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Homework 1

Problem 1

$\text{gen}(B1) = \{(a, 1), (b, 2)\}$

$\text{kill}(B1) = \{\}$

$\text{in}(B1) = \{\}$

$\text{out}(B1) = \{(a, 1), (b, 2)\}$

$\text{gen}(B2) = \{(c, 3), (d, 4)\}$

$\text{kill}(B2) = \{(d, 5)\}$

$\text{in}(B2) = \{(a, 1), (b, 2), (b, 8), (d, 5), (e, 9)\}$

$\text{out}(B2) = \{(a, 1), (b, 2), (b, 8), (c, 3), (d, 4), (e, 9)\}$

$\text{gen}(B3) = \{(d, 5)\}$

$\text{kill}(B3) = \{(d, 4), (d, 6)\}$

$\text{in}(B3) = \{(a, 1), (b, 2), (b, 8), (c, 3), (d, 4), (d, 6), (e, 7), (e, 9)\}$

$\text{out}(B3) = \{(a, 1), (b, 2), (b, 8), (c, 3), (d, 5), (e, 7), (e, 9)\}$

$\text{gen}(B4) = \{(d, 6), (e, 7)\}$

$\text{kill}(B4) = \{(d, 5), (e, 9)\}$

$\text{in}(B4) = \{(a, 1), (b, 2), (b, 8), (c, 3), (d, 5), (e, 7), (e, 9)\}$

$\text{out}(B4) = \{(a, 1), (b, 2), (b, 8), (c, 3), (d, 6), (e, 7)\}$

$\text{gen}(B5) = \{(b, 8), (e, 9)\}$

$\text{kill}(B5) = \{(b, 2), (e, 7)\}$

$\text{in}(B5) = \{(a, 1), (b, 2), (b, 8), (c, 3), (d, 5), (e, 7), (e, 9)\}$

$\text{out}(B5) = \{(a, 1), (b, 8), (c, 3), (d, 5), (e, 9)\}$

$\text{gen}(B6) = \{(a, 10), (b, 11)\}$

$\text{kill}(B6) = \{(a, 1), (b, 8)\}$

$\text{in}(B6) = \{(a, 1), (b, 8), (c, 3), (d, 5), (e, 9)\}$

$\text{out}(B6) = \{(a, 10), (b, 11), (c, 3), (d, 5), (e, 9)\}$

Problem 2

$\text{gen}(B1) = \{\}$

$\text{kill}(B1) = \{\}$

$\text{in}(B1) = \{\}$

$\text{out}(B1) = \{\}$

$\text{gen}(B2) = \{(a+b), (c-a)\}$

$\text{kill}(B2) = \{\}$

$\text{in}(B2) = \{\}$

$\text{out}(B2) = \{(a+b), (c-a)\}$

$\text{gen}(B3) = \{(b+d)\}$

$\text{kill}(B3) = \{(b+d)\}$

$\text{in}(B3) = \{(a+b)\}$

$\text{out}(B3) = \{(a+b)\}$

$\text{gen}(B4) = \{(a+b), (e+1)\}$

$\text{kill}(B4) = \{(e+1)\}$

$\text{in}(B4) = \{(a+b)\}$

$\text{out}(B4) = \{(a+b)\}$

$\text{gen}(B5) = \{(a+b), (c-a)\}$

$\text{kill}(B5) = \{(a+b)\}$

$\text{in}(B5) = \{(a+b)\}$

$\text{out}(B5) = \{(c-a)\}$

$\text{gen}(B6) = \{(b*d), (a-d)\}$

$\text{kill}(B6) = \{(c-a), (b*d)\}$

$\text{in}(B6) = \{(c-a)\}$

$\text{out}(B6) = \{(a-d)\}$

Problem 3

$\text{gen}(B1) = \{\}$

$\text{kill}(B1) = \{a, b\}$

$\text{in}(B1) = \{\}$

$\text{out}(B1) = \{a, b\}$

$\text{gen}(B2) = \{a, b, c\}$

$\text{kill}(B2) = \{c, d\}$

$\text{in}(B2) = \{a, b\}$

$\text{out}(B2) = \{a, b, c\}$

$\text{gen}(B3) = \{b, d\}$

$\text{kill}(B3) = \{d\}$

$\text{in}(B3) = \{a, b, c\}$

$\text{out}(B3) = \{a, b, c, d\}$

$\text{gen}(B4) = \{a, b, e\}$

$\text{kill}(B4) = \{d, e\}$

$\text{in}(B4) = \{a, b, c\}$

$\text{out}(B4) = \{a, b, c\}$

$\text{gen}(B5) = \{a, c\}$

$\text{kill}(B5) = \{b\}$

$\text{in}(B5) = \{a, c, d\}$

$\text{out}(B5) = \{b, d\}$

$\text{gen}(B6) = \{a, b, d\}$

$\text{kill}(B6) = \{a\}$

$\text{in}(B6) = \{b, d\}$

$\text{out}(B6) = \{\}$

Problem 4

a) No. Because if we find the addition of $(a+ib)$ and $(a+ib)$ it does not result in $(a+ib)$. And the meet of x and x should result in x .

b) No. Because if we find the multiplication of $(a+ib)$ and $(a+ib)$ it does not result in $(a+ib)$. And the meet of x and x should result in x .

c) Yes

d) Yes

Problem 5

(a) The property set is the lattice of all subsets of the variables in the problem. As it is a must problem, \leq is the superset operation.

Merge is the intersection operator. $\text{out}(j) = \{\cap \text{in}(i), i \text{ is successor of } j\}$

Transfer functions: $\text{in}(j) = \text{gen}(j) \cup (\text{out}(j) - \text{kill}(j))$

For the expression, $j: x=y+z$, $\text{gen}(j)=\{x\}$, $\text{kill}(j)=\{\}$

(b) Yes, the functions are distributive and monotone. Proof:

$$f(X \vee Y)$$

$$= \text{gen}(j) \cup ((X \cap Y) \cap \text{pres}(j))$$

$$= (\text{gen}(j) \cup (X \cap \text{pres}(j))) \cap (\text{gen}(j) \cup (Y \cap \text{pres}(j)))$$

$$f(X) \vee f(Y)$$

$$= ((X \cap \text{pres}(j)) \cup \text{gen}(j)) \cap ((Y \cap \text{pres}(j)) \cup \text{gen}(j))$$

As, $f(X \vee Y) = f(X) \vee f(Y)$, the transfer function is distributive. And all distributive functions are monotone.

Problem 6

(a) The four classical dataflow analyses are bit vector dataflow analyses because they satisfies the two conditions as below:

1. The property space of the analyses are finite. As they are subsets of the universal set of reaching definitions, variables or expressions. They are related by subset or superset depending on whether they are must/may problems.

2. The transfer functions of all the analyses contain $\text{in}(j)$, $\text{out}(j)$, $\text{kill}(j)$ and $\text{gen}(j)$. Here $\text{kill}(j)$ and $\text{gen}(j)$ are the constants that do not depend on the $\text{in}()$ or $\text{out}()$. Thus the $\text{kill}(j)$ and $\text{gen}(j)$ are the constants Y_f^1 and Y_f^2 . Y the argument of the function is $\text{in}(j)$ in forward problems and $\text{out}(j)$ in backward problems.

Thus, they are bit vector dataflow analyses.

