How Many of All Bugs Do We Find? A Study of Static Bug Detectors

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Static Bug Detection

Error Prone

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- General framework
- Scalable static analysis
- Set of checkers for specific bug patterns

How Many Bugs Do They Find?

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This talk:

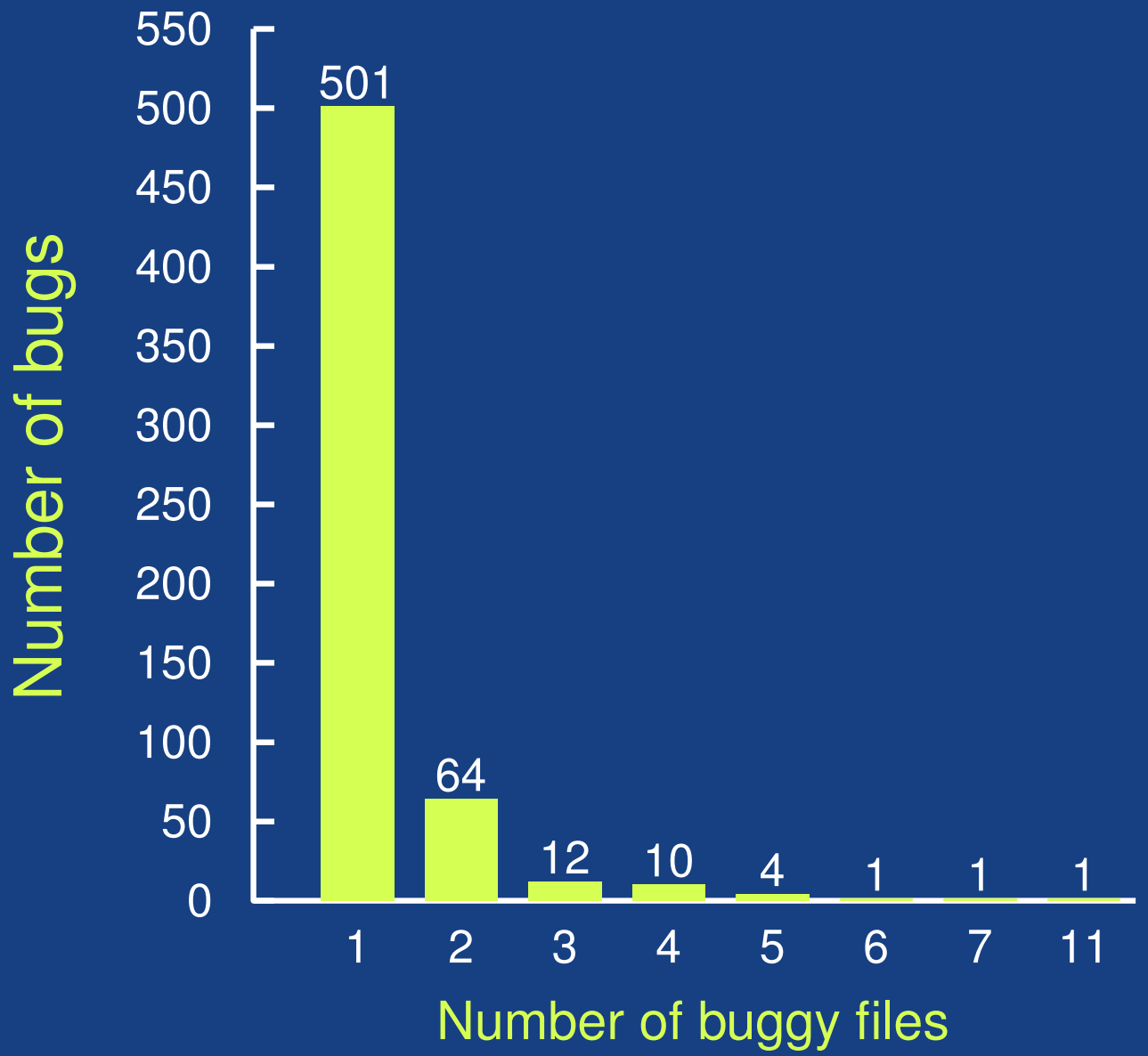
Empirical study with 594 real-world Java bugs and 3 popular static checkers

Real-World Bugs

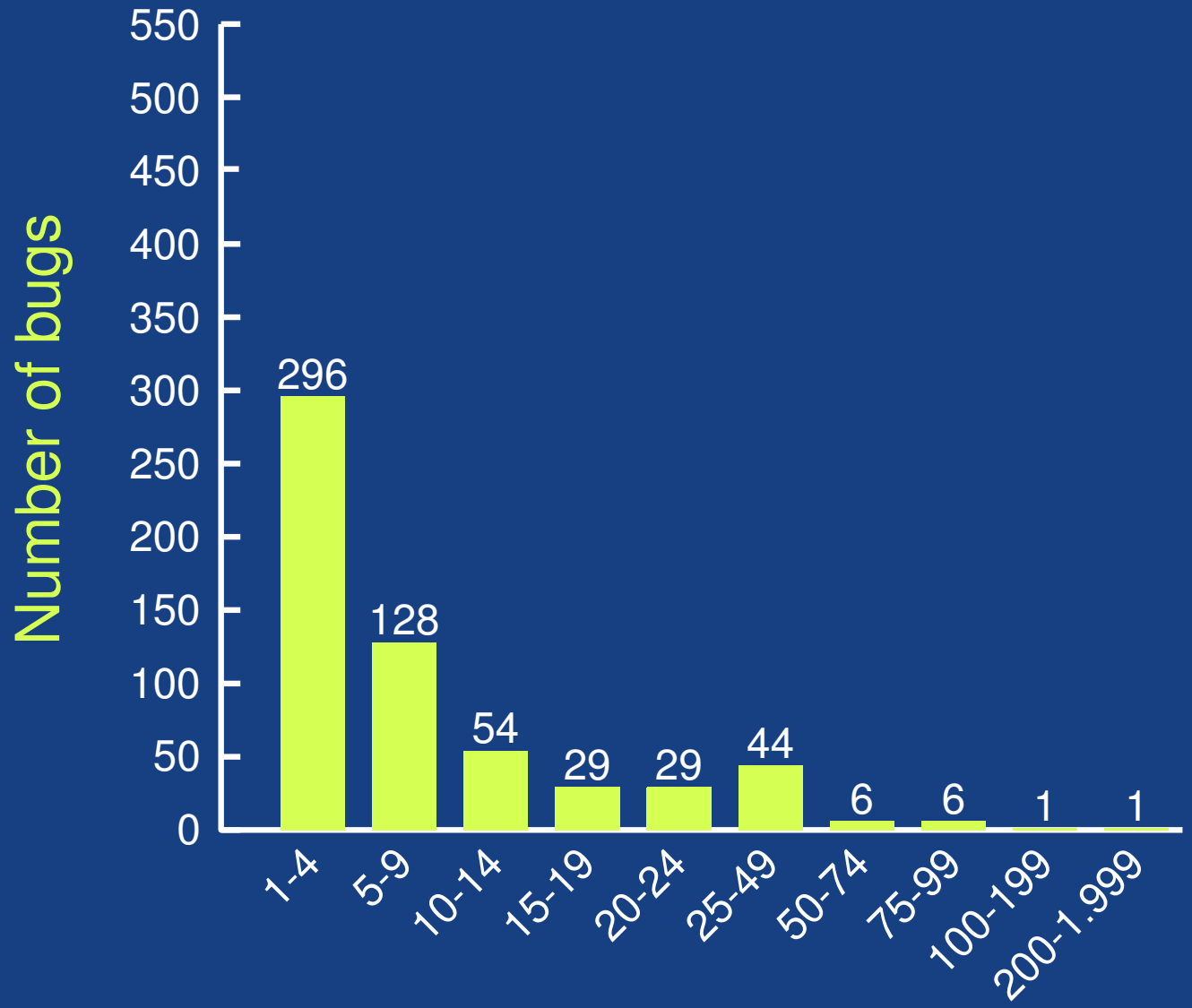
- **594 bugs from 15 popular Java projects**
  - Extended version of Defects4J data set
- **Why this set?**
  - Gathered independently
  - Used in other bug-related studies *
  - Contains real fixes by developers

* Just et al., 2014 (mutation testing); Shamshiri et al., 2015 (test generation); Pearson et al., 2017 (fault localization); Martinez et al., 2017 (program repair)

Defects4J: Files Involved in Bug



Defects4J: Size of Bug Fix



Previous Approach

How to determine which bugs are found?

[Thung et al., 2012]

- Get diff between buggy and fixed code
- Run tool on code with buggy lines
- If warning on buggy line: Bug found
- Result: 50% – 95% of all bugs found

Previous Approach

How to determine which bugs are found?

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- Get diff between buggy and fixed code
- Run tool on code with buggy lines
- If warning on buggy line: Bug found
- Result: 50% – 95% of all bugs found
- **Limitation:**
  - No check that warning points to bug
  - One tool flags up to 57% of all lines

Methodology: Overview

Bugs + fixes

Bug detectors

Methodology: Overview

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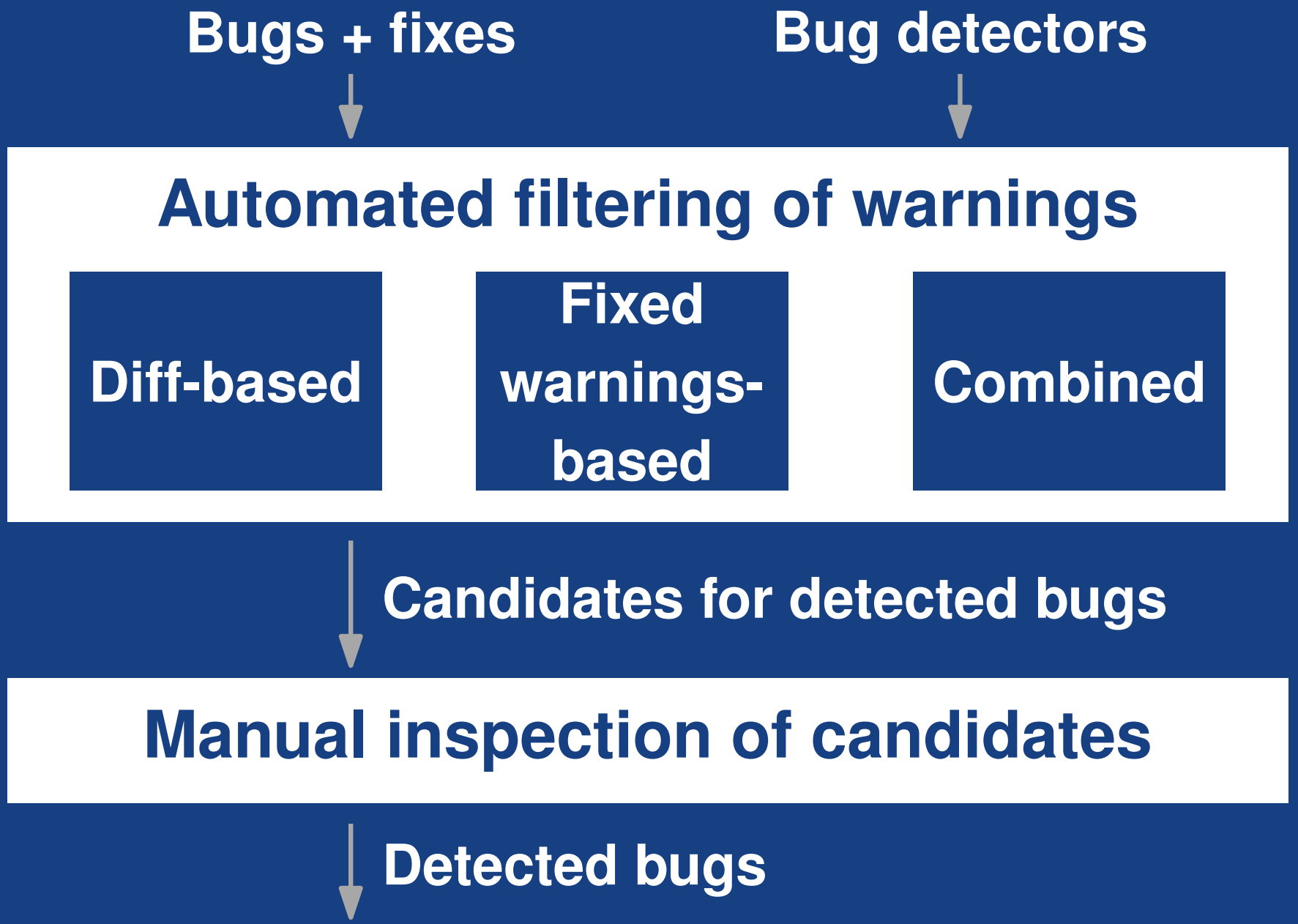
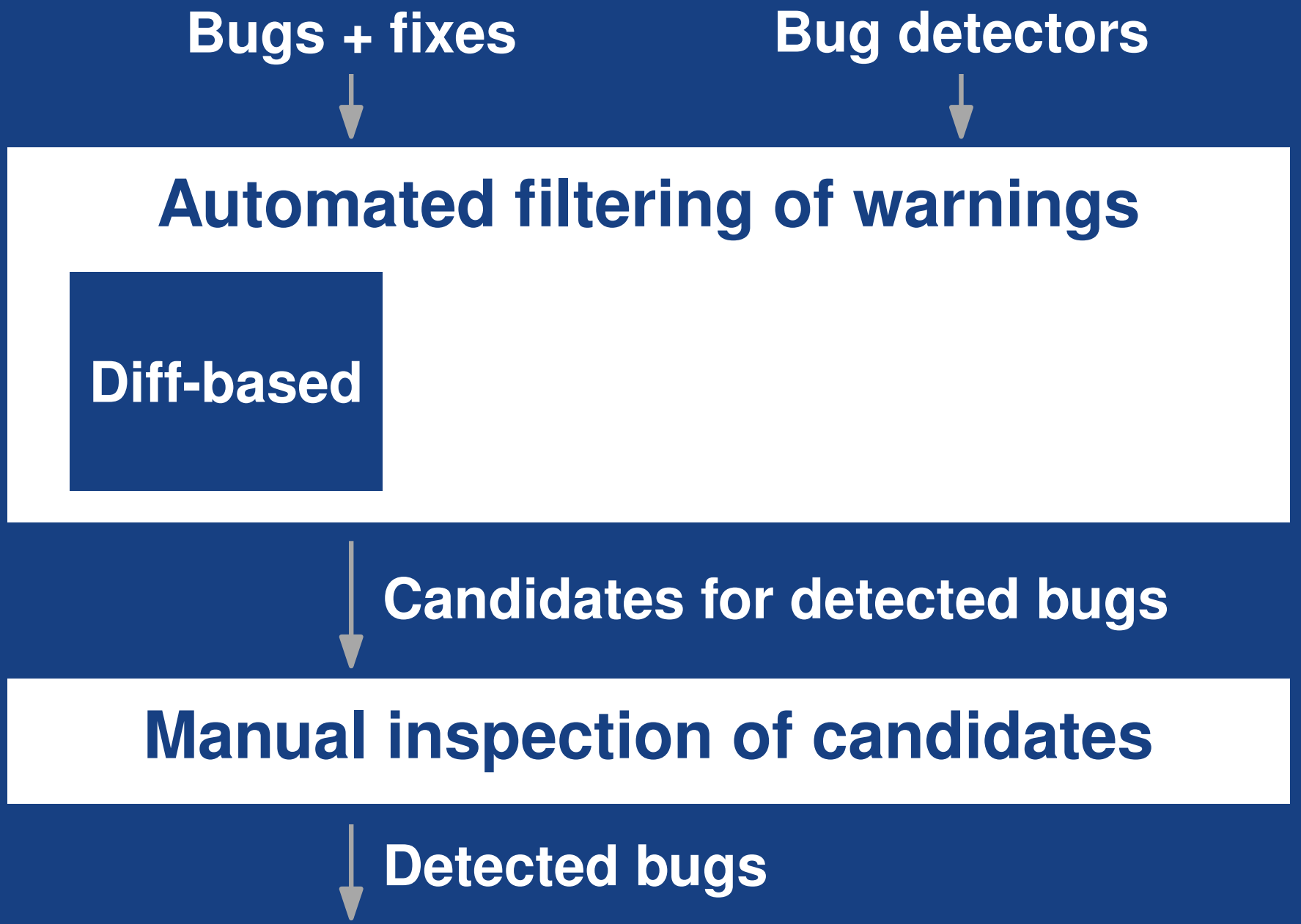


Methodology: Diff-based



Methodology: Diff-based

1) Identify lines changed to fix bug

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Buggy file:

Fixed file:

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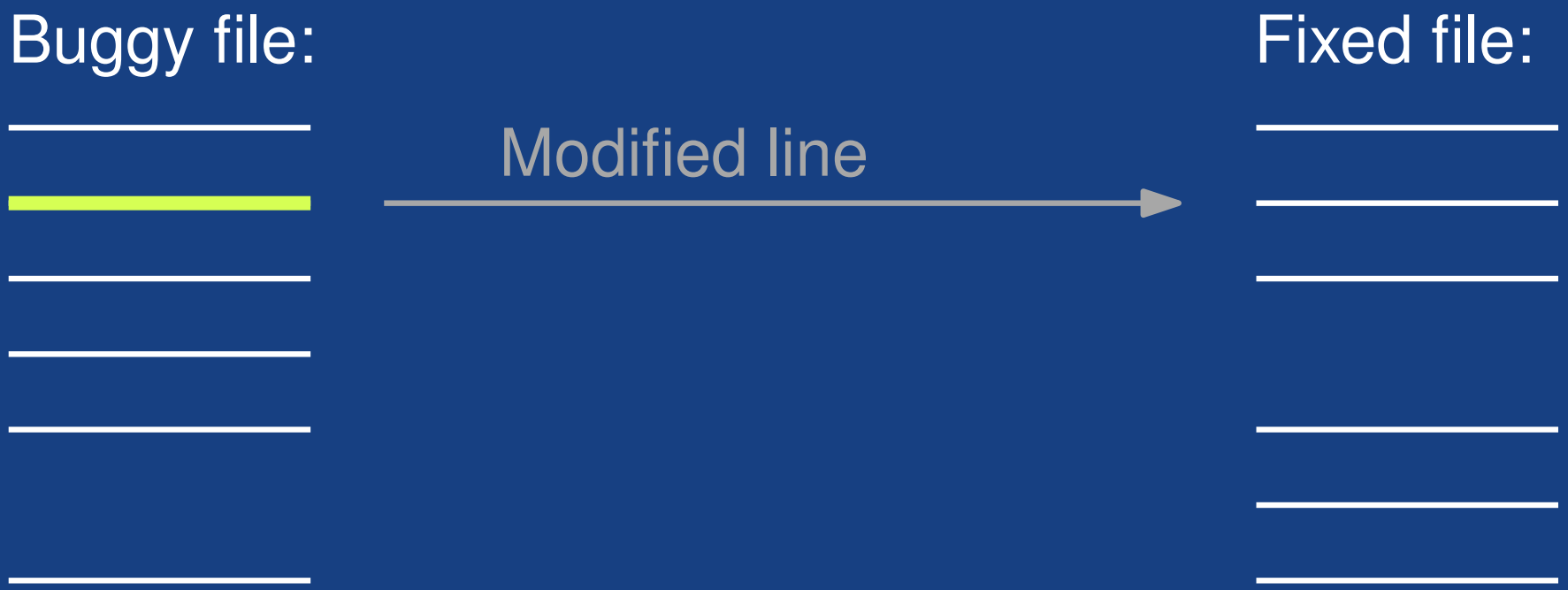

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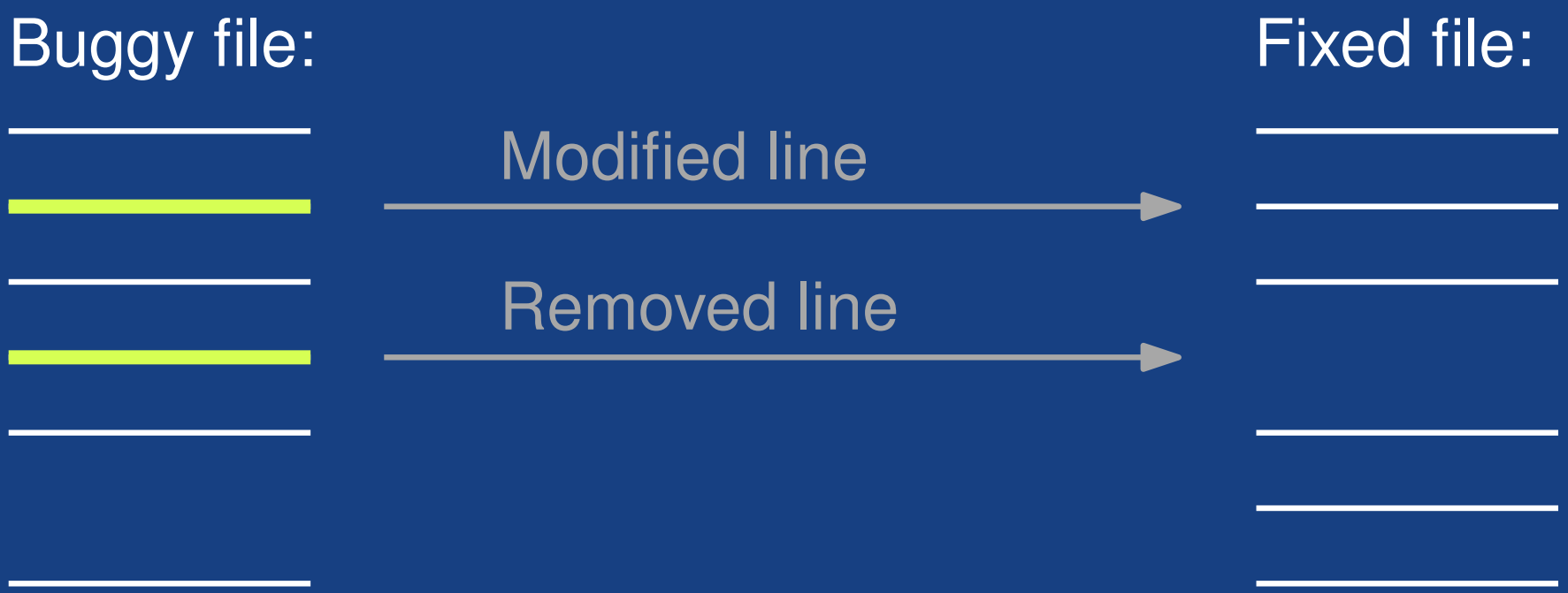

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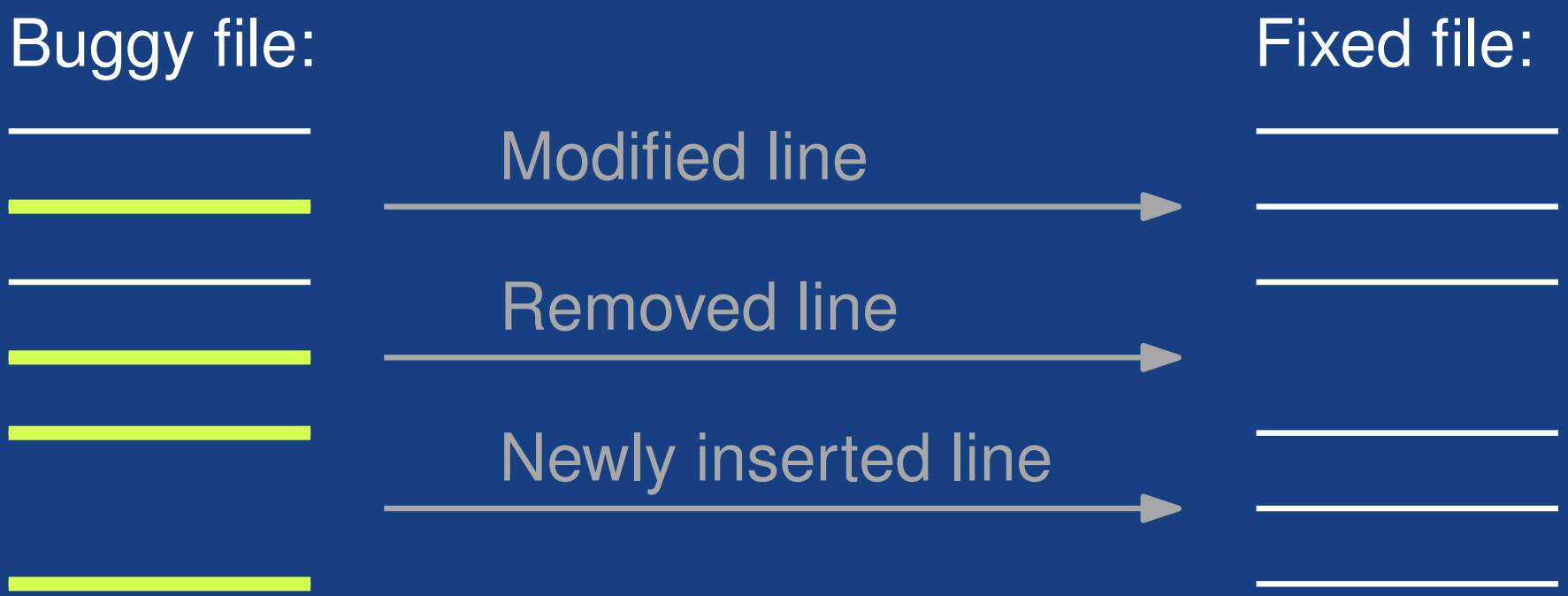

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Candidate for detected bug

Example:

```
public Dfp multiply(final int x) {
  return multiplyFast(x);
}
```


```
public Dfp multiply(final int x) {
  if (x >= 0 && x < RADIX) {
    return multiplyFast(x);
  } else {
    return multiply(newInstance(x));
  }
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Example:

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Bug fix

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Warning:
Missing
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-1

+1

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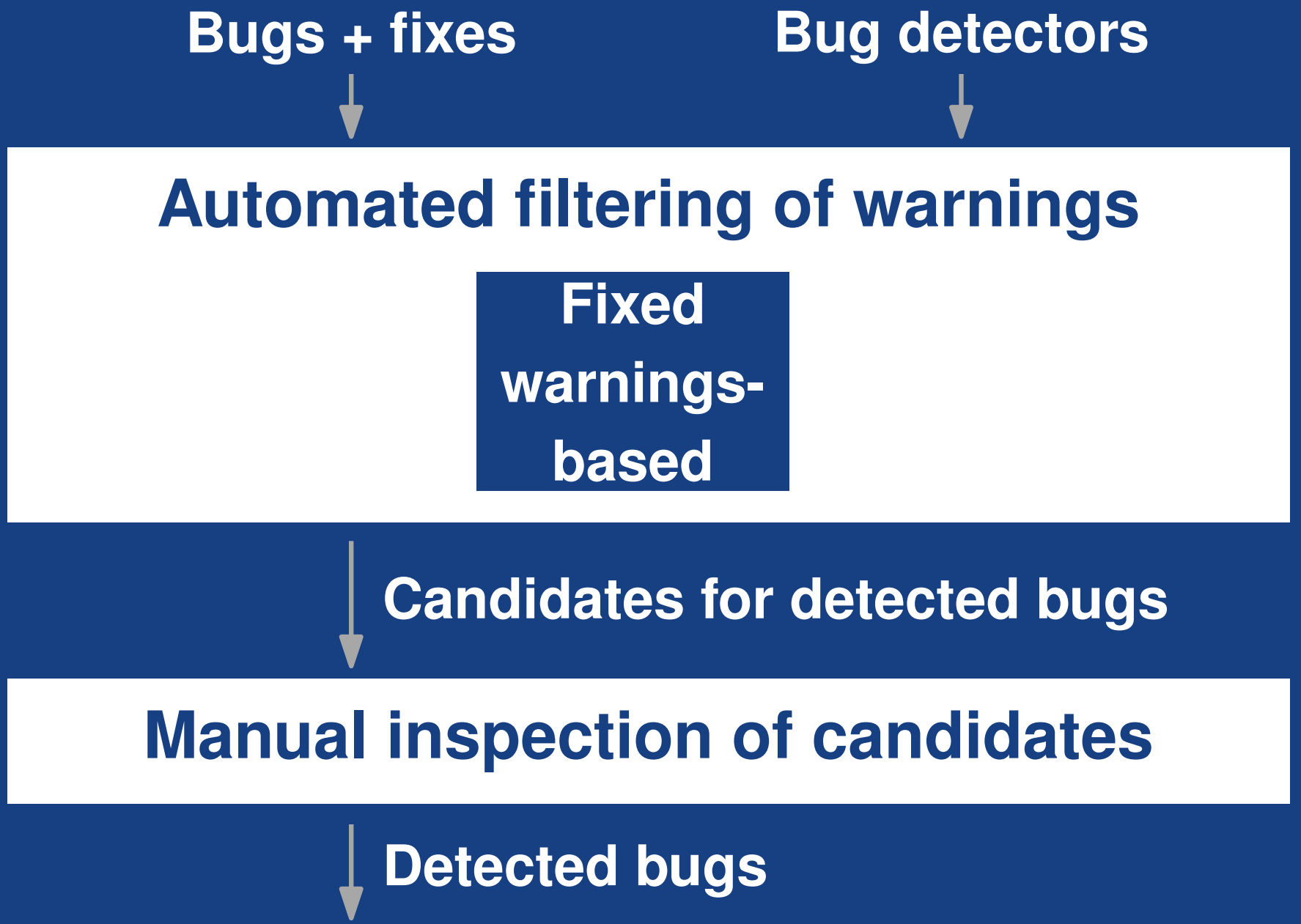
Candidate for detected bug

Method.: Fixed Warnings-based



Method.: Fixed Warnings-based

1) Compare warnings before and after fix

2) Warning that disappears was for bug

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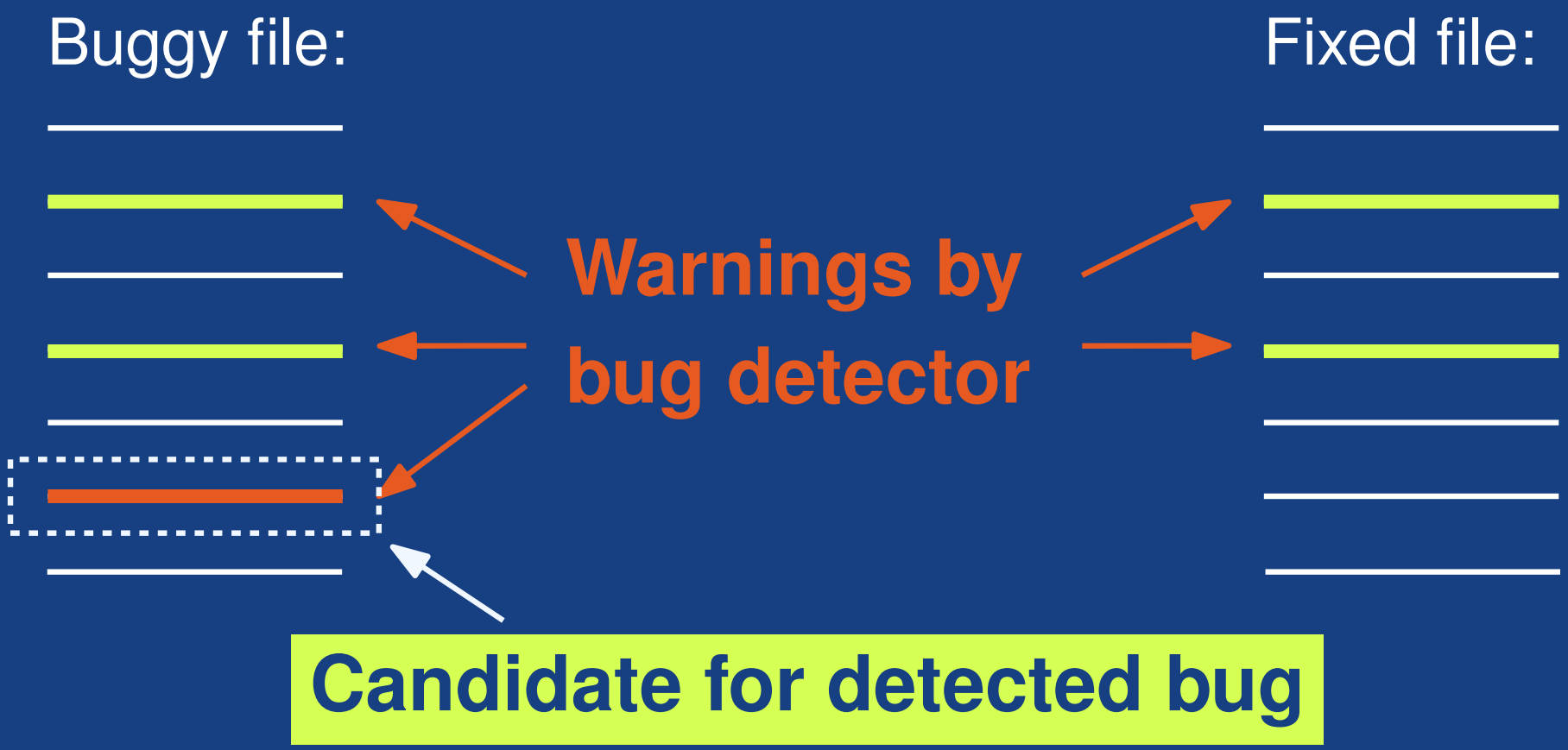

Example

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public Week(Date time, TimeZone zone) {
   this(time,
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      Locale.getDefault());
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Bug fix

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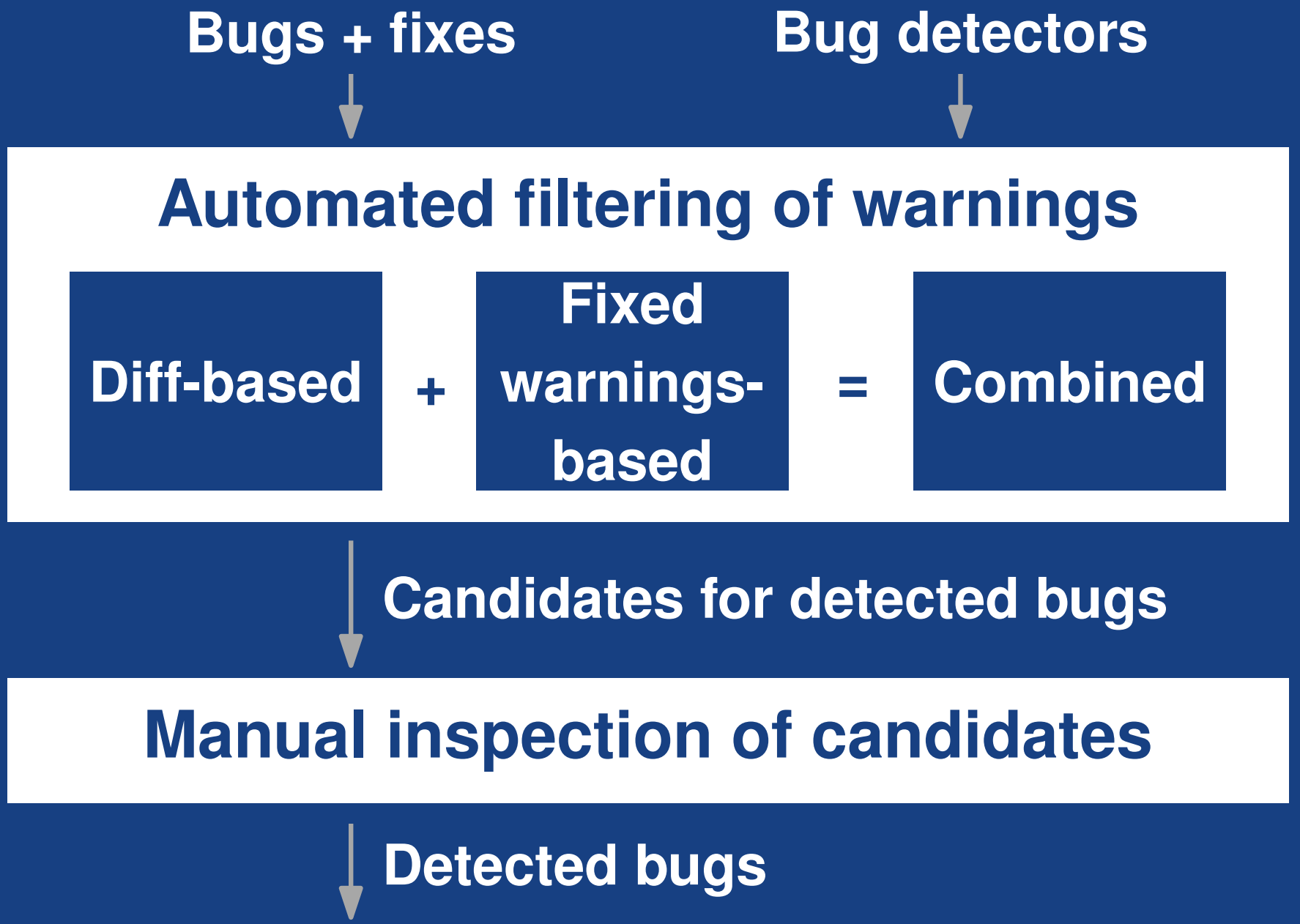
Warning: Chaining constructor ignores argument

Candidate for detected bug

Methodology: Combined



Results

Warnings to Inspect

	All warnings			
	Per bug			
Tool	Min	Max	Avg	Total
Error Prone	0	148	7.58	4,402
Infer	0	36	0.33	198
SpotBugs	0	47	1.1	647
Total				**5,247**

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97% of all warnings are removed by the automated filtering step

Manual Inspection

Distinguish coincidental matches from actually detected bugs

Candidate = (bug, warning)

Full match

Partial match

Mismatch

Created by Freepik

Manual Inspection: Example

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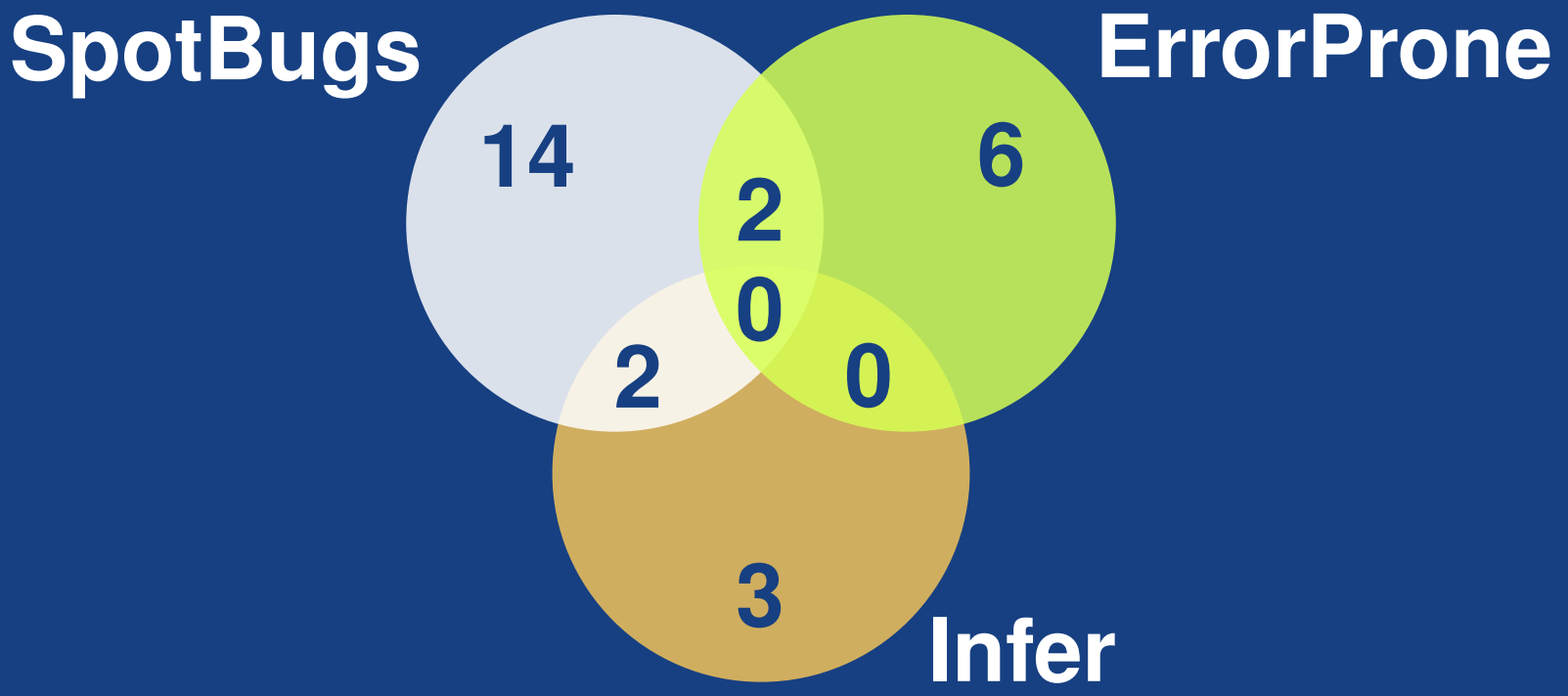
Warning: Chaining constructor ignores argument

Full match

Most Bugs are Missed

Three tools together:

Detect 27 of 594 bugs (less than 5%)



Why are Most Bugs Missed?

Manual inspection of random sample of 20 missed bugs:

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Manual inspection of random sample of 20 missed bugs:

14 are domain-specific

- Unrelated to any of the supported bug patterns
  - Application-specific algorithms
  - Forgot to handle special case
- Difficult to decide whether behavior is intended

Why are Most Bugs Missed? (2)

Manual inspection of random sample of 20 missed bugs:

6 are near misses

- Root cause is targeted by bug detector, but current implementation misses the bug
- Detector targets similar, but not the same, problem

Conclusion

- Novel methodology to measure how many of a set of bugs are detected
- Popular static bug detectors miss most bugs
- Main reason: Domain-specific bugs vs. generic bug patterns
- Huge potential for future work on bug detection

Implications for Future Work

Huge potential for:

- Bug detectors that catch domain-specific bugs
- More sophisticated yet precise static analyses
- Generalizations of existing bug checkers
- Bug finding techniques other than static analysis, e.g., test generation