Merging Equivalent Contexts for Scalable Heap-Cloning-Based Context-Sensitive Points-to Analysis

Work of Guoqing Xu and Atanas Rountev

Hakjoo Oh
2009.01.17

Background

- BDD
  - provides an effective representation for context-sensitive points-to relationships
  - automatically merges *equivalent contexts*

Motivation

- BDD
  - is slower than non-BDD analysis (2x)
  - is not effective as much with heap-cloning

Goal

- develop a technique for
  - merging equivalent contexts explicitly
- application to points-to analysis with heap-cloning

Equivalent Contexts

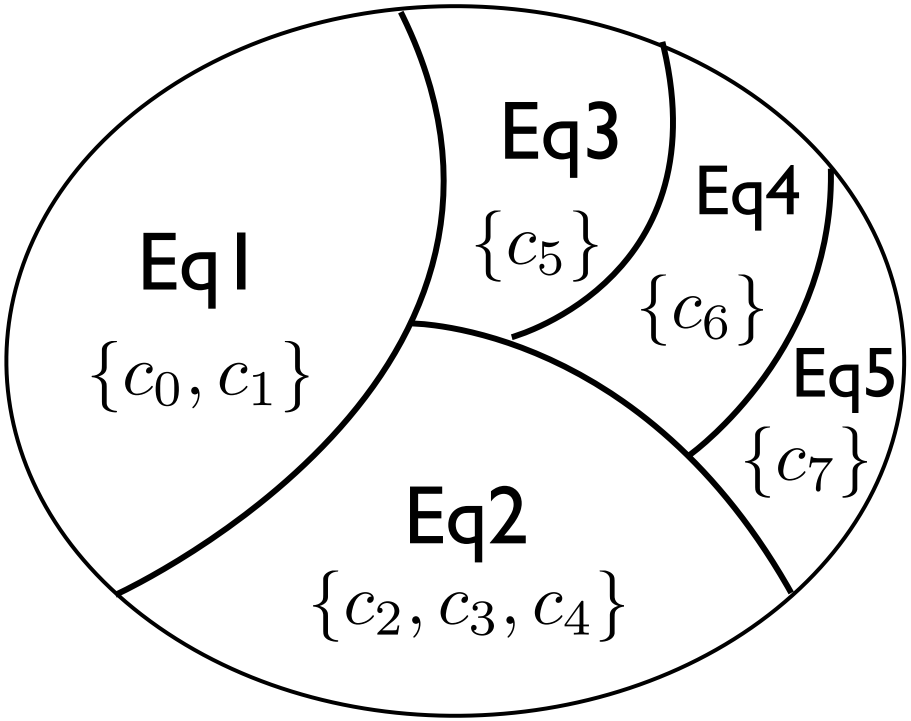
- a coarse-grained (procedure-level) def.
  - for a method m

$$c_0 \text{ and } c_1 \text{ are equivalent iff}$$
$$\forall p \in Ptr_m.\ pt(p, c_0) = pt(p, c_1)$$

Equivalent Contexts

(for a method m)

set of all contexts

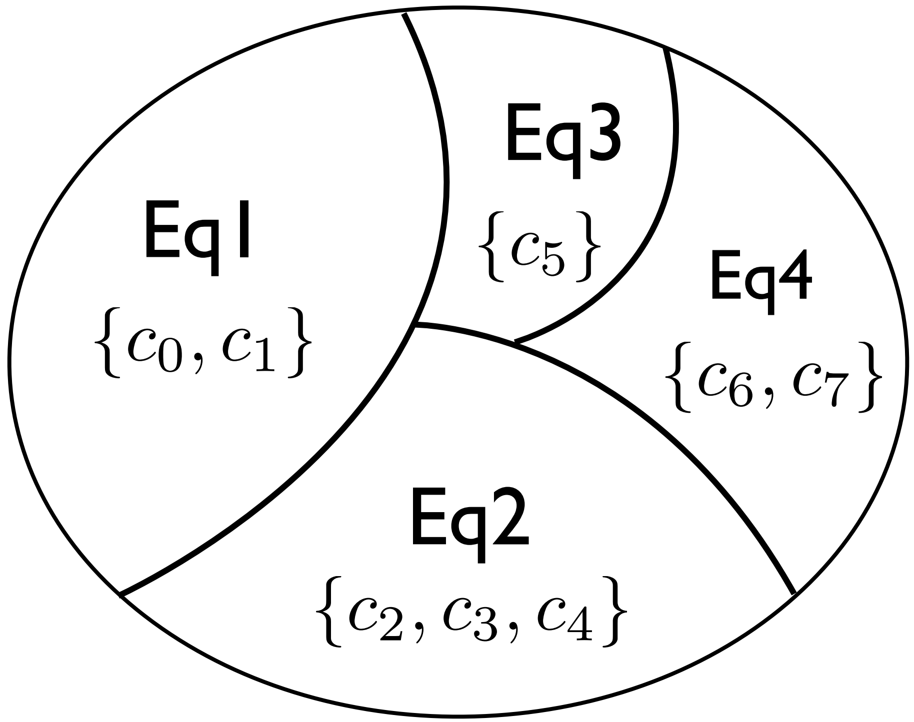


$$(c_0, c_1) \in R^m_{eq} \text{ iff } \forall p \in Ptr_m.\ pt(p, c_0) = pt(p, c_1)$$

Equivalent Contexts

(for a pointer p in m)

set of all contexts (for a pointer p in m)



$$(c_0, c_1) \in R_{eq}^{p,m} \text{ iff } pt(p, c_0) = pt(p, c_1)$$

Points-to Relationships with Heap-Cloning

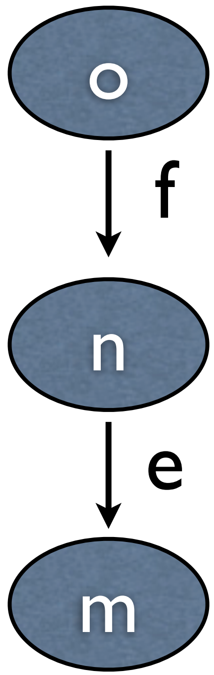
- (p,cp,o,co), a fully context-sensitive rep.
  - cp: from main to the p-defining method
  - co: from main to the o-creating method

Inlining-based Analysis

- By bottom-up, inline each method with
  - variable renaming
  - parameter passing
- At main, apply intraprocedural analysis

$$p^{(a,d,l)} := \cdots := malloc_o^{(a,e)}$$

$$(p, adl, o, ae)$$



$$p^{(f,e)} := q^{(f,e)}$$

$$p^{(e)} := q^{(e)}$$

$$p := q$$

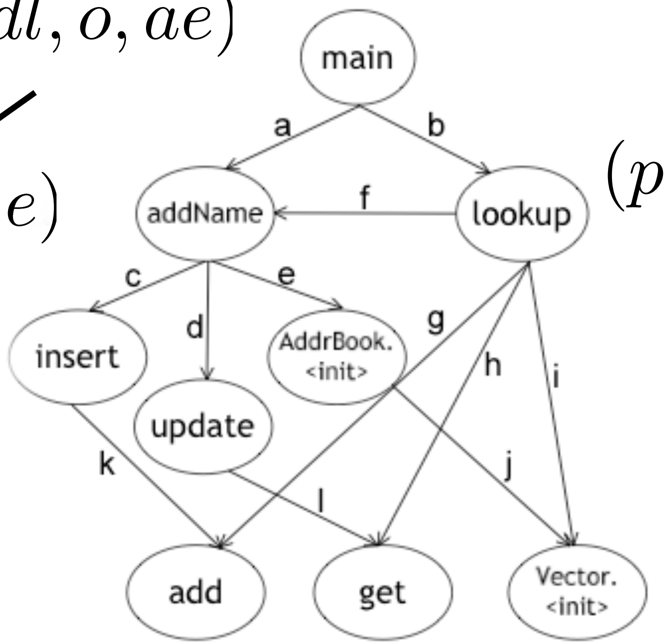
Key Idea of Merging

(p, adl, o, ae) is equivalent to $(p, bfdl, o, bfe)$?

(p, adl, o, ae)

(p, dl, o, e)

created in addName



$(p, bfdl, o, bfe)$

$(p, dl, o, e) \longleftarrow (p, fdl, o, fe)$

created in addName

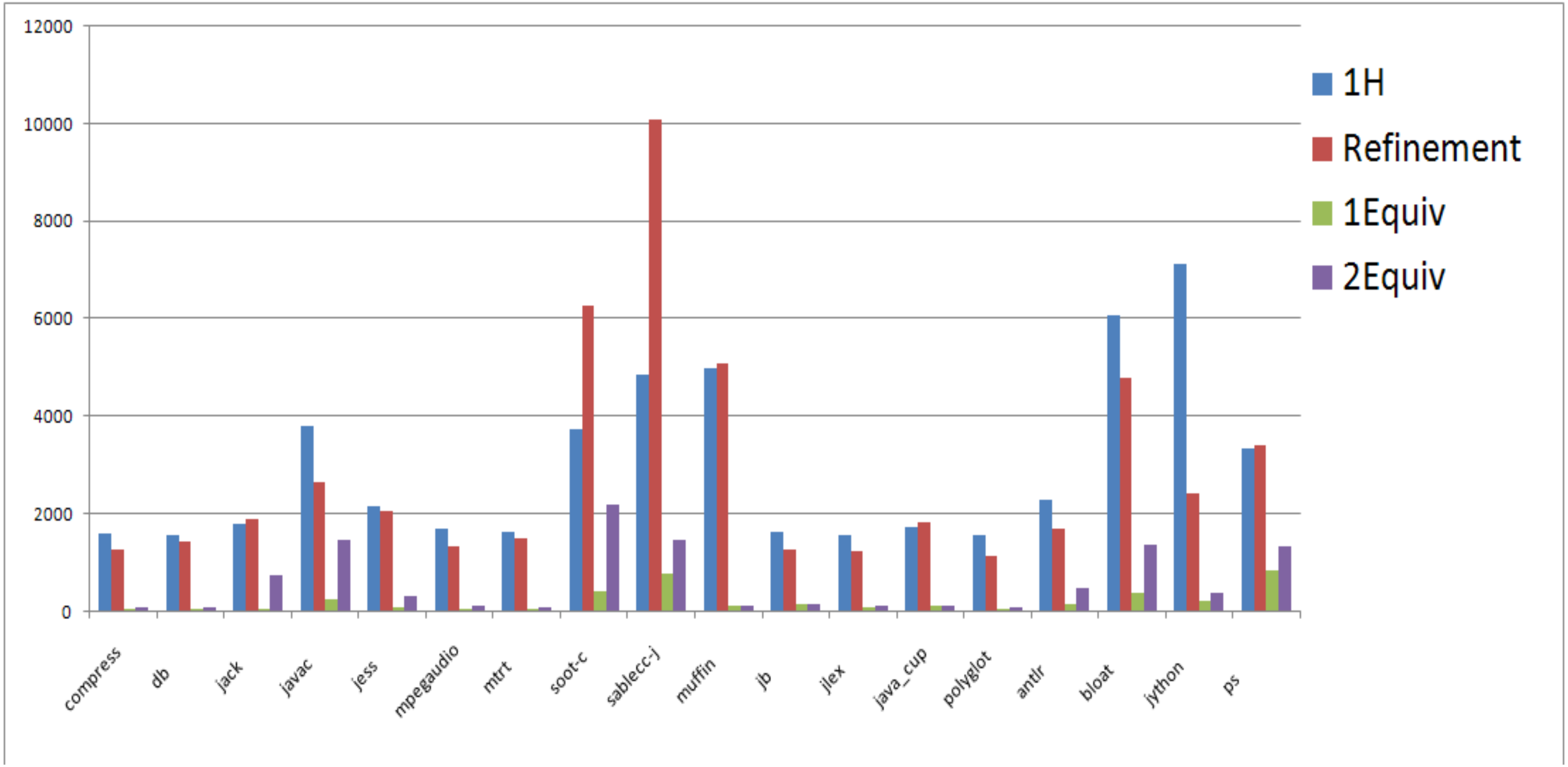
creation of (p, dl, o, e) is not related to callers of addName

=> we can merge call-paths a, bf for (p,dl,o,e) : URC

Points-to Analysis

- clone pointers and targets only for URCs

Performance



Conclusion

- Non-BDD-based technique that merges equivalent contexts with heap-cloning
- Faster than BDD-implementation when cloning heaps