CSC 553: Principles of Compilation

TuTh 12:30 PM – 1:45 PM, Gould-Simpson Room 701

Description of Course

This course considers advanced topics in compilation. Emphasis will be placed on advanced topics in code generation, register allocation, and optimization. Specific topics discussed will include: intermediate program representations; code generation and machine independent peephole optimization; register allocation; formulation and solution of data flow analysis problems; optimization using data flow information; memory-hierarchy optimizations: profile-guided code placement. If time permits, we will discuss advanced topics such as: JIT compilers; theoretical foundations of program analysis; compilation pipeline, static and dynamic linking.

The best way to learn something is to do it. To that end, this class has a semester-long programming project where we implement an optimizing compiler for a significant subset of C.

Note to students: CS Department policies require me to include below the catalog description of this course. Please note, however, that this catalog description is no longer accurate and should not be relied upon as a list of topics that will be covered in class this semester.

Catalog description: "Detailed study of advanced compilation: translator writing systems, attribute grammars, flow analysis, optimization, register allocation, code generation, compiling for modern architectures."

Course Prerequisites

CSC 453 and CSC 473 (or their equivalents), or permission of the instructor

Instructor and Contact Information

Instructor: Saumya Debray

Office: Gould-Simpson 735; (520) 621-4527

Email: debray@arizona.edu

Office Hours: TuTh 2:00-3:00, or if my office door is open, or by appointment.

D2L site: https://d2l.arizona.edu/d2l/home/1345907

Course Objectives

Specific topics to be discussed include: intermediate program representations; code generation and machine-independent optimization; register allocation; formation and solution of dataflow analysis problems; code optimization using data flow information; memory hierarchy optimizations and profile-guided code placement. If time permits, we will discuss advanced topics such as: JIT compilers; theoretical foundations of program analysis; compilation pipeline: structure of binary files, static and dynamic linking.

There is a significant project component to the course.

Expected Learning Outcomes

Students who successfully complete this course should be able to understand and explain:

- intermediate representations used by compilers, including: abstract syntax trees;

three-address code; and basic blocks and control flow graphs;
- code generation via syntax-directed translation;
- program analysis: control-flow analysis and data-flow analysis; formulation and iterative solution of data-flow equations;
- machine-independent and machine-dependent code optimization; memory hierarchy optimization; profile-guide code placement; instruction scheduling;
- (as time permits) just-in-time compilation and dynamic code optimization; theoretical foundations of program analysis: dataflow analysis frameworks; the compilation pipeline: structure of binary files, static and dynamic linking.

Absence and Class Participation Policy

Attendance will be expected, but not recorded. Attendance will not be factored into final grades. However, students are fully responsible for all material presented or assigned in class. For this reason, and because participating in the course and attending lectures are vital to the learning process, attendance is strongly recommended.

If you anticipate being absent, are unexpectedly absent, or are unable to participate in class online activities, please contact me as soon as possible. To request a disability-related accommodation to this attendance policy, please contact the Disability Resource Center at (520) 621-3268 or drc-info@email.arizona.edu. If you are experiencing unexpected barriers to your success in your courses, I strongly encourage you to see the Graduate Program Coordinator (GPC). The GPC will provide options and alternatives as appropriate for individual student situations. Also, the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office is located in the Robert L. Nugent Building, room 100, or call 520-621-7057.

The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at https://catalog.arizona.edu/policy/class-attendance-and-participation

The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable: http://policy.arizona.edu/human-resources/religious-accommodation-policy.

Absences pre-approved by the UA Dean of Students (or dean's designee) will be honored. See https://deanofstudents.arizona.edu/policies/attendance-policies-and-practices

Illnesses and Emergencies

- If you feel sick, or may have been in contact with someone who is infectious, stay home. Except for seeking medical care, avoid contact with others and do not travel.
- Notify your instructor(s) if you will be missing up to one week of course meetings and/or assignment deadlines.
- If you must miss the equivalent of more than one week of class and have an emergency, the Dean of Students is the proper office to contact (DOS-deanofstudents@email.arizona.edu). The Dean of Students considers the following as qualified emergencies: the birth of a child, mental health hospitalization, domestic violence matter, house fire, hospitalization for physical health (concussion/emergency surgery/coma/COVID-19 complications/ICU), death of immediate family, Title IX matters, etc.
- Please understand that there is no guarantee of an extension when you are absent from class and/or miss a deadline.

Makeup Policy for Students Who Register Late

Students who register after the first class meeting may not make up any missed work.

Course Communications

Course communications will be made through:

- D2L (for announcements, lecture notes and recordings, due dates, and grades).
- Piazza (for questions and discussions). The Piazza website for this class is http://piazza.com/arizona/fall2023/csc553.
- Gradescope (for assignments). The Gradescope website for this class is https://www.gradescope.com/courses/548198.

Important: Please enroll yourself for this class in Piazza and Gradescope. The access codes for this have been posted in D2L (under Announcements).

Required Texts and Materials

This class has no required text. Technical papers from the literature will be assigned during the course of the semester, and the instructor's lecture notes (on the class D2L site noted above) will be available as a reference.

Scheduled Topics/Activities

Week no.	Week of	Lecture Topic	Assignments and Exams
1	08/21/2023	Overview; Syntax trees and symbol tables	Assg 0 start: 08/25
2	08/28/2023	Intermediate code generation	Assg 0 due: 09/01
3	09/04/2023	Code generation	Assg 1 MS 1 start: 09/05
4	09/11/2023	Code generation	Assg 1 MS 1 due: 09/15; Assg 1 MS 2 start: 09/15
5	09/18/2023	Control flow analysis	Assg 1 MS 2 due: 09/22; Assg 1 MS 3 start: 09/22
6	09/25/2023	Dataflow analysis, code optimization	Assg 1 MS 3 due: 09/29
7	10/02/2023	Dataflow analysis, code optimization	Assg 2 start: 10/06
8	10/09/2023	Dataflow analysis, code optimization	**Midterm exam: 10/12**
9	10/16/2023	Register allocation	Assg 2 due: 10/20
10	10/23/2023	Register allocation	Assg 3 start: 10/27
11	10/30/2023	Instruction scheduling	
12	11/06/2023	SSA representation	Assg 3 due: 11/10
13	11/13/2023	Advanced topics	Assg 4 start: 11/17
14	11/20/2023	Advanced topics	
15	11/27/2023	Advanced topics	Assg 4 due: 12/01
16	12/04/2023	review	
			Final exam: 12/13

Assignments and Examinations

Programming Assignments

The course has a programming project where students implement an optimizing compiler for a subset of the C programming language. This project is divided into a number of programming assignments, each implementing a distinct component of an optimizing compiler.

Collaboration: All assignments are individual (i.e., there is no partnering).

Timeliness: Assignments are due at the time stated on the assignment spec and should be uploaded to the class website in Gradescope. Late submissions will not be accepted.

Schedule (subject to change with advance notice):

Assg No.	Topic	Start date	Due date
0	Syntax tree traversal	08/25/2023	09/01/2023
1	Code generation	09/05/2023	09/29/2023
	Milestone 1	09/05/2023	09/15/2023
	Milestone 2	09/15/2023	09/22/2023
	Milestone 3	09/22/2023	09/29/2023
2	Machine-independent optimization	10/06/2023	10/20/2023
3	Register allocation	10/27/2023	11/10/2023
4	Optimization/term paper	11/17/2023	12/01/2023

Exams

Exams will be held in the regular classroom for the class (Gould-Simpson 701) as follows:

- Midterm: Thu Oct 12, 2023: 12:30 – 1:45 pm (75 minutes)
- Final: Wed Dec 13, 2023: 1:00 – 2:15 pm (75 minutes)

Without prior arrangements, missed exams result in a grade of zero. If you will be absent on the date of an exam due to religious reasons or because of a pre-approved absence by the Dean of Students, please contact me ahead of time to work out an alternative time for your exam.

Final Examination

Wed Dec 13 at 1 PM in Gould-Simpson 701. See https://registrar.arizona.edu/faculty-staff-resources/room-class-scheduling/schedule-classes/final-exams for Final Exam Regulations and Schedule.

Grading Scale and Policies

Grades will be computed based on the following weights for the various components of the class:

Midterm exam	25%
Final exam	25%
Programming project and term paper	50%
Programming Project: Assignment 0	0.5%
Programming Project: Assignment 1 Milestone 1	4.0%
Programming Project: Assignment 1 Milestone 2	4.0%
Programming Project: Assignment 1 Milestone 3	4.0%
Programming Project: Assignment 2	12.5%
Programming Project: Assignment 3	12.5%
Programming Project: Assignment 4/Term Paper	12.5%

Your grade will be determined by the overall weighted average of your scores, computed using the weights given above, based on the following mapping:

Weighted average	Grade
≥ 90	A
≥ 80 but below 90	B
≥ 65 but below 80	C
≥ 55 but below 65	D

< 55	E

Grading procedure

The size of the programs involved in the project makes it impractical to manually examine your source code to determine its correctness. Instead, we will use the following procedure:

- You will develop and test your code using your own test cases. It is permissible for students to share test cases.
- I will make my test cases public after the submission deadline.
- Your code will be graded on my test cases using a grading script. You will be awarded a preliminary score based on the number of test cases failed.
- If you were penalized more than once for the same problem, you will have the option of bringing this to my attention over the two weeks following notification of your preliminary score. Specifically, you will need to provide me with the following items (you can do this either via email or in person):
    - a list of the specific problems in your code; and
    - for each problem, the test cases that failed as a result.
- Based on this, I may adjust your preliminary score where appropriate, based on my assessment of the seriousness of the problems. *However, any such adjustment will always be positive, i.e., you will not be penalized—but may be rewarded—for identifying and explaining the problems in your code.*

Department of Computer Science Grading Policy

1. I expect the following timeline for grading assignments and exams:
    - Preliminary score on programming assignments: These will be auto-graded and you should get your preliminary score almost immediately after submission. In the event of a problem with the auto-grader, I expect you will get your score within (at most) a day or two of submission.
    - Term paper: Within a week of submission.
    - Midterm and final exams: Within 48 hours of the exam.
2. Grading delays beyond promised return-by dates will be announced as soon as possible with an explanation for the delay.

Incomplete (I) or Withdrawal (W):

Requests for incomplete (I) or withdrawal (W) must be made in accordance with University policies, which are available at http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete and http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal respectively.

Dispute of Grade Policy

All regrade requests for programming assignments must be made within two weeks of when the grade is returned. All regrade requests for midterm exams must be made within one week of when the graded exam is returned.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See https://deanofstudents.arizona.edu/student-rights-responsibilities/academic-integrity .

Uploading material from this course to a website other than those set up for this class (D2L,

Gradescope, class piazza) is strictly prohibited and will be considered a violation of the course policy and a violation of the code of academic integrity. Obtaining material associated with this course (or previous offerings of this course) on a site other than D2L (or the class piazza), such as Chegg, Course Hero, etc. or accessing these sites during a quiz or exam is a violation of the code of academic integrity. Any student determined to have uploaded or accessed material in an unauthorized manner will be reported to the Dean of Students for a Code of Academic Integrity violation, with a recommended sanction of a failing grade in the course.

The University Libraries have some excellent tips for avoiding plagiarism, available at https://new.library.arizona.edu/research/citing/plagiarism.

Selling class notes and/or other course materials to other students or to a third party for resale is not permitted without the instructor's express written consent. Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

Programming assignments: what's allowed and what isn't

It is permissible to discuss problems with others in broad terms, e.g., the structure or approach of a program. It is not permissible to discuss concrete details of solutions to a particular assignment before the due date/time for that assignment. In other words, you can talk to each other in English, but not in C/Unix.

The work you turn in for credit should be substantially your own. It is permissible to share test inputs with other students; collaboration beyond this on programming assignments is not permitted.

It is permissible to use modest amounts of "publicly visible" code — code that is available in books or magazines, or which has been distributed/discussed in class — in programming assignments, *as long as the authorship of such code is adequately and explicitly acknowledged*. It is not permissible to solicit code from others. It is also not permissible to use code written by students in previous terms. Please check with me ahead of time if you'd like to use someone else's code in order to make sure that the amount of code is indeed modest.

For the purposes of this course, cheating is considered to be any attempt to pass off someone else's work as your own. Cheating will not be tolerated: any student caught cheating or helping another student cheat in exams or programming assignments, will be given a failing grade in the course. I intend to interpret the phrase "helping another student cheat" broadly: for example, if another student gains access to your code because you forgot to logout, or were careless about listings that were dumped into the recycling bin, you have helped that student cheat. For the same reason, you should be very careful about posting your code to publicly visible media, e.g., Piazza or Github.

Obtaining Help

- **Advising:** If you have questions about your academic progress this semester, or your chosen degree program, consider contacting your graduate program coordinator and faculty advisor. Your program coordinator, faculty advisor, and the Graduate Center can guide you toward university resources to help you succeed.**Computer Science students** are encouraged to email gradadvising@cs.arizona.edu for advising related questions.
- **Life challenges:** If you are experiencing unexpected barriers to your success in your courses, please note the Dean of Students Office is a central support resource for all students and may be helpful. The Dean of Students Office can be reached at 520-621-7057 or DOS-deanofstudents@email.arizona.edu.
- **Physical and mental-health challenges**: If you are facing physical or mental health challenges this semester, please note that Campus Health provides quality medical and mental health care. For medical appointments, call 520-621-9202. For After Hours care, call

(520) 570-7898. For the Counseling & Psych Services (CAPS) 24/7 hotline, call (520) 621-3334.

- **UA Ombuds**: The UA Ombuds Office (https://ombuds.arizona.edu/) helps with a wide variety of issues, concerns, questions, conflicts, and challenges. The primary mission of the Ombuds Program is to assist individuals in resolving conflict, facilitating communication, and assisting the University by surfacing issues and providing feedback on emerging or systemic concerns. Communications with the Ombuds Committee are informal and off-the-record. The Ombuds Committee is governed by the following standards: (1) Confidentiality; (2) Impartiality: (3) Informality; and (4) Independence.

Class Recordings

For lecture recordings, which are used at the discretion of the instructor, students must access content in D2L only. Students may not modify content or re-use content for any purpose other than personal educational reasons. All recordings are subject to government and university regulations. Therefore, students accessing unauthorized recordings or using them in a manner inconsistent with UArizona values and educational policies (Code of Academic Integrity and the Student Code of Conduct) are also subject to civil action.

Department of Computer Science Code of Conduct

The Department of Computer Science is committed to providing and maintaining a supportive educational environment for all. We strive to be welcoming and inclusive, respect privacy and confidentiality, behave respectfully and courteously, and practice intellectual honesty. Disruptive behaviors (such as physical or emotional harassment, dismissive attitudes, and abuse of department resources) will not be tolerated. The complete Code of Conduct is available on our department web site. We expect that you will adhere to this code, as well as the UA Student Code of Conduct, while you are a member of this class.

Classroom Behavior Policy

To foster a positive learning environment, students and instructors have a shared responsibility. We want a safe, welcoming, and inclusive environment where all of us feel comfortable with each other and where we can challenge ourselves to succeed. To that end, our focus is on the tasks at hand and not on extraneous activities (e.g., texting, chatting, reading a newspaper, making phone calls, web surfing, etc.).

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students.

Accessibility and Accommodations

At the University of Arizona, we strive to make learning experiences as accessible as possible. If you anticipate or experience barriers based on disability or pregnancy, please contact the Disability Resource Center (520-621-3268, https://drc.arizona.edu/) to establish reasonable accommodations.

Nondiscrimination and Anti-harassment Policy

The University of Arizona is committed to creating and maintaining an environment free of discrimination. In support of this commitment, the University prohibits discrimination, including harassment and retaliation, based on a protected classification, including race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, or genetic information. For more information, including how to report a concern, please see http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy

Additional Resources for Students

UA Academic policies and procedures are available at http://catalog.arizona.edu/policies

Visit the UArizona COVID-19 page for regular updates.

Campus Health
http://www.health.arizona.edu/
Campus Health provides quality medical and mental health care services through virtual and in-person care. Voluntary, free, and convenient COVID-19 testing is available for students on Main Campus. COVID-19 vaccine is available for all students at Campus Health.
Phone: 520-621-9202

Counseling and Psych Services (CAPS)
https://health.arizona.edu/counseling-psych-services
CAPS provides mental health care, including short-term counseling services.
Phone: 520-621-3334

The Dean of Students Office's Student Assistance Program
https://deanofstudents.arizona.edu/support/student-assistance
Student Assistance helps students manage crises, life traumas, and other barriers that impede success. The staff addresses the needs of students who experience issues related to social adjustment, academic challenges, psychological health, physical health, victimization, and relationship issues, through a variety of interventions, referrals, and follow up services.
Email: DOS-deanofstudents@email.arizona.edu
Phone: 520-621-7057

Survivor Advocacy Program
https://survivoradvocacy.arizona.edu/
The Survivor Advocacy Program provides confidential support and advocacy services to student survivors of sexual and gender-based violence. The Program can also advise students about relevant non-UA resources available within the local community for support.
Email: survivoradvocacy@email.arizona.edu
Phone: 520-621-5767

Campus Pantry

Any student who has difficulty affording groceries or accessing sufficient food to eat every day, or who lacks a safe and stable place to live and believes this may affect their performance in the course, is urged to contact the Dean of Students for support. In addition, the University of Arizona Campus Pantry is open for students to receive supplemental groceries at no cost. Please see their website at: campuspantry.arizona.edu for open times.

Furthermore, please notify me if you are comfortable in doing so. This will enable me to provide any resources that I may possess.

Safety on Campus and in the

For a list of emergency procedures for all types of incidents, please visit the website of the Critical Incident Response Team (CIRT): https://cirt.arizona.edu/case-emergency/overview

Also watch the video available at
https://arizona.sabacloud.com/Saba/Web_spf/NA7P1PRD161/common/learningeventdetail/crtfy0000000000003560

Confidentiality of Student Records

http://www.registrar.arizona.edu/ferpa

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.