Lund University
Computer Science Department

A Precise Framework for Source-Level Control-Flow Analysis

21st IEEE International Working Conference on Source Code Analysis and Manipulation

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Introduction

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The main challenges were:

- Large engineering effort for each source language
- The syntax doesn't always reflect the program's semantics

Our approach

We build the CFGs as extension of the AST using Reference Attribute Grammars (RAGs)

- **Declarative** specification
- Handle **implicit control flow**
- Overcome the limitations of an earlier framework

Research questions

- How can we reduce the engineering effort ?
- How can we fill the gap between *syntax and semantics* ?
- Is our new approach competitive performance-wise?

Intraprocedural RAG-based CFGs

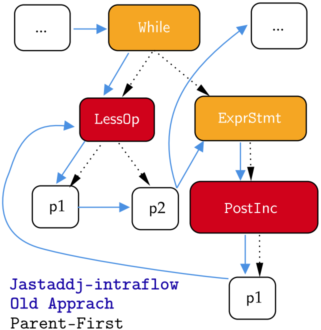
We removed the limitations of the previous approach

Code

```
while(p1<p2){
  p1++;
}
```

Legend

🟧🟥▨□ AST node	🟥 Misplaced	→ succ
▨ Not in CFG	🟧 Redundant	⋯► Child relation



Jastaddj-intraflow
Old Apprach
Parent-First

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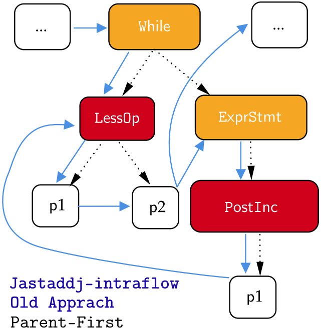

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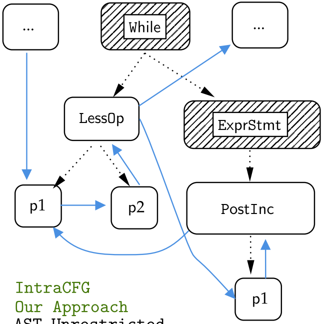
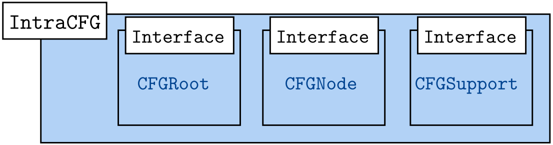


IntraCFG
Our Approach
AST-Unrestricted

Modular architecture



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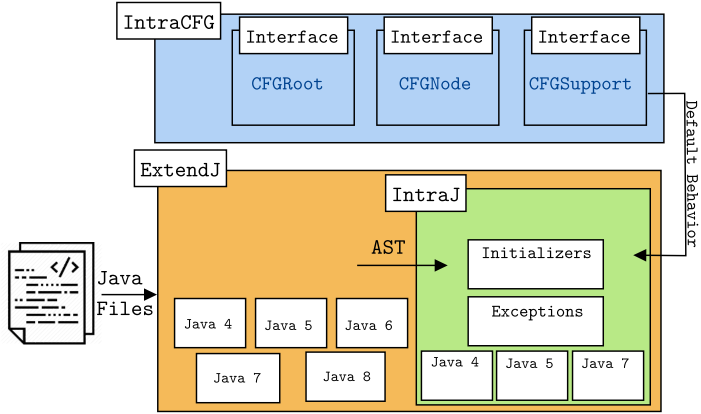

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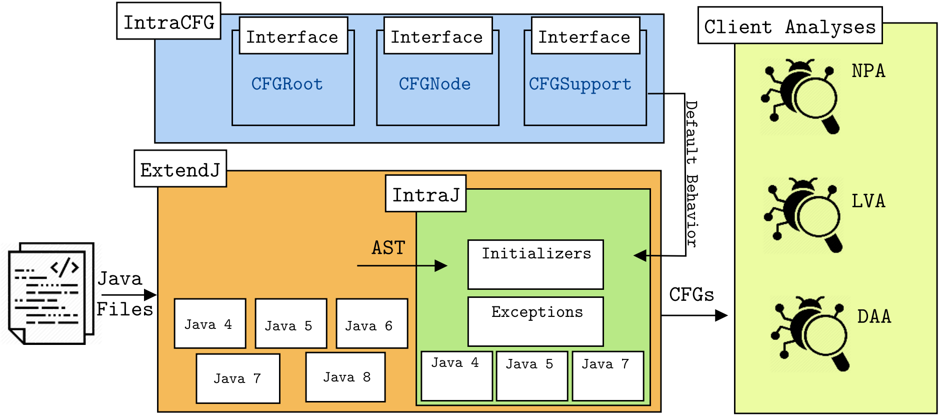

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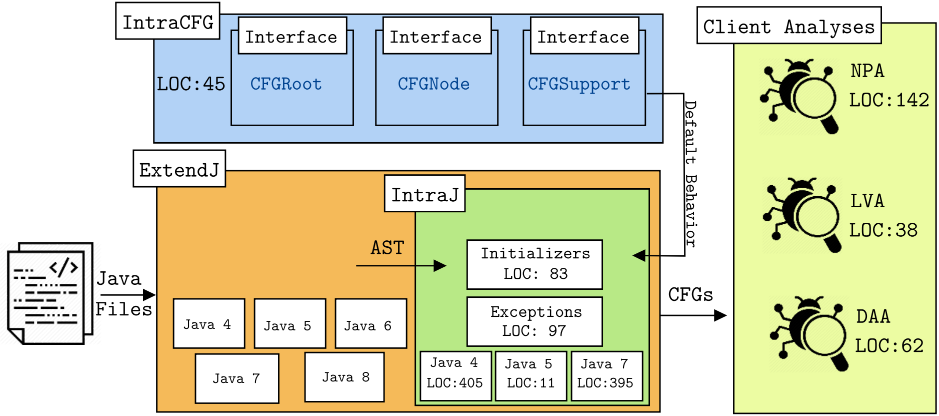
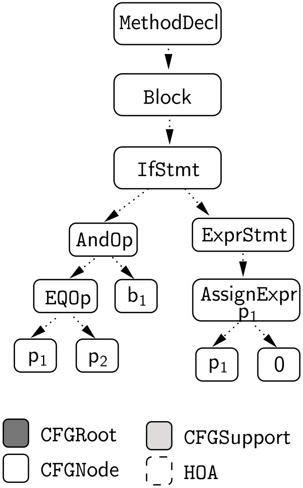


Framework overview



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foo(int p1, int p2, Boolean b1){
  if(p1==p2 && b1)
    p1 = 0;
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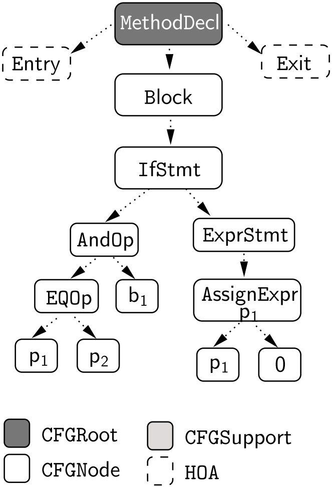

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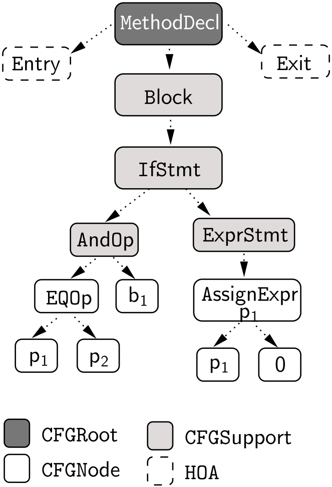

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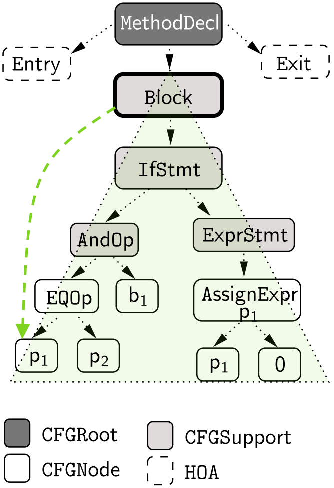

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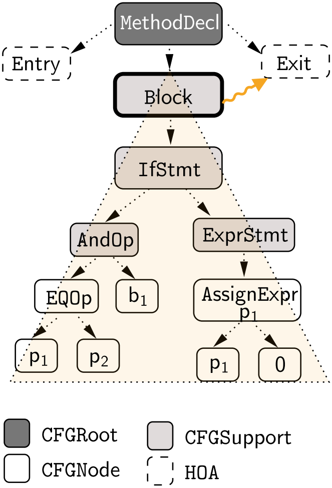

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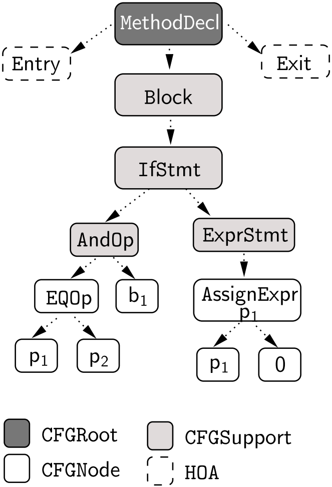

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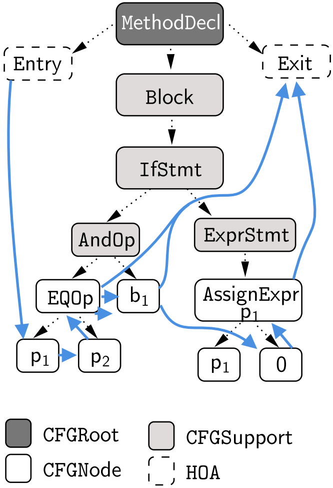

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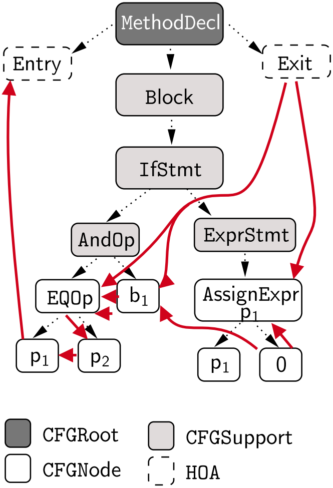

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- The pred is computed as the inverse of succ

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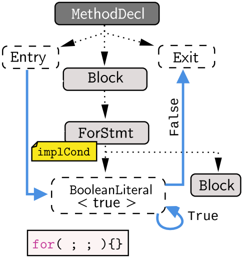

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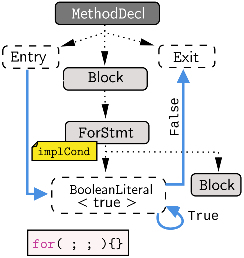

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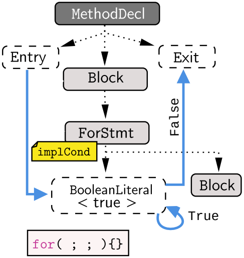

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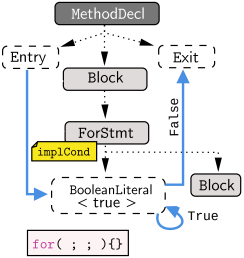

- We used Circular attribute to compute mutually depended attributes
  - The attribute may depends on its own value
  - Computes a fixpoint

Client analyses

We validate IntraJ by implementing three different dataflow analyses:

- `NullPointerAnalysis` - **NPA** **MAY** - **FORWARD**
- `LiveVariableAnalysis` - **LVA** **MAY** - **BACKWARD**
- `DeadAssignmentAnalysis` - **DAA** uses **LVA**

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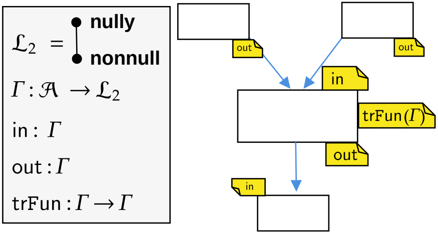

$\mathcal{L}_2 =$ **nully** / **nonnull**

$\Gamma : \mathcal{A} \to \mathcal{L}_2$

in : Γ

out : Γ

trFun : $\Gamma \to \Gamma$

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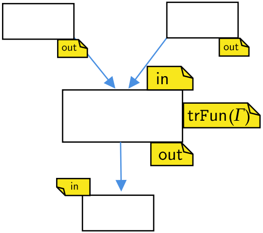


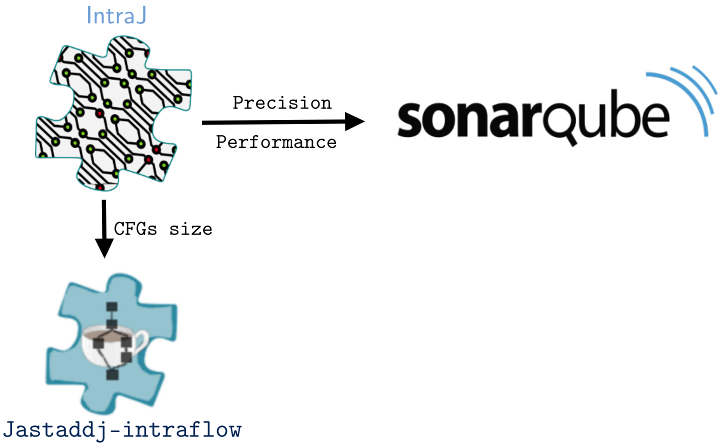
- Default behaviour for `CFGNodes`

```
trFun(Γ){
  return Γ;
}
```

- Specialised behaviour for `AssignExpr`

```
trFun(Γ){
  if(rhs.mayBeNull())
    Γ.put(lhs.decl(),nully);
  else
    Γ.put(lhs.decl(),nonnull);
  return Γ;
}
```

Overview



IntraJ

Precision

Performance

CFGs size

Jastaddj-intraflow

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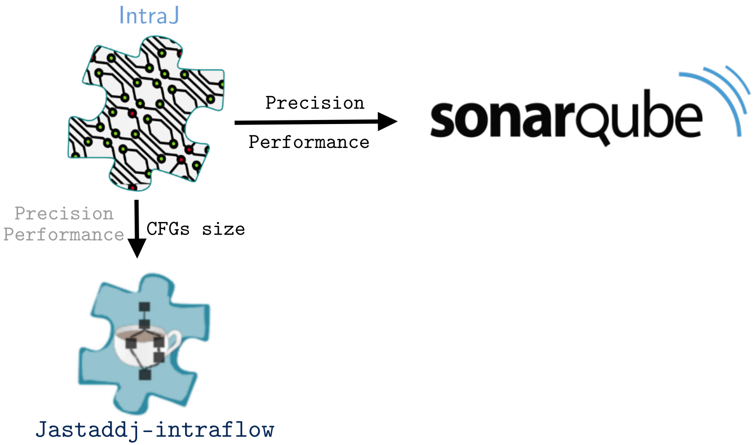

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sonarqube

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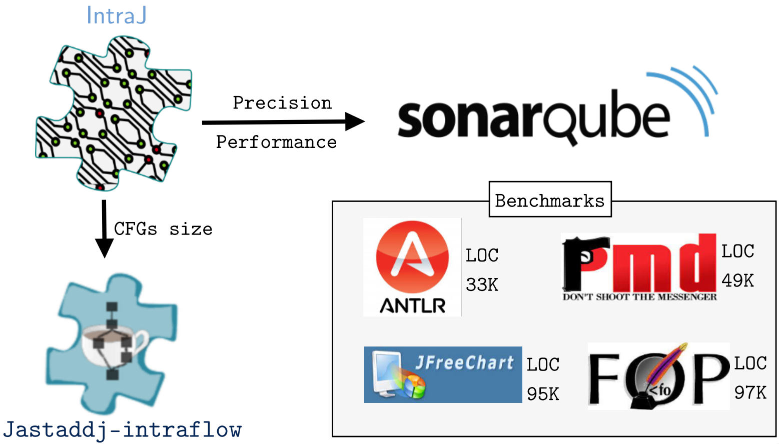


Benchmarks

ANTLR	LOC 33K
pmd DON'T SHOOT THE MESSENGER	LOC 49K
JFreeChart	LOC 95K
FOP	LOC 97K

Benchmark Projects

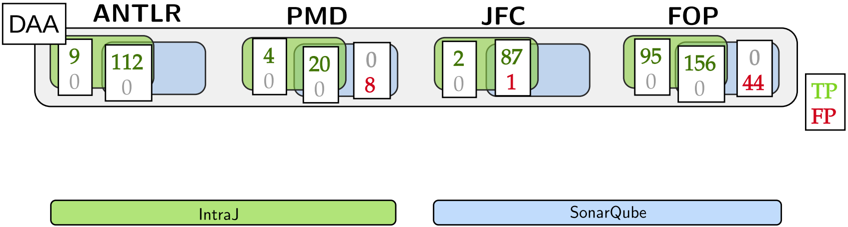
IntraJ reduces the CFGs size by 30% - 40%

Benchmark	Qty	IntraJ	JJI	%
ANTLR	Nodes	76˙925	116˙523	**-39.9**
	Edges	85˙028	136˙528	**-37.7**
PMD	Nodes	103˙739	182˙864	**-43.2**
	Edges	108˙639	202˙842	**-46.4**
JFC	Nodes	219˙419	331˙368	**-33.7**
	Edges	220˙256	363˙642	**-39.4**
FOP	Nodes	239˙096	347˙125	**-31.1**
	Edges	240˙068	379˙269	**-36.6**

By removing all the redundant nodes

IntraJ vs SonarQube

We evaluated IntraJ against SonarQube



DAA

ANTLR
9
0
112
0

PMD
4
0
20
0
0
8

JFC
2
0
87
1

FOP
95
0
156
0
0
44

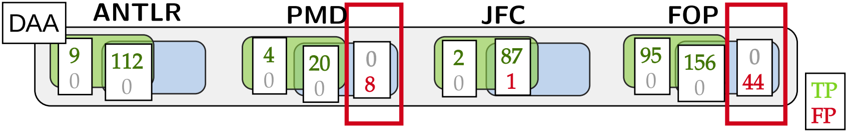
TP
FP

IntraJ

SonarQube

IntraJ vs SonarQube

We evaluated **IntraJ** against **SonarQube**



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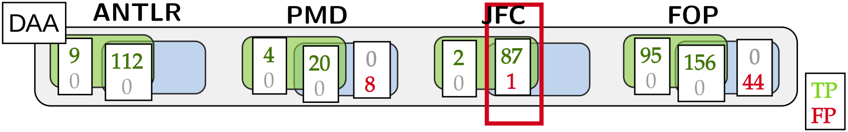

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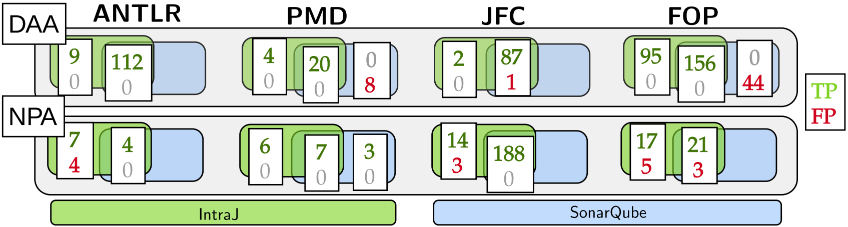

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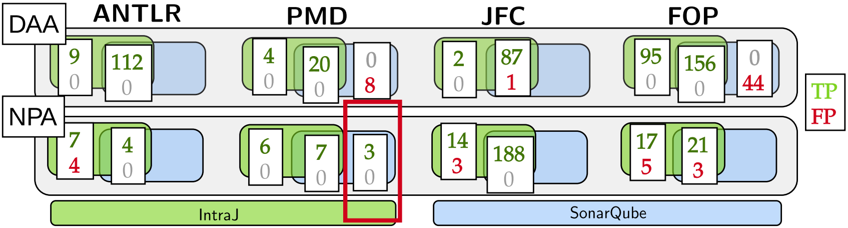

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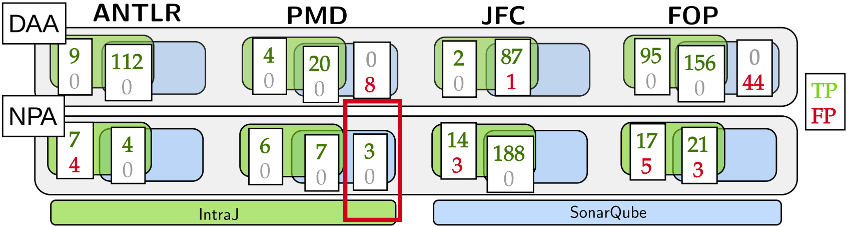

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	IntraJ	SQ	IntraJ	SQ	IntraJ	SQ
ANTLR	2.14	4.91	0.53	0.24	0.90	12.35
PMD	3.56	10.76	0.47	0.18	0.80	12.40
JFC	4.29	10.81	0.75	0.24	1.62	10.71
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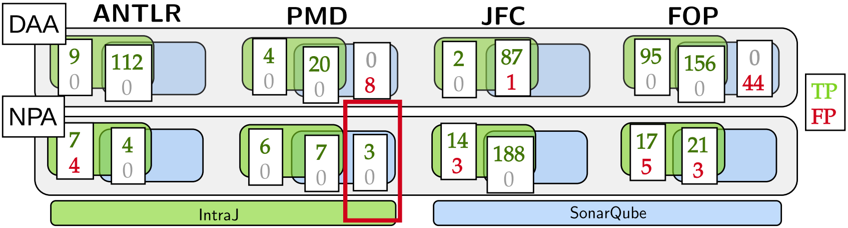

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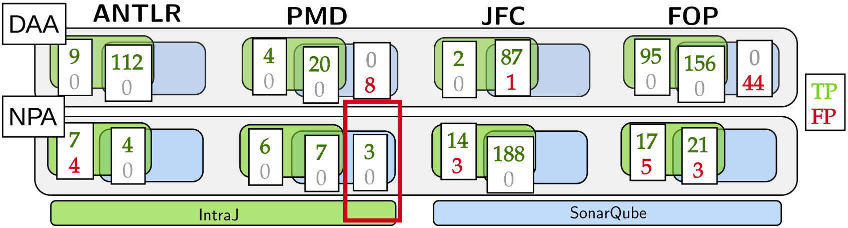

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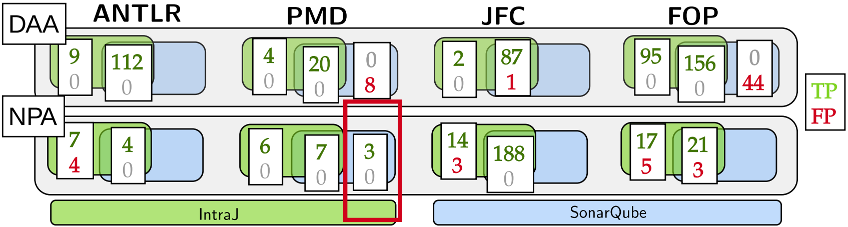

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