CS 442 / 542: Introduction to Parallel Processing

Fall 2022

Instructor:	Prof. Amanda Bienz	**Email:**	bienz@unm.edu
Classroom:	MechE 218	**Class Time:**	M/W/F 11:00 – 11:50
Office:	FEC 3060	**Office Hours:**	Th/F 2:00-3:00

Course Description: CS 442/542 is a senior and graduate level course in parallel programming, covering shared memory, distributed memory, and heterogeneous systems. The course focuses on understanding parallel concepts, reformulating algorithms for parallelism, and modeling and optimizing the performance of parallel applications. At the end of the semester, you should be able to model the performance of a parallel application, determine performance bottlenecks, and reduce bottlenecks found in the models.

Course Content: This course covers many topics in parallelism, including:

- Concept of parallelism in programming
- Parallel performance models
- Distributed memory parallelism
  - Message-Passing Interface (MPI)
  - Distributed system topologies
  - Performance versus scalability
  - Collectives
  - Point-to-point communication
  - Dense and sparse linear algebra
  - Distributed system performance models
  - Reliability and Fault Tolerance
  - Parallel I/O
- MPI+X
  - Shared memory parallelism
  - Threading and OpenMP for shared memory systems
  - State-of-the-art CPU + GPU systems
  - CUDA overview (brief)
  - OpenMP for accelerators
  - Heterogeneous performance models
- Recent research in parallel computing

Course Format: This is a fully face-to-face course. The course will not be live-streamed online. However, all classes will be recorded, and recordings will be posted within 24 hours of the end of class. If you are unable to find a recording, please send an email to bienz@unm.edu. In the event that a recording is unsuccessful, you will be responsible for finding notes for missed material.

Grading: Grades are given based on the standard 10-point scale (90-100 A, 80-89 B, etc.). There will be pluses and minuses (e.g. 90-93 is A-). There will be no curve for the course. The grades are broken down as follows:

- Professionalism (5%)
- In-class questions (5%)
- Tutorials (10%)
- Midterm Exam (15%)
- Homework assignments (30%)
- Final project (35%)

Course Materials: There is no textbook required for this course. However, the following books are helpful resources.

- Parallel and High Performance Computing by Robert Robey and Yuliana Zamora
  ISBN 9781617296468
- Introduction to High Performance Computing for Scientists and Engineers by Georg Hager and Gerhard Wellein
  ISBN 9781439811924
- Introduction to Parallel Computing (2nd Edition) by Ananth Grama, George Karypis, Vipin Kumar, and Anshul Gupta
  ISBN 9780201648652

The class will loosely follow "Parallel and High Performance Computing" (listed above).

Prerequisites: As a senior and graduate level class, it is expected that you have basic programming experience and are able to program in either C, C++, or Fortran as these are the languages that support OpenMP and MPI. You will be able to use Python instead at times, but there may be assignments requiring either C, C++, or Fortran. You will be allowed to do homework assignments in the language of your choice, but all solutions will be posted in C++ (or Python for scripting). Finally, as all parallel programs will be compiled and run on UNIX systems, command line experience is useful. Instructions will be given for how to compile and run a simple program on these systems. Students are expected to have varying backgrounds in the topics of computer architecture, Parallel programming, and numerical methods. Prior to taking this course, each student should have experience with at least one of the following topics.

- Computer architecture (CS341)
- Big data computing (CS567)
- Scientific computing (CS471 / MATH471)

Attendance Policy: All classes can be attended in person. Attendance is not required, but you will be responsible for material covered during each class. In the event you are unable to attend a course, a recording of the class should be posted online within 24 hours. If a recording is not available, please send an email to bienz@unm.edu. In the event that a recording is unsuccessful for any reason, you will be responsible to find notes that cover content for days not attended. All slides will be posted online before each class.

There will be in-class questions due after each class. Missed in-class questions cannot be made up, but the lowest score will be dropped. The purpose of the in-class questions is to show how much of the covered material is understood and to determine if further time should be spent on a topic. In total, they only count for 5% of the final grade for the course.

Incomplete and Late Assignments: All homework assignments are due on Fridays at 5pm. Grading of assignments will not begin before Monday at 9am. Late assignments will be accepted for full credit if turned in before grading begins. However, emails and piazza questions about assignments are not guaranteed to be answered after the Friday 5pm deadline. Late assignments are accepted but penalized until grades are returned unless a valid excuse is communicated before the deadline. If the deadline is missed due to unforeseeable circumstances, we will work something out. Barring a valid excuse, an assignment will be accepted for a 50% reduction once grading has begun. Once grades have been returned, assignments will no longer be accepted. Grades will typically be returned within 2 weeks of the deadline.

Regrading Requests: Requests for regrading of assignments or exams should be made within two weeks of the date from which the assignment is returned. Assignments will not be regraded after that point. Regrading requests can be made via email.

Academic Integrity: Each student is expected to maintain the highest standards of honesty and integrity in academic and professional matters. The University reserves the right to take disciplinary action, up to and including dismissal, against any student who is found guilty of academic dishonesty or otherwise fails to meet the standards. Any student judged to have engaged in academic dishonesty in course work may receive a reduced or failing grade for the work in question and/or for the course. Academic dishonesty includes, but is not limited to, dishonesty in quizzes, tests, or assignments; claiming credit for work not done or done by others; hindering the academic work of other students; misrepresenting academic or professional qualifications within or without the University; and nondisclosure or misrepresentation in filling out applications or other University records.

Online Resources: This class has a zero tolerance policy for Chegg and similar online resources. Much of the material for this course has been developed by Professor Bienz. Course assignments, in-class questions, and exams should not be redistributed or posted online without permission. If you are caught using Chegg or a similar resource, you will automatically fail the course.

You will use github for tutorials and semester projects. You are welcome to make these repositories public, and I encourage you to showcase your semester projects!

Accommodations for Disabilities: UNM is committed to providing courses that are inclusive and accessible for all participants. As your instructor, it is my objective to facilitate an accessible classroom setting, in which students have full access and opportunity. If you are experiencing physical or academic barriers, or concerns related to mental health, physical health and/or COVID-19, please consult with me after class, via email/phone or during office/check-in hours (I am not legally permitted to inquire about the need for accommodations). We can meet your needs in collaboration with the Accessibility Resource Center (https://arc.unm.edu/) at arcsrvs@unm.edu or by phone (505) 277-3506.
Support: Contact me at bienz@unm.edu or in office hours and contact Accessibility Resource Center (https://arc.unm.edu/) at arcsrvs@unm.edu (505) 277-3506 . **Credit-Hours:** This is a three credit-

hour course. Class meets for three 50-minute sessions of direct instruction for fifteen weeks during the Fall 2022 semester. Please plan for a minimum of six hours of out-of-class work (or homework, study, assignment completion, and class preparation) each week.

Sexual Harassment and Title XI: Our classroom and our university should always be spaces of mutual respect, kindness, and support, without fear of discrimination, harassment, or violence. Should you ever need assistance or have concerns about incidents that violate this principle, please access the resources available to you on campus. Please note that, because UNM faculty, TAs, and GAs are considered "responsible employees" by the Department of Education, any disclosure of gender discrimination (including sexual harassment, sexual misconduct, and sexual violence) made to a faculty member, TA, or GA must be reported by that faculty member, TA, or GA to the university's Title IX coordinator. For more information on the campus policy regarding sexual misconduct, please see: https://policy.unm.edu/university-policies/2000/2740.html.

COVID-19: UNM is a mask friendly, but not a mask required, community. To be registered or employed at UNM, Students, faculty, and staff must all meet UNM's Administrative Mandate on Required COVID-19 vaccination. If you are experiencing COVID-19 symptoms, please do not come to class. If you have a positive COVID-19 test, please stay home for five days and isolate yourself from others, per the Centers for Disease Control (CDC) guidelines. If you do need to stay home, please communicate with me at bienz@unm.edu; I can work with you to provide alternatives for course participation and completion. UNM faculty and staff know that these are challenging times. Please let us know that you need support so that we can connect you to the right resources and please be aware that UNM will publish information on websites and email about any changes to our public health status and community response.

Support:

Student Health and Counseling (SHAC) at (505) 277-3136. If you are having active respiratory symptoms (e.g., fever, cough, sore throat, etc.) AND need testing for COVID-19; OR If you recently tested positive and may need oral treatment, call SHAC.

LoboRESPECT Advocacy Center (505) 277-2911 can offer help with contacting faculty and managing challenges that impact your UNM experience.

Tentative Class Schedule The following is an example of what the course schedule may look like. This schedule will be adjusted as needed throughout the semester. For an up-to-date schedule, check out the course webpage www.amandabienz.com/cs442. If you have any additional topics related to parallelism that you would like to cover, please let me know!

Date	Content
Aug 22	Course Info, Introduction to Parallel Processing
Aug 24	Cmake and Github Overview
Aug 26	Serial Performance
Aug 29	Serial Optimizations
Aug 31	Vector Operations
Sep 2	Performance Modeling
Sep 5	Shared Memory Systems
Sep 7	Distributed Systems
Sep 9	**Labor Day – No Class**
Sep 12	CARC System Overview
Sep 14	Spack Overview
Sep 16	Point-to-point Communication
Sep 19	Collective Communication
Sep 21	Parallel Debugging
Sep 23	Distributed Matrix Multiplication
Sep 26	Advanced Point-to-Point Communication
Sep 28	Sparse Matrices and Irregular Communication
Sep 30	Parallel Performance
Oct 3	Profiling and Tracing
Oct 5	Parallel Performance Modeling
Oct 7	Collective Algorithms

Oct 10	Performance of Collective Algorithms
Oct 12	MPI Communicators and Topologies
Oct 14	**Fall Break – No Class**
Oct 17	Parallel I/O
Oct 19	Sandia Guest Lecture – **Date likely to move!**
Oct 21	MPI I/O
Oct 24	One-Sided Communication
Oct 26	MPI Research Topics
Oct 28	MidTerm Review
Oct 31	Tentative Midterm Data – **Date likely to move!**
Nov 2	Shared Memory Programming - OpenMP
Nov 4	OpenMP False Sharing
Nov 7	OpenMP Performance Modeling
Nov 9	OpenMP Numa Regions
Nov 11	GPU Introduction
Nov 14	All about CUDA
Nov 16	OpenMP Offloading
Nov 18	MPI + X
Nov 21	MPI Shared Memory
Nov 23	MPI + CUDA
Nov 25	**Thanksgiving Break – No Class**
Nov 28	Heterogeneous Performance
Nov 30	Kokkos
Dec 2	Charm++

Dec 5	Additional Parallel Topics
Dec 7	Additional Parallel Topics
Dec 9	Additional Parallel Topics
Final Exam Period	**Poster Presentations**