High Performance Computing

COM403P

Week-5

Vector Multiplication

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Objective

Vector 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 100000

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

   start = omp_get_wtime();

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

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

       c[i] = a[i] * b[i];
   }

   end = omp_get_wtime();

   exec = end - start;

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

   return 0;
}
```

Parallel Code

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```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++)
       {
           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], rows, MPI_LONG_DOUBLE, dest, mtype, MPI_COMM_WORLD);
           MPI_Send(&b[offset], rows, 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], rows, MPI_LONG_DOUBLE, source, mtype, MPI_COMM_WORLD,
&status);

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

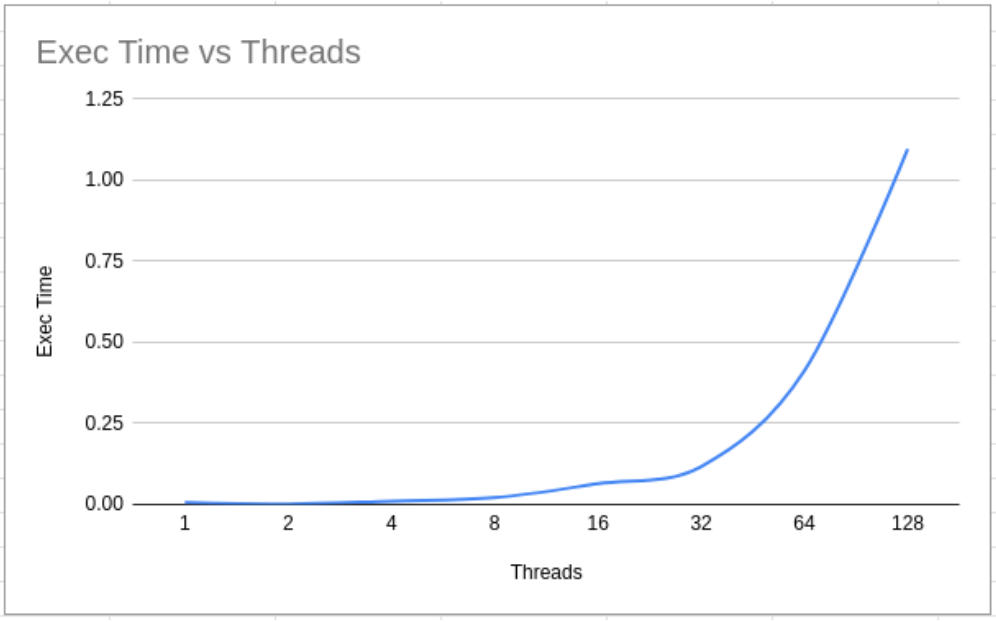
```
        // for(i = 0; i < SIZE;i++)
        // {
        //     // printf("\n");
        //     for(int j = 0; j < SIZE;j++)
        //     {
        //         // printf("%6.2Lf  ",c[i][j]);
        //     }
        // }

        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, MPI_LONG_DOUBLE, MASTER, mtype, MPI_COMM_WORLD,&status);
        MPI_Recv(&b, rows, MPI_LONG_DOUBLE, MASTER, mtype, MPI_COMM_WORLD,&status);


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

        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, MPI_LONG_DOUBLE, dest, mtype, MPI_COMM_WORLD);

    }
    MPI_Finalize();

    return 0;
}
```

Observations

no of processors	Exec Time	Speedup	Parallelization Factor
1	0.005653	1	0
2	0.001123	1.412288513	0.2432744851
4	0.010292	0.1541002721	-3.659520807
8	0.02087	0.07599425012	-4.05296343
16	0.064126	0.02473255778	13.14417823
32	0.117006	0.01355486043	121.2904582
64	0.412533	0.003844540922	1122.806011
128	1.096704	0.001446151377	6674.741908

Threads vs Time



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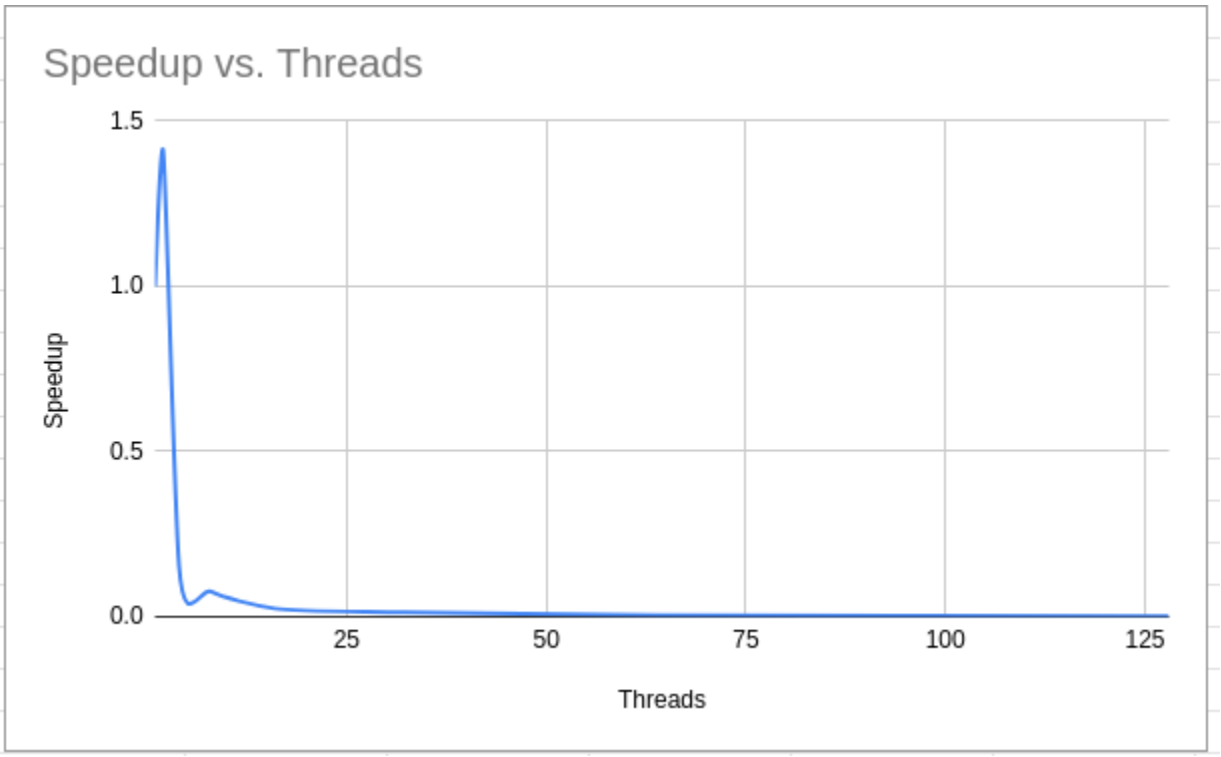
Speedups vs Threads



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)