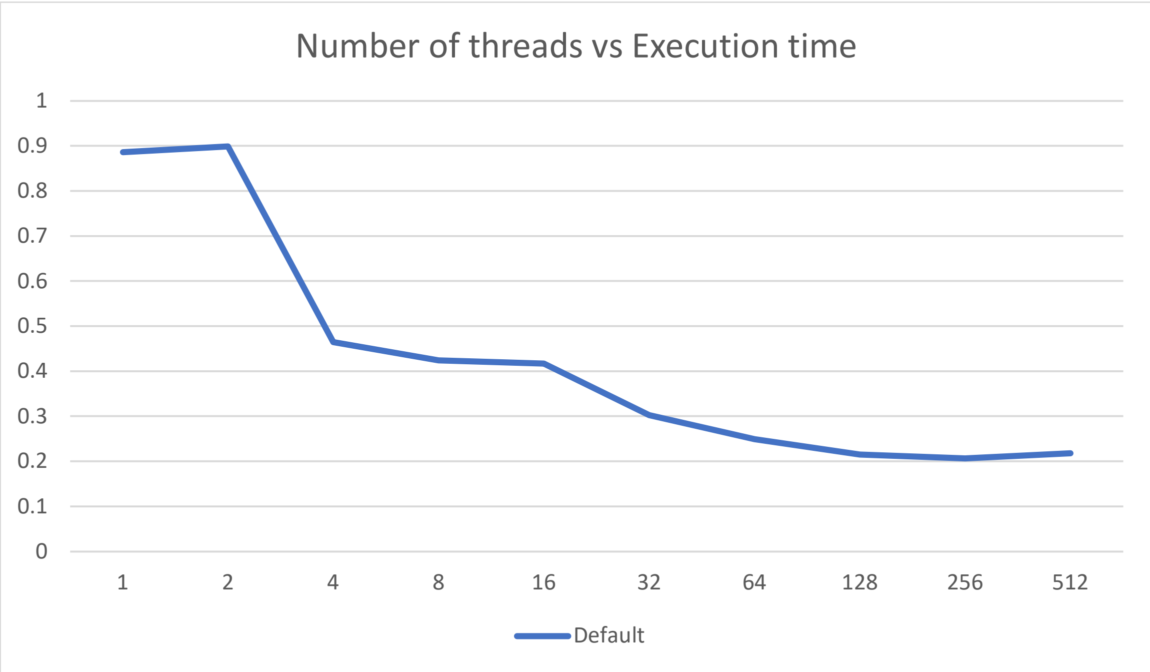
ASSUMPTION

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

SCREENSHOTS

```
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$ gcc -fopenmp pisingle.c -lm
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$ ./a.out
sum= 3.141593 Thread count: 1 Time taken is: 0.886230
sum= 3.141593 Thread count: 2 Time taken is: 0.898926
sum= 3.141593 Thread count: 4 Time taken is: 0.464844
sum= 3.141593 Thread count: 8 Time taken is: 0.423828
sum= 3.141593 Thread count: 16 Time taken is: 0.416992
sum= 3.141593 Thread count: 32 Time taken is: 0.302734
sum= 3.141593 Thread count: 64 Time taken is: 0.249023
sum= 3.141593 Thread count: 128 Time taken is: 0.215332
sum= 3.141593 Thread count: 256 Time taken is: 0.206543
sum= 3.141593 Thread count: 512 Time taken is: 0.218262
shyam@shyam-Inspiron-14-5408:~/Academics/Lab-Fall-2021/PDC/Lab6$
```

PLOTS



INFERENCE

As more threads are allocated, the workload is distributed, thus the overall execution time decreases. Guided scheduling behaves similarly to dynamic scheduling but seems to handle load imbalance better.