AUTOMATED BUG NEIGHBORHOOD ANALYSIS FOR IDENTIFYING INCOMPLETE BUG FIXES

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Existing Techniques

- Automated techniques to detect Java runtime exceptions (e.g., null-pointer exceptions)
  - ESC/Java [Flanagan et al. PLDI 2002]
  - SALSA [Loginov et al. ISSTA 2008]
  - XYLEM [Nanda and Sinha ICSE 2009]
  - XYLEM w/ Stack trace [Sinha et al. ISSTA 2009]

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- Research that has investigated bug fixes
  - Evaluating static analysis defect warnings on production software [Ayewah, et al. PASTE 2007]
  - Tracking defect warnings across versions [Spacco, Hovemeyer, and Pugh MSR 2006]

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Techniques don't identify whether attempted bug fixes are complete

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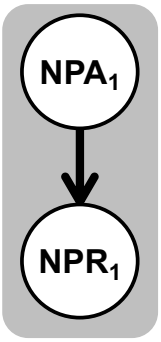

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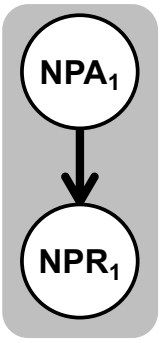

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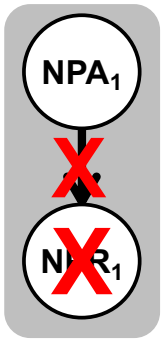

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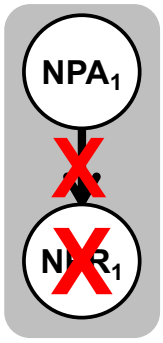

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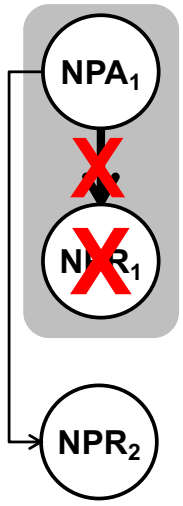

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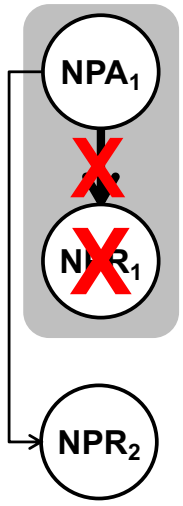

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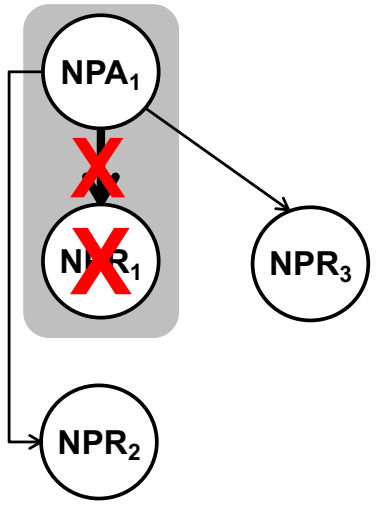

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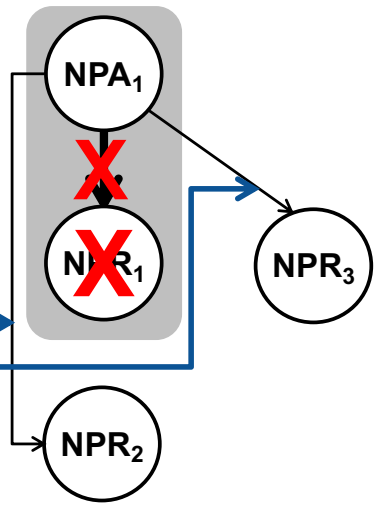
Potential unfixed pairs related to NPA_1
→ **Incomplete fix**



Our Work

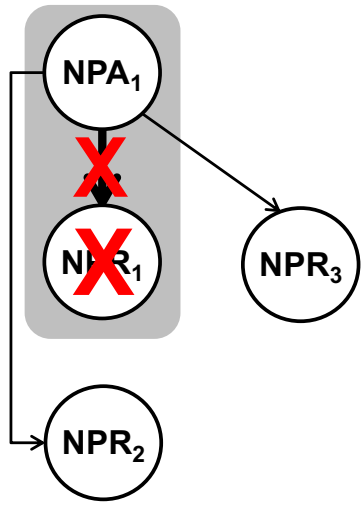
- Bug neighborhood analysis
  - Computes potential unfixed (NPA, NPR) pairs
- Classification of attempted bug fixes as complete or incomplete
- Empirical studies using open-source and commercial software
  - Neighborhood can be large and complex
  - Attempted bug fixes can be incomplete

Outline

- Bug Neighborhoods (BN)
- Technique
- Empirical Evaluation
- Conclusion

Bug Neighborhood (BN)

- Potential unfixed (NPA, NPR) pairs related to NPA_1 and NPR_1
- BN is induced by 4 types of NPAs and NPRs identified by our approach
  - Maybe NPR
  - Forward NPR
  - Maybe NPA
  - Backward NPA



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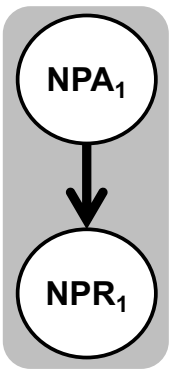

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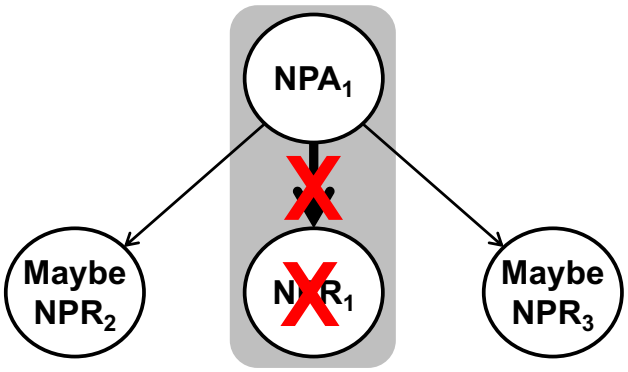
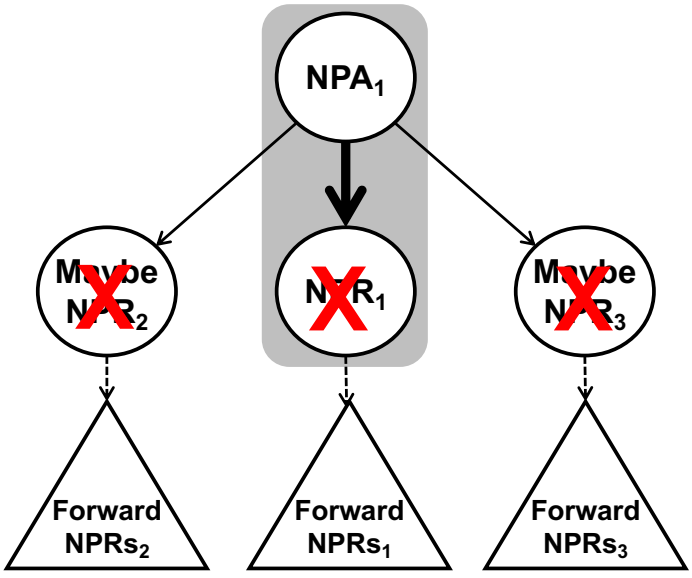


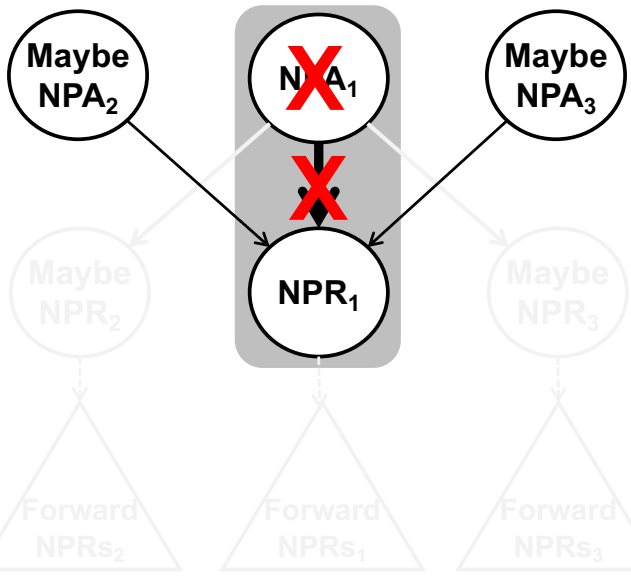
- NPRs that might be reached by NPA_1 in other executions

Forward NPRs



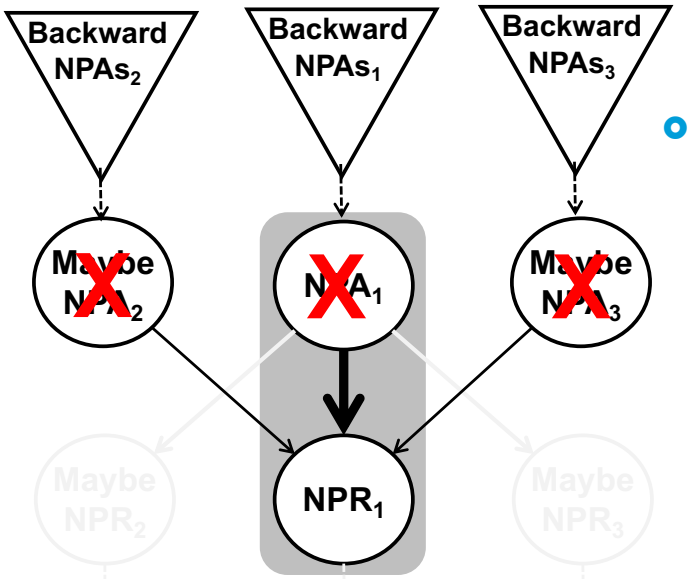
- NPRs that might be reachable from NPA_1 after NPR_1 and Maybe NPRs are fixed

Maybe NPAs



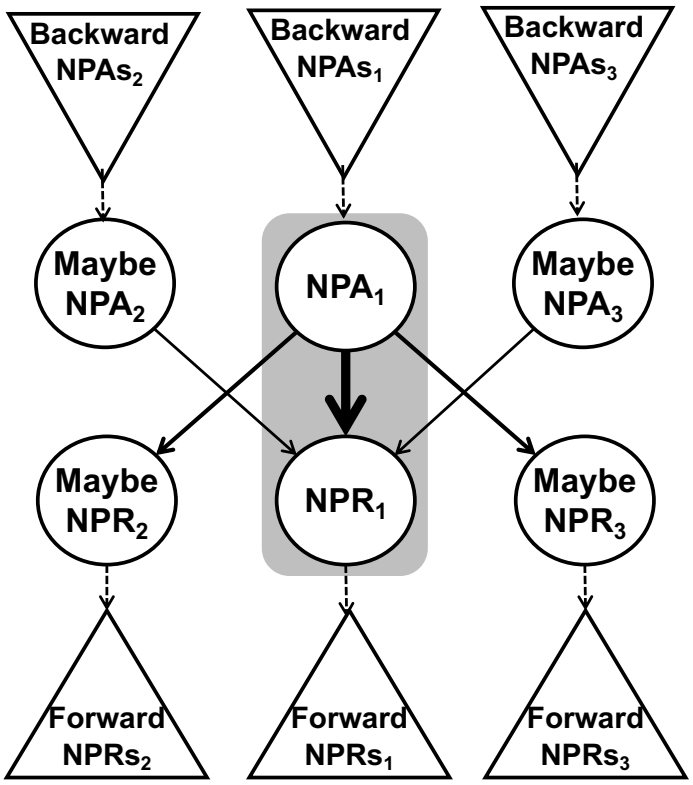
- NPAs that might reach NPR_1 in other executions

Backward NPAs



- NPAs that might reach NPR_1 after NPA_1 and Maybe NPAs are fixed

Bug Neighborhood (BN)



BN for (NPA_1, NPR_1)
(NPA1, Maybe NPR2)
(NPA1, Maybe NPR3)
(Maybe NPA2, NPR1)
(Maybe NPA3, NPR1)
(NPA1, Forward NPR1)
…
(NPA1, Forward NPRn)
(Backward NPA_1, NPR_1)
…
(Backward NPA_n, NPR_1)

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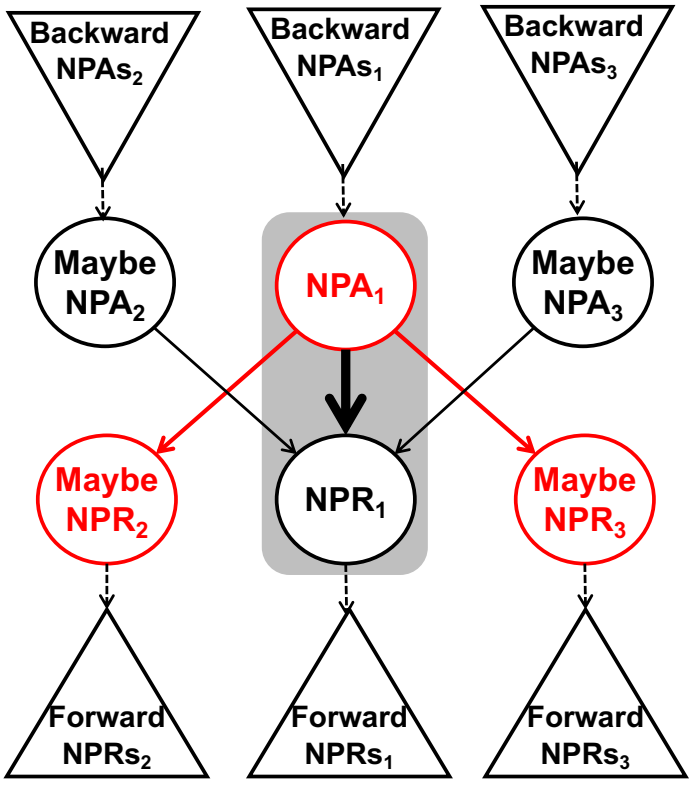

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Definitions

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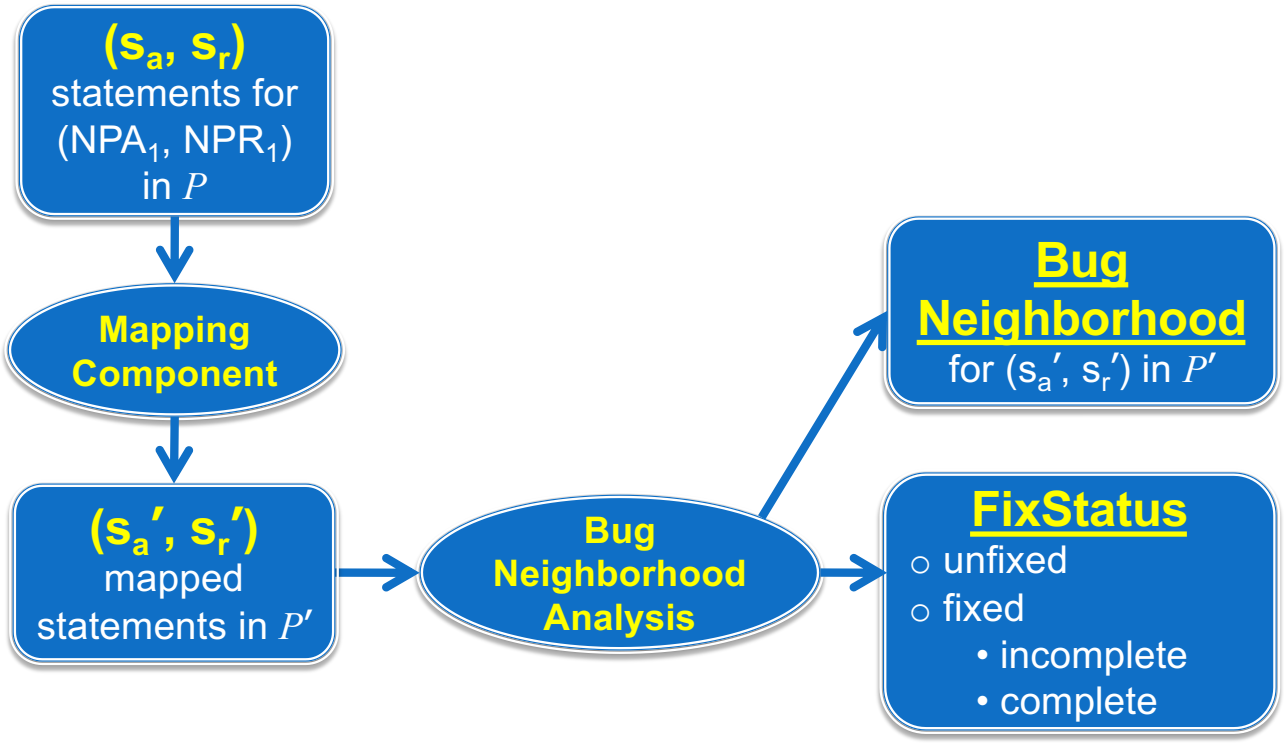
- Complete fix: attempted fix (i.e. change from P to P') for (NPA_1, NPR_1) in which the BN for associated pair in P' is empty

Algorithm



Example

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(S_a, S_r): (1, 3)

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Empirical Setup: Tools

- Finding (NPA, NPR) pairs: XYLEM
  [Nanda and Sinha ICSE2009]

- Integrated our analysis into XYLEM
  - Mapping pairs between P and P'
  - Identifying BN for a (S_a', S_r') pair in P'
    (No Backward NPAs implementation)

Empirical Setup: Subjects

Subject	Classes	Methods	Bytecode Instructions	(NPA, NPR) Pairs
Ant-1.6.0	1858	17204	443254	167
Lucene-2.2.0	381	2815	72691	86
Tomcat-4.1.27	260	4077	101075	97
App-A	278	3933	98225	63
App-B	169	1876	46286	119
App-C	2488	13746	340896	107

Study 1: BN Categories and Sizes

Goal: To examine characteristics of BNs

Method

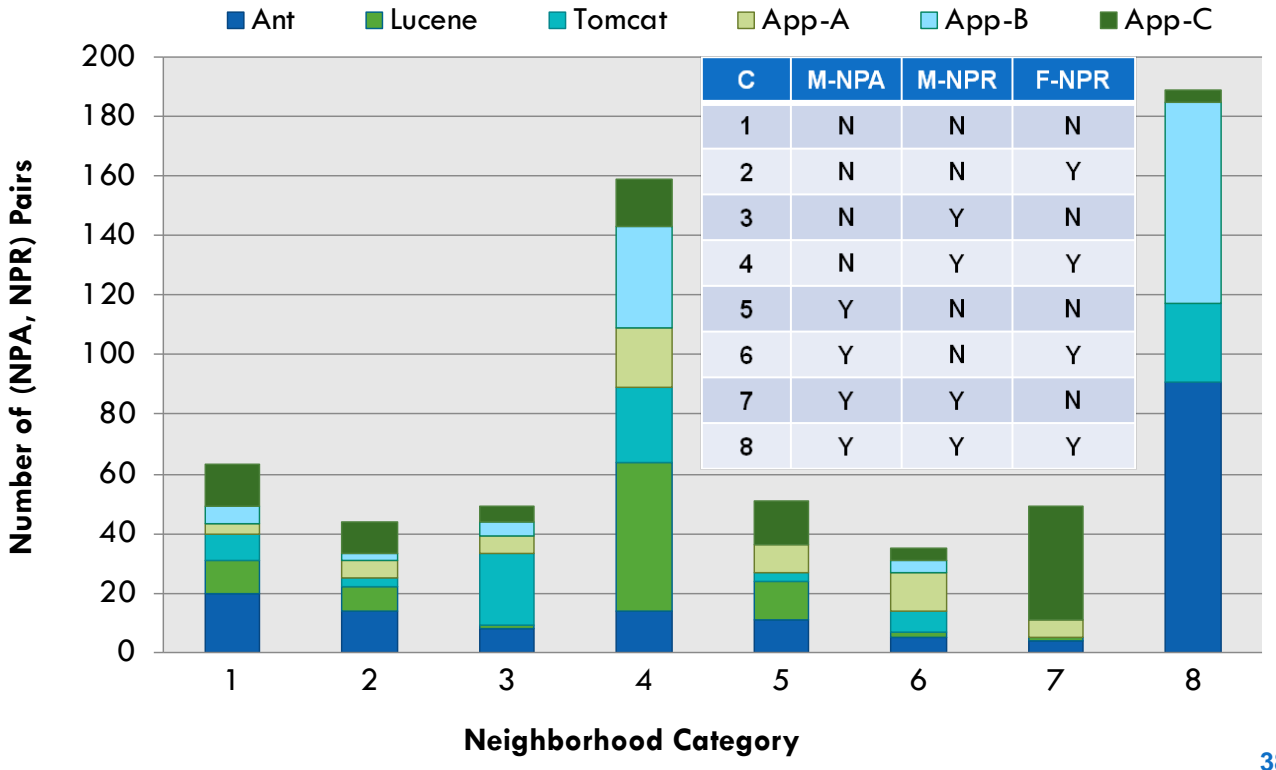
For each (NPA, NPR)

- Compute BN and BN size
- Classify
  - BN in 1 of 8 categories
  - BN size in 1 of 3 categories

BN Categories

Category	Maybe NPA Present	Maybe NPR Present	Forward NPR Present
1	NO	NO	NO
2	NO	NO	YES
3	NO	YES	NO
4	NO	YES	YES
5	YES	NO	NO
6	YES	NO	YES
7	YES	YES	NO
8	YES	YES	YES

Occurrences of Each BN Category

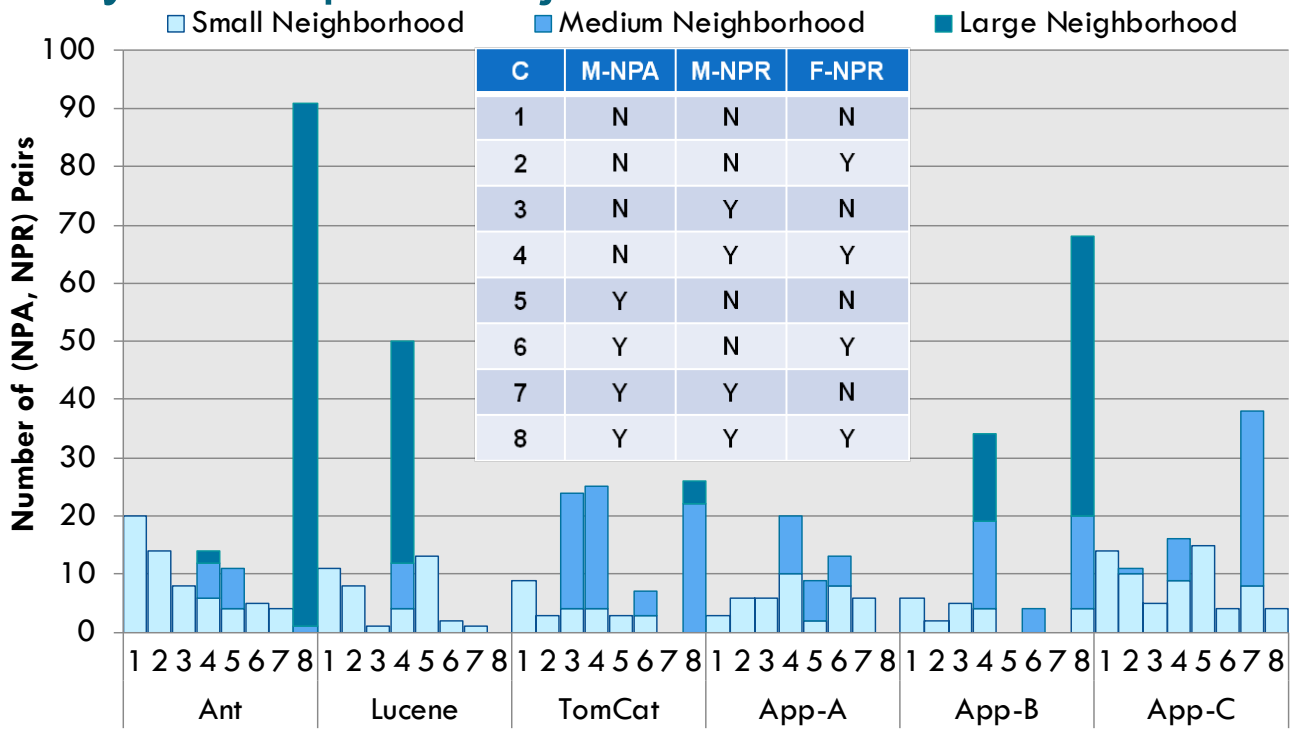


C	M-NPA	M-NPR	F-NPR
1	N	N	N
2	N	N	Y
3	N	Y	N
4	N	Y	Y
5	Y	N	N
6	Y	N	Y
7	Y	Y	N
8	Y	Y	Y

BN Size Categories

- Small: pairs ≤ 5
- Medium: $5 <$ pairs ≤ 15
- Large: pairs > 15

Occurrences of Each BN Category by Sizes per Subject



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2	N	N	Y
3	N	Y	N
4	N	Y	Y
5	Y	N	N
6	Y	N	Y
7	Y	Y	N
8	Y	Y	Y

Neighborhood Categories per Subjects

Study 2: Completeness of Fixes

Goal: To investigate existence and frequency of incomplete fixes

Method

For each (NPA, NPR) in P'

- Verified mapping from P (manually)
- If mapping is accurate, compute BN for (NPA, NPR) pair (manually verified)

Completeness of Attempted Bug Fixes

Subject	# Incomplete Fixes / # Attempted Fixes	BN Categories of Incomplete Fixes	BN Sizes of Incomplete Fixes
Ant	4 / 26	C2, C4, C4, C5	1 x Small, 3 x Medium
Lucene	3 / 17	C4, C4, C4	1 x Small, 2 x Large
Tomcat	0 / 9	—	—
App-A	0 / 7	—	—

C	M-NPA	M-MPR	F-NPR
2	N	N	Y
4	N	Y	Y
5	Y	N	N

Future Work

- Implement Backward NPAs and precise mapping component
- Perform more experiments with more subjects
  - Correlation between incomplete fixes and BN category or size
  - Comparison of results from open-source projects and industrial projects
- Guide developers in addressing an incomplete fix and making it complete

Contributions

- New bug neighborhood analysis
  - Determines completeness of attempted bug fixes
- Technique that helps developers prevent incomplete fixes in new revisions
- Empirical studies that show
  - large and complex BNs do occur frequently
  - Attempted bug fixes are incomplete in practice

Q & A