

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

- ▶ Domain
 - ▶ For a single variable v of type τ , all possible constants of type τ
- ▶ Semilattice
 - ▶ What is \wedge ?
 - ▶ What is \top ?
 - ▶ What is \perp ?

Special Values for CP

- ▶ *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!

NAC vs *Undef*

- ▶ *NAC* \Rightarrow *too many* definitions seen for a variable v to declare v is **NOT** a constant
- ▶ *Undef* \Rightarrow *too few* definitions seen to declare anything about the variable
- ▶ \top is *Undef*, \perp is *NAC*

CP Meet \wedge

- ▶ Recall the requirement

$$\top \wedge x = x$$

$$\perp \wedge x = \perp$$

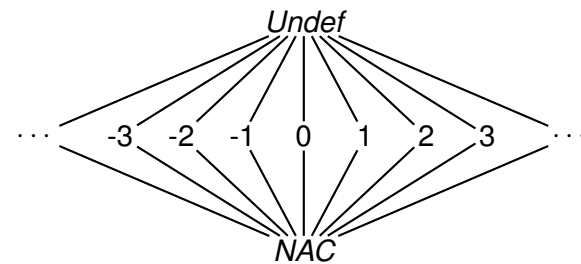
$$Undef \wedge c = c$$

$$NAC \wedge c = NAC$$

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

$$c \wedge c = c$$

CP Semilattice for an integer variable



- ▶ Infinite domain, but finite height

CP Semilattice

- ▶ 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
$x = c \text{ // const}$	$\{x \rightarrow c\}$
$x = y + z$	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 $\{x \rightarrow NAC\}$ else if $\{z \rightarrow NAC\}$ in IN then $\{x \rightarrow NAC\}$ else $\{x \rightarrow Undef\}$
$x = \text{complicated expr}$	$\{x \rightarrow NAC\}$

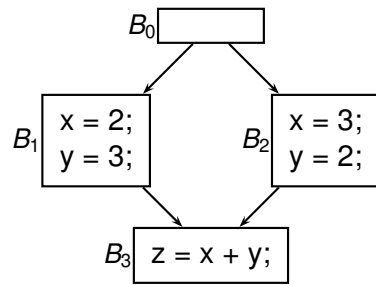
Monotonicity of CP

- ▶ Case analysis on transfer function f
- ▶ $NAC \leq c \leq Undef$
- ▶ $x = c$ has constant transfer function.
- ▶ $x = \text{complicated expr}$ 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 $Undef, c_2, NAC$
- ▶ Vary y over $Undef, c_1, NAC$
- ▶ Confirm that x does not “increase”
- ▶ Do this for all z choices.
- ▶ Similarly, fix y and vary z .

Nondistributivity of CP



- ▶ All paths:
 - ▶ $B_0 \rightarrow B_1 \rightarrow B_3$
 - ▶ $B_0 \rightarrow B_2 \rightarrow B_3$
- ▶ Value of z is 5 along both the paths.
- ▶ MOP value for z is 5.
- ▶ MFP value for z is *NAC*. (Exercise)
- ▶ MFP value \neq MOP value (MFP < MOP)