COSE312: Compilers

Lecture 17 — Data-Flow Analysis (3)

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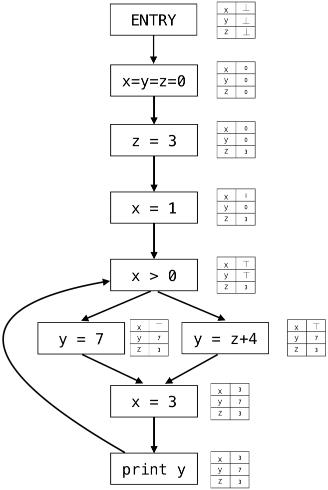
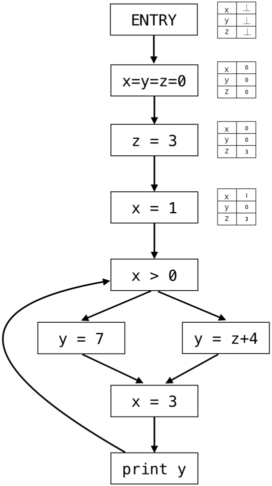
Constant Propagation Analysis

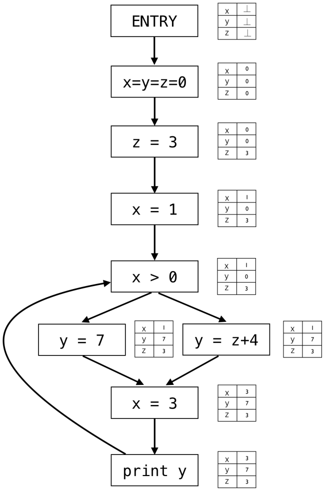
For each program point, determine whether a variable has a constant value whenever execution reaches that point.



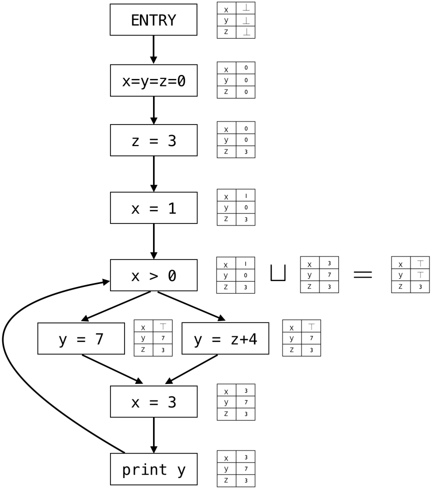
How It Works (1)



How It Works (2)



How It Works (3)

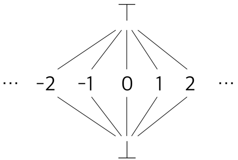


Abstract Domain

- Each variable is associated with an abstract value:

$$\begin{array}{rcl} \mathbb{D} & = & \mathbf{\mathit{Var}} \rightarrow \mathbb{C} \\ \mathbb{C} & = & \{\ldots, -2, -1, 0, 1, 2, \ldots\} \cup \{\bot, \top\} \end{array}$$

- The elements in $\mathbb{C}$ are partially ordered (i.e., $\mathbb{C}$ is a *poset*):



$$\forall c_1, c_2 \in \mathbb{C}.\ c_1 \sqsubseteq c_2 \text{ iff } c_1 = \bot \ \vee\ c_2 = \top \ \vee\ c_1 = c_2$$

- The elements in $\mathbb{D}$ are also partially ordered:

$$\forall d_1, d_2 \in \mathbb{D}.\ d_1 \sqsubseteq d_2 \text{ iff } \forall x \in \mathit{Var}.\ d_1(x) \sqsubseteq d_2(x)$$

Abstract Domain

- The *join* between domain elements:

$$c_1 \sqcup c_2 = \begin{cases} c_2 & c_1 = \bot \\ c_1 & c_2 = \bot \\ c_1 & c_1 = c_2 \\ \top & \text{o.w.} \end{cases}$$

$$d_1 \sqcup d_2 = \lambda x \in Var.\ d_1(x) \sqcup d_2(x)$$

Transfer Functions

Transfer functions model the program execution in terms of the abstract domain:

- Transfer function for $z = 3$:

$$\lambda d \in \mathbb{D}.\ [z \mapsto 3]d$$

- Transfer function for $x > 0$:

$$\lambda d \in \mathbb{D}.\ d$$

- Transfer function for $y = z + 4$:

$$\lambda d \in \mathbb{D}.\ \begin{cases} \bot & d(z) = \bot \\ \top & d(z) = \top \\ d(z) + 4 & \text{o.w.} \end{cases}$$

Constant Propagation Analysis

Final outcome:

$$\textbf{out} : Block \rightarrow (Var \rightarrow \mathbb{C})$$

Equation:

$$\begin{array}{rcl} \textbf{out}(ENTRY) & = & \lambda x.\ \bot \\ \textbf{out}(B) & = & f_B(\bigsqcup_{P \hookrightarrow B} \textbf{out}(P)) \end{array}$$

Fixed point algorithm:

For all $i, \textbf{out}(B_i) = \emptyset$
while (changes to any **out** occur) {
   For all i, update
      $\textbf{out}(B_i) = f_{B_i}(\bigsqcup_{P \hookrightarrow B_i} \textbf{out}(P))$
}