Final Year B. Tech., Sem VII 2022-23

High Performance Computing Lab

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Assignment No. 8

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1. **Study and implement 2D Convolution using MPI. Use different number of processes and analyze the performance.**

```
#include <assert.h>

#include <math.h>

#include <string.h>

#include <stdio.h>

#include <stdlib.h>

#include <mpi.h>


typedef struct

{

   float r;

   float i;

} complex;

static complex ctmp;
```

```
#define C_SWAP(a, b) \
   {              \
      ctmp = (a);  \
      (a) = (b);   \
      (b) = ctmp;  \
   }

#define N 512

void c_fft1d(complex *r, int n, int isign)
{
   int m, i, i1, j, k, i2, l, l1, l2;
   float c1, c2, z;
   complex t, u;

   if (isign == 0)
      return;

   /* Do the bit reversal */
   i2 = n >> 1;
   j = 0;
   for (i = 0; i < n - 1; i++)
```

```
{
   if (i < j)
      C_SWAP(r[i], r[j]);
   k = i2;
   while (k <= j)
   {
      j -= k;
      k >>= 1;
   }
   j += k;
}

/* m = (int) log2((double)n); */
for (i = n, m = 0; i > 1; m++, i /= 2)
   ;

/* Compute the FFT */
c1 = -1.0;
c2 = 0.0;
l2 = 1;
for (l = 0; l < m; l++)
{
```

```
l1 = l2;
l2 <<= 1;
u.r = 1.0;
u.i = 0.0;
for (j = 0; j < l1; j++)
{
    for (i = j; i < n; i += l2)
    {
        i1 = i + l1;

        /* t = u * r[i1] */
        t.r = u.r * r[i1].r - u.i * r[i1].i;
        t.i = u.r * r[i1].i + u.i * r[i1].r;

        /* r[i1] = r[i] - t */
        r[i1].r = r[i].r - t.r;
        r[i1].i = r[i].i - t.i;

        /* r[i] = r[i] + t */
        r[i].r += t.r;
        r[i].i += t.i;
    }
```

```
            z = u.r * c1 - u.i * c2;


            u.i = u.r * c2 + u.i * c1;
            u.r = z;
        }
        c2 = sqrt((1.0 - c1) / 2.0);
        if (isign == -1) /* FWD FFT */
            c2 = -c2;
        c1 = sqrt((1.0 + c1) / 2.0);
    }


    /* Scaling for inverse transform */
    if (isign == 1)
    { /* IFFT*/
        for (i = 0; i < n; i++)
        {
            r[i].r /= n;
            r[i].i /= n;
        }
    }
}
```

```
void getData(char fileName[15], complex **data)
{
   FILE *fp = fopen(fileName, "r");

   int i, j, result;

   for (i = 0; i < N; i++)
   {
      for (j = 0; j < N; j++)
      {
         result = fscanf(fp, "%g", &data[i][j].r);
         data[i][j].i = 0.00;
      }
   }

   fclose(fp);
}

void transpose(complex **data, complex **transp)
{
   int i, j;
   for (i = 0; i < N; i++)
```

```
        for (j = 0; j < N; j++)
            transp[j][i] = data[i][j];
}

void mmpoint(complex **data1, complex **data2, complex **data3)
{

   int i, j;

   float real, imag;

   for (i = 0; i < N; i++)
   {
      for (j = 0; j < N; j++)
      {
         data3[i][j].r = (data1[i][j].r * data2[i][j].r) - (data1[i][j].i * data2[i][j].i);
         data3[i][j].i = (data1[i][j].r * data2[i][j].i) + (data1[i][j].i * data2[i][j].r);
      }
   }
}

void printfile(char fileName[15], complex **data)
```

```
{

    FILE *fp = fopen(fileName, "w");

    int i, j;

    for (i = 0; i < N; i++)
    {
        for (j = 0; j < N; j++)
        {
            fprintf(fp, "   %.7e", data[i][j].r);
        }
        fprintf(fp, "\n");
    }

    fclose(fp);
}

int main(int argc, char **argv)
{
    int my_rank, p, source = 0, dest, x;
```

```
complex **data1, **data2, **data3, **data4;
data1 = malloc(N * sizeof(complex *));
data2 = malloc(N * sizeof(complex *));
data3 = malloc(N * sizeof(complex *));
data4 = malloc(N * sizeof(complex *));
for (x = 0; x < N; x++)
{
   data1[x] = malloc(N * sizeof(complex *));
   data2[x] = malloc(N * sizeof(complex *));
   data3[x] = malloc(N * sizeof(complex *));
   data4[x] = malloc(N * sizeof(complex *));
}
complex *vec;

char fileName1[15] = "sample/in1";
char fileName2[15] = "sample/in2";
char fileName3[15] = "mpi_out_test";

MPI_Status status;

MPI_Init(&argc, &argv);
```

```
MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);

MPI_Comm_size(MPI_COMM_WORLD, &p);

/* Setup description of the 4 MPI_FLOAT fields x, y, z, velocity */
MPI_Datatype mystruct;
int blocklens[2] = {1, 1};
MPI_Aint indices[2] = {0, sizeof(float)};
MPI_Datatype old_types[2] = {MPI_FLOAT, MPI_FLOAT};

/* Make relative */
MPI_Type_struct(2, blocklens, indices, old_types, &mystruct);
MPI_Type_commit(&mystruct);

int i, j;

double startTime, stopTime;

// Starting and send rows of data1, data2

int offset;
```

```
int tag = 345;

int rows = N / p;

int lb = my_rank * rows;
int hb = lb + rows;

printf("%d have lb = %d and hb = %d\n", my_rank, lb, hb);

// Starting and send rows of data1, data2

if (my_rank == 0)
{
    getData(fileName1, data1);
    getData(fileName2, data2);

    /* Start Clock */
    printf("\nStarting clock.\n");
    startTime = MPI_Wtime();

    for (i = 1; i < p; i++)
    {
```

```
        offset = i * rows;
        for (j = offset; j < (offset + rows); j++)
        {
           MPI_Send(&data1[j][0], N, mystruct, i, tag, MPI_COMM_WORLD);
           MPI_Send(&data2[j][0], N, mystruct, i, tag, MPI_COMM_WORLD);
        }
    }
}
else
{

    for (j = lb; j < hb; j++)
    {
        MPI_Recv(data1[j], N, mystruct, 0, tag, MPI_COMM_WORLD, &status);
        MPI_Recv(data2[j], N, mystruct, 0, tag, MPI_COMM_WORLD, &status);
    }
}

// Doing fft1d forward for data1 and data2 rows

vec = (complex *)malloc(N * sizeof(complex));
```

```
for (i = lb; i < hb; i++)
{
   for (j = 0; j < N; j++)
   {
      vec[j] = data1[i][j];
   }
   c_fft1d(vec, N, -1);
   for (j = 0; j < N; j++)
   {
      data1[i][j] = vec[j];
   }
}

free(vec);

vec = (complex *)malloc(N * sizeof(complex));

for (i = lb; i < hb; i++)
{
   for (j = 0; j < N; j++)
   {
      vec[j] = data2[i][j];
```

```
    }
    c_fft1d(vec, N, -1);
    for (j = 0; j < N; j++)
    {
        data2[i][j] = vec[j];
    }
}

free(vec);

// Receving rows of data1, data2

if (my_rank == 0)
{
    for (i = 1; i < p; i++)
    {
        offset = i * rows;
        for (j = offset; j < (offset + rows); j++)
        {
            MPI_Recv(data1[j], N, mystruct, i, tag, MPI_COMM_WORLD, &status);
            MPI_Recv(data2[j], N, mystruct, i, tag, MPI_COMM_WORLD, &status);
        }
```

```
    }
}
else
{

    for (j = lb; j < hb; j++)
    {
        MPI_Send(&data1[j][0], N, mystruct, 0, tag, MPI_COMM_WORLD);
        MPI_Send(&data2[j][0], N, mystruct, 0, tag, MPI_COMM_WORLD);
    }
}

// Starting and send columns of data1, data2

if (my_rank == 0)
{
    transpose(data1, data3);
    transpose(data2, data4);

    for (i = 1; i < p; i++)
    {
        offset = i * rows;
```

```
        for (j = offset; j < (offset + rows); j++)
        {
            MPI_Send(&data3[j][0], N, mystruct, i, tag, MPI_COMM_WORLD);
            MPI_Send(&data4[j][0], N, mystruct, i, tag, MPI_COMM_WORLD);
        }
    }
}
else
{
    for (j = lb; j < hb; j++)
    {
        MPI_Recv(data3[j], N, mystruct, 0, tag, MPI_COMM_WORLD, &status);
        MPI_Recv(data4[j], N, mystruct, 0, tag, MPI_COMM_WORLD, &status);
    }
}

// Doing fft1d forward for data1 and data2 columns

vec = (complex *)malloc(N * sizeof(complex));

for (i = lb; i < hb; i++)
{
```

```
    for (j = 0; j < N; j++)
    {
        vec[j] = data3[i][j];
    }
    c_fft1d(vec, N, -1);
    for (j = 0; j < N; j++)
    {
        data3[i][j] = vec[j];
    }
}

free(vec);

vec = (complex *)malloc(N * sizeof(complex));

for (i = lb; i < hb; i++)
{
    for (j = 0; j < N; j++)
    {
        vec[j] = data4[i][j];
    }
    c_fft1d(vec, N, -1);
```

```
    for (j = 0; j < N; j++)
    {
        data4[i][j] = vec[j];
    }
}

free(vec);

// Receving columns of data1, data2

if (my_rank == 0)
{
    for (i = 1; i < p; i++)
    {
        offset = i * rows;
        for (j = offset; j < (offset + rows); j++)
        {
            MPI_Recv(data3[j], N, mystruct, i, tag, MPI_COMM_WORLD, &status);
            MPI_Recv(data4[j], N, mystruct, i, tag, MPI_COMM_WORLD, &status);
        }
    }
}
```

```
else
{
   for (j = lb; j < hb; j++)
   {
      MPI_Send(&data3[j][0], N, mystruct, 0, tag, MPI_COMM_WORLD);
      MPI_Send(&data4[j][0], N, mystruct, 0, tag, MPI_COMM_WORLD);
   }
}

if (my_rank == 0)
{
   transpose(data3, data1);
   transpose(data4, data2);
   mmpoint(data1, data2, data3);
}

// Starting and send rows of data1, data2

if (my_rank == 0)
{
   for (i = 1; i < p; i++)
   {
```

```
        offset = i * rows;
        for (j = offset; j < (offset + rows); j++)
        {
            MPI_Send(&data3[j][0], N, mystruct, i, tag, MPI_COMM_WORLD);
        }
    }
}
else
{

    for (j = lb; j < hb; j++)
    {
        MPI_Recv(data3[j], N, mystruct, 0, tag, MPI_COMM_WORLD, &status);
    }
}

// Doing fft1d forward for data1 and data2 rows

vec = (complex *)malloc(N * sizeof(complex));

for (i = lb; i < hb; i++)
{
```

```
    for (j = 0; j < N; j++)
    {
        vec[j] = data3[i][j];
    }
    c_fft1d(vec, N, 1);
    for (j = 0; j < N; j++)
    {
        data3[i][j] = vec[j];
    }
}

free(vec);

// Receving rows of data1, data2

if (my_rank == 0)
{
    for (i = 1; i < p; i++)
    {
        offset = i * rows;
        for (j = offset; j < (offset + rows); j++)
        {
```

```
            MPI_Recv(data3[j], N, mystruct, i, tag, MPI_COMM_WORLD, &status);
        }
    }
}
else
{
    for (j = lb; j < hb; j++)
    {
        MPI_Send(&data3[j][0], N, mystruct, 0, tag, MPI_COMM_WORLD);
    }
}

// Starting and send columns of data1, data2

if (my_rank == 0)
{
    transpose(data3, data4);
    for (i = 1; i < p; i++)
    {
        offset = i * rows;
        for (j = offset; j < (offset + rows); j++)
        {
```

```
            MPI_Send(&data4[j][0], N, mystruct, i, tag, MPI_COMM_WORLD);
        }
    }
}
else
{
    for (j = lb; j < hb; j++)
    {
        MPI_Recv(data4[j], N, mystruct, 0, tag, MPI_COMM_WORLD, &status);
    }
}
// Doing fft1d forward for data1 and data2 columns
vec = (complex *)malloc(N * sizeof(complex));
for (i = lb; i < hb; i++)
{
    for (j = 0; j < N; j++)
    {
        vec[j] = data4[i][j];
    }
    c_fft1d(vec, N, 1);
    for (j = 0; j < N; j++)
    {
```

```
        data4[i][j] = vec[j];
    }
}

free(vec);
// Receiving columns of data1, data2
if (my_rank == 0)
{
    for (i = 1; i < p; i++)
    {
        offset = i * rows;
        for (j = offset; j < (offset + rows); j++)
        {
            MPI_Recv(data4[j], N, mystruct, i, tag, MPI_COMM_WORLD, &status);
        }
    }
}
else
{
    for (j = lb; j < hb; j++)
    {
        MPI_Send(&data4[j][0], N, mystruct, 0, tag, MPI_COMM_WORLD);
```

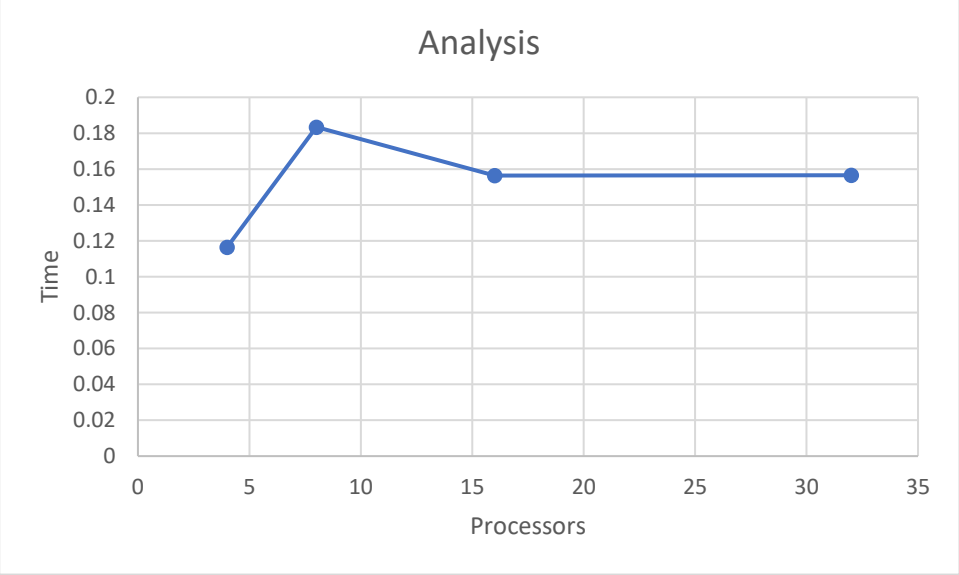
```
        }
    }
    if (my_rank == 0)
    {
        transpose(data4, data3);
        /* Stop Clock */
        stopTime = MPI_Wtime();


        printf("\nElapsed time = %lf s.\n", (stopTime - startTime));
        printf("---------------------------------------------\n");
    }
    MPI_Finalize();
    if (my_rank == 0)
    {
        printfile(fileName3, data3);
    }
    free(data1);
    free(data2);
    free(data3);
    free(data4);
    return 0;
}
```

```
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 4 .\2DConvolution.exe
3 have lb = 384 and hb = 512
2 have lb = 256 and hb = 384
1 have lb = 128 and hb = 256
0 have lb = 0 and hb = 128

Starting clock.

Elapsed time = 0.214802 s.
-----------------------------------------
```

```
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 8 .\2DConvolution.exe
1 have lb = 64 and hb = 128
7 have lb = 448 and hb = 512
5 have lb = 320 and hb = 384
4 have lb = 256 and hb = 320
2 have lb = 128 and hb = 192
3 have lb = 192 and hb = 256
6 have lb = 384 and hb = 448
0 have lb = 0 and hb = 64

Starting clock.

Elapsed time = 0.248371 s.
-----------------------------------------
```

```
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 16 .\2DConvolution.exe
11 have lb = 352 and hb = 384
2 have lb = 64 and hb = 96
14 have lb = 448 and hb = 480
5 have lb = 160 and hb = 192
9 have lb = 288 and hb = 320
10 have lb = 320 and hb = 352
6 have lb = 192 and hb = 224
1 have lb = 32 and hb = 64
15 have lb = 480 and hb = 512
12 have lb = 384 and hb = 416
13 have lb = 416 and hb = 448
4 have lb = 128 and hb = 160
7 have lb = 224 and hb = 256
3 have lb = 96 and hb = 128
8 have lb = 256 and hb = 288
0 have lb = 0 and hb = 32

Starting clock.

Elapsed time = 1.401557 s.
-----------------------------------------
```

```
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 32 .\2DConvolution.exe
3 have lb = 48 and hb = 64
5 have lb = 80 and hb = 96
4 have lb = 64 and hb = 80
6 have lb = 96 and hb = 112
7 have lb = 112 and hb = 128
10 have lb = 160 and hb = 176
11 have lb = 176 and hb = 192
12 have lb = 192 and hb = 208
13 have lb = 208 and hb = 224
14 have lb = 224 and hb = 240
15 have lb = 240 and hb = 256
17 have lb = 272 and hb = 288
18 have lb = 288 and hb = 304
16 have lb = 256 and hb = 272
20 have lb = 320 and hb = 336
2 have lb = 32 and hb = 48
19 have lb = 304 and hb = 320
21 have lb = 336 and hb = 352
23 have lb = 368 and hb = 384
25 have lb = 400 and hb = 416
22 have lb = 352 and hb = 368
24 have lb = 384 and hb = 400
29 have lb = 464 and hb = 480
26 have lb = 416 and hb = 432
27 have lb = 432 and hb = 448
28 have lb = 448 and hb = 464
31 have lb = 496 and hb = 512
30 have lb = 480 and hb = 496
0 have lb = 0 and hb = 16

Starting clock.

Elapsed time = 0.158853 s.
-----------------------------------------
PS D:\Walchand\7 Semester\HPC\Assignment_8>
```



2. Implement dot product using MPI. Use different number of processes and analyze the performance.

```
#include <stdio.h>

#include <mpi.h>

#include <unistd.h>

#include <math.h>

#include <time.h>

#include <stdlib.h>


#define NELMS 100000

#define MASTER 0

#define MAXPROCS 16


int dot_product();

void init_lst();

void print_lst();


int main() {

  int i,n,vector_x[NELMS],vector_y[NELMS];

  int prod,sidx,eidx,size;

  int pid,nprocs, rank;

  double stime,etime;
```

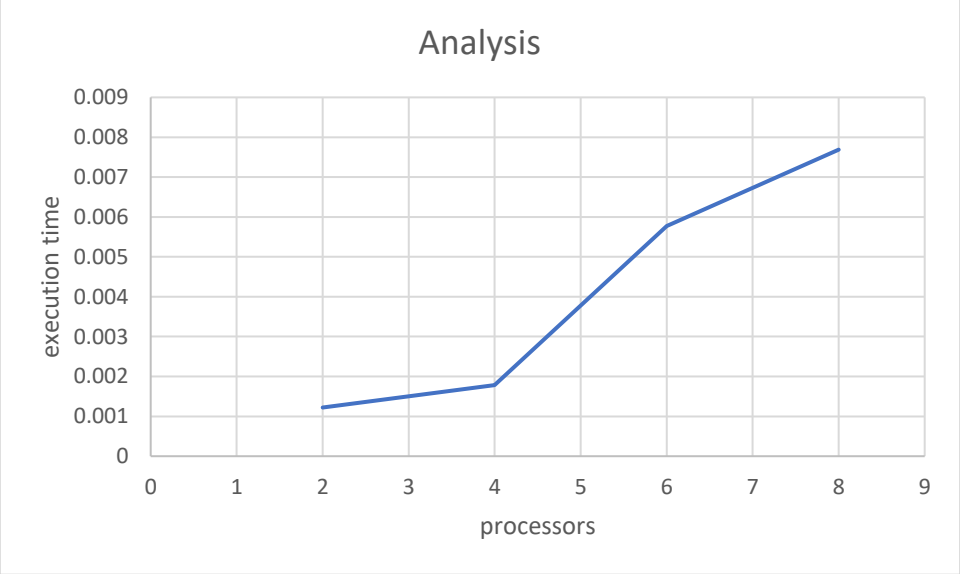
```
MPI_Status status;

MPI_Comm world;


n = 100000;

if (n > NELMS) { printf("n=%d > N=%d\n",n,NELMS); exit(1); }


MPI_Init(NULL, NULL);

world = MPI_COMM_WORLD;

MPI_Comm_size(MPI_COMM_WORLD, &nprocs);

MPI_Comm_rank(MPI_COMM_WORLD, &pid);


int portion = n / nprocs;

sidx = pid * portion;

eidx = sidx + portion;

init_lst(vector_x, n);

init_lst(vector_y, n);


int tmp_prod[nprocs];

for (i = 0; i < nprocs; i++)

  tmp_prod[i] = 0;


stime = MPI_Wtime();
```

```
if (pid == MASTER) {
  prod = dot_product(sidx, eidx, vector_x, vector_y, n);
  for (i = 1; i < nprocs; i++)
    MPI_Recv(&tmp_prod[i-1], 1, MPI_INT, i, 123, MPI_COMM_WORLD, &status);
}
else {
  prod = dot_product(sidx, eidx, vector_x, vector_y, n);
  MPI_Send(&prod, 1, MPI_INT, MASTER, 123, MPI_COMM_WORLD);
}

if (pid == MASTER) {
  for (i = 0; i < nprocs; i++)
    prod += tmp_prod[i];
}

etime = MPI_Wtime();

if (pid == MASTER) {
  //print_lst(vector_x,n);
  //print_lst(vector_y,n);
  printf("pid=%d: final prod=%d\n",pid,prod);
```

```
    printf("pid=%d: elapsed=%f\n",pid,etime-stime);
  }
  MPI_Finalize();
}

int dot_product(int s,int e, int x[], int y[], int n){
  int i,prod=0;

  for (i = s; i < e; i++)
    prod = prod + x[i] * y[i];

  return prod;
}

void init_lst(int *l,int n){
  int i;
  for (i=0; i<n; i++) *l++ = i;
}
void print_lst(int l[],int n){
  int i;

  for (i=0; i<n; i++) {
```

```
    printf("%d ", l[i]);
  }
  printf("\n");
}
```

```
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 2 .\dot_product.exe
pid=0: final prod=216474736
pid=0: elapsed=0.001613
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 4 .\dot_product.exe
pid=0: final prod=216474736
pid=0: elapsed=0.001010
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 8 .\dot_product.exe
pid=0: final prod=216474736
pid=0: elapsed=0.004282
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 16 .\dot_product.exe
pid=0: final prod=216474736
pid=0: elapsed=0.004272
PS D:\Walchand\7 Semester\HPC\Assignment_8>
```



3. Implement Prefix sum using MPI. Use different number of processes and analyze the performance.

```
#include <stdio.h>

#include<stdlib.h>

#include <math.h>

#include "mpi.h"


int main(int argc, char* argv[]){

   int  my_rank; /* rank of process */

   int  p;       /* number of processes */

   MPI_Status status ;   /* return status for receive */

   int value;


   /* start up MPI */

   MPI_Init(&argc, &argv);


   /* find out process rank */

   MPI_Comm_rank(MPI_COMM_WORLD, &my_rank);


   /* find out number of processes */

   MPI_Comm_size(MPI_COMM_WORLD, &p);

   int prefix_arr[p];
```

```
/* getting input and scatter values */
if(my_rank == 0){
   int i;
   for(i = 0; i < p; ++i){
      prefix_arr[i] = i + 1;
   }
}

double start = MPI_Wtime();

//all call scatter
MPI_Scatter(prefix_arr, 1, MPI_INT, &value, 1, MPI_INT, 0, MPI_COMM_WORLD);

/*
prefix sum:
   repeat log n times
   each time, if we are the chosen one, we receve a value from someone and add to ours
   otherwise, we send to the chosen one
*/
int i;
int logn = log2(p);
```

```
    for(i = 0; i <= logn; i++){
        int lower_bound = pow(2,i);
        int upper_bound = p - lower_bound;
        if(upper_bound < lower_bound){
            upper_bound = lower_bound;
        }

        if(my_rank < lower_bound){
            int send = (int) (my_rank + pow(2,i));
            if(send >= p)
                continue;

            printf("%d sending to %d\n", my_rank, (int) (my_rank+pow(2,i)));
            MPI_Send(&value, 1, MPI_INT, (int) (my_rank+pow(2,i)), 0,
MPI_COMM_WORLD);
        }
        else if(my_rank >= upper_bound){
            int recv = (int) (my_rank - pow(2,i));
            if(recv >= p)
                continue;

            int recv_value;
```

```
        printf("%d receving..\n", my_rank);
        MPI_Recv(&recv_value, 1, MPI_INT, (my_rank - pow(2,i)), 0,
MPI_COMM_WORLD, &status);
        value += recv_value;
      }
      else{
        int send = (int) (my_rank + pow(2,i));
        int recv = (int) (my_rank - pow(2,i));
        if(send >= p || recv >= p)
          continue;

        printf("%d sending to %d\n", my_rank, (int) (my_rank+pow(2,i)));
        MPI_Send(&value, 1, MPI_INT, (int) (my_rank+pow(2,i)), 0,
MPI_COMM_WORLD);

        printf("%d receving..\n", my_rank);
        int recv_value;
        MPI_Status status;
        MPI_Recv(&recv_value, 1, MPI_INT, (my_rank - pow(2,i)), 0,
MPI_COMM_WORLD, &status);
        value += recv_value;
      }
    }
```

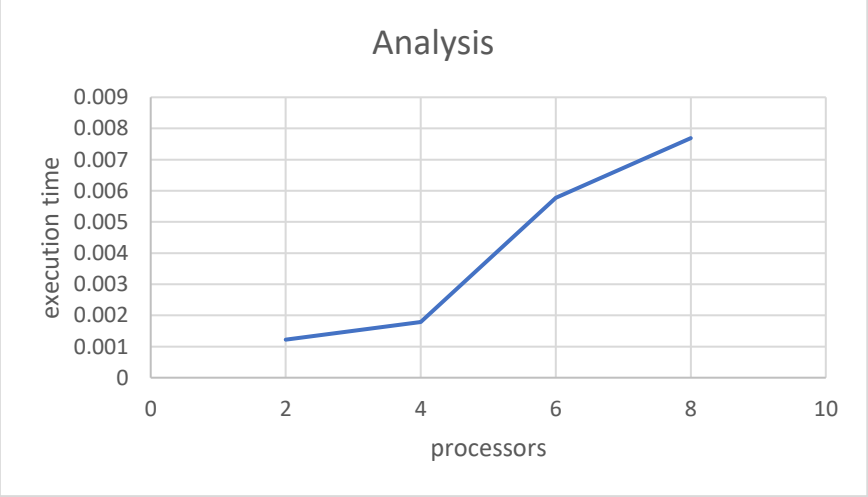
```
    //after algorithm, each processor hols its own prefix sum
    //we gather at rank
    int gather[p];
    MPI_Gather(&value, 1, MPI_INT, gather, 1, MPI_INT, 0, MPI_COMM_WORLD);

    if(my_rank == 0){
        double end = MPI_Wtime();

        printf("Execution Time: %f\n", end - start);
    }

    /* shut down MPI */
    MPI_Finalize();

    return 0;
}
```

```
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 2 .\prefix_sum.exe
0 sending to 1
Execution Time: 0.002235
1 receving..
```

```
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 4 .\prefix_sum.exe
2 sending to 3
2 receving..
2 receving..
0 sending to 1
0 sending to 2
Execution Time: 0.001605
1 sending to 2
1 receving..
1 sending to 3
3 receving..
3 receving..
```

```
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 6 .\prefix_sum.exe
5 receving..
5 receving..
5 receving..
1 sending to 2
1 receving..
1 sending to 3
1 sending to 5
3 sending to 4
3 receving..
3 sending to 5
3 receving..
4 sending to 5
4 receving..
4 receving..
4 receving..
2 sending to 3
2 receving..
2 sending to 4
2 receving..
0 sending to 1
0 sending to 2
0 sending to 4
Execution Time: 0.002312
```

```
PS D:\Walchand\7 Semester\HPC\Assignment_8> mpiexec -n 8 .\prefix_sum.exe
2 sending to 3
2 receving..
2 sending to 4
2 receving..
2 sending to 6
3 sending to 4
3 receving..
3 sending to 5
3 receving..
3 sending to 7
4 sending to 5
4 receving..
4 sending to 6
4 receving..
4 receving..
1 sending to 2
1 receving..
1 sending to 3
1 sending to 5
6 sending to 7
6 receving..
6 receving..
6 receving..
5 sending to 6
5 receving..
5 sending to 7
5 receving..
5 receving..
7 receving..
7 receving..
7 receving..
0 sending to 1
0 sending to 2
0 sending to 4
Execution Time: 0.003443
PS D:\Walchand\7 Semester\HPC\Assignment_8>
```



Github Link: https://github.com/SayaliDesai4/HPC-Practicals