Feature-Sensitive Coverage for Conformance Testing of Programming Language Implementations

Jihyeok Park [1], Dongjun Youn [2], Kanguk Lee [2], and Sukyoung Ryu [2]

[1] KOREA UNIVERSITY [2] KAIST

June 21, 2023

PLRG

PLDI Orlando 2023

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Our Idea

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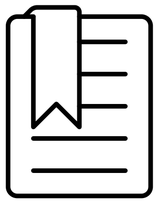
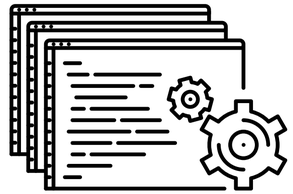


Specification
of **L_1**



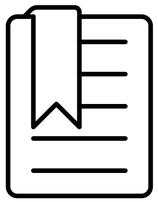
Implementations
of **L_1**

Programming Language **L_1**

Conformance Testing of PL Implementations

$A ::= BC$
Syntax

$[\![-]\!]$
Semantics



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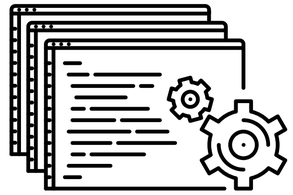

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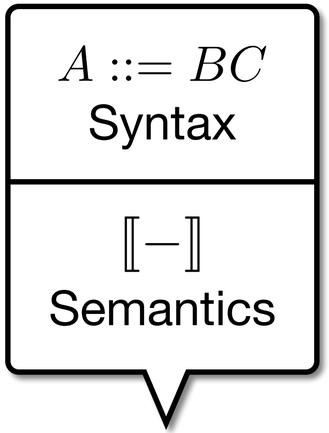

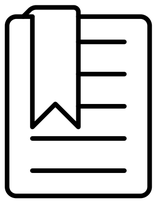

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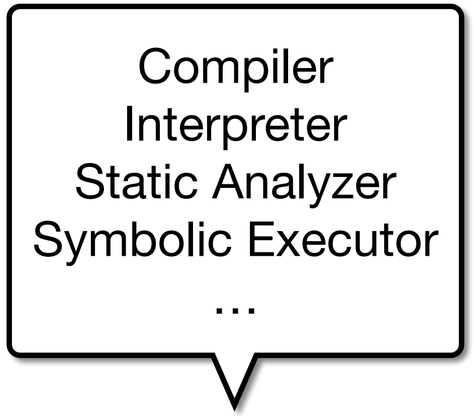

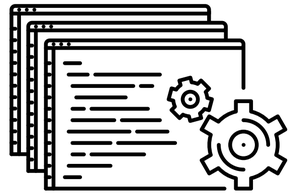

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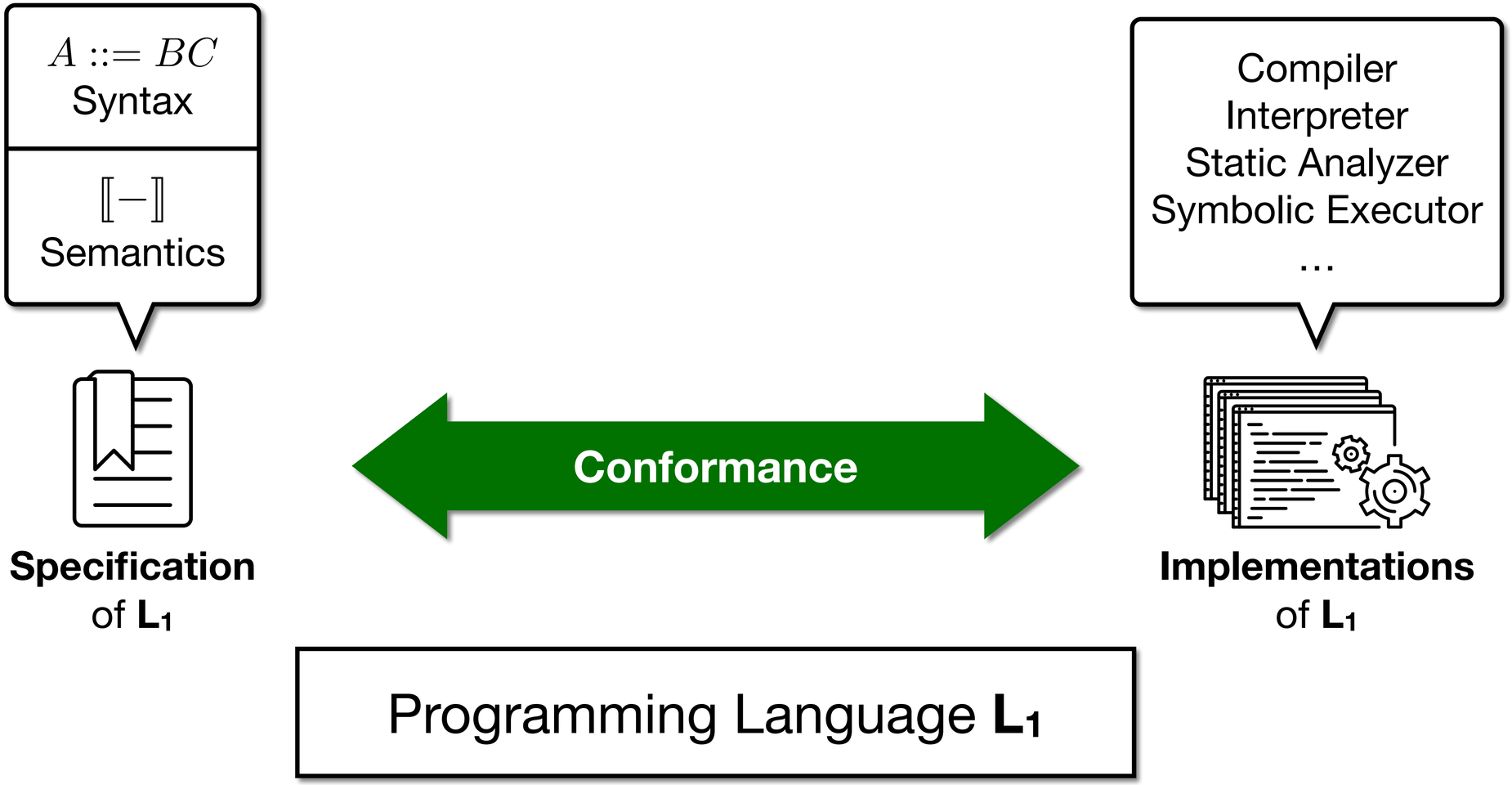

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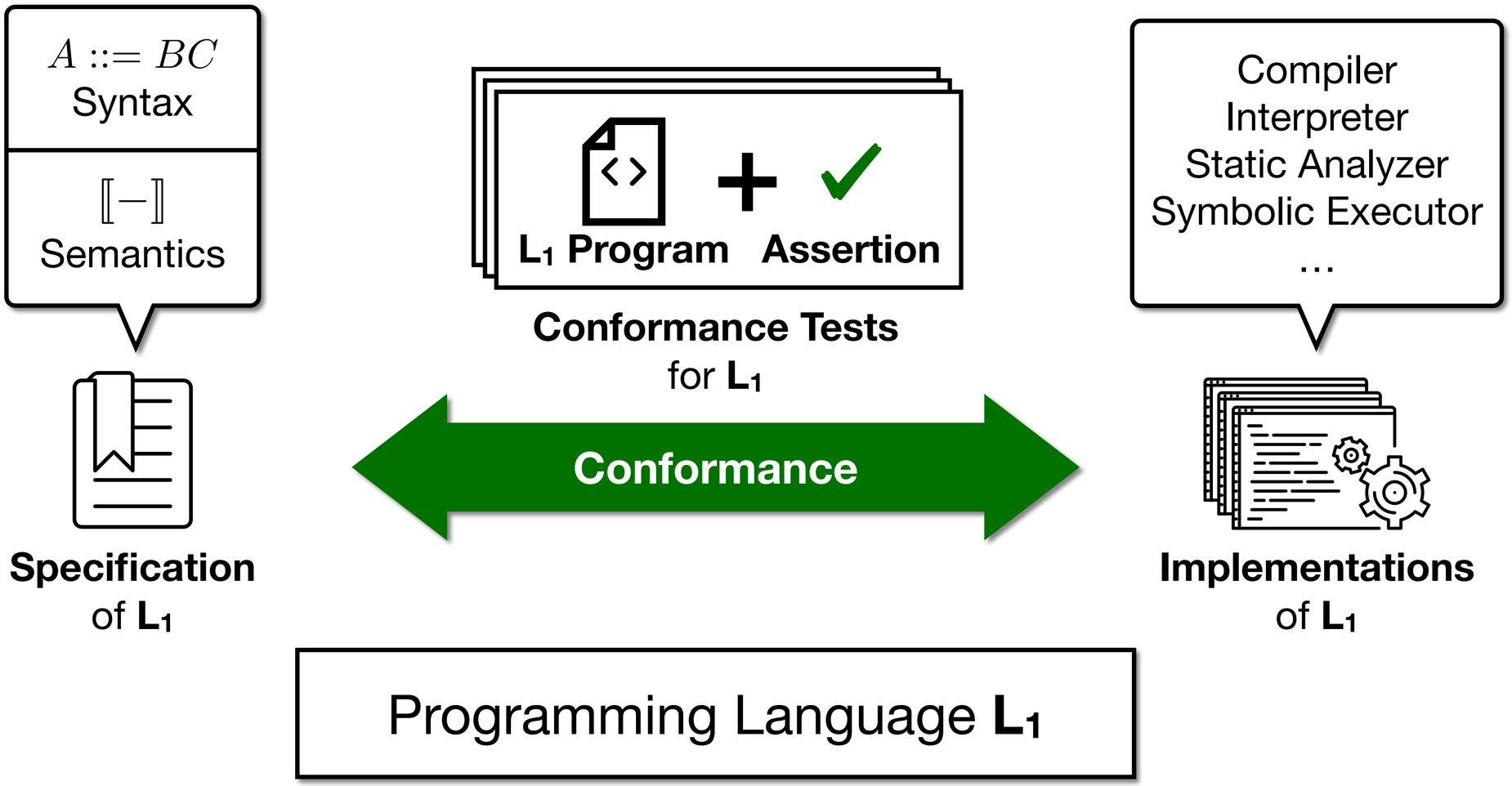

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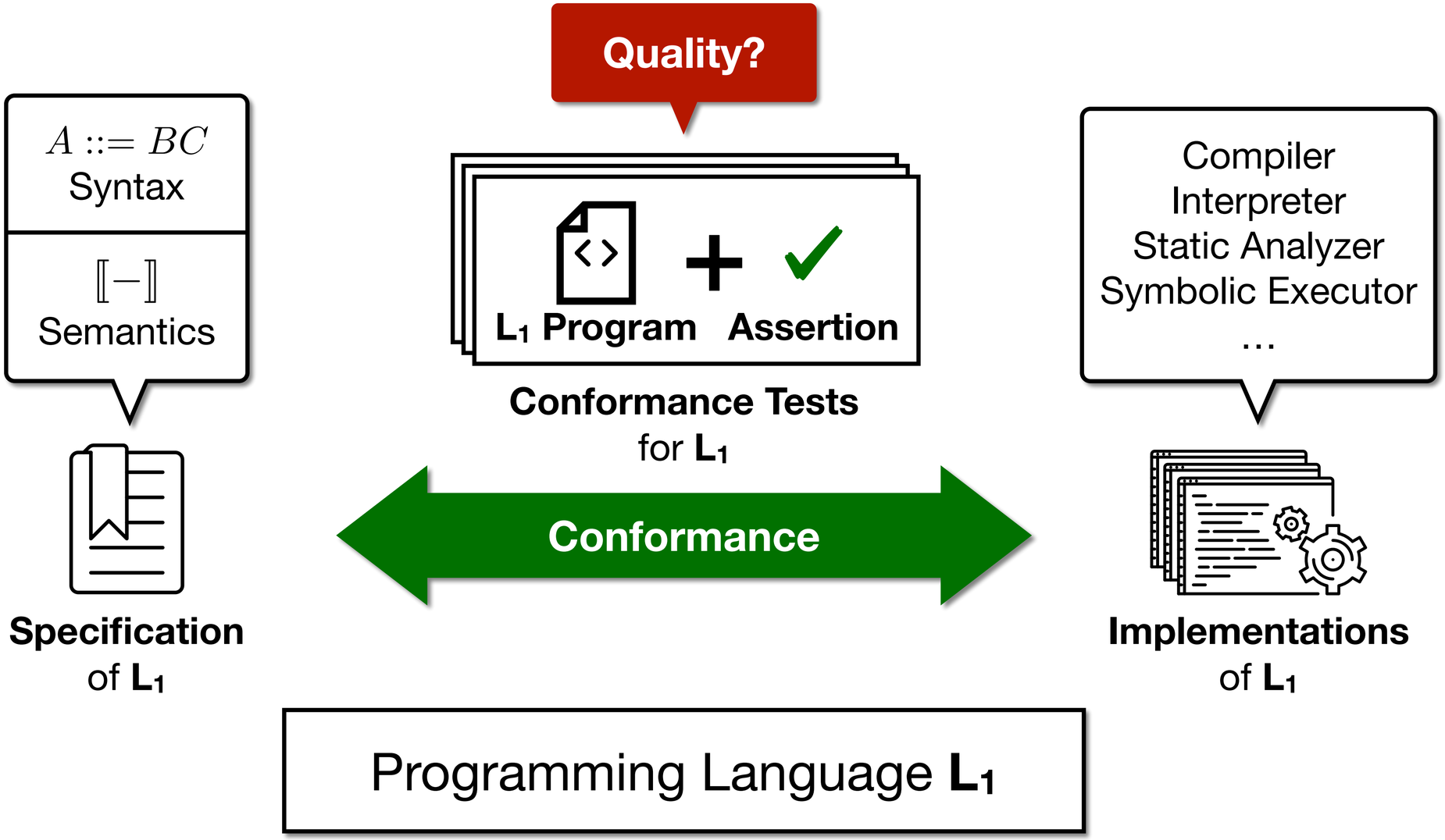
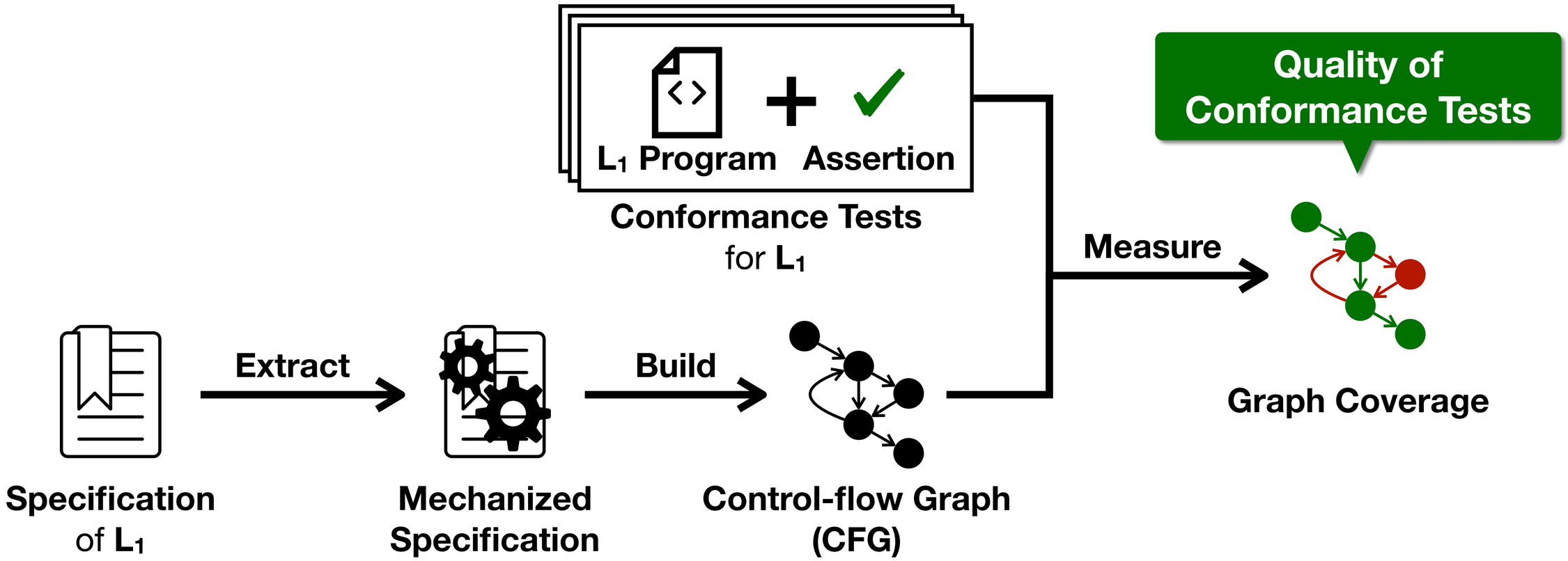


Graph Coverage for Language Specification



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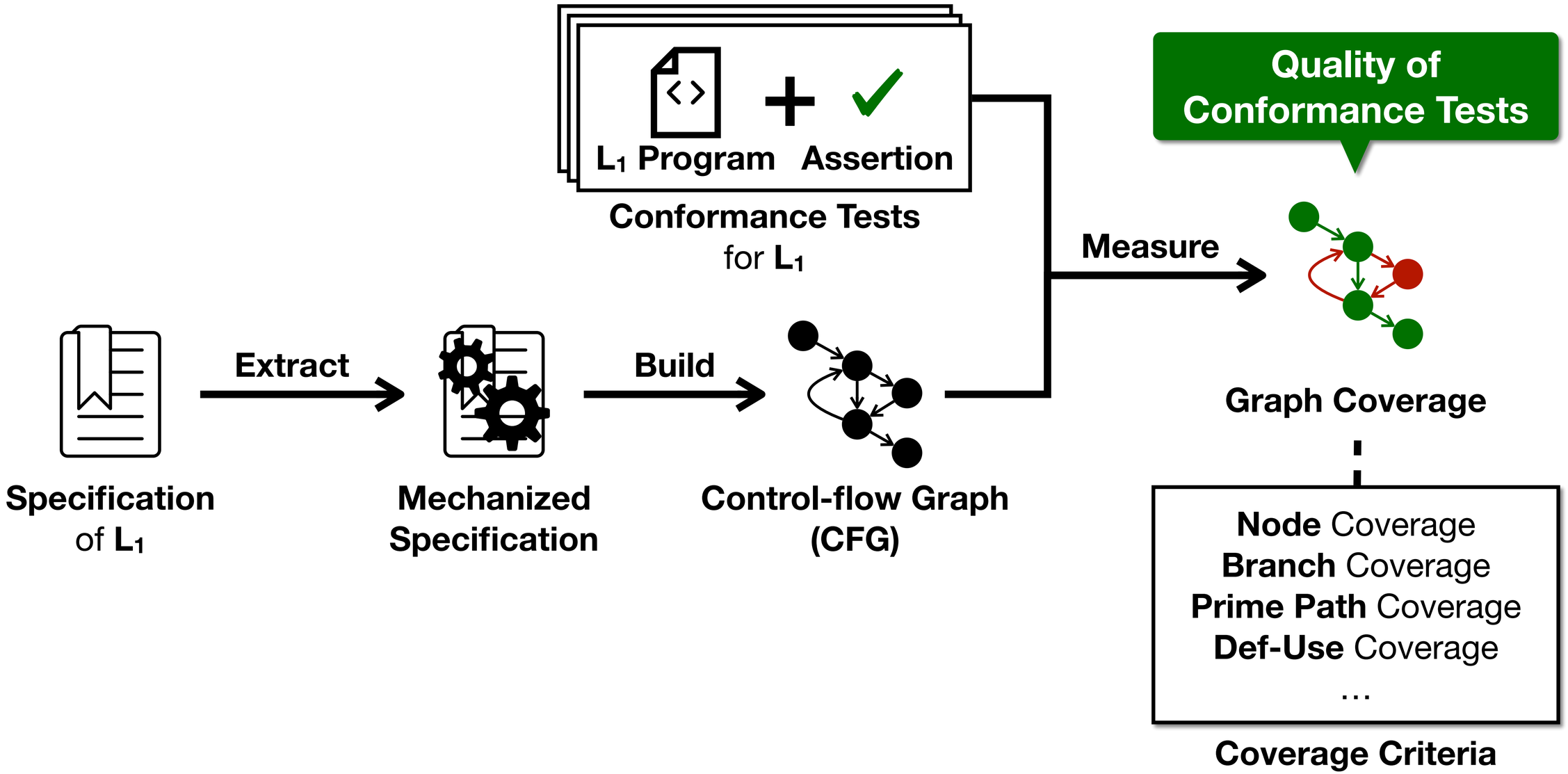

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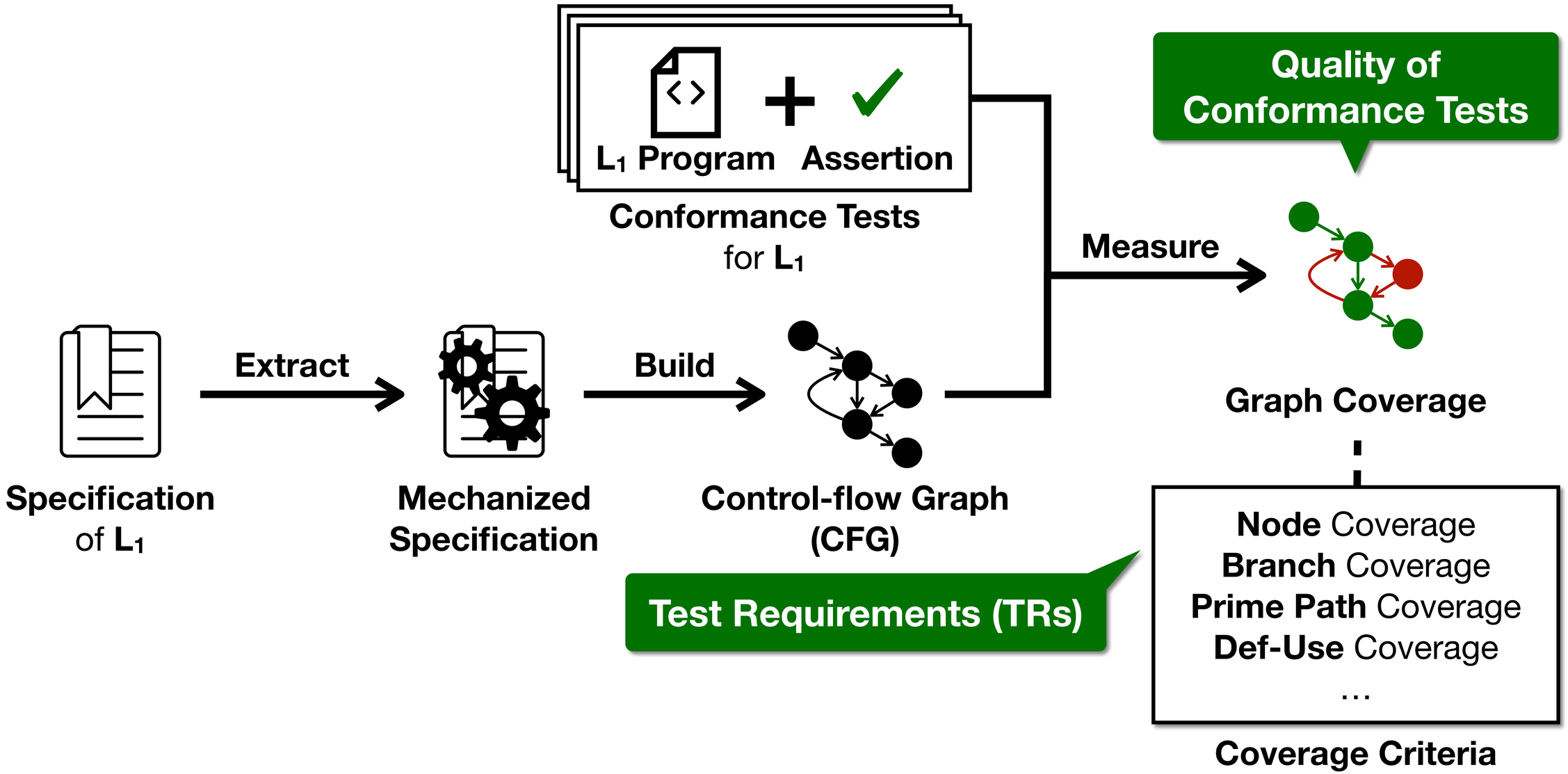

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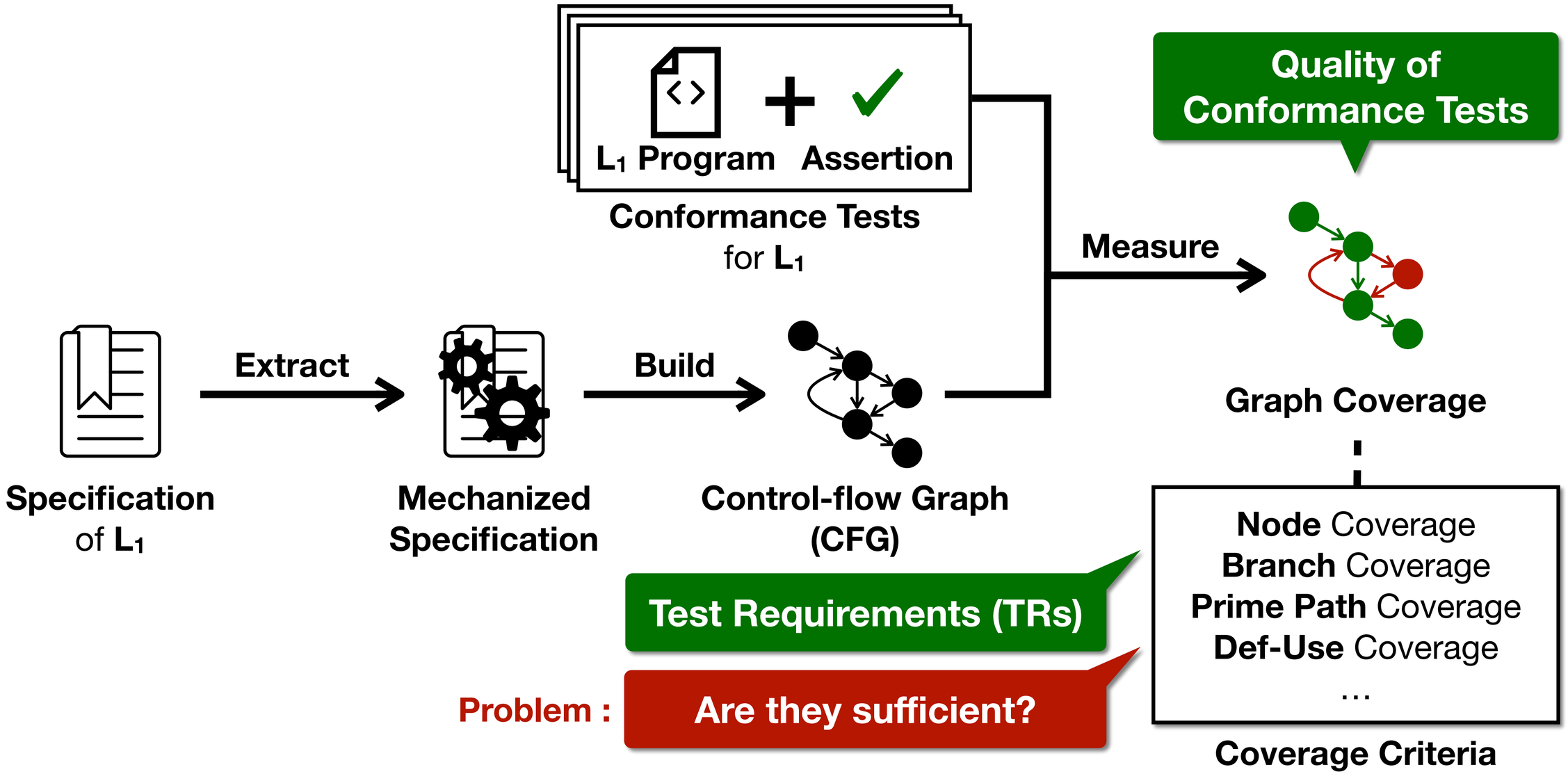
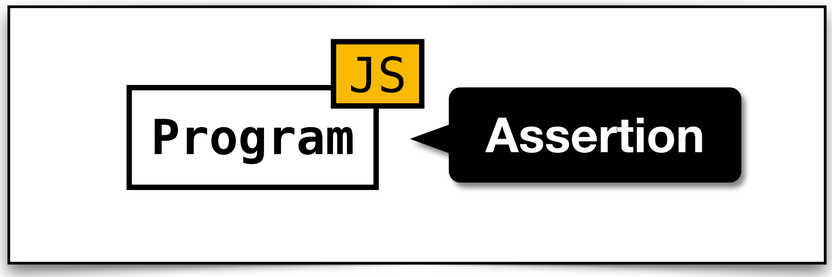


Motivating Example — JavaScript

- JavaScript is a **dynamically-typed language** with **complex semantics**
- It is not easy to understand even simple **addition/subtraction operations**.



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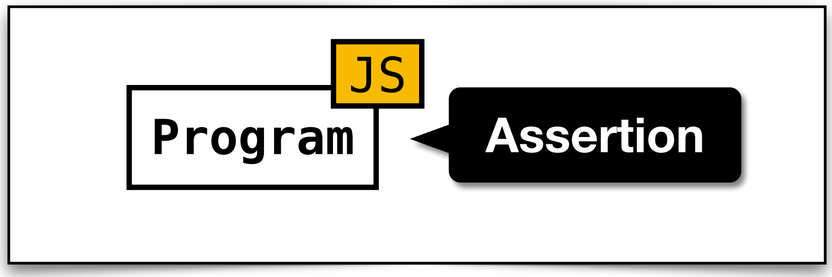

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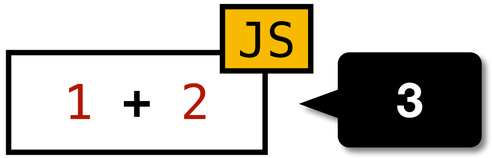

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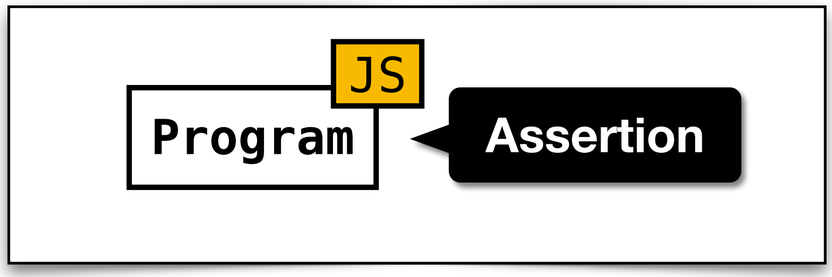

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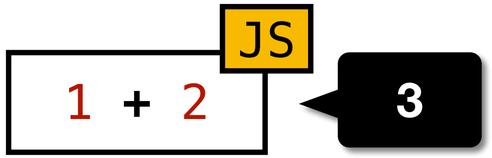

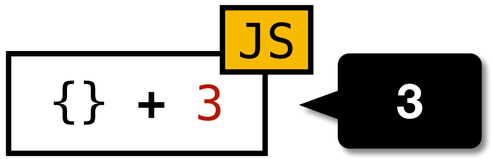

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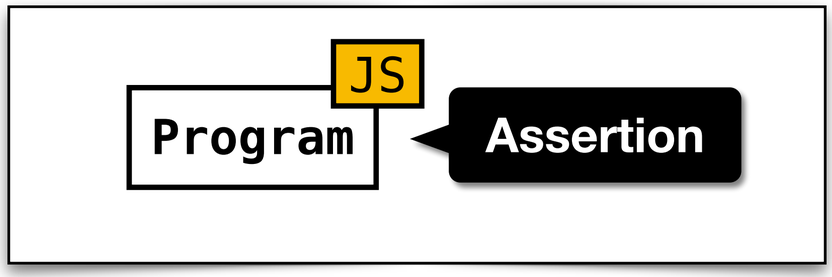

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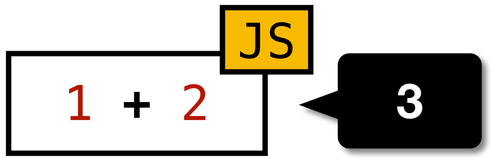

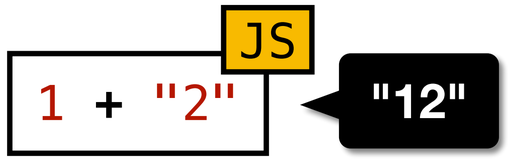

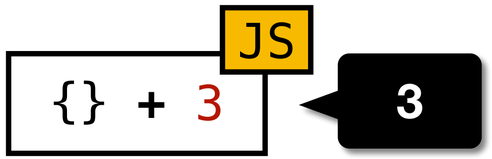

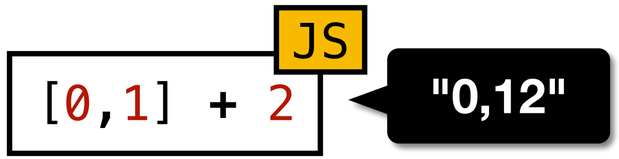

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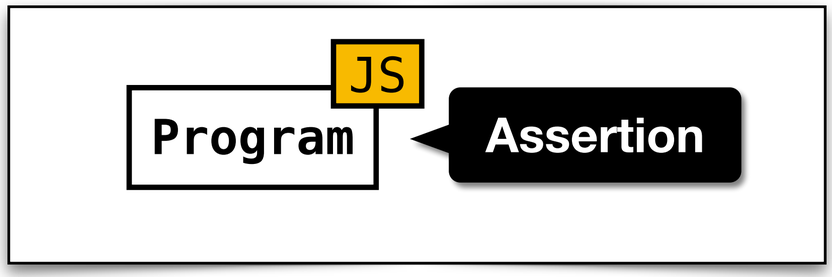

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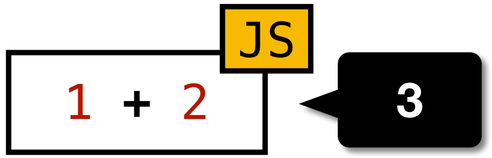

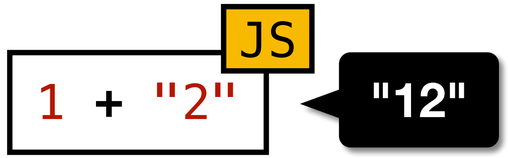

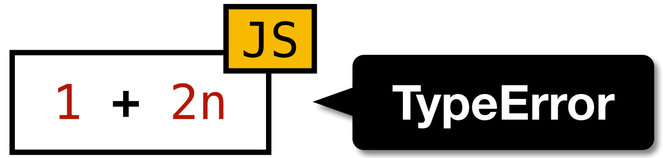

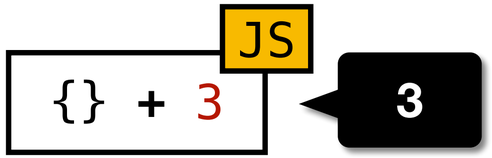

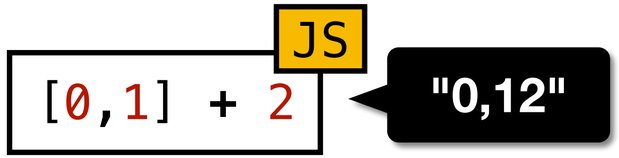

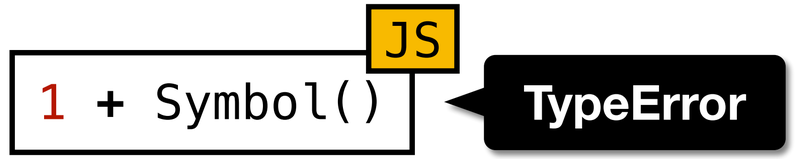

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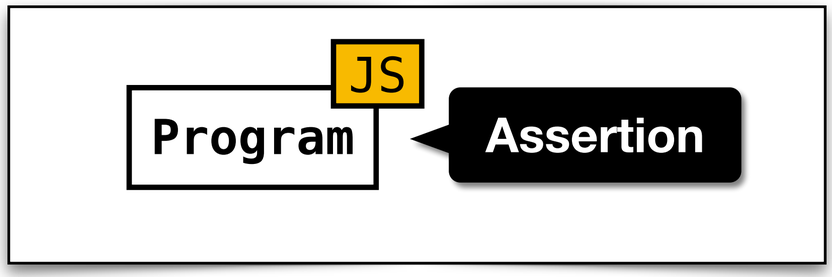

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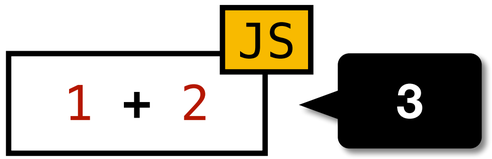

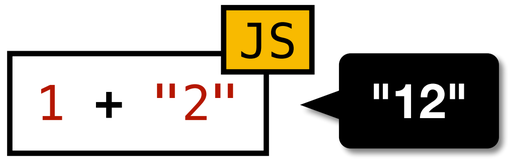

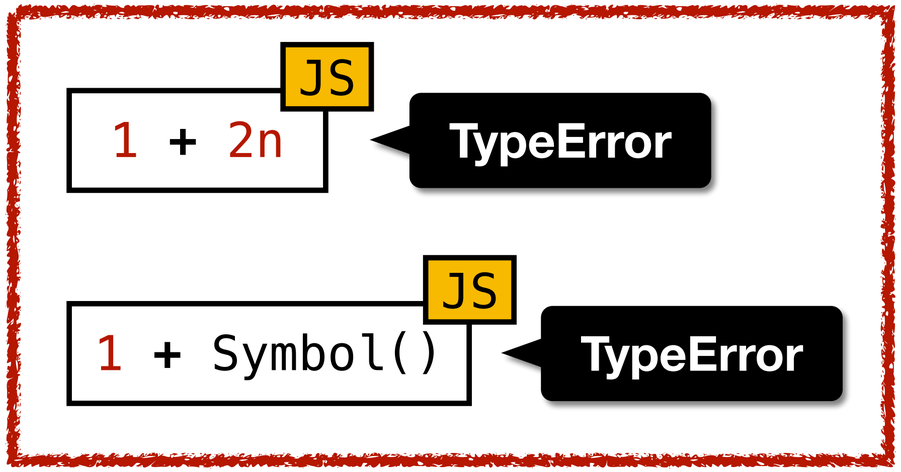

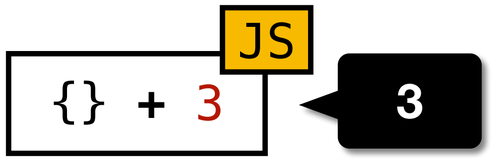

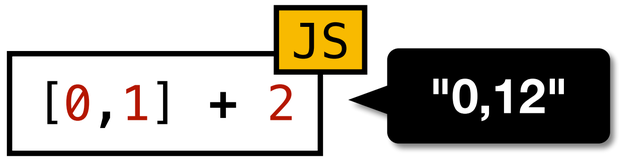

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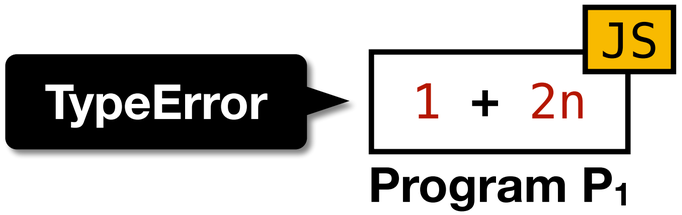

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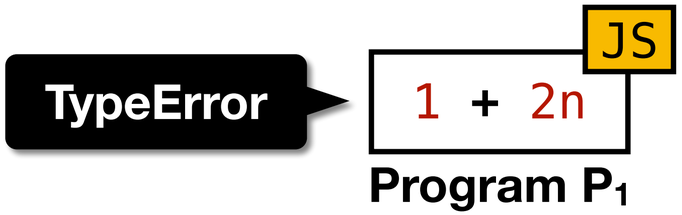

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Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, **+**, *MulExpr*).

Abstract Algorithms in **ECMA-262** (ES13, 2022), **JavaScript Language Specification**

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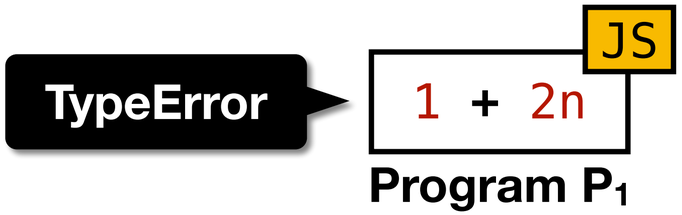

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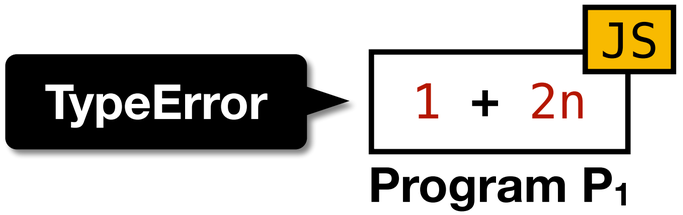

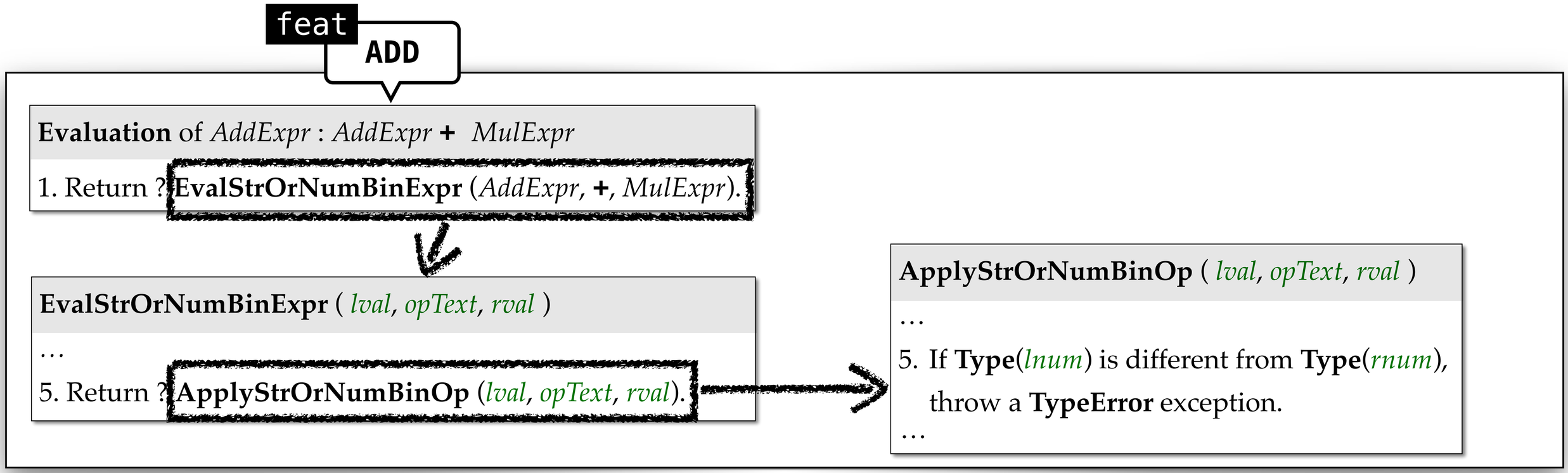

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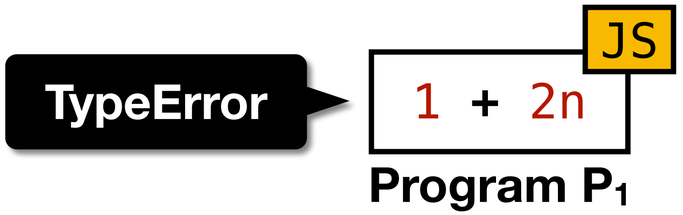

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1

Abstract Algorithms in **ECMA-262** (ES13, 2022), **JavaScript Language Specification**

PLRG

Motivating Example 1

Node Coverage

TR = Node

TypeError

JS

```
1 + 2n
```

Program P_1

feat

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Abstract Algorithms in **ECMA-262** (ES13, 2022), **JavaScript Language Specification**

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Node Coverage

TR = Node

TypeError JS `1 + 2n` — **Program P_1** — 1 — **cover**

TypeError JS `1 - 2n` — **Program P_2**

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Abstract Algorithms in **ECMA-262** (ES13, 2022), **JavaScript Language Specification**

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TypeError

JS

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1 + 2n
```

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Program P_1 cover

TypeError

JS

```
1 - 2n
```

Program P_2

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feat **SUB**

Evaluation of *AddExpr* : *AddExpr* **–** *MulExpr*

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Motivating Example 1

Node Coverage

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TypeError `JS` `1 + 2n` **1**

Program P_1 **cover**

TypeError `JS` `1 - 2n` **1**

Program P_2 **cover**

`feat` **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, **+**, *MulExpr*).

EvalStrOrNumBinExpr (*lval*, *opText*, *rval*)

…

5. Return ? **ApplyStrOrNumBinOp** (*lval*, *opText*, *rval*).

`feat` **SUB**

Evaluation of *AddExpr* : *AddExpr* **–** *MulExpr*

1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, **–**, *MulExpr*).

ApplyStrOrNumBinOp (*lval*, *opText*, *rval*)

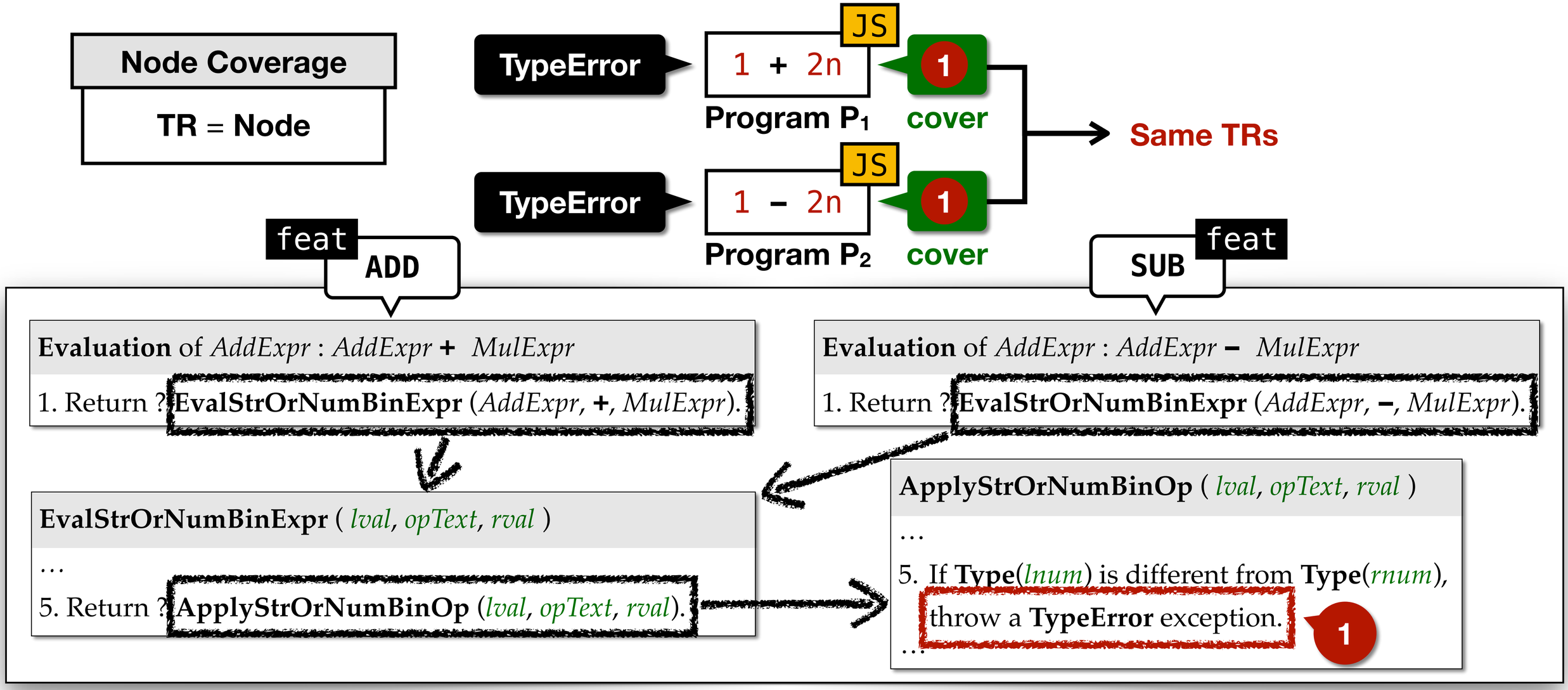
…

5. If **Type**(*lnum*) is different from **Type**(*rnum*),
   throw a **TypeError** exception. **1**

…

Abstract Algorithms in **ECMA-262** (ES13, 2022), **JavaScript Language Specification**

Motivating Example 1



Abstract Algorithms in **ECMA-262** (ES13, 2022), **JavaScript Language Specification**

Motivating Example 1

Node Coverage

TR = Node

TypeError — JS `1 + 2n` — **Program P_1** — 1 — cover

TypeError — JS `1 - 2n` — **Program P_2** — 1 — cover

→ **Same TRs** — **Cannot Distinguish P_1 and P_2**

`feat` **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, **+**, *MulExpr*).

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…

5. Return ? **ApplyStrOrNumBinOp** (*lval*, *opText*, *rval*).

`feat` **SUB**

Evaluation of *AddExpr* : *AddExpr* **−** *MulExpr*

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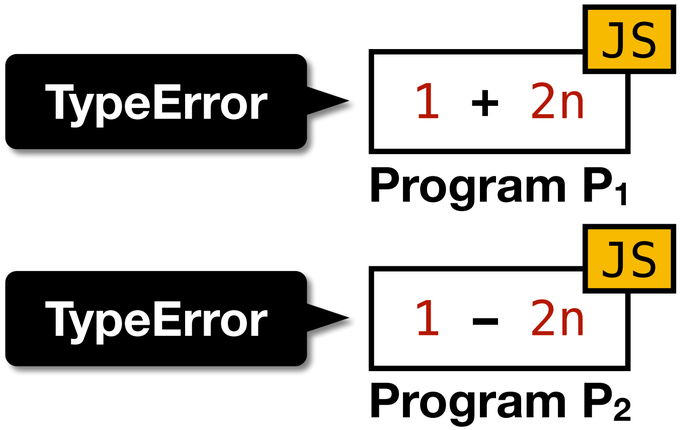
Abstract Algorithms in **ECMA-262** (ES13, 2022), **JavaScript Language Specification**

Feature-Sensitive (FS) Coverage

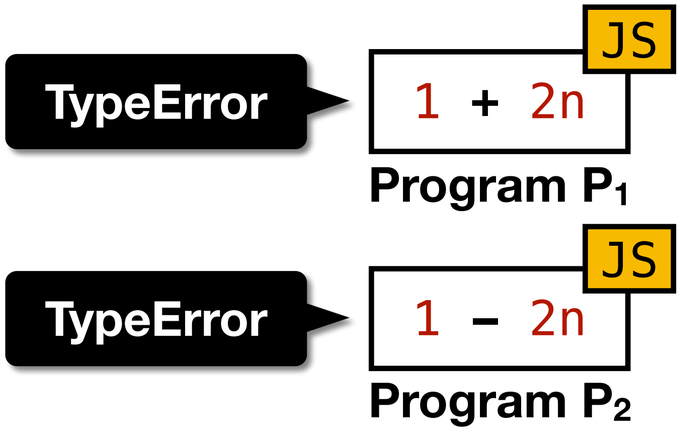


- Feature-Sensitive **(FS)** coverage criterion **divides**

  the given TRs with the **innermost enclosing** language **features**

FS Coverage
TR = (Feature, given **TR)**

Feature-Sensitive (FS) Coverage



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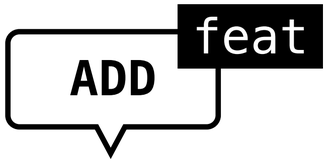

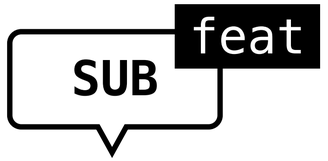

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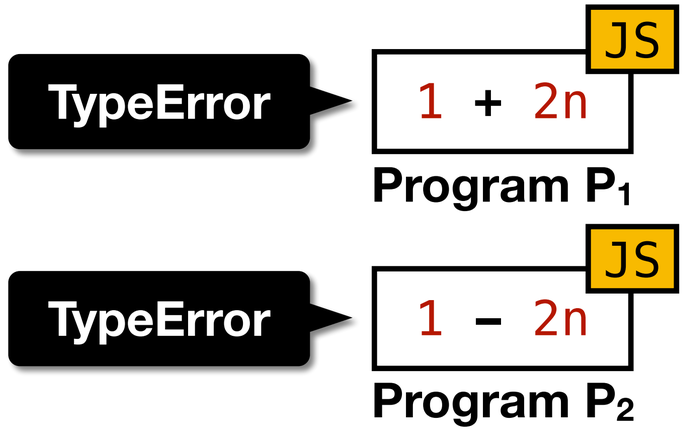
Feature-Sensitive (FS) Coverage

FS Node Coverage

TR = (Feature, Node)



- **F**eature-**S**ensitive **(FS)** coverage criterion **divides**

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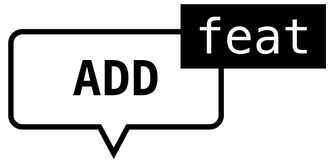
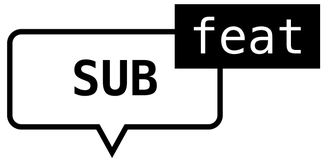
FS Coverage

TR = (Feature, given **TR)**





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Feature-Sensitive (FS) Coverage

FS Node Coverage

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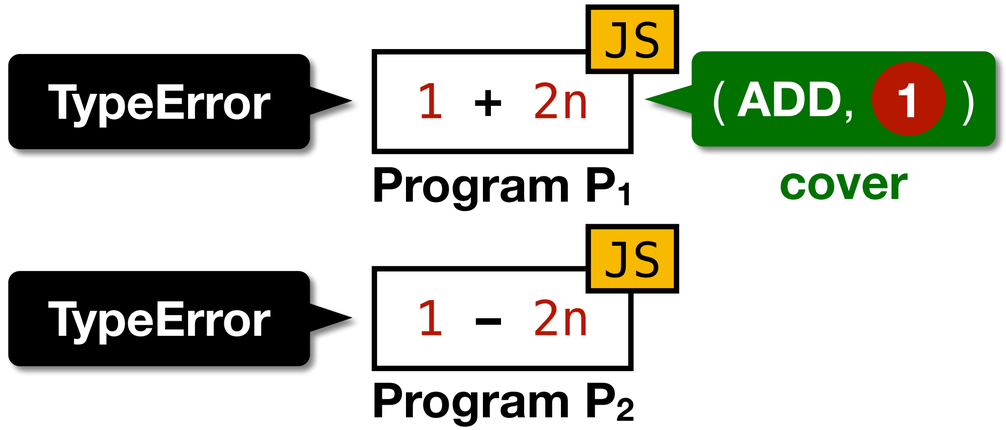

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FS Coverage

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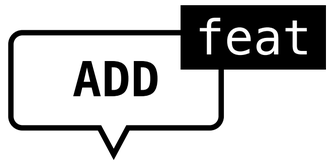

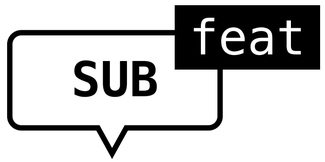

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Feature-Sensitive (FS) Coverage

FS Node Coverage

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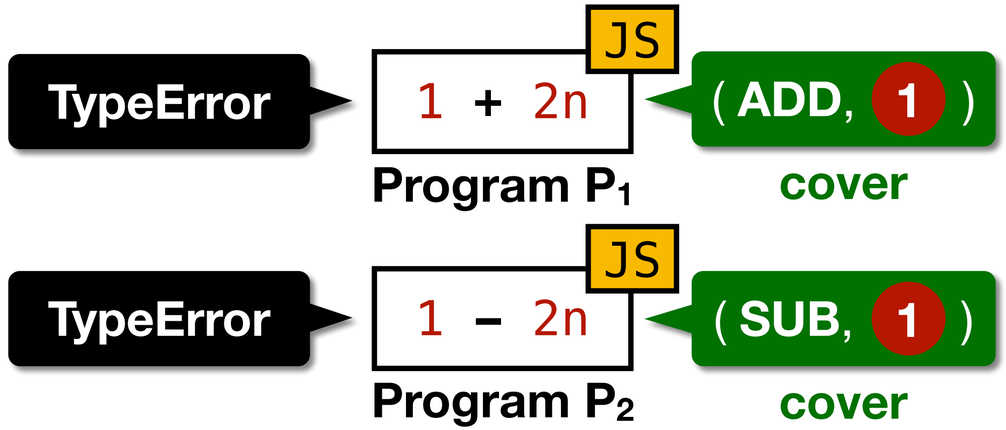

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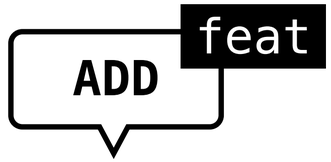

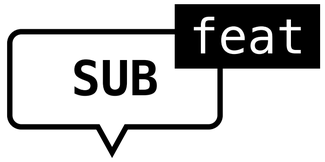

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Feature-Sensitive (FS) Coverage

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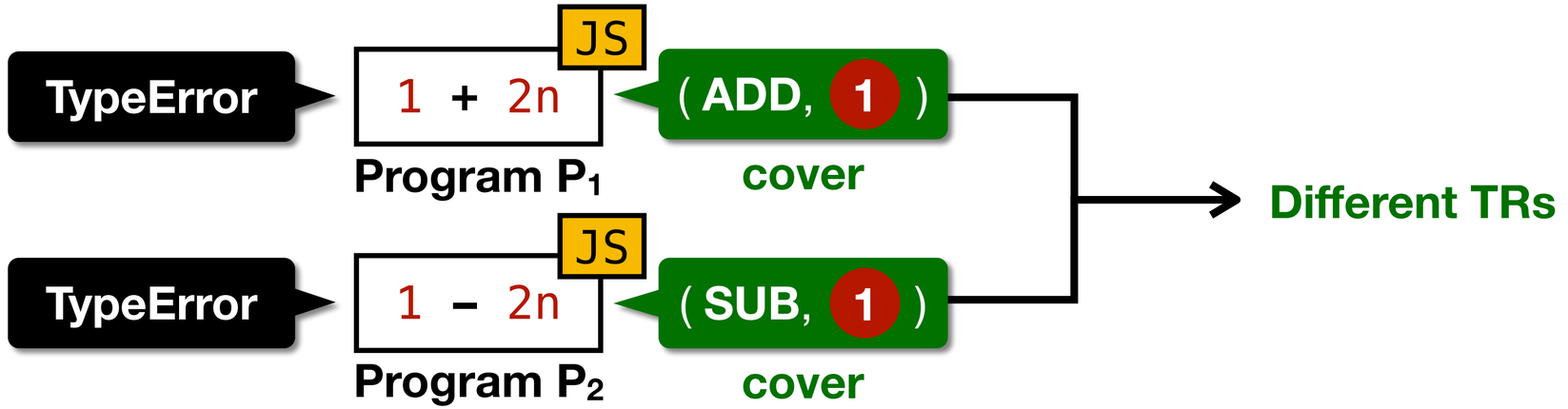

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FS Coverage

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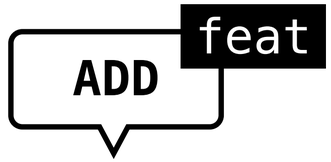

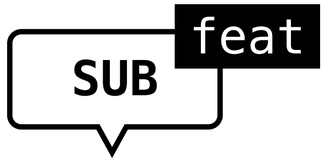

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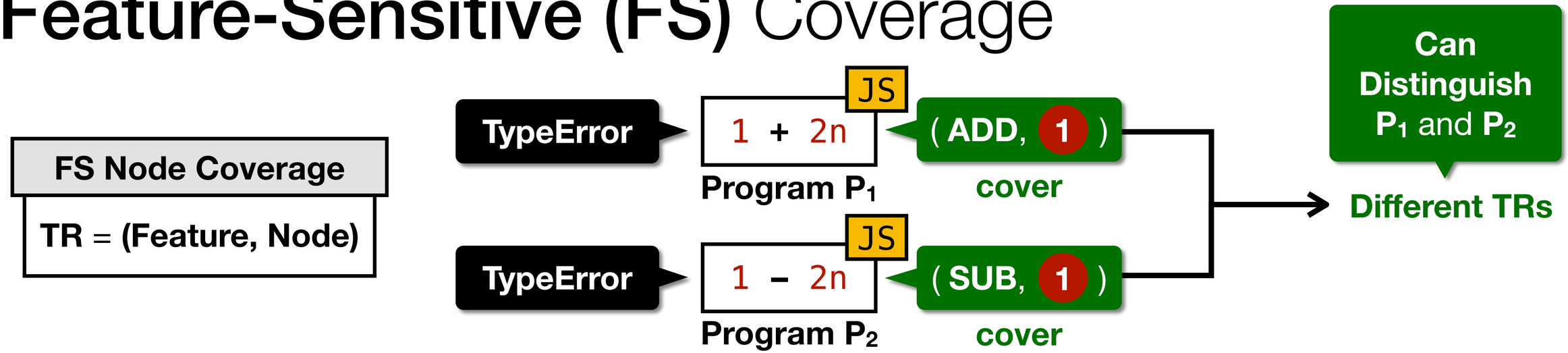

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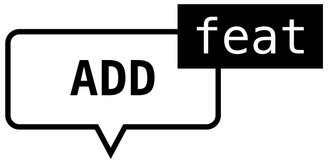
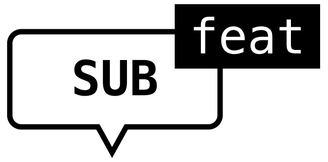
FS Coverage

TR = (Feature, given **TR)**





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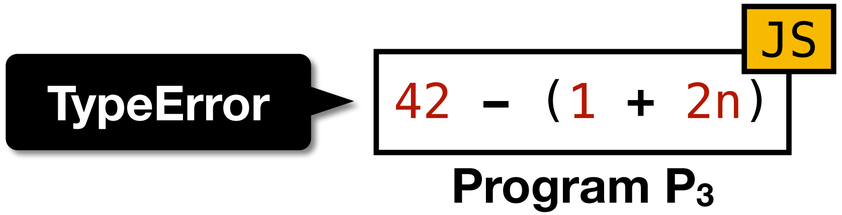
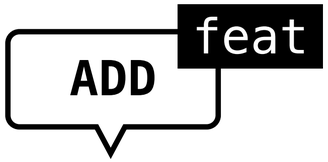
1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, **–**, *MulExpr*).

k-Feature-Sensitive (k-FS) Coverage



- k-**F**eature-**S**ensitive (**k-FS**) coverage criterion **divides** the given TRs with at most **k-innermost enclosing** language **features**

k-FS Coverage
TR = (Feature$^{\leq k}$, given **TR)**



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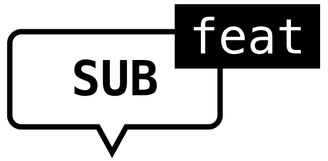


Evaluation of *AddExpr* : *AddExpr* **–** *MulExpr*
1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, **–**, *MulExpr*).

k-Feature-Sensitive (k-FS) Coverage

2-FS Node Coverage

TR = (Feature$^{\leq 2}$, Node)

TypeError

JS

```
42 - (1 + 2n)
```

Program P_3

- k-Feature-Sensitive (**k-FS**) coverage criterion **divides** the given TRs with at most **k-innermost enclosing** language **features**

k-FS Coverage

TR = (Feature$^{\leq k}$, given TR)

feat **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*
1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, **+**, *MulExpr*).

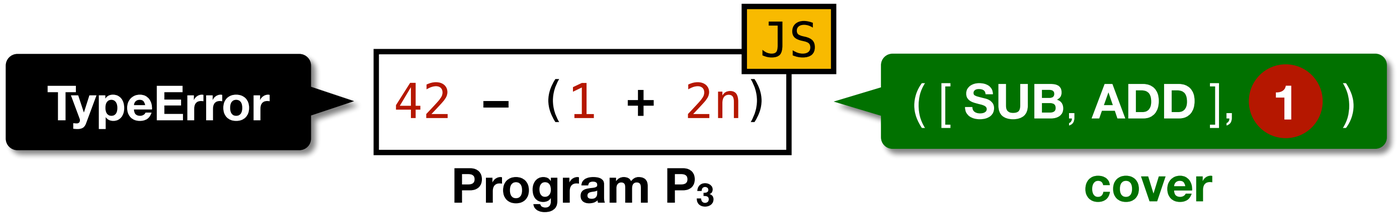
feat **SUB**

Evaluation of *AddExpr* : *AddExpr* **–** *MulExpr*
1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, **–**, *MulExpr*).

k-Feature-Sensitive (k-FS) Coverage

2-FS Node Coverage

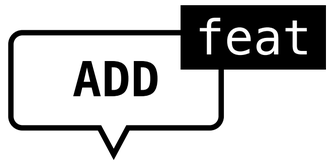
TR = (Feature$^{\leq 2}$, Node)

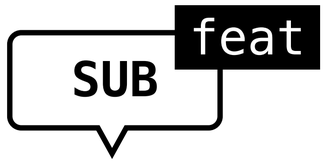


- k-**F**eature-**S**ensitive (**k-FS**) coverage criterion **divides** the given TRs with at most **k-innermost enclosing** language **features**

k-FS Coverage

TR = (Feature$^{\leq k}$, given **TR)**





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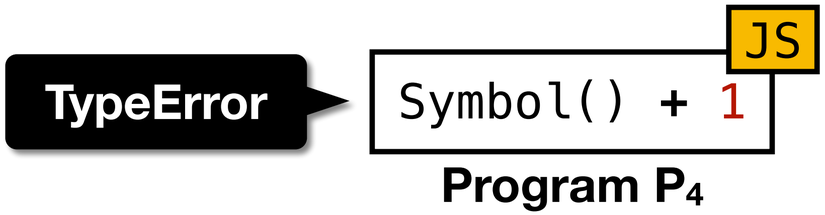
Motivating Example 2



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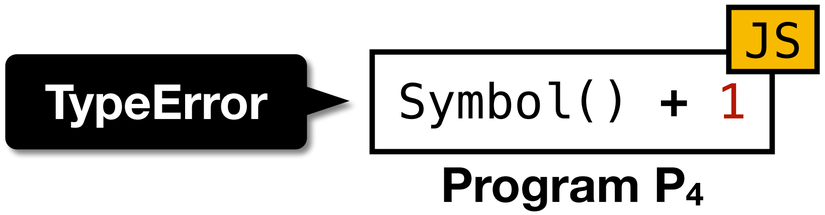

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Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

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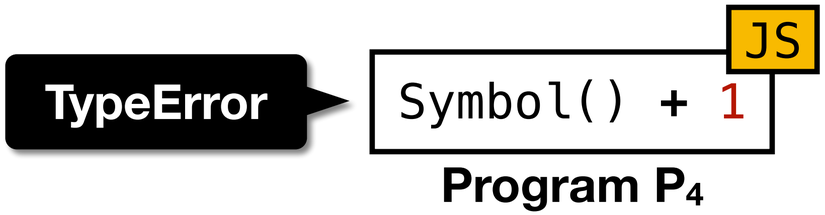

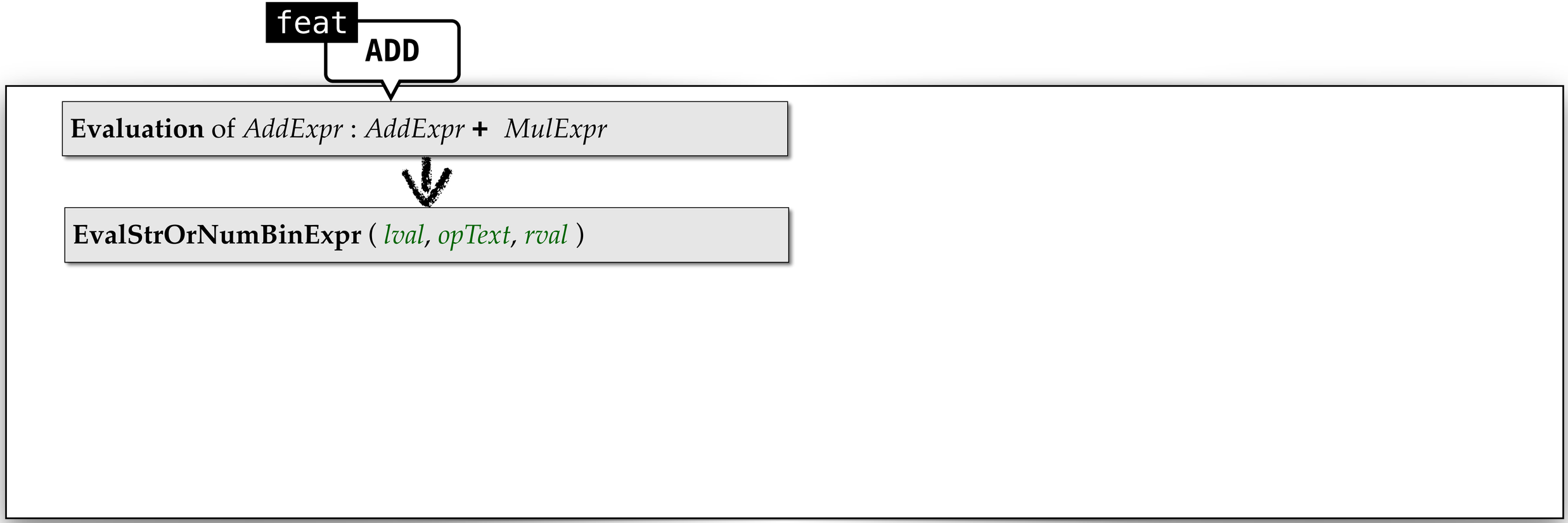

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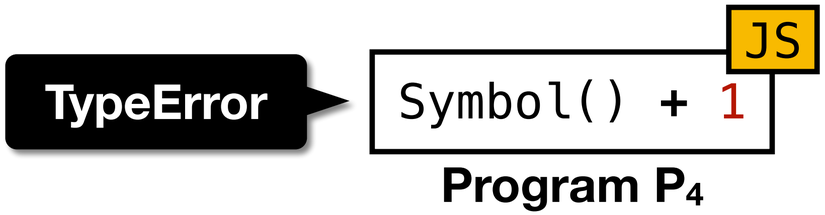

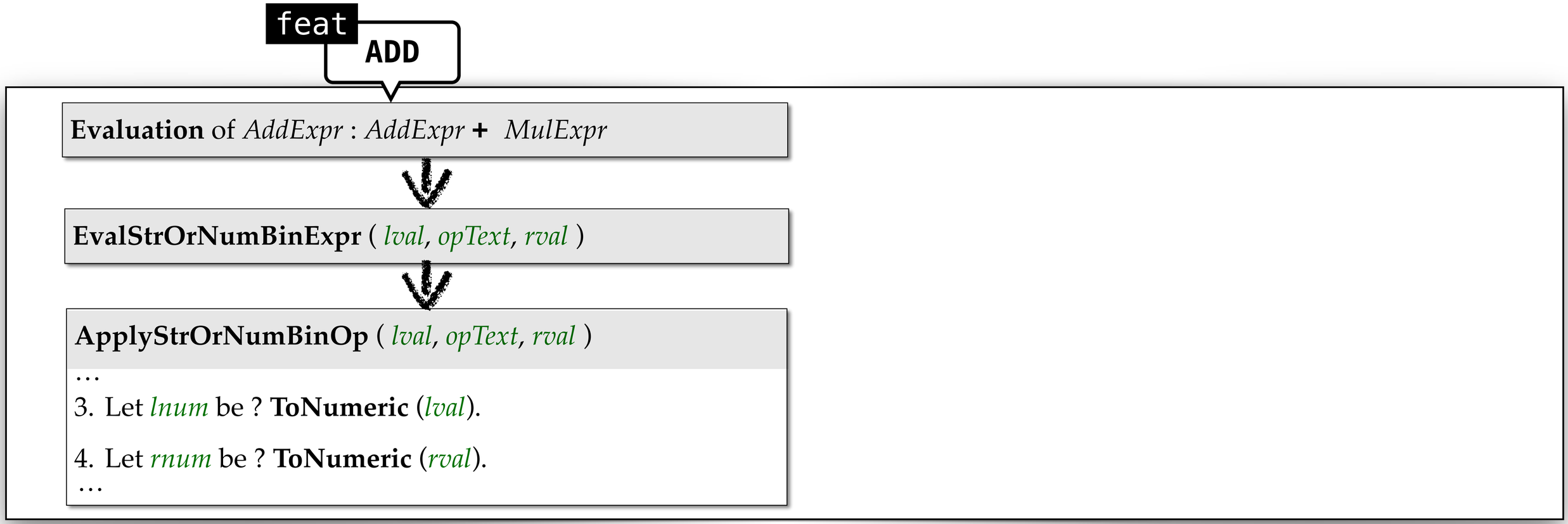

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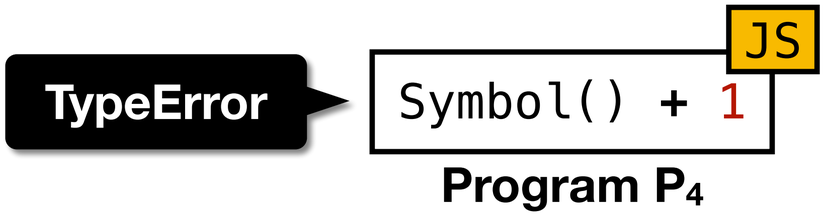

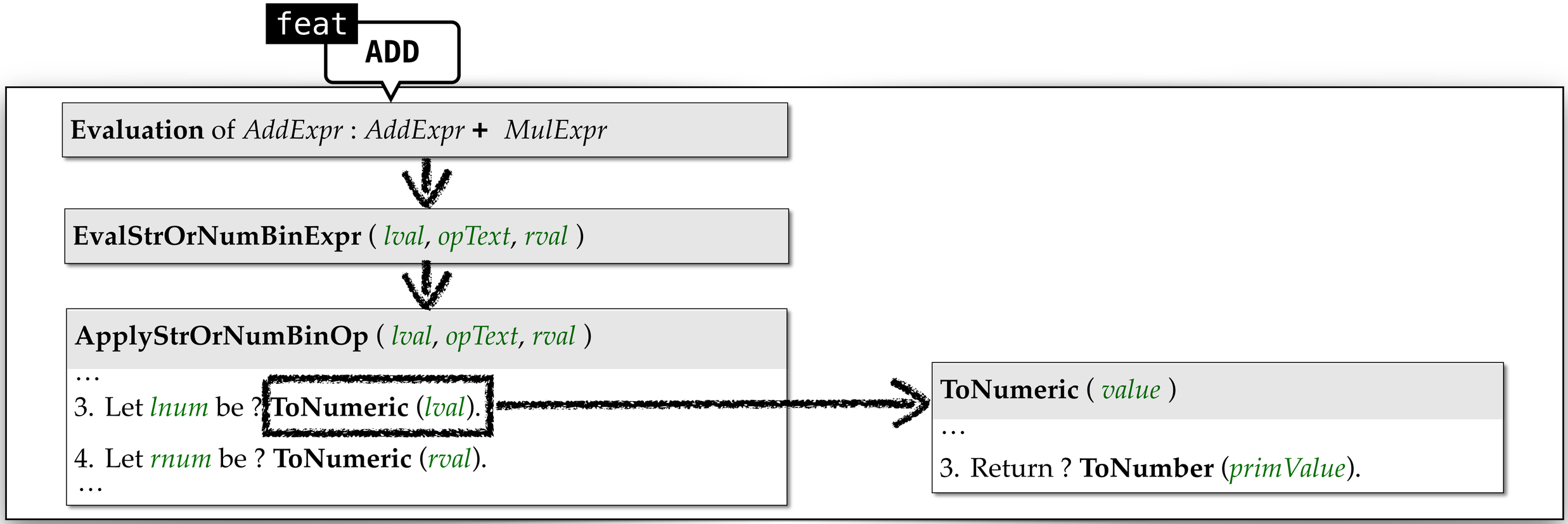

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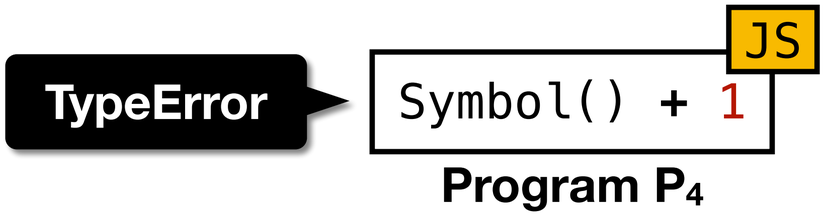


feat **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

EvalStrOrNumBinExpr (*lval*, *opText*, *rval*)

ApplyStrOrNumBinOp (*lval*, *opText*, *rval*)

…

3. Let *lnum* be ? **ToNumeric** (*lval*).

4. Let *rnum* be ? **ToNumeric** (*rval*).

…

ToNumeric (*value*)

…

3. Return ? **ToNumber** (*primValue*).

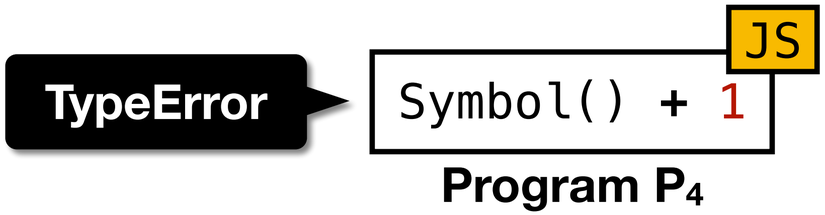
ToNumber (*argument*)

…

6. If **Type** (*argument*) is Symbol,
   throw a **TypeError** exception.

…

Motivating Example 2



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…

2

Motivating Example 2

1-FS Node Coverage

TR = (Feature, Node)

TypeError

JS

```
Symbol() + 1
```

Program P_4

`feat` **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

EvalStrOrNumBinExpr (*lval*, *opText*, *rval*)

ApplyStrOrNumBinOp (*lval*, *opText*, *rval*)

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Motivating Example 2

1-FS Node Coverage

TR = (Feature, Node)

TypeError

JS

```
Symbol() + 1
```

Program P_4

(ADD, 2)

cover

feat **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

EvalStrOrNumBinExpr (*lval*, *opText*, *rval*)

ApplyStrOrNumBinOp (*lval*, *opText*, *rval*)

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…

3. Return ? **ToNumber** (*primValue*).

ToNumber (*argument*)

…

6. If **Type** (*argument*) is Symbol,

throw a **TypeError** exception.

…

2

Motivating Example 2

1-FS Node Coverage

TR = (Feature, Node)

TypeError `Symbol() + 1` JS

Program P_4

(**ADD**, **2**) **cover**

TypeError `1 + Symbol()` JS

Program P_5

`feat` **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

EvalStrOrNumBinExpr (*lval*, *opText*, *rval*)

ApplyStrOrNumBinOp (*lval*, *opText*, *rval*)

…

3. Let *lnum* be ? **ToNumeric** (*lval*).

4. Let *rnum* be ? **ToNumeric** (*rval*).

…

ToNumeric (*value*)

…

3. Return ? **ToNumber** (*primValue*).

ToNumber (*argument*)

…

6. If **Type** (*argument*) is Symbol,

throw a **TypeError** exception. **2**

…

Motivating Example 2

1-FS Node Coverage

TR = (Feature, Node)

TypeError `Symbol() + 1` JS

Program P_4

(**ADD**, **2**) **cover**

TypeError `1 + Symbol()` JS

Program P_5

`feat` **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

EvalStrOrNumBinExpr (*lval*, *opText*, *rval*)

ApplyStrOrNumBinOp (*lval*, *opText*, *rval*)

…

3. Let *lnum* be ? **ToNumeric** (*lval*).

4. Let *rnum* be ? **ToNumeric** (*rval*).

…

ToNumber (*argument*)

…

6. If **Type** (*argument*) is Symbol,

throw a **TypeError** exception.

…

2

ToNumeric (*value*)

…

3. Return ? **ToNumber** (*primValue*).

Motivating Example 2

1-FS Node Coverage

TR = (Feature, Node)

TypeError `Symbol() + 1` JS — **Program P_4** — **(ADD, 2)** **cover**

TypeError `1 + Symbol()` JS — **Program P_5** — **(ADD, 2)** **cover**

`feat` **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

EvalStrOrNumBinExpr (*lval*, *opText*, *rval*)

ApplyStrOrNumBinOp (*lval*, *opText*, *rval*)

…

3. Let *lnum* be ? **ToNumeric** (*lval*).

4. Let *rnum* be ? **ToNumeric** (*rval*).

…

ToNumeric (*value*)

…

3. Return ? **ToNumber** (*primValue*).

ToNumber (*argument*)

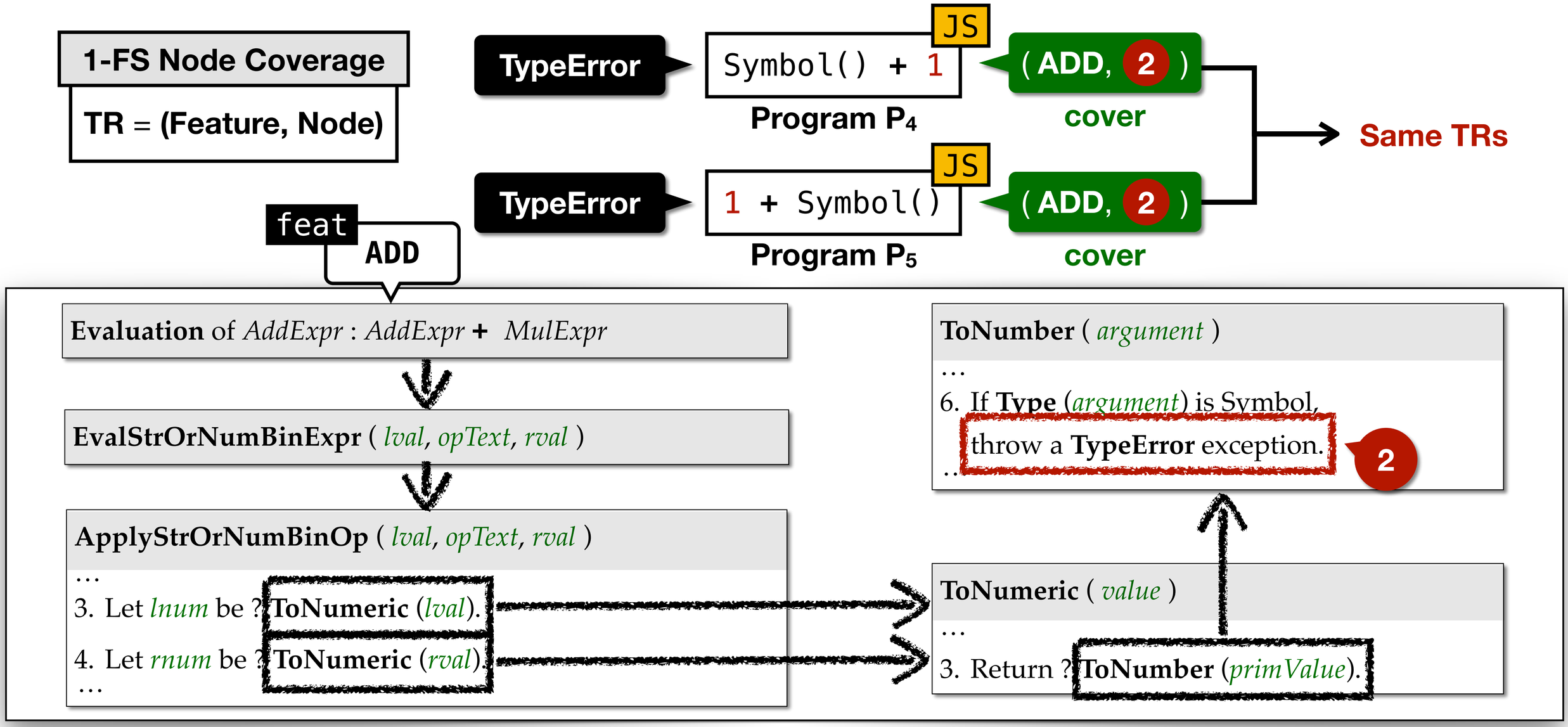
…

6. If **Type** (*argument*) is Symbol,

throw a **TypeError** exception. 2

…

Motivating Example 2



Motivating Example 2

1-FS Node Coverage

TR = (Feature, Node)

TypeError `Symbol() + 1` (JS) — **Program P_4** — **(ADD, 2)** **cover**

TypeError `1 + Symbol()` (JS) — **Program P_5** — **(ADD, 2)** **cover**

Cannot Distinguish P_4 and P_5

Same TRs

`feat` **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

EvalStrOrNumBinExpr (*lval*, *opText*, *rval*)

ApplyStrOrNumBinOp (*lval*, *opText*, *rval*)

…

3. Let *lnum* be ? **ToNumeric** (*lval*).

4. Let *rnum* be ? **ToNumeric** (*rval*).

…

ToNumeric (*value*)

…

3. Return ? **ToNumber** (*primValue*).

ToNumber (*argument*)

…

6. If **Type** (*argument*) is Symbol,

throw a **TypeError** exception. **2**

…

Motivating Example 2

1-FS Node Coverage

TR = (Feature, Node)

TypeError `Symbol() + 1` JS — **Program P_4** — **(ADD, 2)** **cover**

TypeError `1 + Symbol()` JS — **Program P_5** — **(ADD, 2)** **cover**

Cannot Distinguish P_4 and P_5

Same TRs

`feat` **ADD**

Evaluation of *AddExpr* : *AddExpr* **+** *MulExpr*

3 call

EvalStrOrNumBinExpr (*lval*, *opText*, *rval*)

4 call

ApplyStrOrNumBinOp (*lval*, *opText*, *rval*)

…

3. Let *lnum* be ? **ToNumeric** (*lval*). — 5 call

4. Let *rnum* be ? **ToNumeric** (*rval*). — 6 call

…

ToNumeric (*value*) — 7 call

…

3. Return ? **ToNumber** (*primValue*).

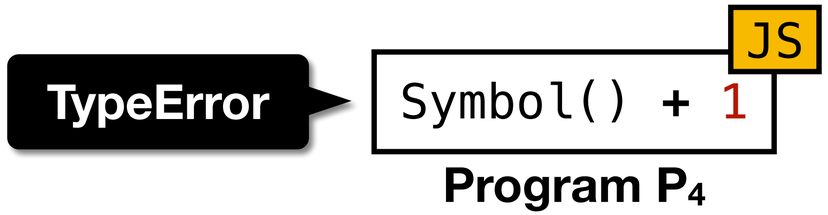
ToNumber (*argument*)

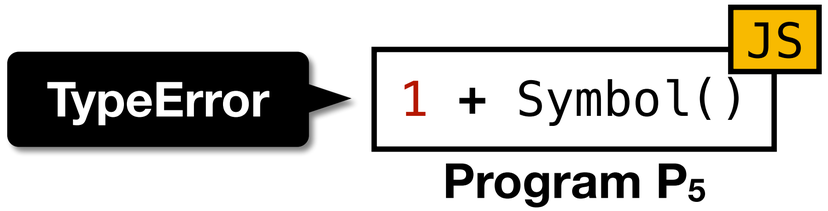
…

6. If **Type** (*argument*) is Symbol, throw a **TypeError** exception. — 2

…

k-Feature-Call-Path-Sensitive (k-FCPS) Coverage



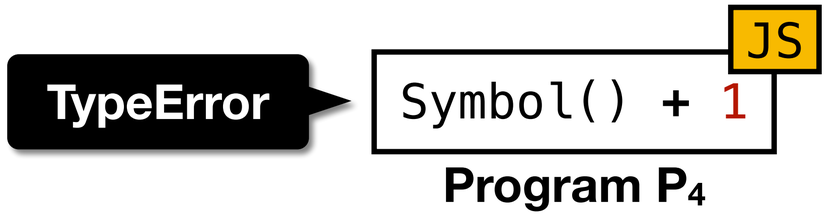


- k-**F**eature-**C**all-**P**ath-**S**ensitive (k-**FCPS**) coverage criterion divides the k-FS TRs with the **call-paths from** the innermost enclosing language feature

k-FCPS Coverage

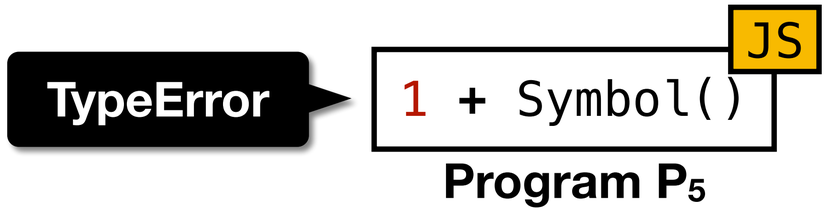
TR = (Feature$^{\leq k}$, Call-Path, given **TR)**

k-Feature-Call-Path-Sensitive (k-FCPS) Coverage



1-FCPS Node Coverage

TR = (Feature, Call-Path, Node)



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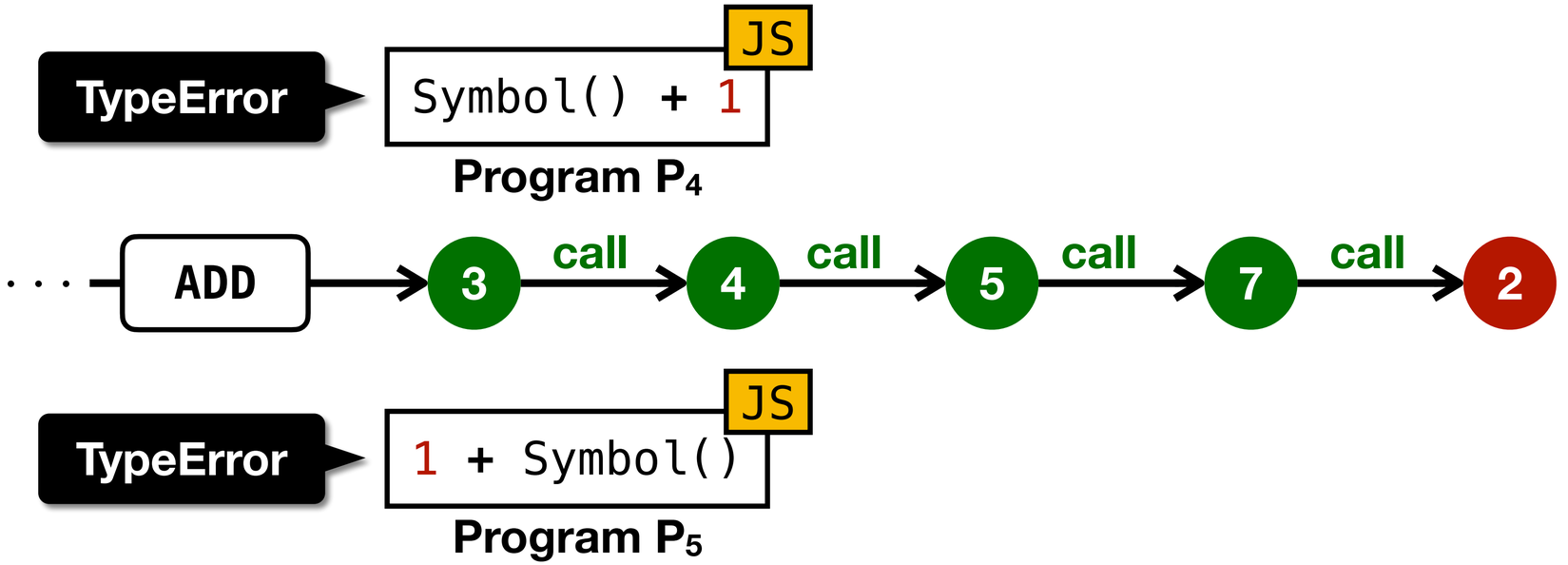
k-Feature-Call-Path-Sensitive (k-FCPS) Coverage



1-FCPS Node Coverage

TR = (Feature, Call-Path, Node)

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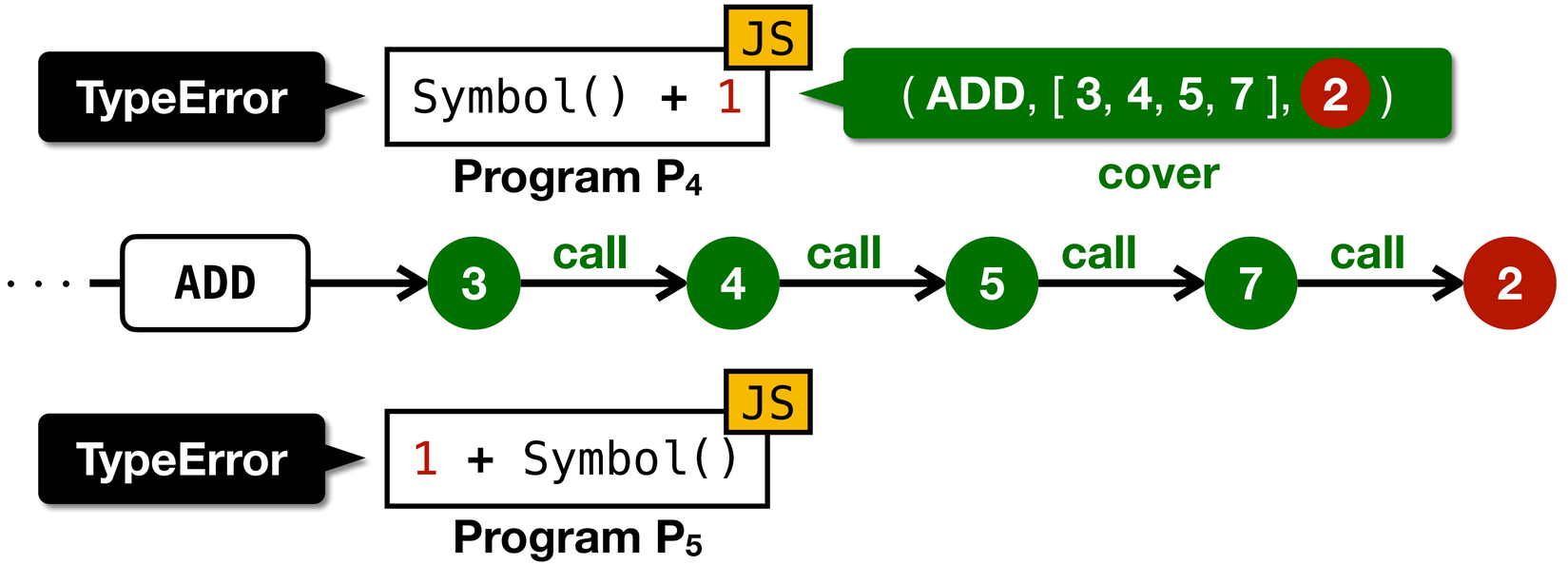
k-Feature-Call-Path-Sensitive (k-FCPS) Coverage



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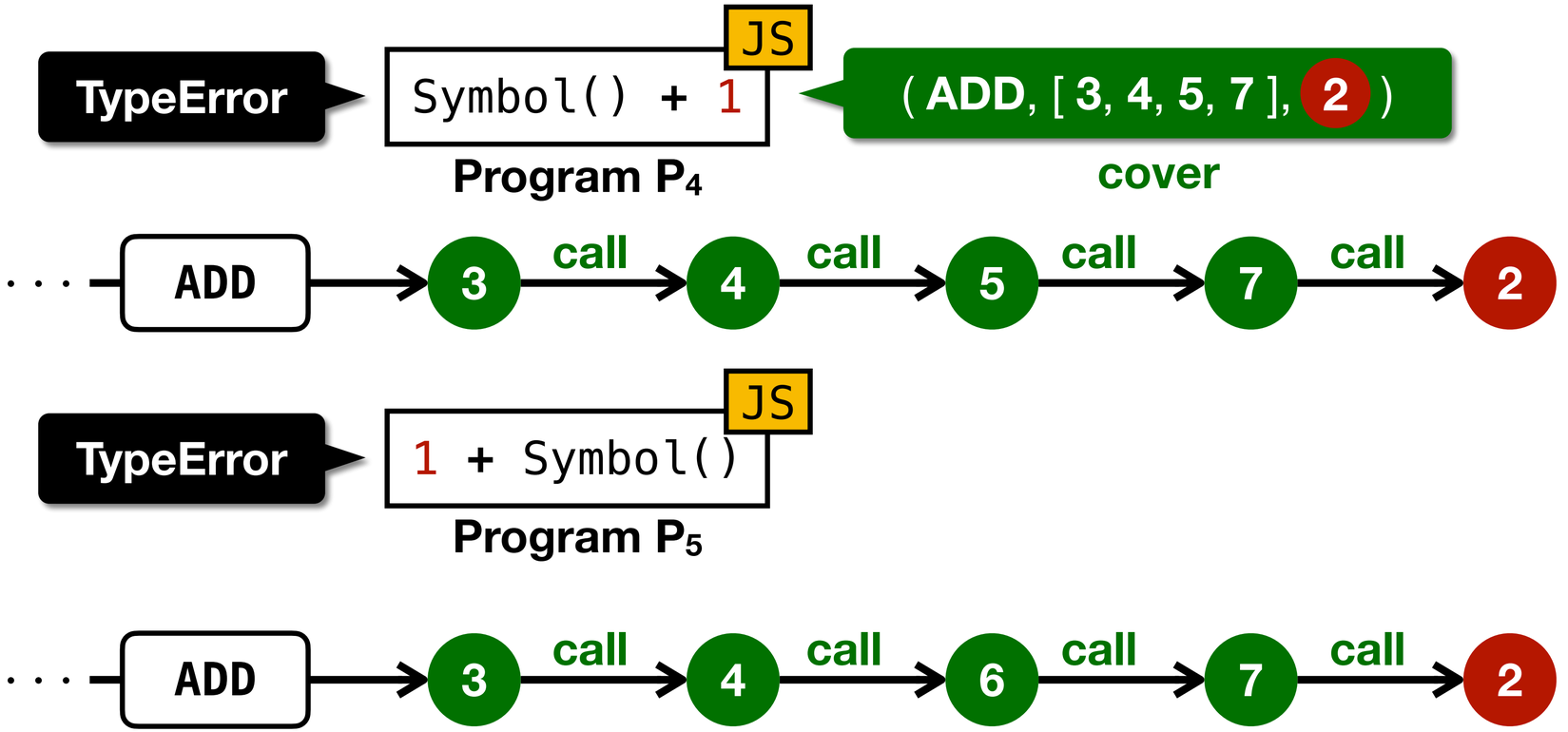
k-Feature-Call-Path-Sensitive (k-FCPS) Coverage



1-FCPS Node Coverage

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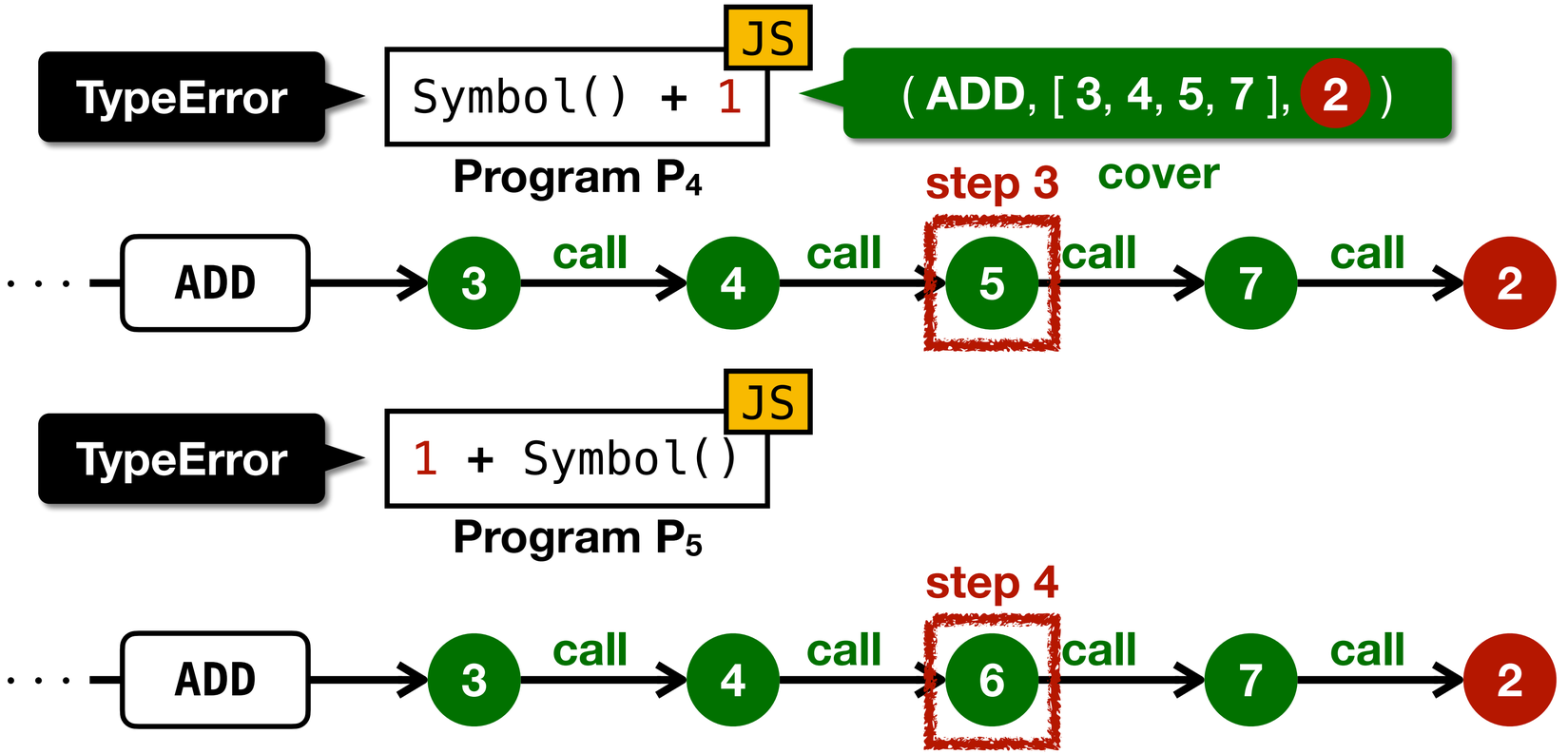
k-FCPS Coverage

TR = (Feature$^{\leq k}$, Call-Path, given **TR)**

k-Feature-Call-Path-Sensitive (k-FCPS) Coverage



1-FCPS Node Coverage

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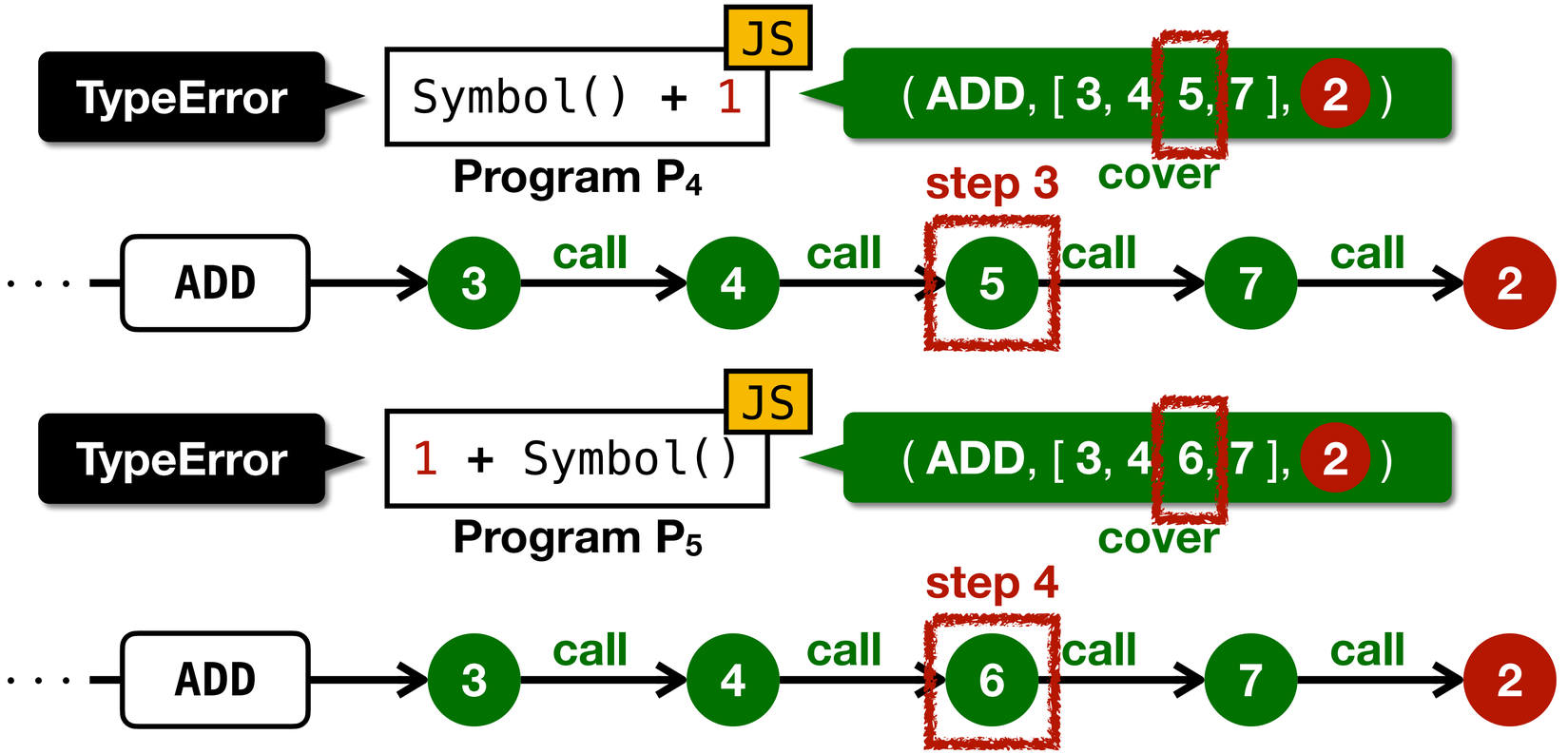
k-Feature-Call-Path-Sensitive (k-FCPS) Coverage



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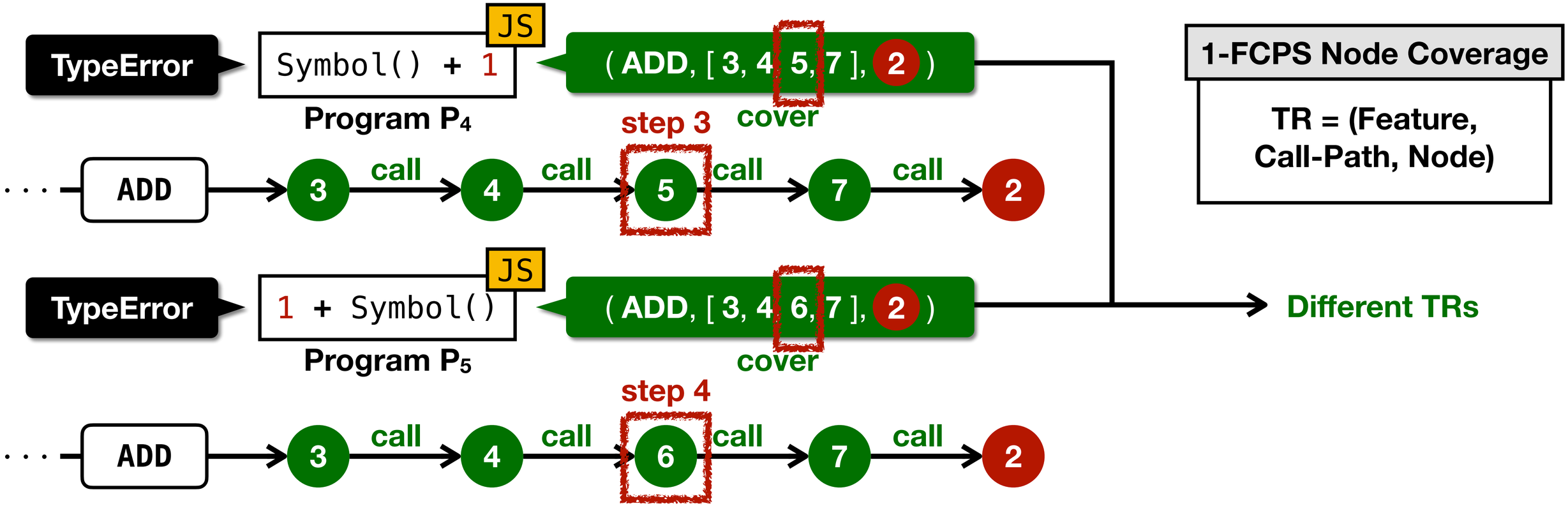

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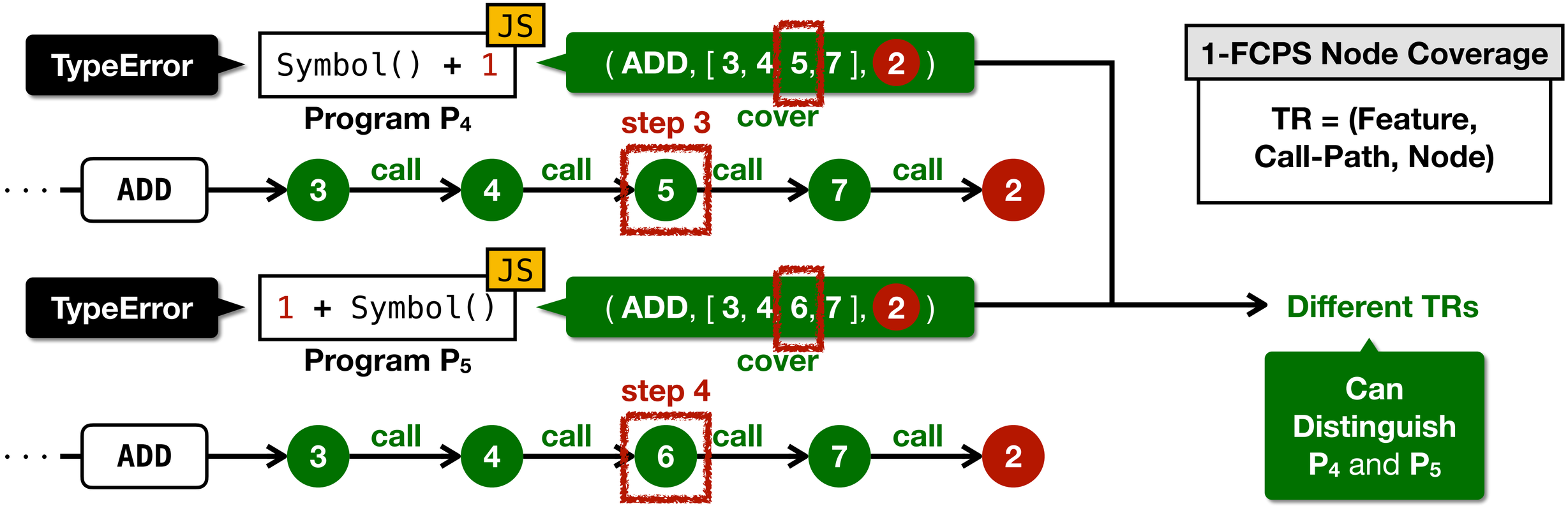

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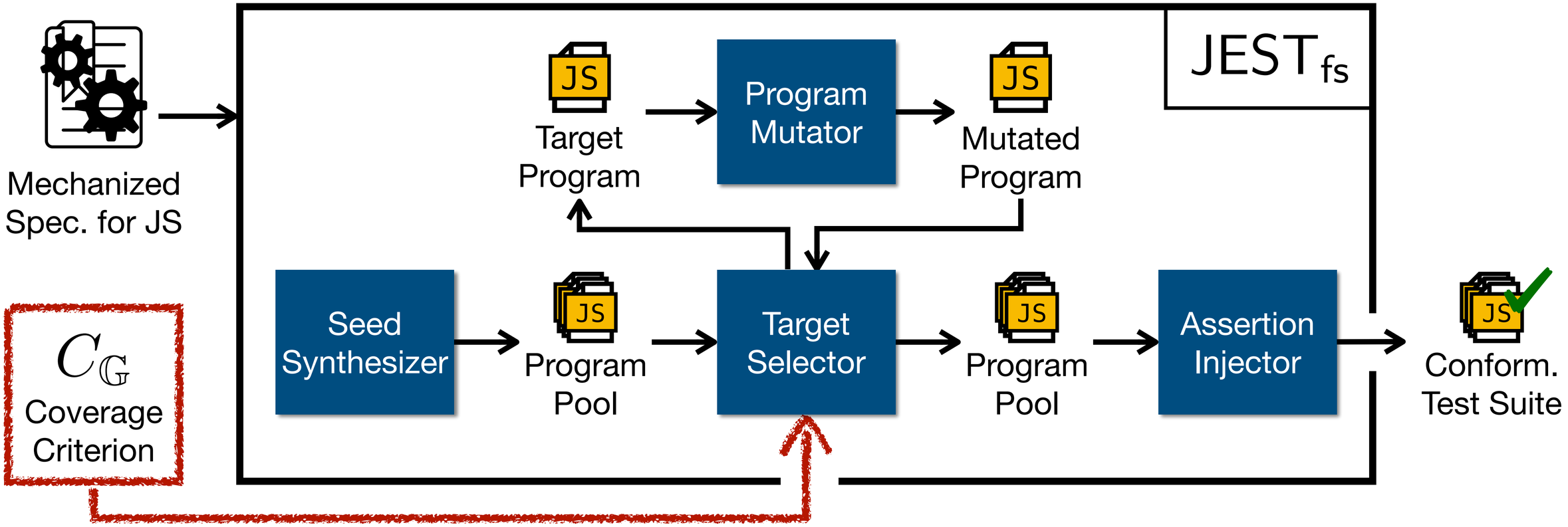
k-FCPS Coverage

TR = (Feature$^{\leq k}$, Call-Path, given **TR)**

Implementation — JEST$_{fs}$

- **JEST** [1] is a **JavaScript conformance test generator** using **Coverage-Guided Fuzzing**
- We implemented **JEST$_{fs}$** as an extension of **JEST** with k**-FS** and k**-FCPS** coverage criteria



[1] Park et al., "JEST: N+1-version Differential Testing of Both JavaScript Engines and Specification", ICSE 2021

Evaluation

5 different k-FS and k-FCPS coverage criteria

- **JEST$_{fs}$** in 50 hours with **0-FS** / **1-FS** / **2-FS** / **1-FCPS** / **2-FCPS**
- **JavaScript Specification** — ECMA-262 for **ES13 (2022)**
- **JavaScript Implementations** — **4 Engines** and **4 Transpilers**

Kind	Name	Version	Release
Engine	**V8**	v10.8.121	2022.10.06
	JSC	v615.1.10	2022.10.26
	GraalJS	v22.2.0	2022.07.26
	SpiderMonkey	v107.0b4	2022.10.24
Transpiler	**Babel**	v7.19.1	2022.09.15
	SWC	v1.3.10	2022.10.21
	Terser	v5.15.1	2022.10.05
	Obfuscator	v4.0.0	2022.02.15

RQ1) Conformance Bug Detection

Kind	Name	Version	Release	# Detected Unique Bugs		
				# New	# Confirmed	# Reported
Engine	V8	v10.8.121	2022.10.06	0	0	4
	JSC	v615.1.10	2022.10.26	15	15	24
	GraalJS	v22.2.0	2022.07.26	9	9	10
	SpiderMonkey	v107.0b4	2022.10.24	1	3	4
	Total			**25**	**27**	**42**
Transpiler	Babel	v7.19.1	2022.09.15	30	30	35
	SWC	v1.3.10	2022.10.21	27	27	41
	Terser	v5.15.1	2022.10.05	1	1	18
	Obfuscator	v4.0.0	2022.02.15	0	0	7
	Total			**58**	**58**	**101**
Total				**83**	**85**	**143**

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Total				**83**	**85**	**143**

RQ2) Effectiveness of k-FS Coverage Criteria

Coverage Criteria $C_{\mathbb{G}}$	# Covered k-F(CP)S-TR (k)			# Syn. Test	# Bug
	# Node	# Branch	# Total		
0-FS node-or-branch (0-fs)	10.0	5.6	15.6	2,111	55
1-FS node-or-branch (1-fs)	79.3	45.7	125.0	6,766	83
1-FCPS node-or-branch (1-fcps)	179.7	97.6	277.3	9,092	87
2-FS node-or-branch (2-fs)	1,199.8	696.3	1,896.1	97,423	102
2-FCPS node-or-branch (2-fcps)	2,323.1	1,297.6	3,620.7	122,589	111

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2-FCPS node-or-branch (2-fcps)	2,323.1	1,297.6	3,620.7	122,589	111

+28

Spec.

Expected

Terminated

```
for (let {} = 0; 0; ) ;
```

Wrong Result

Crash

Babel

Synthesized with **1-FS** but not with **0-FS**

RQ2) Effectiveness of k-FS Coverage Criteria

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+28

+19

Spec.

Expected

Terminated

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2-FCPS node-or-branch (2-fcps)	2,323.1	1,297.6	3,620.7	122,589	111

+28

+19

Spec.

Expected

Terminated

```
for (let {} = 0; 0; ) ;
```

Wrong Result

Crash

Babel

Synthesized with **1-FS** but not with **0-FS**

Spec.

Expected

"f"

```
class C { async ["f"](){} }
C.prototype.f.name
```

Wrong Result

"async"

JSC

Synthesized with **2-FS** but not with **1-FS**

RQ3) Effectiveness of k-FCPS Coverage Criteria

Coverage Criteria $C_{\mathbb{G}}$	# Covered k-F(CP)S-TR (k)			# Syn. Test	# Bug
	# Node	# Branch	# Total		
0-FS node-or-branch (0-fs)	10.0	5.6	15.6	2,111	55
1-FS node-or-branch (1-fs)	79.3	45.7	125.0	6,766	83
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RQ3) Effectiveness of k-FCPS Coverage Criteria

Coverage Criteria $C_{\mathbb{G}}$	# Covered k-F(CP)S-TR (k)			# Syn. Test	# Bug
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+4

RQ3) Effectiveness of k-FCPS Coverage Criteria

Coverage Criteria $C_{\mathbb{G}}$	# Covered k-F(CP)S-TR (k)			# Syn. Test	# Bug
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+4

+9

RQ3) Effectiveness of k-FCPS Coverage Criteria

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2-FCPS node-or-branch (2-fcps)	2,323.1	1,297.6	3,620.7	122,589	111

+4

+9

Spec.

Expected

RangeError

```
String.prototype
      .normalize
      .call(0, "");
```

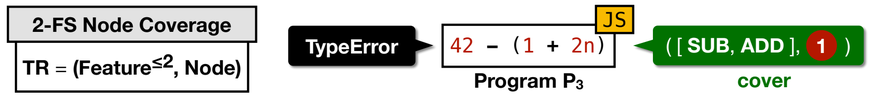
Wrong Result

Terminated

GraalJS

Synthesized with **1-FCPS** or **2-FCPS** but not with **1-FS** or **2-FS**

k-Feature-Sensitive (k-FS) Coverage



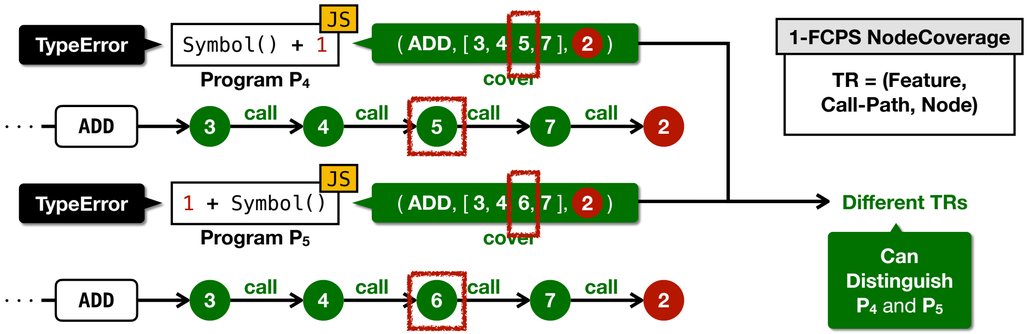
- k-Feature-Sensitive (k-FS) coverage criterion **divides** the given TRs with the at most k-**innermost enclosing** language **features**

FS Coverage
TR = (Feature≤k, given TR)

Evaluation of *AddExpr* : *AddExpr* + *MulExpr*
1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, +, *MulExpr*).

Evaluation of *AddExpr* : *AddExpr* − *MulExpr*
1. Return ? **EvalStrOrNumBinExpr** (*AddExpr*, −, *MulExpr*).

k-Feature-Call-Path-Sensitive (k-FCPS) Coverage

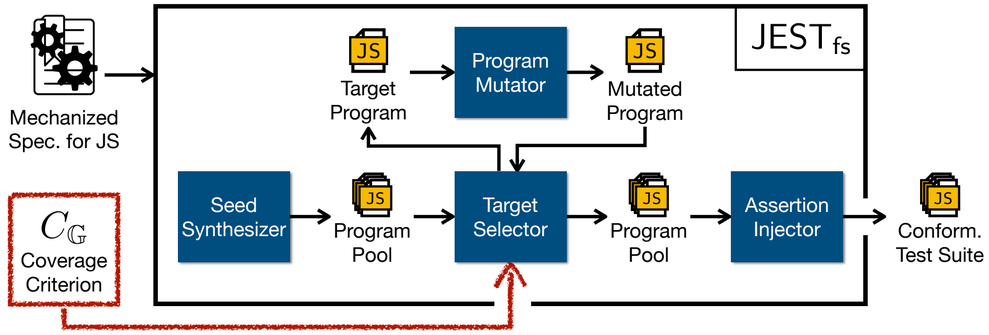


- k-Feature-Call-Path-Sensitive (k-FCPS) coverage criterion divides the k-FS TRs with the **call-paths from** the innermost enclosing language feature

FS Coverage
TR = (Feature≤k, Call-Path, given TR)

Implementation — JEST$_{fs}$

- **JEST** [1] is a **JavaScript conformance test generator** using **Coverage-Guided Fuzzing**
- We implemented **JEST$_{fs}$** as an extension of **JEST** with k-**FS** and k-**FCPS** coverage criteria



[1] Park et al., "JEST: N+1-version Differential Testing of Both JavaScript Engines and Specification", ICSE 2021

RQ2) Effectiveness of k-FS Coverage Criteria

Coverage Criteria $C_{\mathbb{G}}$	# Covered k-F(CP)S-TR (k)			# Syn. Test	# Bug
	# Node	# Branch	# Total		
0-FS node-or-branch (0-fs)	10.0	5.6	15.6	2,111	55
1-FS node-or-branch (1-fs)	79.3	45.7	125.0	6,766	83
1-FCPS node-or-branch (1-fcps)	179.7	97.6	277.3	9,092	87
2-FS node-or-branch (2-fs)	1,199.8	696.3	1,896.1	97,423	102
2-FCPS node-or-branch (2-fcps)	2,323.1	1,297.6	3,620.7	122,589	111

+28
+19

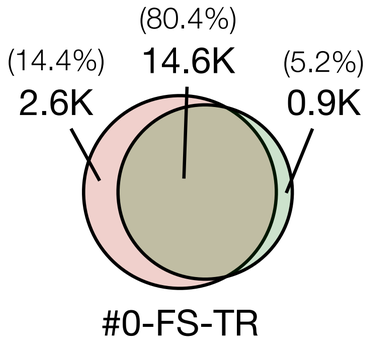
RQ3) Effectiveness of k-FCPS Coverage Criteria

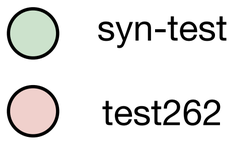
Coverage Criteria $C_{\mathbb{G}}$	# Covered k-F(CP)S-TR (k)			# Syn. Test	# Bug
	# Node	# Branch	# Total		
0-FS node-or-branch (0-fs)	10.0	5.6	15.6	2,111	55
1-FS node-or-branch (1-fs)	79.3	45.7	125.0	6,766	83
1-FCPS node-or-branch (1-fcps)	179.7	97.6	277.3	9,092	87
2-FS node-or-branch (2-fs)	1,199.8	696.3	1,896.1	97,423	102
2-FCPS node-or-branch (2-fcps)	2,323.1	1,297.6	3,620.7	122,589	111

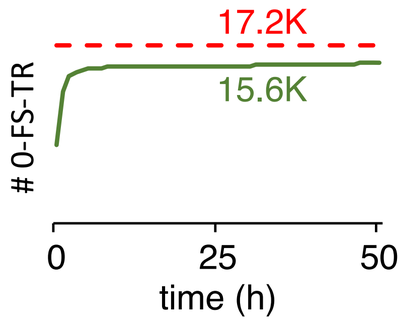
+4
+9

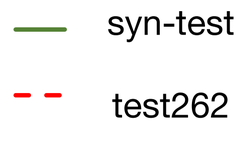
Backup Slides

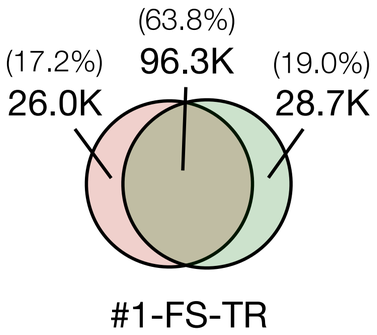
RQ4) Comparison with Test262

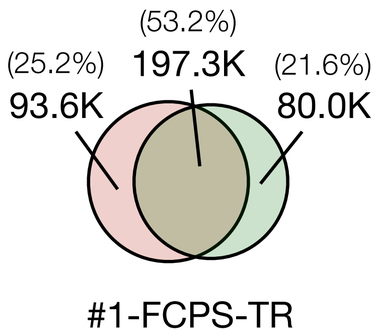


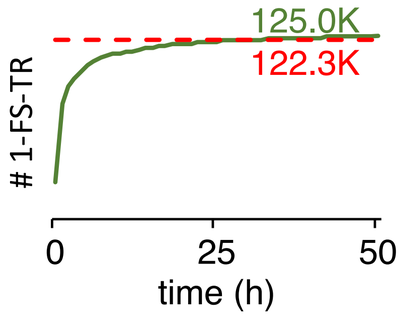


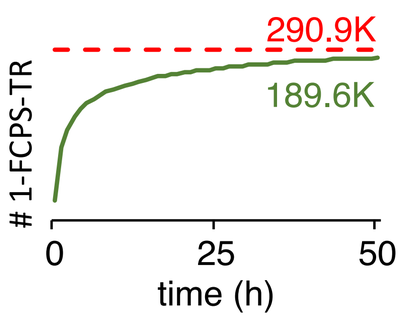


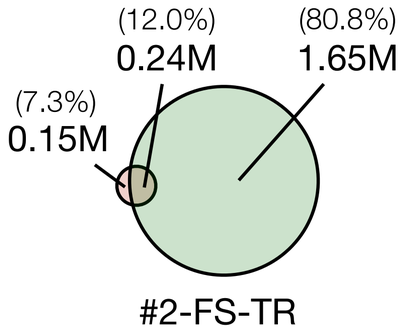


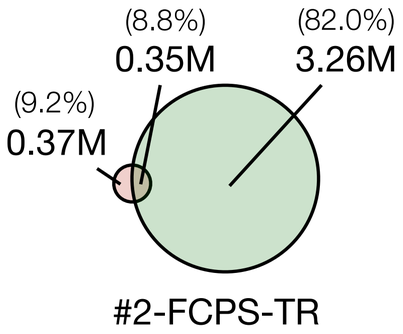


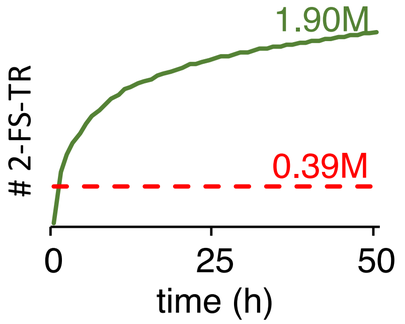


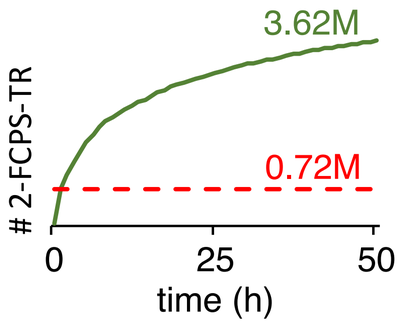












PLRG