Walchand College of Engineering, Sangli
Department of Computer Science and Engineering

Class: Final Year (Computer Science and Engineering)

Year: 2023-24 **Semester:** 1

Course: High Performance Computing Lab

Practical No. 5

PRN: 2020BTECS00057

Title of practical: Implementation of OpenMP programs.

Implement following Programs using OpenMP with C:

1. Implementation of sum of two lower triangular matrices.
2. Implementation of Matrix-Matrix Multiplication.

Problem Statement 1: Implementation of sum of two lower triangular matrices.

Code:

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

int main(){
    int dimention;

    printf("Enter dimention for matrix = ");
    scanf("%d",&dimention);

    //Serial Code
    int m1[dimention][dimention];
    int count=0;
    printf("\nSerial\n");

    double start_time_serial = omp_get_wtime();
    for(int i=0;i<dimention;i++){
        for(int j=0;j<dimention;j++){
            m1[i][j]=++count;
            printf("%d\t",m1[i][j]);
        }
        printf("\n");
    }
```

```
    int sum=0;
    for(int i=0;i<dimention;i++){
        for(int j=0;j<dimention;j++){
            if(i>j) sum+=m1[i][j];
        }
    }

    int sum2=0;
    for(int i=0;i<dimention;i++){
        for(int j=0;j<dimention;j++){
            if(j<dimention-i)   continue;
            else    sum2+=m1[i][j];
        }
    }
    double end_time_serial = omp_get_wtime();
    printf("\nLeft Lower Triangle Sum = %d",sum);
    printf("\nRight Lower Triangle Sum = %d",sum2);
    printf("\nTwo Lower Triangles Sum = %d",(sum+sum2));

    //Parallel code
    count=0;
    printf("\nParallel\n");
    double start_time_parallel = omp_get_wtime();
    #pragma omp parallel for ordered num_threads(8)
    for(int i=0;i<dimention;i++){
        for(int j=0;j<dimention;j++){
            m1[i][j]=++count;
            printf("%d\t",m1[i][j]);
        }
        printf("\n");
    }

    sum=0;
    #pragma omp parallel for num_threads(8)
    for(int i=0;i<dimention;i++){
        for(int j=0;j<dimention;j++){
            if(i>j) sum+=m1[i][j];
        }
    }

    sum2=0;
    #pragma omp parallel for num_threads(8)
    for(int i=0;i<dimention;i++){
        for(int j=0;j<dimention;j++){
            if(j<dimention-i)   continue;
```

Screenshots:

Keeping number of threads constant and varying size of Data.

Threads = 8, Matrix size = 10

```
Left Lower Triangle Sum = 1708
Right Lower Triangle Sum = 2169
Two Lower Triangles Sum = 3877

Serial Method Time: 0.014000 seconds

Parallel Method Time: 0.006000 seconds
```

Threads = 8, Matrix size = 100

```
Left Lower Triangle Sum = 17598578
Right Lower Triangle Sum = 14845903
Two Lower Triangles Sum = 32444481

Serial Method Time: 0.468000 seconds

Parallel Method Time: 0.473000 seconds
```

Threads = 8, Matrix Size = 200

```
Left Lower Triangle Sum = 131710943
Right Lower Triangle Sum = 187292670
Two Lower Triangles Sum = 319003613

Serial Method Time: 1.825000 seconds

Parallel Method Time: 1.981000 seconds
```

Keeping data constant and increasing number of threads.

Threads = 2, Matrix size = 10

```
Left Lower Triangle Sum = 2976
Right Lower Triangle Sum = 3190
Two Lower Triangles Sum = 6166

Serial Method Time: 0.009000 seconds

Parallel Method Time: 0.005000 seconds
```

Threads = 2, Matrix size = 200

```
Left Lower Triangle Sum = 338712810
Right Lower Triangle Sum = 371246169
Two Lower Triangles Sum = 709958979

Serial Method Time: 1.810000 seconds

Parallel Method Time: 1.915000 seconds
```

Threads = 4, Matrix size = 10

```
Left Lower Triangle Sum = 1883
Right Lower Triangle Sum = 2159
Two Lower Triangles Sum = 4042

Serial Method Time: 0.018000 seconds

Parallel Method Time: 0.006000 seconds
```

Threads = 10, Matrix size = 10

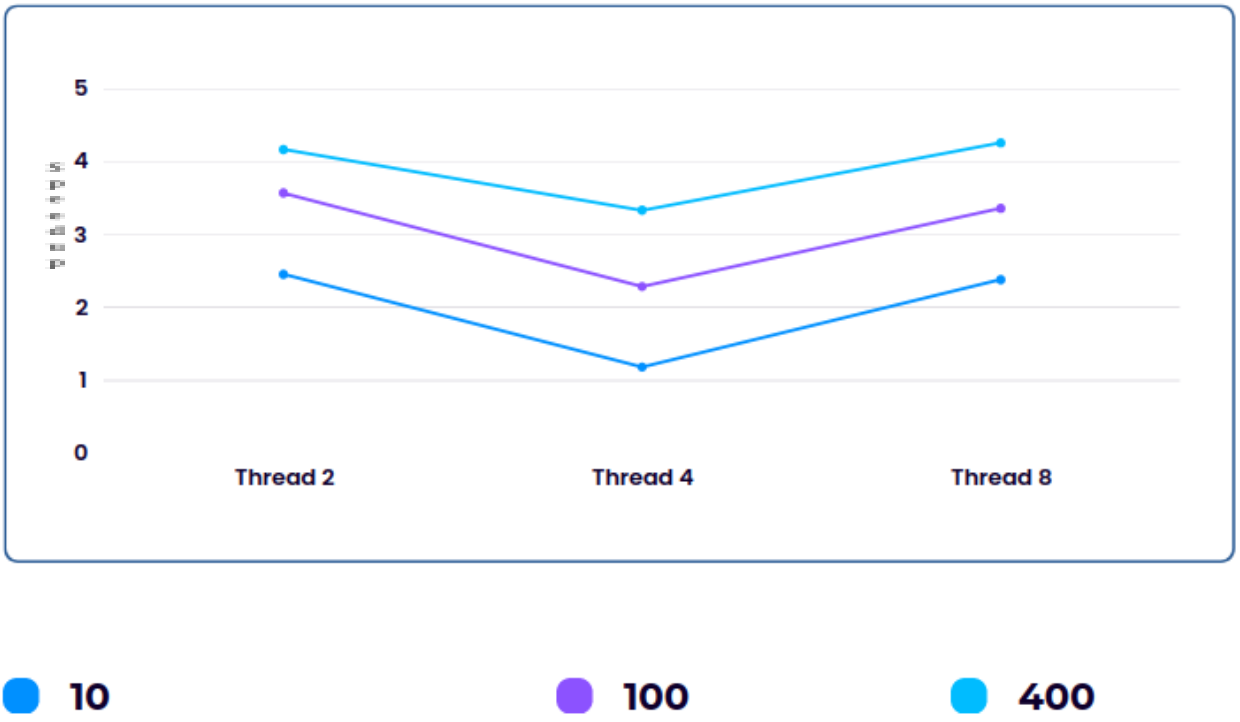
```
Left Lower Triangle Sum = 1942
Right Lower Triangle Sum = 2381
Two Lower Triangles Sum = 4323

Serial Method Time: 0.013000 seconds

Parallel Method Time: 0.008000 seconds
```

Information:

It is observed that keeping threads constant i.e., 8 we will get same difference in serial and parallel time, there is no affect of change in data size. On other hand by varying the number threads to appropriate amount will give significantly reduce in time of parallel execution.

Analysis:

Number of Threads	Data Size	Sequential Time(sec)(Ts)	Parallel Time(sec)(Tp)	Speedup(Ts/Tp)
8	10	0.001400	0.006000	0.233333
8	100	0.468000	0.473000	0.989429
8	200	1.825000	1.981000	0.921252
2	10	0.001400	0.005000	0.280000
2	100	0.468000	0.450000	1.040000
2	200	1.825000	1.915000	0.953003
4	10	0.001400	0.006000	0.233333
4	100	0.468000	0.479000	0.977035
4	200	1.825000	1.894000	0.963569
10	10	0.001400	0.008000	0.175000
10	100	0.468000	0.485000	0.964948
10	200	1.825000	1.858000	0.982239



Problem Statement 2: Implementation of Matrix-Matrix Multiplication.

Code:

```c
#include <stdio.h>
#include <omp.h>
#include<time.h>

int main()
{
   int i,j,k,N;
   printf("Enter size = ");
   scanf("%d",&N);
   int A[N][N];
   int B[N][N];
   int C[N][N];
   clock_t st = clock();
   for (i= 0; i< N; i++)
   {
       for (j= 0; j< N; j++)
       {
           A[i][j] = i+j;
           B[i][j] = i+j;
           C[i][j] = 0;
       }
   }
   printf("\nMatrix\n");
   for (i= 0; i< N; i++)
   {
       for (j= 0; j< N; j++)
       {
           printf("%d\t",A[i][j]);
       }
       printf("\n");
   }
   #pragma omp parallel for private(i,j,k) shared(A,B,C) num_threads(4)
   for (i = 0; i < N; i++)
   {
       for (j = 0; j < N; j++)
       {
           for (k = 0; k < N; k++)
           {
               C[i][j] += A[i][k] * B[k][j];
           }
       }
```

```
    }
    printf("\nAnswer\n");
    for (i = 0; i < N;
    i++)
    {
        for (j = 0; j < N; j++)
        {

                printf("%d\t",C[i][j]);

        }
        printf("\n");
    }
    clock_t et = clock();
    double elapsed_time = (double)(et - st) / CLOCKS_PER_SEC;
    double elapsed_miliseconds = elapsed_time * 1000;
    printf("\nTime taken: %f miliseconds",
    elapsed_miliseconds); printf("\nTime taken: %f
    seconds\n", elapsed_time);
}
```

Screenshots:

Keeping number of threads constant and varying size of Data.

Threads = 4, Matrix size = 10

```
Time taken: 25.000000 miliseconds
Time taken: 0.025000 seconds
```

Threads = 4, Matrix size = 100

```
Time taken: 2374.000000 miliseconds
Time taken: 2.374000 seconds
```

Threads = 4, Matrix size = 400

```
Time taken: 18446.000000 miliseconds
Time taken: 18.446000 seconds
```

Keeping data constant and increasing number of threads.

Threads = 2, Matrix size = 100

```
Time taken: 1140.000000 miliseconds
Time taken: 1.140000 seconds
```

Threads = 8, Matrix size = 100

```
Time taken: 1175.000000 miliseconds
Time taken: 1.175000 seconds
```

Threads = 20, Matrix size = 100

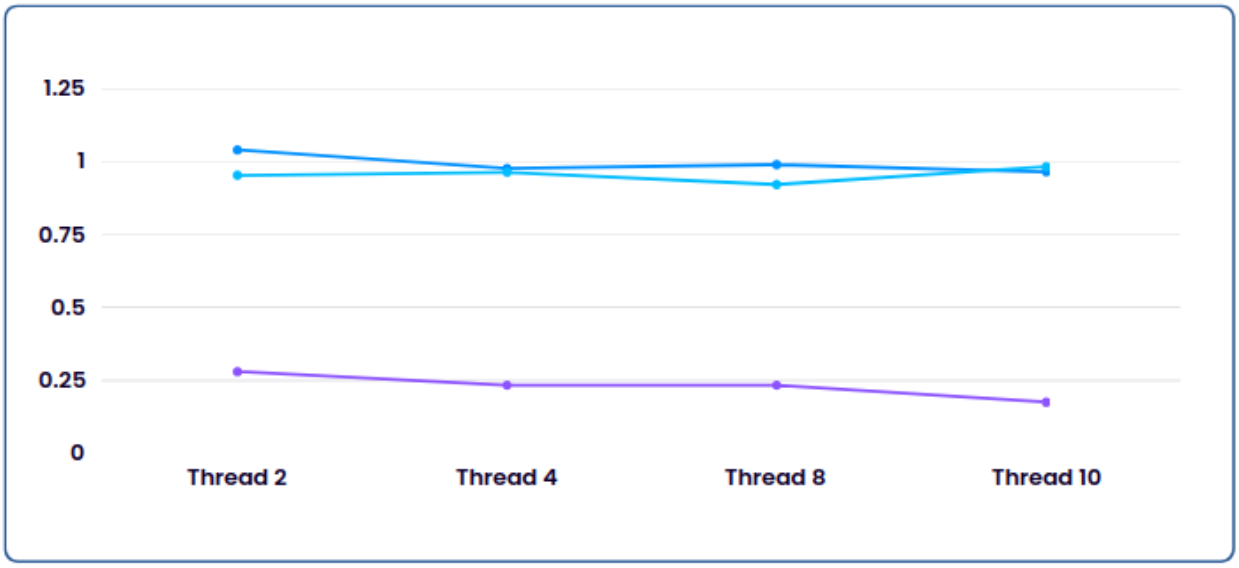
```
Time taken: 1177.000000 miliseconds
Time taken: 1.177000 seconds
```

Information:

Problem is calculating the matrix multiplication by varying the size of the matrix. It is noted that as we increase the size of the matrix the time required for sequential execution is more while parallel execution complete the same task in lesser time. Even when we increase the number of threads, more execution speed is achieved by parallelism.

Analysis:

Number of Threads	Data Size	Sequential Time(sec)(Ts)	Parallel Time(sec)(Tp)	Speedup(Ts/Tp)
4	10	0.057000	0.025000	2.280000
4	100	2.790000	2.374000	1.175232
4	400	61.349000	18.446000	3.325870
2	10	0.057000	0.016000	3.562500
2	100	2.790000	1.140000	2.447368
2	400	61.349000	14.753000	4.158408
8	10	0.057000	0.017000	3.352941
8	100	2.790000	1.175000	2.374468
8	400	61.349000	14.434000	4.250312
20	100	2.790000	1.177000	2.370433


1.25
1
0.75
0.5
0.25
0
Thread 2
Thread 4
Thread 8
Thread 10
10
100
200