ME614 Fall 2018 - HPC Homework

Introduction to Parallel Computing

(Due October 10, 2018)

Please submit your homework on Blackboard in the form of a (1) report in PDF (keep file size smaller than 5MB) and (2) a working code, zipped in one file. The submitted code needs to run and create all (and possibly only) the plots you are including in your report. The use of LaTeX for your report is strongly recommended (but not required) and you can start with a template from http://www.latextemplates.com/. Discussions and sharing of ideas are encouraged but individually prepared submissions (codes, figures, written reports, etc.) are required. Due to the sensitivity of some numerical results to the specific coding choices, and sometimes even hardware, it is easy for the instructor to flag homeworks as suspicious. A plagiarism detection algorithm will be run against all codes submitted. Do NOT include in your submisison any files that are not required (e.g. the syllabus, zip files with python libraries, other PDFs, sample python sessions etc).

Points will be deducted from late submissions at a rate of 20% of the overall homework value per day late. Homeworks are due at 11:59 PM of the due date.

Problem 1

Let $\{x_i\}\ \forall i \in \{0, \ldots, N-1\}$ be a collection of uniformly spaced points, with spacing Δx, discretizing a given one-dimensional interval $[x_0, x_{N-1}]$ in space, with $x_0 = 0$ and $x_{N-1} = L$ fixed and of your choice. Create a balanced partition (single-constraint) of the following set of points $\{x_i\}$ for a generic number of MPI processes. It is acceptable for your code NOT to work if the number of grid points is not an integer-multiple of the number of processors. Pick a function to sample and a degree of discretization of your choosing, and perform the following task by without any ghost cell communication between the MPI segments:

(a) Using $N_{\text{procs}} = 1$, 2, 4, 8, and 16 processes (and more if you can), evaluate and plot in a single figure on a log-log scale the absolute truncation error, $\epsilon_{TR} = \texttt{rms}\left(\left|\widehat{\frac{du}{dx}} - \frac{du}{dx}\right|\right)$ against the inverse grid spacing Δx^{-1} by varying the total number of points in the range $N = 10^1 - 10^9$ (if you can). What is the behavior of the truncation error? is it N_{procs}-dependent? Comment on your results.

[50%]

(b) Once again for all values of N_{procs} in part (a), perform weak and strong scaling analysis of your MPI program. For definitions of weak and strong scaling, refer to https://www.sharcnet.ca/help/index.php/Measuring_Parallel_Scaling_Performance. Plot (separately) the weak and strong scaling efficiencies against the total number of processes, with horizontal dashed reference lines for 50%, 75%, and 100% efficiencies.

[45%]

(c) Repeat the tasks (a) and (b) by including ghost-cell-value communications, emulating what would actually happen in a parallel CFD code where communication is needed because: (1) the solution is unsteady and MPI subdomains need to be synchronized in time; (2) there is (obviously) no analytical solution that can be used to populate the ghost cells.

[5%]