

Distributed Systems Assignment 1

MPI Programming

Due: January 22, 11:55PM

1 Overview

This assignment deals with parallel programming using the message passing model. In this assignment you will construct parallel solutions to certain problems and implement them using the Message Passing Interface: MPI in either C or C++.

2 Important Points

For this assignment, you will be using the Open MPI library to code solutions to different problems in C/C++.

- **Installation Guide:** <https://ireneli.eu/2016/02/15/installation/>
- **Introduction to MPI in C:** <http://condor.cc.ku.edu/~grobe/docs/intro-MPI-C.shtml>
- **MPI Documentation:** <https://www.rookiehpc.com/mpi/docs/index.php>
- **Template:** Link
- All your programs should run for **minimum 1** and **maximum 11** processes.
- For those who are not able to run their programs with 11 or less process use one of the following commands:
 - `mpirun -np 11 -use-hwthread-cpus ./a.out`
 - `mpirun -np 11 -oversubscribe ./a.out`

3 Problems

You are supposed to use the above given template for implementing each of the below given programs. Additionally, your program will be given two arguments, path to an input file and an output file from which your program will obtain the input and output the result into respectively.

Problem 1 (10 points)

Use the numerical identity that the sum of the reciprocals of the squares of integers converges to $\frac{\pi^2}{6}$.

Input

An integer N denoting the number of terms in the series that your program has to use. For $N = 4$, series would be $\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \frac{1}{4^2}$.

Output

A floating point number, denoting the estimated value of $\frac{\pi^2}{6}$ rounded off to six decimal places.

Constraints

$$2 \leq N \leq 10^4$$

Sample Test Cases**Sample Input 1**

2

Sample Output 1

1.250000

Sample Input 2

100

Sample Output 1

1.634984

Problem 2 (30 points)

Given an array of numbers, your task is to return the array in sorted order by implementing parallel quicksort.

Input

The first line of input contains size of array N . The second line of input contains N space separated integers.

Output

The output is a space separated sorted array.

Constraints

$$2 \leq N \leq 10^6$$

Sample Test Cases**Sample Input**

7

9 3 -11 100 2 4 1

Sample Output

-11 1 2 3 4 9 100

Problem 3 (60 points)

Given an undirected graph G , find a proper edge coloring of the graph using $\Delta(G) + 1$ colors or fewer. No 2 adjacent edges should have a same color. $\Delta(G)$ is the maximum degree of any vertex in G .

Input

First line contains two integers N M , denoting the number vertices and edges of the graph. Then, there are M lines, each of which contains 2 integers u and v , which means there is an edge in graph joining vertices u and v . i^{th} line here corresponds to edge i .

Output

First line should contain a single integer x denoting the number of colors used. Second line should contain M integers (c_1, c_2, \dots, c_N) , where c_i represents color of the edge i . $1 \leq c_i \leq x$

Constraints

$$1 \leq N \leq 100$$

$$1 \leq M \leq 500$$

Sample Test Cases

Sample Input

3 3

1 2

2 3

3 1

Sample Output

3

1 2 3

4 Submission Instructions

Your submission is expected to be a `<RollNumber>.zip` file containing a directory with the same name as your roll number that holds the following files:

- A program file for each of the mentioned problems with the name: `<RollNumber>_<ProblemNumber>.cpp`
- A brief report describing and analyzing your solution as: `README.md`

Since your codes will be evaluated automatically, you have to follow the output format strictly.

NOTE: Strict actions would be taken against anyone found involved in any kind of plagiarism either from the internet or from other students. If we find any of the codes implementing the question in serial manner or using other algorithms than mentioned in the question, then it will result in serious penalties.