EE/CSCI 451
Fall 2020
Homework 3

Assigned: September 11, 2020
Due: September 17, 2020, AOE
Total Points: 100

1 [10 points]

Explain the following terms:

1. PRAM
2. Cannon's algorithm
3. Blocking and non-blocking send/receive
4. Single Program Multiple Data
5. Loosely synchronous

2 [30 points]

In the class, we discussed a shared memory parallel algorithm for matrix multiplication using Pthreads (Lecture 4, Slide Titled: Matrix Multiplication using Shared Variable). Write a PRAM algorithm for $n \times n$ matrix multiplication using the same idea. Assume reading from the same memory location by more than one processor in the same cycle is allowed. You should make sure your algorithm does not update the same location by more than one processor in the same cycle. Assume n^2 processors are used. What is the total time in terms of cycles? (Hint: First write a simple PRAM code based on the Pthreads code. Check if there are concurrent write operations to the same location. If yes, redistribute write operations of the threads.)

3 [10 points]

Considering the following serial code performed based on an $n \times n$ matrix A.

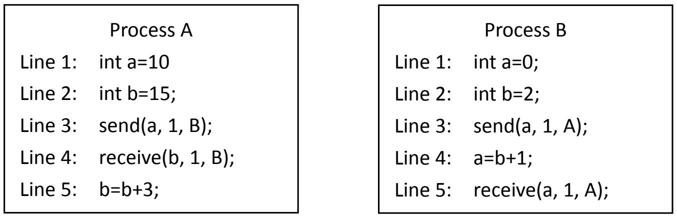
```
for (i = 1; i < n-1; i++)
     for (j = 1; j < n-1; j++)
            A[i][j]= A[i][j-1]+A[i-1][j];
```

Suppose we parallelize the execution of the serial code using OpenMP as shown below, will the parallel execution obtain the same output A as the serial execution? Explain.

```
omp_set_num_threads(4)
for (i = 1; i < n-1; i++)
     #pragma omp parallel for shared(A, i) private(j) schedule(dynamic)
     for (j = 1; j < n-1; j++)
            A[i][j]= A[i][j-1]+A[i-1][j];
```

4 [20 points]

The figure below shows two processes, Process A and B. Assume there are no other processes.



```
Process A
Line 1:   int a=10
Line 2:   int b=15;
Line 3:   send(a, 1, B);
Line 4:   receive(b, 1, B);
Line 5:   b=b+3;
```

```
Process B
Line 1:   int a=0;
Line 2:   int b=2;
Line 3:   send(a, 1, A);
Line 4:   a=b+1;
Line 5:   receive(a, 1, A);
```

Figure 1: Problem 4

- If Process A and Process B use blocking send/receive, is deadlock possible? Why? If there is deadlock, how will you modify the code to avoid deadlock.
- If Process A and Process B use non-blocking send/receive, is it safe for Process B to immediately execute Line 4 after Line 3 returns? Explain.

5 [30 points]

In the class, we discussed the Cannon's algorithm for matrix multiplication $C = A \times B$. In this problem we will implement the Cannon's algorithm using MPI. The matrix size is $n \times n$ and there are p^2 nodes laid out in a $p \times p$ two-dimensional array. Assuming i and j are the ranks of Node$_{ij}$ in the row and column communication domain ($0 \leq i, j < p$), respectively. The initial alignment of data has been completed.

- Write a complete pseudo code by using **blocking** message passing primitives for inter-node communication to perform Cannon's algorithm. Specify the local and global variables in your pseudo code.
- Rewrite your pseudo code by using **non-blocking** message passing primitives. Note that your pseudo code needs to enable overlap of data communication and local computation.
- What is the total data communicated among all the nodes? Use order notation.