1. The output results are

There are 50847534 primes less than or equal to 1000000000

largest prime under 1000000000 is: 999999937

for all the cores, I get the same results.

Full results are attached at the end.

When I used different job request methods, I get different results.

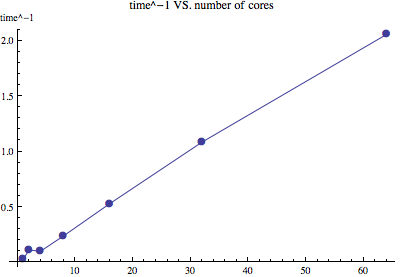
One method is #PBS –l nodes=64:ppn=1

One method is #PBS –l nodes=6:ppn=12

The performance for nodes=64:ppn=1

|  |  |  |
| --- | --- | --- |
| # of cores | Time for calculation | Time^-1 |
| 1 | 33.837660 | 0.0295529 |
| 2 | 8.926943 | 0.11202 |
| 4 | 9.832782 | 0.101701 |
| 8 | 4.159676 | 0.240403 |
| 16 | 1.883718 | 0.530865 |
| 32 | 0.920974 | 1.08581 |
| 64 | 0.485961 | 2.05778 |

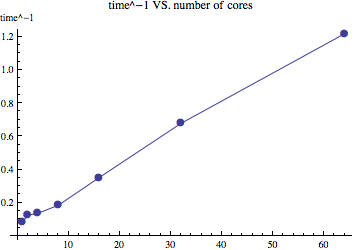
The following is the graph for time^-1 vs. number of cores



it seems that number of cores and performance have linear relationship.

Performance for nodes= nodes=6:ppn=12

|  |  |  |
| --- | --- | --- |
| # of cores | Time for calculation | Time^-1 |
| 1 | 11.775532 | 0.0849219 |
| 2 | 8.025935 | 0.124596 |
| 4 | 7.340342 | 0.136233 |
| 8 | 5.410584 | 0.184823 |
| 16 | 2.841941 | 0.351872 |
| 32 | 1.474556 | 0.67817 |
| 64 | 0.821028 | 1.21799 |



It also seems that number of cores and performance have linear relationship. But the performance of this version is not as good as the first one.

2.

For this problem, I permutated ji loop to ij loop in order to parallel i loop and make it possible to mpi reduce, send, bcase, receive multiple elements (e.g. MPI\_Send(&hzp[nxp],ny,MPI\_DOUBLE,id+1,10,MPI\_COMM\_WORLD);) of array during the calculation.

the output results are

Minhz= -3.055476047; Maxhz = 117.505802697; Mean= 0.866054434, RMS = 8.271862954

mpi\_Minhz= -3.055476047; mpi\_Maxhz = 117.505802697; mpi\_Mean= 0.866054434, mpi\_RMS = 8.271862954

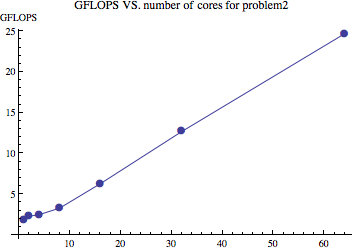
the results using all different number of cores are the same as the sequential codes. MPI code is correct!

The full results and the code are attached at the end.

The performance

|  |  |  |
| --- | --- | --- |
| Number of cores | GFLOPS | Time |
| Seq. reference | 1.7 | 9.3 |
| 1 | 1.8 | 8.9 |
| 2 | 2.3 | 6.9 |
| 4 | 2.5 | 6.5 |
| 8 | 3.3 | 4.9 |
| 16 | 6.3 | 2.5 |
| 32 | 12.7 | 1.3 |
| 64 | 24.7 | 0.6 |

The following is the graph for GFLOPS vs. number of cores.



Code for problem 2

“fdtd-par-final.c”

#include <unistd.h>

#include <stdio.h>

#include <math.h>

#include <sys/time.h>

#include "mpi.h"

//#include "../MyMPI.h"

#define nx 4000

//#define nx 500

#define ny 4000

//#define ny 500

#define tmax 100

//#define tmax 1000

#define coeff1 0.5

#define coeff2 0.7

double ex[nx][ny];

double ey[nx][ny];

double hz[nx][ny];

double g\_hz[nx][ny];

double gg\_hz[nx][ny];

void check();

void dump();

void mpi\_check();

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

double rtclock();

int tt,i,j,nt;

double clkbegin, clkend;

double t, maxdiff;

double g\_t;

int id; // process ID number

int p; // number of processes

MPI\_Init (&argc, &argv);

MPI\_Comm\_rank (MPI\_COMM\_WORLD, &id);

MPI\_Comm\_size (MPI\_COMM\_WORLD, &p);

MPI\_Barrier(MPI\_COMM\_WORLD);

// Initialize arrays

if(id==p-1){

for (i=0; i<nx; i++){

for (j=0; j<ny; j++) {

ex[i][j] = sin(i)\*(1-sin(j));

}

}

for (i=0; i<nx; i++) {

for (j=0; j<ny; j++) {

ey[i][j] = cos(i)\*(1-cos(j));

}

}

printf("\n");

for (i=0; i<nx; i++) {

for (j=0; j<ny; j++) {

hz[i][j] = sin(i)\*(1-cos(j));

}

}

clkbegin = rtclock();

for (tt=0; tt<tmax; tt++){

for (j=0; j<ny; j++)

ey[0][j] = tt;

for (j=0; j<ny; j++) {

for (i=1; i<nx; i++){

ey[i][j] = ey[i][j] - coeff1\*(hz[i][j]-hz[i-1][j]);

}

}

for (j=1; j<ny; j++){

for (i=0; i<nx; i++){

ex[i][j] = ex[i][j] - coeff1\*(hz[i][j]-hz[i][j-1]);

}

}

for (j=0; j<ny-1; j++){

for (i=0; i<nx-1; i++){

hz[i][j] = hz[i][j] -

coeff2\*(ex[i][j+1]-ex[i][j]+ey[i+1][j]-ey[i][j]);

}

}

}

clkend = rtclock();

t = clkend-clkbegin;

printf ("Sequential GFLOPS: %.1f, Time: %.1f\n", 10.0\*nx\*ny\*tmax/t/1e9,t);

check();

}

if (id==p-1){

printf("seq end!\n");

}

MPI\_Barrier(MPI\_COMM\_WORLD);

int nxp;

int m = nx%p;

MPI\_Status status;

// mpi initialize

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

for(j=0;j<ny;j++){

g\_hz[i][j]=0.0;

gg\_hz[i][j]=0.0;

}

if (m==0)

nxp = nx/p;

else

{

if (id<m) nxp = nx/p+1;

else nxp = nx/p;

}

double exp[nxp+2][ny];

double eyp[nxp+2][ny];

double hzp[nxp+2][ny];

int offset;

if (id>=m) offset=m;

else offset=0;

for (i=1; i<nxp+1; i++){

for (j=0; j<ny; j++) {

exp[i][j] = sin(i-1+id\*nxp+offset)\*(1-sin(j));

}

}

for (i=1; i<nxp+1; i++) {

for (j=0; j<ny; j++) {

eyp[i][j] = cos(i-1+id\*nxp+offset)\*(1-cos(j));

}

}

for (i=1; i<nxp+1; i++) {

for (j=0; j<ny; j++) {

hzp[i][j] = sin(i-1+id\*nxp+offset)\*(1-cos(j));

}

}

MPI\_Barrier(MPI\_COMM\_WORLD);

//mpi calculate

clkbegin = rtclock();

int is, ie;

if (id==0) is=2;

else is=1;

if (id==p-1) ie=nxp-1;

else ie=nxp;

// MPI\_Barrier(MPI\_COMM\_WORLD);

if(id<p-1) MPI\_Send(&hzp[nxp],ny,MPI\_DOUBLE,id+1,10,MPI\_COMM\_WORLD);

if(id>0) MPI\_Recv(&hzp[0],ny,MPI\_DOUBLE,id-1,10,MPI\_COMM\_WORLD,&status);

if(id>0) MPI\_Send(&eyp[1],ny,MPI\_DOUBLE,id-1,20,MPI\_COMM\_WORLD);

if(id<p-1) MPI\_Recv(&eyp[nxp+1],ny,MPI\_DOUBLE,id+1,20,MPI\_COMM\_WORLD,&status);

MPI\_Barrier(MPI\_COMM\_WORLD);

for (tt=0; tt<tmax; tt++){

if(id ==0)

for (j=0; j<ny; j++)

eyp[1][j] = tt;

for (i=is; i<=nxp; i++)

{

for (j=0; j<ny; j++){

eyp[i][j] = eyp[i][j] - coeff1\*(hzp[i][j]-hzp[i-1][j]);

}

}

// MPI\_Barrier(MPI\_COMM\_WORLD);

if(id>0) MPI\_Send(&eyp[1],ny,MPI\_DOUBLE,id-1,tt+tmax,MPI\_COMM\_WORLD);

if(id<p-1) MPI\_Recv(&eyp[nxp+1],ny,MPI\_DOUBLE,id+1,tt+tmax,MPI\_COMM\_WORLD,&status);

MPI\_Barrier(MPI\_COMM\_WORLD);

for (i=1; i<=nxp; i++){

for (j=1; j<ny; j++){

exp[i][j] = exp[i][j] - coeff1\*(hzp[i][j]-hzp[i][j-1]);

}

}

for (i=1; i<=ie; i++){

for (j=0; j<ny-1; j++){

hzp[i][j] = hzp[i][j] -

coeff2\*(exp[i][j+1]-exp[i][j]+eyp[i+1][j]-eyp[i][j]);

}

}

// MPI\_Barrier(MPI\_COMM\_WORLD);

if(id<p-1) MPI\_Send(&hzp[nxp],ny,MPI\_DOUBLE,id+1,tt,MPI\_COMM\_WORLD);

if(id>0) MPI\_Recv(&hzp[0],ny,MPI\_DOUBLE,id-1,tt,MPI\_COMM\_WORLD,&status);

MPI\_Barrier(MPI\_COMM\_WORLD);

}

if(id<p-1) MPI\_Send(&hzp[nxp],ny,MPI\_DOUBLE,id+1,tt,MPI\_COMM\_WORLD);

if(id>0) MPI\_Recv(&hzp[0],ny,MPI\_DOUBLE,id-1,tt,MPI\_COMM\_WORLD,&status);

clkend = rtclock();

MPI\_Barrier(MPI\_COMM\_WORLD);

t = clkend-clkbegin;

MPI\_Reduce(&t,&g\_t,1,MPI\_DOUBLE,MPI\_MAX,0,MPI\_COMM\_WORLD);

// check

MPI\_Barrier(MPI\_COMM\_WORLD);

for (i=1; i<=nxp; i++){

for (j=0; j<ny; j++)

g\_hz[i-1+id\*nxp+offset][j]=hzp[i][j];

}

MPI\_Barrier(MPI\_COMM\_WORLD);

for (i=0; i<nx; i++){

MPI\_Reduce(&g\_hz[i],&gg\_hz[i],ny,MPI\_DOUBLE,MPI\_SUM,0,MPI\_COMM\_WORLD);

}

MPI\_Barrier(MPI\_COMM\_WORLD);

if(id==0) {

printf ("MPI parellel GFLOPS: %.1f, Time: %.1f\n", 10.0\*nx\*ny\*tmax/g\_t/1e9,g\_t);

mpi\_check();

}

MPI\_Finalize();

}

double rtclock()

{

struct timezone Tzp;

struct timeval Tp;

int stat;

stat = gettimeofday (&Tp, &Tzp);

if (stat != 0) printf("Error return from gettimeofday: %d",stat);

return(Tp.tv\_sec + Tp.tv\_usec\*1.0e-6);

}

void check()

{

double maxval, minval, mean, rms;

int i,j;

minval = maxval = hz[0][0];

mean = rms = 0.0;

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

for (j=0;j<ny;j++)

{

if (hz[i][j] < minval) minval = hz[i][j];

if (hz[i][j] > maxval) maxval = hz[i][j];

mean += hz[i][j]/(1.0\*nx\*ny);

rms += hz[i][j]\*hz[i][j]/(1.0\*nx\*ny);

}

rms = sqrt(rms);

printf("Minhz= %18.9f; Maxhz = %18.9f; Mean= %18.9f, RMS = %18.9f\n", minval,maxval,mean,rms);

}

void mpi\_check()

{

double maxval, minval, mean, rms;

int i,j;

minval = maxval = hz[0][0];

mean = rms = 0.0;

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

for (j=0;j<ny;j++)

{

if (gg\_hz[i][j] < minval) minval = gg\_hz[i][j];

if (gg\_hz[i][j] > maxval) maxval = gg\_hz[i][j];

mean += gg\_hz[i][j]/(1.0\*nx\*ny);

rms += gg\_hz[i][j]\*gg\_hz[i][j]/(1.0\*nx\*ny);

}

rms = sqrt(rms);

printf("mpi\_Minhz= %15.9f; mpi\_Maxhz = %15.9f; mpi\_Mean= %15.9f, mpi\_RMS = %15.9f\n", minval,maxval,mean,rms);

}

For One method is #PBS –l nodes=64:ppn=1

--------------------------------------------------------------

Programming Assignment 4, Problem 1

--------------------------------------------------------------

--- 1 core ---

There are 50847534 primes less than or equal to 1000000000

SIEVE (1) 33.837660

largest prime under 1000000000 is: 999999937

--- 2 core ---

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (2) 8.926943

--- 4 core ---

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (4) 9.832782

--- 8 core ---

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (8) 4.159676

--- 16 core ---

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (16) 1.883718

--- 32 core ---

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (32) 0.920974

--- 64 core ---

There are 50847534 primes less than or equal to 1000000000

largest prime under 1000000000 is: 999999937

SIEVE (64) 0.485961

One method is #PBS –l nodes=6:ppn=12

--------------------------------------------------------------

Programming Assignment 4, Sieve, 1 processes

--------------------------------------------------------------

There are 50847534 primes less than or equal to 1000000000

SIEVE (1) 15.660846

largest prime under 1000000000 is: 999999937

--------------------------------------------------------------

Programming Assignment 4, Sieve, 2 processes

--------------------------------------------------------------

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (2) 10.039494

--------------------------------------------------------------

Programming Assignment 4, Sieve, 4 processes

--------------------------------------------------------------

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (4) 9.351460

--------------------------------------------------------------

Programming Assignment 4, Sieve, 8 processes

--------------------------------------------------------------

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (8) 7.867141

--------------------------------------------------------------

Programming Assignment 4, Sieve, 16 processes

--------------------------------------------------------------

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (16) 5.385425

--------------------------------------------------------------

Programming Assignment 4, Sieve, 32 processes

--------------------------------------------------------------

largest prime under 1000000000 is: 999999937

There are 50847534 primes less than or equal to 1000000000

SIEVE (32) 2.527521

--------------------------------------------------------------

Programming Assignment 4, Sieve, 64 processes

--------------------------------------------------------------

There are 50847534 primes less than or equal to 1000000000

SIEVE (64) 1.389446

largest prime under 1000000000 is: 999999937

--------------------------------------------------------------

Programming Assignment 4, problem2 fdtd, 1 processes

--------------------------------------------------------------

Sequential GFLOPS: 1.7, Time: 9.3

Minhz= -3.055476047; Maxhz = 117.505802697; Mean= 0.866054434, RMS = 8.271862954

seq end!

MPI parellel GFLOPS: 1.8, Time: 8.9

mpi\_Minhz= -3.055476047; mpi\_Maxhz = 117.505802697; mpi\_Mean= 0.866054434, mpi\_RMS = 8.271862954

--------------------------------------------------------------

Programming Assignment 4, problem2 fdtd, 2 processes

--------------------------------------------------------------

Sequential GFLOPS: 1.7, Time: 9.3

Minhz= -3.055476047; Maxhz = 117.505802697; Mean= 0.866054434, RMS = 8.271862954

seq end!

MPI parellel GFLOPS: 2.3, Time: 6.9

mpi\_Minhz= -3.055476047; mpi\_Maxhz = 117.505802697; mpi\_Mean= 0.866054434, mpi\_RMS = 8.271862954

--------------------------------------------------------------

Programming Assignment 4, problem2 fdtd, 4 processes

--------------------------------------------------------------

Sequential GFLOPS: 1.6, Time: 9.8

Minhz= -3.055476047; Maxhz = 117.505802697; Mean= 0.866054434, RMS = 8.271862954

seq end!

MPI parellel GFLOPS: 2.5, Time: 6.5

mpi\_Minhz= -3.055476047; mpi\_Maxhz = 117.505802697; mpi\_Mean= 0.866054434, mpi\_RMS = 8.271862954

--------------------------------------------------------------

Programming Assignment 4, problem2 fdtd, 8 processes

--------------------------------------------------------------

Sequential GFLOPS: 1.7, Time: 9.3

Minhz= -3.055476047; Maxhz = 117.505802697; Mean= 0.866054434, RMS = 8.271862954

seq end!

MPI parellel GFLOPS: 3.3, Time: 4.9

mpi\_Minhz= -3.055476047; mpi\_Maxhz = 117.505802697; mpi\_Mean= 0.866054434, mpi\_RMS = 8.271862954

--------------------------------------------------------------

Programming Assignment 4, problem2 fdtd, 16 processes

--------------------------------------------------------------

Sequential GFLOPS: 1.6, Time: 9.8

Minhz= -3.055476047; Maxhz = 117.505802697; Mean= 0.866054434, RMS = 8.271862954

seq end!

MPI parellel GFLOPS: 6.3, Time: 2.5

mpi\_Minhz= -3.055476047; mpi\_Maxhz = 117.505802697; mpi\_Mean= 0.866054434, mpi\_RMS = 8.271862954

--------------------------------------------------------------

Programming Assignment 4, problem2 fdtd, 32 processes

--------------------------------------------------------------

Sequential GFLOPS: 1.7, Time: 9.4

Minhz= -3.055476047; Maxhz = 117.505802697; Mean= 0.866054434, RMS = 8.271862954

seq end!

MPI parellel GFLOPS: 12.7, Time: 1.3

mpi\_Minhz= -3.055476047; mpi\_Maxhz = 117.505802697; mpi\_Mean= 0.866054434, mpi\_RMS = 8.271862954

--------------------------------------------------------------

Programming Assignment 4, problem2 fdtd, 64 processes

--------------------------------------------------------------

Sequential GFLOPS: 1.6, Time: 9.8

Minhz= -3.055476047; Maxhz = 117.505802697; Mean= 0.866054434, RMS = 8.271862954

seq end!

MPI parellel GFLOPS: 24.7, Time: 0.6

mpi\_Minhz= -3.055476047; mpi\_Maxhz = 117.505802697; mpi\_Mean= 0.866054434, mpi\_RMS = 8.271862954