

CS 378 Programming for Correctness and Performance

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The University of Texas at Austin

Spring 2024

1 Course Logistics

1.1 Teaching Team

<i>Instructor</i>	Dr. Devangi N. Parikh
What to call me	Dr. Parikh
Pronouns	she/her/hers
Email	dnp@cs.utexas.edu
Office Hours	W 2:00p-3:00p M 1:00p-2:00p (shared with CS 311)

1.2 Class Meeting Times and Location

Time	TTh 2:00p--3:30p
Location	PAR 203

1.3 Course Modality

This course has been designated as a hybrid course. This means that classes will be *either* online or in-person. When the classes are held in person, there will not be a simultaneous remote option. However, recordings of the class (online or in-person) will be made available to you soon after class.

2 What will I learn in this course?

Computers are now essential in everyday life. Incorrect and/or slow programs lead to frustration in the best case and disaster in the worst. Thus, how to construct correct programs that can attain high performance is a skill that all who program computers must master.

In this course, we teach “goal-oriented programming” the way Edsger Dijkstra intended: You will learn how to derive programs hand-in-hand with their proofs of correctness. Matrix computations (linear algebra) is the domain from which we draw examples. Typically, we end up with a family of algorithms (programs) all of which compute a given operation. From this family we can then pick the algorithm that has desirable properties. For example, one algorithm may be easier to parallelize than another algorithm or it may inherently be able to attain better performance on a given architecture. You will then learn techniques for mapping the appropriate algorithms to computer architectures so that they can attain high performance.

2.1 Prerequisites

You need to have taken a course on linear algebra. You need to have prior experience with basic proof techniques and predicate logic as taught in CS311 or a discrete mathematics class. Major programming assignments will be in the C programming language. You need to either know rudimentary C, or be able to learn it quickly.

2.2 Text/Materials

This class is based on materials developed by Prof. Robert van de Geijn, Dr. Maggie Myers, and Dr. Devangi N. Parikh. You can access these materials from ulaff.net.

You need to install Matlab on your computer. UT has a site license. Instructions on how to access the license will be provided.

2.3 Learning Objectives

By the end of the semester you should be able to:

- Code in C, use makefiles to compile code, and use pointer arithmetic for computing the addresses of the arrays.
- Understand how the implementation of your code affects the performance of the code.
- Transform your implementation such that it takes advantage of the various architecture features available.
- Translate your code so that you can use vector instructions.
- Block code for cache hierarchy.
- Parallelize (not paralyze) your code.
- Calculate the peak performance of your machine.
- Prove that simple code segments of your code are correct.
- Derive your code to be correct.
- Derive a family of algorithms for a given linear algebra operation.
- Compare/contrast/analyze the performance of the members of a family of algorithms and reason which algorithm will perform better.
- Typeset in LaTeX.

2.4 Detailed Calendar

Date	Day	Topic
Jan 16 2024	Tuesday	Motivating Activity
Jan 18 2024	Thursday	Review: Linear algebra operations
Jan 23 2024	Tuesday	Accessing and storing matrices in memory
Jan 25 2024	Thursday	Floating point error, absolute and relative error, project support
Jan 30 2024	Tuesday	Loop ordering and its effect on performance
Feb 01 2024	Thursday	Matrix multiplication as a loop around other matrix operations
Feb 06 2024	Tuesday	Vector registers, instruction latency and throughput
Feb 08 2024	Thursday	Importance of hiding instruction latency, microkernels
Feb 13 2024	Tuesday	Memory hierarchy
Feb 15 2024	Thursday	Amortizing data movement
Feb 20 2024	Tuesday	Importance of contiguous memory access
Feb 22 2024	Thursday	Multicore programming
Feb 27 2024	Tuesday	FLAME worksheet
Feb 29 2024	Thursday	FLAME worksheet
Mar 05 2024	Tuesday	Review: logic and reasoning
Mar 07 2024	Thursday	Hoare triple and weakest precondition
Mar 12 2024	Tuesday	Spring Break
Mar 14 2024	Thursday	Spring Break
Mar 19 2024	Tuesday	Deriving simple code segments
Mar 21 2024	Thursday	Deriving if statements
Mar 26 2024	Tuesday	Deriving while loops
Mar 28 2024	Thursday	Advanced Matrix Operations
Apr 02 2024	Tuesday	Advanced Matrix Operations
Apr 04 2024	Thursday	Advanced Matrix Operations
Apr 09 2024	Tuesday	Explorations: Extrapolating Goto Algorithm to other operations
Apr 11 2024	Thursday	Explorations: Extrapolating Goto Algorithm to other operations
Apr 16 2024	Tuesday	Exam
Apr 18 2024	Thursday	Explorations: Beyond linear algebra operations
Apr 23 2024	Tuesday	Project Presentations
Apr 25 2024	Thursday	Project Presentations

3 How will we communicate?

Canvas. We will be heavily relying on Canvas, UT's Learning Management System. Each week, the topic, assignments, and assessments for that week will be posted to Canvas. Please check Canvas regularly.

Ed Discussion. We will be using Ed as our class' discussion board. Ed will be the preferred and quickest way to communicate with the teaching team.

You must read the discussion board at least once per day, and should post course-related technical or administrative questions or problems there. You are encouraged to respond to your class-mates posts. I expect you to make good use of the discussion board when you have technical or administrative questions or problems. Our TAs and I will be closely monitoring the discussion board.

Course-related announcements will be cross-posted on the discussion board. Every time I check throughout the semester, you must have read at least 85% of the discussion board posts (as recorded by the discussion board, so you must read them through the website, not through emails).

You are responsible for any and all information posted to the discussion board by any of the course staff. You are expected to read all announcements within twelve hours of being posted.

Emails to you. In this course, email will be used as a means of communication with students. You are responsible for regularly checking (at least every 24 hours) both your CS email and your email officially registered with UT for class work and announcements.

Emails to the Instructor or TAs. Email is not the best way to get in touch with the teaching team. If you need to have a personal conversation with one of us, please approach us at office hours or after class.

To follow up, we may ask you to send us an email. In this case, emails to course staff should begin with “CS378” in the subject line, followed by a brief description of the purpose of your email. I teach multiple classes, and by following this format, I can ensure I can better address your questions in a timely manner. If you miss this detail, a response to your email may be delayed indefinitely, since this lack of information in your email will cause unnecessary back-and-forth email exchanges to figure out who you are, and which course your query is related to.

Do not use Canvas messages to contact the teaching team. If you use Canvas Messages, you may not receive a reply.

Last-minute assistance requests by email will not be supported. More generally, you cannot expect to get detailed answers to technical questions by email. If you must send an email, spend extra time to ensure that you are both brief and clear. Email is a valuable tool for communicating with the instructional team. But be sure to use it properly and follow the rules of good email etiquette (e.g., no flaming, spamming, etc.). Although it’s easy for you to dash off an email question, it takes a lot of thought and effort on our part to answer it.

In general, if you have a question to which you can find the answer somewhere like the Syllabus, Canvas, Ed, Textbooks, please do not email us regarding these questions.

4 How will I learn?

Lectures. During the class period, I will lecture a bit to introduce you to concepts relevant to the topic of the day. We will then work on problems. You will have time to attempt these problems on your own, and we will discuss the solutions. Some classes may have a coding component as well. You are expected to follow along and actively participate.

Assignments. There will be regular assignments that will reinforce what you have learned in class and review your understanding.

You will work on these assignments alone and you must show your work to get credit for the problems.

Exam. The exam will be held in person during class period. There will be no alternate mode of taking the exams. There will be no make-up exam. More details regarding administration of the exam will be given a week before the exam. The exam is your opportunity to demonstrate what you have learned so far.

Textbook. The Programming for Correctness and Programming for Performance materials available at ulaff.net will be your best friend. There are videos included in these materials on all topics covered in the course. Use these resources, when you get stuck with your understanding and need some extra help. You may find some additional practice problems there as well. While I will not explicitly assign readings from the textbook, you should get into the habit of referring to the textbook when you need additional information.

5 How will I succeed in this class?

Keep up with content. I will not require you to come to class, but as you soon will realize, showing up to class will actually benefit you in several. You will learn from the content introduced in the class, as well as the activities planned during class. I will give you plenty of opportunities to work on problems. In addition, there is a lot of material to cover, so please keep up with the class. If there's something you do not understand, please come office hours of the teaching team. We are here to help you. Do not leave all the learning for the night before the exam. I will not be able to help you then.

Be respectful. You can expect that as the instructor, I am concerned about the educational experience of each student in the class, respectful of individual differences, encouraging of creativity, reasonably open and accessible to discuss material and assignments, thorough in evaluating assignments, and rigorous yet supportive in maintaining high standards for performance.

As a student, you are expected to work individually and with others, to create an atmosphere that is safe, valuing of one another, and open to diverse perspectives. Everyone is expected to show courtesy, civility, and respect for one another. Comments or postings that degrade or ridicule another, whether based on individual or cultural differences, are unacceptable.

Participation/Engagement. Thinking is not a spectator sport. You need to participate in class by communicating your understanding and testing others' understanding with questions and dialogue. This course requires active participation, which is crucial to your success in this course and your career in CS. The more you put into it, the more you will get out of it. Active participation includes being prepared to discuss readings, assignments, and concepts, engaging yourself in classroom activities and discussion, and putting your best effort in both formal and informal assignments. Regardless of the format we use to conduct class sessions, consider your participation to be the equivalent to a face-to-face class session and be prepared to engage actively and thoughtfully with me and your peers.

Keep an open mind. Under the current circumstances, I am working on giving you the best experience I can during this semester. Class logistics may need to be tweaked if they are not working. Please keep an open mind and be patient and flexible, while we work through the class.

Talk to me. I always want to hear from you! This is a big class, at first, I may not have the opportunity to see you in person, but I do still want to get to know you. Ask me questions, introduce yourself, and do not be shy. This is a judgment-free zone.

6 How will I know how I am doing in the class?

6.1 Assessments

Projects. There will be four programming projects during the semester. The due date for each project will be clearly stated in class. Each project is designed to explore topics related to high performance computing, which will be introduced during the lectures. You will have the opportunity to drive your learning in the direction of your choosing. You will be introduced to the frontier in high performance linear algebra software development.

The code you submit as part of your project must be your own. While you are encouraged to collaborate with others in class to deepen your understanding, you may not look at or copy anyone's code. Your code cannot be copied to any source on the internet. Plagiarism detection software will be used on the projects to find students who have copied code from one another. Any program that you submit must be yours, and yours alone.

The projects will constitute 50% of your final grade.

Assignments. There will be three assignments during the semester. The dates of each assignment (release and due dates) will be announced in class. These assignments that will reinforce what you have learned in class and review your understanding.

The assignments will constitute 30% of your final grade.

Exam. The exam is scheduled for *April 11, 2024*.

The exam will constitute 15% of your final grade.

Participation. Your class presence and participation in class will constitute 5% of your final grade.

6.2 Late Submissions and Missed Assignments

You will have a total of 6 slip days in increments of 1 day units (that is, 1 minute to 24 hours late = 1 slip day, etc.) to use throughout the semester to extend your project or assignment deadline. However, you may use up to two slip days on any particular assignment. Other than that, you may divide your slip days across the projects in any way you wish, subject to the 4 slip days total and the maximum 2 slip day per assignment. Slip days are to account for unexpected life circumstances and emergencies. Use your slip days wisely. If you use all your slip days and are unable to turn in your project on time for any reason then you will receive a 0 for that project.

6.3 Final Grades

To summarize, your final grade will comprise of the following assessments

Category	% of Final Grade
Projects	50%
Assignments	30%
Exam	15%
Participation	5%

Final grades will be assigned according to the following standard criteria:

Final Average	Letter Grade
94-100	A
90-93	A-
87-89	B+
84-86	B
80-83	B-
77-79	C+
74-76	C
70-73	C-
60-69	D
0-59	F

6.4 Academic Dishonesty

The University and the Department are committed to preserving the reputation of your UT degree. To guarantee that every degree means what it says it means, we must enforce a strict policy on academic honesty: Every piece of work that you turn in with your name on it must be yours. Students who violate University rules on scholastic dishonesty in assignments or exams are subject to disciplinary penalties, including the possibility of a lowered or 0 grade on an assignment or exam, failure in the course, and/or dismissal from the University. Plagiarizing the work of others (classmates or from the internet) will be considered academic dishonesty and will not be tolerated. You may not search for code to the projects given in the class on the internet. Moreover, you may not copy these solutions or be inspired by them and claim they are your own work. Plagiarism detection software will be used on the programs submitted in this class. If cheating is discovered, a report will be made to the Dean of Students.

7 Whole-Person Care

7.1 Personal Pronouns

Professional courtesy and sensitivity are especially important with respect to how we address each other, and we strive to address you in the ways you prefer. Class rosters are provided to the instruction with the student's chosen name, which you may update through UTDirect (https://utdirect.utexas.edu/apps/ais/chosen_name/student/). That said, we will gladly honor your request to address you by a name that is different from what appears on the official roster and by the pronouns you use (she/he/they/ze, etc). Please advise us of any changes early in the semester so that we may make appropriate updates to our records.

7.2 Students with Disabilities

My policy is to fully support all students with disabilities to the best of my ability. At no time is it required that you disclose the nature of your disability to me, and I will not ask you to do so.

If you are a student with a UT-acknowledged disability, I ask that you meet with me 1-1 to discuss accommodations as soon as you have your accommodation letter in hand. I do ask that you meet with me by the 12th class day so that we can put your accommodations in place as soon as possible.

If you are a student with a disability that has not yet been acknowledged by UT's Services for Students with Disabilities, I hope that you will be willing to let me know that you need accommodations. I ask that you meet with me 1-1 to develop a plan for your success this semester.

University-required language: The University of Texas at Austin provides upon request appropriate academic accommodations for qualified students with disabilities. For more information, contact the Division of Diversity and Community Engagement, Services for Students with Disabilities at 471-6259, 471-4641 TTY.

7.3 Policy on Children in Class

Children are always welcome. I understand that if you have childcare responsibilities, you are a special-level of exhausted. Please talk to me if you need help.

7.4 Policy on Outside Responsibilities and Other Circumstances

At all times, we are not just our academic selves but our whole selves, with responsibilities and pressures from outside the classroom. If you find that those responsibilities or circumstances are preventing you from participating in this class, please contact me as soon as possible.

7.5 Religious Holy Days

Religion (or lack thereof) is an important part of who we are. If a holy day observed by your religion falls during the semester and you require accommodations due to that, please let me know as soon as possible. Email is an acceptable form of communication, though please use the format described in [Emails to the Instructor or TAs](#) so I am more likely to receive it. In order to guarantee accommodations around exams and other big deadlines, I will need notice of at least two weeks. If you are unable (or forget!) to provide that notice, please contact me anyway in case I can still accommodate you.

University-required language: A student who is absent from an examination or cannot meet an assignment deadline due to the observance of a religious holy day may take the exam on an alternate day or submit the assignment up to 24 hours late without penalty, ONLY if proper notice of the planned absence has been given. Notice must be given at least 14 days prior to the classes which will be missed. For religious holy days that fall within the first 2 weeks of the semester, notice should be given on the first day of the semester. Notice must be personally delivered to the instructor and signed and dated by the instructor, or sent certified mail. Email notification will be accepted if received, but a student submitting email notification must receive email confirmation from the instructor.

7.6 Mental Health Counseling

Counselors are available Monday-Friday 8am-5pm at the UT Counseling and Mental Health Center (CMHC) on the 5th floor of the Student Services Building (SSB) in person and by phone (512-471-3515). The 24/7 UT Crisis Line is 512-471-2255.

7.7 Emergency Situations

If you experience an emergency situation during the semester, Student Emergency Services is here to help you. They can help in the event of family emergencies, medical or mental health concerns, and interpersonal violence, among other situations. If you experience such an emergency, you may contact them directly through email (studentemergency@austin.utexas.edu) or by phone (512-471-5017), or you may contact one of us and we will assist you with the process.

7.8 Safety Information

If you have concerns about the safety or behavior of students, TAs, Professors, or others, call the Behavioral Concerns Advice Line at 512-232-5050. Your call can be anonymous.

7.9 Title IX Reporting

[Senate Bill 212 \(SB 212\)](#)¹, which went into effect as of January 1, 2020, is a Texas State Law that requires all employees (both faculty and staff) at a public or private post-secondary institution to promptly report any knowledge of any incidents of sexual assault, sexual harassment, dating violence, or stalking "committed by or against a person who was a student enrolled at or an employee of the institution at the time of the incident". Please note that the instructors and the TAs for this class are mandatory reporters and MUST share with the Title IX office any information about sexual harassment/assault shared with us by a student whether in-person or as part of a journal or other class assignment. Note that a report to the Title IX office does not obligate a victim to take any action, but this type of information CANNOT be kept strictly confidential except when shared with designated confidential employees. A confidential employee is someone a student can go to and talk about a Title IX matter without triggering that employee to have to report the situation to have it automatically investigated. If you would like to speak with someone who can provide support or remedies without making an official report to the university, please email advocate@austin.utexas.edu. For more information about reporting options and resources, visit <http://www.titleix.utexas.edu/>, contact the Title IX Office via email at titleix@austin.utexas.edu, or call 512-471-0419.

7.10 Online Privacy

Web-based, password-protected class sites are associated with all academic courses taught at The University. Syllabi, handouts, assignments and other resources are types of information that may be available within these sites. Site activities could include exchanging e-mail, engaging in class discussions and chats, and exchanging files. In addition, electronic class rosters will be a component of the sites. Students who do not want their names included in these electronic class rosters must restrict their directory information in the Office of the Registrar, Main Building, Room 1. For information on restricting directory information see: <https://onestop.utexas.edu/student-records/personal-information/>.

¹capitol.texas.gov/tlodocs/86R/billtext/html/SB00212F.htm

8 Course Policies Caveat

This syllabus is a plan of action for the semester. It is NOT a contract and is subject to change. As the instructor, I reserve the right to make additions, deletions, and modifications to the syllabus and the course requirements with reasonable notification to the students enrolled in the course. You are responsible for any changes announced in class or on Canvas/Piazza.

9 Acknowledgment and Copyrights

Acknowledgements. In preparation for this course, I have used course materials from Maggie Myers, Robert van de Geijn, Tze Meng Low (CMU) and Victor Eijkhout (TACC). In preparation of this syllabus, I have used language from Maggie Myers, Robert van de Geijn, and Alison Norman.

Copyright Notice. These course materials, including, but not limited to, lecture notes, homework, quizzes and exams are part of a first course in Computer Science. You must have my written permission to use these materials and share these materials outside of the classroom.

This copyright extends to any and all video or audio recordings of this class.

I do not grant to you the right to publish these materials for profit in any form.