Refining the Reconstructed Runtime Architecture of Object-oriented softwares

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Plan

1. Introduction & problem statement
2. State of the art
3. Proposed approach
4. Conclusion & Perspectives

1. **Introduction & problem statement**

2. State of the art

3. Proposed approach

4. Conclusion & Perspectives

Introduction & problem statement (1/2)

- Software evolution is inescapable.
- For developers, it is crucial to understand the structure of the system before attempting to modify it.
- The global understanding can not be achieved by just reviewing the source code.
- Instead, the architecture of the system is needed.
- Problem 01: ***"software architecture erosion"***
    - Architecture descriptions are, if available, outdated and incorrect.
- Solution: "***Control software architecture erosion"***
    - Minimize erosion.
    - Prevent erosion.
    - Repair erosion**: Architecture recovery**.

Introduction & problem Statement (2/2)

- Problem 02: ***Unreadable architectures in the case of large systems***

- Solution:

    - Mitigate the complexity of the architecture by

        - ***1. Refinement:*** *with* lifespans and probability of existence at run-time.
        - ***2. Abstraction:*** *identification* of composite structures and use of thresholds to make a visualization with a Level of Detail (LoD).

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State of the art (1/5)

- The reconstruction process begins with a phase of system's information extraction.
- Extracted information can be categorized as either static or dynamic.
- Several approaches were proposed
  - Classification: Ducasse, S, & Pollet, D. *"Software architecture reconstruction: A process-oriented taxonomy"*. IEEE Transactions on Software Engineering, 2009.
  - Empirical comparison: Lutellier, Thibaud, et al. "*Comparing software architecture recovery techniques using accurate dependencies*.". 37th IEEE International Conference on Software Engineering (*ICSE*). 2015.
- **Focus in our approach:** Works that reconstruct the run-time architecture.

State of the art (2/5)

I. Paolo Tonella and Alessandra Potrich, "*Reverse Engineering of Object Oriented Code*", 2005.

- **Purpose:** document an object oriented software system.
- **Approach:** reverse engineering of class, object, interaction, state and package diagrams.
  - The basic program representation for the static analysis to extract all diagrams is an **Object Flow Graph (OFG).**

1. Object Flow Graph:

- An OFG allows tracking the lifetime of the objects from their creation along their assignment to program variables.
- Steps for constructing an **OFG:**

1. Simplify Java language into an abstract language (Declarations* Statements*).
2. Construct the graph (nodes = program locations, edges = assignments).

Example (1/3)

```
public class BinaryTreeNode {

BinaryTreeNode left, right;

public void

addLeft(BinaryTreeNode n)

 {left = n;}

public void

addRight(BinaryTreeNode n)

 {right = n;}

}
```

1

```
public class BinaryTree {
BinaryTreeNode root;

public void build()
{  root = new BinaryTreeNode();
   BinaryTreeNode curNode = root;
   While(...)
  {
   curNode.addLeft(new BinaryTreeNode());
   curNode.addRight(new BinaryTreeNode());
  }
}
static public void main()
{
BinaryTree bt = new BinaryTree();
bt.build();
}
```

2

Example (2/3)

- **Abstract language**

1- Declarations

1

BinaryTreeNode.left
BinaryTreeNode.right

BinaryTreeNode.addLeft(BinaryTreeNode.addLeft.n)
BinaryTreeNode.addRight(BinaryTreeNode.addRight.n)

2

BinaryTree.root
BinaryTree.build()
BinaryTree.main()

2- Statements

1

BinaryTreeNode.left = BinaryTreeNode.addLeft.n
BinaryTreeNode.right = BinaryTreeNode.addRight.n

2

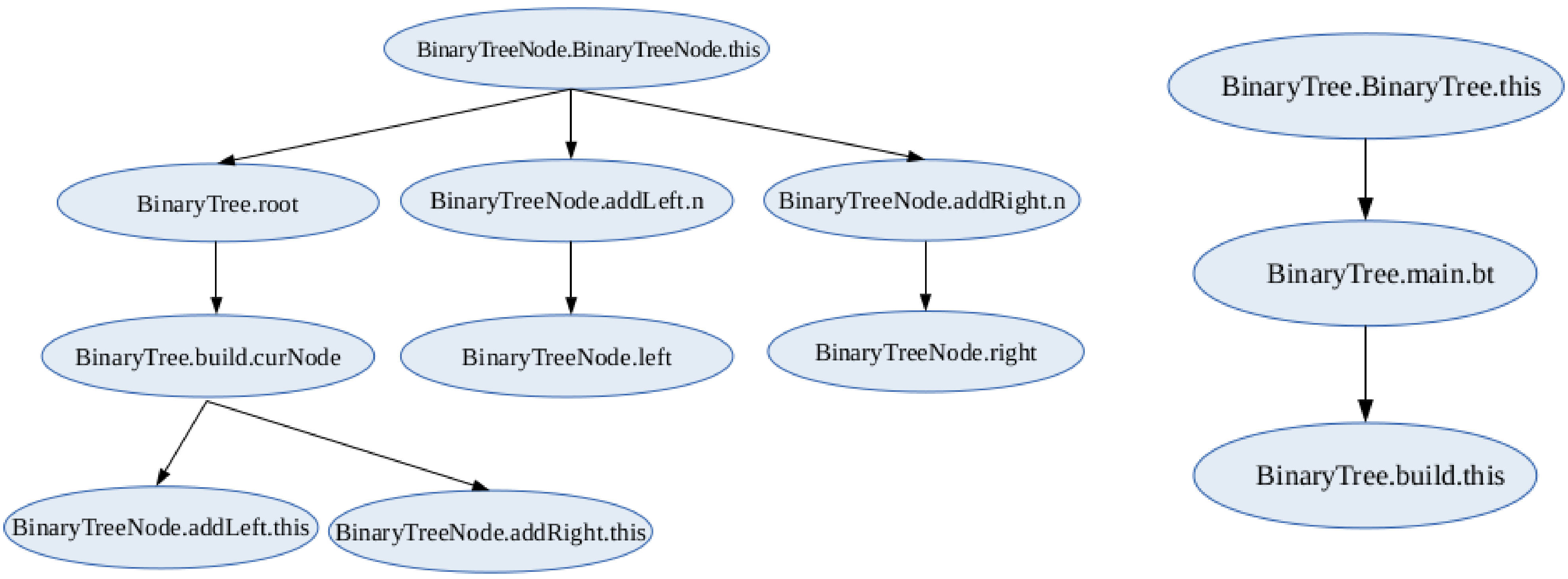
BinaryTree.root = BinaryTreeNode.BinaryTreeNode.this
BinaryTree.build.curNode = BinaryTree.root

BinaryTreeNode.addLeft.n = *BinaryTreeNode.BinaryTreeNode.this*
BinaryTreeNode.addLeft.this= BinaryTree.build.curNode

BinaryTreeNode.addRight.n = *BinaryTreeNode.BinaryTreeNode.this*
BinaryTreeNode.addRight.this = BinaryTree.build.curNode

BinaryTree.main.bt = *BinaryTree.BinaryTree.this*
BinaryTree.build.this = BinaryTree.main.bt

Example (3/3)



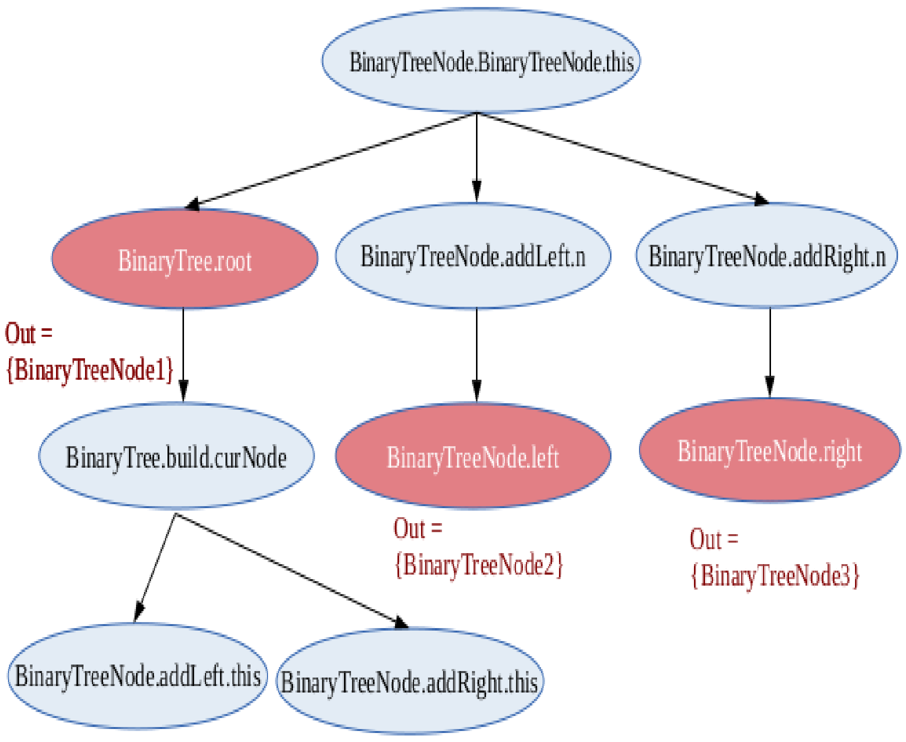
State of the art (3/5)

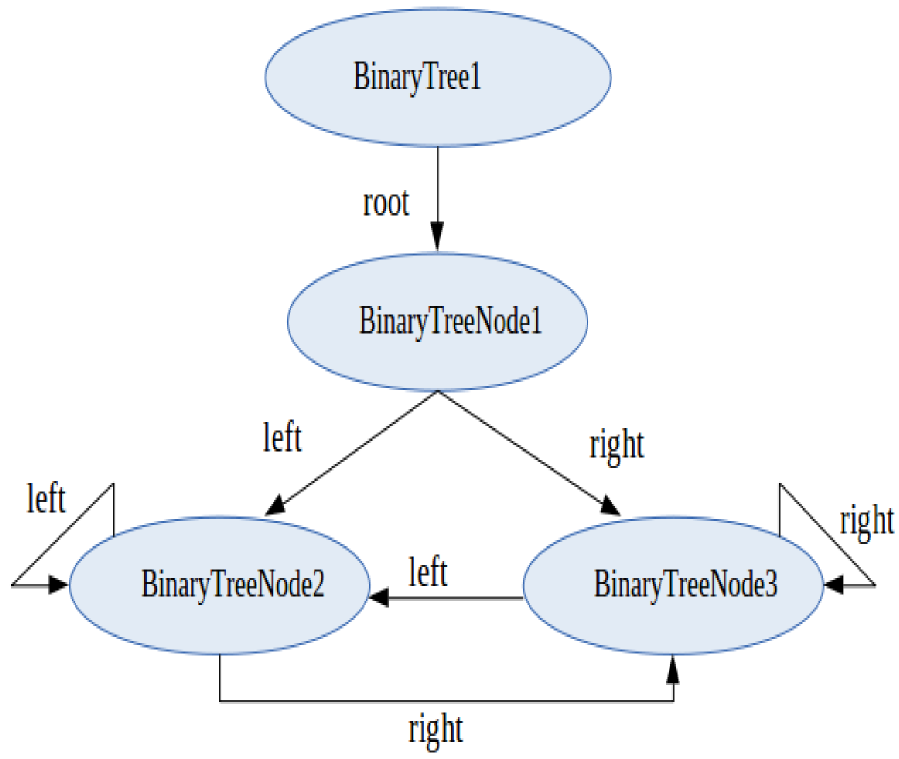
2. Static object diagram

- Represents the set of objects created by a given program and the relationships holding among them.
- Objects are identified by allocation sites with a control-flow insensitive way
- The OFG is used to determine the inter-object relationships.
- The presence of a relationship between two objects in the graph means that there is a path in the program along which the first object can reference the second through an attribute.
- The relations between the objects in this graph are a conservative super-set of those that really exist in execution time.

Analysis Type	Refinement		Abstraction	
	lifespans	Prob. of exist	Relations of composition	Viz. with LoD
Static				

Example





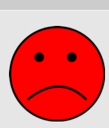
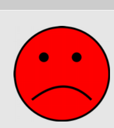
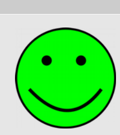
Out sets of attributes

out[BinaryTree.root] = {BinaryTreeNode1}
out[BinaryTreeNode.left] = {BinaryTreeNode2}
out[BinaryTreeNode.right] = {BinaryTreeNode3}

State of the art (4/5)

II. Flanagan, Cormac, and Stephen N. Freund. "*Dynamic architecture extraction*." Formal Approaches to Software Testing and Runtime Verification (*FATES*). 2006.

- **Purpose:** aid understanding and reasoning about object oriented systems
- **Approach:** *AARDVARK* tool for the reconstruction of object models
  - **Steps**:
  1) Execute an instrumented target program that records a log of all object allocations and field writes.
  2) Use the logs to reconstruct a snapshot of the heap for each execution.
  3) Apply a sequence of abstraction-based operations to each heap.
  4) Combine the results into a single object model.

Analysis Type	Refinement		Abstraction	
	lifespans	Prob. of exist	Relations of composition	Viz. with LoD
Dynamic				

State of the art (5/5)

III. Abi-Antoun, M., Ammar, N., & Hailat, Z.. “*Extraction of ownership object graphs from object-oriented code: an experience report*”. In Proceedings of the 8th International ACM SIGSOFT conference on Quality of Software Architectures (QoSA). 2012.

- **Purpose:** allow detailed understanding by achieving hierarchy in static object diagrams.
- **Approach:** SCHOLIA technique to statically extract a hierarchical runtime architecture from object oriented code using annotations.
    - **Steps:**
        1) The developer pick an object as a starting point then use local modular ownership annotations to impose an hierarchy on objects.
        2) A static analysis extracts a global object graph from the annotated program.

Analysis Type	Refinement		Abstraction	
	lifespans	Prob. of exist	Relations of composition	Viz. with LoD
Static	☹	☹	☺	☹

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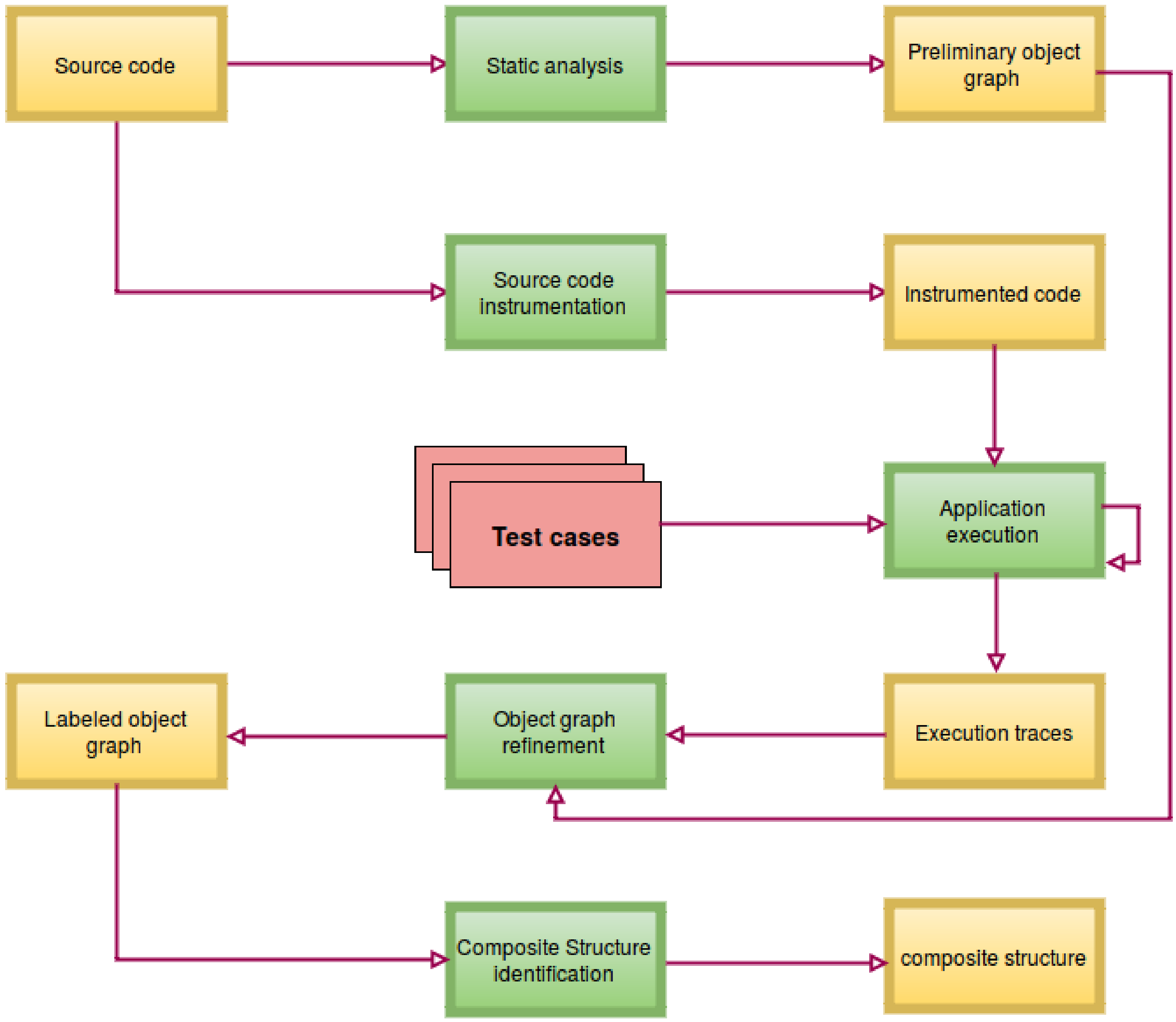
Proposed approach (1/4)

- Static information is valuable to understand the structure of the system.
  - **Limit**: extracted information is potentially true.
- Dynamic information exposes the system's behavior.
  - **Limit**: provide a partial picture of the system.
- **Proposal**
  - Refining the static architecture using the informations contained in the dynamic architecture.

Proposed approach (2/4)



Proposed approach (3/4)

- **1st Step:** Static analysis
  - Create a preliminary object graph: nodes represent objects and edges represent dependencies between objects.
- **2nd Step:** Source code instrumentation to generate execution traces
  - Targets: object creation/destruction and dependency establishment/breaking.
  - The execution of the instrumented code generates traces.
  - Each trace contains informations about:
    - Creation/destruction of objects.
    - Establishment/breaking of dependencies.
    - Timestamps.

Proposed approach (4/4)

- **3rd Step:** Refining the object graph by analyzing the execution traces
  - Inserting two kinds of labels:
    - Lifespans: measured using the creation and destruction timestamps.
    - Probabilities: the ratio of the number of times that a node/edge exist in the execution traces to the total number of execution traces.
- **4th step:** Construction of the composite structure

Analysis Type	Refinement		Abstraction	
	lifespans	Prob. of exist	Relations of composition	Viz. with LoD
Hybrid				

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Conclusion & perspectives

- The proposed approach allows :
    - Building a graph representing objects and their dependencies.
    - Enriching the graph with probabilities and lifespans.
    - Identifying composition relations between objects and use of thresholds.
- Perspectives:
    - Implementation of the approach.
    - Experiment the approach on a large and extensively used systems.

Thank you

Questions ?
Comments ?