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HW4

1. Abstract Domain A (+, -, 0)
   Concrete Domain D: INT
   Variable ‘x’:
   - If x is negative ($x < 0$): it belongs to the abstract domain ‘-‘
   - If x is zero ($x == 0$): it belongs to the abstract domain ‘0’
   - If x is positive ($x > 0$): it belongs to the abstract domain ‘+’
   Variable y:
   - If y is negative ($y < 0$): it belongs to the abstract domain ‘-‘
   - If y is zero ($y == 0$): it belongs to the abstract domain ‘0’
   - If y is positive ($y > 0$): it belongs to the abstract domain ‘+’
   Variable a:
   - If both x and y are in abstract domain ‘-‘, a will be in ‘-‘
   - If either x or y (or both) are in abstract domain ‘+’, a will be in ‘+’
   - When x and y are both in abstract domain ‘0’, a will be in ‘0’
   - When x is in ‘0’ or when y is in ‘0’, a will be in ‘0’
2. e = i | e * e | e + e | e < e
   μ: Exp → Int

   $\mu(i) = i$
   $\mu(e_1 * e_2) = \mu(e_1) \times \mu(e_2)$
   $\mu(e_1 + e_2) = \mu(e_1) + \mu(e_2)$

   σ: Exp → {+,-,0}

   $\sigma(i) = (+ \text{ if } i > 0$
   $0 \text{ if } i = 0$
   $- \text{ if } i < 0)$
   $\sigma(e_1 * e_2) = \sigma(e_1)\ \bar{x}\ \sigma(e_2)$
   $\sigma(e_1 + e_2) = \sigma(e_1) \mp \sigma(e_2)$

x̄	+	0	-
+	+	0	-
0	0	0	0
-	-	0	+

γ(T) = Int

∓	+	0	-	T
+	+	+	T	T
0	+	0	-	T
-	T	-	-	T
T	T	T	T	T

μ: Exp → Bool

   $\mu(e1 < e2) = 1$ if $\mu(e1) < \mu(e2)$
   $\mu(e1 < e2) = 0$ if $\mu(e1) >= \mu(e2)$

σ: Exp → {+,-,0}

   $\sigma(e1 < e2) = (+$ if $= 1$, 0 if $= 0)$

3. The results will depend on the input value of x and y in the concrete domain.

   1: int func(int x, int y){

   2: int a

   $\mu(a) = 0$

   $\sigma(a) = 0$

   3: if (x < 0){

   If $\sigma(x) =$ '-', then $x < 0$ (negative).

   If $\sigma(x) =$ '0', then $x == 0$ (zero).

   If $\sigma(x) =$ '+', then $x > 0$ (positive).

   4: if (y < 0){

   If $\sigma(y) =$ '-', then $y < 0$ (negative).

   If $\sigma(y) =$ '0', then $y == 0$ (zero).

   If $\sigma(y) =$ '+', then $y > 0$ (positive).

   5: a = x

   $\mu(a) = \mu(x)$

   $\sigma(a) = \sigma(x)$

   6: a = a * y

   $\mu(a) = \mu(a) \times \mu(y)$

   $\sigma(a) = \sigma(a) \bar{x} \sigma(y)$

   7: a = a + 1

   $\mu(a) = \mu(a) + 1$

   $\sigma(a) = \sigma(a) \mp \sigma(1)$

   8: } else {

   $\sigma(y) =$ '+'

   9: a = 2

   $\mu(a) = 2$

   $\sigma(a) =$ '+'

   10: }

   11: } else {

   $\sigma(x) =$ '+'

   12: a = 2

   $\mu(a) = 2$

   $\sigma(a) =$ '+'

   13: }

   14: return a

   $\mu(return) = \mu(a)$

   $\sigma(return) = \sigma(a)$

4. Based on the analysis of the abstract domains and abstract semantics applied to the function, the property appears to hold for all possible inputs of x and y. The property characterizes how the sign of a is determined based on the signs of x and y, and it correctly accounts for various input scenarios.