Lecture 6

Global Common Subexpression Elimination

- I Available Expressions Analysis
- II Eliminating CSEs

Reference: Muchnick 13.1



Global Common Subexpression



- Availability of an expression E at point P
 - DEFINITION: Along every path to P in the flow graph:
 - E must be evaluated at least once
 - no variables in E redefined after the last evaluation
 - · Observations: E may have different values on different paths

Formulating the Problem

- Domain:
 - a bit vector, a bit for each textually unique expression in the program
- Forward or Backward?
- Lattice Elements?
- Meet Operator?
 - · check: commutative, idempotent, associative
- Partial Ordering
- Top?
- Bottom?
- Boundary condition: entry/exit node?
- Initialization for iterative algorithm?

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Transfer Functions

- · Can use the same equation as reaching definitions
 - out[b] = gen[b] U (in[b] kill[b])
- Start with the transfer function for a single instruction
 - When does the instruction generate an expression?
 - When does it kill an expression?
- Calculate transfer functions for complete basic blocks
 - · Compose individual instruction transfer functions

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Composing Transfer Functions

• Derive the transfer function for an entire block



• Since out1 = in2 we can simplify:

- out2 = gen2 U ((gen1 U (in1 kill1)) kill2) out2 = gen2 U (gen1 - kill2) U (in1 - (kill1 U kill2)) out2 = gen2 U (gen1 - kill2) U (in1 - (kill2 U (kill1 - gen2)))
- Result
 - gen = gen2 U (gen1 kill2)
 - kill = kill2 U (kill1 gen2)

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II. Eliminating CSEs

- Available expressions (across basic blocks)
 - provides the set of expressions available at the start of a block
- Value Numbering (within basic block)
 - · Initialize Values table with available expressions
- If CSE is an "available expression" => transform the code
 - Original destination may be:
 - a temporary register
 - overwritten
 - · different from the variables on other paths
 - A solution: Copy the expression to a new variable at each evaluation reaching the redundant use
 - Textbook discusses another solution



III. Limitation: Textually Identical Expression

• Commutative operations



· sort the operands



Further Improvements

- Examples
 - · Expressions with more than two operands



• Textually different expressions may be equivalent

```
add t1 = x, y
beq t1, t2, L1
cpy z = x
add t3 = z, y
```



Another Example



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Summary

	Reaching Definitions	Available Expressions
Domain	Sets of definitions	Sets of expressions
Transfer function $f_b(x)$ Generate \cup Propagate		
direction of function	forward: $out[b] = f_b(in[b])$	forward: $out[b] = f_b(in[b])$
Generate	Genb: exposed definitions	Genb: exprs. evaluated
Propagate	x - Kill _b : killed definitions	x - Kill _b : exprs. killed
Merge operation	\cup (in[b]= \cup out[predecessors])	\cap (in[b]= \cap out[predecessors])
Initialization	out[entry] = \emptyset	$out[entry] = \emptyset$
	$out[b] = \emptyset$	out[b] = all expressions

Other Optimizations

Constant Propagation:

Copy Propagation:

Dead Code Elimination:

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