



## **Assignment 3**

### **Distributed Systems**

**Name: Nouran Ahmed Fouad Ali**

**Section:5**

**ID:1701596**

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## Detailed Description:

**First::** MPI parallelization to compute the value of  $\cos(x)$ :

First I implemented the definition of factorial function then use MPI in the main, first MPI\_Init then MPI\_Comm\_size then MPI\_Comm\_rank then if the rank is equal to zero, I ask the user to enter the upper limit and then the angle and MPI\_Send and if the rank is not equal to zero I use MPI\_Recv.

I convert the degree angle to radian and save the start time then implement for loop to calculate the cosine using the expression.

If rank not equal to zero MPI\_Send else MPI\_Recv and get the end time.

Now, I can calculate the duration by subtracting the start and end time.

And print the cosine value and the time duration if rank equal zero.

Finally, MPI\_Finalize.

**Second::** Sequential version of this computation:

First, I ask the user to enter the upper limit and then the angle.

I convert the degree angle to radian and save the start time then implement for loop to calculate the cosine using the expression.

Then get the end time.

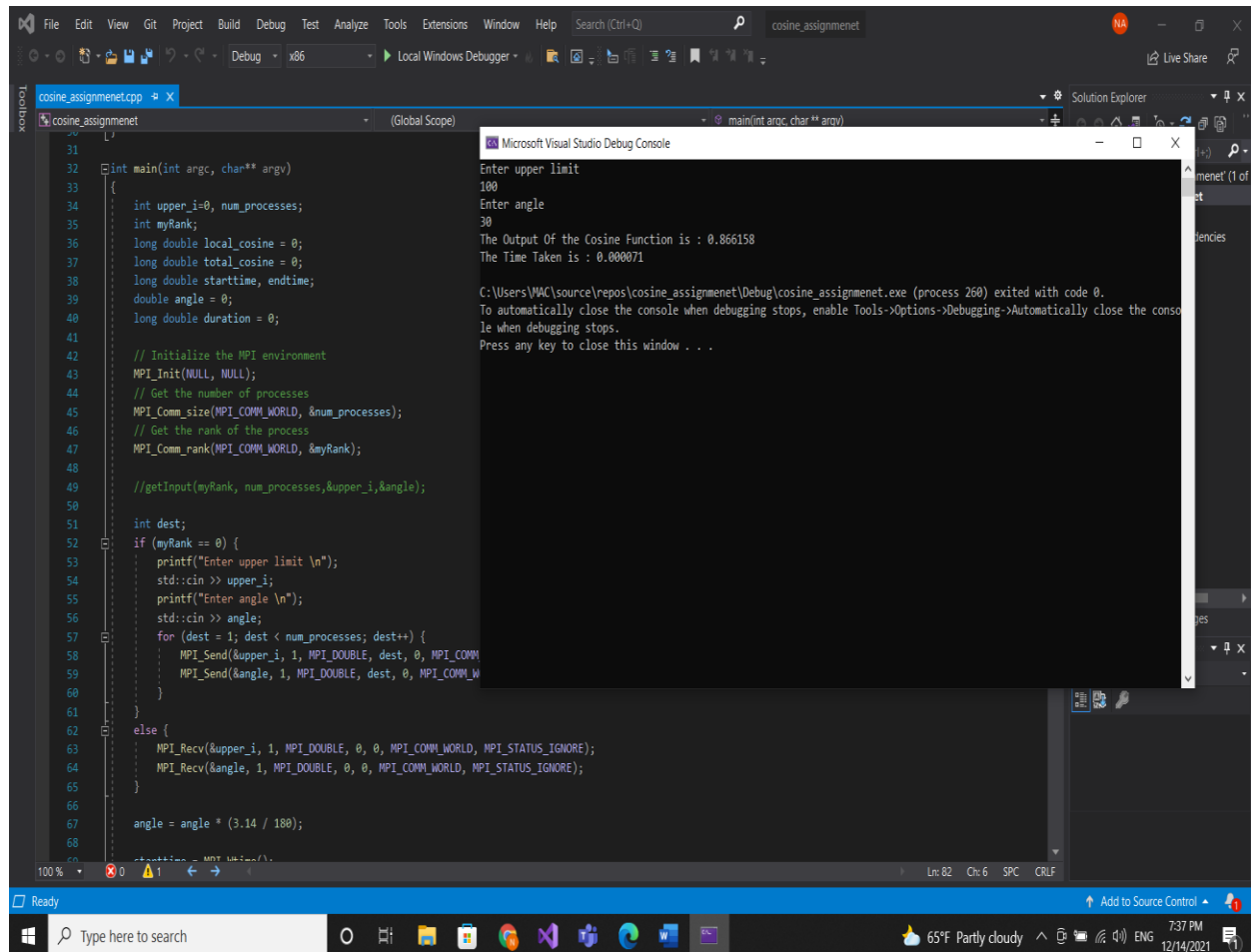
Now, I can calculate the duration by subtracting the start and end time.

And print the cosine value and the time duration.

## Detailed Analysis:

**First ::** MPI parallelization to compute the value of  $\cos(x)$ :

For Upper Limit = 100 and angle = 30



The screenshot displays the Microsoft Visual Studio IDE with the file `cosine_assignmentnet.cpp` open. The code is written in C++ and uses MPI for parallelization. The `main` function initializes MPI, gets the number of processes and the rank of the current process, and then enters a loop to calculate the cosine of an angle. The angle is 30 degrees, and the upper limit is 100. The code calculates the cosine of the angle for each process and then sums the results. The output of the program is shown in the Microsoft Visual Studio Debug Console.

```
31 int main(int argc, char** argv)
32 {
33     int upper_i=0, num_processes;
34     int myRank;
35     long double local_cosine = 0;
36     long double total_cosine = 0;
37     long double starttime, endtime;
38     double angle = 0;
39     long double duration = 0;
40
41     // Initialize the MPI environment
42     MPI_Init(NULL, NULL);
43     // Get the number of processes
44     MPI_Comm_size(MPI_COMM_WORLD, &num_processes);
45     // Get the rank of the process
46     MPI_Comm_rank(MPI_COMM_WORLD, &myRank);
47
48     //getInput(myRank, num_processes,&upper_i,&angle);
49
50     int dest;
51     if (myRank == 0) {
52         printf("Enter upper limit \n");
53         std::cin >> upper_i;
54         printf("Enter angle \n");
55         std::cin >> angle;
56         for (dest = 1; dest < num_processes; dest++) {
57             MPI_Send(&upper_i, 1, MPI_DOUBLE, dest, 0, MPI_COMM_WORLD);
58             MPI_Send(&angle, 1, MPI_DOUBLE, dest, 0, MPI_COMM_WORLD);
59         }
60     }
61     else {
62         MPI_Recv(&upper_i, 1, MPI_DOUBLE, 0, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
63         MPI_Recv(&angle, 1, MPI_DOUBLE, 0, 0, MPI_COMM_WORLD, MPI_STATUS_IGNORE);
64     }
65
66     angle = angle * (3.14 / 180);
67
68     starttime = MPI_Wtime();
69     for (int i = 0; i < upper_i; i++) {
70         local_cosine = cos(angle);
71         angle = angle + 2 * 3.14 / upper_i;
72     }
73     MPI_Send(&local_cosine, 1, MPI_DOUBLE, 0, 0, MPI_COMM_WORLD);
74     MPI_Wait(&dest, MPI_STATUSES_IGNORE);
75     total_cosine = local_cosine;
76     MPI_Finalize();
77     return 0;
78 }
```

Microsoft Visual Studio Debug Console

```
Enter upper limit
100
Enter angle
30
The Output Of the Cosine Function is : 0.866158
The Time Taken is : 0.000071

C:\Users\VMAC\source\repos\cosine_assignmentnet\Debug\cosine_assignmentnet.exe (process 260) exited with code 0.
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.
Press any key to close this window . . .
```

For Upper Limit = 100 and angle = 45

```
File Edit View Git Project Build Debug Test Analyze Tools Extensions Window Help Search (Ctrl+Q) cosine_assignmentnet
Debug x86 Local Windows Debugger
cosine_assignmentnet.cpp X
cosine_assignmentnet (Global Scope) main(int argc, char** argv)
31
32 int main(int argc, char** argv)
33 {
34     int upper_i=0, num_processes;
35     int myRank;
36     long double local_cosine = 0;
37     long double total_cosine = 0;
38     long double starttime, endtime;
39     double angle = 0;
40     long double duration = 0;
41
42     // Initialize the MPI environment
43     MPI_Init(NULL, NULL);
44     // Get the number of processes
45     MPI_Comm_size(MPI_COMM_WORLD, &num_processes);
46     // Get the rank of the process
47     MPI_Comm_rank(MPI_COMM_WORLD, &myRank);
48
49     //getInput(myRank, num_processes,&upper_i,&angle);
50
51     int dest;
52     if (myRank == 0) {
53         printf("Enter upper limit \n");
54         std::cin >> upper_i;
55         printf("Enter angle \n");
56         std::cin >> angle;
57         for (dest = 1; dest < num_processes; dest++) {
58             MPI_Send(&upper_i, 1, MPI_DOUBLE, dest, 0, MPI_COMM_WORLD);
59             MPI_Send(&angle, 1, MPI_DOUBLE, dest, 0, MPI_COMM_WORLD);
60
61         }
62     }
63     'cosine_assignmentnet.exe' (Win32): Loaded 'C:\Windows\System32\kernel.appcore.dll'.
64     The thread 0x3f78 has exited with code 0 (0x0).
65     The thread 0x1884 has exited with code 0 (0x0).
66     The thread 0x34fc has exited with code 0 (0x0).
67     The program '[9384] cosine_assignmentnet.exe' has exited with code 0 (0x0).
68
100 %
Ready Type here to search 65°F Partly cloudy 7:38 PM 12/14/2021
```

Microsoft Visual Studio Debug Console

```
Enter upper limit
100
Enter angle
45
The Output Of the Cosine Function is : 0.707388
The Time Taken is : 0.000073

C:\Users\WAC\source\repos\cosine_assignmentnet\Debug\cosine_assignmentnet.exe (process 9384) exited with code 0.
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.
Press any key to close this window . . .
```

For Upper Limit = 100 and angle = 60

```
31
32 int main(int argc, char** argv)
33 {
34     int upper_i=0, num_processes;
35     int myRank;
36     long double local_cosine = 0;
37     long double total_cosine = 0;
38     long double starttime, endtime;
39     double angle = 0;
40     long double duration = 0;
41
42     // Initialize the MPI environment
43     MPI_Init(NULL, NULL);
44     // Get the number of processes
45     MPI_Comm_size(MPI_COMM_WORLD, &num_processes);
46     // Get the rank of the process
47     MPI_Comm_rank(MPI_COMM_WORLD, &myRank);
48
49     //getInput(myRank, num_processes, &upper_i, &angle);
50
51     int dest;
52     if (myRank == 0) {
53         printf("Enter upper limit \n");
54         std::cin >> upper_i;
55         printf("Enter angle \n");
56         std::cin >> angle;
57         for (dest = 1; dest < num_processes; dest++) {
58             MPI_Send(&upper_i, 1, MPI_DOUBLE, dest, 0, MPI_COMM_WORLD);
59             MPI_Send(&angle, 1, MPI_DOUBLE, dest, 0, MPI_COMM_WORLD);
60
61         }
62     }
63
64     Show output from: Debug
65     'cosine_assignmentnet.exe' (Win32): Loaded 'C:\Windows\System32\kernel.appcore.dll'.
66     The thread 0x3ce4 has exited with code 0 (0x0).
67     The thread 0x3d98 has exited with code 0 (0x0).
68     The thread 0x778 has exited with code 0 (0x0).
69     The program '[10816] cosine_assignmentnet.exe' has exited with code 0 (0x0).
```

Microsoft Visual Studio Debug Console

```
Enter upper limit
100
Enter angle
60
The Output Of the Cosine Function is : 0.500460
The Time Taken is : 0.000072

C:\Users\VMC\source\repos\cosine_assignmentnet\Debug\cosine_assignmentnet.exe (process 10816) exited with code 0.
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.
Press any key to close this window . . .
```

**Second::** sequential version of this computation:

For Upper Limit = 100 and angle = 30

```
10     res *= i;
11     return res;
12 }
13
14 int main(int argc, char** argv)
15 {
16     int upper_i = 0;
17     double angle = 0;
18     long double time_taken = 0;
19     long double cosine = 0;
20     printf("Enter Upper value of i: ");
21     scanf_s("%d", &upper_i);
22     printf("Enter Angle: ");
23     scanf_s("%lf", &angle);
24     angle = angle * (3.14 / 180);
25     clock_t t;
26     t = clock();
27
28     for (int i = 0; i < upper_i; i++)
29     {
30         cosine += (pow(-1, i) * pow(angle, 2 * i)) / (factorial(2 * i));
31     }
32     printf("Cosine value is %f\n", cosine);
33     t = clock() - t;
34     time_taken = ((double)t) / CLOCKS_PER_SEC; // in seconds
35
36     printf("fun() took %f seconds to execute\n", time_taken);
37 }
```

Microsoft Visual Studio Debug Console

```
Enter Upper value of i: 100
Enter Angle: 30
Cosine value is 0.866158
fun() took 0.001000 seconds to execute

C:\Users\WAC\source\repos\Cosine\Debug\Cosine.exe (process 8648) exited with code 0.
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.
Press any key to close this window . . .
```

Output

```
Show output from: Debug
'Cosine.exe' (Win32): Loaded 'C:\Windows\System64\kernel.appcore.dll'.
'Cosine.exe' (Win32): Loaded 'C:\Windows\System64\msvcrt.dll'.
'Cosine.exe' (Win32): Loaded 'C:\Windows\System64\rpcrt4.dll'.
The thread 0x23b0 has exited with code 0 (0x0).
The thread 0x3be8 has exited with code 0 (0x0).
The program '[8648] Cosine.exe' has exited with code 0 (0x0).
```

For Upper Limit = 100 and angle = 45

The screenshot displays the Visual Studio IDE with a C++ project named 'Cosine'. The code in 'Cosine.cpp' implements a function to calculate the cosine of an angle using a Taylor series expansion. The main function prompts the user for an upper limit and an angle, then calls the cosine function and prints the result and execution time.

```
10     res += i;  
11     return res;  
12 }  
13  
14 int main(int argc, char** argv)  
15 {  
16     int upper_i = 0;  
17     double angle = 0;  
18     long double time_taken = 0;  
19     long double cosine = 0;  
20     printf("Enter Upper value of i: ");  
21     scanf_s("%d", &upper_i);  
22     printf("Enter Angle: ");  
23     scanf_s("%lf", &angle);  
24     angle = angle * (3.14 / 180);  
25     clock_t t;  
26     t = clock();  
27  
28     for (int i = 0; i < upper_i; i++)  
29     {  
30         cosine += (powl(-1, i) * pow(angle, 2 * i)) / (fac  
31     }  
32     printf("Cosine value is %f \n", cosine);  
33     t = clock() - t;  
34     time_taken = ((double)t) / CLOCKS_PER_SEC; // in second  
35  
36     printf("fun() took %f seconds to execute \n", time_take  
37 }
```

The Microsoft Visual Studio Debug Console shows the program's execution with the following output:

```
Enter Upper value of i: 100  
Enter Angle: 45  
Cosine value is 0.707388  
fun() took 0.001000 seconds to execute  
  
C:\Users\WAC\source\repos\Cosine\Debug\Cosine.exe (process 16056) exited with code 0.  
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console  
when debugging stops.  
Press any key to close this window . . .
```

The Output window at the bottom shows the debug output, including the loading of system DLLs and the exit of the program with code 0.

```
Show output from: Debug  
'Cosine.exe' (Win32): Loaded 'C:\Windows\System64\kernel.appcore.dll'.  
'Cosine.exe' (Win32): Loaded 'C:\Windows\System64\msvcrt.dll'.  
'Cosine.exe' (Win32): Loaded 'C:\Windows\System64\rpcrt4.dll'.  
The thread 0x38e8 has exited with code 0 (0x0).  
The thread 0x414 has exited with code 0 (0x0).  
The program '[16056] Cosine.exe' has exited with code 0 (0x0).
```



For Upper Limit = 100 and angle = 60

The screenshot shows the Visual Studio IDE with a C++ project named 'Cosine'. The code in 'Cosine.cpp' implements a function to calculate the cosine of an angle using a Taylor series expansion. The main function prompts the user for an upper limit and an angle, then calls the cosine function and prints the result and execution time.

```
10     res += i;
11     return res;
12 }
13
14 int main(int argc, char** argv)
15 {
16     int upper_i = 0;
17     double angle = 0;
18     long double time_taken = 0;
19     long double cosine = 0;
20     printf("Enter Upper value of i: ");
21     scanf_s("%d", &upper_i);
22     printf("Enter Angle: ");
23     scanf_s("%lf", &angle);
24     angle = angle * (3.14 / 180);
25     clock_t t;
26     t = clock();
27
28     for (int i = 0; i < upper_i; i++)
29     {
30         cosine += (pow(-1, i) * pow(angle, 2 * i)) / (factorial(2 * i));
31     }
32     printf("Cosine value is %f \n", cosine);
33     t = clock() - t;
34     time_taken = ((double)t) / CLOCKS_PER_SEC; // in seconds
35
36     printf("fun() took %f seconds to execute \n", time_taken);
37 }
```

The Microsoft Visual Studio Debug Console shows the following output:

```
Enter Upper value of i: 100
Enter Angle: 60
Cosine value is 0.500460
fun() took 0.001000 seconds to execute

C:\Users\VMC\source\repos\Cosine\Debug\Cosine.exe (process 1588) exited with code 0.
To automatically close the console when debugging stops, enable Tools->Options->Debugging->Automatically close the console when debugging stops.
Press any key to close this window . . .
```

The Output window shows the following debug output:

```
Show output from: Debug
'Cosine.exe' (Win32): Loaded 'C:\Windows\System32\kernel.appcore.dll'.
'Cosine.exe' (Win32): Loaded 'C:\Windows\System32\ws2_32.dll'.
'Cosine.exe' (Win32): Loaded 'C:\Windows\System32\user32.dll'.
The thread 0x21c0 has exited with code 0 (0x0).
The thread 0x38a0 has exited with code 0 (0x0).
The program '[1588] Cosine.exe' has exited with code 0 (0x0).
```