High Performance Computing

COM403P

Week-6

Matrix Multiplication

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Objective

Matrix Multiplication for given n x n double precision floating point numbers.

Serial Code

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

#define SIZE 100

int main()
{
   double a[SIZE][SIZE], b[SIZE][SIZE], c[SIZE][SIZE], rand_a, rand_b;
   double start, end, exec;

   start = omp_get_wtime();

   for (int i = 0; i < SIZE; i++)
   {
       for(int j = 0; j < SIZE; j++)
       {
           rand_a = rand();
           rand_b = rand();

           a[i][j] = i*rand_a;
           b[i][j] = i*rand_b;

           // for(int k = 0; k < 100000; k++)
           c[i][j] = a[i][j] * b[i][j];
       }
   }

   end = omp_get_wtime();

   exec = end - start;

   printf("Serial Exec time - %f\n", exec);

   return 0;
}
```

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Parallel Code

```c
#include <stdio.h>
#include <stdlib.h>
#include <mpi.h>
#include <time.h>

#define MASTER 0
#define FROM_MASTER 1
#define FROM_WORKER 2

#define SIZE 100

int main()
{
   MPI_Init(NULL, NULL);

   long double a[SIZE][SIZE], b[SIZE][SIZE], c[SIZE][SIZE], rand_a, rand_b;
   double start, end, exec;
   int i,j,k;

   int avgrow, extra;
   int offset, mtype;
   int dest, rows;
   int source;
   MPI_Status status;

   start = MPI_Wtime();

   int taskid;
   MPI_Comm_rank(MPI_COMM_WORLD,&taskid);

   int numtasks;
   MPI_Comm_size(MPI_COMM_WORLD,&numtasks);

   int workers = numtasks -1;

   if(taskid == MASTER)
   {
       for (i = 0; i < SIZE; i++)
       {
```

```
            for(j = 0; j < SIZE; j++)
            {
                a[i][j] = (i+j)*1.22;
                b[i][j] = (i+j)*1.22;
            }
        }

//-------------------------------------------------------------------------------------------
--------------
        // Master sending Data to Worker tasks

        avgrow = SIZE/workers;
        extra = SIZE%workers;

        offset = 0;
        mtype = FROM_MASTER;

        for(dest = 1; dest <= workers; dest++)
        {
            rows = (dest <= extra)?avgrow+1:avgrow;

            // printf("Sending %d rows to task-%d offset=%d\n",rows,dest,offset);

            MPI_Send(&offset, 1, MPI_INT, dest, mtype, MPI_COMM_WORLD);
            MPI_Send(&rows, 1, MPI_INT, dest, mtype, MPI_COMM_WORLD);
            MPI_Send(&a[offset][0], rows*SIZE, MPI_LONG_DOUBLE, dest, mtype,
MPI_COMM_WORLD);
            MPI_Send(&b[offset][0], rows*SIZE, MPI_LONG_DOUBLE, dest, mtype,
MPI_COMM_WORLD);

            offset += rows;
        }


//-------------------------------------------------------------------------------------------
--------------
        //Receiving results from Workers

        mtype = FROM_WORKER;
        for(i = 1; i <= workers; i++)
        {
            source = i;
```

```
            MPI_Recv(&offset, 1, MPI_INT, source, mtype, MPI_COMM_WORLD, &status);
            MPI_Recv(&rows, 1, MPI_INT, source, mtype, MPI_COMM_WORLD, &status);
            MPI_Recv(&c[offset][0], rows*SIZE, MPI_LONG_DOUBLE, source, mtype,
MPI_COMM_WORLD, &status);

            // printf("Received results from task=%d\n", source);
        }
        // printf("Result Matrix\n");

        // for(i = 0; i < SIZE;i++)
        // {
        //     // printf("\n");
        //     for(int j = 0; j < SIZE;j++)
        //     {
        //         // printf("%6.2Lf  ",c[i][j]);
        //     }
        // }
        end = MPI_Wtime();

        exec = end - start;
        printf("MPI Exec time - %f\n", exec);
    }


//-------------------------------------------------------------------------------------------
-------------




//-------------------------------------------------------------------------------------------
--------------
    //Worker Task
    if(taskid > MASTER)
    {
        mtype = FROM_MASTER;

        MPI_Recv(&offset, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD,&status);
        MPI_Recv(&rows, 1, MPI_INT, MASTER, mtype, MPI_COMM_WORLD,&status);
        MPI_Recv(&a, rows*SIZE, MPI_LONG_DOUBLE, MASTER, mtype, MPI_COMM_WORLD,&status);
        MPI_Recv(&b, rows*SIZE, MPI_LONG_DOUBLE, MASTER, mtype, MPI_COMM_WORLD,&status);

        for(k = 0; k < SIZE; k++)
        {
```

```
            for(i = 0; i < rows; i++)
            {
                c[i][k] = a[i][k] * b[i][k];
            }
        }

        mtype = FROM_WORKER;

        MPI_Send(&offset,1, MPI_INT, MASTER,mtype, MPI_COMM_WORLD);
        MPI_Send(&rows,1, MPI_INT, MASTER,mtype, MPI_COMM_WORLD);
        MPI_Send(&c, rows*SIZE, MPI_LONG_DOUBLE, dest, mtype, MPI_COMM_WORLD);

    }
    MPI_Finalize();

    return 0;
}
```

Observations

no of processors	Exec Time	Speedup	Parallelization Factor
1	0.000359	1	0
2	0.002854	0.5557112824	-0.666246322
4	0.0126	0.1258730159	-4.629676335
8	0.057482	0.02759124596	-11.74779319
16	0.392194	0.004043917041	82.0949979
32	1.652586	0.000959707997	1734.972678
64	7.239875	0.0002190645557	19776.7459
128	23.03238	0.00006885957943	140372.641

Threads vs Time

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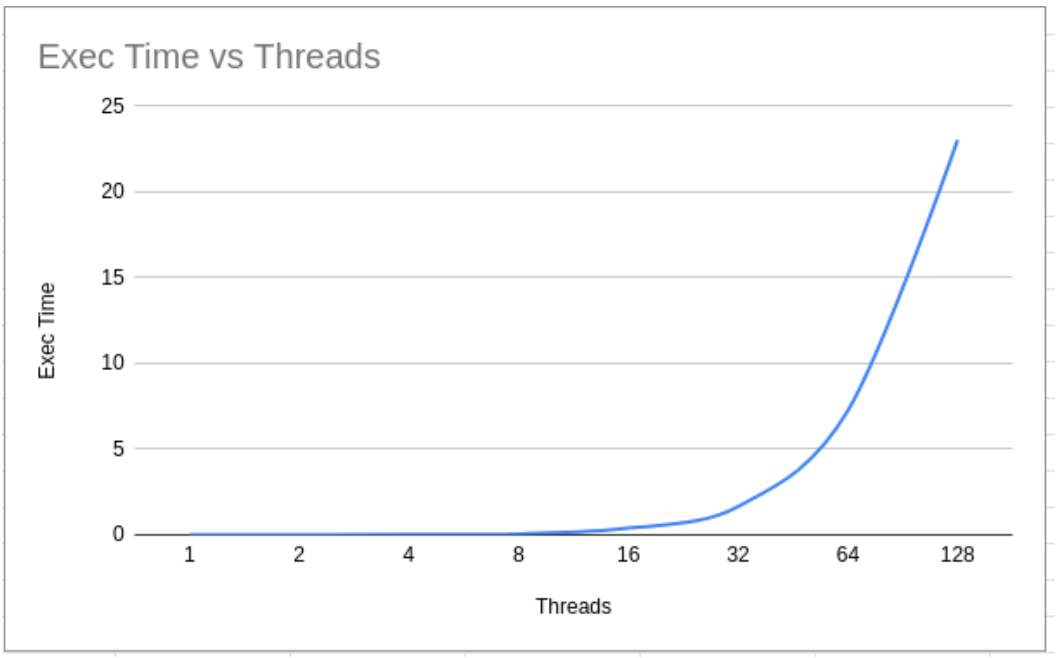
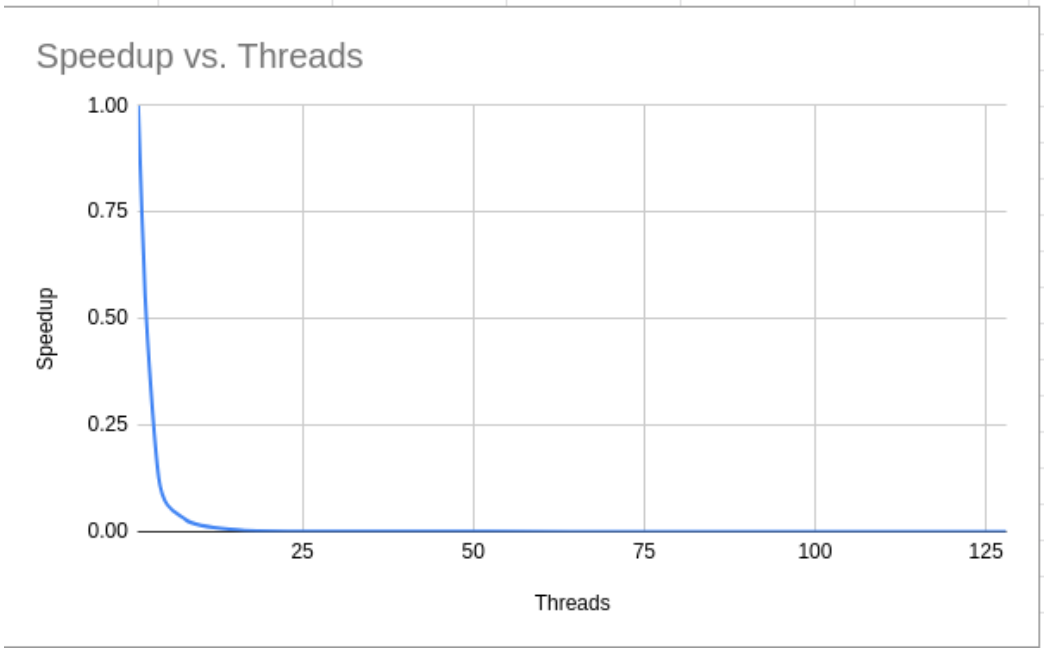


Speedups vs Threads



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Inferences

Since MPI is a distributed memory architecture, the communication overhead between nodes causes the parallel code to run slower compared to serial code (running in 1 node or only in master)