Course Overview

CS 132: Compiler Design
January 17, 2001

Compilers and Interpreters

- Compilers translate code from one language (*source language*) to another (*target language*).
  - Ideally, the translation preserves meaning
  - Target often assembly or machine language, but could be bytecodes, or C, ...
- Interpreters execute code as given
- In practice, the boundary is fuzzier.

To Interpret or Compile?

- It is true that...
  - some languages are easier to compile than others.
  - some languages have been historically compiled, and others have been historically interpreted.
  - some languages require an interactive system
- But compilation or interpretation is *not* an intrinsic property of the language!

Bad Example

"...it's clear that a well-written program in Java could never run as fast as a well-written program in C or C++. That's because the Java bytecode is interpreted, not compiled. Programs written in C are compiled into binaries which can be executed by a specific computer processor. Programs written in Java require one more step – they must be interpreted by the Java `virtual machine' before running on a particular computer architecture. As a result, a computer running a Java program has to execute more machine-language instructions to do the same amount of work than a computer running an equivalent program written in C."

Simson Garfinkel, Salon Magazine, 1/8/2001

Why Compilers are Interesting

- Use ideas from both theory and systems
  - Finite automata, context-free grammars, graph algorithms, lattices, formal semantics, …
  - Assembly/machine language, data layout, memory management, register usage, calling conventions, cache behavior, cycle counts, CPU pipelines …

Challenges

- Perfect information about code usually undecidable.
  - Is this function ever called at run-time?
  - Can these two pointers ever alias?
  - Is this array access guaranteed to be in-bounds?
  - Is this loop always executed at least once?
  - Does this function always look at its argument?
  - Which functions can be bound to this variable?
- Accurate approximations can be expensive or require source of *entire* program.

Challenges

- Optimization tasks frequently NP-complete
  - Put variables into registers so as to minimize the number of loads and stores
  - Order a list of instructions, respecting dependencies, so as to minimize the number of cycles required.
  - Lay out data in memory so as to minimize cache conflicts/memory contention

Optimality

- Define a fully-optimizing compiler to be one which computes the smallest-possible code for all programs.

  Theorem: For a nontrivial language there is no fully-optimizing compiler.

Is the Task Hopeless?

- Of course not!

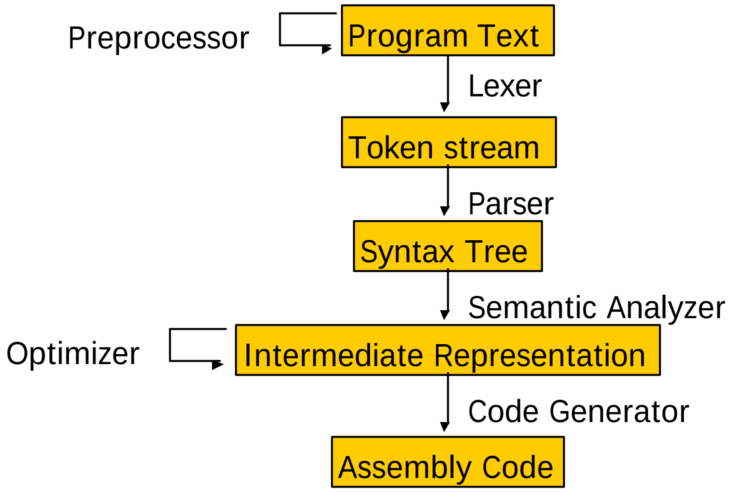
- Compilers just use a lot of heuristics and coarse approximations
  - Ideally, *safe* approximations
  - Code isn't perfect, but is usually "good enough"
  - Over time, these improve (smarter techniques, faster machines)

Is the Task Hopeless?

Theorem [Full Employment for Compiler Writers]:

For any optimizing compiler there exists a better one.

Generic Compiler



Books

- Required Text:
  - *Modern Compiler Implementation in ML* by Andrew Appel.
- “Optional” Texts [No assigned readings, but you need to know the material]:
  - *SPARC Architecture, Assembly Language Programming, and C (2nd Ed.)* by Richard Paul.
  - *Introduction to Programming using SML* by Michaell Hansen and Hans Richel.

Structure of This Course

- Core material:
  - First half of Appel’s text
  - Covers phases of a compiler for the *Tiger* language (to be described momentarily)
- Plus:
  - Discussion of other topics (from Appel and lecture notes) as time permits
  - E.g., Code optimizations, compiling functional or object-oriented languages, …

Homeworks

- All from Appel’s text
  - Read the first 12 chapters
  - Implement the code described in the “Program” sections of these chapters.
  - Programming assignments assigned approximately weekly
- The course requires a fair bit of coding
  - After the first assignment, you will work in pairs.
  - Randomly assigned for each assignment.

Why Use Standard ML?

- Strengths of SML match up well with demands of compiler writing:
  - Symbolic manipulation
    - Pattern-matching and `datatypes`
  - Modularity and interfaces
    - Structures and signatures
  - Plus safety, garbage collection, etc.

Tiger Language

- "Simple but nontrivial language of the Algol family"
  - This family includes Pascal and C
- Includes
  - Assignment, `for` and `while` loops, conditionals, strings, printing, …
  - Arrays
  - Nested function definition
  - Heap-allocated records
    - Can program linked lists

Sample Tiger Code

```
/* A program to solve the 8-queens problem*/
let
  var N := 8

  type intArray = array of int

  var row := intArray[N] of 0
  var col := intArray[N] of 0
  var diag1 := intArray[N+N-1] of 0
  var diag2 := intArray[N+N-1] of 0

  function printboard() =
     (for i := 0 to N-1 do
       (for j := 0 to N-1 do
          print(if col[i]=j then
                 " O" else " .");
        print("\n"));
      print("\n"))
```

```
  function try(c:int) =
    (if c=N then
        printboard()
     else
        for r := 0 to N-1 do
          if (row[r]=0 &
              diag1[r+c]=0 &
              diag2[r+7-c]=0) then
             (row[r]:=1;
              diag1[r+c]:=1;
              diag2[r+7-c]:=1;
              col[c]:=r;
              try(c+1);
              row[r]:=0;
              diag1[r+c]:=0;
              diag2[r+7-c]:=0))
in
   try(0)
End
```

Grading

- Grade is determined as follows:

  80% : Result of weekly assignments

  20% : Class participation

- No final or midterm.

Assignment 1

- Read Chapter 1, do the PROGRAM part.
- Turn in before next Wednesday’s class.
- More details on Assignments web page.