

Lecture 23: Static Single Assignment (SSA) Form

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Static Single Assignment (SSA) Form

Static Single Assignment (SSA) Form is a style of intermediate representation where there is at most a single assignment to any variable (virtual register.)

SSA makes many optimizations easier, and is especially useful for *global* optimizations, since every use of a variable is connected to exactly one assignment, even if the use and assignment are in different basic blocks.

SSA concerns

- ▶ How to convert to SSA form
- ▶ Dealing with control joins
- ▶ What can we do with code in SSA form?

Conversion to SSA form, control joins

Slides from Seth Goldstein and Todd Mowry at CMU:

<http://www.cs.cmu.edu/afs/cs/academic/class/15745-s12/public/lectures/L13-SSA-Concepts-1up.pdf>

SSA lecture from CS 6120 by Adrian Sampson at Cornell:

<https://www.cs.cornell.edu/courses/cs6120/2022sp/lesson/6/>

What can we do with code in SSA form?

- ▶ Global register allocation
- ▶ Global value numbering

Global register allocation, interference graph

The fundamental constraint of register allocation is that if two values are live at the same time, they must be stored in different locations.

Idea: construct a *interference graph*:

- ▶ Each node represents a variable (vreg) and its live range (set of locations where the vreg has a live value)
- ▶ Two nodes are connected by an edge if the live ranges overlap
- ▶ Nodes connected by an edge can't use the same register

Note: CFG doesn't need to be in SSA form for this to work!

- ▶ However, when the CFG is in SSA form, the interference graph has properties that make it easier to color

Register allocation by graph coloring

Build the interference graph.

Color each node in the interference graph. Each color represents a register. Two nodes connected by an edge can't have the same color.

Challenges:

- ▶ k -coloring a graph is NP-hard for $k > 2$
 - ▶ Solution: use heuristics
 - ▶ SSA form: optimal coloring is polynomial time!
- ▶ If we have k registers, the graph might not be k -colorable
 - ▶ Solution: spills and restores
 - ▶ SSA form: number of registers is equal to the size of the interference graph's largest clique

Register allocation via graph coloring

Lecture slides from Marek Perkowski at Portland State U:

<https://web.cecs.pdx.edu/~mperkows/temp/register-allocation.pdf>

Global Value Numbering

In SSA, each name represents a single value.

Global value numbering: assign a value number to each name, such that if two names have the same value number, they are guaranteed to be the same value at runtime.

If a computation yields a value number that is already available, update uses of the recomputed value to be uses of the “original” computation of that value.