CS 701

Charles N. Fischer

Fall 2003

http://www.cs.wisc.edu/~fischer/cs701.html

Class Meets

Tuesdays & Thursdays, 11:00 — 12:15
2321 Engineering Hall

Instructor

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Key Dates

- September 23: Project 1 due
- October 21: Project 2 due (tentative)
- October 23: Midterm (tentative)
- November 18: Project 3 due (tentative)
- December 11: Project 4 due
- December ??: Final Exam, date to be determined

Class Text

There is no required text.

Handouts and Web-based reading will be used.

Suggested reference:

Advanced Compiler Design & Implementation,
by Steven S. Muchnick,
published by Morgan Kaufman.

Instructional Computers

Departmental SPARC Processors (nova1-nova60)

You may use your own workstation if it is has a SPARC processor
(test using **`dmesg|grep cpu`**)

Otherwise log onto a SPARC processor to do SPARC-specific assignments

CS701 Projects

1. SPARC Code Optimization
2. Global Register Allocation
   (using Graph Coloring)
3. Global Code Optimizations
4. Individual Research Topics

Academic Misconduct Policy

- You must do your assignments—no copying or sharing of solutions
- You may discuss general concepts and Ideas
- All cases of Misconduct *must* be reported.
- Penalties may be severe.

Reading Assignment

- Get Handout #2 (Chapter 15, Code Optimization) from DoIt.
- Read Chapters 0-6 and Appendices G&H of the SPARC Architecture Manual. Also skim Appendix A.
- Read section 15.2 of Chapter 15.
- Read Assignment #1

Overview of Course Topics

1. Register Allocation

Local Allocation

Avoid unnecessary loads and stores within a *basic block*. Remember and reuse register contents.
Consider effects of *aliasing*.

Global Allocation

Allocate registers within a single subprogram. Choose "most profitable" values. Map several values to the *same* register.

Interprocedural Allocation

Avoid saves and restores across calls.
Share globals in registers.

2. Code Scheduling

We can reorder code to reduce latencies and to maximize ILP (*Instruction Level Parallelism*). We must respect *data dependencies* and *control dependencies*.

```
ld   [a],%r1      ld [a],%r1
add %r1,1,%r2     mov 3,%r3
mov 3,%r3         add %r1,1,%r2
  (before)          (after)
```


3. Automatic Instruction Selection

How do we map an IR (*Intermediate Representation*) into Machine Instructions?

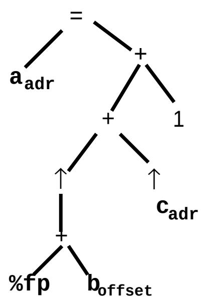
Can we guarantee the *best* instruction sequence?

Idea—Match instruction patterns (represented as trees) against an IR that is a low-level tree. Each match is a generated instruction; the best overall match is the best instruction sequence.

Example:

a=b+c+1;

In IR tree form:



Generated code:

ld [%fp+b_{offset}],%r1

ld [c_{adr}],%r2

add %r1,%r2,%r3

add %r3,1,%r4

st %r4,[a_{adr}]

Why use four *different* registers?

4. Peephole Optimization

Inspect generated code sequences and replace pairs/triples/tuples with better alternatives.

(before)	(after)

`ld [a],%r1`
`mov const,%r2`
`add %r1,%r2,%r3`
	`ld [a],%r1`
	`add %r1,const,%r3`

`mov 0,%r1` `OP %r1,%r2,%r3`	`OP %g0,%r2,%r3`

But why not just generate the better code sequence to begin with?

5. Cache Improvements

We want to access data & instructions from the L1 cache whenever possible; misses into the L2 cache (or memory) are *expensive*!

We will layout data and program code with consideration of cache sizes and access properties.

6. Local & Global Optimizations

Identify unneeded or redundant code.

Decide where to place code.

Worry about debugging issues (how reliable are current values and source line numbers after optimization?)

7. Program representations

- Control Flow Graphs
- Program Dependency Graphs
- Static Single Assignment Form (SSA)

Each program variable is assigned to in only *one* place.

After an assignment $x_i = y_j$, the relation $x_i = y_j$ *always* holds.

Example:

`if (a)`
`    x = 1`
`else x = 2;`
`print(x)`
	`if (a)`
	`    `x_1` =1`
	`else `x_2` =2;`
	$x_3 = \phi(x_1,x_2)$
	`print(`x_3`)`

8. Data Flow Analysis

Determine invariant properties of subprograms; analysis can be extended to entire programs.

Model abstract execution.

Prove correctness and efficiency properties of analysis algorithms.