Multi-Core Programming
EE 5885 – 04
Dept. of Electrical and Computer Engineering
ASSIGNMENT 3, Points: 30, Due Date: 03/18/2021 by 4:00 PM

Prob. 1 **Points: 4**

Draw the iteration space dependency graph of the following code snippet of a program: Show the ISDG for the first four "i" iterations and first five "j" iterations. Indicate the range of "i" and "j" iterations on the ISDG.

```
f o r ( i n t i = 1 ; i < K−1; i++)
        {
        f o r ( i n t j = 0 ; j < M ; j++)
                {
                a [ i ] [ j ] = a [ i −1] [ j ] + a [ i+1] [ j ] ;
                }
        }
```

- Identify the dependencies.

Prob. 2 **Points: 4**

The OpenMP based code snippet to count the number of odd numbers in an array is shown below:

```
int data[N];
int oddCount  = 0;

#pragma omp parallel for
{
        for(int i = 0;i<N;i++)
        {
                if(data[i] % 2)
                {
                        oddCount++;
                }
        }
}
```

- Is the above code correct? If the code is not correct, explain the error.
- If the code is not correct, suggest a solution to fix the error in the code.

Prob. 3 **Points: 10**

Complete the OpenMP based parallel program to perform matrix multiplication using the given template code:

- **Examine the modified matrix multiplication sequential code, and identify the difference to the code discussed in the class.**
- **All three nested loops of the matrix multiplication algorithm has to be parallelized.**
- **The innermost loop has to be parallelized using a suitable clause with the parallel for OpenMP construct.**
- Provide plots of the execution time for the sequential and parallel version for varying matrix sizes.
- Provide a plot of the speedup achieved for varying matrix sizes.
- The matrix multiplication algorithm provided has a computational complexity of O(MNP) where,
    - M is the number of rows of Matrix-A
    - N is the number of Columns of Matrix-B
    - P is the inner dimension i.e., either the number of columns of Matrix-A or the number of rows of Matrix-B.
    - If, Matrix-A and Matrix-B are of the same dimensions, then the computation complexity can be written as $O(M^3)$.
- Determine whether the computational complexity of the parallel version has changed by analyzing the execution times with increasing matrix sizes**. (Hint: Trend line).**

Prob. 4 **Points: 12**

Modify the program developed for Prob. 3 as follows:

- Add a function to compute the transpose of Matrix-B.
- Add two new functions (Sequential and Parallel Implementations) to perform matrix multiplication using the transpose of Matrix-B (Note: the product should still be equal to the product obtained using Matrix A and Matrix B).
- Provide a single plot of the execution times of sequential multiplication with
    a) Matrix B
    b) Matrix B transpose
- Provide a single plot of the execution times of parallel multiplication with
    c) Matrix B
    d) Matrix B transpose
- Provide a plot of the speedup achieved for varying matrix sizes for all the three versions (Sequential transpose, parallel, and parallel transpose).
- Discuss why the speedup is significantly higher when the transpose is used **(Hint: Locality).**