ECE 595.3

Course Run
ECE595.3: Introduction to Compilers – Optimization

Instructor
• Milind Kulkarni, Associate Professor of Electrical and Computer Engineering, Purdue University

Audience

First- or second-year graduate students who have taken ECE 595.1 and ECE 595.2. Students are expected to have programming experience, especially with data structures and recursion.

Course Description

This course covers advanced topics in compiler optimization: dataflow analysis and pointer analysis to perform global optimizations, and both low-level loop transformations such as loop-invariant code motion and high-level loop transformations such as loop tiling. The course also explains how compiler generate code for pointers and arrays. Students will build a compiler that performs a basic pointer analysis.

Course Learning Outcomes

After completing this course, you will be able to:
• Explain how programs handle pointers, and how compilers generate code for them
• Explain how compilers generate code for arrays
• Explain dataflow analysis, including specific instances: liveness and available expressions
• Explain pointer analysis and how to implement it
• Explain loop optimizations and why they are useful
• Extend a compiler to add support for pointers and arrays and implement a pointer analysis

Required Text and Materials

There is no required text for this class. However, students may find the book Engineering a Compiler, by Cooper and Torczon (2nd edition, Morgan Kauffman, ISBN: 978-0120884780) helpful.

Gradescope

Gradescope will be used in this course as a method for grading your submitted problem sets.
GitHub
Programming assignments will be managed through GitHub classroom

Prerequisites
Comfort with programming, especially data structures and recursion. Experience with object oriented programming will also be beneficial.

Students must have taken ECE 595.1 — Introduction to Compilers – Compiler Basics

Grading
This course will be graded based on the following criteria:

<table>
<thead>
<tr>
<th>Assessment Type</th>
<th>Description</th>
<th>% of Final Grade</th>
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</thead>
<tbody>
<tr>
<td>Problem sets</td>
<td>There will be 2 problem sets that will test your knowledge of theoretical aspects of this course</td>
<td>20%</td>
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<tr>
<td>Programming assignments</td>
<td>There will be 2 programming assignments that will walk students through building a compiler that can translate C code into RISC-V assembly</td>
<td>60%</td>
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<tr>
<td>Exam</td>
<td>There will be a final exam summarizing the content of the course</td>
<td>20%</td>
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Course Content and Activities

<table>
<thead>
<tr>
<th>Week</th>
<th>Module</th>
<th>Lessons</th>
<th>Activities &amp; Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.1 Welcome and Introduction</td>
<td>Getting Started/Overview</td>
<td>Lecture Videos Handouts</td>
</tr>
<tr>
<td></td>
<td>1.2 Recap</td>
<td>What have we learned?</td>
<td>Lecture Videos Handouts</td>
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<td></td>
<td>1.3 Pointers</td>
<td>Pointer basics L-values and R-values revisited Code generation for pointers</td>
<td>Lecture Videos Handouts Quiz: Pointers, l-values and r-values</td>
</tr>
<tr>
<td>2</td>
<td>2.1 Arrays</td>
<td>Array basics Syntactic sugar and desugaring</td>
<td>Lecture Videos Handouts</td>
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2.2 Control flow graphs
- Code generation for arrays
  - What are control flow graphs?
  - Building control flow graphs from code
- Quiz: Array and pointer equivalence
  - Lecture Videos
  - Handouts
  - Programming assignment: add pointers and arrays to language

3.1 Data flow analysis
- Introduction to dataflow analysis
  - Constant propagation
  - Liveness
- Lattice theory
  - Available expressions
  - Reaching definitions
- Lecture Videos
- Handouts

3.2 Lattice theory
- Lecture Videos
- Handouts
  - Problem set: Liveness and available expressions

4.1 Pointer analysis
- What is pointer analysis?
  - Flow-sensitive pointer analysis
- Loop optimization overview
  - Loop invariant code motion
  - Strength reduction
- Lecture Videos
- Handouts
  - Quiz: CSE

4.2 Loop optimization
- Lecture Videos
  - Handouts
  - Quiz: Liveness
  - Programming assignment: Pointer analysis

5.1 High-level loop optimization
- High level loop optimization
  - Reasoning about locality
  - Dependences in loops
- Lecture Videos
  - Handouts

5.2 Dependences
- Loop interchange
  - Finding dependences
- Loop tiling
  - Dependence checking
- Lecture Videos
  - Handouts

Estimated Effort
- 10-12 hours/week
- 5 weeks total

Languages
Content: English  |  Videos: English  |  Transcripts: English

Course Difficulty
- Introductory
Accessibility Support
Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let an instructor know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: mailto:drc@purdue.edu or by phone: 765-494-1247.
Visit edX’s Website Accessibility Policy for information about accessibility on edX.

Course Help
To get help with course content, click the Discussion tab and post a question in “Course Q&A”. By commenting in the pinned discussion post, the course team will be able to respond to your question more quickly.
Technical Help
For general questions about using the edX platform, please refer to these resources:

- Technical Documentation: https://docs.edx.org
- Learner Help Center: https://support.edx.org/hc/en-us
- To get help with a technical problem, visit the Help link to contact edX Support.

Discussion Guidelines
Please follow the Discussion Guidelines when contributing to discussions in this course. Here are a few of the key points you should remember:

- Do not use offensive language. Present ideas appropriately.
- Be cautious in using Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular and/or slang language. This could possibly lead to misinterpretation.
- Keep an “open-mind” and be willing to express even your minority opinion.
- Make substantive posts or comments. Avoid comments that do not contribute to the discussion, like "thanks" or "good post."
- Do not hesitate to ask for feedback.
- Be concise and to the point. Give other students the opportunity to join in the discussion.
- Think and edit before you push the “Send” button.
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