

University of Saskatchewan
Department of Computer Science

Parallel Programming for Scientific Computing
(CMPT 851)

Instructor: Dr. Raymond J. Spiteri

ASSIGNMENT 01

Due: 1:00 p.m. Tuesday, February 11, 2014

1. [25 marks]
 - (a) Get a user account on WestGrid. What is your username?
 - (b) Login to `bugaboo.westgrid.ca`. Give the output when you issue the command `finger spiteri`.
 - (c) What does the `w` command do? Give the output when you issue the command `w` on `bugaboo.westgrid.ca`.
 - (d) Login to `socrates.usask.ca` and `moneta.usask.ca` and start up MATLAB. Report the output from the command `ver`.
 - (e) What is the significance in the lack of difference between the two outputs when it comes to parallel programming?

2. [25 marks] When we discussed floating-point addition, we assumed each functional unit took the same amount of time. Suppose now that the fetch and store operations each take 2 ns and the remaining operations each take 1 ns.
 - (a) How long does a floating-point addition take?
 - (b) How long does an unpipelined addition of 1000 pairs of floating-point numbers take?
 - (c) How long does a pipelined addition of 1000 pairs of floating-point numbers take?
 - (d) The time required for fetch and store operations may vary considerably depending on where they happen to be stored in memory when they are needed. Suppose that fetches from level-1 cache, level-2 cache, and main memory take 1, 2, and 50 ns, respectively. What happens to the pipeline if there is a level-1 cache miss on a fetch of one of the operands? What about for a level-2 cache miss?

3. **[25 marks]** Suppose a program must execute 10^{12} instructions in order to solve a problem. Suppose a single processor can execute 10^6 instructions per second.

How many days will it take the single processor to solve the problem?

Now suppose we modify the program to run on a distributed-memory system with $p = 1000$ processors in such a way that each processor will execute $10^{12}/p$ instructions and send $10^9(p - 1)$ messages.

How long will it take to solve the problem if messages take 10^{-9} s to send?

How about if messages take 10^{-3} s to send?

Assume the program completes as soon as it has executed its instructions and sent its messages and that any other overhead is negligible.

Give three examples of what might be considered as overhead.

4. **[25 marks]** Find the global minimum of the function

$$f(x, y) = e^{\sin(50x)} + \sin(60e^y) + \sin(70 \sin x) + \sin(\sin(80y)) - \sin(10(x + y)) + \frac{x^2 + y^2}{4}.$$

This was Problem 4 of the SIAM 100-digit challenge. The goal was to compute the answer correct to 10 significant digits. We are going to compare the performance of several programs to obtain a rough this answer; we will improve our results in future assignment questions. A bit of straightforward analysis yields that the global minimum must lie not too far from the origin, so we restrict our attention to the domain $\{(x, y) \in [-1, 1] \times [-1, 1]\}$.

- Write a *purely scalar* MATLAB program to sample $f(x, y)$ on a regular grid of the domain with 8^3 points in each direction. Find the minimum value obtained and record the execution time.
- Vectorize the program from part (a). Record the execution time. Comment on the relative execution time.
- Use the `parfor` construct to parallelize the program from part (a). Record the execution time using $p = 2, 4,$ and 8 processes. Comment on the parallel performance of this program relative to the previous two.
- Repeat parts (a)–(c) with 8^4 points and comment on the difference in the outcomes.

Note: The answers to all three parts should be the same; you should verify that this is the case in the output of your program(s).

5. **[0 marks]** Write a description of the project you propose to undertake for this course. Please include mathematical or algorithmic details as well as desired outcomes.