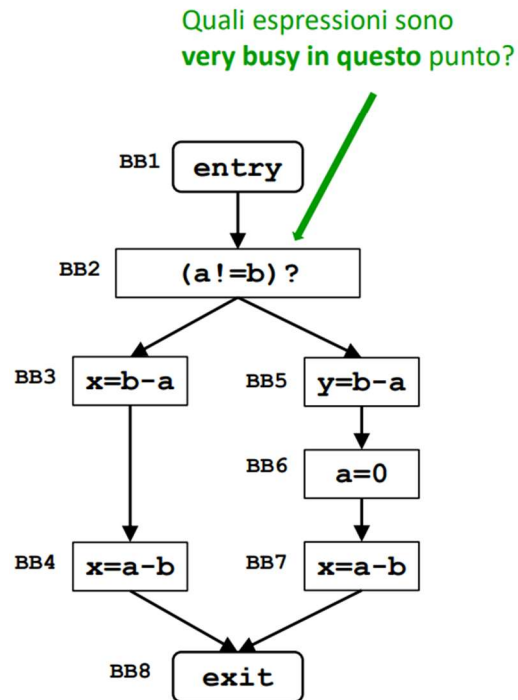


## Assignment 2 – Dataflow Analysis

## Very Busy Expressions

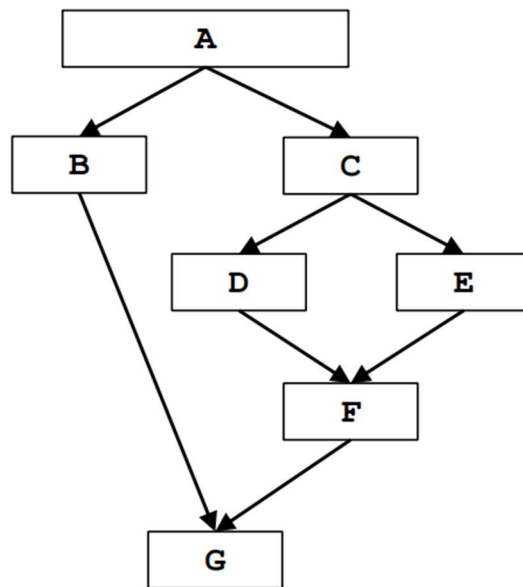


|                         | DataFlow Very Busy Expressions                           |
|-------------------------|--|
| Domain                  | L'insieme di tutte le espressioni $E = \{a-b, b-a\}$     |
| Direction               | Backward   |
| Transfer function       | $IN[BBi] = GEN[BBi] \cup (OUT[BBi] \setminus KILL[BBi])$ |
| Meet Operation          | Intersezione   |
| Boundary Condition      | $OUT[exit] = \emptyset$                                  |
| Initial interior points | $IN[BBi] = E; \forall BBi \neq exit$                     |

|     | Iterazione 1 |             |
|-----|--------------|-------------|
|     | IN[B]        | OUT[B]      |
| BB1 | {b-a}        | {b-a}       |
| BB2 | {b-a}        | {b-a}       |
| BB3 | {a-b, b-a}   | {a-b}       |
| BB4 | {a-b}        | $\emptyset$ |
| BB5 | {b-a}        | $\emptyset$ |
| BB6 | $\emptyset$  | {a-b}       |
| BB7 | {a-b}        | $\emptyset$ |
| BB8 | $\emptyset$  | $\emptyset$ |

L'unica very busy expression nel punto indicato è {b-a}

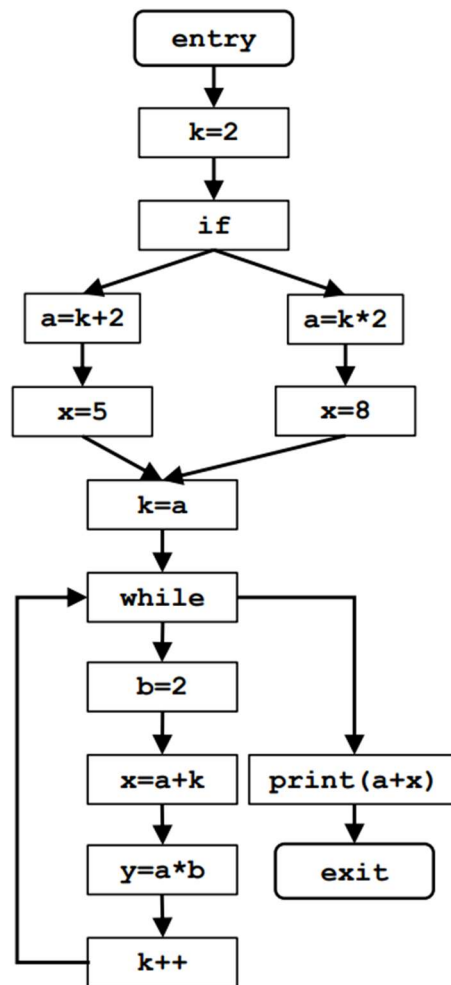
## Dominator Analysis



|                         | <b>DataFlow Dominators</b>  |
|-------------------------|---|
| Domain                  | L'insieme di tutti i basic blocks.  |
| Direction               | Forward   |
| Transfer function       | $OUT[BBi] = IN[BBi] \cup BBi$   |
| Meet Operation          | Intersezione  |
| Boundary Condition      | EntryPoint = A, $IN[A] = \emptyset$   |
| Initial interior points | $OUT[BBi] = \{\text{insieme di tutti i BB}\}$ , dove BBi è diverso dall'entry point |

|   | Iterazione 1 |           |
|---|--------------|-----------|
|   | IN[B]        | OUT[B]    |
| A | $\emptyset$  | {A}       |
| B | {A}          | {A, B}    |
| C | {A}          | {A, C}    |
| D | {A, C}       | {A, C, D} |
| E | {A, C}       | {A, C, E} |
| F | {A, C}       | {A, C, F} |
| G | {A}          | {A, G}    |

## Constant Propagation



|                         | <b>DataFlow Constant Propagation</b>  |
|-------------------------|---|
| Domain                  | L'insieme di coppie (v,c) dove v sono tutte le variabili (k, a, x, b, y) e c è o un valore del dominio della variabile o il simbolo ? |
| Direction               | Forward   |
| Transfer function       | $IN[BBi] = GEN[BBi] \cup (OUT[BBi] \setminus KILL[BBi])$  |
| Meet Operation          | Intersezione (dove intersecare due elementi (v0, c0), (v0, ?) ritorna (v0, ?)   |
| Boundary Condition      | $OUT[entry] = \emptyset$  |
| Initial interior points | Per tutti i blocchi diversi da entry, $OUT[BBi] = \text{tutto il dominio}$  |

|              |      | Iterazione 1                              |   | Iterazione 2                                |   | Iterazione 3             |        |
|--------------|------|---|---|---|---|--------------------------|--------|
|              |      | IN[B]                                     | OUT[B]                                    | IN[B]                                       | OUT[B]                                      | IN[B]                    | OUT[B] |
| "k=2"        | BB1  | $\emptyset$                               | { (k, 2) }                                |   |   |                          |        |
| "if"         | BB2  | {(k, 2) }                                 | { (k, 2) }                                |   |   |                          |        |
| "a=k+2"      | BB3  | { (k, 2) }                                | {(a,4), (k, 2)}                           |   |   |                          |        |
| "x=5"        | BB4  | {(a,4), (k, 2) }                          | {(a,4), (k, 2),<br>(x,5) }                |   |   |                          |        |
| "a=k*2"      | BB5  | {(k, 2) }                                 | {(a,4), (k, 2)}                           |   |   |                          |        |
| "x=8"        | BB6  | {(a,4), (k, 2) }                          | {(a,4), (k, 2),<br>(x,8) }                |   |   |                          |        |
| "k=a"        | BB7  | {(a,4), (k, 2),<br><b>(x,?)</b> }         | {(a,4), <b>(k, 4)</b> ,<br>(x,?)}         |   |   |                          |        |
| "while"      | BB8  | {(a,4), (k, 4),<br>(x,?)}                 | {(a,4), (k, 4),<br>(x,?)}                 | {(a, 4), (k, ?), (x,<br>?)}                 | {(a, 4), (k, ?), (x,<br>?)}                 | {(a, 4), (k, ?), (x, ?)} |        |
| "b=2"        | BB9  | {(a,4), (k, 4),<br>(x,?)}                 | {(a,4), (b,2),<br>(k,4), (x,?)}           | {(a, 4), (k, ?), (x,<br>?)}                 | {(a, 4), (b, 2), (k,<br>?), (x, ?)}         |                          |        |
| "x=a+k"      | BB10 | {(a,4), (b,2),<br>(k,4), (x,?)}           | {(a,4), (b,2),<br>(k,4), (x,8)}           | {(a, 4), (b, 2), (k,<br>?), (x, ?)}         | {(a, 4), (b, 2), (k,<br>?), (x, ?)}         |                          |        |
| "y=a*b"      | BB11 | {(a,4), (b,2),<br>(k,4), (x,8)}           | {(a,4), (b,2),<br>(k,4), (x,8),<br>(y,8)} | {(a, 4), (b, 2), (k,<br>?), (x, ?)}         | {(a, 4), (b, 2), (k,<br>?), (x, ?), (y, 8)} |                          |        |
| "k++"        | BB12 | {(a,4), (b,2),<br>(k,4), (x,8),<br>(y,8)} | {(a,4), (b,2),<br>(k,5), (x,8),<br>(y,8)} | {(a, 4), (b, 2), (k,<br>?), (x, ?), (y, 8)} | {(a, 4), (b, 2), (k,<br>?), (x, ?), (y, 8)} |                          |        |
| "print(a+x)" | BB13 | {(a,4), (k,4),<br>(x, ?)}                 | {(a,4), (k,4), (x,<br>?)}                 | {(a, 4), (k, ?), (x,<br>?)}                 | {(a, 4), (k, ?), (x,<br>?)}                 |                          |        |
| "exit"       | BB14 | {(a,4), (k,4),<br>(x, ?)}                 | {(a,4), (k,4), (x,<br>?)}                 | {(a, 4), (k, ?), (x,<br>?)}                 | {(a, 4), (k, ?), (x,<br>?)}                 |                          |        |

L'algoritmo converge a partire dall'inizio della terza iterazione

OUT[entry] =  $\emptyset$

IN[BB1] =  $\emptyset$

OUT[BB1] = {(k,2)}

IN[BB2] = {(k,2)}

OUT[BB2] = {(k,2)}

IN[BB3] = {(k,2)}

OUT[BB3] = {(a,4), (k,2)}

IN[BB4] = OUT[BB3] = {(a,4), (k,2)}

OUT[BB4] = {(a,4), (k,2), (x,5)}

IN[BB5] = OUT[BB2] = {(k,2)}

OUT[BB5] = {(a,4), (k,2)}

IN[BB6] = OUT[BB5] = {(a,4), (k,2)}

OUT[BB6] = {(a,4), (k,2), (x,8)}

IN[BB7] = MEET(OUT[BB4], OUT[BB6]) = MEET( {(a,4), (k,2), (x,5)}, {(a,4), (k,2), (x,8)} ) = {(a,4), (k,2), (x, ?)}

OUT[BB7] = {(a,4), (k,4), (x, ?)}

IN[BB8] = MEET(OUT[BB7], OUT[BB12]) = {(a,4), (k,4), (x, ?)}

OUT[BB8] = {(a,4), (k,4), (x, ?)}

IN[BB9] = {(a,4), (k,4), (x, ?)}

OUT[BB9] = {(a,4), (b,2), (k,4), (x,?)}

IN[BB10] = {(a,4), (b,2), (k,4), (x,?)}

OUT[BB10] = {(a,4), (b,2), (k,4), (x,8)}

IN[BB11] = {(a,4), (b,2), (k,4), (x,8)}

OUT[BB11] = {(a,4), (b,2), (k,4), (x,8), (y,8)}

IN[BB12] = {(a,4), (b,2), (k,4), (x,8), (y,8)}

OUT[BB12] = {(a,4), (b,2), (k,5), (x,8), (y,8)}

IN[BB13] = OUT[BB8] = {(a,4), (k,4), (x, ?)}

OUT[BB13] = {(a,4), (k,4), (x, ?)}

IN[BB14] = {(a,4), (k,4), (x, ?)}

OUT[BB14] = {(a,4), (k,4), (x, ?)}

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#### SECONDA ITERAZIONE

IN[BB8] = MEET( OUT[BB7], OUT[BB12] ) = MEET( {(a,4), (k,4), (x, ?)}, {(a,4), (b,2), (k,5), (x,8), (y,8)} ) = {(a, 4), (k, ?), (x, ?)}

OUT[BB8] = {(a, 4), (k, ?), (x, ?)}

IN[BB9] = {(a, 4), (k, ?), (x, ?)}

OUT[BB9] = {(a, 4), (b, 2), (k, ?), (x, ?)}

IN[BB10] = {(a, 4), (b, 2), (k, ?), (x, ?)}

OUT[BB10] = {(a, 4), (b, 2), (k, ?), (x, ?)}

IN[BB11] = {(a, 4), (b, 2), (k, ?), (x, ?)}

OUT[BB11] = {(a, 4), (b, 2), (k, ?), (x, ?), (y, 8)}

IN[BB12] = {(a, 4), (b, 2), (k, ?), (x, ?), (y, 8)}

OUT[BB12] = {(a, 4), (b, 2), (k, ?), (x, ?), (y, 8)}

IN[BB13] = {(a, 4), (k, ?), (x, ?)}

OUT[BB13] = {(a, 4), (k, ?), (x, ?)}

IN[BB14] = {(a, 4), (k, ?), (x, ?)}

OUT[BB14] = {(a, 4), (k, ?), (x, ?)}

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#### ITERAZIONE 3

IN[BB8] = MEET( OUT[BB7], OUT[BB12] ) = MEET( {(a,4), (k,4), (x, ?)}, {(a, 4), (b, 2), (k, ?), (x, ?), (y, 8)} ) = {(a, 4), (k, ?), (x, ?)}