CS455: Introduction to High Performance Computing

Credit Hours: 4/3 (Graduate/Undergraduate)

I. Course Details

Instructor: Zhiling Lan
Email: zlan@uic.edu
Class Schedule: Tuesday and Thursday, 3:30 PM to 4:45 PM
Location: TBH 180G

II. Course Information

Prerequisite(s)

CS 361 Systems Programming or consent of the instructor.

Course Goals

The primary goal of this course is to provide a comprehensive introduction to high-performance computing (HPC) and its applications. The course aims to equip students with a thorough understanding of parallel system components and organizational structures, while exposing them to the challenges and opportunities involved in developing and utilizing large-scale heterogeneous systems. Additionally, the course offers foundational knowledge of HPC architecture, parallel programming paradigms, performance analysis, and software techniques. As an introductory course, it lays the groundwork for students to leverage HPC capabilities for advanced research and complex problem-solving across various disciplines. Practical skills are emphasized through targeted programming assignments that provide initial hands-on experience with parallel systems, positioning students to effectively apply their knowledge to real-world challenges. Upon completion of this course, students will be able to:

- **Understand HPC and Its Role:** Describe how HPC impacts major problem-solving domains, such as aerospace, medicine, and science. Explain the role and significance of HPC systems in contemporary research.
- **Comprehend HPC Architecture:** Understand the organization and operation of HPC systems. Identify and explain the fundamental components of shared-memory and distributed-memory systems. Understand the organization and operation of HPC systems. Identify and explain the fundamental components of shared-memory and distributed-memory systems.
- **Apply Parallel Computing Techniques:** Understand the basic principles of parallel computing and apply various paradigms, algorithms, and programming languages to develop parallel systems.
- **Engage in Practical Programming:** Develop and implement programs that utilize parallel processing systems, effectively applying HPC resources to computational problems.
- **Demonstrate Critical Thinking and Problem Solving:** Analyze and evaluate different HPC solutions for complex scenarios, assessing the performance and efficiency of systems and programs.
- **Apply Knowledge Across Disciplines:** Demonstrate the capability to utilize HPC in diverse STEM fields to accelerate discovery and innovation.

III. Course Topics

Week	Topic
week 1	Overview
week 2	Parallel platforms and programming models
week 3-4	Performance analysis
week 5-6	Shared memory architectures and programming (Pthreads, openMP)
week 7	Distributed memory architectures and Communication
week 8	Midterm
week 9-11	Distributed memory programming (MPI)
week 12-13	GPU architecture and programming (CUDA)
week 14-15	Special topics
Final week	Final exam

IV. Course Materials

Textbooks:

– T. Sterling, M. Anderson, and M. Brodowicz, *High Performance Computing: Modern Systems and Practices* (2nd Ed), Morgan Kaufmann Publishers, ISBN-10 0128230355, ISBN-13 978-0128230350, 2024. [recommended]

– A. Grama, V. Kumar et al., *Introduction to Parallel Computing* (2nd Ed), Addison Wesley, ISBN-10 0201648652, ISBN-13 978-0201648652, 2003. [recommended]

– D. Kirk and W. Hwu, *Programming Massively Parallel Processors* (4th Ed), Morgan Kaufmann, ISBN-10 0323912311, ISBN-13 978-0323912310, 2022. [recommended]

– R. Robey and Y. Zamora, *Parallel and High Performance Computing*, Manning Publishers, ISBN-10 1617296465, ISBN-13 978-1617296468, 2021. [recommended]

Computing Resources

– Advanced Cyberinfrastructure for Education and Research (ACER) UIC HPC center
– Chameleoncloud (`https://www.chameleoncloud.org/`)
– Argonne Leadership Computing Facility (DOE Office of Science supercomputing center)

Recommended Websites:

– `https://www.cplusplus.com`
– `https://www.openmp.org`
– `https://www.mpi-forum.org`
– Visual Studio Code (modern editor)

V. Grading

Undergraduate Student (3 credit hours)

– Assignments: 40%
– Attendance and Participation: 10%
– Midterm Exam: 25% (first half of course material)
– Final Exam: 25% (second half of course material)

Graduate Student (4 credit hours)

- Assignments (one extra assignment): 40%
- Attendance and Participation: 10%
- Midterm Exam: 25% (first half of course material)
- Final Exam: 25% (second half of course material)

VI. General Policies

- All exams are closed book and closed notes unless otherwise specified.
- No makeup assignments or exams will be provided.
- Late assignments incur a deduction of 20% per day (including weekends and university holidays).
- Submissions beyond five days late will receive a score of 0.
- Students are responsible for all material presented in class and in assigned readings.
- Course documents (including lecture notes and sample code) will be shared on the class website and GitHub repository on a best-effort basis.
- **Academic Integrity:** All submitted work must be your own. Cheating or plagiarism will result in disciplinary action. Review UIC Community Standards and Academic Integrity Policy.
- **Generative AI Use Policy:** Use of generative AI is allowed for coding snippets, projects, and related activities provided that:
  - AI usage is transparently disclosed.
  - AI is used to aid learning and not as a replacement for understanding.
  - AI is not permitted during quizzes, exams, or assessments.
- **Electronic Communication:** Course-related messages will be sent to your @uic.edu account. The course website and UIC Blackboard will be used for posting grades and materials.