CS738: Advanced Compiler Optimizations

Constant Propagation

Amey Karkare

karkare@cse.iitk.ac.in

http://www.cse.iitk.ac.in/~karkare/cs738
Department of CSE, IIT Kanpur

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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- ▶ Semilattice
  - ▶ What is $\bigwedge$?

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  - What is $\top$?

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  - What is $\bot$?

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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!

- ► *NAC* ⇒ *too many* definitions seen for a variable *v* to declare *v* is **NOT** a constant

NAC vs Undef

- *NAC* ⇒ *too many* definitions seen for a variable *v* to declare *v* is **NOT** a constant
- *Undef* ⇒ *too few* definitions seen to declare anything about the variable

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*; $\bot$ is *NAC*

CP Meet $\bigwedge$

- Recall the requirement

$$\top \bigwedge x = x$$

$$\bot \bigwedge x = \bot$$

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Undef $\bigwedge c = c$

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$c_1 \bigwedge c_2 = NAC$ when $c_1 \neq c_2$

CP Meet $\bigwedge$

- Recall the requirement

$$\top \bigwedge x = x$$

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$Undef \bigwedge c = c$

$NAC \bigwedge c = NAC$

$c_1 \bigwedge c_2 = NAC$ when $c_1 \neq c_2$

$c \bigwedge c = c$

CP Semilattice for an integer variable
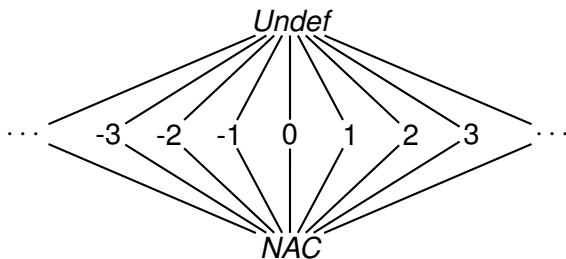
- Infinite domain, but finite height

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- ▶ 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 = $ complicated expr	

Computing GEN

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Computing GEN

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Statement	GEN
$x = c$ // const	$\{x \rightarrow c\}$
$x = y + z$	if $\{y \rightarrow c_1, z \rightarrow c_2\}$ in IN then $\{x \rightarrow c_1 + c_2\}$
$x = complicated\ expr$	

Computing GEN

▶ Informal representation

Statement	GEN
$x = c$ // 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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$x = complicated$ $expr$	

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

- ▶ Case analysis on transfer function *f*

Monotonicity of CP

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- ▶ *NAC* $\leq c \leq$ *Undef*
- ▶ $x = c$ has constant transfer function.

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- ▶ *NAC* ≤ *c* ≤ *Undef*
- ▶ *x* = *c* has constant transfer function.
- ▶ *x* = *complicated expr* also has constant transfer function

Monotonicity of CP

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

Monotonicity of CP: $x = y + z$

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- ▶ 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
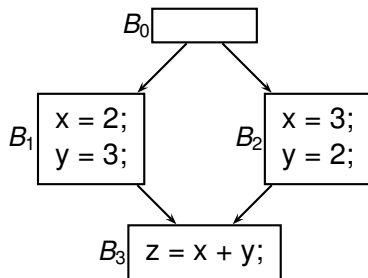
▶ All paths:

Nondistributivity of CP
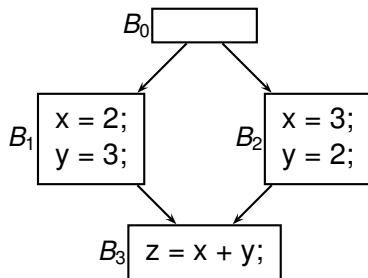
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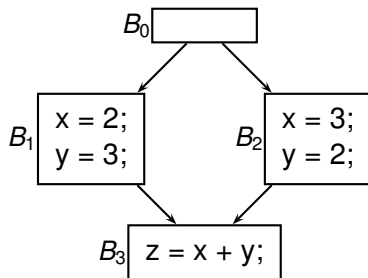   - $B_0 \rightarrow B_1 \rightarrow B_3$

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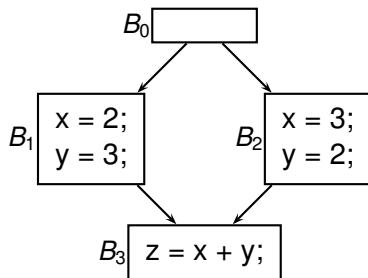
- All paths:
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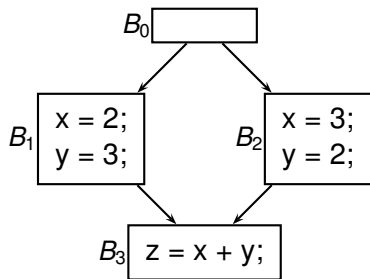
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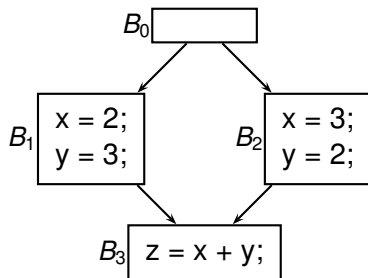 - $B_0 \rightarrow B_2 \rightarrow B_3$
- Value of z is 5 along both the paths.

Nondistributivity of CP
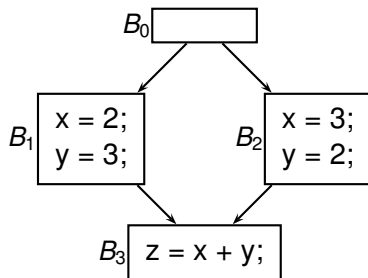

- All paths:
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- MOP value for z is 5.

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    - $B_0 \to B_2 \to B_3$
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- MOP value for z is 5.
- MFP value for z is *NAC*. (Exercise)

Nondistributivity of CP

- ▶ All paths:
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    - ▶ $B_0 \to B_2 \to B_3$
- ▶ 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)