Metrics to Identify Where Object-Oriented Program Comprehension Benefits from the Runtime Structure

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Code structure is different from runtime structure

- Developers often need to understand both code and runtime structure
- Runtime structure is hard to understand from looking at code
- No good sense of how different code and runtime structure are
- We propose metrics to measure difference between code and runtime structure
- Many tools focus on code structure; tools for reverse engineering runtime structure are less mature

Hierarchy of classes vs. Hierarchy of objects

```
+-java
  +-util
  | +-Hashtable
  |   +-Entry
  | +-class
  +-package
  | +-class
  |   +-innerclass
```

```
+-root
  +- TLD1
  | +- object1:B
  |   +- MAPS
  |     +- hash1:Hashtable
  |   +- OWNED
  |     +- hash2:Hashtable
  +- TLD2
  | +- object2:B
  |       +- OWNED
  |           +- hash3:Hashtable
```

Hierarchy of classes vs. Hierarchy of objects

```
+-java
  +-util
  | +-Hashtable
  |   +-Entry
  | +-class
  +-package
  | +-class
  |   +-innerclass
```

- Packages and classes
- Shows `Hashtable` once

```
+-root
  +- TLD1
  | +- object1:B
  |   +- MAPS
  |     +- hash1:Hashtable
  |   +- OWNED
  |     +- hash2:Hashtable
  +- TLD2
  | +- object2:B
  |       +- OWNED
  |           +- hash3:Hashtable
```

- Objects and groups of objects
- Shows multiple objects of type `Hashtable`

- Using hierarchy of objects leads to **less time and effort** for some code modification tasks [Ammar and Abi-Antoun, WCRE'12]

Objects matter (in addition to types), but specific instances do NOT matter

- Merge objects that have same *role*
- Object with same type can have different roles
- Collapse objects underneath other objects

```
+- object1:B
  +- MAPS
   | +- hash:Hashtable<String,String>
   |   +- KEYS
   |     +- key1:String
   |     +- key2:String
   |     +- key3:String
   |   +- VALUES
   |     +- val1:String
   |     +- val2:String
   |     +- val3:String
```

Objects matter (in addition to types), but specific instances do NOT matter

- Merge objects that have same *role*
- Object with same type can have different roles
- Collapse objects underneath other objects

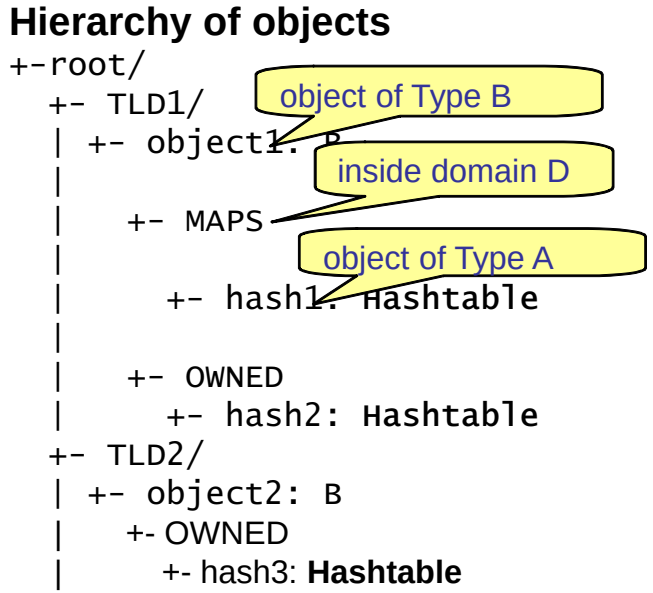
```
+- object1:B
  +- MAPS
  | +- hash:Hashtable<String,String>
  |   +- KEYS
  |     +- key:String
  |   +- VALUES
  |     +- val:String
```

Strategies for merging objects

- Dynamic analysis: hierarchical abstract heap [Marron et al., TSE'13]
- Static analysis: sound, hierarchical Ownership Object Graph (OOG) [Abi-Antoun and Aldrich, OOPSLA'09]
  - Extracted from code with annotations
  - **Abstract object** merges objects of same type and in same domain
  - **Domain** = named, conceptual group of objects
  - Edges are **points-to** relations - due to field references

Describe role of object by *type+group+hierarchy*

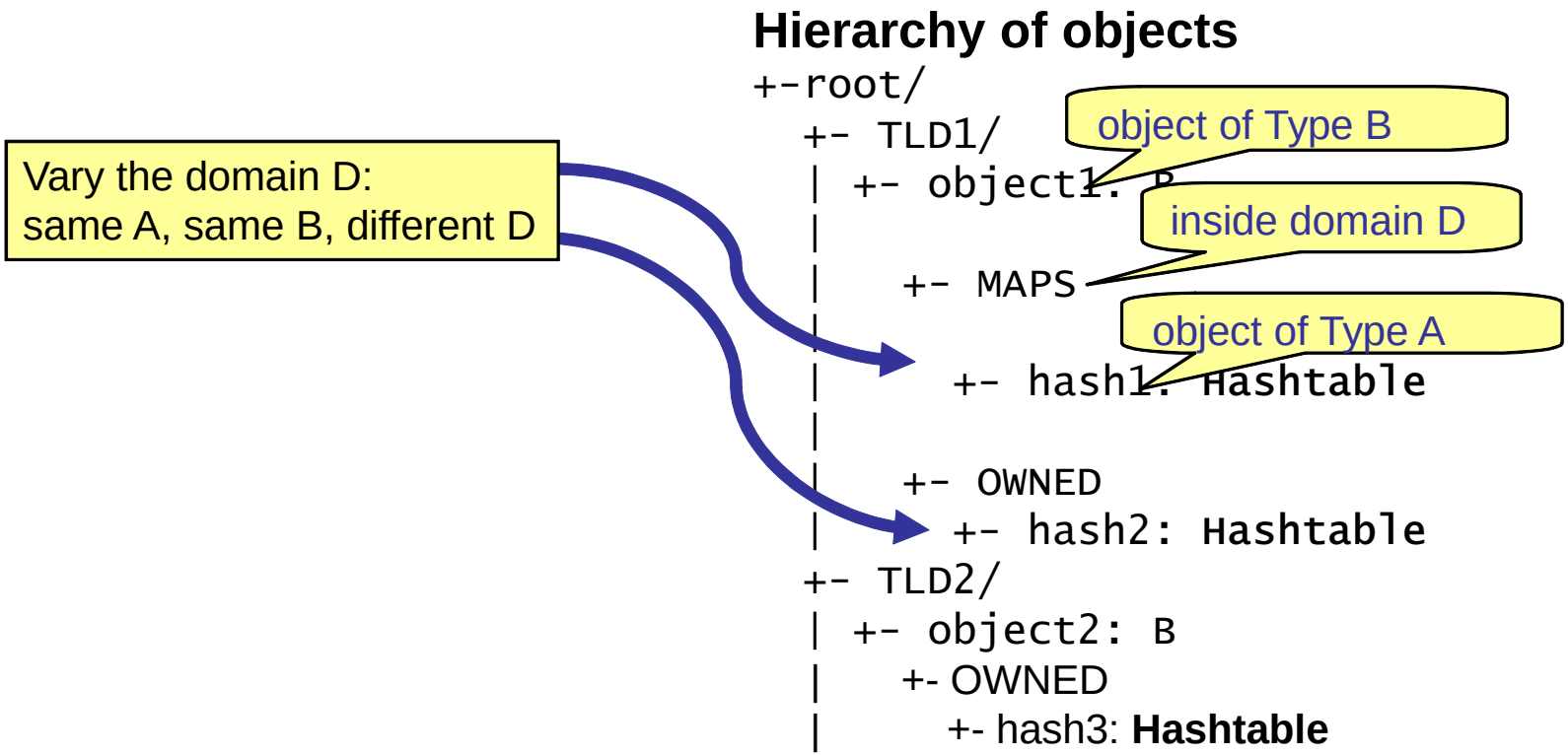
- Object hierarchy in OOG
  - Each object has domains,
  - Each domain has objects
- Describe role of an object, not just by type, but by named groups (domains) or by position in object hierarchy
- Triplet $\prec A, D, B \succ$:
  - object of type A
  - in domain D
  - in parent object of type B



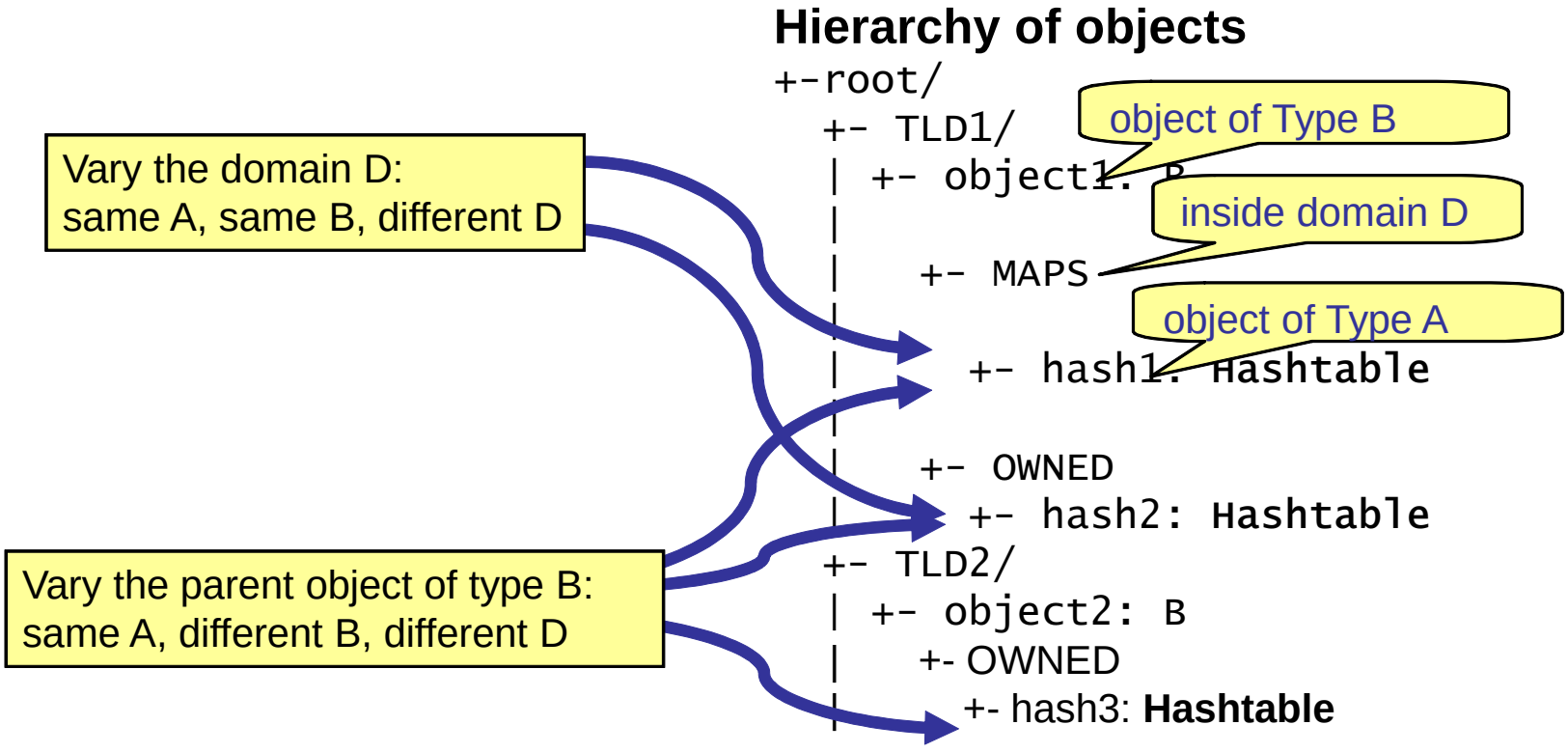
Measure differences code vs. runtime structure

- **One** class to **many** abstract objects
  - **Which-A-In-B**,
  - Which-A-In-Which-B
- **Many** object creation expressions to **one** abstract object
  - **Object Scattering**
- Unexpected enclosing declarations for objects, domains and edges
  - **Pulled Objects**,
  - Inherited Domains,
  - Inherited Edges,
  - Lifted Edges
- More precise edges based on *type+group+hierarchy*
  - **Edge precision**

Measure *Which-A-In-B*: count triplet pairs of same *A*, same *B*, different *D*



Measure *Which-A-In-Which-B*: count triplet pairs of same *A*, different *B*, different *D*



Results: *Which-A-In-B* in MiniDraw

- MiniDraw: framework for board games
  1,500 LOC, 31 classes and 17 interfaces

Table : $\prec A, D, B \succ$ triplets from MiniDraw that satisfy the metric *Which-A-in-B*, grouped by the raw type A.

A	**D**	**B**
ArrayList		
`ArrayList<FigureChangeListener>`	`owned`	`BoardDrawing`
`ArrayList<Figure>`	`owned`	`BoardDrawing`
`ArrayList<BoardFigure>`	`MAPS`	`BoardDrawing`
HashMap		
`HashMap<Position, List<BoardFigure> >`	`MAPS`	`BoardDrawing`
`HashMap<String,BoardFigure>`	`owned`	`BoardDrawing`

Many creation expressions to **one** abstract object

- Object creation expressions for one abstract object are scattered in multiple declaring types
- Object *scattering(O)*: number of distinct declaring types of *O*

$$scatteringFactor(O) = 1 - \frac{1}{scattering(O)}$$

Many creation expressions to **one** abstract object

Type declarations

```
class BreakthroughPieceFactory {
  p = new Position(row,col);
}

class MoveCommand{
  from = new Position( ... )
  to = new Position( ... );
}
```

Hierarchy of objects

```
+- main:Breakthrough
  +- MODEL
  | +- p:Position
```

- In MiniDraw:
  - 3 creation expressions
  - **2** enclosing type declarations
  - 1 abstract object
- *scattering(`p:Position`)* = 2
- *scatteringFactor(`p:Position`)*=0.5

Enclosing type declaration vs. type of parent object

≺`Figure,DATA,Breakthrough`≻ created in enclosing type `Board`

```
class Board {
  f = new Figure();
}
class Breakthrough{
  b = new Board();
}
```

Parent of `f:Figure` is `main:Breakthrough` NOT `board:Board`

```
+- main:Breakthrough
  +- CTRL
  | +- board:Board
  +- DATA
  | +- f:Figure
```

Precision of points-to edges

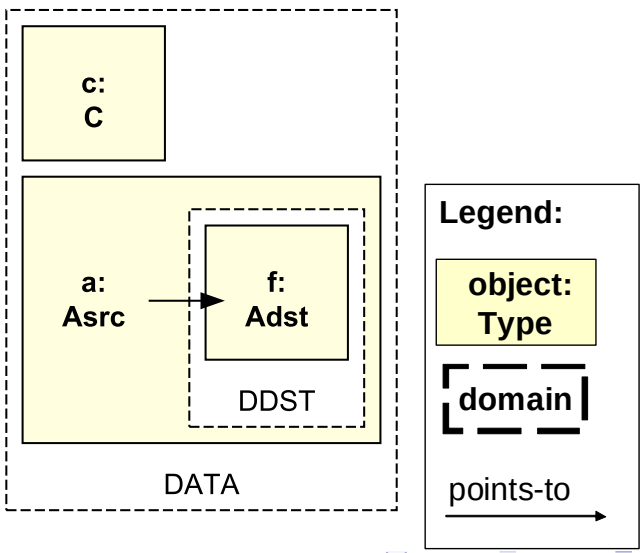
- More precise edges between objects
- Edge identified by pair of triplets and field name

points-to edge $E_f : \langle \prec A_{src}, D_{src}, B_{src} \succ, \prec A_{dst}, D_{dst}, B_{dst} \succ, f \rangle$

$$precision(E_f) = 1 - \frac{concrete\ subtypes\ A_{dst}\ in\ OOG}{all\ possible\ subtypes\ of\ type\ C\ of\ field\ f}$$

```
class Asrc {
  C f;
}
class Adst extends C {
}

Asrc a = new Asrc();
C c = new C();
a.f = new Adst();
```



Precision of points-to edges

Field Declaration (C f)	$\prec A_{src}, D_{src}, B_{src} \succ$
`Tool fChild`	$\prec$ `SelectionTool, CTRL, BreakThrough` $\succ$

AllPossibleSubClasses **(`Tool`) (7)**	*OOGPossibleSubTypes* **(`Tool`) (3)**
`NullTool`, `SelectAreaTracker`, `BoardActionTool`, `SelectionTool`, `DragTracker`, `SelectionTool`, `DragTracker`	`NullTool`, `SelectAreaTracker`, `DragTracker`

$$precision(E_{fchild}) = 1 - \frac{3}{7} = 0.57$$

Conclusion

- Recent work: for some tasks, developers using *type+hierarchy+group* spent less time and explored fewer code elements than developers using only *type*

  [Ammar and Abi-Antoun, WCRE'12]

- This work: use metrics to better understand how different code and runtime structure are
- Future work: run metrics across 8 systems (100 KLOC)
  - Find systems for which differences are higher
  - Find where in a system differences are higher

Future Work: compute metrics across systems