Parallel and distributed programming
Assignment 1: 2D numerical integration

IT, Uppsala University, March-May, 2019

Problem formulation

You are given an MPI code (`integral.c`) that integrates numerically the one-dimensional integral

$$I_{1D} = \int_0^1 \frac{4}{1+x^2}\,dx.$$

The numerical method is the midpoint rule,

$$\int_0^1 \frac{4}{1+x^2}\,dx \approx h\sum_{i=1}^{n}\frac{4}{1+x_i^2} = h\sum_{i=1}^{n}\frac{4}{1+((i-0.5)h)^2}.$$

Recall that the trivial parallel implementation of the latter formula is, given p processes, we slice the sum into p pieces, attach one interval to each of them to compute a partial sum, and then collect the local sums into one process, which will know the answer.
Your task is to compute in parallel the two-dimensional integral

$$I_{2D} = \int_0^2 \left(\int_0^2 (x + \sin(y) + 1)\,dx \right) dy.$$

The exact answer is $I_{2D} = 10 - 2\cos(2) \approx 10.832293673094284$.

Task 1 Parallellize the computation. To this end, divide the processes into a $p \times 1$ mesh as equally as possible, and assign a strip of the computational domain to each of them as illustrated in Figure 1. The result should be collected at process 0 and it should output the number of intervals N, the result I_{2D}^m and the time, for instance, as
`100000 10.832177 81.241344`.
The output should be written in a file named `A1output`.

Task 2 Study the parallel performance and the scalability of your implementation, considering both *fixed problem size* and *scaled problem size* scalability. Plot the speedup, including the ideal speedup as a reference.

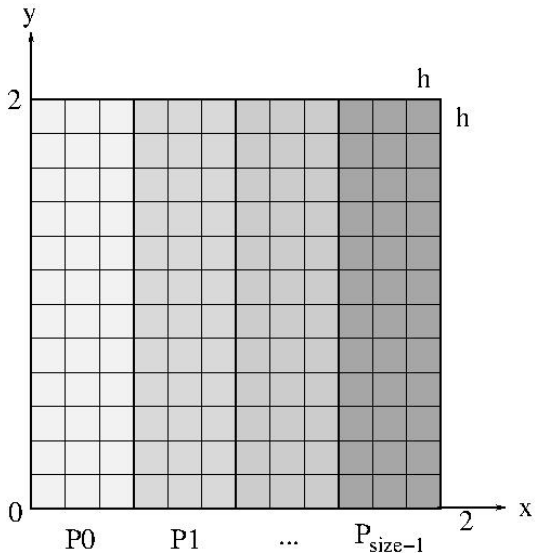

Figure 1

Writing a report

Write a short informal report summarizing your experiments and results, and upload it (as .pdf) in the student portal, together with your source code, following the instructions below.

Structure of the file to be uploaded in the Student portal

The functionality of the code will be tested automatically. Therefore, the code and the uploaded file must obey certain requirements.
Regarding the code, the number of intervals N, same in each direction, should be an input parameter, read from `stdin`. Note, that h in Figure 1 is $h = 2/N$,
The uploaded file must be named `A1.tar.gz`. The file should contain a directory, named `A1`, with the following files:

- the report in .pdf format, named `A1_Report.pdf`,
- the code, named `2dintegral.c`,
- a `makefile` that, upon the command `>make` produces an executable named `2dintegral` and upon the command `>make clean` removes an existing executable with that name,
- the output file `A1output`.

If the uploaded file has a different name or a different structure, the assignment will be rejected without further considerations.