SYLLABUS

CSc 453, Compilers and Systems Software

Fall 2020

Location and times: MW 2:00-3:15, via zoom
(zoom link for lectures and office hours posted in D2L)
Class website: http://www2.cs.arizona.edu/classes/cs453/fall20/

Description of Course
This course covers the design and implementation of translator-oriented systems software such as compilers and interpreters. Topics covered include lexical analysis, parsing, and syntax-directed code generation. This class has a significant programming component.

Course Prerequisites or Co-requisites
Courses: CSc 252, CSc 345, CSc 352
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
See the class website for current office hours for the instructor and the TA.

Instructor:
Saumya Debray
Email: cs453staff@cs.arizona.edu or debray@email.arizona.edu

Teaching assistant:
Nicholas Kunzler
Email: cs453staff@cs.arizona.edu or nkkunzler@email.arizona.edu

Course Objectives and Expected Learning Outcomes
Students who successfully complete this course should be able to understand and explain:

- the structure of compilers; phases of compilation, including lexical analysis (scanning), syntax analysis (parsing), semantic analysis, intermediate and final code generation;
- the use of regular expressions to specify lexical tokens and the use of finite state automata to recognize tokens;
- the use of context-free grammars to specify programming language syntax, and the use of parsers to recognize context-free languages;
- intermediate representations, including abstract syntax trees and three-address code;
- syntax-directed translation and code generation;
- interpreters and interpretation; Just-in-time (JIT) compilation.

As part of the course, students will implement a compiler for a significant subset of C.
CSC COVID 19 Policy:
All Fall 2020 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 to take midterm exams and attendance will not be factored into final grades.

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

- **Meeting Times:** The class will meet MW 2:00-3:15 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:**
  - 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.
  - [Campus Health](https://health.arizona.edu/) is testing for COVID-19. Please call (520) 621-9202 before visiting in person.
  - Visit the [UArizona COVID-19](https://covid19.arizona.edu/) page for regular updates.

Pandemic-Related Information

- **Academic advising:** If you have questions about your academic progress this semester, or your chosen degree program, consider contacting your department’s academic advisor(s). Your academic advisor and the [Advising Resource Center](https://advising.arizona.edu/) can guide you toward university resources to help you succeed. [Computer Science major students](mailto:advising@cs.arizona.edu) are encouraged to email advising@cs.arizona.edu for academic 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](mailto:DOSdeanofstudents@email.arizona.edu) can be reached at 520-621-2057 or DOSdeanofstudents@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.
- **Remote / online only after Thanksgiving:** After the Thanksgiving holiday, we are scheduled to move to remote teaching. This class will continue to meet via Zoom, and submit assignments via GradeScope, as before.
- **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.
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/cs453/fall20/.
- D2L (for announcements, due dates, and grades)
- Piazza (for questions and discussions). The Piazza website for this class is https://piazza.com/arizona/fall2020/csc453/home.
- Gradescope (for assignment submission). The Gradescope website for this class is https://www.gradescope.com/courses/159552.

Important: Students are responsible for enrolling themselves 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. The primary reference material will be the instructor’s lecture notes, which will be made available to students on the class website. Additionally, students may use the following book (available online for free) as an optional secondary reference:

Assignments and Examinations: Schedule/Due Dates

Programming Assignments

The course has a programming project where students implement a complete compiler for a subset of the C programming language. This project is divided into a number of programming assignments, each of which builds on all of the previous assignments. Each assignment further consists of a sequence of milestones implementing different components of the 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>Milestone</th>
<th>Topic</th>
<th>Start date</th>
<th>Due date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>Lexical analysis (full C-- language)</td>
<td>09/02/2020</td>
<td>09/08/2020</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Parsing for G0 subset of C--</td>
<td>09/09/2020</td>
<td>09/15/2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>Parsing for G1 subset of C--</td>
<td>09/18/2020</td>
<td>09/27/2020</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Parsing and Type checking for G2</td>
<td>09/28/2020</td>
<td>10/04/2020</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>AST construction G2 subset of C--</td>
<td>10/05/2020</td>
<td>10/11/2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Final code generation for a subset of G2</td>
<td>10/16/2020</td>
<td>10/25/2020</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Final code generation for G2</td>
<td>10/26/2020</td>
<td>11/01/2020</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Parser for full C-- language</td>
<td>11/09/2020</td>
<td>11/15/2020</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Type checking + AST generation for C--</td>
<td>11/16/2020</td>
<td>11/22/2020</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Final code generation for C--</td>
<td>11/30/2020</td>
<td>12/06/2020</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:** Wed Oct 14, 2020
- **Final exam:** Fri Dec 11 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
Fri Dec 11 at 1PM

Final Exam Regulations: see https://www.registrar.arizona.edu/courses/final-examination-regulations-and-information
Final Exam Schedule: see 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>Homework assignments</td>
<td>10%</td>
</tr>
<tr>
<td>Midterm exam</td>
<td>20%</td>
</tr>
<tr>
<td>Final exam</td>
<td>20%</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.
score. Specifically, you will need to provide me with the following items (you can do this either via email or in person):
  o a list of the specific problems in your code; and
  o 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](http://catalog.arizona.edu/policy/grades-and-grading-system#incomplete) **and** [http://catalog.arizona.edu/policy/grades-and-grading-system#Withdrawal](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>8/24 to 8/28</td>
<td>Compilers: overview</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>8/31 to 9/4</td>
<td>Lexical analysis (scanning)</td>
<td>9/2: Assg 1 ms 1 start</td>
</tr>
<tr>
<td>3</td>
<td>9/7 to 9/11</td>
<td>Context-free grammars Recursive descent parsing</td>
<td>9/8: Assg 1 ms 1 due 9/9: Assg 1 ms 2 start</td>
</tr>
<tr>
<td>4</td>
<td>9/14 to 9/18</td>
<td>Recursive descent parsing</td>
<td>9/15: Assg 1 ms 2 due</td>
</tr>
<tr>
<td>5</td>
<td>9/21 to 9/25</td>
<td>Semantic checking</td>
<td>9/18: Assg 2 ms 1 start 9/27: Assg 2 ms 1 due</td>
</tr>
<tr>
<td>6</td>
<td>9/28 to 10/2</td>
<td>Abstract syntax trees (ASTs) Runtime environments</td>
<td>9/28: Assg 2 ms 2 start 10/4: Assg 2 ms 2 due</td>
</tr>
<tr>
<td>7</td>
<td>10/5 to 10/9</td>
<td>ASTs and code generation</td>
<td>10/5: Assg 2 ms 3 start 10/11: Assg 2 ms 3 due</td>
</tr>
<tr>
<td>8</td>
<td>10/12 to 10/16</td>
<td>Code generation</td>
<td>10/14: Midterm exam 10/16: Assg 3 ms 1 start</td>
</tr>
<tr>
<td>9</td>
<td>10/19 to 10/23</td>
<td>Theory: ambiguity, FIRST and FOLLOW sets, LL(1) grammars</td>
<td>10/25: Assg 3 ms 1 due</td>
</tr>
<tr>
<td>10</td>
<td>10/26 to 10/30</td>
<td>Recursive descent parsing: associativity and precedence</td>
<td>10/26: Assg 3 ms 2 start 11/1: Assg 3 ms 2 due</td>
</tr>
<tr>
<td>11</td>
<td>11/2 to 11/6</td>
<td>Recursive descent parsing: associativity and precedence</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>11/9 to 11/13</td>
<td>Short-circuit evaluation of Boolean expressions</td>
<td>11/9: Assg 4 ms 1 start 11/15: Assg 4 ms 1 due</td>
</tr>
<tr>
<td>14</td>
<td>11/23 to 11/27</td>
<td>Interpreters</td>
<td>11/26 to 11/29: Thanksgiving</td>
</tr>
<tr>
<td>15</td>
<td>11/30 to 12/4</td>
<td>JIT compilers</td>
<td>11/30: Assg 4 ms 3 start 12/6: Assg 4 ms 3 due</td>
</tr>
<tr>
<td>16</td>
<td>12/7 to 12/9</td>
<td>review</td>
<td>12/9: last day of classes 12/11: Final exam</td>
</tr>
<tr>
<td></td>
<td>12/11</td>
<td></td>
<td></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 website. 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.

Students are asked to refrain from disruptive behaviors during lecture. Students observed engaging in disruptive activity will be asked to cease this behavior. Those who continue to disrupt the class will be asked to leave lecture or discussion and may be reported to the Dean of Students.

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.

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 CSc 453 students in previous terms. Please check with me or the TA 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.

**UA Nondiscrimination and Anti-harassment Policy**

The University is committed to creating and maintaining an environment free of discrimination; see [http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy](http://policy.arizona.edu/human-resources/nondiscrimination-and-anti-harassment-policy)

Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others.

**Additional Resources for Students**

UA Academic policies and procedures are available at [http://catalog.arizona.edu/policies](http://catalog.arizona.edu/policies)

Student Assistance and Advocacy information is available at [http://deanofstudents.arizona.edu/student-assistance/students/student-assistance](http://deanofstudents.arizona.edu/student-assistance/students/student-assistance)

**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](http://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.