Università della Svizzera italiana

Institute of Computing CI

High-Performance Computing **2022**

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Solution for Project 5

Due date: 30.11.2022, 23:59

HPC 2022 — Submission Instructions
(Please, notice that following instructions are mandatory: submissions that don't comply with, won't be considered)

- Assignments must be submitted to iCorsi (i.e. in electronic format).
- Provide both executable package and sources (e.g. C/C++ files, Matlab). If you are using libraries, please add them in the file. Sources must be organized in directories called:
  Project_number_lastname_firstname
  and the file must be called:
  project_number_lastname_firstname.zip
  project_number_lastname_firstname.pdf
- The TAs will grade your project by reviewing your project write-up, and looking at the implementation you attempted, and benchmarking your code's performance.
- You are allowed to discuss all questions with anyone you like; however: (i) your submission must list anyone you discussed problems with and (ii) you must write up your submission independently.

This project will introduce you a parallel space solution of a nonlinear PDE using MPI.

1. Task 1 - Initialize and finalize MPI [5 Points]

Initialize MPI: use MPI_Init()
Get current rank and number of ranks: use MPI_Comm_rank() and MPI_Comm_size()
Finalize MPI: use MPI_Finalize();

2. Task 2 - Create a Cartesian topology [10 Points]

Create the dimension of the decomposition depending on the number of ranks
use MPI_Dims_create()

Create a non-periodic Cartesian topology for the grid of domains
use MPI_Cart_create()

Identify coordinates of the current rank in the domain grid
use MPI_Cart_coords()

Identify neighbours of the current rank: east, west, north and south directions
use MPI_Cart_shift()

3. Task 3 - Change linear algebra functions [5 Points]

Add a collective operation to compute the dot product. And add a collective operation to compute the norm.
use MPI_Allreduce()

4. Task 4 - Exchange ghost cells [45 Points]

Copy data to the send buffers (buffN, buffS, buffE, buffW) by MPI_Isend(), and receive to ghost cells (bndN, nbdS, bndE, bndW) by MPI_Irecv().

After finishing interior grid-point computations, used MPI_Waitall() at each process to ensure that exchange with all its neighbors is complete.

5. Task 5 - Testing [20 Points]

Plot time to solution for these grid sizes for 1-10 threads and 1, 2, 4 MPI ranks.

5.1. 1 MPI rank

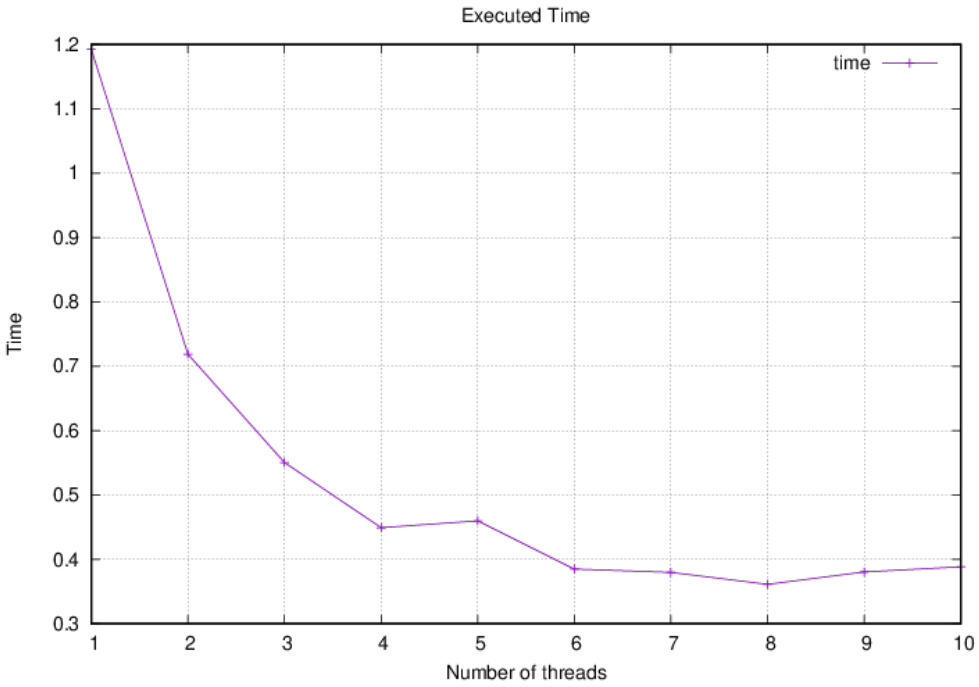

Figure 1: 1 MPI rank, 128 x 128

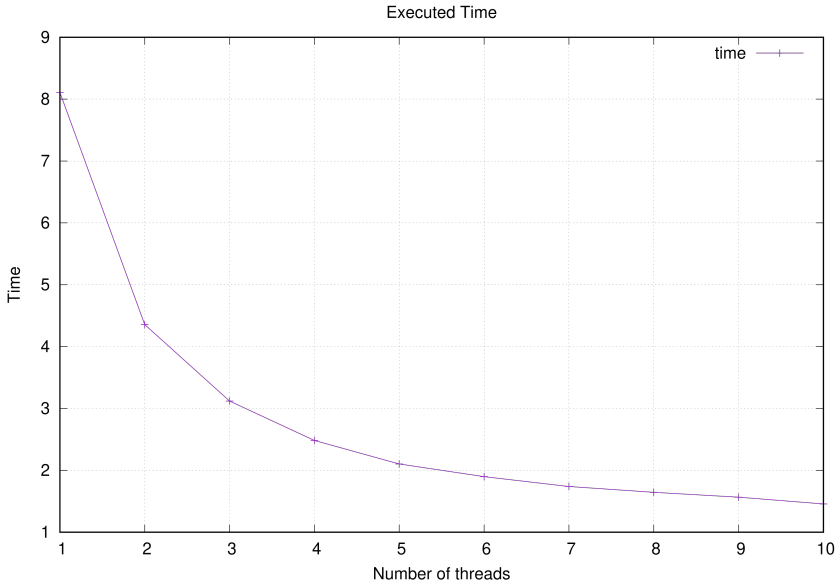

Figure 2: 1 MPI rank, 256 x 256

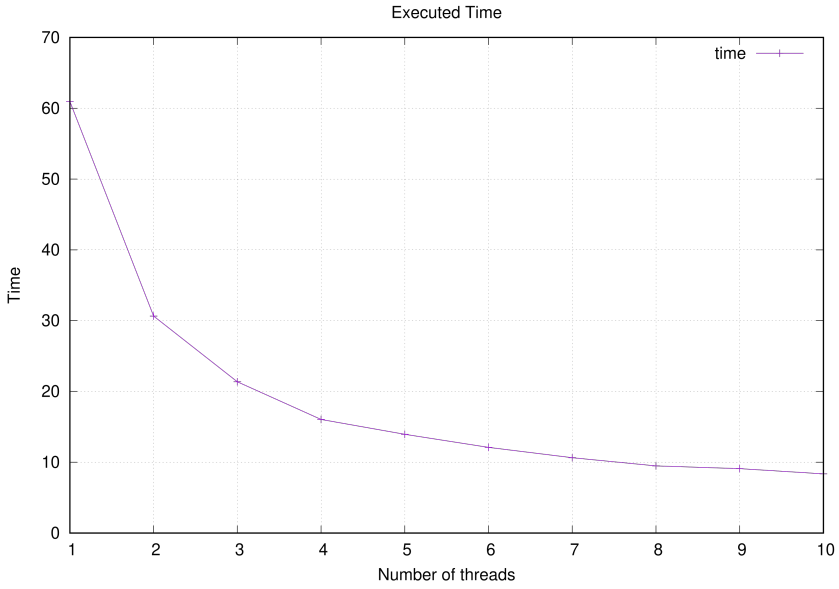

Figure 3: 1 MPI rank, 512 x 512

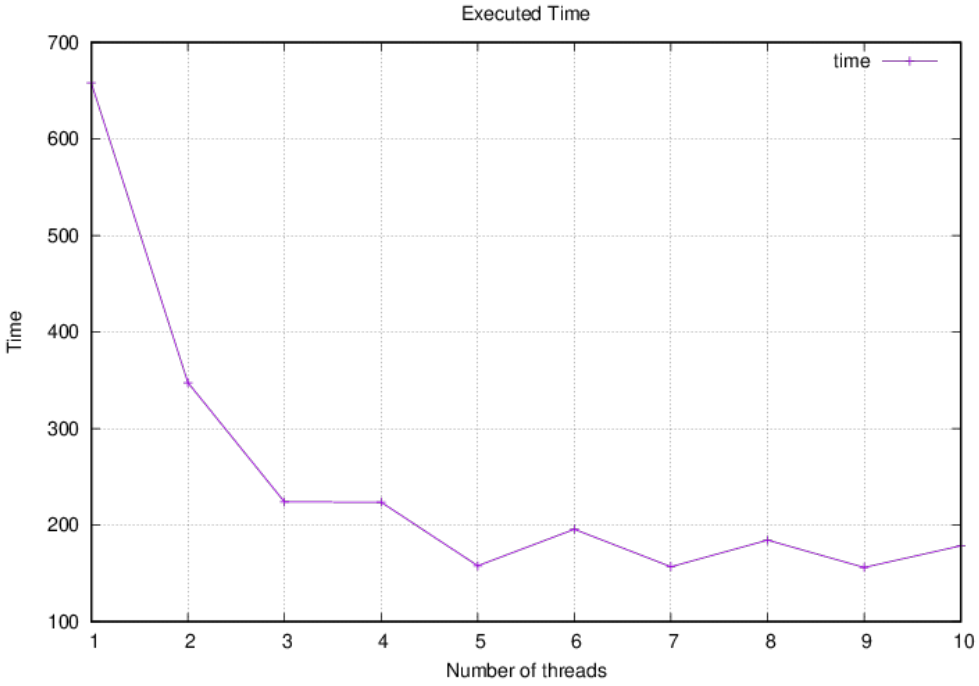

Figure 4: 1 MPI rank, 1024 x 1024

5.2. 2 MPI rank

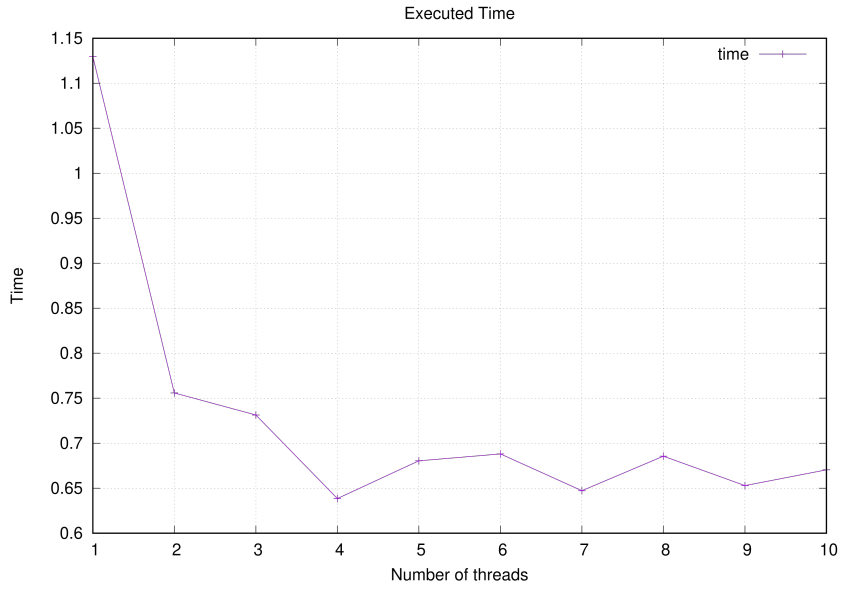

Figure 5: 2 MPI rank, 128 x 128

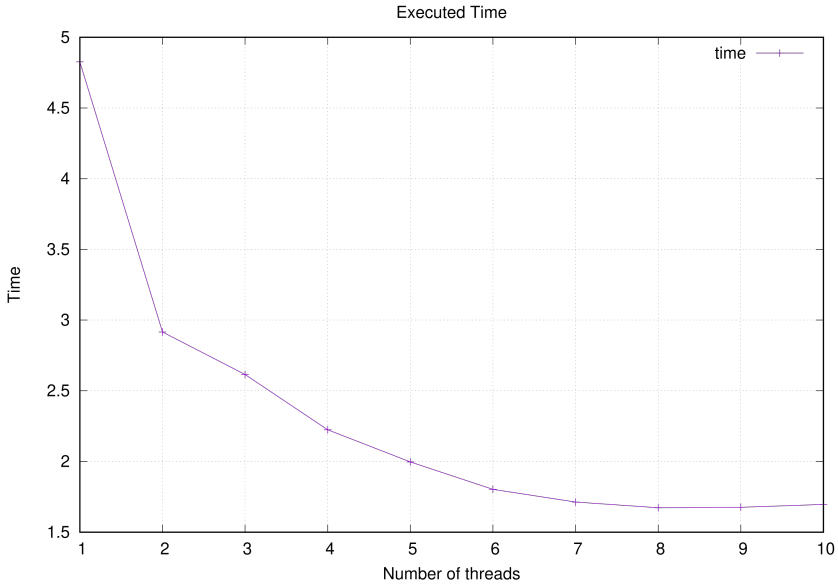

Figure 6: 2 MPI rank, 256 x 256

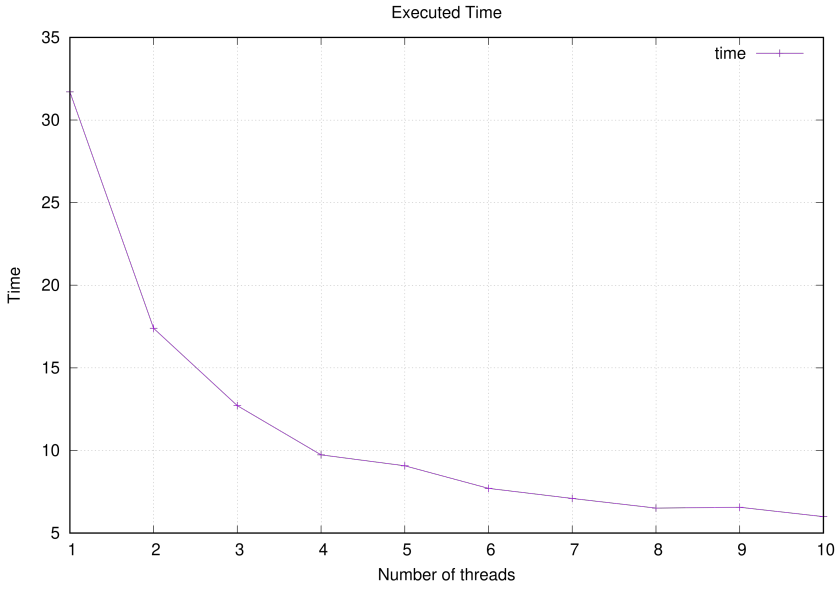

Figure 7: 2 MPI rank, 512 x 512

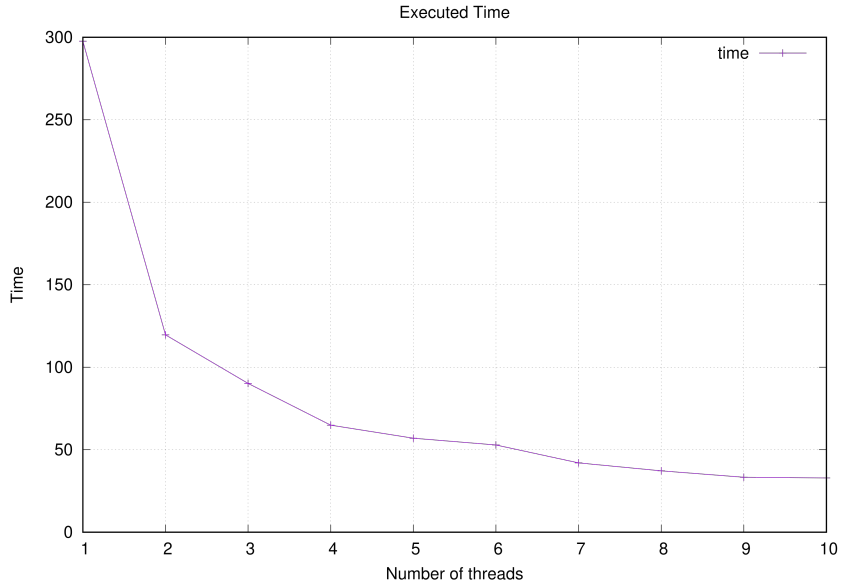

Figure 8: 2 MPI rank, 1024 x 1024

5.3. 4 MPI rank

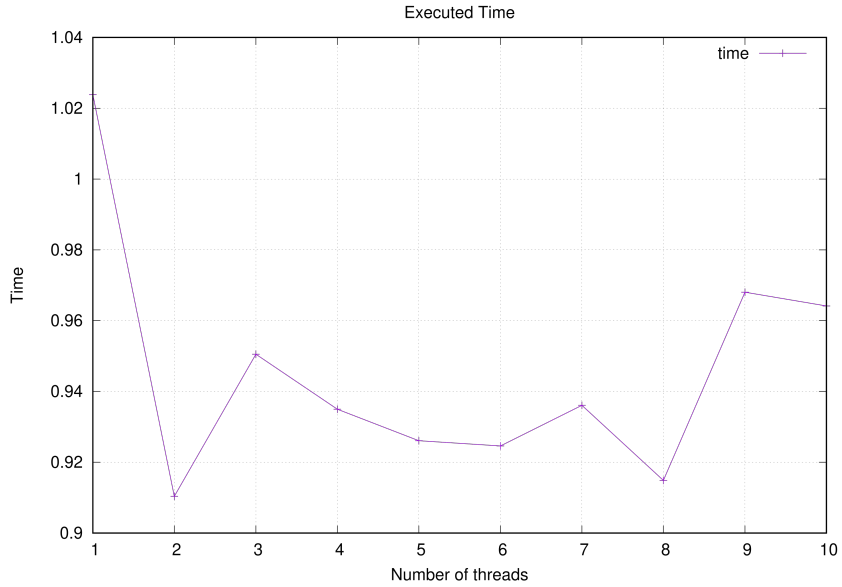

Figure 9: 4 MPI rank, 128 x 128

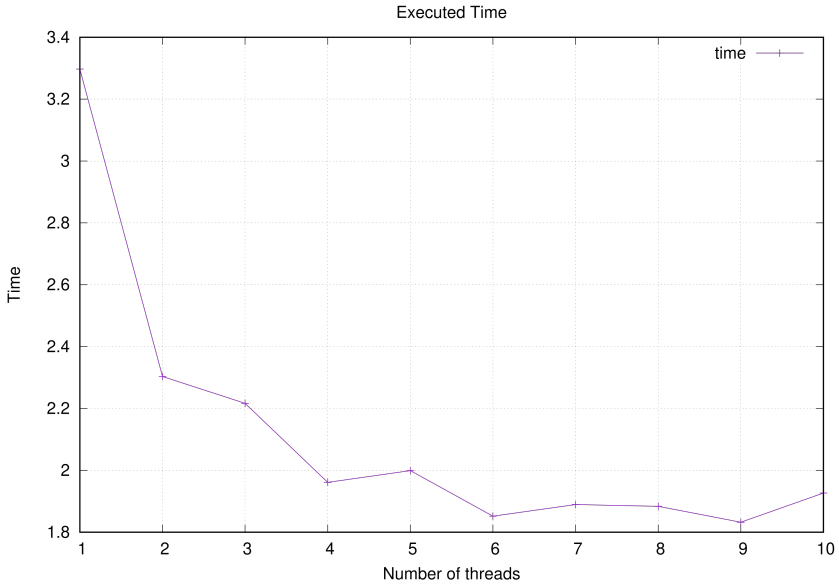

Figure 10: 4 MPI rank, 256 x 256

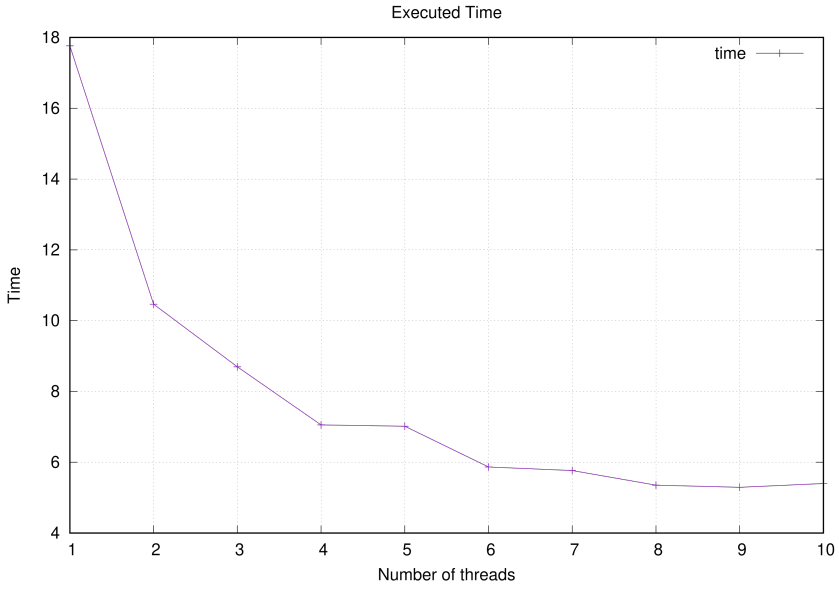

Figure 11: 4 MPI rank, 512 x 512

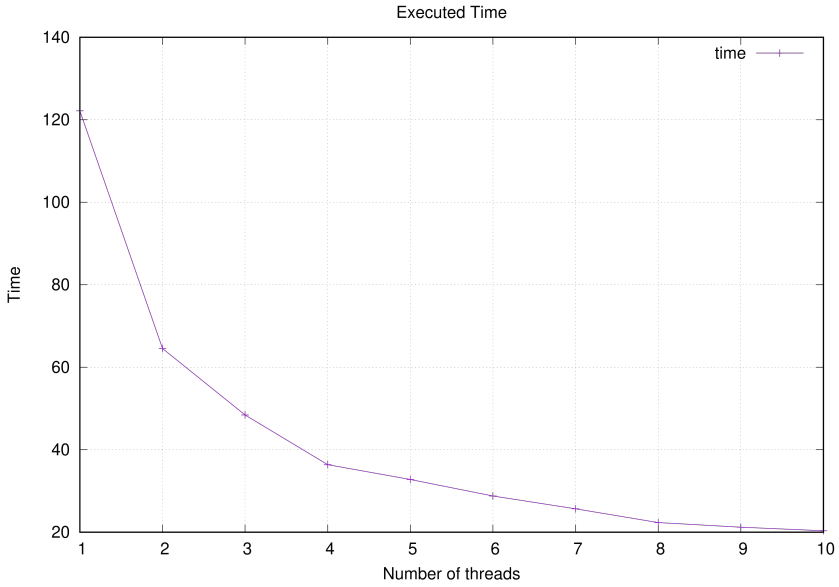

Figure 12: 4 MPI rank, 1024 x 1024

5.4. Analysis

5.4.1. Strong scaling

When chooing the same MPI rank, the total runtimes will decrease with the increasement of threads at first. And when the number of threads exceeds 6, the runtimes slowly decay and become stable. And the performance for each thread decrease with the increasement of threads.

5.5. Weak scaling

It shows that the runtimes increase when the number of process increase, even if per process workload does not change. Because the time of data transfer which is from the communication among different processes also increase.

6. Task 6 - Quality of the Report [15 Points]

Additional notes and submission details

Submit the source code files (together with your used `Makefile`) in an archive file (tar, zip, etc.) and summarize your results and the observations for all exercises by writing an extended Latex report. Use the Latex template from the webpage and upload the Latex summary as a PDF to iCorsi.

- Your submission should be a gzipped tar archive, formatted like project_number_lastname_firstname.zip or project_number_lastname_firstname.tgz. It should contain:
  - all the source codes of your MPI solutions.
  - your write-up with your name project_number_lastname_firstname.pdf,
- Submit your .tgz through Icorsi.