CS738: Advanced Compiler Optimizations

Sparse Conditional Constant Propagation

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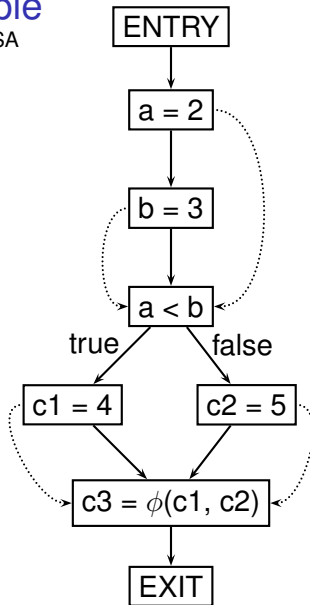- ▶ Finds all simple constant

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- Improved analysis time over Simple Constant Propagation
- Finds all simple constant
  - Same class as Simple Constant Propagation

Motivating Example

Dashed edges denote SSA
def-use chains

Preparations for SSC Analysis

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  - Same as *def-use* chains

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- ▶ Initialize worklist *WL* with SSA edges whose def is not ⊤

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- ► If expression can not be evaluated at compile time, assign ⊥
- ► Else (for expression contains variables) assign ⊤
- ► Initialize worklist *WL* with SSA edges whose def is not ⊤
- ► Algorithm terminates when *WL* is empty

- Take an SSA edge E out of WL

SSC Algorithm: Iterative Actions

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- ▶ If the meet value is different from use value, replace the use by the meet
- ▶ Recompute the def d at the use end of E
- ▶ If the recomputed value is *lower* than the stored value, add all SSA edges originating at d

Meet for ϕ-function

$$v = \phi(v_1, v_2, \ldots, v_k)$$

$$\Rightarrow \text{ValueOf}(v) = v_1 \wedge v_2 \wedge \ldots \wedge v_n$$

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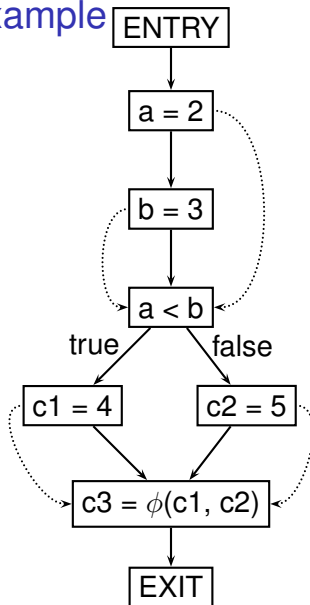- ▶ Each SSA edge is examined at most twice, for each lowering

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- ▶ Each SSA edge is examined at most twice, for each lowering
- ▶ Theoritical size of SSA graph: $O(V \times E)$
- ▶ Practical size: linear in the program size

SSC: Practice Example

What if we change "c1 = 4" to "c1 = 5"?

Sparse Condtional Constant Propagation (SCC)

► Constant Propagation with *unreachable code elimination*

Sparse Condtional Constant Propagation (SCC)

- ▶ Constant Propagation with *unreachable code elimination*
- ▶ Ignore definitions that reach a use via a non-executable edge

SCC Algorithm: Key Idea

$$v = \phi(v_1, v_2, \ldots, v_k)$$

$$\Rightarrow \text{ValueOf}(v) = \bigwedge_{i \in ExecutablePath} v_i$$

We ignore paths that are not "yet" marked executable

SCC Algorithm: Preparations

► Two Worklists

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  - Flow Worklist (*FWL*)

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- Execution Halts when **both** worklists are empty

SCC Algorithm: Preparations

- ▶ Two Worklists
  - ▶ Flow Worklist (*FWL*)
    - ▶ Worklist of flow graph edges
  - ▶ SSA Worklist (*SWL*)
    - ▶ Worlist of SSA graph edges
- ▶ Execution Halts when **both** worklists are empty
- ▶ Associate a flag, the *ExecutableFlag*, with every flow graph edge to control the evaluation of ϕ-function in the destination node

SCC Algorithm: Initialization

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SCC Algorithm: Initialization

- Initialize *FWL* to contain edges leaving ENTRY node
- Initialize *SWL* to empty
- Each *ExecutableFlag* is false initially
- Each value is $\top$ initially (Optimistic)

▶ Remove an item from either worklist

SCC Algorithm: Iterations

- Remove an item from either worklist
- process the item (described next)

▶ Item is flow graph edge

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SCC Algorithm: Processing *FWL* Item

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  - ▶ **Visit-**ϕ for all ϕ-functions in the destination
  - ▶ If only one of the *ExecutableFlag*s of incoming flow graph edges for dest is true (dest visted for the first time), then **VisitExpression** for all expressions in dest

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- ▶ Item is flow graph edge
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- ▶ Otherwise
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  - ▶ If only one of the *ExecutableFlag*s of incoming flow graph edges for dest is true (dest visted for the first time), then **VisitExpression** for all expressions in dest
  - ▶ If the dest contains only one outgoing flow graph edge, add that edge to *FWL*

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- ▶ If dest is a ϕ-function, **Visit-ϕ**

SCC Algorithm: Processing *SWL* Item

- ▶ Item is SSA edge
- ▶ If dest is a ϕ-function, **Visit-ϕ**
- ▶ If dest is an expression and any of *ExecutableFlag*s for the incoming flow graph edges of dest is true, perform **VisitExpression**

$$v = \phi(v_1, v_2, \ldots, v_k)$$

- If i^{th} incoming edge's *ExecutableFlag* is true,
  $val_i = $ ValueOf(v_i) else $val_i = \top$

SCC Algorithm: Visit-ϕ

$$v = \phi(v_1, v_2, \ldots, v_k)$$

- If i^{th} incoming edge's *ExecutableFlag* is true,
  $val_i = \text{ValueOf}(v_i)$ else $val_i = \top$
- $\text{ValueOf}(v) = \bigwedge_i val_i$

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  - ▶ If the expression is part of assignment, add all outgoing SSA edges to *SWL*

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    - ▶ if the value is constant c, only the corresponding flow graph edge is added to *FWL*

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  - ▶ if the expression controls a conditional branch, then
    - ▶ if the result is $\perp$, add all outgoing flow edges to *FWL*
    - ▶ if the value is constant c, only the corresponding flow graph edge is added to *FWL*
    - ▶ Value can not be $\top$ (why?)

▶ Each SSA edge is examined twice

SCC Algorithm: Complexity

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SCC Algorithm: Complexity

- Each SSA edge is examined twice
- Flow graph nodes are visited once for every incoming edge
- Complexity = O(# of SSA edges + # of flow graph edges)

SCC Algorithm: Correctness and Precision

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- ▶ SCC is at least as powerful as Conditional Constant Propagation (CC)
  - ▶ Finds all constants as CC does
- ▶ PROOFs: In paper **Constant propagation with conditional branches** by **Mark N. Wegman, F. Kenneth Zadeck**, ACM TOPLAS 1991.

Practice Example


```
ENTRY

a = 2

b = 3

a < b
   true      false

c1 = 4      c2 = 5

c3 = φ(c1, c2)

EXIT
```