

CS738: Advanced Compiler Optimizations

Constant Propagation

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Agenda

- ▶ Using data flow analysis to identify “constant expressions” in a program
- ▶ Identify similarity/differences with bit-vector data flow analyses discussed earlier
- ▶ Other properties of constant propagation

Constant Propagation

- ▶ CP: Replace expressions that evaluate to same constant “c” every time they are executed, by the value “c”

DF Framework for CP

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- ▶ *NAC*: not a constant
 - ▶ If variable is inferred not to be a constant
 - ▶ Multiple (different valued) defs, non-const defs, assigned an “un-interpreted” value, ...
- ▶ *Undef*: No definition of the variable is seen yet - nothing known!

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- ▶ *Undef* \Rightarrow *too few* definitions seen to declare anything about the variable
- ▶ \top is *Undef*; \perp is *NAC*

CP Meet \bigwedge

- ▶ Recall the requirement

$$\top \bigwedge x = x$$

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$$c_1 \wedge c_2 = \text{NAC} \text{ when } c_1 \neq c_2$$

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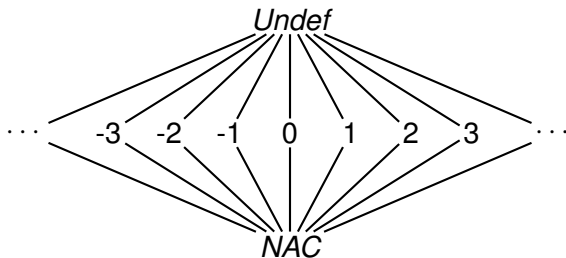
$$\text{Undef} \wedge c = c$$

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$$c \wedge c = c$$

CP Semilattice for an integer variable



- Infinite domain, but finite height

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- ▶ Previous figure was semilattice for one variable of one type
- ▶ CP Semilattice = Product of such lattices for all variables (of all types)
- ▶ Each semilattice has a **finite** height

Computing GEN

► Informal representation

Statement	GEN
$x = c$ // const	
$x = y + z$	
$x = \textit{complicated}$ \textit{expr}	

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► Informal representation

Statement	GEN
$x = c \text{ // const}$	$\{x \rightarrow c\}$
$x = y + z$	if $\{y \rightarrow c_1, z \rightarrow c_2\}$ in IN then $\{x \rightarrow c_1 + c_2\}$ else if $\{y \rightarrow NAC\}$ in IN then $\{x \rightarrow NAC\}$
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Computing GEN

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$x = \textit{complicated} \textit{expr}$	$\{x \rightarrow NAC\}$

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- ▶ Case analysis on transfer function f
- ▶ $NAC \leq c \leq Undef$
- ▶ $x = c$ has constant transfer function.
- ▶ $x = \textit{complicated expr}$ also has constant transfer function
- ▶ See the next slide for $x = y + z$ (and similar statements)

Monotonicity of CP: $x = y + z$

- Fix z to be one of *Undef*, c_2 , *NAC*

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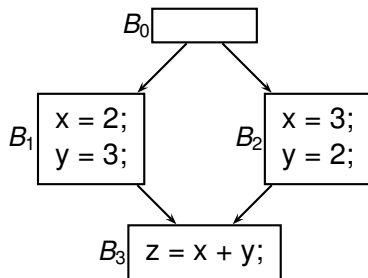
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- ▶ Do this for all z choices.

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- ▶ Do this for all z choices.
- ▶ Similarly, fix y and vary z .

Nondistributivity of CP

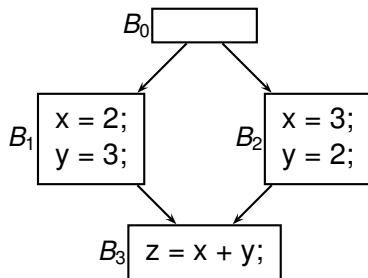
► All paths:



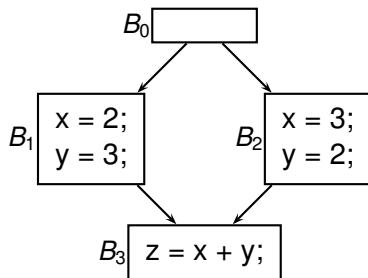
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► $B_0 \rightarrow B_1 \rightarrow B_3$



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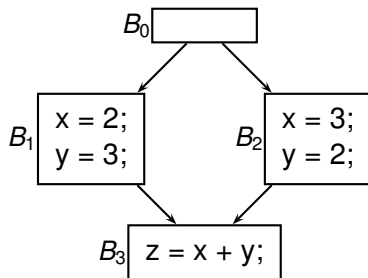


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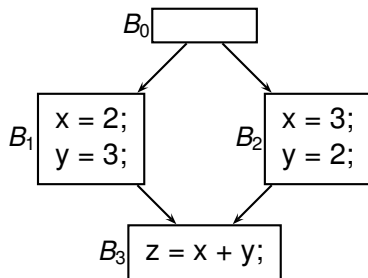
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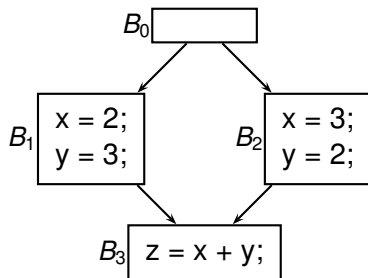
► Value of z is 5 along both the paths.

Nondistributivity of CP



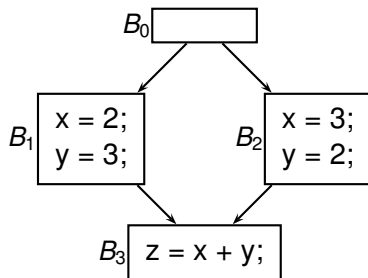
- ▶ All paths:
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- ▶ MOP value for z is 5.

Nondistributivity of CP



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- ▶ MFP value for z is *NAC*. (Exercise)

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- ▶ MOP value for z is 5.
- ▶ MFP value for z is *NAC*. (Exercise)
- ▶ MFP value \neq MOP value (MFP < MOP)