



CPEG/ELEG 652 - Principles of Parallel Computer Architectures

Credits: 3, Section(s): 010

Semester: Spring, Year: 2021

Meeting Days, Times, Location and Room:

Lecture: Mondays, Wednesdays and Fridays, 9:05-9:55AM

Online via Zoom

Tentative Syllabus

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1. Instructor Information

Instructor Contact Information

Instructor name: Rudolf Eigenmann

Instructor preferred pronouns: he/him/his

Email address: eigenman@udel.edu

Office location: 202 Evans Hall

Office hours: On request. Please email at least 24 hours in advance or schedule in class.

Teaching Assistant(s) Contact Information

TA name: no TA is available for this class

2. Course Description

Description

All of today's computer architectures are parallel. Computer architects, developers of the software stack, application programmers, and even end users need to be aware of the way the omnipresent parallelism affects their work. In this course, you will learn the basic structures of parallel hardware and software, how parallel hardware is exposed to system and application software, and how software can best take advantage of the potential offered by parallelism.

Topics include, but are not limited to: relevance of parallel computing today; levels of parallelism; programming models with abstract view of the underlying architecture; components of parallel architectures; system topologies; special-purpose architectures; parallel programming languages, libraries, and tools; porting and optimizing parallel applications; performance evaluation; national and international parallel systems; parallel applications.

This course will expose you to a large range of topics related to parallelism, so it is introductory. For in-depth studies of the materials you will have to take additional, advanced course offerings.

Prerequisites

Begins at a level that assumes experience in introductory undergraduate courses such as digital system design, computer architecture, and microprocessor based systems.

Course Delivery

Online Synchronous

3. Learning Outcomes

At the conclusion of this course, you should have the ability to:

1. Explain the reasons and history why most computer architectures are parallel
2. Understand the many different levels of parallelism and how to exploit them
3. Recognize and describe shared-memory, distributed-memory and co-processor architectures
4. Understand and articulate the challenges, models, and basic constructs for programming these architectures
5. Explain the national infrastructure of high-performance computing resources and how to obtain access
6. Understand and describe basic concepts and transformations of parallel program optimization
7. Explain principles and tools for performance analysis of, debugging, and testing parallel programs
8. Understand and describe how parallel computers are applied in science and engineering

4. Learning Resources

Recommended Learning Materials

These books are recommended resources. They include much more than presented in the course. The lectures will include additional material from research papers and other sources.

- *Computer Architecture: A Quantitative Approach, 5th Edition* by John Hennessy and David Patterson, Morgan Kaufmann 2011.
- *Parallel Computer Organization and Design* by Michel Dubois, Murali Annavaram, and Per Stenstrom, Cambridge 2012.
- *Using OpenMP, Portable Shared Memory Parallel Programming* by Barbara Chapman, Gabriele Jost and Ruud van der Pas, MIT Press 2007.
- *Beginning MPI (An Introduction in C)* by Wesley Kendall, Amazon Digital Services LLC 2013.
- *Parallel Programming in C with MPI and OpenMP* by Michael J. Quinn, McGraw-Hill Education 2008.

Online lecture material:

piazza.com/illinois/fall2018/cs420cse402ece492/resources
https://computing.llnl.gov/tutorials/parallel_comp
portal.xsede.org/group/xup/online-training

Technology

Canvas: In this class, Canvas, UD's online learning management system, will be used for sharing lecture material and communicating general course information.

Information on how to use Canvas is available through the [Canvas Student Guide](#).

Canvas can also be accessed via [MyUD](#).

Zoom: In this class, Zoom will be used for video conferencing. The specific zoom link will be announced via Canvas.

Zoom is a web-based application that can be used from a computer, tablet, or phone. From a computer, click the class web link and be sure to install the small program that will download to your computer. You only need to install the program once. From a mobile device, download the free Zoom app and type in the class meeting ID number.

A microphone and camera are recommended for online meetings. Information on how to test your computer's audio and video can be found on [Zoom's website](#). Learn more info about [Zoom at UD](#).

[Computer Access](#): For class projects you will need access to a parallel computer. As most computers are parallel today, you may get started on a workstation you have access to or even your laptop. However, obtaining an account on one of the larger UD compute clusters, such as [Caviness](#) or a departmental server, is recommended.

5. Learning Assessment

Final Grade Breakdown

The final course grade will be calculated using the following components:

Course Component	Percentage of Total
Midterm Exam	20%
Final Exam	30%
Project	25%
Class Participation	15%
Homework	10%

Homework

The homework assignment each week will be to do background research on any topic related to the material presented in class that week. In half a page to one page, provide a reference to the material you found (a paper, a textbook, a magazine article, a video, a quote from a person, etc.) and *describe in what way the information supports, contradicts, or complements the material presented in class*. Send your homework to the instructor by email before the first lecture of the following week.

Quizzes

There will be occasional quizzes on recently-learned material. Students may be called upon to explain their answer. Quizzes will factor into class participation, whereby the effort made will count at least as much as a correct answer.

Project

Every student will propose a computational application that you will execute on a parallel machine of your choice. You will improve the application in some way that aims to enhance the performance and analyze the results. You will describe your experience in a project report of 4-6 pages.

The objective of this project is that you gain experience in

1. identifying code sections in a program that should/can be parallelized,
2. learning about a parallel programming model and language,
3. possibly installing a compiler and/or library to facilitate your project,
4. identifying a parallel machine on which to run and measure the program, and
5. analyzing parallel program performance.

For obtaining a good grade, what counts is not so much that you can speed up your program, but that you demonstrate in your report an understanding of these five points. The expectation is that you spend two to three hours per week on this project.

Please create a Google folder (not a shared drive) in which you place all your project files, including a copy of the project proposal and final project report. In addition, please create a “lab book”, in which you record what you did. Date every entry. There should be at least one entry per week that briefly describes what you have done that week, or say “I was not able to work on the project this week.”

Format and submission of project proposal and final report:

At the end of the **second week of classes**, submit a project proposal of ½ to 1 page. The proposal should begin with the course number, a project title, and your name. Email the proposal to the instructor with subject line CPEG/ELEG652 Project Proposal, in addition to placing it in the project Google folder.

By the end of the semester, expand the text into a 4-6 page report and submit by Tuesday, May 18 23:59 (hard deadline) with subject line CPEG/ELEG652 Project Report Your Name. Also, place the report in your Google folder.

In addition to sections of your choosing, include the following sections:

- Application: Describe the application code, both from a science perspective and from the computer science perspective (language, lines of code, etc.)
- Project objectives: Describe the improvements you planned to apply to the code and why. Be sure to include all such steps, even those that did not improve the performance or even caused slow-down. One usually learns a lot from the latter!
- Results: Explain how you measured “performance” and why. Then show these measurement results. Be sure to *discuss* the results. A measured number is not a result. How you interpret the number is what counts.
- Time spent in the project: Include a pie chart (or equivalent) showing 4 to 6 major categories of what consumed time in your project. Indicate the total hours spent.

Be sure that you explain all included figures sufficiently.

Project Presentation

You will give a short (10-minute) presentation of your project in the last week of the semester.

Exams

Both the midterm and the final will be individual, oral exams of 20 minutes, per student. At least two weeks before exam time, please schedule an exam appointment with the instructor

- in the week of March 29, for the midterm exam, and
- in the final exam week (optionally in the last week of classes)

The midterm exam will cover material discussed in class up to that point. The final exam is comprehensive.

Exams will be conversation style. A common question is “tell me what you have learned in class”. The emphasis is on understanding the concepts. There will be at least one question about the syllabus

6. Course Calendar

Approximate schedule

Week/Date	Theme/Topic	Learning Outcomes Addressed
1 (02/15/2021)	Introduction and relevance of parallel computing today. Levels of parallelism	1,2
2 (02/22/2021)	Basic parallel programming models and architectures	3,4
3 (03/01/2021)	./. Shared-memory models	3,4
4 (03/08/2021)	./. Distributed-memory models	3,4
5 (03/15/2021)	Accelerators and special-purpose architectures	3,4
6 (03/22/2021)	Advanced elements of parallel architectures	3,4
7 (03/29/2021)	Midterm exams	
8 (04/05/2021)	National High-performance computer systems	5
9 (04/12/2021)	Optimizing parallel programs - concepts and program analysis	6
10 (04/19/2021)	Optimizing parallel programs - basic program transformations	6
11 (04/26/2021)	Performance Evaluation, debugging testing	7
12 (05/03/2021)	Parallel applications in science and engineering	8
13 (05/10/2021)	Project presentations	
14 (05/17/2021)	Review	

7. Course Policy Document

Course Specific Policies

Attendance

Students are expected to attend all their scheduled classes and not to be absent without adequate reason. Further information may be found at [UD's attendance policy](#). If you participate online, please keep your camera on, as a general rule. Please discuss with the instructor, if you feel uncomfortable doing so.

Absences on religious holidays listed in university calendars are recognized as an excused absence. Nevertheless, students are urged to remind the instructor of their intention to be absent on a particular upcoming holiday. Absences on religious holidays not listed in university calendars, as well as absences due to athletic participation or other extracurricular activities in which students are official representatives of the university, shall be recognized as excused absences when the student informs the instructor in writing during the first two weeks of the semester of these planned absences for the semester.

If an absence becomes unavoidable, be sure to check with another student if there have been important announcements.

Communication

Course announcements will be posted using Canvas.

It is best to ask all questions during the class. The instructor will call in 5 minutes before class starts and be available at the end. Be sure to mention before class starts, if you wish to bring up questions at the end.

For email questions, please allow 24 hours for the instructor to respond.

UD Policies

Academic Integrity

Please familiarize yourself with UD policies regarding academic dishonesty. To falsify the results of one's research, to steal the words or ideas of another, to cheat on an assignment, to re-submit the same assignment for different classes, or to allow or assist another to commit these acts corrupts the educational process. Students are expected to do their own work and neither give nor receive unauthorized assistance. Complete details of the university's academic integrity policies and procedures can be found at sites.udel.edu/studentconduct/sgup/ Office of Student Conduct, 218 Hulliher Hall, (302) 831-2117. E-mail: student-conduct@udel.edu

Harassment and Discrimination

The University of Delaware works to promote an academic and work environment that is free from all forms of discrimination, including harassment. As a member of the community, your rights, resource and responsibilities are reflected in the non-discrimination and sexual misconduct policies. Please familiarize yourself with these policies at www.udel.edu/oei. You can report any concerns to the University's Office of Equity & Inclusion, at 305 Hulliher Hall, (302) 831-8063 or you can report anonymously through UD Police (302) 831-2222 or the EthicsPoint Compliance Hotline at www1.udel.edu/compliance. You can also report any violation of UD policy on harassment, discrimination, or abuse of any person at this site: sites.udel.edu/sexualmisconduct/how-to-report/

Faculty Statement on Disclosures of Instances of Sexual Misconduct

If, at any time during this course, I happen to be made aware that a student may have been the victim of sexual misconduct (including sexual harassment, sexual violence, domestic/dating violence, or stalking), I am obligated by federal law to inform the university's Title IX Coordinator. The university needs to know information about such incidents

to, not only offer resources, but to ensure a safe campus environment. The Title IX Coordinator will decide if the incident should be examined further. If such a situation is disclosed to me in class, in a paper assignment, or in office hours, I promise to protect your privacy--I will not disclose the incident to anyone but the Title IX Coordinator.

For more information on Sexual Misconduct policies, where to get help, and reporting information, please refer to www.udel.edu/sexualmisconduct. At UD, we provide 24/7/365 crisis assistance and victim advocacy and counseling. Contact 302-831-1001 to get in touch with a sexual offense support advocate, as well as confidential and anonymous counseling services for other concerns.

Accommodations for Students with Disabilities

Any student who thinks he/she may need an accommodation based on a disability should contact the Office of Disability Support Services (DSS) office as soon as possible. Students who have documentation of their need for accommodation should register via the SAM platform: andes.accessiblelearning.com/UDELI/. Reach DSS in the following ways: Phone: 302-831-4643, fax: 302-831-3261, [DSS website](#). Email: dssoffice@udel.edu or visit at 240 Academy Street, Alison Hall Suite 130.

During COVID-19, Disability Support Services staff are available remotely. Please call 302-831-4643 during business hours (8-5 M-F) or email dssoffice@udel.edu for assistance.

Non-Discrimination

The University of Delaware does not discriminate against any person on the basis of race, color, national origin, sex, gender identity or expression, sexual orientation, genetic information, marital status, disability, religion, age, veteran status or any other characteristic protected by applicable law in its employment, educational programs and activities, admissions policies, and scholarship and loan programs as required by Title IX of the Educational Amendments of 1972, the Americans with Disabilities Act of 1990, Section 504 of the Rehabilitation Act of 1973, Title VII of the Civil Rights Act of 1964, and other applicable statutes and University policies. The University of Delaware also prohibits unlawful harassment including sexual harassment and sexual violence.

For inquiries or complaints related to non-discrimination policies, please contact: Office of Equity & Inclusion-
oei@udel.edu, 305 Hullihen Hall Newark, DE 19716 (302) 831-8063

For complaints related to Section 504 of the Rehabilitation Act of 1973 and/or the Americans with Disabilities Act, please contact: Office of Disability Support Services, dssoffice@udel.edu, Alison Hall, Suite 130, Newark, DE 19716 (302) 831-4643 OR contact the [U.S. Department of Education - Office for Civil Rights](#)