ANKARA YILDIRIM BEYAZIT UNIVERSITY

CENG 316 – Parallel Programming

Project2 - Report

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Project Summary

In this project, we implemented parallel calculation of gravitational force interaction of stars in a galaxy. We utilized multi process parallelism via MPI and OpenMP library. We used Newton's universal law of attraction when making calculations. We generated two source code, first source code work with MPI, and other is working with combination of MPI - OpenMP libraries (hybrid).

Project Pseudocode

- **Sequential Algorithm Pseudocode**

```
get variables from input
Allocate stars pointer and gravitational force array
Read_file(Argument one, Argument two,Argument tree); //Get Stars From File
calculate_gravitational_force(Argument one, Argument two,Argument tree,Argument four, Argument five){
    Start time
    for i 0 to Count
        for k 0 to Count
            if i not equals to k do
                Calculate Distance, Calculate force between two stars, Add to total
    Finish time
}
calculate_2Norm(Argument one, Argument two,Argument tree){
    for i 0 to Count
        total *= pow(Argument one, Argument two);
}
write_file(Argument one, Argument two);
```

- **Parallel Algorithm Pseudocode**

```
get variables from input
Allocate stars and Partial Gravitational Force List with malloc
if my_rank equals to 0 {
    Allocate gravitational force list and get stars from file
    Read_file(Argument one, Argument two,Argument tree) //Get Stars From File
    start time
}
Stars are scattering to processes by MPI_Bcast
calculate_gravitational_force(Argument one, Argument two,Argument tree,Argument four, Argument five)
Forces are collecting from other process's partial forces in Process0 by using MPI_Gather
calculatePartial_2Norm(Argument one, Argument two,Argument tree)
get partial norm from other processes by using MPI_Reduce

if my_rank equals to 0  {
    print time-norm
    write_file(Argument one, Argument two)
}
```

Parallel Algorithm in Foster Methodology

Foster's Design Methodology has four steps which are Partitioning, Communication, Agglomeration and Mapping. If we explain Foster's Methodology in terms of these steps; firstly, we stored stars in pointer array, defined a array which name partialForceList. Each process calculated own partial norm with using this array. After dividing the problem, we used MPI library with collective communication method which involves participation of all processes in a communicator. First, we used MPI_Barrier to examine synchronization problem. In project, the process 0 sends the same data to all processes in communicator to work on data. After operations, we implemented MPI_Gather to take elements from other processes and gather them to process 0. We used Step of agglomeration to our project, there isn't any process like process '1' must be executed before process '2' can be executed. Also we does not need reduce communication. Because of these reason aggregate them into a single composite process does not make sense for us. Lastly, in mapping steps our data mapped to each process.

- We used **Data Parallelism** because we scattered stars into processes and calculated result, every processes used same function, so we adapted **Data Parallelism**. If we used different functions for calculate stars, then we can say Task Parallelism, but functions are common, so it is **Data Parallelism.**

Scalability Results

Weak Scalability:

Process Count	Problem Size	Average Time(s)
1	10000	3,832
2	20000	8,288
4	40000	17,330

Strong Scalability:

Process Count	Problem Size	Average Time(s)
1	50000	94,739
2	50000	50,824
4	50000	25,349

Results of Hybrid Parallel Code

1. **Result with 4 Processes (**3 times executed code**):**

```
qurkan@ubuntu:~/Desktop/proje$ mpicc -g -o  deneme hybrid.c -lm
qurkan@ubuntu:~/Desktop/proje$ mpirun -n 4 ./deneme stars_575000.txt 50000
Star informations were got from file !

Calculating From 0.Process ...  ( the process may take a long time )
Calculating From 1.Process ...  ( the process may take a long time )
Calculating From 2.Process ...  ( the process may take a long time )
Calculating From 3.Process ...  ( the process may take a long time )
Calculating was finished by 2.Process!
Calculating was finished by 0.Process!
Calculating was finished by 1.Process!
Calculating was finished by 3.Process!
Calculating Time is : 28.200924  Seconds
2-Norm :  5.9105034375131E+00
Gravitational Forces were writed to file!
qurkan@ubuntu:~/Desktop/proje$ mpirun -n 4 ./deneme stars_575000.txt 50000
Star informations were got from file !

Calculating From 0.Process ...  ( the process may take a long time )
Calculating From 2.Process ...  ( the process may take a long time )
Calculating From 3.Process ...  ( the process may take a long time )
Calculating From 1.Process ...  ( the process may take a long time )
Calculating was finished by 2.Process!
Calculating was finished by 3.Process!
Calculating was finished by 1.Process!
Calculating was finished by 0.Process!
Calculating Time is : 25.718274  Seconds
2-Norm :  5.9105034375131E+00
Gravitational Forces were writed to file!
qurkan@ubuntu:~/Desktop/proje$ mpirun -n 4 ./deneme stars_575000.txt 50000
Star informations were got from file !

Calculating From 0.Process ...  ( the process may take a long time )
Calculating From 1.Process ...  ( the process may take a long time )
Calculating From 2.Process ...  ( the process may take a long time )
Calculating From 3.Process ...  ( the process may take a long time )
Calculating was finished by 1.Process!
Calculating was finished by 2.Process!
Calculating was finished by 0.Process!
Calculating was finished by 3.Process!
Calculating Time is : 25.614462  Seconds
2-Norm :  5.9105034375131E+00
Gravitational Forces were writed to file!
```

2. **Result with 2 Processes (**3 times executed code**):**

```
qurkan@ubuntu:~/Desktop/proje$ mpicc -g -o  deneme hybrid.c -lm
qurkan@ubuntu:~/Desktop/proje$ mpirun -n 2 ./deneme stars_575000.txt 50000

Star informations were got from file !

Calculating From 1.Process ...  ( the process may take a long time )
Calculating From 0.Process ...  ( the process may take a long time )
Calculating was finished by 1.Process!
Calculating was finished by 0.Process!
Calculating Time is : 49.283426  Seconds
2-Norm :  5.9105034375131E+00
Gravitational Forces were writed to file!
qurkan@ubuntu:~/Desktop/proje$ mpirun -n 2 ./deneme stars_575000.txt 50000
Star informations were got from file !

Calculating From 0.Process ...  ( the process may take a long time )
Calculating From 1.Process ...  ( the process may take a long time )
Calculating was finished by 0.Process!
Calculating was finished by 1.Process!
Calculating Time is : 48.989302  Seconds
2-Norm :  5.9105034375131E+00
Gravitational Forces were writed to file!
qurkan@ubuntu:~/Desktop/proje$ mpirun -n 2 ./deneme stars_575000.txt 50000
Star informations were got from file !

Calculating From 1.Process ...  ( the process may take a long time )
Calculating From 0.Process ...  ( the process may take a long time )
Calculating was finished by 0.Process!
Calculating was finished by 1.Process!
Calculating Time is : 49.354686  Seconds
2-Norm :  5.9105034375131E+00
Gravitational Forces were writed to file!
qurkan@ubuntu:~/Desktop/proje$
```

3. **Result with 1 Process (**3 times executed code**):**

```
qurkan@ubuntu:~/Desktop/proje$ mpicc -g -o  deneme hybrid.c -lm
qurkan@ubuntu:~/Desktop/proje$ mpirun -n 1 ./deneme stars_575000.txt 50000

Star informations were got from file !

Calculating From 0.Process ...  ( the process may take a long time )
Calculating was finished by 0.Process!
Calculating Time is : 93.027308  Seconds
2-Norm :  5.9105034375131E+00
Gravitational Forces were writed to file!
qurkan@ubuntu:~/Desktop/proje$ mpirun -n 1 ./deneme stars_575000.txt 50000
Star informations were got from file !

Calculating From 0.Process ...  ( the process may take a long time )
Calculating was finished by 0.Process!
Calculating Time is : 100.096227  Seconds
2-Norm :  5.9105034375131E+00
Gravitational Forces were writed to file!
qurkan@ubuntu:~/Desktop/proje$ mpirun -n 1 ./deneme stars_575000.txt 50000
Star informations were got from file !

Calculating From 0.Process ...  ( the process may take a long time )
Calculating was finished by 0.Process!
Calculating Time is : 96.635169  Seconds
2-Norm :  5.9105034375131E+00
Gravitational Forces were writed to file!
qurkan@ubuntu:~/Desktop/proje$
```

Average results

Process Count	Average Time(s)
1	96,586 s
2	49,208 s
4	26,510 s