CSc 553, Principles of Compilation

Spring 2021

Location and times: TuTh 12:30-1:45, via zoom
(zoom link for lectures and office hours posted in D2L)

Class website: http://www2.cs.arizona.edu/classes/cs553/spring21/

Description of Course
This course covers advanced topics in compilation. Specific topics discussed include:
intermediate program representations; code generation and machine-independent peephole
optimization; register allocation; formation and solution of dataflow analysis problems; code
optimization using data flow information; memory hierarchy optimizations and profile-guided
code placement; instruction scheduling.

Course Prerequisites or Co-requisites
Courses: CSc 453 and CSc 473 (or their equivalents).

Knowledge: Proficiency in programming in C. Familiarity with software development in a
Unix/Linux environment, including tools such as editors, debuggers, make, etc.

Instructor and Contact Information
Instructor: Saumya Debray
Email: debray@email.arizona.edu
Office hours: See the class website for current office hours.

CSC COVID 19 Policy:
All Spring 2021 CSC courses, whether In-Person, In-Person Flex, or Live Online, will provide
recorded lectures for students along with office hour accommodations via Zoom. Additionally,
In-Person and In-Person Flex courses will accommodate students who cannot attend class in-
person to take midterm exams. Attendance will not be factored into final grades for any
computer science course during the Spring 2021 semester.

Course Format and Teaching Methods
This class is scheduled to be taught in the LIVE ONLINE modality.

- Meeting Times: The class will meet TuTh 12:30-1:45 PM via Zoom. The zoom link has been
  posted to the D2L site for this class. Lectures will be recorded and posted to D2L.
- Class attendance:
  o 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.
  o Campus Health is testing for COVID-19. Please call (520) 621-9202 before visiting in person.
  o Visit the UArizona COVID-19 page for regular updates.
Pandemic-Related Information for All Modalities

- **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 520-621-2057 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.

- **Exams:** Information about exams, including when and where they will be administered and how long they will be open, is given later in this document.

- **Equipment and software requirements:** For this class you will need daily access to the following hardware: regular access to reliable internet signal; laptop or web-enabled device able to send and receive audio and video; ability to develop, test, and debug software in C (either on your own computer, or else via remote login to a CS Department server such as lectura).

- **Staying current:** You are required to complete homework and programming assignments, listed in more detail below, on your own time to accomplish the course objectives listed above.

- **Class Recordings:**
  - Lectures will be recorded and posted to D2L.
  - For lecture recordings, 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 are subject to suspension or civil action.

Course Objectives and 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; basic blocks and control flow graphs; and static single-assignment form (SSA);
- 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;
- theoretical foundations of program analysis: dataflow analysis frameworks, abstract interpretation;
- (as time permits) just-in-time compilation and dynamic code optimization.

As part of the course, students will implement an optimizing compiler for a significant subset of C and also study research papers from current research literature.
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 an advisor; advisors 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 http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop

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/absences

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:

- The class website at https://www2.cs.arizona.edu/classes/cs553/spring21/.
- D2L (for announcements, lecture notes and recordings, due dates, and grades)
- Piazza (for questions and discussions). The Piazza website for this class is https://piazza.com/class/kjk91cniwr2ar.
- Gradescope (for assignment submission). The Gradescope website for this class is https://www.gradescope.com/courses/222039

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

Required Texts or Readings
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 website noted above) will be available as a reference.
Assignments and Examinations: Schedule/Due Dates

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.

You will submit the code for each assignment at the submission portal for that assignment in GradeScope. You can submit your code as many times as you want prior to the submission deadline. Your submission will be auto-graded when it is uploaded and you will receive your score within a few minutes of submission (barring exceptional circumstances beyond the instructor’s control, e.g., if the GradeScope website crashes).

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

Timeliness: Assignments are due at or before the submission deadline given on the assignment spec. Late submissions will not be accepted.

Schedule: The schedule for these assignments is as follows (Note: this is subject to change with advance notice):

<table>
<thead>
<tr>
<th>Assg No.</th>
<th>Topic</th>
<th>Start date</th>
<th>Due date</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Syntax tree traversal</td>
<td>1/20/2021</td>
<td>1/25/2021</td>
</tr>
<tr>
<td>1</td>
<td>Code generation</td>
<td>1/27/2021</td>
<td>2/24/2021</td>
</tr>
<tr>
<td>2</td>
<td>Machine-independent optimization</td>
<td>3/3/2021</td>
<td>3/17/2021</td>
</tr>
<tr>
<td>3</td>
<td>Register allocation</td>
<td>3/24/2021</td>
<td>4/7/2021</td>
</tr>
<tr>
<td>4</td>
<td>Optimization/term paper</td>
<td>4/14/2021</td>
<td>4/28/2021</td>
</tr>
</tbody>
</table>

Exams:

Exams will be administered online in GradeScope. Each exam (midterm and final) will be a timed test of 80 minutes duration (75 mins + 5 mins to setup/cleanup). To give students additional flexibility, each exam will be available for a 24-hour period: it will open at 8 AM on the day of the exam and close at 8 AM the next day. You can begin working on the exam at any time during his window. However, once you begin working on the exam, you have 80 minutes to complete it. (Note: if you begin working on it less than 80 minutes before the closing time, you will not have the full 80 mins for the exam.)

- **Midterm exam**: Thu March 16, 2021
- **Final exam**: Wed May 12, 2021 at 1pm

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, contact me ahead of time so that we can work out an alternative time for your exam.

Final Examination or Project

- Wed May 12 at 1PM

Final Exam Regulations: see [https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information](https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information)
Final Exam Schedule: see [http://www.registrar.arizona.edu/schedules/finals.htm](http://www.registrar.arizona.edu/schedules/finals.htm)
Grading Scale and Policies

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

<table>
<thead>
<tr>
<th>Component</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midterm exam</td>
<td>25%</td>
</tr>
<tr>
<td>Final exam</td>
<td>25%</td>
</tr>
<tr>
<td>Programming assignments</td>
<td>50%</td>
</tr>
</tbody>
</table>

(Note: different assignments have different degrees of difficulty and therefore will have different weights. See the class web page for details.)

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

<table>
<thead>
<tr>
<th>Weighted average</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 90</td>
<td>A</td>
</tr>
<tr>
<td>≥ 80 but below 90</td>
<td>B</td>
</tr>
<tr>
<td>≥ 70 but below 80</td>
<td>C</td>
</tr>
<tr>
<td>≥ 60 but below 70</td>
<td>D</td>
</tr>
<tr>
<td>&lt; 60</td>
<td>E</td>
</tr>
</tbody>
</table>

University policy regarding grades and grading systems is available at http://catalog.arizona.edu/policy/grades-and-grading-system

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.

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.

Scheduled Topics/Activities

<table>
<thead>
<tr>
<th>Week no.</th>
<th>Week of</th>
<th>Lecture Topic</th>
<th>Assignments and Exams</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/11/2021</td>
<td>Overview</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1/18/2021</td>
<td>Syntax trees and symbol tables; Intermediate code generation</td>
<td>Assg 0 start: 1/20</td>
</tr>
<tr>
<td>3</td>
<td>1/25/2021</td>
<td>Code generation</td>
<td>Assg 0 due: 1/25</td>
</tr>
<tr>
<td>4</td>
<td>2/1/2021</td>
<td>Code generation</td>
<td>Assg 1 start: 1/27</td>
</tr>
<tr>
<td>5</td>
<td>2/8/2021</td>
<td>Control flow analysis</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2/15/2021</td>
<td>Dataflow analysis, code optimization</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2/22/2021</td>
<td>Dataflow analysis, code optimization</td>
<td>Assg 1 due: 2/24</td>
</tr>
<tr>
<td>8</td>
<td>3/1/2021</td>
<td>Dataflow analysis, code optimization</td>
<td>Assg 2 start: 3/3</td>
</tr>
<tr>
<td>9</td>
<td>3/8/2021</td>
<td>Register allocation</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3/15/2021</td>
<td>Register allocation</td>
<td>Midterm exam: 3/16 Assg 2 due: 3/17</td>
</tr>
<tr>
<td>11</td>
<td>3/22/2021</td>
<td>Instruction scheduling</td>
<td>Assg 3 start: 3/24</td>
</tr>
<tr>
<td>12</td>
<td>3/29/2021</td>
<td>SSA representation</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>4/5/2021</td>
<td>Theory: Dataflow analysis frameworks</td>
<td>Assg 3 due: 4/7</td>
</tr>
<tr>
<td>14</td>
<td>4/12/2021</td>
<td>Theory: Dataflow analysis frameworks</td>
<td>Assg 4 start: 4/14</td>
</tr>
<tr>
<td>15</td>
<td>4/19/2021</td>
<td>Theory: Abstract interpretation</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>5/3/2021</td>
<td>review</td>
<td>Final exam: 5/12</td>
</tr>
</tbody>
</table>

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.

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 http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity.

Uploading material from this course to a website other than D2L (or the 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.

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 homeworks, exams, or programming assignments, will be given a failing grade in the course. I intend to interpret the phrase "helping another student cheat" broadly: e.g., 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.
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

Campus Health
http://www.health.arizona.edu/
Campus Health provides quality medical and mental health care services through virtual and in-person care.
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
http://deanofstudents.arizona.edu/student-assistance/students/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.

**Title IX**

The University of Arizona is committed to removing educational barriers created by sex discrimination and sexual harassment. Sex discrimination under Title IX can include acts of violence based on sex, such as sexual assault, domestic violence, dating violence, and stalking. If you (or someone you know) has experienced or experiences any of these incidents, you have options for help at the University. The University of Arizona has staff members trained to support you in navigating campus life, accessing health and counseling services, providing academic and housing accommodations, helping with legal protective orders, and more.

Please be aware that UA faculty and instructors who work with students are required to report allegations of sex discrimination to the Title IX Office. This means that if you tell me about a situation involving sexual harassment, sexual assault, dating violence, domestic violence, or stalking that involves another student or employee, or that happens on campus or in a UA program, I must share that information with the Title IX Coordinator. Although I have to make that notification, you will have choices regarding whether or not you want to pursue a formal complaint against anyone on campus. Our goal is to make sure you are aware of the range of options available to you and have access to the resources you need.

If you wish to speak to someone privately, you can contact any of the following on-campus resources:

- Counseling & Psych Services (CAPS), [https://health.arizona.edu/counseling-psych-services](https://health.arizona.edu/counseling-psych-services), 520-621-6490, 520-570-7898 (after hours)
- Oasis Sexual Assault, Relationship Violence, and Trauma Services, [https://health.arizona.edu/counseling-oasis](https://health.arizona.edu/counseling-oasis) (same phone as CAPS)
- Campus Health, [https://health.arizona.edu/home](https://health.arizona.edu/home), (520) 621-6490
- University of Arizona Ombuds, [https://ombuds.arizona.edu/](https://ombuds.arizona.edu/), (520)-626-5589
- Title IX section on sexual assault support & resources ([https://titleix.arizona.edu/title-ix/sexual-harassment-violence](https://titleix.arizona.edu/title-ix/sexual-harassment-violence)) has more information, as well as a link explaining options if you have a concern, need assistance/support, or would like to file a complaint.

**Confidentiality of Student Records**


**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.

**Land Acknowledgement Statement**

The University of Arizona sits on the original homelands of indigenous peoples who have stewarded this land since time immemorial. Aligning with the university’s core value of a diverse and inclusive community, it is an institutional responsibility to recognize and acknowledge the people, culture, and history that make up the Wildcat community. At the institutional level, it is important to be proactive in broadening awareness throughout campus to ensure our students feel represented and valued.