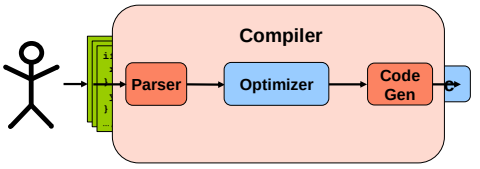
Advanced Compiler Design

CSE 231

Instructor: Sorin Lerner

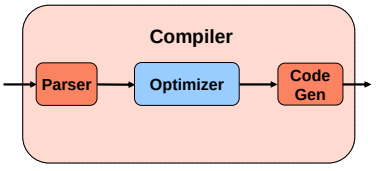
1

Let's look at a compiler



2

Let's look at a compiler



3

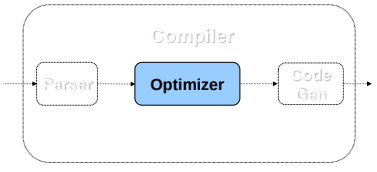
Advanced Optimizer Design

CSE 231

Instructor: Sorin Lerner

4

What does an optimizer do?



1. Compute information about a program
2. Use that information to perform program transformations
   (with the goal of improving some metric, e.g. performance)

5

What do these tools have in common?

- Bug finders
- Program verifiers
- Code refactoring tools
- Garbage collectors
- Runtime monitoring system
- And… optimizers

6

What do these tools have in common?

- Bug finders
- Program verifiers
- Code refactoring tools
- Garbage collectors
- Runtime monitoring system
- And… optimizers

They all analyze and transform programs
We will learn about the techniques underlying all these tools

7

Program Analyses, Transformations, and Applications

CSE 231

Instructor: Sorin Lerner

8

Course goals

- Understand basic techniques
  - cornerstone of a variety of program analysis tools
  - useful no matter what your future path
- Get a feel for compiler research/implementation
  - useful for research-oriented students
  - useful for implementation-oriented students

9

Course topics

- Representing programs
- Analyzing and transforming programs
- Applications of these techniques

10

Course topics (more details)

- Representations
  - Abstract Syntax Tree
  - Control Flow Graph
  - Dataflow Graph
  - Static Single Assignment
  - Control Dependence Graph
  - Program Dependence Graph
  - Call Graph

11

Course topics (more details)

- Analysis/Transformation Algorithms
  - Dataflow Analysis
  - Interprocedural analysis
  - Pointer analysis

12

Course topics (more details)

- Applications
  - Scalar optimizations
  - Loop optimizations
  - Object oriented optimizations
  - Program verification
  - Bug finding

13

Course pre-requisites

- No compilers background necessary
- No familiarity with lattices
  - I will review what is necessary in class
- Familiarity with functional/OO programming
  - Optimization techniques for these kinds of languages
- Know C/C++ or an object oriented language
  - Project will be in C++
- Standard ugrad cs curriculum likely enough
  - Talk to me if you're concerned

14

Course work

- In-class midterm (30%)
  - Date posted on web site
- In-class midterm (30%)
  - Date posted on web site
- Course project (40%)

15

Course project

- Goal of the project
  - Get some hands on experience with compilers
  - Two options, most will do option 1
- **Option 1: LLVM project**
  - Implement some analyses in LLVM, three milestones
  - Hand in your code and it's auto-graded
- **Option 2: Research (by instructor approval)**
  - Pick some interesting idea, and try it out
  - Proposals due at the beginning of the second week
  - Can leverage your existing research

16

LLVM Project

- M1: Simple instrumentation
- M2: Analysis framework
- M3: Implement Analyses in framework
- You will extend LLVM. This will require C++
  - If you don't know C++, you should be super confident that you can learn it. Otherwise, drop the class
- To be done alone

17

Research Project

- Requires instructor approval
  - You need to come up with your own idea…
  - … by the end of week 1
  - Most students doing this will be PhD students
  - It's ok to leverage or overlap with existing research
- To be done alone
- I envision at most 10 people doing this

18

Readings

- Paper readings throughout the quarter
- Seminal papers and state of the art
- Gives you historical perspective
- Shows you lineage from idea to practice

19

Administrative info

- Class web page is up
  - https://ucsd-pl.github.io/cse231/wi19/
  - (or Google “Sorin Lerner”, follow “Teaching Now”)
  - Will post lectures, readings, project info, etc.
- Piazza link on web page
  - Use for questions, answers
  - Especially LLVM/project Q&A

20

Academic Integrity

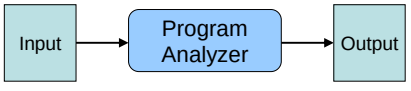
- Governed by Policy on Integrity of Scholarship (http://senate.ucsd.edu/Operating-Procedures/Senate-Manual/Appendices/2)
- Allegations are handled by Academic Integrity Office (https://students.ucsd.edu/academics/academic-integrity)
- Course penalty for cheating in 231 may result in failing the assignment or the entire class
- Cheaters may be subject to additional administrative sanctions

21

Questions?

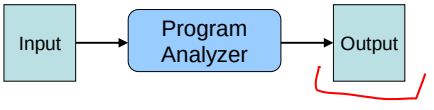
22

Program Analyzer Issues (discuss)



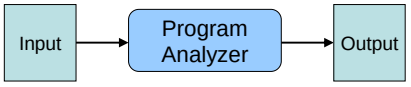
23

Program Analyzer Issues (discuss)



24

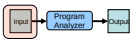
Program Analyzer Issues (discuss)



25

Instructor's discussion notes

Input issues



- Input is a program, but…
- What language is the program written in?
  - imperative vs. functional vs. object-oriented? maybe even declarative?
  - what pointer model does the language use?
  - reflection, exceptions, continuations?
  - type system trusted or not?
  - one often analyzes an intermediate language... how does one design such a language?

26

Instructor's discussion notes

Input issues

- How much of the program do we see?
  - all?
  - one file at a time?
  - one library at a time?
  - reflection…
- Any additional inputs?
  - any human help?
  - profile info?

27

Instructor's discussion notes

Analysis issues

- Analysis/compilation model
  - Separate compilation/analysis
    - quick, but no opportunities for interprocedural analysis
  - Link-time
    - allows interprocedural and whole program analysis
    - but what about shared precompiled libraries?
    - and what about compile-time?
  - Run-time
    - best optimization/analysis potential (can even use run-time state as additional information)
    - can handle run-time extensions to the program
    - but severe pressure to limit compilation time
  - Selective run-time compilation
    - choose what part of compilation to delay until run-time
    - can balance compile-time/benefit tradeoffs

28

Instructor's discussion notes

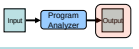
Analysis issues

- Does running-time matter?
  - for use in IDE?
  - or in overnight compile?

29

Instructor's discussion notes

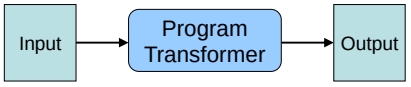
Output issues



- Form of output varies widely, depending on analysis
  - alias information
  - constantness information
  - loop terminates/does not terminate
- Correctness of analysis results
  - depends on what the results are used for
  - are we attempting to design algorithms for solving undecidable problems?
  - notion of approximation
  - statistical output

30

Program Transformation Issues (discuss)



31

Instructor's discussion notes

Input issues

- A program, and …
- Program analysis results
- Profile info?
- Environment: # of CPUs, # of cores/CPU, cache size, etc.
- Anything else?

32

Instructor's discussion notes

Transformation issues

- What is profitable?
- What order to perform transformations?
- What happens to the program representation?
- What happens to the computed information? For example alias information? Need to recompute?

33

Instructor's discussion notes

Output issues

- Output in same IL as input?
- Should the output program behave the same way as the input program?

34