# 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.