CPSC 424/524: Parallel Programming Techniques (Fall 2018)

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Yale University

This course offers a practical introduction to high-performance computing (HPC) and a number of programming methodologies for using parallel computers, including multicore processors, network-connected Linux clusters, and accelerators such as programmable Graphics Processing Units (GPUs). The course will emphasize techniques suitable for applications in a broad range of scientific and engineering disciplines. The goal is to introduce students to the principles of parallel computation, and to a number of algorithms and programming techniques that perform well on modern parallel computers such as those in wide use for both academic research and commercial applications.

The course will cover the principles and applications of three primary programming paradigms: (a) shared-memory multithreading on symmetric multiprocessors using OpenMP; (b) message passing on tightly-coupled Linux clusters using MPI; and (c) massively parallel multithreading on GPU accelerators using CUDA. The lectures will cover the most important aspects of these paradigms, but students will be expected to learn many of the details from the texts, on-line resources, and, especially, the programming exercises that are an extremely important part of the course.

The course will also address certain aspects of related topics such as:

- Processor/cluster architecture relevant to HPC, including memory hierarchies, vector extensions, and add-on accelerators such as GPUs;
- Performance measurement, tuning, and debugging; and
- Parallel methods for important algorithms (e.g., linear algebra, N-Body problems).

Students will be expected to complete programming assignments every 2-3 weeks using Yale's HPC Linux clusters. The class will be taught using the C programming language, although final projects may be done using programming languages other than C. There will be a midterm exam and either a final exam (required for students registered in CPSC 424, except by special permission) or a final project (required for students registered in CPSC 524). Graduate students enrolled in CPSC 524 are strongly encouraged to select final projects related to their research interests. The course grade will be based on programming exercises (55%), mid-term exam (15%), final exam/project (25%), and class participation/instructor judgment (5%).

The course is suitable for upper-level undergraduates or graduate students in Computer Science, Mathematics, or any science, social science, or engineering discipline. Students must have programming experience in C or C++, and they must have knowledge of data structures (equivalent at least to CPSC223b, *Data Structures and Programming Techniques*) and basic linear algebra (equivalent to MATH 222a or b or 225a or b, *Linear Algebra*). Students should consult with the instructor in advance on questions concerning background or prerequisites.

Enrollment may be capped at 30-50 students at the instructor's discretion. (This will be announced in Canvas and at the first lecture.) If the class is capped, preference may be given to juniors and seniors and to students whose research involves advanced computation. Students intending to take this class should email Dr. Sherman at the address below with the following information as early as possible: Name; NetID; School; Major/Department; Class/Year; whether you intend to take CPSC424 or CPSC524; and a sentence or two stating your reasons for taking this class. If the class is oversubscribed, some students may be placed on a waiting list during shopping period in case vacancies occur. Space allowing, auditors are permitted. Please contact Dr. Sherman with any questions.

Lectures: Mon/Wed, 9:00am-10:15am, AKW 200. First meeting: 8/29/2018. This class meets during Reading Period.

Textbooks:

1. *Introduction to High Performance Computing for Scientists and Engineers,* by Georg Hager & Gerhard Wellein. (CRC Press 2010). Online: https://www.taylorfrancis.com/books/e/9781439811931). ***New edition due out in late 2018.***
2. *Programming Massively Parallel Processors, 2nd or 3rd Ed.*, by David B. Kirk & Wen-mei W. Hwu (Morgan Kaufmann 2016, ISBN 978-0-12-811986-0). The 2nd edition is online: http://www.books24x7.com/marc.asp?bookid=51033. The 3rd edition may be purchased for ~$72 at Amazon or other online retailers.

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Office Hours: Time and location TBD.