



School of Engineering

Information

Technology Program

ITP 439 – Compiler Development

Units: 4

Spring 2022—M/W—Time: 5-6:50PM

Location: SGM 601

Remote Attendance:

The general expectation of the University is that students will attend in-person unless they have an approved accommodation, are stuck overseas, or are currently experiencing symptoms and should isolate. This course will accommodate remote students, though students are encouraged to attend in person if at all possible.

Instructor: Sanjay Madhav

Office: TBD

Office Hours: TBD

Contact Info: All general course/assignments questions should be asked on Piazza (every student will receive an invitation at the start of the semester).

Personal questions should be directed via email at madhav@usc.edu.

Teaching Assistants: TBD

Office: TBD

Office Hours: TBD

Contact Info: Via Piazza.

Course Description

Students will learn about practical applications of techniques used to develop a programming language compiler. Topics covered include how to parse the program's text, represent the program in memory, optimize the code, and generate machine code. Throughout the semester, students will implement components of a working compiler for a subset of C called University Simple C, which was created specifically for this course. This compiler is implemented in C++. Students will also use the extremely popular and industry-standard LLVM framework for many aspects of the compiler.

Learning Objectives

- Gain a fundamental understanding of how compilers work, focusing on optimization and the back end
- Implement several aspects of a working compiler for a C programming language subset
- Learn how to work with an existing large-scale code base (the LLVM library)
- Learn how to read and comprehend papers in the field

Prerequisite(s): CSCI 104 or ITP 365. Junior standing or higher recommended.

Course Notes

Lecture slides and assignments will all be posted on Blackboard. Course discussions will occur on Piazza. Assignments will be submitted on GitHub.

Technological Proficiency and Hardware/Software Required

Students should have access to their own computer running either Windows, MacOS, or Linux, and should be familiar with the basic operation of their computer.

Required Readings and Supplementary Materials

Cooper, Keith and Linda Torczon. *Engineering a Compiler (Second Edition)*. Morgan Kaufman. 2012. ISBN-10: 012088478X.

Additional readings such as excerpts from other books or research papers will be provided on Blackboard.

Description and Assessment of Assignments

There are six different C++ programming assignments in this course, and students will have two or three weeks per programming assignment. The assignments are as follows:

1. Recursive descent parser
2. Semantics and Symbol Table Generation
3. Generation of LLVM IR
4. Static Single Assignment form
5. Optimization passes
6. Register allocation via graph coloring

Programming assignments each have a suite of unit tests. Student grades are based on the percentage of unit tests the assignment passes.

There are also five short problem sets assigned in between these programming assignments. These problem sets both reinforce concepts and help prepare for the exam.

Additionally, we will read 5 papers during the semester. Students will be required to answer a handful of questions prior to the start of the "Paper Discussion" class meetings. During these meetings, students will break into small groups and work through a worksheet in their group as well as participate in larger course discussions. It will not be possible to record these meetings or support Zoom during them due to the nature of the discussion. However, students who are unable to attend in-person will be allowed to complete the worksheet asynchronously and submit it for full credit.

There is a midterm and final exam. The final exam is cumulative.

Grading Breakdown

| Item | % of Grade |
|--------------------------------------|------------|
| Programming Assignments (5% each) | 30 |
| Problem Sets (3% each) | 15 |
| Paper Summaries/Discussion (3% each) | 15 |
| Midterm Exam | 20 |
| Final Exam | 20 |
| | |
| Total | 100 |

Grading Scale

Course final grades will be determined using the following scale

| | |
|----|--------------|
| A | 93-100 |
| A- | 90-92 |
| B+ | 87-89 |
| B | 83-86 |
| B- | 80-82 |
| C+ | 77-79 |
| C | 73-76 |
| C- | 70-72 |
| D+ | 69 |
| D | 67-69 |
| D- | 66 |
| F | 65 and below |

Half percentage points will be rounded up to the next whole percentage. For instance, 89.5% is an A-, but 89.4% is a B+.

Assignment Submission Policy

Programming assignments must be submitted to student's GitHub repositories by 11:59PM of the deadline date or will be considered late. Programming assignments that do not compile will receive a 0. Problem sets will be due at 11:59PM on the designated due date.

Late Policy

For programming assignments, students are given four "slip" days for the entire semester. These slip days can be used one at a time or all at once. Upon consumption of these slip days, students will be assessed a 25% penalty per day late, for up to three additional days. If a student uses all his or her slip days, extensions will only be given in the event of a documented emergency.

Problem sets will be accepted up to one day late with a late penalty of 25%.

Make-up Policy for Exams

To make up for a missed exam, the student must provide a satisfactory reason (as determined by the instructor) along with documentation. Make-up exams are only allowed under extraordinary circumstances.

Plagiarism and Individual Work Policy

In this class, programming assignments are expected to represent the individual effort of each student. All programming assignment submissions will be compared with current, previous, and future students' submissions using MOSS, which is a code plagiarism identification program. If your code significantly matches another student's submission, you will be referred to SJACS with a recommended penalty of an F in the course.

It is okay to discuss solutions to specific problems with other students, but it is not okay to look through another student's code. It does not matter if this code is online or from a student you know, it is cheating. Do not share your code with anyone else in this or a future section of the course, as allowing someone else to copy your code carries the same penalty as copying the code yourself.

Course Material Policy

Do not reproduce, distribute, or post any lecture material, assignments, assignment solutions, or exams publicly without written consent of the instructor. You may take notes and make copies of course materials for your own use. You may not post course materials on sites such as CourseHero. Doing so is a copyright violation and in some cases may also be an academic integrity violation that will be dealt with accordingly.

Course Schedule

| | Lecture Topics | Readings | Due Dates |
|------|---|--|------------------------------------|
| 1/10 | Intro; Compiler Basics; Scanning | Ch. 1; §2.1-2.3 | |
| 1/12 | Top-down parsing | §3.1-3.3 | |
| 1/17 | MLK Day (No class) | | |
| 1/19 | Bottom-up parsing; Semantic Analysis Basics | §3.4; §4.1-4.2; §5.5 | PS1 DUE 1/21 @ 11:59PM |
| 1/24 | Examples of Compilers; Reading Papers | "How to Read a Paper" (Keshav) | |
| 1/26 | Context Sensitive/Attribute Grammars | §4.3-4.4 | PA1 DUE 1/28 @ 11:59PM |
| 1/31 | Paper Discussion #1 | "LLVM" | Paper Qs DUE start of class |
| 2/2 | IR; Generating Expressions; Control Flow | §5.1-5.3; §7.1-7.4; §7.8 | PS2 DUE 2/4 @ 11:59PM |
| 2/7 | Arrays, Strings, Calling Conventions | §6.1-6.3; §7.5-7.7; §7.9 | |
| 2/9 | OOLs; Basics of Optimization | §6.4-6.6; §8.1-8.4 | PA2 DUE 2/11 @ 11:59PM |
| 2/14 | Paper Discussion #2 | "A Simple Graph-Based Intermediate Representation" | Paper Qs DUE start of class |
| 2/16 | Midterm Review | | |
| 2/21 | President's Day (No class) | | |
| 2/23 | Midterm Exam | | |
| 2/28 | Dominators and Data-flow Analysis | §9.1-9.2.2 | |
| 3/2 | SSA (Braun Algorithm) | "Simple and Efficient SSA Construction" | PA3 DUE 3/4 @ 11:59PM |
| 3/7 | Paper Discussion #3 | "Tree SSA" | Paper Qs DUE start of class |
| 3/9 | Building SSA Form (Cytron Algorithm) | §9.3.4-9.3.6; | PS3 DUE 3/11 @ 11:59PM |
| | Spring Break | | |
| 3/21 | Optimization Passes, Code Motion, and Instruction Selection | §10.3; §11.1-11.7; | |
| 3/23 | SIMD and Auto-Vectorization | | PA4 DUE 3/25 @ 11:59PM |
| 3/28 | Global Register Allocation | §13.1-13.4; | |
| 3/30 | Instruction Scheduling | §12.1-12.6; | PS4 DUE 4/1 @ 11:59PM |
| 4/4 | Paper Discussion #4 | "Linear Scan Register Allocation" | Paper Qs DUE start of class |
| 4/6 | Intraprocedural Analysis; Aliasing | | PA5 DUE 4/8 @ 11:59PM |
| 4/11 | Deconstruction of SSA; Basics of Static Analysis | | |
| 4/13 | Software Security and Compilers | | PS5 DUE 4/15 @ 11:59PM |
| 4/18 | Paper Discussion #5 | "Valgrind" | Paper Qs DUE start of class |
| 4/20 | Directive-Based and Automatic Parallelization Techniques | | |
| 4/25 | TBD | | |
| 4/27 | Final Exam Review | | PA6 DUE 4/29 @ 11:59PM |
| | Final Exam | | |

For due dates, "PS" is a Problem Set and "PA" is a Programming Assignment. Paper Qs refer to the questions related to that day's paper which must be completed prior to the start of class.

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism – presenting someone else’s ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, “Behavior Violating University Standards” <https://policy.usc.edu/scampus-part-b/>. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, <http://policy.usc.edu/scientific-misconduct>.

Support Systems

Student Counseling Services (SCS) - (213) 740-7711 – 24/7 on call

Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. <https://engemannshc.usc.edu/counseling/>

National Suicide Prevention Lifeline - 1-800-273-8255

Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. <http://www.suicidepreventionlifeline.org>

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 - 24/7 on call

Free and confidential therapy services, workshops, and training for situations related to gender-based harm. <https://engemannshc.usc.edu/rsvp/>

Sexual Assault Resource Center

For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: <http://sarc.usc.edu/>

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086

Works with faculty, staff, visitors, applicants, and students around issues of protected class. <https://equity.usc.edu/>

Bias Assessment Response and Support

Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. <https://studentaffairs.usc.edu/bias-assessment-response-support/>

The Office of Disability Services and Programs

Provides certification for students with disabilities and helps arrange relevant accommodations. <http://dsp.usc.edu>

Student Support and Advocacy – (213) 821-4710

Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. <https://studentaffairs.usc.edu/ssa/>

Diversity at USC

Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. <https://diversity.usc.edu/>

USC Emergency Information

Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible, <http://emergency.usc.edu>

USC Department of Public Safety – 213-740-4321 (UPC) and 323-442-1000 (HSC) for 24-hour emergency assistance or to report a crime.

Provides overall safety to USC community. <http://dps.usc.edu>