MSc in CSTE
High Performance Technical Computing

Assignment

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Hand in date: 22/1/18 (FT), 5/2/18 (PT), 09:30am

1 Introduction

In this assignment you are asked to examine the application of distributed memory parallel programming techniques for the numerical solution of the heat conduction equation. In order to do this, we will consider the following problem.

A wall 1 ft. thick and infinite in other directions (see Figure 1) has an initial uniform temperature T_{in} of 100°F. The surface temperatures T_{sur} at the two sides are suddenly increased and maintained at 300°F. The wall is composed of nickel steel (40% Ni) with a diffusivity of $D = 0.1\ ft^2/hr$. Please compute the temperature distribution within the wall as a function of time.

The governing equation to be solved is the unsteady one-space dimensional heat conduction equation, which in Cartesian coordinates is:

$$\frac{\partial T}{\partial t} = D \frac{\partial^2 T}{\partial x^2}$$

2 HPC Tasks

1. First devise a way to parallelise and then analyse your algorithms for the following methods:
    - FTCS Simple Explicit (Forward time, central space, explicit)
    - Laasonen Simple Implicit (Forward time, central space, implicit)
    - Crank-Nicholson (Trapezoidal)

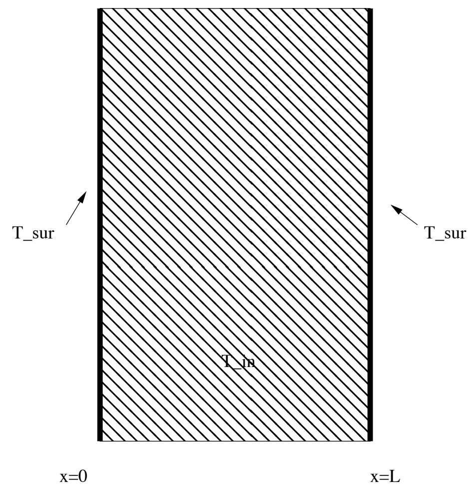

Figure 1: Nomeclature and Problem Domain

For each method two sets of step sizes are to be used:

(a) $\Delta x = 0.5$ and $\Delta t = 0.1$

(b) $\Delta x = 0.005$ and $\Delta t = 0.001$

In all cases the solution is to be printed and plotted for all x locations for $t = 0.5hrs$.

2. Implement your algorithms in a program written in C/C++/FORTRAN and coupled with MPI.

3. Compare the numerical solutions obtained by the serial programs and the parallel programs with the analytical solution.

4. Measure the cost of communication in the boundary exchange and the cost of computing a time-step for each process.

5. Measure the performance of your serial and parallel codes and discuss. How does the parallel program performance compare to the theoretical one? Is the performance of your parallel program expected?

6. Replace your linear system solver with an appropriate one from an external mathematical library. Study how the performance of a different implementation of the linear system solver affects the overall performance of an implicit scheme for the solution of the prescribed PDE.

7. Based on your results, reason on the problem sizes deemed necessary in order for MPI parallelisation to become efficient for the above numerical algorithms.

3 Report

Write a report to present and discuss your findings. The report should be no less than 1,500 words and must not exceed 3,000 words. The report can contain any number of figures. All figures and tables in the report should be numbered and discussed. The report should include a description of the design of your solution explaining your choices. The source code and a sample scheduler script should be included as Appendices to the report.

The source program will need to compile on Delta using the intel compilers. Your simulations for the above tasks should be performed on Delta using the working nodes.

The report should be submitted electronically via the **TurnItInUK** link by 9:30am on the 22$^{\text{nd}}$ January (full-time students) or the 5$^{\text{th}}$ February (part-time students).

The source code and the sample scheduler script must also be submitted via the **Blackboard** link by the prescribed deadline, for the assignment submission to be considered complete.

4 Marking

The assignment will be assessed based on the following marking scheme:

- 20% Introduction, methodology, conclusions
- 40% Source code, design
- 30% Discussion and analysis of the results
- 10% Report structure, presentation, references