

High-Performance Computing and Numerical Projects

Department of Informatics, University of Oslo

Planned start: Fall semester 2018

High-Performance Computing and Numerical Projects: a new 10-ECTS course for both CS students and others

Course content. Effective use of modern computing systems, spanning from laptop PCs to supercomputers, is essential for the computational science. The course teaches the fundamental concepts in parallel programming and high-performance computing, such as work load division, communication, speedup, code optimization and typical parallel architectures. The most basic communication commands in MPI and programming directives in OpenMP will be taught. Use of multicore PCs and PC clusters will also be lectured, together with a brief description about programming GPUs for parallel computing. In addition to being one basic ingredient of the curriculum for the "Master program in Computational Science", this course can also be useful for other students, as well as scientific staff at UiO, who want to learn the fundamental knowledge about efficiently applying modern computer architectures to solving computation-heavy scientific problems.

Learning outcomes. The course introduces a variety of central algorithms and methods essential for studies in high-performance computing. Through hands-on exercises and projects, the students will be exposed to fundamental research problems in the field of high-performance computing, with the aim to reproduce state of the art scientific results. The students will learn to develop and structure large codes for studying these systems, get acquainted with computing facilities and learn to handle large scientific projects. A good scientific and ethical conduct is emphasized throughout the course. More specifically, after this course you will

- Be capable of effectively using laptop/desktop computers;
- Be capable of extending suitable numerical code to computer clusters;
- Be informed about cutting-edge non-CPU hardware;

- Be ready to learn about more advanced parallel computing.

Prerequisites

Basic knowledge in programming and numerics. Required courses are the equivalents to the University of Oslo mathematics courses MAT1100, MAT1110, MAT1120 and at least one of the corresponding computing and programming courses INF1000/INF1110 or MAT-INF1100/MAT-INF1100L/BIOS1100/KJM-INF1xxx.

Overlap: 5 ECTS overlap with INF3380.

The course has two central parts

1. Effective use of a laptop PC or desktop computer
2. HPC beyond a laptop/desktop

Effective use of a laptop PC or desktop computer.

- Quick overview of modern computer hardware;
- Simple performance modeling (realistic performance upper bound);
- Good programming practices – “clean code”;
- Data structure and array-based programming;
- Single-core optimizations (loop optimization, vectorization, etc.);
- Thread-based multicore programming via OpenMP.

HPC beyond a laptop/desktop.

- Typical cluster architecture and H/W performance characteristics;
- Parallelism, work/data partitioning, collaboration;
- Basic issues of parallel program design;
- MPI programming;
- Hybrid parallel programming (MPI+ OpenMP);
- A peek into non-CPU hardware: GPU.

All the above topics will be supported by examples, hands-on exercises and project work.

Computational aspects play a central role and the students are expected to work on numerical examples and projects which illustrate the theory and algorithms. Some of the projects can be coordinated with the Data analysis and machine learning course (course code to be added).

Practicalities.

1. Four lectures per week, Fall semester, 10 ECTS;
2. XXX hours of laboratory sessions for work on hands-on exercises and/or computational projects;
3. One mandatory assignment (a prescribed numerical problem, intended for using a shared-memory computer system);
4. One project (with the possibility of configuring an individual project for each student, in the numerical problem, target parallel hardware, programming language);
5. Weekly small assignments;
6. Final exam which counts xxx
7. Organized by the Departments of Informatics;
8. Possible teacher first time: Xing Cai;
9. The course is part of the CS Master of Science program, but is open to other bachelor and Master of Science students at the University of Oslo;
10. Grading scale: Grades are awarded on a scale from A to F, where A is the best grade and F is a fail;
11. The course will be offered as a 4XXX and 3XXX course.

Possible textbooks.

- Georg Hager and Gerhard Wellein, Introduction to High Performance Computing for Scientists and Engineers (Chapman & Hall/CRC Computational Science, 2010)