Michigan State University
Spring 2022

CSE 415: Introduction to Parallel Computing
MW 10:20 - 11:40 am

Part 1: Course Information

Course Website: Desire2Learn (D2L)

Instructor: H. Metin Aktulga
Email: hma@msu.edu (preferred)
Office: Engineering 1126 – also reachable through email or cell
Cell Phone: 765-409-3890 (anytime for urgent matters)

Teaching Assistant: Mehmet "Cagri" Kaymak
Email: kaymakme@msu.edu
Office: Engineering 3100

Teaching Modality: Online-synchronous to start the semester, in-person when allowed
Help Room Hours: Mon 10:20 – 11:50 AM
Class (Synchronous): Wed 10:20 – 11:40 AM

Instructor's Office Hours: Mon 12 – 1 PM, also by appointment
TA Office Hours: Wed 12 – 1:30 PM, also by appointment

Recorded lecture material will be made available through D2L weekly. You are expected to go over them before Wednesday.
Wednesday classes will be a brief review of video material followed by examples and discussions. There may be pop quizzes on Wednesdays.
Monday classes will be help room sessions attended by the instructor and the TA. You will have the opportunity to get help regarding the assignments or ask questions about the class material.

Zoom Meeting Info:
https://msu.zoom.us/j/97930337991
Meeting ID: 979 3033 7991
Passcode: 129440

One tap mobile
+13126266799,,97930337991# US (Chicago)

Dial by your location
+1 301 715 8592 US (Washington DC)
+1 312 626 6799 US (Chicago)
+1 646 876 9923 US (New York)
+1 253 215 8782 US (Tacoma)
+1 346 248 7799 US (Houston)
+1 669 900 6833 US (San Jose)

Course Description

Parallel computing has traditionally been used for solving challenging science and engineering problems. However, with the recent drastic changes in computer architecture, parallel computing has moved into the center stage. Parallelism is now everywhere. Newest smartphones have multiple cores, massively parallel GPUs are being used for general purpose computing, high performance CPUs are becoming many-core chips with hundreds of threads, modern data centers and supercomputers are powered by millions of compute nodes. Parallelism in various forms is the new norm in computer architecture. Therefore, professionals and researchers from different backgrounds (computer scientists, computational scientists and engineers, data analysts and software engineers) need a solid understanding of the fundamental concepts in parallel computing and need to be able to use them effectively. The key aim of this course is to have you start thinking in parallel, develop skills for high performance parallel algorithm design, and learn how to write efficient and scalable parallel codes using state-of-the-art technologies.

Prerequisite

CSE 331 (or equivalent): Fundamental algorithms and data structures in CS, ability to program well in C, C++, or Fortran, and willingness to search for alternative ways of problem solving. A basic understanding of computer organization and architecture will be helpful (though not required).

Textbook & Course Materials

- **Required:** An Introduction to Parallel Programming, 2nd Edition by Peter Pacheco and Matthew Malensek, Publisher: Morgan Kaufmann, ISBN-13: 9780128046180.
- **Recommended:** Multicore and GPU Programming: An Integrated Approach by Gerassimos Barlas, Elsevier, ISBN: 978-0-12-417137-4. A free electronic version is available via MSU Libraries https://www-sciencedirect-com.proxy2.cl.msu.edu/book/9780124171374/multicore-and-gpu-programming
- Lecture slides will be posted on D2L.

Further Reading Material

1. Georg Hager and Gerhard Wellein, Introduction to HPC for Scientists and Engineers (recent, more technical)
2. Ananth Grama, et. al. Introduction to Parallel Computing (advanced topics, more theoretical)

Course Requirements

- Internet connection (DSL, LAN, or cable connection desirable)
- Access to Desire2Learn (D2L), or other delivery platform.
- Ability to scan and upload documents (e.g. CamScanner or Adobe Scanner app)

If you do not have the necessary technology and/or equipment to adequately address the above requirements, the College of Engineering will make every attempt to assist you in obtaining access by loaning this technology for use during the semester. Please be aware that supplies are limited, and we may not be able to fulfill all requests. If you need assistance securing technology (laptops, tablets, web cams, hotspots), please contact Theodore Caldwell, Assistant Dean for Equity and Inclusion, by email at tc@msu.edu.

Course Delivery Structure

This course will be delivered in an online-synchronous mode for at least the first three weeks of the semester. Once allowed by the university, it will be delivered in-person. You will need your MSU NetID to login to the course from the D2L homepage (http://d2l.msu.edu). Students may forward their D2L email to an external email address (https://help.d2l.msu.edu/node/4410), if desired.

In D2L, you will access online lessons, course materials, and additional resources. Activities may consist of readings, discussion forums, email, and other online activities.

D2L Technical Assistance

If you need technical assistance at any time during the course or to report a problem, you can:

- visit the Distance Learning Services Support Site
- visit the Desire2Learn Help Site (http://help.d2l.msu.edu/)
- or call Distance Learning Services: (800) 500-1554 or (517) 355-2345.

Resource Persons with Disabilities (RCPD)

- To make an appointment with a specialist, contact: (517) 353-9642
  or TTY: (517) 355-1293
- Web site for RCPD: http://MYProfile.rcpd.msu.edu

Class Recordings

Each online session of this course will be recorded. The recordings will be available to students registered for this class. This is intended to supplement the classroom experience. Students are expected to follow appropriate university policies and maintain the security of passwords used to access recorded lectures. Recordings may not be reproduced, shared with those not in the class, or uploaded to other online environments. Doing so may result in disciplinary action. If the instructor or another University office plan other uses for the recordings beyond this class, students identifiable in the recordings will be notified to request consent prior to such use.

Contingency Planning

In the case of connectivity issues, particularly during exams, please contact the instructor via phone (765-409-3890) or email (hma@msu.edu).

Face Coverings and Appropriate Distancing

"SPARTANS have always worn helmets. Today, we wear masks."

Campus health and safety depends on all of us. As part of the essential effort to slow the spread of COVID-19, Michigan State University is directing everyone to take personal responsibility to protect the health and safety of all MSU faculty, staff, students and visitors. (https://msu.edu/together-we-will/keeping-spartans-safe/?utm_source=reopening-email&utm_medium=email&utm_campaign=faculty-staff). This includes wearing a face covering indoors and maintaining a 6-foot physical distance. Please refer to the MSU Community Compact, "Together We Will" (https://msu.edu/together-we-will/).

Part 2: Course Contents and Objectives

Topics (in no particular order)**:**

- **Why parallel computing?** Motivation, historical and current trends
- **Modern parallel architectures:** Multi-core and many-core CPUs, general purpose GPUs, cache and memory hierarchy, massively parallel platforms, interconnect networks, routing and switches
- **Using HPCC systems:** Connecting and interacting with the HPCC systems, overview of Linux command line, running parallel jobs at HPCC
- **Parallel computing paradigms:** Pipelining, threading, SIMD parallelism, shared memory parallelism, distributed memory parallelism
- **Principles of parallel algorithm design:** Problem decomposition, load balancing, communication & synchronization, data locality
- **Parallel programming models:** Shared memory programming with OpenMP, distributed memory programming with MPI, introduction to GPU programming with CUDA, overview of C++11 threads
- **Performance analysis and optimization of parallel codes:** Amdahl's law, strong/weak scaling, performance modeling, performance tools
- **Applications of parallel programming:** Gaussian elimination, N-body computations

Learning Objectives

At the completion of this class, you will be able to:

- Identify the kind of problems that require parallel computing,
- Distinguish between different architectures to build parallel computers/supercomputers, and the tradeoffs involved in terms of cost vs. performance,

- Model the performance and scalability of a given computational kernel and identify the performance bottlenecks in it; formulate different ways to resolve those bottlenecks,
- Identify different types of parallelism available on modern hardware, and articulate on what kind of programming models are most suitable to leverage the different types of hardware parallelism
- Develop parallel algorithms that partition a problem among several processes, and utilize various synchronization and communication primitives to deliver a correct solution to the problem,
- Compile, execute and measure the performance of parallel programs on an HPC cluster,
- Write efficient and scalable programs for shared memory architectures using thread parallelism, specifically using the OpenMP programming model,
- Utilize different kinds of communication operations (point-to-point, collective, blocking, non-blocking, one sided) to facilitate data transfer between different compute nodes in a distributed memory cluster,
- Estimate the cost and time for communications between processes on a given cluster topology using
- different protocols,
- Write efficient and scalable programs for distributed memory architectures using message passing parallelism, specifically using the MPI library,
- Articulate on the major architectural differences between a traditional CPU and the general purpose GPU cards, and the implications of these differences on designing and algorithms for GPUs.
- Write efficient and scalable programs for GPUs using massive thread parallelism, specifically using the CUDA programming model,
- Apply the performance modeling and parallel programming skills developed throughout the course on real-life problems such as stencil computations, sparse linear algebra and graph related problems.

Computational Resources

The systems at the High Performance Computing Center (HPCC) will be used for class assignments and final projects. You will get accounts for classroom use.

Course Outline/Schedule

Please refer to D2L for specific meeting dates and times. Activity and assignment details will be explained in detail within each week's corresponding learning module. If you have any questions, please contact your instructor.

Part 4: Grading Policy

Graded Course Activities (tentative)

We will use a form of *contract grading.* You will be able to choose how you want to be graded from a list of pre-determined schemes (see below for details). Your choices must

be submitted via email to the instructor within 3 days (72 hours) of receiving your *graded* midterm. If you fail to submit your choice, you will be graded based on the *default scheme*.

	Default	Option 1	Option 2	Option 3	Option 4
Homework (5-7 assignments)	50	40	40	40	60
Quizzes (6-8 in total)	10	10	10	10	10
Midterm (~8th week, in-class)	20	25	20	15	15
Final exam	20	25	30	35	15

Grading Scale (tentative)

The table below presents the grading scale to be used in this course.

Percentage	≥90%	≥84%	≥78%	≥70%	≥62%	≥54%	≥46%	<46%
Grade	4.0	3.5	3.0	2.5	2.0	1.5	1.0	0.0

Completing Assignments

Assignments for this course will be submitted through MSU's GitLab, details will follow**.** Assignments must be submitted by the given deadline or special permission must be requested from instructor before the due date unless a student has late work days available (see below). Extensions will not be given beyond the next assignment except under extreme circumstances.

Late Work Policy

You will have 6 late days (without any penalties) to submit your homework assignments. These are in addition to any late days you may need due to medical/personal emergencies (must provide proper documentation). You can either choose to use all your late days on a single homework or spread them among different assignments. However, if you choose to use a late day, you MUST notify the TA via email before the homework submission deadline.

Viewing Grades

In general, you can expect homework assignments and exams to be graded within 7-10 days. All grades will be posted to the D2L gradebook.

Testing and Assessments

Midterm and final exam will be conducted in person. In case the university does not allow in person exams, proctoring over Zoom will be the alternative. Both exams will be open

book and open notes, but students are NOT allowed to use internet resources or get help from other people. For online exams, to minimize the possibility of exam rule violations, students are required to turn on their cameras (either their computer webcams or phone cameras) and share their computer screens during the full exam duration. The instructor will be randomly checking the screens & cameras during the session, which will be recorded. If a student does not have a working webcam/phone camera, they need to contact the instructor as soon as possible to work out a solution. Completed exams will be turned in to the TA electronically through email unless otherwise instructed**.**

Part 5: Course Policies

Important Notes

With proper notice, the instructor reserves the right to modify course policies, the course calendar, assignment specifications or grading criteria, if necessary.

Make-ups for graded activities may be arranged if a student's absence is caused by documented illness or personal emergency. A written explanation (including supporting documentation) must be submitted to your course instructor; if the explanation is acceptable, an alternative to the graded activity will be arranged. Whenever possible, make-up arrangements must be completed prior to the scheduled activity.

Participation

Students are expected to participate in all course activities as listed on the course calendar. Participation will be tracked for synchronous lectures. For online classes, if a student's time zone or other commitments are an issue, they must communicate with the instructor as early as possible. Any extenuating circumstances which impact on your participation in the course should be discussed with your lecture instructor as soon as those circumstances are known.

Inform Your Instructor of Any Accommodations Needed

Michigan State University is committed to providing equal opportunity for participation in all programs, services and activities. Requests for accommodations by persons with disabilities may be made by contacting the Resource Center for Persons with Disabilities at 517-884-RCPD or on the web at rcpd.msu.edu. Once your eligibility for an accommodation has been determined, you will be issued a verified individual services accommodation ("VISA") form. Please present this form to me at the start of the term and/or two weeks prior to the accommodation date (test, project, etc). Requests received after this date will be honored whenever possible.

Diversity and Inclusion Statement

I consider this classroom to be a place where you will be treated with respect. I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities,

national origins, religious affiliations, sexual orientations, ability — and other visible and nonvisible differences. Likewise, all members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class.

Code of Conduct

- Expressions, attitudes or behavior that violate the above diversity and inclusion policy will NOT be tolerated.
- Similarly, expressions, attitudes or behavior that prevent or interfere with other students' learning in the class will NOT be tolerated.
- No food in the class unless you order the same food for everyone else in the class.
- Drinks are okay as long as they are soft drinks, tea or coffee.
- No texting, email or other kinds of instant messaging during class.

Tolerance and Civility

"MSU strives to build an academic community with living and learning environments that expects tolerance of viewpoints and civility toward others, whether at public forums, athletic events, in residential communities, classrooms or laboratories.

We call upon all who participate in university events to promote tolerance and civil behavior and to hold themselves to high standards that reflect the university's commitment to respect viewpoints that may be different from their own. Only by respecting individuals with diverse perspectives and ideas can we build an environment of civility that is conducive to advancing knowledge and transforming lives."

The Office of Institutional Equity policies can be found at:

- Disability and Reasonable Accommodation Policy- https://oie.msu.edu/policies/disability-and-reasonable-accommodation-policy.html
- Policy on RVSM- https://oie.msu.edu/policies/rvsm.html

Drops and Adds

The last day to add this course is the end of the first week of classes. The last day to drop this course (with a 100% refund & no grade reported or no refund & no grade reported) can be found on the University's Academic Calendar at https://reg.msu.edu/ROInfo/Calendar/Academic.aspx. You should immediately make a copy of your amended schedule to verify that you have added or dropped this course.

Commercialized Lecture Notes

Commercialization of lecture notes and university-provided course materials is **not permitted** in this course.

Academic Honesty

The Department of Computer Science and Engineering adheres to the policies on academic honesty as specified in General Student Regulations 1.0, Protection of Scholarship and Grades, and in the all-University Policy on Integrity of Scholarship and Grades, which are included in Spartan Life; Student Handbook and Resource Guide. Students who plagiarize will receive a 0.0 on the assignment/test/quiz.

Spartan Code of Honor Academic Pledge

"As a Spartan, I will strive to uphold values of the highest ethical standard. I will practice honesty in my work, foster honesty in my peers, and take pride in knowing that honor is worth more than grades. I will carry these values beyond my time as a student at Michigan State University, continuing the endeavor to build personal integrity in all that I do." (adopted by ASMSU on March 3, 2016,endorsed by Academic Governance on March 22, 2016, and recognized by the Provost, President, and Board of Trustees on April 15, 2016).

Tuition Refund Period

Details can be found at https://reg.msu.edu/ROInfo/Calendar/Academic.aspx

Religious Observance

Michigan State University has long had a policy to permit students, faculty/academic staff, and support staff to observe those holidays set aside by their chosen religious faith. If you wish to be absent from class to observe a religious holiday, make arrangements in advance with the instructor.

Final Exam Policy can be found at https://reg.msu.edu/ROInfo/Calendar/FinalExam.aspx