Dataflow Analysis Assignment

Very Busy Expression

	Dataflow Problem X
Domain	Sets of Expression
Direction	Backward: in[b] = f_b(out[b]) out[b] = ∧ in(succ[b])
Transfer function	$f_b(x) = Gen_b \cup (x - Kill_b)$
Meet Operation (∧)	∩
Boundary Condition	out[exit] = ∅
Initial interior points	in[b] = U

Iterazione 1

OUT[BB_8] = $\emptyset$

IN[BB_8] = Gen_{BB_8} ∪ (OUT[BB_8] - $Kill_{BB_8}$) = $\emptyset \cup (\emptyset - \emptyset) = \emptyset$

OUT[BB_7] = IN[BB_8] = $\emptyset$

IN[BB_7] = Gen_{BB_7} ∪ (OUT[BB_7] - $Kill_{BB_7}$) = $\{a-b\} \cup (\emptyset - \emptyset) = \{a-b\}$

OUT[BB_6] = IN[BB_7] = $\{a-b\}$

IN[BB_6] = Gen_{BB_6} ∪ (OUT[BB_6] - $Kill_{BB_6}$) = $\emptyset \cup (\{a-b\} - \{a-b\}) = \emptyset$

OUT[BB_5] = IN[BB_6] = $\emptyset$

IN[BB_5] = Gen_{BB_5} ∪ (OUT[BB_5] - $Kill_{BB_5}$) = $\{b-a\} \cup (\emptyset - \emptyset) = \{b-a\}$

OUT[BB_4] = IN[BB_8] = $\emptyset$

IN[BB_4] = Gen_{BB_4} ∪ (OUT[BB_4] - $Kill_{BB_4}$) = $\{a-b\} \cup (\emptyset - \emptyset) = \{a-b\}$

OUT[BB_3] = IN[BB_4] = $\{a-b\}$

IN[BB_3] = Gen_{BB_3} ∪ (OUT[BB_3] - $Kill_{BB_3}$) = $\{b-a\} \cup (\{a-b\} - \emptyset) = \{a-b,\ b-a\}$

OUT[BB_2] = IN[BB_3] ∩ IN[BB_5]= $\{a-b,\ b-a\} \cap \{b-a\} = \{b-a\}$

IN[BB_2] = Gen_{BB_2} ∪ (OUT[BB_2] - $Kill_{BB_2}$) = $\emptyset \cup (\{b-a\} - \emptyset) = \{b-a\}$

OUT[BB_1] = IN[BB_2] = $\{b-a\}$

IN[BB_1] = Gen_{BB_1} ∪ (OUT[BB_1] - $Kill_{BB_1}$) = $\emptyset \cup (\{b-a\} - \emptyset) = \{b-a\}$

BitVector = <b-a, a-b>

	Iterazione 1	
	IN[B]	OUT[B]
BB1	<10>	<10>
BB2	<10>	<10>
BB3	<11>	<01>
BB4	<01>	<00>
BB5	<10>	<00>
BB6	<00>	<01>
BB7	<01>	<00>
BB8	<00>	<00>

Dominator Analysis

	Dataflow Problem X
Domain	Sets of Basic Blocks
Direction	Forward: out[b] = f_b(in[b]) in[b] = ∧ out(pred[b])
Transfer function	f_b(x) = b ∪ x
Meet Operation (∧)	∩
Boundary Condition	in[entry] = ∅
Initial interior points	out[b] = U

Iterazione 1

IN$[A]$ = ∅

OUT$[A]$ = {A} ∪ ∅ = {A}

IN$[B]$ = OUT$[A]$ ={A}

OUT$[B]$ = {B} ∪ {A} = {A, B}

IN$[C]$ = OUT$[A]$ = {A}

OUT$[C]$ = {C} ∪ {A} = {A, C}

IN$[D]$ = OUT$[C]$ = {A, C}

OUT$[D]$ = {D} ∪ {A, C} = {A, C, D}

IN$[E]$ = OUT$[C]$ = {A, C}

OUT$[E]$ = {E} ∪ {A, C} = {A, C, E}

IN$[F]$ = OUT$[D]$ ∩ OUT$[E]$= {A, C, D} ∩ {A, C, E} = {A, C}

OUT$[F]$ = {F} ∪ {A, C} = {A, C, F}

IN$[G]$ = OUT$[B]$ ∩ OUT$[F]$= {A, B} ∩ {A, C, F} = {A}

OUT$[G]$ = {G} ∪ {A} = {A, G}

BitVector = <A,B,C,D,E,F,G>

	Iterazione 1	
	IN[B]	OUT[B]
A	<0000000>	<1000000>
B	<1000000>	<1100000>
C	<1000000>	<1010000>
D	<1010000>	<1011000>
E	<1010000>	<1010100>
F	<1010000>	<1010010>
G	<1000000>	<1000001>

Constant Propagation

	Dataflow Problem X
Domain	Sets of Pairs (variable, costant)
Direction	Forward: out[b] = f_b(in[b]) in[b] = $\wedge$ out(pred[b])
Transfer function	$f_b(x) = Gen_b \cup (x - Kill_b)$
Meet Operation ($\wedge$)	$\cap$
Boundary Condition	in[entry] = $\emptyset$
Initial interior points	out[b] = U

Iterazione 1

IN[BB_1] = Ø

OUT[BB_1] = Gen_{BB_1} ∪ (IN[BB_1] - $Kill_{BB_1}$) = Ø ∪ $(\emptyset - \emptyset) = \emptyset$

IN[BB_2] = Ø

OUT[BB_2] = Gen_{BB_2} ∪ (IN[BB_2] - $Kill_{BB_2}$) = Ø ∪ $(\{(k,2)\} - \emptyset) = \{(k,2)\}$

IN[BB_3] = OUT[BB_2] = $\{(k,2)\}$

OUT[BB_3] = Gen_{BB_3} ∪ (IN[BB_3] - $Kill_{BB_3}$) = Ø ∪ $(\{(k,2)\} - \emptyset) = \{(k,2)\}$

IN[BB_4] = OUT[BB_3] = $\{(k,2)\}$

OUT[BB_4] = Gen_{BB_4} ∪ (IN[BB_4] - $Kill_{BB_4}$) = $\{(a,4)\} \cup (\{(k,2)\} - \emptyset) = \{(k,2),(a,4)\}$

IN[BB_5] = OUT[BB_4] = $\{(k,2),(a,4)\}$

OUT[BB_5] = Gen_{BB_5} ∪ (IN[BB_5] - $Kill_{BB_5}$) = $\{(x,5)\} \cup (\{(k,2),(a,4)\} - \emptyset) = \{(k,2),(a,4),(x,5)\}$

IN[BB_6] = OUT[BB_3] = $\{(k,2)\}$

OUT[BB_6] = Gen_{BB_6} ∪ (IN[BB_6] - $Kill_{BB_6}$) = $\{(a,4)\} \cup (\{(k,2)\} - \emptyset) = \{(k,2),(a,4)\}$

IN[BB_7] = OUT[BB_6] = $\{(k,2),(a,4)\}$

OUT[BB_7] = Gen_{BB_7} ∪ (IN[BB_7] - $Kill_{BB_7}$) = $\{(x,8)\} \cup (\{(k,2),(a,4)\} - \emptyset) = \{(k,2),(a,4),(x,8)\}$

IN[BB_8] = OUT[BB_5] ∩ OUT[BB_7] = $\{(k,2),(a,4),(x,5)\} \cap \{(k,2),(a,4),(x,8)\} = \{(k,2),(a,4)\}$

OUT[BB_8] = Gen_{BB_8} ∪ (IN[BB_8] - $Kill_{BB_8}$) = $\{(k,4)\} \cup (\{(k,2),(a,4)\} - \{(k,2)\}) = \{(k,4),(a,4)\}$

IN[BB_9] = OUT[BB_8] ∩ OUT[BB_{13}] =$\{(k,4),(a,4)\} \cap U = \{(k,4),(a,4)\}$

OUT[BB_9] = Gen_{BB_9} ∪ (IN[BB_9] - $Kill_{BB_9}$) = Ø ∪ $(\{(k,4),(a,4)\} - \emptyset) = \{(k,4),(a,4)\}$

IN[BB_{10}] = OUT[BB_9] = $\{(k,4),(a,4)\}$

OUT[BB_{10}] = $Gen_{BB_{10}}$ ∪ (IN[BB_{10}] - $Kill_{BB_{10}}$) = $\{(b,2)\} \cup (\{(k,4),(a,4)\} - \emptyset) = \{(k,4),(a,4),(b,2)\}$

IN[BB_{11}] = OUT[BB_{10}] = $\{(k,4),(a,4),(b,2)\}$

OUT[BB_{11}] = $Gen_{BB_{10}}$ ∪ (IN[BB_{10}] - $Kill_{BB_{10}}$) = $\{(x,8)\} \cup (\{(k,4),(a,4),(b,2)\} - \emptyset) = \{(k,4),(a,4),(b,2),(x,8)\}$

IN[BB_{12}] = OUT[BB_{11}] = $\{(k,4),(a,4),(b,2),(x,8)\}$

OUT[BB_{12}] = $Gen_{BB_{12}}$ ∪ (IN[BB_{12}] - $Kill_{BB_{12}}$) = $\{(y,8)\} \cup (\{(k,4),(a,4),(b,2),(x,8)\} - \emptyset) = \{(k,4),(a,4),(b,2),(x,8),(y,8)\}$

IN[BB_{13}] = OUT[BB_{12}] = $\{(k,4),(a,4),(b,2),(x,8),(y,8)\}$

OUT[BB_{13}] = $Gen_{BB_{13}}$ ∪ (IN[BB_{13}] - $Kill_{BB_{13}}$) = $\{(k,5)\} \cup (\{(k,4),(a,4),(b,2),(x,8)\} - \{(k,4)\}) = \{(k,5),(a,4),(b,2),(x,8),(y,8)\}$

IN[BB_{14}] = OUT[BB_9] = $\{(k,4),(a,4)\}$

OUT[BB_{14}] = $Gen_{BB_{14}}$ ∪ (IN[BB_{14}] - $Kill_{BB_{14}}$) = Ø ∪ $(\{(k,4),(a,4)\} - \emptyset) = \{(k,4),(a,4)\}$

IN[BB_{15}] = OUT[BB_{14}] = $\{(k,4),(a,4)\}$

OUT[BB_{15}] = $Gen_{BB_{15}}$ ∪ (IN[BB_{15}] - $Kill_{BB_{15}}$) = Ø ∪ $(\{(k,4),(a,4)\} - \emptyset) = \{(k,4),(a,4)\}$

Iterazione 2

IN[BB_1] = Ø

OUT[BB_1] = Ø

IN[BB_2] = Ø

OUT[BB_2] = $\{(k,2)\}$

IN[BB_3] = $\{(k,2)\}$

OUT[BB_3] = $\{(k,2)\}$

IN[BB_4] = $\{(k,2)\}$

OUT[BB_4] = $\{(k,2),(a,4)\}$

IN[BB_5] = $\{(k,2),(a,4)\}$

OUT[BB_5] = $\{(k,2),(a,4),(x,5)\}$

IN[BB_6] = $\{(k,2)\}$

OUT[BB_6] = $\{(k,2),(a,4)\}$

IN[BB_7] = $\{(k,2),(a,4)\}$

OUT[BB_7] = $\{(k,2),(a,4),(x,8)\}$

IN[BB_8] = $\{(k,2),(a,4)\}$

OUT[BB_8] = $\{(k,4),(a,4)\}$

IN[BB_9] = OUT[BB_8] ∩ OUT[BB_{13}] =$\{(k,4),(a,4)\} \cap \{(k,5),(a,4),(b,2),(x,8),(y,8)\} = \{(a,4)\}$

OUT[BB_9] = Gen_{BB_9} ∪ (IN[BB_9] - $Kill_{BB_9}$) = $\emptyset \cup (\{(a,4)\} - \emptyset) = \{(a,4)\}$

IN[BB_{10}] = OUT[BB_9] = $\{(a,4)\}$

OUT[BB_{10}] = $Gen_{BB_{10}}$ ∪ (IN[BB_{10}] - $Kill_{BB_{10}}$) = $\{(b,2)\} \cup (\{(a,4)\} - \emptyset) = \{(a,4),(b,2)\}$

IN[BB_{11}] = OUT[BB_{10}] = $\{(a,4),(b,2)\}$

OUT[BB_{11}] = $Gen_{BB_{10}}$ ∪ (IN[BB_{10}] - $Kill_{BB_{10}}$) = $\emptyset \cup (\{(a,4),(b,2)\} - \emptyset) = \{(a,4),(b,2)\}$

IN[BB_{12}] = OUT[BB_{11}] = $\{(a,4),(b,2)\}$

OUT[BB_{12}] = $Gen_{BB_{12}}$ ∪ (IN[BB_{12}] - $Kill_{BB_{12}}$) = $\{(y,8)\} \cup (\{(a,4),(b,2)\} - \emptyset) = \{(a,4),(b,2),(y,8)\}$

IN[BB_{13}] = OUT[BB_{12}] = $\{(a,4),(b,2),(y,8)\}$

OUT[BB_{13}] = $Gen_{BB_{13}}$ ∪ (IN[BB_{13}] - $Kill_{BB_{13}}$) = $\emptyset \cup (\{(a,4),(b,2),(y,8)\} - \emptyset) = \{(a,4),(b,2),(y,8)\}$

IN[BB_{14}] = OUT[BB_9] = $\{(a,4)\}$

OUT[BB_{14}] = $Gen_{BB_{14}}$ ∪ (IN[BB_{14}] - $Kill_{BB_{14}}$) = $\emptyset \cup (\{(a,4)\} - \emptyset) = \{(a,4)\}$

IN[BB_{15}] = OUT[BB_{14}] = $\{(a,4)\}$

OUT[BB_{15}] = $Gen_{BB_{15}}$ ∪ (IN[BB_{15}] - $Kill_{BB_{15}}$) = $\emptyset \cup (\{(a,4)\} - \emptyset) = \{(a,4)\}$

Iterazione 3

IN[BB_1] = Ø

OUT[BB_1] = Ø

IN[BB_2] = Ø

OUT[BB_2] = $\{(k, 2)\}$

IN[BB_3] = $\{(k, 2)\}$

OUT[BB_3] = $\{(k, 2)\}$

IN[BB_4] = $\{(k, 2)\}$

OUT[BB_4] = $\{(k, 2), (a, 4)\}$

IN[BB_5] = $\{(k, 2), (a, 4)\}$

OUT[BB_5] = $\{(k, 2), (a, 4), (x, 5)\}$

IN[BB_6] = $\{(k, 2)\}$

OUT[BB_6] = $\{(k, 2), (a, 4)\}$

IN[BB_7] = $\{(k, 2), (a, 4)\}$

OUT[BB_7] = $\{(k, 2), (a, 4), (x, 8)\}$

IN[BB_8] = $\{(k, 2), (a, 4)\}$

OUT[BB_8] = $\{(k, 4), (a, 4)\}$

IN[BB_9] = OUT[BB_8] ∩ OUT[BB_{13}] =$\{(k, 4), (a, 4)\} \cap \{(a, 4), (b, 2), (y, 8)\} = \{(a, 4)\}$

OUT[BB_9] = $\{(a, 4)\}$

IN[BB_{10}] = $\{(a, 4)\}$

OUT[BB_{10}] = $\{(a, 4), (b, 2)\}$

IN[BB_{11}] = $\{(a, 4), (b, 2)\}$

OUT[BB_{11}] =$\{(a, 4), (b, 2)\}$

IN[BB_{12}] = $\{(a, 4), (b, 2)\}$

OUT[BB_{12}] = $\{(a, 4), (b, 2), (y, 8)\}$

IN[BB_{13}] = $\{(a, 4), (b, 2), (y, 8)\}$

OUT[BB_{13}] = $\{(a, 4), (b, 2), (y, 8)\}$

IN[BB_{14}] = $\{(a, 4)\}$

OUT[BB_{14}] = $\{(a, 4)\}$

IN[BB_{15}] = OUT[BB_{14}] = $\{(a, 4)\}$

OUT[BB_{15}] = $Gen_{BB_{15}}$ ∪ (IN[BB_{15}] - $Kill_{BB_{15}}$) = Ø ∪ $(\{(a, 4)\} - \emptyset) = \{(a, 4)\}$

BitVector = <(a,4),(b,2),(k,2),(k,4),(k,5),(x,5),(x,8),(y,8)>

	Iterazione 1		Iterazione 2		Iterazione 3	
	IN[B]	OUT[B]	IN[B]	OUT[B]	IN[B]	OUT[B]
BB1	<00000000>	<00000000>	<00000000>	<00000000>	<00000000>	<00000000>
BB2	<00000000>	<00100000>	<00000000>	<00100000>	<00000000>	<00100000>
BB3	<00100000>	<00100000>	<00100000>	<00100000>	<00100000>	<00100000>
BB4	<00100000>	<10100000>	<00100000>	<10100000>	<00100000>	<10100000>
BB5	<10100000>	<10100100>	<10100000>	<10100100>	<10100000>	<10100100>
BB6	<00100000>	<10100000>	<00100000>	<10100000>	<00100000>	<10100000>
BB7	<10100000>	<10100010>	<10100000>	<10100010>	<10100000>	<10100010>
BB8	<10100000>	<10010000>	<10100000>	<10010000>	<10100000>	<10010000>
BB9	<10010000>	<10010000>	<10000000>	<10000000>	<10000000>	<10000000>
BB10	<10010000>	<11010000>	<10000000>	<11000000>	<10000000>	<11000000>
BB11	<11010000>	<11010010>	<11000000>	<11000000>	<11000000>	<11010000>
BB12	<11010010>	<11010011>	<11000000>	<11000001>	<11000000>	<11000001>
BB13	<11010011>	<11001011>	<11000001>	<11000001>	<11000001>	<11000001>
BB14	<10010000>	<10010000>	<10000000>	<10000000>	<10000000>	<10000000>
BB15	<10010000>	<10010000>	<10000000>	<10000000>	<10000000>	<10000000>