

# CX 4220/CSE 6220 Introduction to High Performance Computing

Spring 2023

## Programming Assignment 1

Due February 8th, 11:59 PM

### 1 Problem Statement

Write a parallel program in C/C++ to compute the definite integral  $\int_0^1 \frac{4}{1+x^2}$ . Let  $n$  be a large integer and  $h = \frac{1}{n}$ . Compute the definite integral using the approximation

$$\int_0^1 \frac{4}{1+x^2} \approx \frac{1}{n} \sum_{i=1}^n \frac{4}{1+[h(i-0.5)]^2} = \mathbf{s}$$

### 2 Parallel Algorithm

The computation can be easily parallelized by assigning each processor the responsibility to compute  $\frac{n}{p}$  distinct terms in the summation. You should use the following MPI functions:

- Use `MPI_Bcast` function to broadcast  $n$  to all processors.
- Use `MPI_Reduce` function to add the partial sums computed on each processor.
- Use `MPI_Wtime` to time the run-time of the program (measure on processor 0).

### 3 Code framework

#### 3.1 Input & Output Format

Your program should take  $n$  as the input using command line arguments and output the value of the approximation and the time taken to compute this value (comma-separated). For example, if the value of definite integral is  $\mathbf{s}$  and the time taken is  $\mathbf{t}$ , your output should be “ $\mathbf{s}, \mathbf{t}$ ”. (**Note:**  $\mathbf{s}$  should be printed up to 12 decimal points). All output is done through processor with rank 0.

#### 3.2 Deliverables

1. Create a Makefile for your program, and make sure the name of your output executable is “`int_calc`”. If you are not familiar with creating Makefiles, check resources below for help.
2. Write a “`README.txt`” briefly describing how your program works and the machine you used for generating the results.

3. For  $n = 10^6$ , plot a graph of run-time of the program vs. the number of processors for a few chosen values of  $p$ . This run-time should include all computations that contribute to the integral, including any local computations and global reductions. Include your graph and observation regarding the speedup in a PDF file with name “**report.pdf**”. **Make sure to list names of all your teammates at the very beginning of your report.**
4. Submit your a) “**code.zip**” in “Programming Assignment 1 Code” on Gradescope. Your zip file should include all the cpp files, Makefile and “**README.txt**” file; b) your report in “Programming Assignment 1 Report” on Gradescope.

## 4 Resources

1. What is a Makefile and how does it work?: <https://opensource.com/article/18/8/what-how-makefile>
2. PACE ICE cluster guide: [https://docs.pace.gatech.edu/ice\\_cluster/ice-guide/](https://docs.pace.gatech.edu/ice_cluster/ice-guide/). Documentation for writing a PBS script: [https://docs.pace.gatech.edu/software/PBS\\_script\\_guide/](https://docs.pace.gatech.edu/software/PBS_script_guide/)