

Second Assignment

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1 Very Busy Expressions

The search for very busy expressions can be useful for code hoisting, since very busy expressions can be moved from the place they are up to a joint point from which the flow departs.

1.1 Problem formalization

Formally an expression is said to be **very busy** when it is computed along each path that part from the point p without any redefinition of its operands. This information can be used to move the expression to a point of the code in which its computation can be used by all the paths that use the expression.

	Very Busy Expressions
Domain	Sets of expressions
Direction	Backward $in[b] = f_b(out[b])$ $out[b] = \wedge in[succ(b)]$
Transfer function	$f_b(x) = Gen_b \cup (x - Kill_b)$
Meet Operation (\wedge)	\cap
Boundary Condition	$out[exit] = \emptyset$
Initial interior points	$out[b] = U$

Table 1: Very busy expressions summary table

1.2 Example

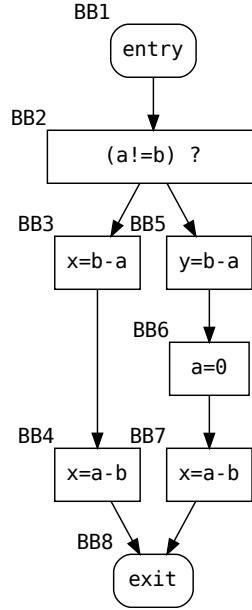


Figure 1: Very Busy Expression Example

	Iteration 1		Iteration 2	
	IN[B]	OUT[B]	IN[B]	OUT[B]
BB1	$\{b - a\}$	$\{b - a\}$	$\{b - a\}$	$\{b - a\}$
BB2	$\{b - a\}$	$\{b - a\}$	$\{b - a\}$	$\{b - a\}$
BB3	$\{b - a\}, \{a - b\}$	$\{a - b\}$	$\{b - a\}, \{a - b\}$	$\{a - b\}$
BB4	$\{a - b\}$	\emptyset	$\{a - b\}$	\emptyset
BB5	$\{b - a\}$	\emptyset	$\{b - a\}$	\emptyset
BB6	\emptyset	$\{a - b\}$	\emptyset	$\{a - b\}$
BB7	$\{a - b\}$	\emptyset	$\{a - b\}$	\emptyset
BB8	\emptyset	\emptyset	\emptyset	\emptyset

Table 2: Very Busy Expression Algorithm Execution Table

2 Dominator Analysis

Dominator analysis is fundamental to create the single static assignment form.

2.1 Problem formalization

A basic block B_1 **dominates** another block B_2 if it is encountered in every path from entry to B_2 .

	Dominator Analysis
Domain	Sets of Basic Blocks
Direction	Forward
Transfer function	$f_b(x) = \{x\} \cup (\bigcap_{m \in \text{preds}(x)} f_b(m))$
Meet Operation (\wedge)	\cap
Boundary Condition	$\text{Dom}[\text{entry}] = \{\text{entry}\}$
Initial interior points	$\text{Dom}[b] = N \quad \forall b \neq \text{entry}$, with N the number of basic blocks of the CFG

Table 3: Dataflow Problem X Properties

2.2 Example

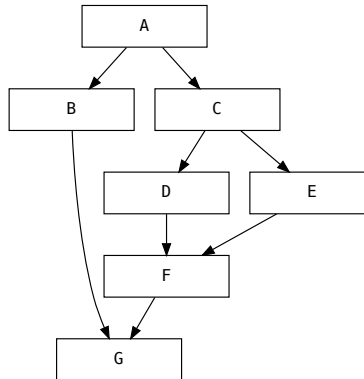


Figure 2: Dominance Analysis example

	DOM[B]
A	$\{A\}$
B	$\{A, B\}$
C	$\{A, C\}$
D	$\{A, C, D\}$
E	$\{A, C, E\}$
F	$\{A, C, F\}$
G	$\{A, G\}$

Table 4: Dominance analysis execution table

3 Constant Propagation

The constant propagation problem aims at finding what are the couples $\langle \text{variable}, \text{constant value} \rangle$ that are available in a certain basic block, so that the variable constant value can be propagated across the blocks.

3.1 Problem formalization

We say that a couple $\langle \text{variable}, \text{constant} \rangle$ is valid at block n if it is guaranteed that the variable x gets that constant value every time that the block is reached.

	Constant Propagation
Domain	Sets of variables and their constant values
Direction	Forward $in[b] = \wedge(out[pred(b)])$ $out[b] = f_b(in[b])$
Transfer function	$f_b(x) = Gen_b \cup (x - Kill_b)$
Meet Operation (\wedge)	\cap
Boundary Condition	$out[entry] = \emptyset \quad in[entry] = \emptyset$
Initial interior points	$out[b] = \emptyset \quad in[b] = U$

Table 5: Constant Propagation Problem Summary Table

3.2 Example

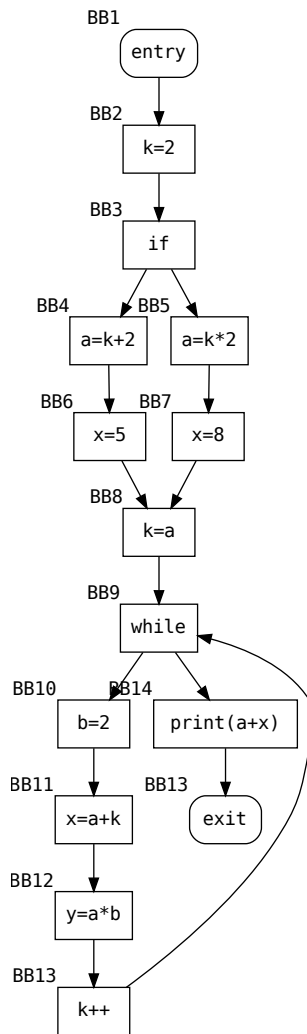


Figure 3: Constant Propagation example

	Iteration 1	
	IN[B]	OUT[B]
BB1	\emptyset	$\langle k, 2 \rangle$
BB2	\emptyset	$\langle k, 2 \rangle$
BB3	$\langle k, 2 \rangle$	$\langle k, 2 \rangle$
BB4	$\langle k, 2 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle$
BB5	$\langle k, 2 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle$
BB6	$\langle k, 2 \rangle, \langle a, 4 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle, \langle x, 5 \rangle$
BB7	$\langle k, 2 \rangle, \langle a, 4 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle, \langle x, 8 \rangle$
BB8	$\langle k, 2 \rangle, \langle a, 4 \rangle$	$\langle k, 4 \rangle, \langle a, 4 \rangle$
BB9	$\langle k, 2 \rangle, \langle a, 4 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle$
BB10	$\langle k, 4 \rangle, \langle a, 4 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle, \langle b, 2 \rangle$
BB11	$\langle k, 4 \rangle, \langle a, 4 \rangle, \langle b, 2 \rangle$	$\langle k, 4 \rangle, \langle a, 4 \rangle, \langle b, 2 \rangle, \langle x, 8 \rangle$
BB12	$\langle k, 4 \rangle, \langle a, 4 \rangle, \langle b, 2 \rangle, \langle x, 8 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle, \langle b, 2 \rangle, \langle x, 8 \rangle, \langle y, 8 \rangle$
BB13	$\langle k, 4 \rangle, \langle a, 4 \rangle, \langle b, 2 \rangle, \langle x, 8 \rangle, \langle y, 8 \rangle$	$\langle k, 5 \rangle, \langle a, 4 \rangle, \langle b, 2 \rangle, \langle x, 8 \rangle, \langle y, 8 \rangle$
BB14	$\langle k, 4 \rangle, \langle a, 4 \rangle$	$\langle k, 4 \rangle, \langle a, 4 \rangle$

Table 6: Constant Propagation Algorithm Execution Table (Iteration 1)

	Iteration 2	
	IN[B]	OUT[B]
BB1	\emptyset	$\langle k, 2 \rangle$
BB2	\emptyset	$\langle k, 2 \rangle$
BB3	$\langle k, 2 \rangle$	$\langle k, 2 \rangle$
BB4	$\langle k, 2 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle$
BB5	$\langle k, 2 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle$
BB6	$\langle k, 2 \rangle, \langle a, 4 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle, \langle x, 5 \rangle$
BB7	$\langle k, 2 \rangle, \langle a, 4 \rangle$	$\langle k, 2 \rangle, \langle a, 4 \rangle, \langle x, 8 \rangle$
BB8	$\langle k, 2 \rangle, \langle a, 4 \rangle$	$\langle k, 4 \rangle, \langle a, 4 \rangle$
BB9	$\langle a, 4 \rangle$	$\langle a, 4 \rangle$
BB10	$\langle a, 4 \rangle$	$\langle a, 4 \rangle, \langle b, 2 \rangle$
BB11	$\langle a, 4 \rangle, \langle b, 2 \rangle$	$\langle a, 4 \rangle, \langle b, 2 \rangle$
BB12	$\langle a, 4 \rangle, \langle b, 2 \rangle$	$\langle a, 4 \rangle, \langle b, 2 \rangle, \langle y, 8 \rangle$
BB13	$\langle a, 4 \rangle, \langle b, 2 \rangle, \langle y, 8 \rangle$	$\langle a, 4 \rangle, \langle b, 2 \rangle, \langle y, 8 \rangle$
BB14	$\langle a, 4 \rangle$	$\langle a, 4 \rangle$

Table 7: Constant Propagation Algorithm Execution Table (Iteration 2)