Detecting and Characterizing Semantic Inconsistencies in Ported Code

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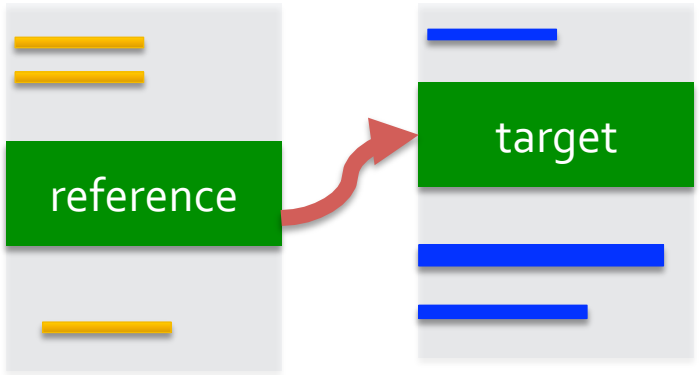
Motivation

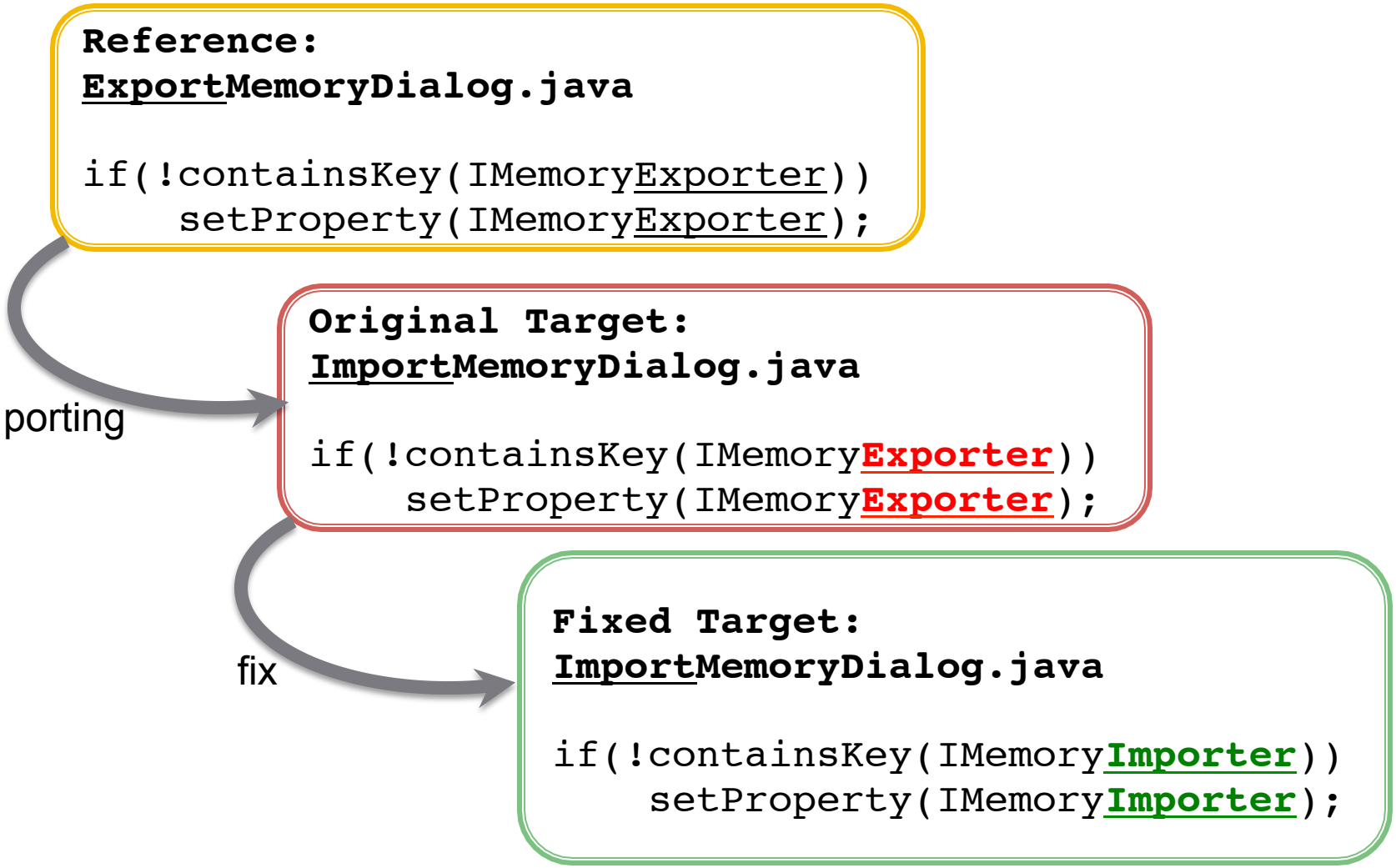
- Port code from a reference to a target implementation.
  [Ray et al., Al-Ekram et al., Kim et al.]
- Adapt ported changes to fit the target context.
  [Kim et al.]
- Faulty adaptation often leads to *porting-error.*
  [Chou et al., Juergens et al., Li et al., Jiang et al.].



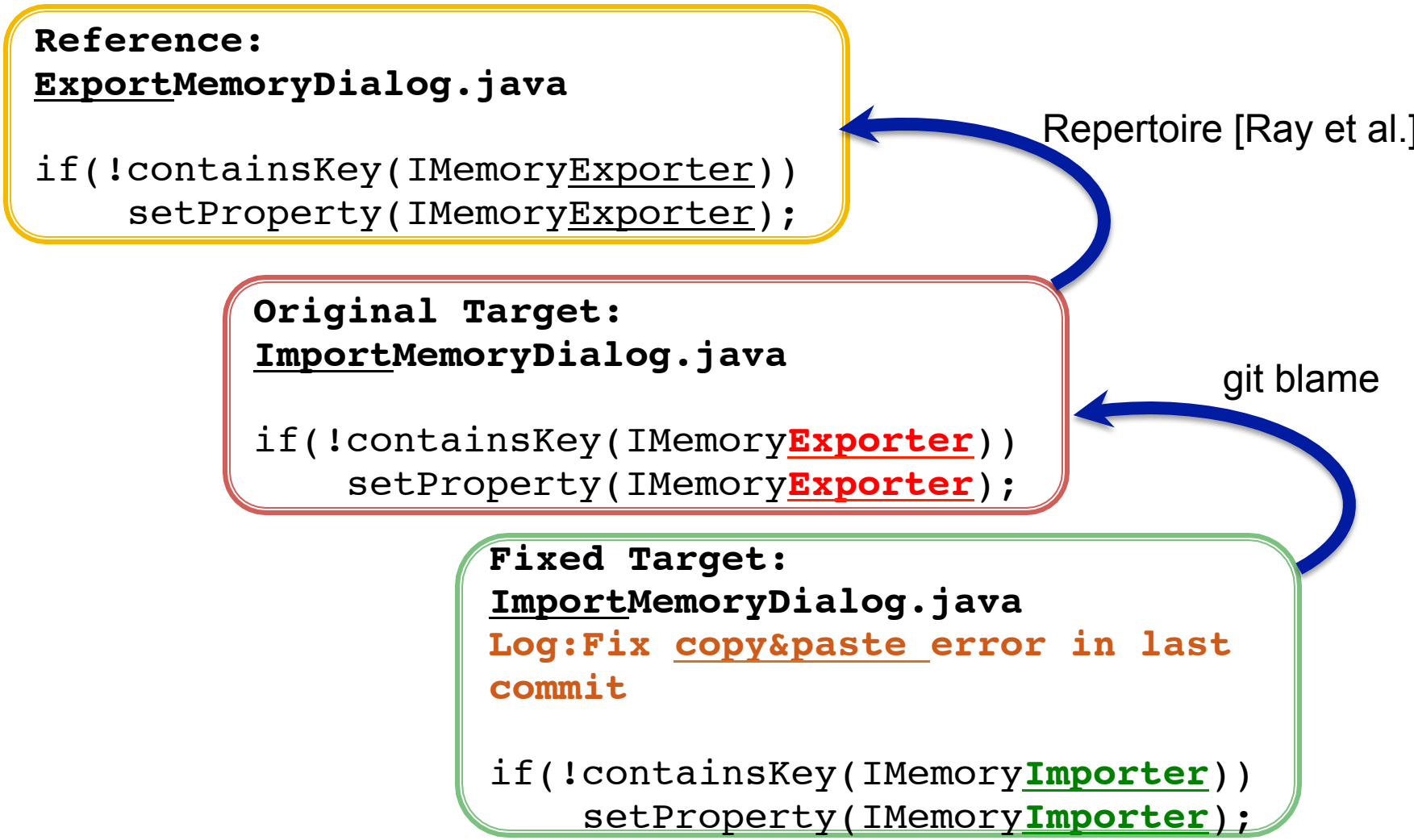
Outline

- Empirical study of porting errors
- Classification scheme for porting errors
- SPA: Semantic Porting Analysis
- Evaluation
- Conclusion

How are porting errors introduced?



Study Methodology



Empirical Study of Porting Errors

	KLOC	Developers	Years	Total
FreeBSD	4,479	405	18	113
Linux	14,998	6839	3	182

Developers frequently introduce porting errors in the codebase.

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Inconsistent Control Flow

Reference	Target
for(p ..) {	for(p) {
for(kg ..) {	
...	...
+ if (ke->ke_cpticks == 0)	+ if (ke->ke_cpticks **==** 0)
+ continue;	+ **continue**;
...	...
. }	}

Inconsistent Identifier Renamings

Reference	Target
…	…
+ bp->b_flags |= B_ASYNC;	+ rabp->b_flags |= B_ASYNC;
+ bp->b_flags &= ~B_INVAL;	+ rabp->b_flags &= ~B_INVAL;
…	…
+ VOP_STRATEGY(vp, bp);	+ VOP_STRATEGY(vp, bp);
…	…

Inconsistent Renamings of Related Identifiers

Reference	Target
…	…
+ if (INDEX < lowest_**ofdm**)	+ if (INDEX < lowest_**ofdm**)
+ **ofdm** |= RATE >>	+ **ofdm** |= RATE >>
OFDM_RATE;	**CCK**_RATE;
…	…

Inconsistent Data Flow

Reference	Target

while ((ch = **getopt**(argc, argv,...)) != -1)
...
switch (ch) {
...
+ case 'o':
+ if (strcmp(**optarg**, "space") == 0) {
+ opt = FS_OPTSPACE;
...
	parse_uuid(const char *s, uuid_t *uuid) {
	...
	switch (*s)
	...
	+ case 'e':
	+ if (strcmp(**optarg**, "efi") == 0) {
	+ uuid_t efi = GPT_ENT_TYPE_EFI;
	...

Redundant Operation

Reference	Target
memset(&tsf_tlv, ...));	**memcpy(*buffer, &tsf_val);**
...	
	memcpy(&tsf_val,
...	time_stamp, ...);
	..
+ memcpy(*buffer, &tsf_tlv);	**+ memcpy(*buffer, &tsf_val);**

Distribution of Porting Errors

	FreeBSD	Linux
Total	113	182
Inconsistent Control Flow	8%	13%
Inconsistent Renaming	48%	41%
Inconsistent Data Flow	28%	14%
Redundant Operations	12%	26%
Other	25%	14%

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SPA Overview

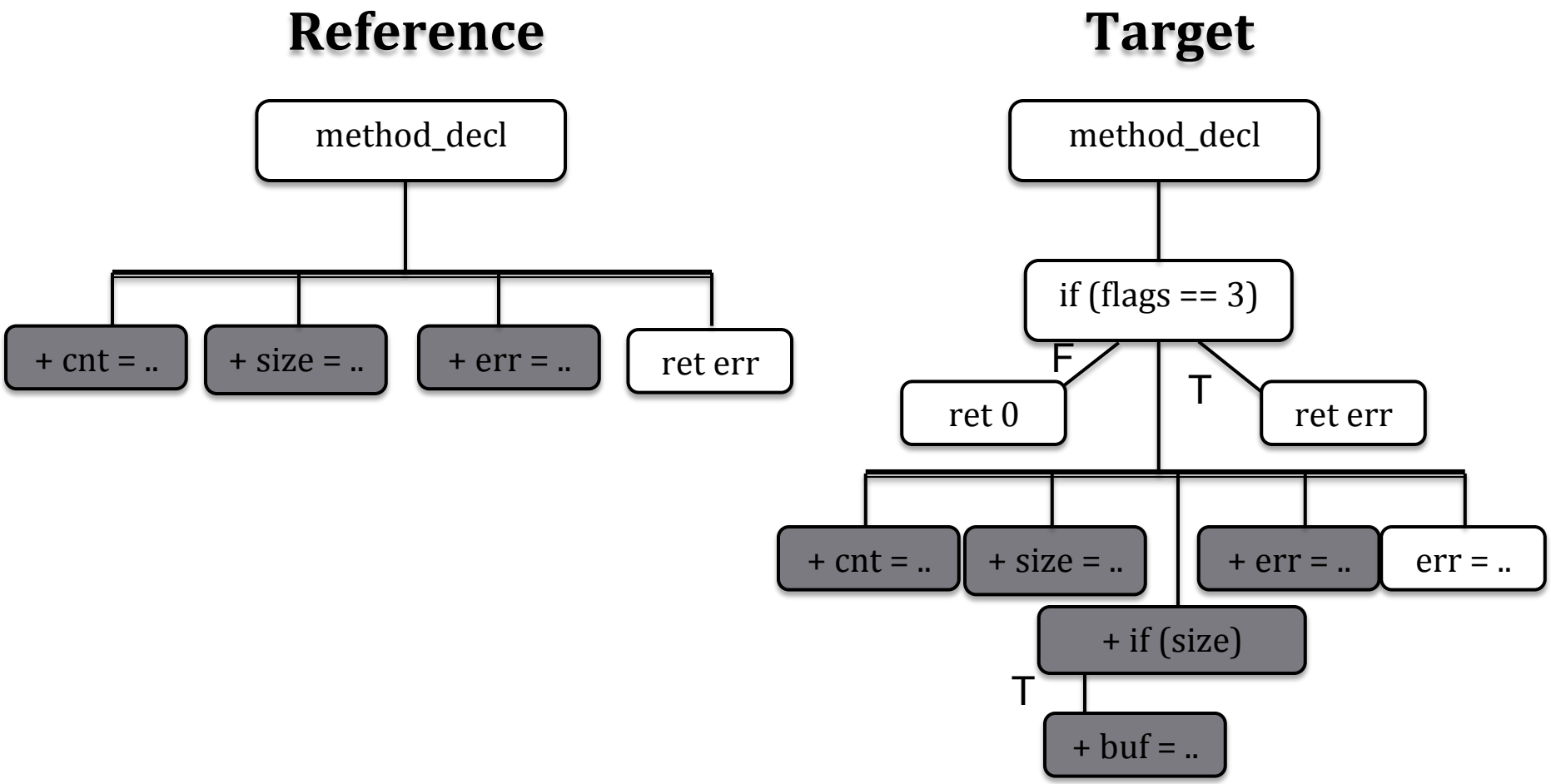
- Input: Reference and Target patches
- Analyze the semantic differences between ported edits in reference and target context.
- Output: Types of potential porting inconsistencies

Motivating Example

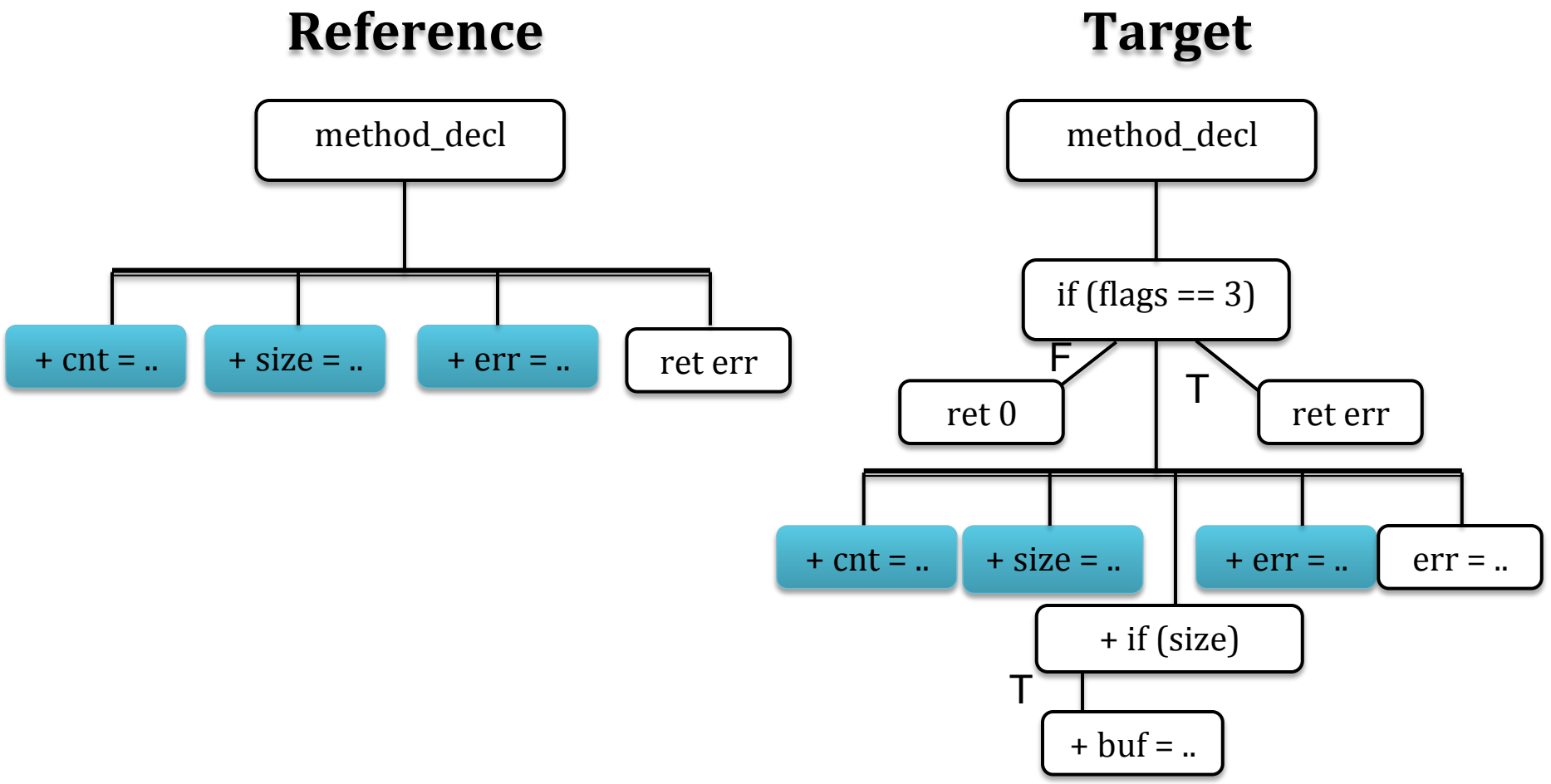
Reference	Target

R(int flags, int bufsize, ostatfs osb)
{
R1. + **cnt = bufsize /size(ostatfs);**
R2. + **size = cnt + size(ostatfs);**
R3. + **err = copy(osb, sp, size);**
R4. return error ;
}
	T(int flags, int bufsize, stat osb)
	{
	T1. if (flags == 3) { return 0; }
	T2. + **cnt = bufsize /size(ostatfs);**
	T3. + **size = cnt + size(stat);**
	T4. + if(size)
	T5. + buf = new stat();
	T6. + **err = copy(osb, buf, size);**
	T7. + err = copy(osb, buf, size);
	T8. return (err);
	}

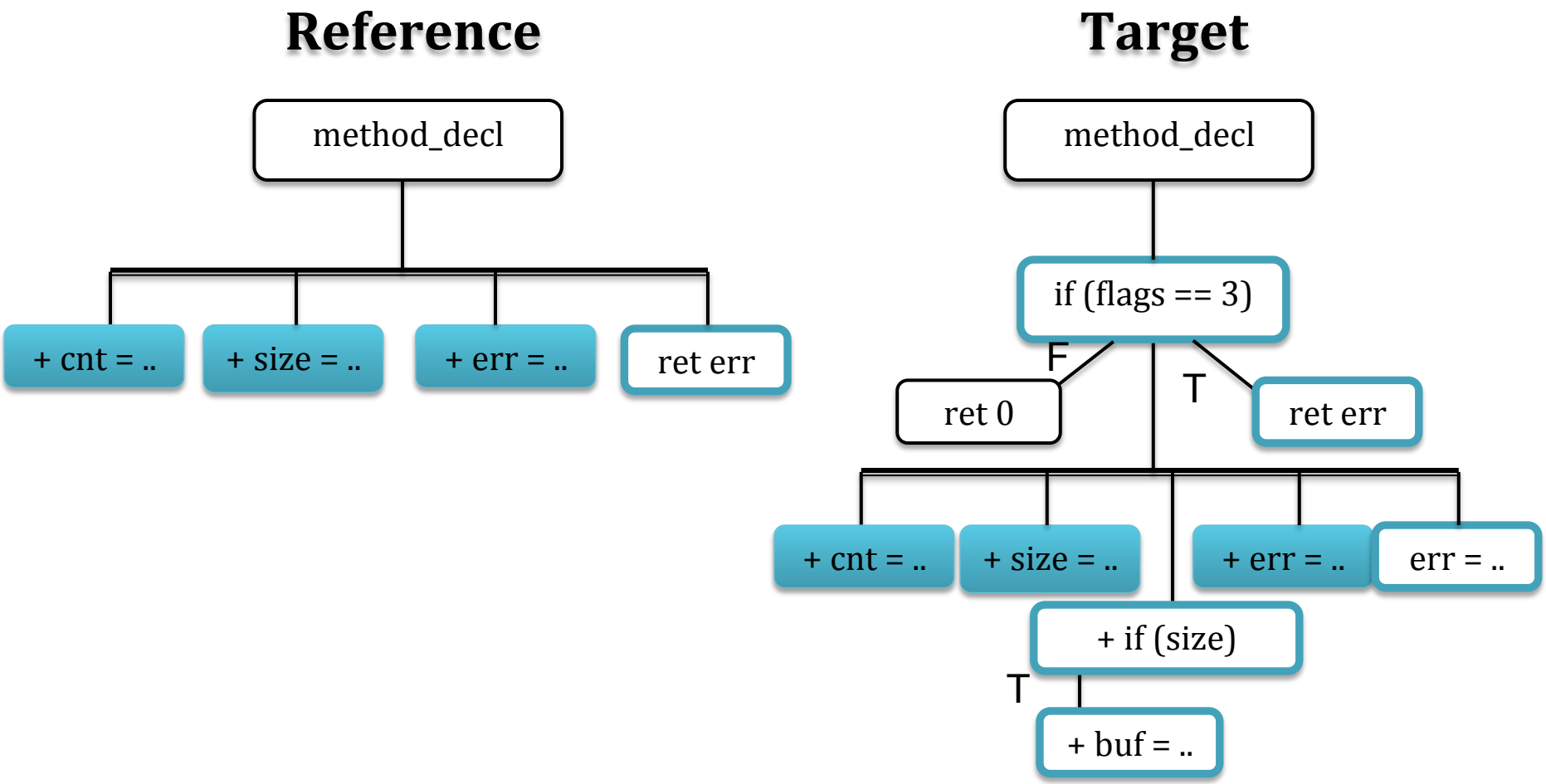
1. Identify Edited Nodes



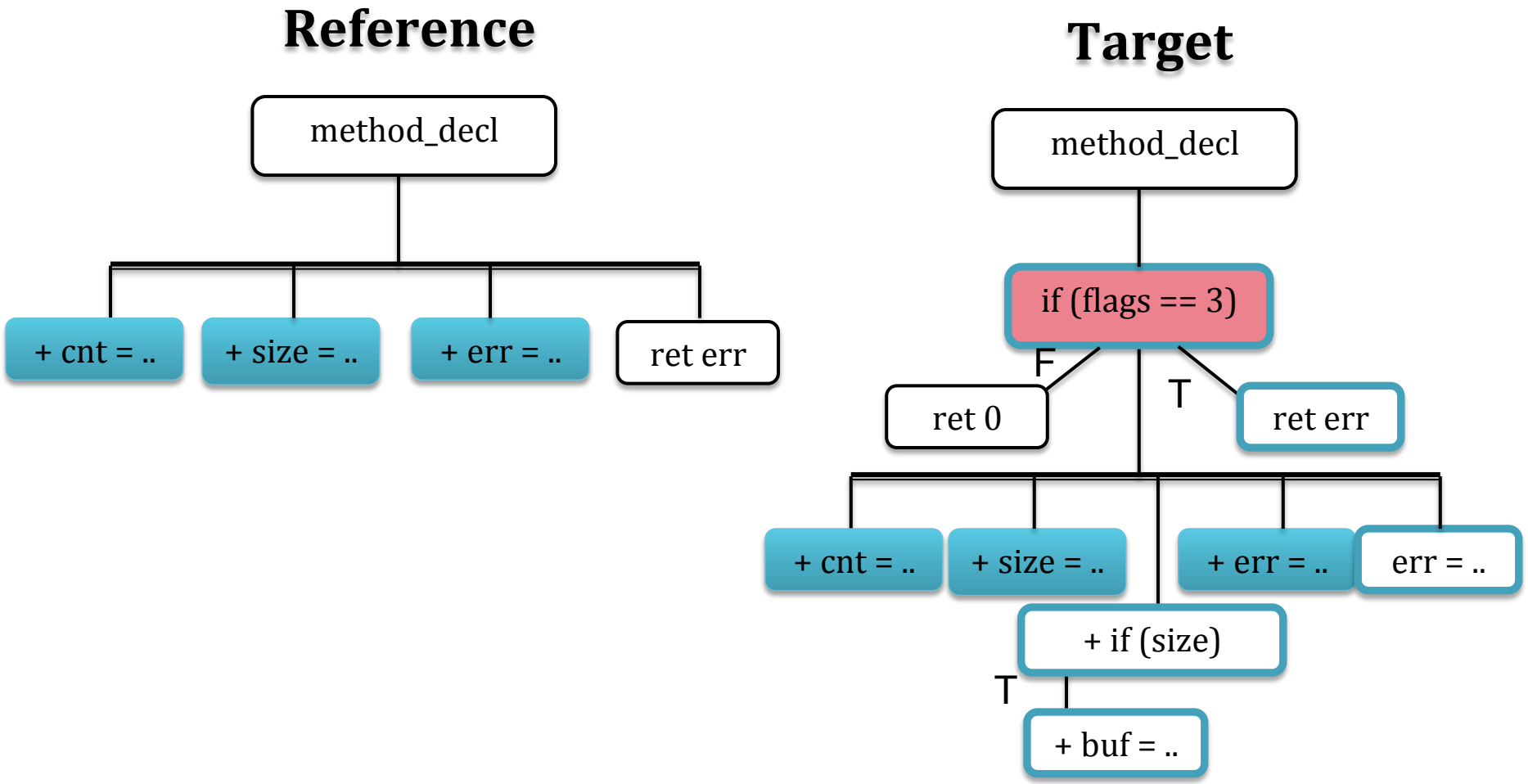
2. Compute Ported Nodes



3. Detect Impacted Nodes



4. Find Inconsistent Control Flow

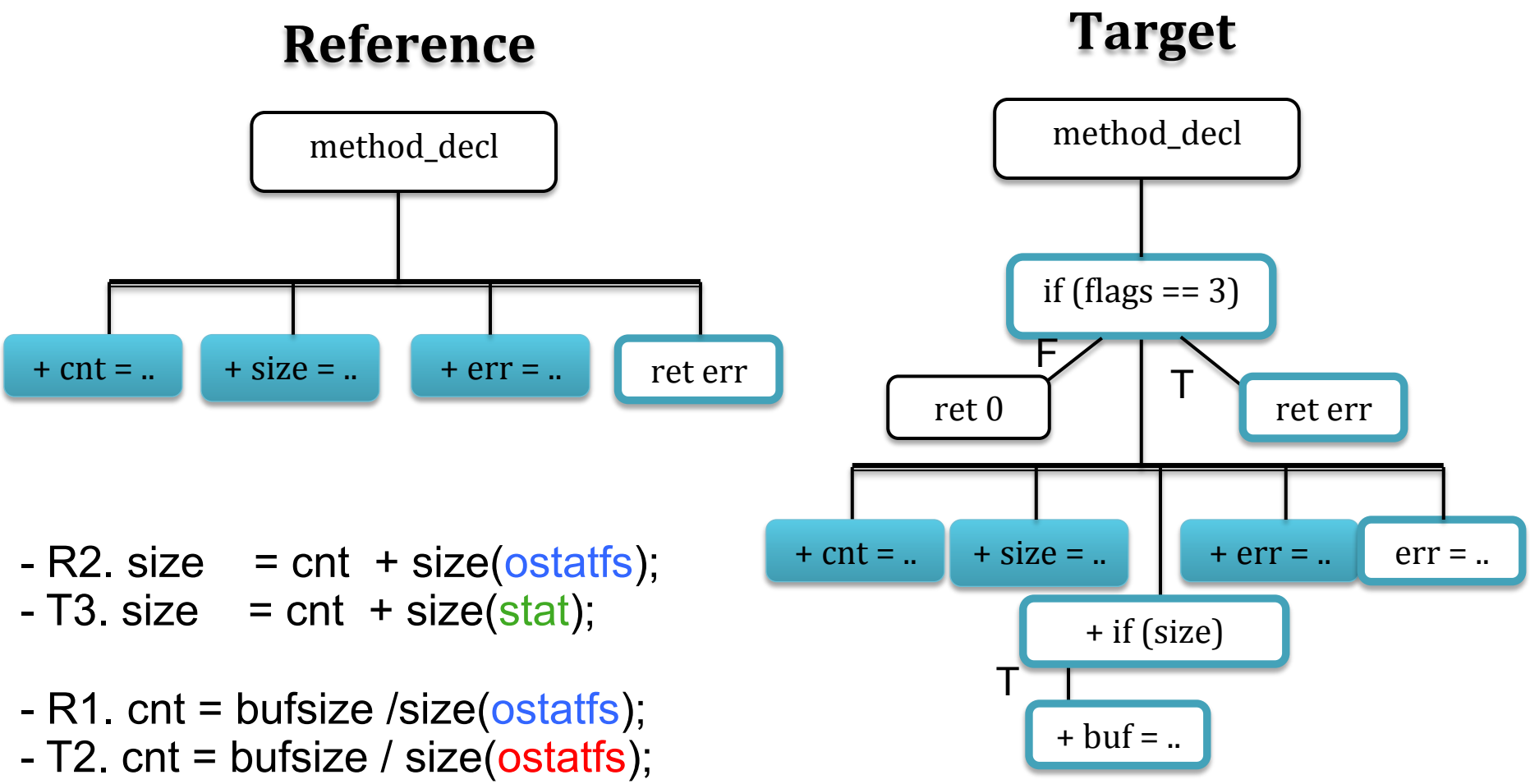


4. Find Inconsistent Control Flow

Reference	Target

R(int flags, int bufsize, ostatfs osb)
{
R1. + cnt = bufsize /size(ostatfs);
R2. + size = cnt + size(ostatfs);
R3. + err = copy(osb, sp, size);
R4. return error ;
}
	T(int flags, int bufsize, stat osb)
	{
	T1. if (flags == 3) { return 0; }
	T2. + cnt = bufsize /size(ostatfs);
	T3. + size = cnt + size(stat);
	T4. + if(size)
	T5. + buf = new stat();
	T6. + err = copy(osb, buf, size);
	T7. + err = copy(osb, buf, size);
	T8. return (err);
	}

5. Detect Inconsistent Renamings



- R2. size = cnt + size(ostatfs);
- T3. size = cnt + size(stat);

- R1. cnt = bufsize /size(ostatfs);
- T2. cnt = bufsize / size(ostatfs);

5. Detect Inconsistent Renamings

Reference	Target

R(int flags, int bufsize, ostatfs osb)
{
R1. + **cnt = bufsize /size(ostatfs);**
R2. + **size = cnt + size(ostatfs);**
R3. + **err = copy(osb, sp, size);**
R4. return error ;
}
	T(int flags, int bufsize, stat osb)
	{
	T1. if (**f**lags == 3) { return 0; }
	T2. + **cnt = bufsize /size(ostatfs);**
	T3. + **size = cnt + size(stat);**
	T4. + if(size)
	T5. + buf = new stat();
	T6. + **err = copy(osb, buf, size);**
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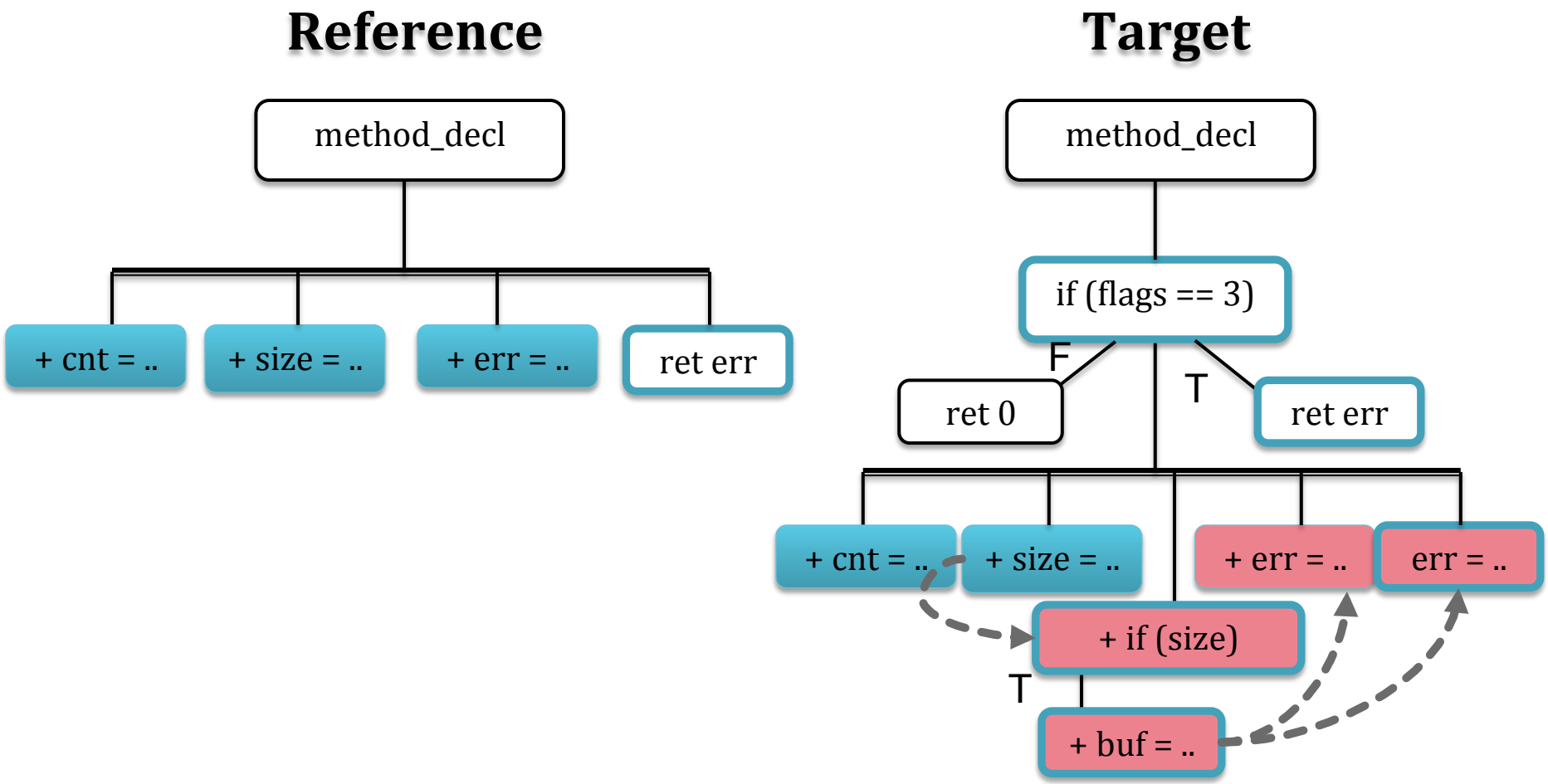
	}

6. Identify Inconsistent Data Flow



6. Identify Inconsistent Data Flow

Reference	Target

R(int flags, int bufsize, ostatfs osb)
{
R1. + **cnt = bufsize /size(ostatfs);**
R2. + **size = cnt + size(ostatfs);**
R3. + **err = copy(osb, sp, size);**
R4. return error ;
}
	T(int flags, int bufsize, stat osb)
	{
	T1. if (flags == 3) { return 0; }
	T2. + **cnt = bufsize /size(ostatfs);**
	T3. + **size = cnt + size(stat);**
	T4. + **if(size)**
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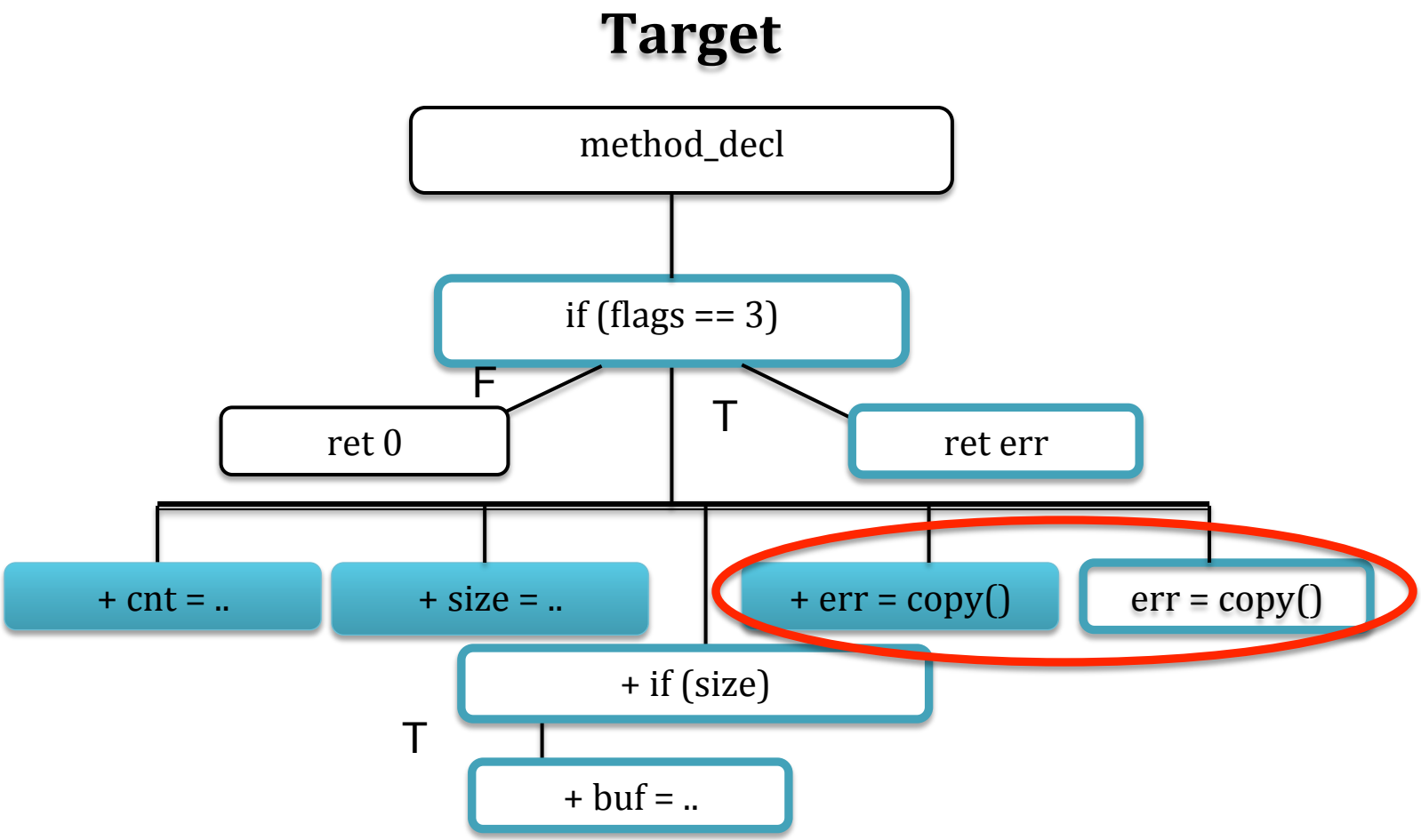
	T7. + **err = copy(osb, buf, size);**
	T8. return (err);
	}

7. Detect Redundant Operation



7. Detect Redundant Operation

Reference	Target

R(int flags, int bufsize, ostatfs osb)
{
R1. + **cnt = bufsize /size(ostatfs);**
R2. + **size = cnt + size(ostatfs);**
R3. + **err = copy(osb, sp, size);**
R4. return error ;
}
	T(int flags, int bufsize, stat osb)
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	T1. if (flags == 3) { return 0; }
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	T8. return (err);
	}

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Evaluation

- RQ1. Can SPA accurately detect porting inconsistencies?
- RQ2. Can SPA accurately categorize porting inconsistencies?

Implementation

- Java static analysis framework
- Extends LASE, Sydit [Meng et al], and uses Crystal [Aldrich et al]

RQ1. Can SPA accurately detect porting inconsistencies?

Reference	Target
	x = x + y
x = 5	x = 5
+ foo(x)	+ foo(x)

SPA correctly reports No Inconsistency

Reference	Target
	i = 0;
for(i=0; i < n;) {	while(i<n) {
+ foo(i)	+ foo(i)
i++;	i++;
}	}

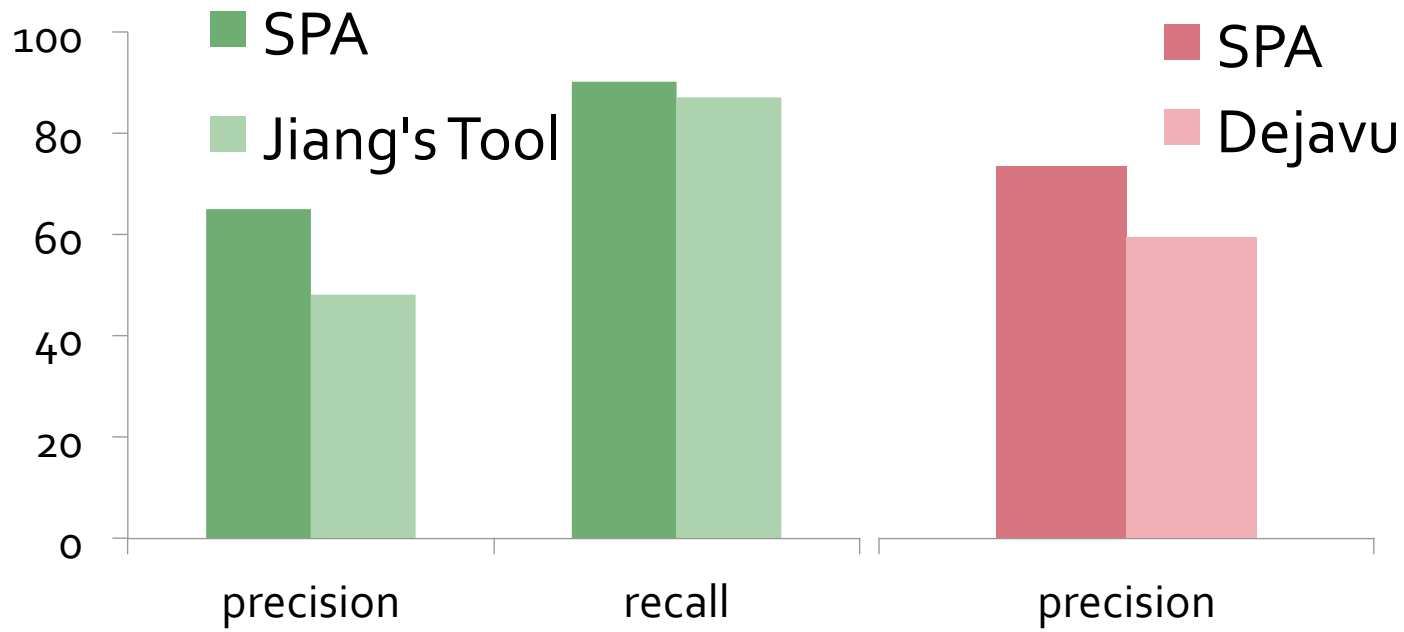
SPA incorrectly reports Inconsistency

RQ1. Can SPA accurately detect porting inconsistencies?

	Eclipse CDT	Mozilla
	SPA	SPA
Total	63	42
Detected	43	34
False positive	15	9
False negative	3	-

SPA detects inconsistencies with 65% to 73% precision and 90% recall.

RQ1. Can SPA accurately detect porting inconsistencies?



SPA improves precision by 14 to 17 percentage points w.r.t. earlier tools.

RQ2. Can SPA accurately categorize porting inconsistencies?

	Incnst Control Flow	Incnst Identifier Renaming	Incnst Related Identifier Renaming	Incnst Data Flow	Total
Detected	33	7	5	17	62
Ground Truth	23	7	4	5	39
False positive	12	2	2	12	26
False negative	2	2	1	0	3

RQ2. Can SPA accurately categorize porting inconsistencies?

Reference	Target
int x; x = 5;	**int x = 5;**
+ foo(x)	+ foo(x)

SPA incorrectly reports as Inconsistent data flow.

RQ2. Can SPA accurately categorize porting inconsistencies?

	Incnst Control Flow	Incnst Identifier Renaming	Incnst Related Identifier Renaming	Incnst Data Flow	Total
SPA	33	7	5	17	62
Ground Truth	23	7	4	5	39
False positive	12	2	2	12	26
False negative	2	2	1	0	3

SPA categorizes inconsistencies with 58% to 63% precision and 92% to 100% recall.

Summary

- Study different types of porting errors in practice.
- Detect and categorize potential porting errors successfully.

Future Work

- Integrate SPA with an integrated development environment (IDE).
- Investigate other complementary approaches to detect porting errors.

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RQ1. Can SPA accurately detect porting inconsistencies?

	Eclipse CDT		Mozilla	
	SPA	Jiang's Tool	SPA	Dejavu
Detected	43	56	34	42
False positive	15	29	9	17
False negative	3	4	-	-

SPA detects inconsistencies with 65% to 73% precision and 90% recall.

SPA improves precision by 14 to 17 percentage points w.r.t. earlier tools.