

### Exercise 3: Collective Communication

- 1) Write a parallel program to find the maximum, minimum, and average values in an array of integers  $A[100]$  using 4 processes as follows:

- Process 0 initializes the array  $A$  by the following code fragment

```
#include <stdio.h>
#include <stdlib.h>

int main() {
    int A[100];

    /* Set random seed */
    srand(1234);

    for (i=0; i < 100; i++)

        /* Set each element randomly to 0-999 */
        A[i] = rand()%1000;
}
```

- Process 0 distributes the array  $A$  to all processes (including itself) by `MPI_Scatter`
- All processes find the local maximum, minimum, and average (sum) values, and then perform reduction for the global values
- Check the result with the sequential version executed at Process 0
- Hint: Use separate `MPI_Reduce` for global maximum, minimum and average values

```
[u6088232@cluster exercise3]$ mpicc -o q1 q1.c
[u6088232@cluster exercise3]$ mpirun -np 2 q1
process[0] now has min = 3, max = 966, average = 231
```

#### 2) Parallel search

- Create an array of random integers in Process 0
- Distribute distinct part of the array to all processes
- Process 0 receives an input integer  $i$  from a user, and broadcasts it to all.

- Count (in parallel) the number of elements in the array that is less than the input integer  $i$ . Use `MPI_reduce` to complete this step.
- Display the result

```
[u6088232@cluster exercise3]$ mpicc -o q2 q2.c
[u6088232@cluster exercise3]$ mpirun -np 2 q2
Enter the number: 70
32 50 3
67 60 53 55
process[0] gets all counts = 7
```

- 3) Given arrays of integers `A[100]` and `B[100]`, write an MPI program to construct `C[100]`, which each element  $C[i] = A[i] + B[i]$ , using `MPI_Scatter` and `MPI_Gather` on 2 processes.

```
[u6088232@cluster exercise3]$ mpirun
```

```
C[0] = 828  
C[1] = 678  
C[2] = 310  
C[3] = 134  
C[4] = 120  
C[5] = 1482  
C[6] = 1510  
C[7] = 1396  
C[8] = 1144  
C[9] = 106  
C[10] = 750  
C[11] = 482  
C[12] = 1932  
C[13] = 466  
C[14] = 336  
C[15] = 742  
C[16] = 1716  
C[17] = 110  
C[18] = 1928  
C[19] = 1802  
C[20] = 1260  
C[21] = 1048  
C[22] = 1456  
C[23] = 978  
C[24] = 710  
C[25] = 520  
C[26] = 1008  
C[27] = 64  
C[28] = 1272  
C[29] = 1472  
C[30] = 1324  
C[31] = 100  
C[32] = 150  
C[33] = 338  
C[34] = 940  
C[35] = 974  
C[36] = 1820  
C[37] = 450  
C[38] = 370  
C[39] = 1668  
C[40] = 1260  
C[41] = 1122  
C[42] = 152  
C[43] = 1896  
C[44] = 1588  
C[45] = 1192  
C[46] = 638  
C[47] = 1304
```

```
C[47] = 1304
C[48] = 6
C[49] = 1272
C[50] = 2132401
C[51] = 2
C[52] = 182846676
C[53] = 32719
C[54] = 217828944
C[55] = 32719
C[56] = 1724256793
C[57] = 32719
C[58] = 2
C[59] = 32719
C[60] = -738158954
C[61] = 55
C[62] = -735960688
C[63] = 55
C[64] = 292359376
C[65] = 32766
C[66] = 369387160
C[67] = 65438
C[68] = 473065056
C[69] = 65485
C[70] = 4196003
C[71] = 0
C[72] = -549040440
C[73] = 32774
C[74] = -45493687
C[75] = 0
C[76] = -738156574
C[77] = 56
C[78] = 2049
C[79] = 1
C[80] = 66332476
C[81] = 0
C[82] = 33
C[83] = 32766
C[84] = -1465757564
C[85] = 110
C[86] = 292360064
C[87] = 32766
C[88] = 584719864
C[89] = 65532
C[90] = -1465754152
C[91] = 110
C[92] = -549065896
C[93] = 32774
C[94] = -134621130
C[95] = 0
C[96] = -738155926
C[97] = 55
C[98] = 7
C[99] = 0
```

```
C[97] = 55
C[98] = 7
C[99] = 0
```

- 4) Given a matrix A[8][8] with some random values, write an MPI program to calculate the summation of all elements using only MPI collective communication on 8 processes. (MPI\_Send/MPI\_Recv are not allowed)

```
[u6088232@cluster exercise3]$ mpicc -o q4 q4.c
[u6088232@cluster exercise3]$ mpirun -np 2 q4
414      339      155      67      60      741      755      698
572      53      375      241      966      233      168      371
858      55      964      901      630      524      728      489
355      260      504      32      636      736      662      50
75      169      470      487      910      225      185      834
630      561      76      948      794      596      319      652
3      636      554      634      160      634      475      867
246      331      251      883      67      914      285      494
sum = 6208
```

- 5) Repeat Question 4 but with 4 processes.

```
[u6088232@cluster exercise3]$ mpirun -np 4 q4
414      339      155      67      60      741      755      698
572      53      375      241      966      233      168      371
858      55      964      901      630      524      728      489
355      260      504      32      636      736      662      50
75      169      470      487      910      225      185      834
630      561      76      948      794      596      319      652
3      636      554      634      160      634      475      867
246      331      251      883      67      914      285      494
sum = 14592
```