Advanced Course on Multi-Threaded Parallel Programming using OpenMP for Multicore/Manycore Systems

February 14-16, 2023

National Taiwan University, Taipei, Taiwan

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http://nkl.cc.u-tokyo.ac.jp/NTU2023W/

Overview

In order to make full use of modern supercomputer systems with multicore/manycore architectures, hybrid parallel programming with message-passing and multithreading is essential. While MPI is widely used for message-passing, OpenMP for CPU and OpenACC for GPU are the most popular ways for multithreading on multicore/manycore clusters. In this 3-day course, we focus on optimization of single node performance using OpenMP for CPU. We "parallelize" a finite-volume method (FVM) code with Krylov iterative solvers for Poisson's equation on Wisteria/BDEC-01 (Odyssey) System (http://nkl.cc.u-tokyo.ac.jp/22s/WisteriaBDEC01.pdf) with Fujitsu/Arm A64FX at the University of Tokyo, which is ranked 23rd in the *Top500* list published in November 2022 (https://www.top500.org/).

In this Winter School, the target application is a 3D FVM code for Poisson's equation by ICCG Method (Conjugate Gradient (CG) iterative method with Incomplete Cholesky preconditioning), which is widely-used in practical applications. Because ICCG includes "data dependency", where writing/reading data to/from memory could occur simultaneously, parallelization using OpenMP is not straight forward. We need certain kind of reordering in order to extract parallelism. In this 3-day course, lectures and exercise on the following issues will be provided:

- Overview of Finite-Volume Method (FVM)
- Kyrilov Iterative Method, Preconditioning
- Implementation of the Program
- Introduction to OpenMP
- Reordering/Coloring Method
- Parallel FVM by OpenMP

Prerequisites

- Experiences in Unix/Linux (vi or emacs)
- Experiences in Programming by C/C++/Fortran
  - https://en.wikipedia.org/wiki/List_of_Unix_commands
  - https://www.gnu.org/software/emacs/manual/
- Fundamental numerical algorithms (Gaussian Elimination, LU Factorization, Jacobi/Gauss-Seidel/SOR Iterative Solvers, Conjugate Gradient Method (CG))
- Experiences in SSH Public Key Authentication Method (optional)

Preparation

- Your PC (Windows, Mac, Linux): The latest version of Anti-Virus software and the latest OS must be installed to your PC.
- **Preparation:** Software/Tools on Your PC
  - Windows-Subsystem-for-Linux (WSL): https://learn.microsoft.com/en-us/windows/wsl/
  - Cygwin (Windows Only): https://www.cygwin.com/
  - ParaView (for Visualization): http://www.paraview.org
- FVM Codes for PC
  - PCG (C. Fortran): http://nkl.cc.u-tokyo.ac.jp/files/fvm.tar
  - ICCG (C): http://nkl.cc.u-tokyo.ac.jp/files/multicore-c.tar
  - ICCG (Fortran): http://nkl.cc.u-tokyo.ac.jp/files/multicore-f.tar

Schedule

Date	Hour	Content
February 14 (Tue), 2023	09:10-10:00	Introduction
	10:10-11:00	Finite Volume Method (FVM) (1/4)
	11:10-12:00	Finite Volume Method (FVM) (2/4)
	13:10-14:00	Finite Volume Method (FVM) (3/4)
	14:10-15:00	Finite Volume Method (FVM) (4/4)
	15:10-16:00	Introduction to OpenMP (1/4)
	16:10-17:00	Login to Odyssey
February 15 (Wed), 2023	09:10-10:00	Introduction to OpenMP (2/4)
	10:10-11:00	Introduction to OpenMP (3/4)
	11:10-12:00	Introduction to OpenMP (4/4)
	13:10-14:00	ICCG Method (1/3)
	14:10-15:00	ICCG Method (2/3)
	15:10-16:00	ICCG Method (3/3)
	16:10-17:00	Reordering (1/4)
February 16 (Thu), 2023	09:10-10:00	Reordering (2/4)
	10:10-11:00	Reordering (3/4)
	11:10-12:00	Reordering (4/4)
	13:10-14:00	Parallel FVM using OpenMP (1/4)
	14:10-15:00	Parallel FVM using OpenMP (2/4)
	15:10-16:00	Parallel FVM using OpenMP (3/4)
	16:10-17:00	Parallel FVM using OpenMP (4/4)

Materials

- http://nkl.cc.u-tokyo.ac.jp/NTU2023W/ (Available soon)
- http://nkl.cc.u-tokyo.ac.jp/22s/ (Lectures at the University of Tokyo)
- Software/Tools on Your PC
- http://nkl.cc.u-tokyo.ac.jp/files/multicore-c.tar
- http://nkl.cc.u-tokyo.ac.jp/files/multicore-f.tar
- http://nkl.cc.u-tokyo.ac.jp/files/fvm.tar