Karlsruhe Institute of Technology

Speeding up context-, object- and field-sensitive SDG generation

Jürgen Graf

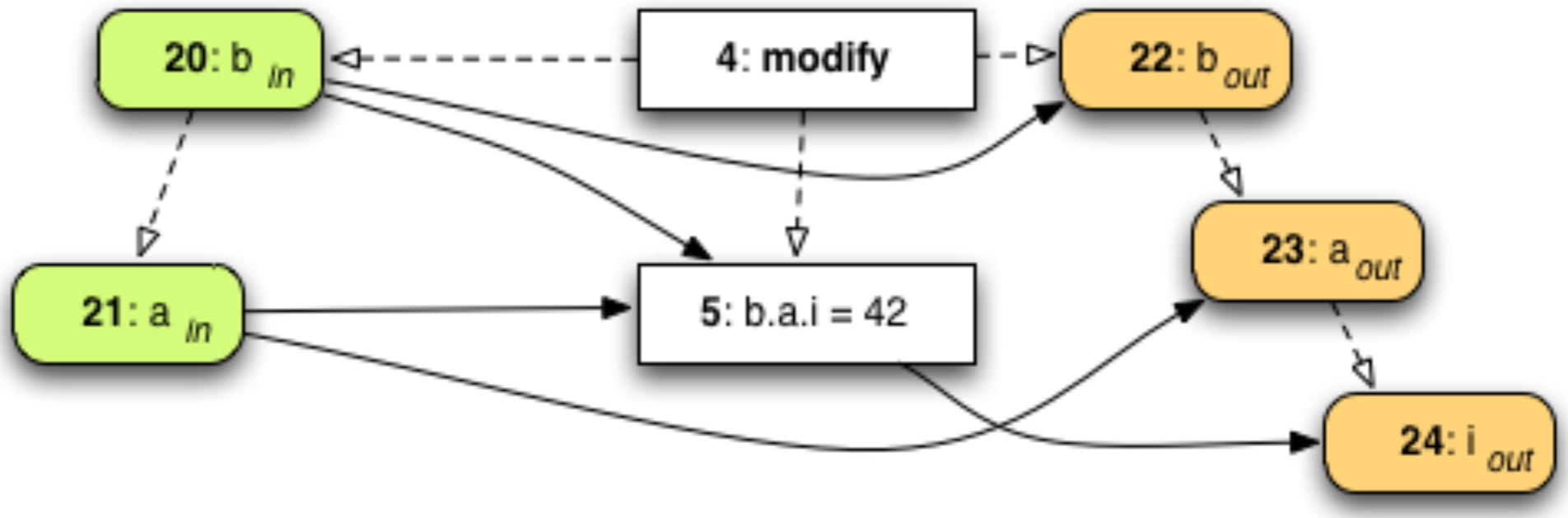

```
theorem nonInterferenceSecurity:
  assumes "[cf1] ≈L [cf2]" and "(-High-) ∉ ⌊HRB-slice (CFG-node (-Low-))⌋CFG" and "valid-edge a"
  and "sourcenode a = (-High-)" and "targetnode a = n" and "kind a = (λs. True)√" and "n ≙ c"
  and "final c'" and "⟨c,[cf1]⟩ ⇒ ⟨c',s1⟩" and "⟨c,[cf2]⟩ ⇒ ⟨c',s2⟩"
  shows "s1 ≈L s2"
proof –
  from High-target-Entry-edge obtain ax where "valid-edge ax" and "sourcenode ax = (-Entry-)"
    and "targetnode ax = (-High-)" and "kind ax = (λs. True)√" by blast
  from `n ≙ c` `⟨c,[cf1]⟩ ⇒ ⟨c',s1⟩` obtain n1 as1 cfs1 where "n –as1→√* n1" and "n1 ≙ c'" and "preds (kinds as1) [(cf1,undefined)]"
    and "transfers (kinds as1) [(cf1,undefined)] = cfs1" and "map fst cfs1 = s1" by(fastsimp dest:fundamental-property)
  from `n –as1→√* n1` `valid-edge a` `sourcenode a = (-High-)` `targetnode a = n` `kind a = (λs. True)√`
  have "(-High-) –a#as1→√* n1" by(fastsimp intro:Cons-path simp:vp-def valid-path-def)
  from `final c'` `n1 ≙ c'` obtain a1 where "valid-edge a1" and "sourcenode a1 = n1" and "targetnode a1 = (-Low-)" and "kind a1 = ↑id"
    by(fastsimp dest:final-edge-Low)
```

Precise System Dependence Graphs

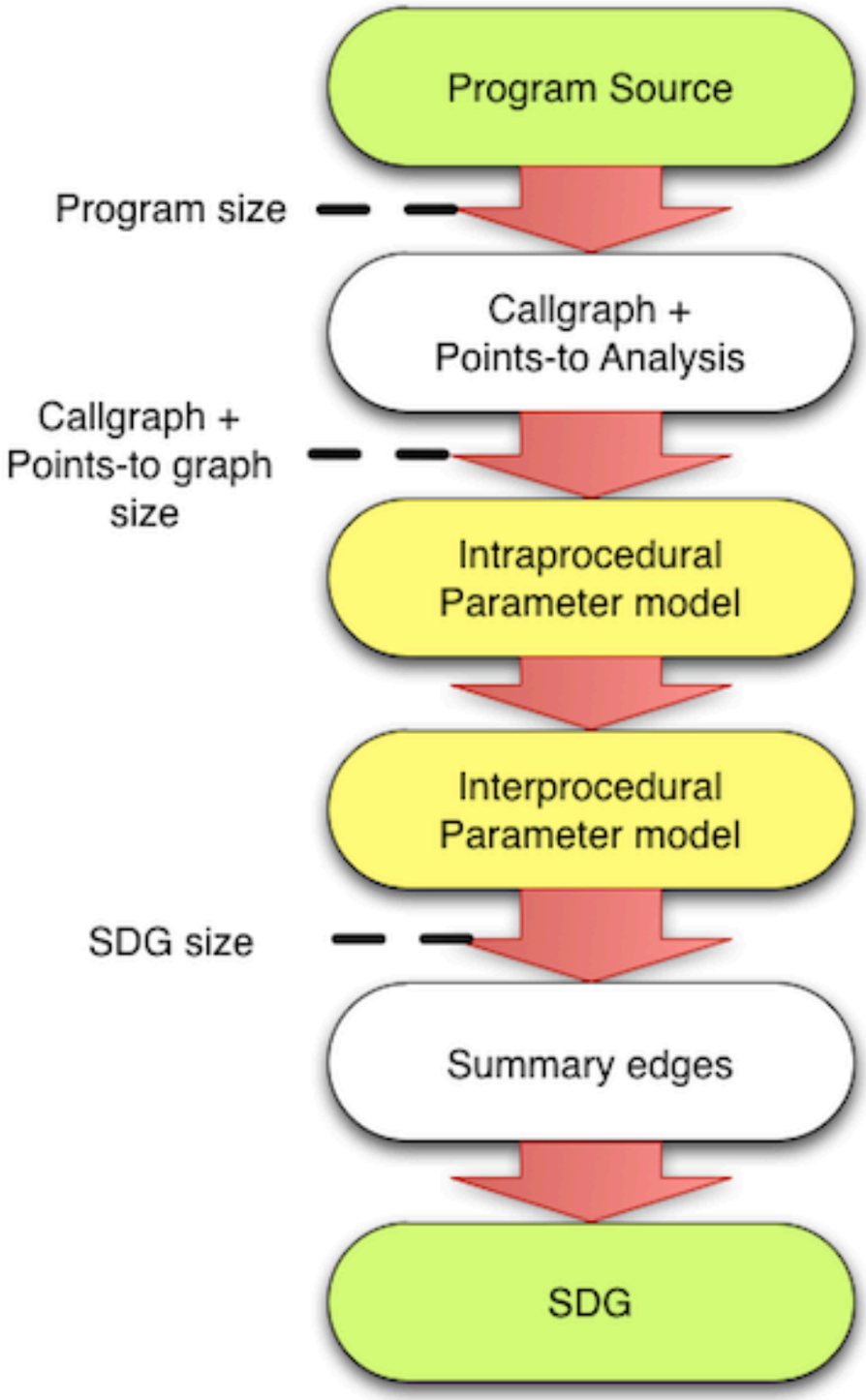
- **Heavy-weight** whole program analysis (**Interprocedural**)
- Object-oriented language (Java)
- System Dependence Graph (SDG)
  - Nodes: Statements
  - Edges: Dependencies between statements
    - A $\rightarrow$ B: A may influence B
    - A $\nrightarrow$ B: A certainly does not influence B
- Used for
  - **Information Flow Control** (IFC)
  - Concurrent Programs, ...

Context-, object- and field-sensitivity

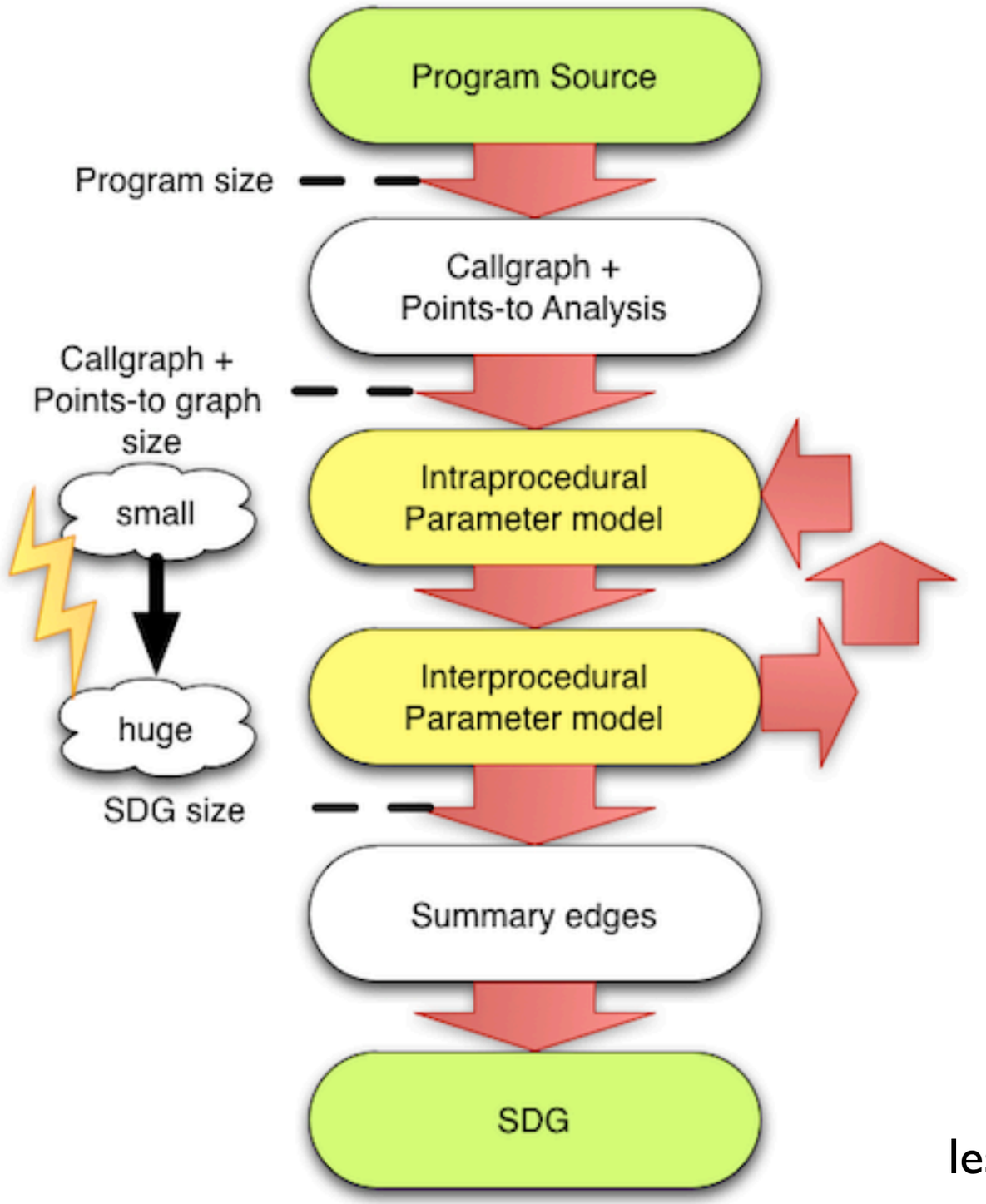
- **Parameter nodes**
  - Read (input) or modified (output) values of a method
  - For each **Parameter** and **Field** of a parameter (**many**!)
  - **Object Trees**: Tree structure for a parameter and its fields
- Points-to / May-alias Analysis

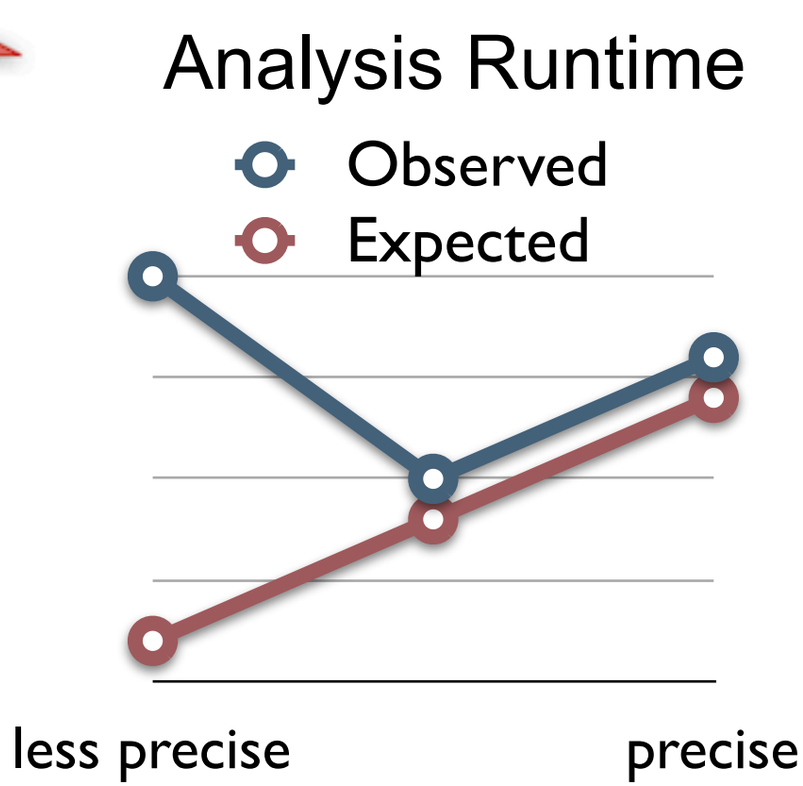


SDG computation

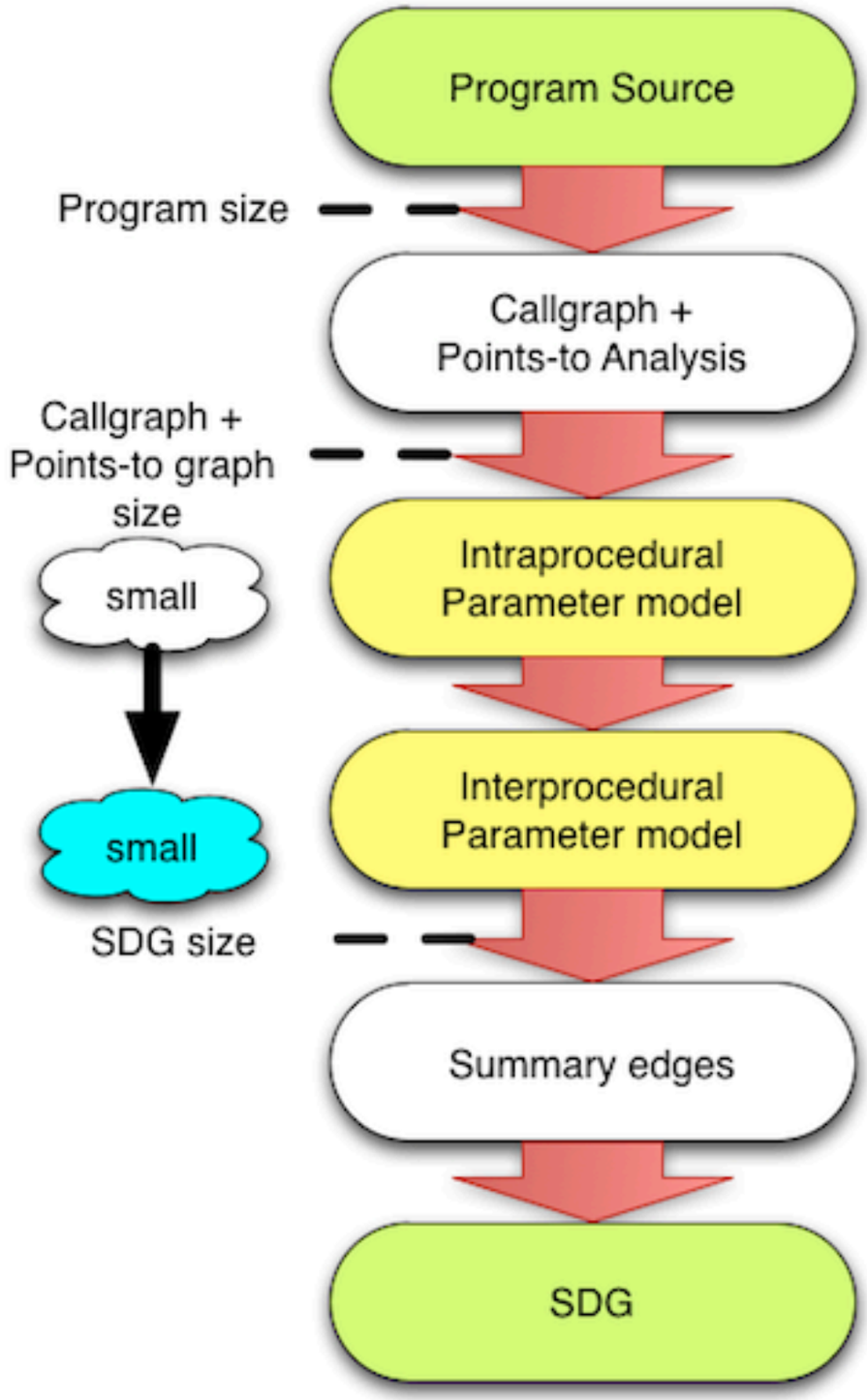


SDG computation with Object Trees





New Object Graph approach



remove scalability problem

maintain precision

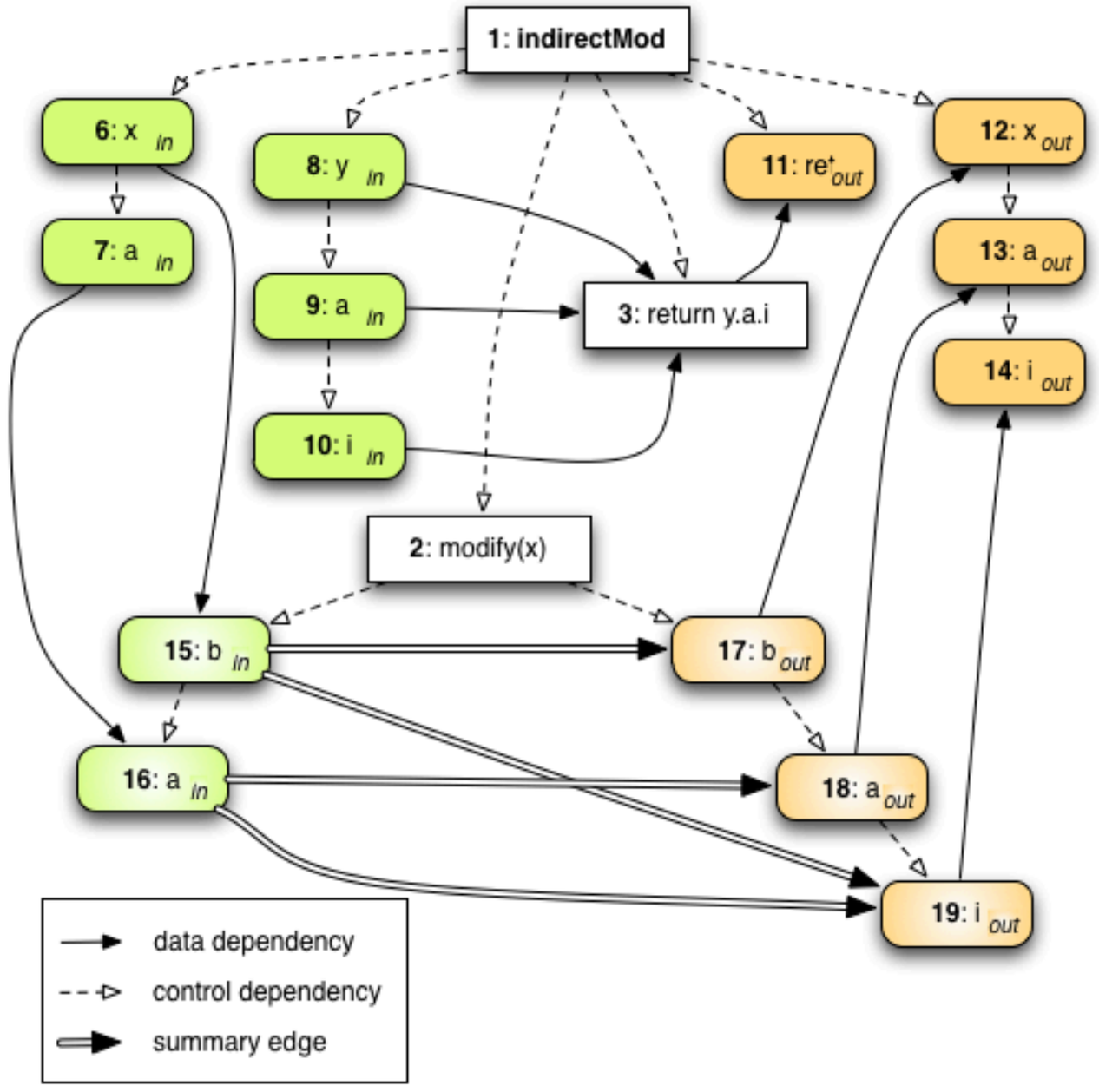
SDGs for object oriented programs

```
void main(String argv[]) {
  indirectMod(new B(), new B())
}


int indirectMod(B x, B y) {
  modify(x);
  return y.a.i;
}

void modify(B b) {
  b.a.i = 42;
}

class B { A a = new A(); }
```



Object Trees for method parameters

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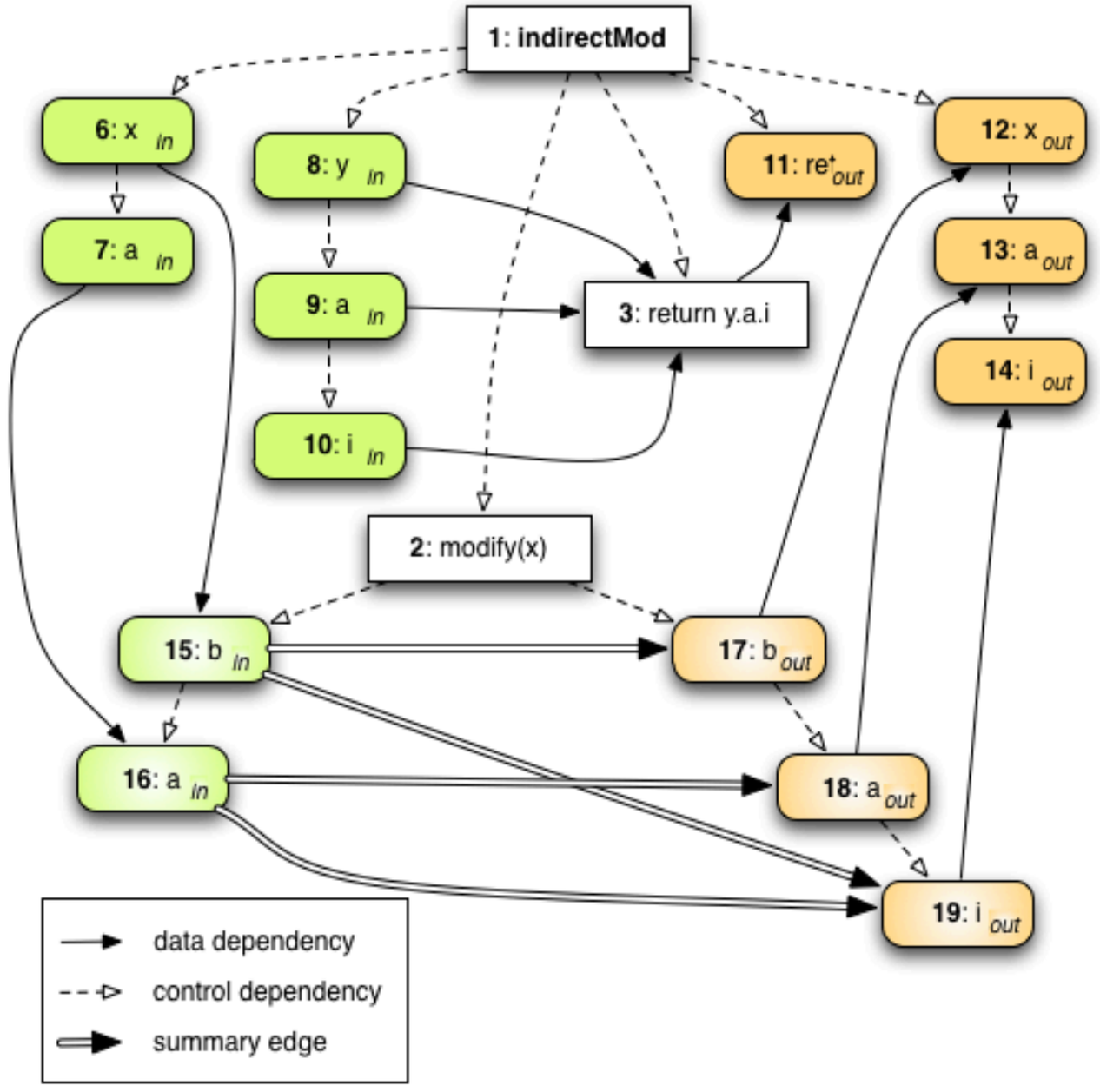
***precise** points-to*

⇒ x.a ≠ y.a



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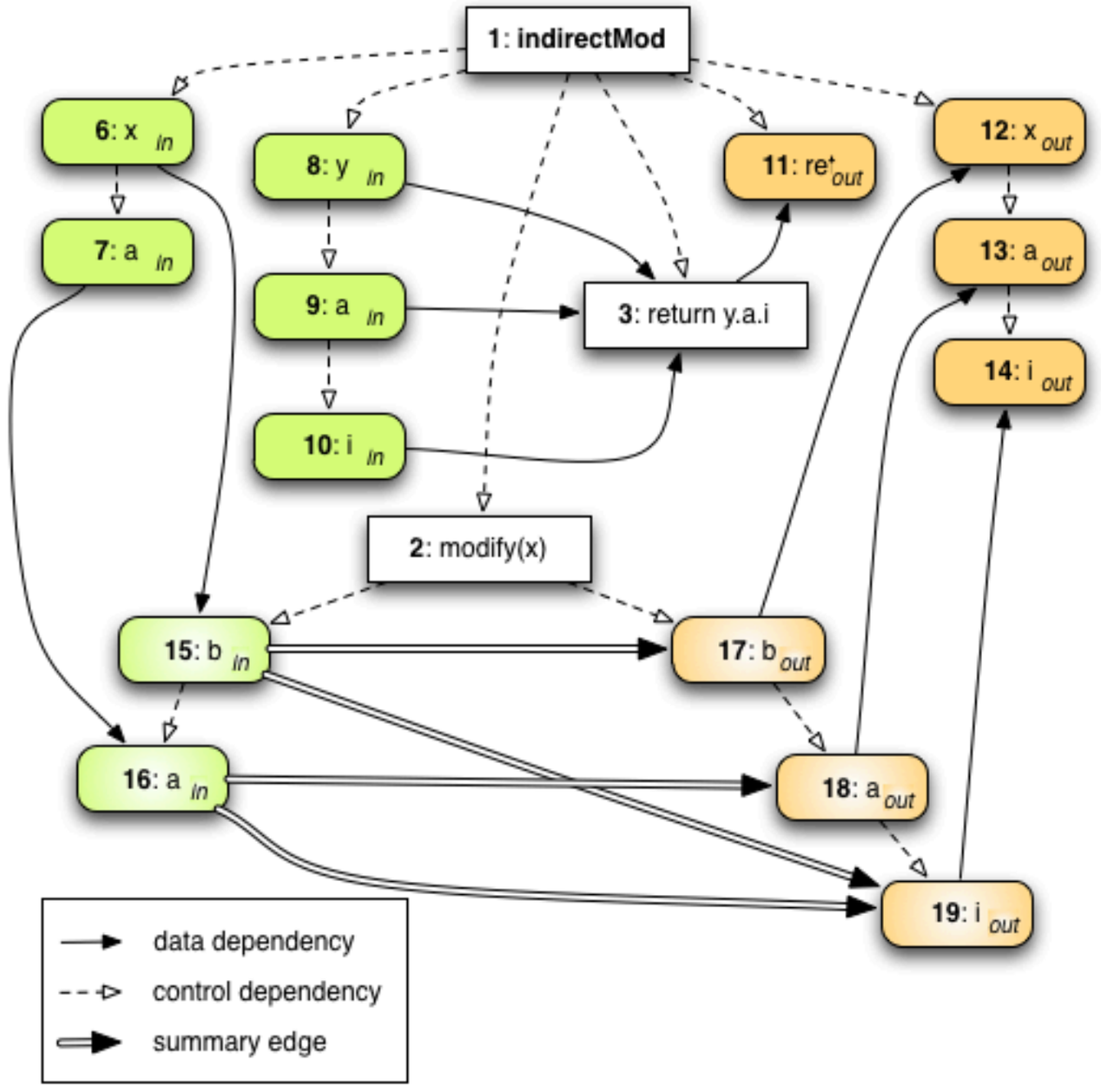
***precise** points-to*

⇒ x.a ≠ y.a

modifies x.a.i

reads y.a.i



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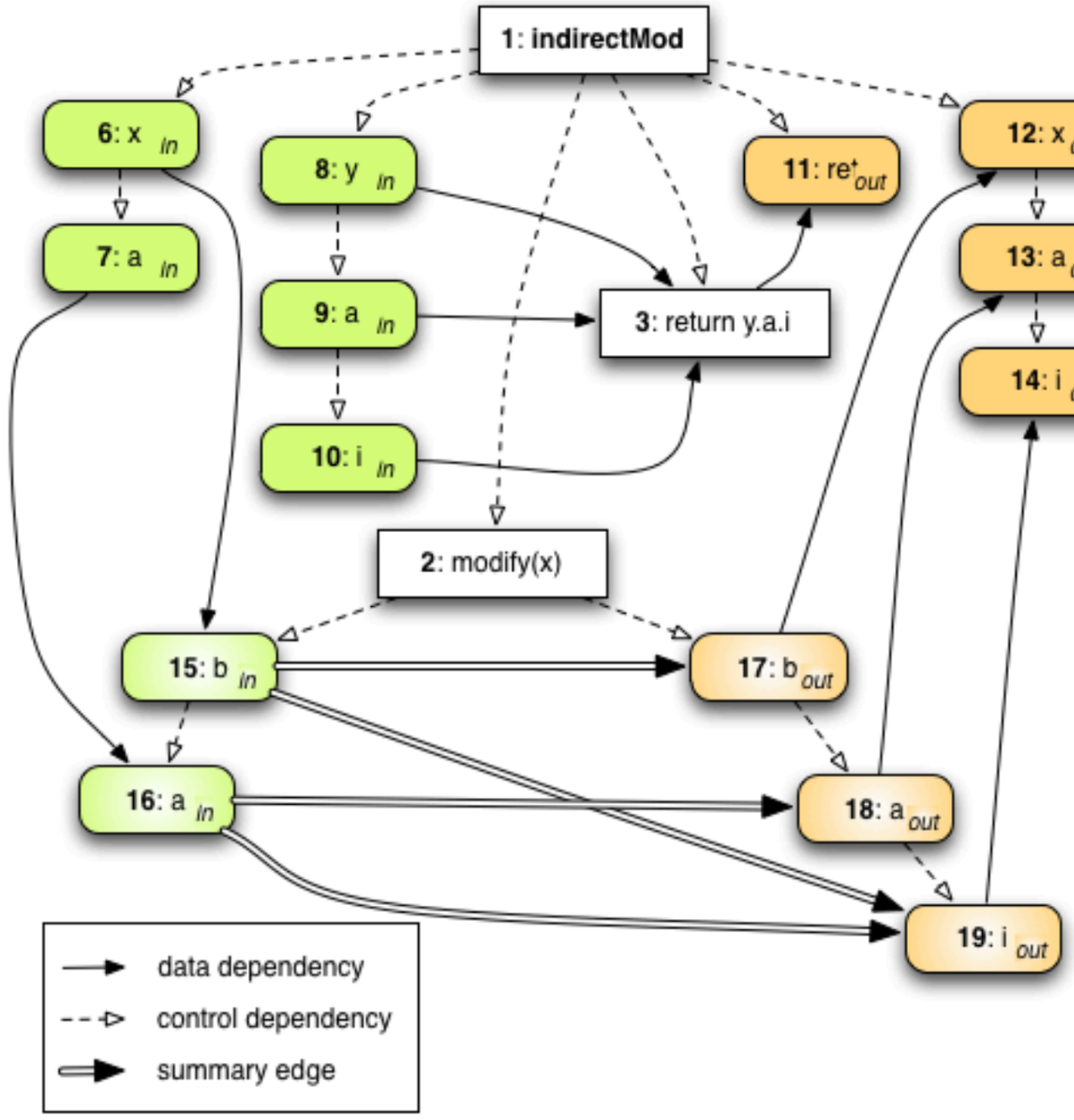
less precise *points-to*

⇒ x.a **?** y.a



Object Tree grows with less precision

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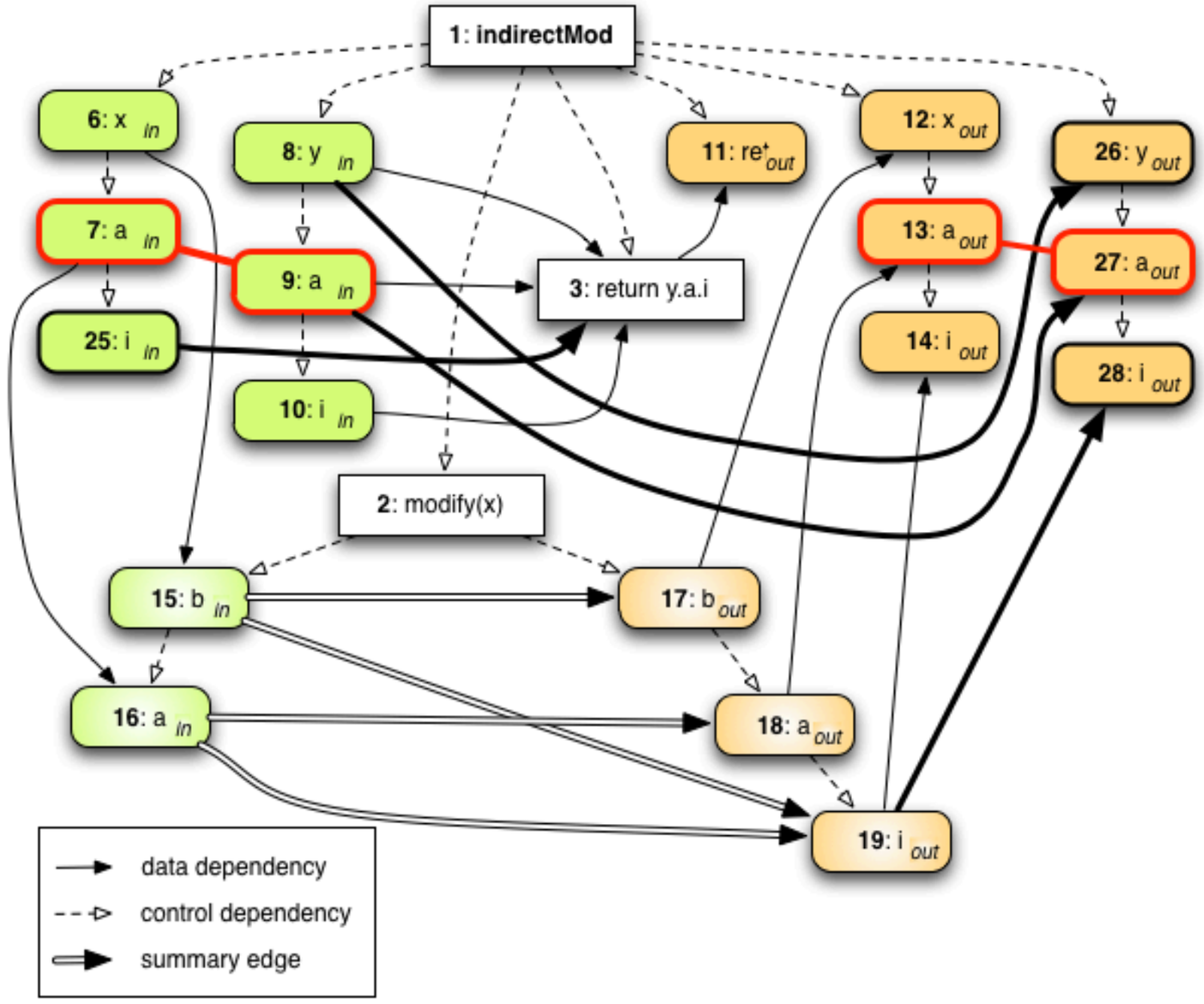

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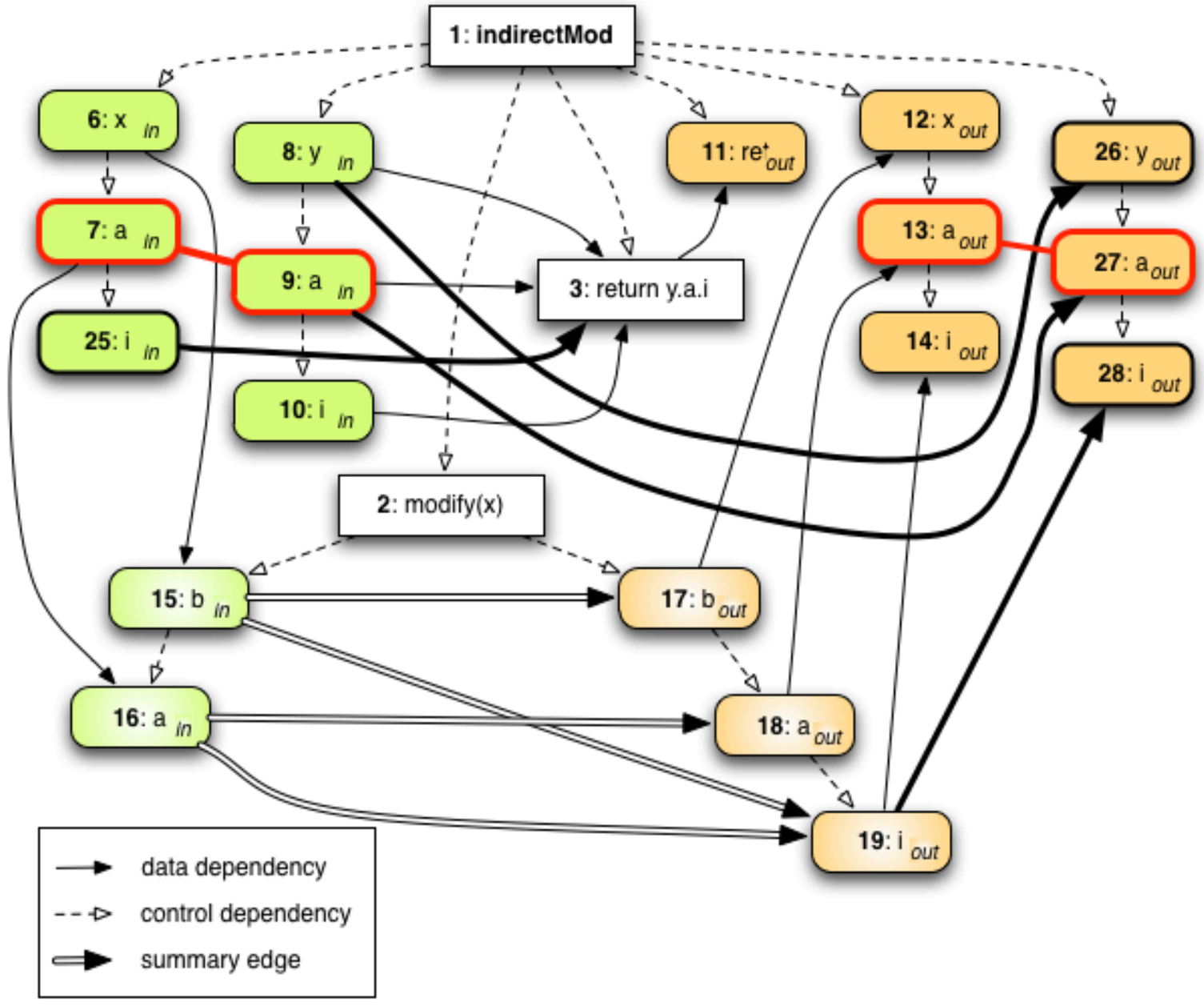
less precise points-to

⇒ x.a **?** y.a

*modifies [**x**,**y**].a.i*

*reads [**x**,**y**].a.i*



Object Graphs share indistinguishable fields

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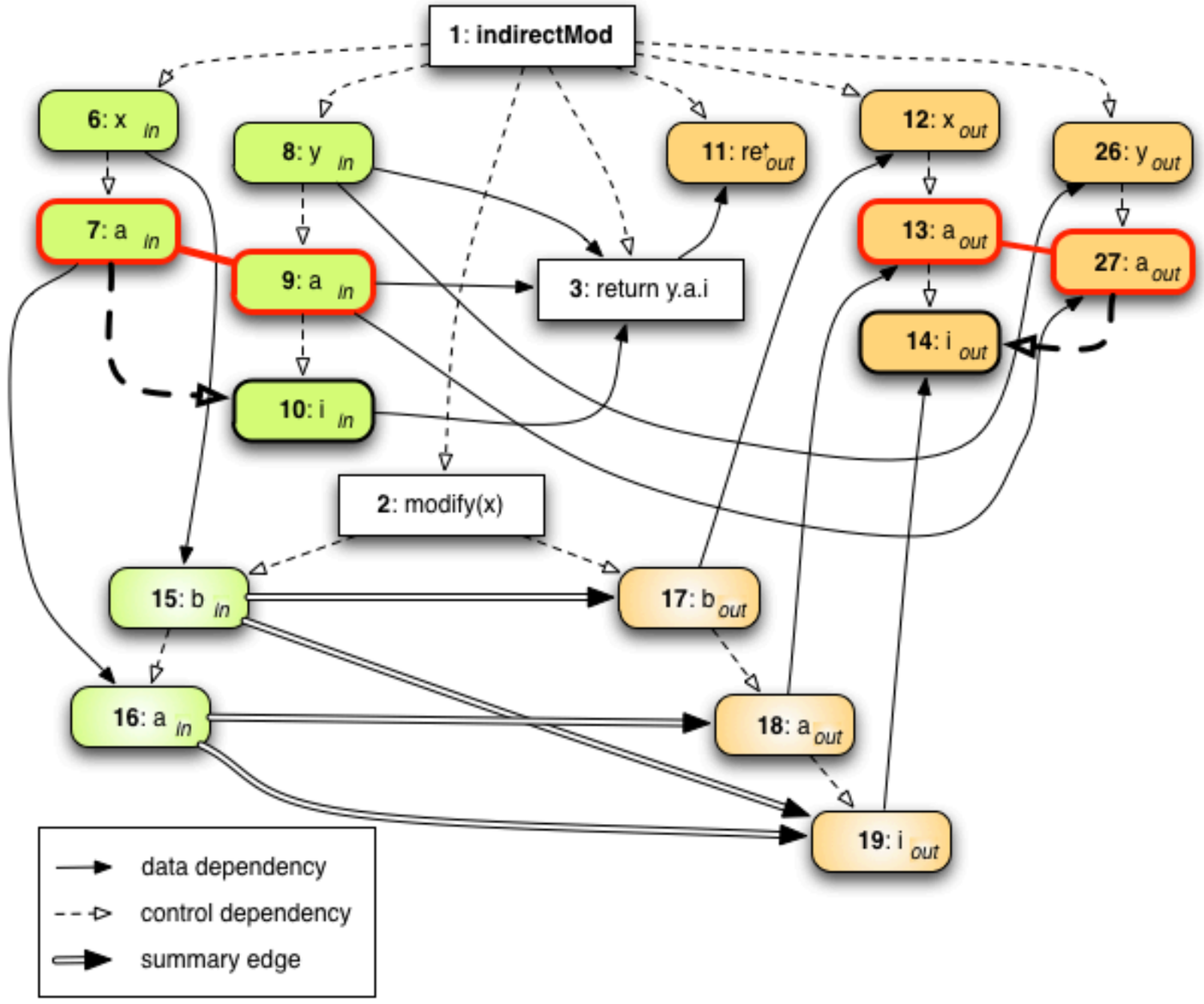


Implementation and Evaluation

SDG Generator using WALA Framework (wala.sf.net)

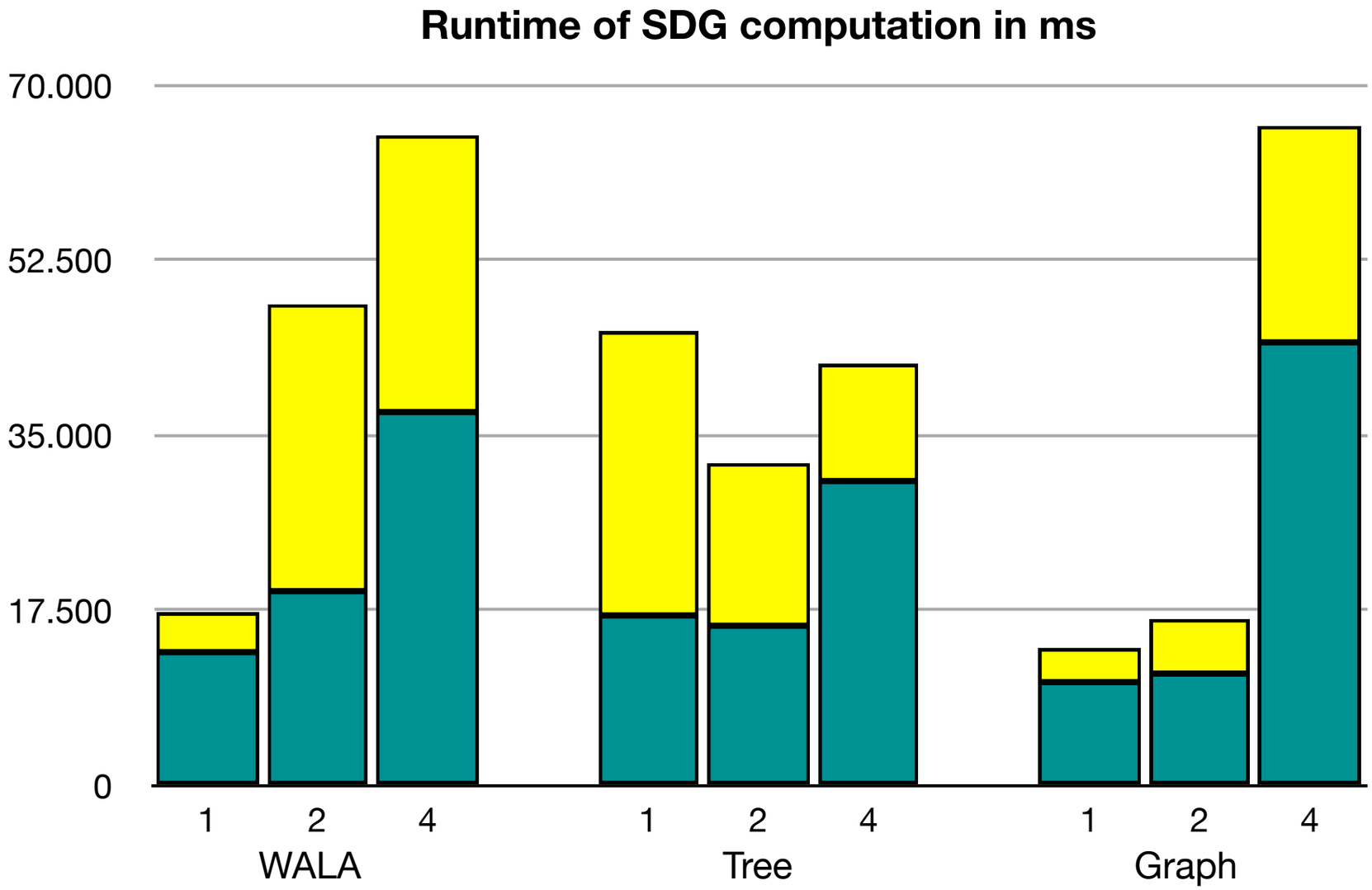
- **3 Parameter Models**
  - **Object Tree**
  - **Object Graph**
    - Optional escape analysis
    - Optimizations for interprocedural parameter node propagation
  - **WALA approach** (unstructured ⇒ less precision)

- **4 Points-to Analyses** (varying in precision)

Evaluation

- 20 programs from 120 - 63.000 LoC
- Many larger ones only with Object Graphs

Runtime


Runtime of SDG computation in ms
70.000
52.500
35.000
17.500
0
1
2
4
WALA
Tree
Graph
Computation phase:
Summary edge
SDG with parameters
Points-to Analysis:
1 Type based
2 Instance based
4 Object sensitive

Conclusion

- Parameter model has huge impact on runtime
- Object Trees suffer from scalability deadlock
- **Object Graphs**
  - Less nodes for less precision ⇒ **larger programs**
  - Less nodes for larger programs
  - **Maintain precision** of Object Trees
  - High precision points-to
    - Use Object Trees
    - Remove propagation optimization
- Additional results
  - Exception flow has a huge impact on precision
  - Precision benefit from points-to analysis varies
  - Advantage of structured parameter models: access path
    - No parameter nodes for side-effects that can not escape

The End

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Questions?

Statement

Static analyses will never be as precise and fast as dynamic analysis techniques. Why are we still trying?