TIVER: Identifying Adaptive Versions of C/C++ Third-Party Open-Source components Using a Code Clustering Technique

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[†]*SBOM (Software Bill Of Materials)*

Motivation

Open-source software (OSS) reuse is widely adopted

-> Can expose system owing to propagated vulnerabilities

-> Reused OSS components, consist of files from various versions

Why: Code-level reuse (C/C++) / Partial reuse / Backporting patches

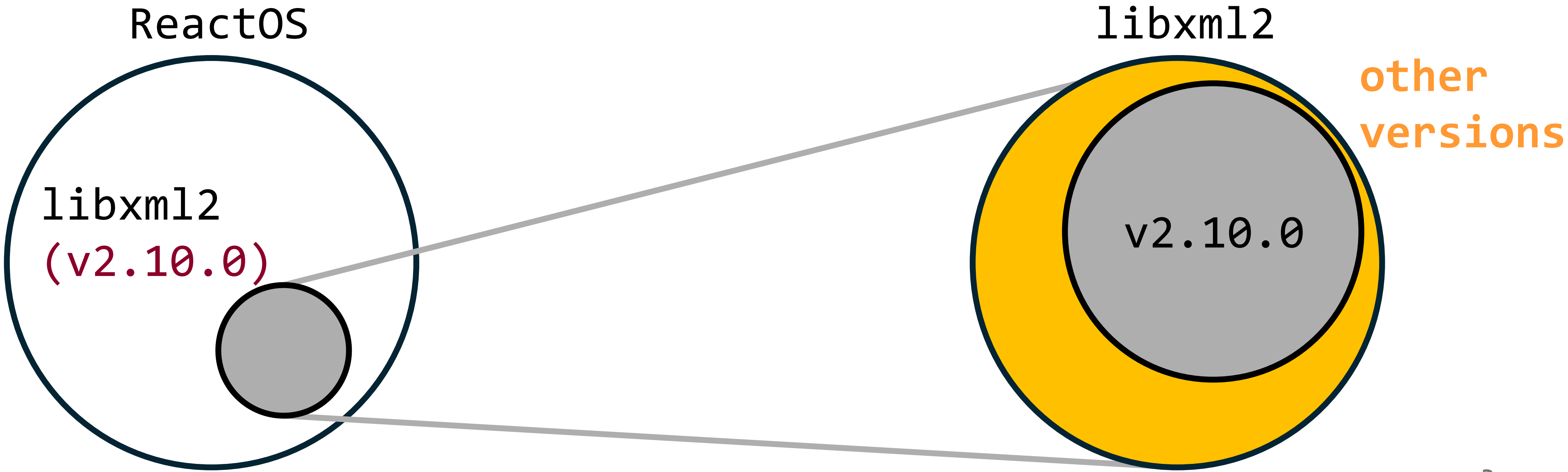
-> Current SBOM[†]: single version per OSS component

-> Is this single-version approach robust enough for modern supply chain security?

Problem

- **Assigning single specific version for reused OSS components**

Single-version approach



Problem

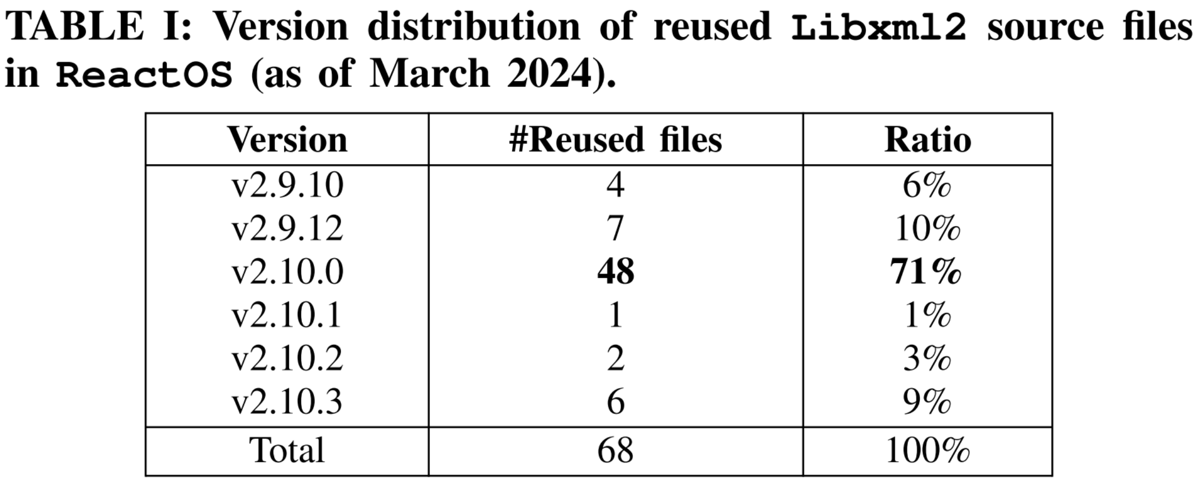
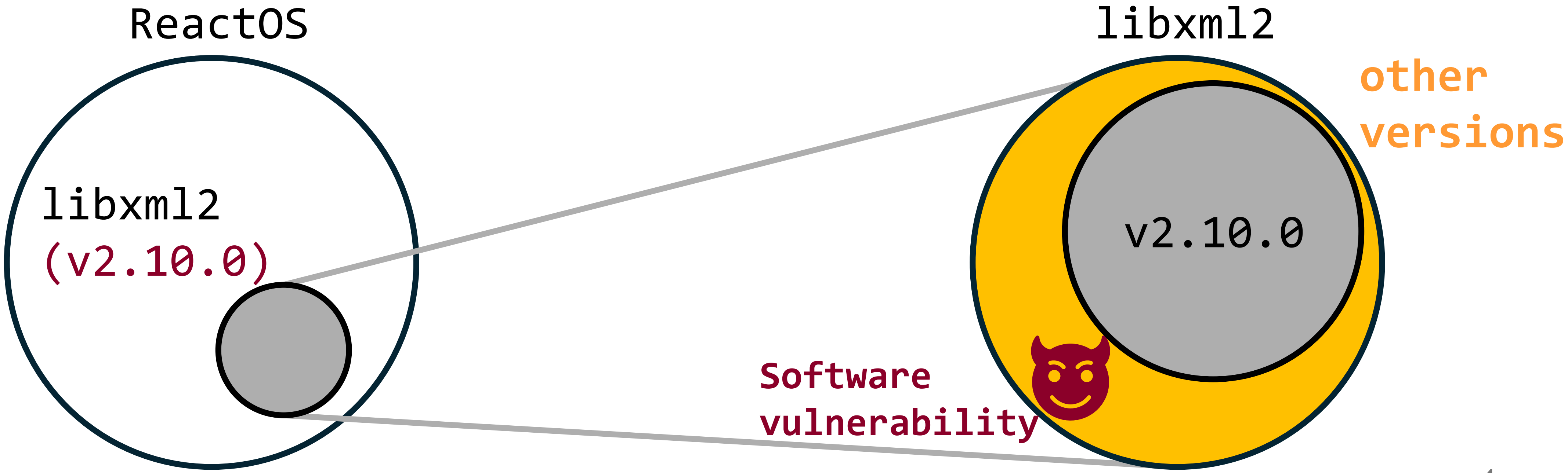


TABLE I: Version distribution of reused Libxml2 source files in ReactOS (as of March 2024).

Version	#Reused files	Ratio
v2.9.10	4	6%
v2.9.12	7	10%
v2.10.0	**48**	**71%**
v2.10.1	1	1%
v2.10.2	2	3%
v2.10.3	6	9%
Total	68	100%

- Assigning si components

Single-version approach



Problem

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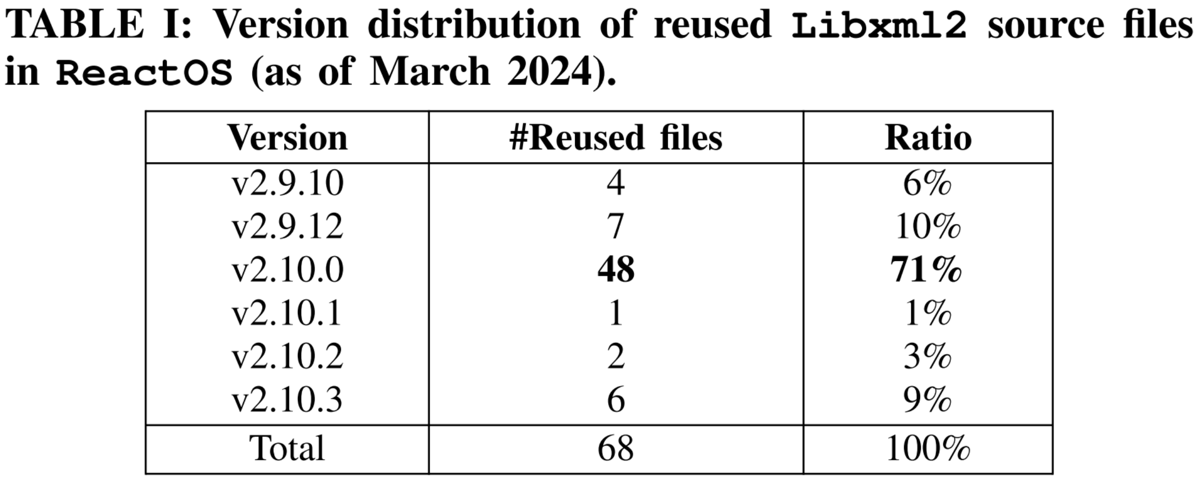

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Single-version approach

Current SBOM cannot be used to identify this vulnerability!!!

Goal

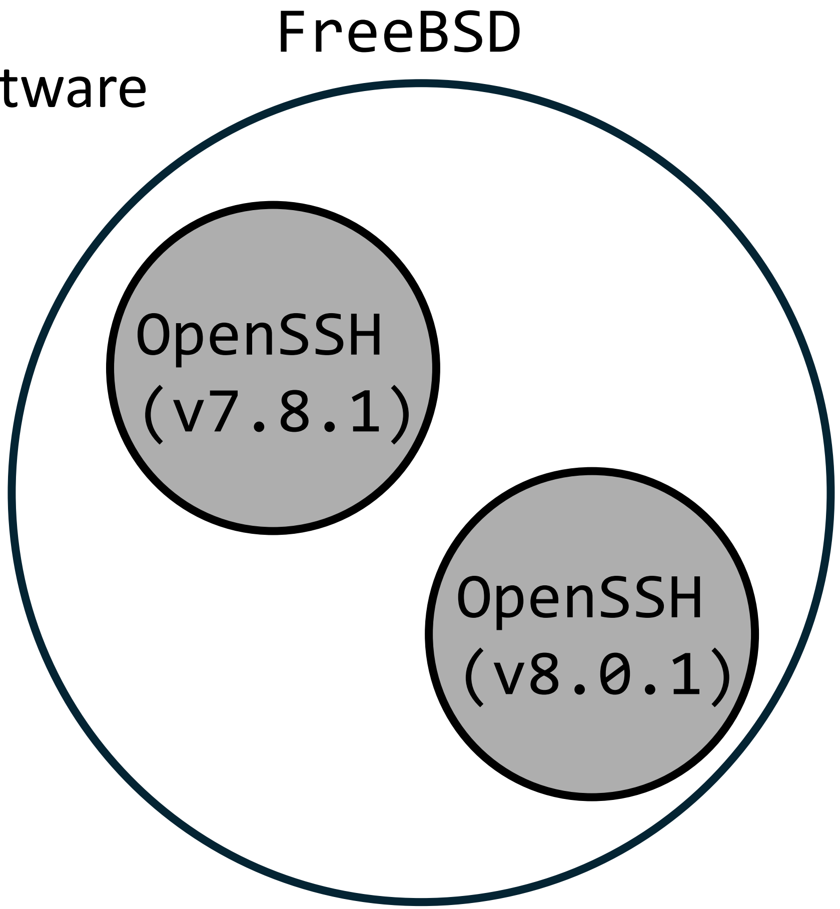
- Identifying *"adaptive version"* of reused OSS components in target software

- ***Adaptive version**: A comprehensive representation that encompasses the various versions present in reused code*

Challenges

1. Duplicate components

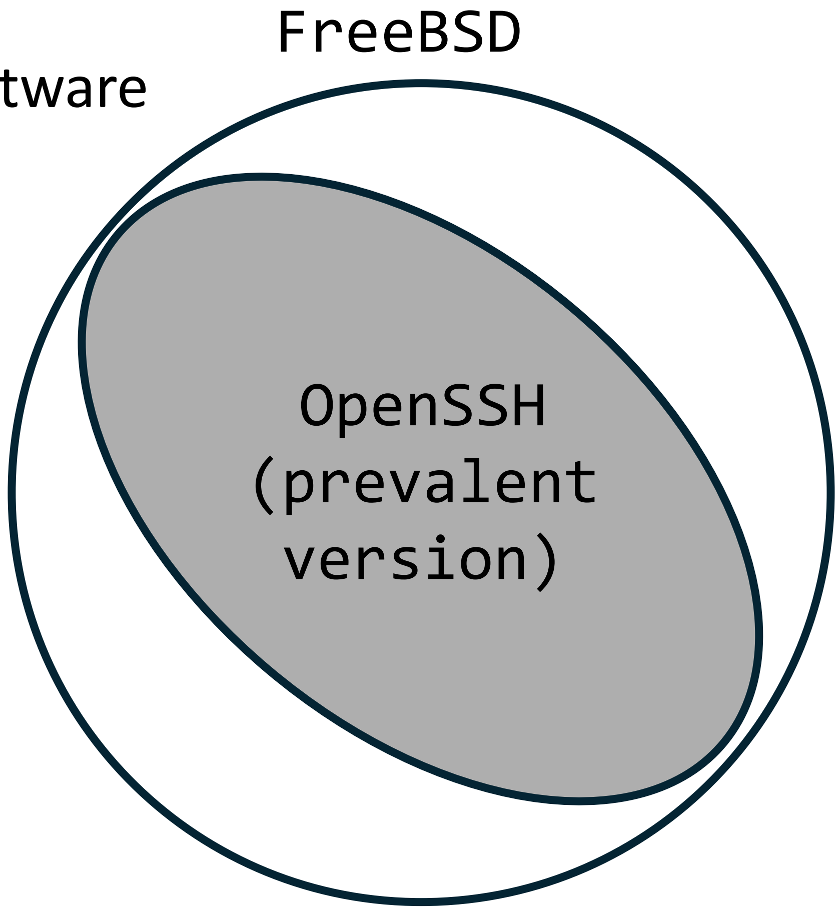
- Same OSS is reused in multiple parts of target software



Challenges

1. Duplicate components

- Same OSS is reused in multiple parts of target software
- How single-version approach handles

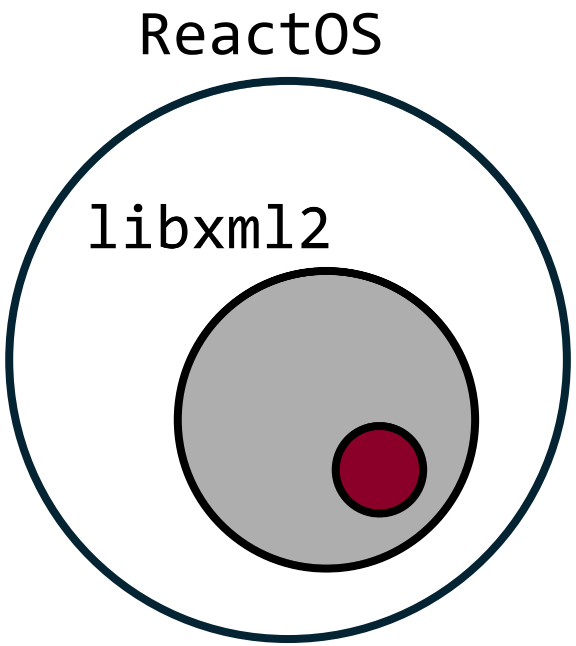


● Commonly used algorithmic code

Challenges

2. Noise

- Code snippets commonly found across diverse OSS
- Interferes accurate version identification by being misclassified as OSS



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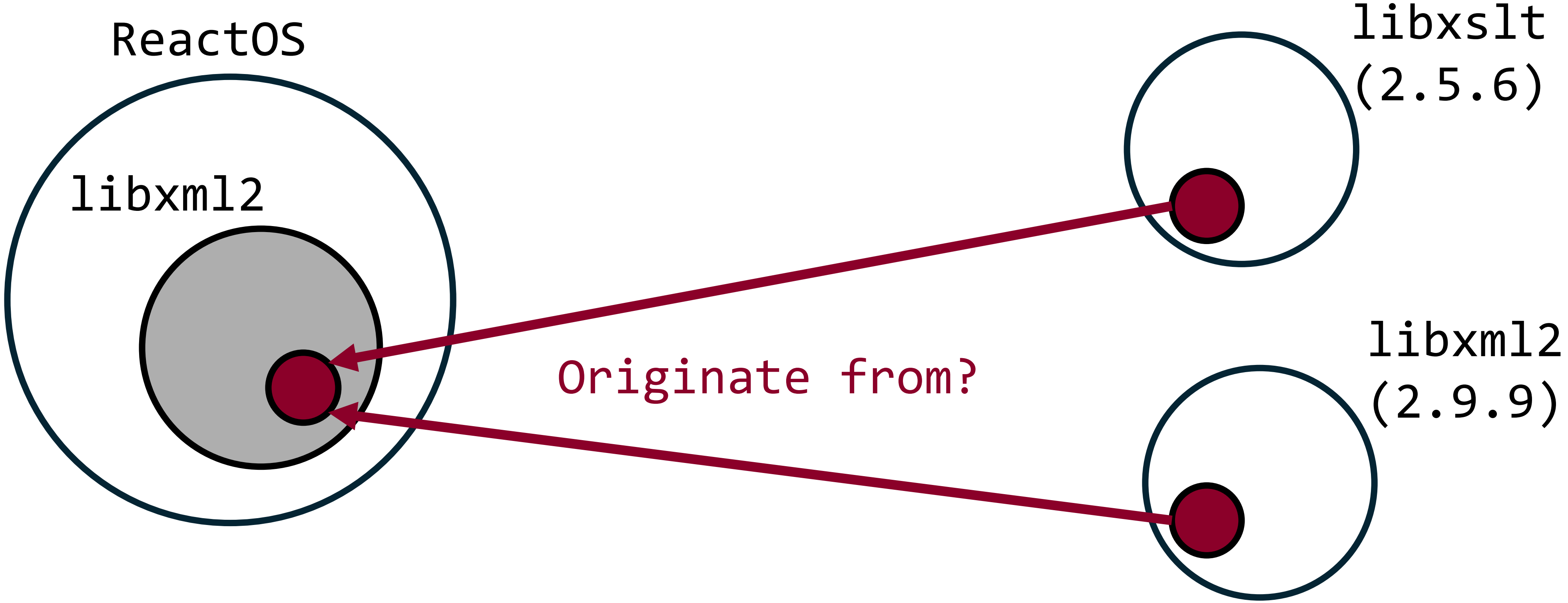

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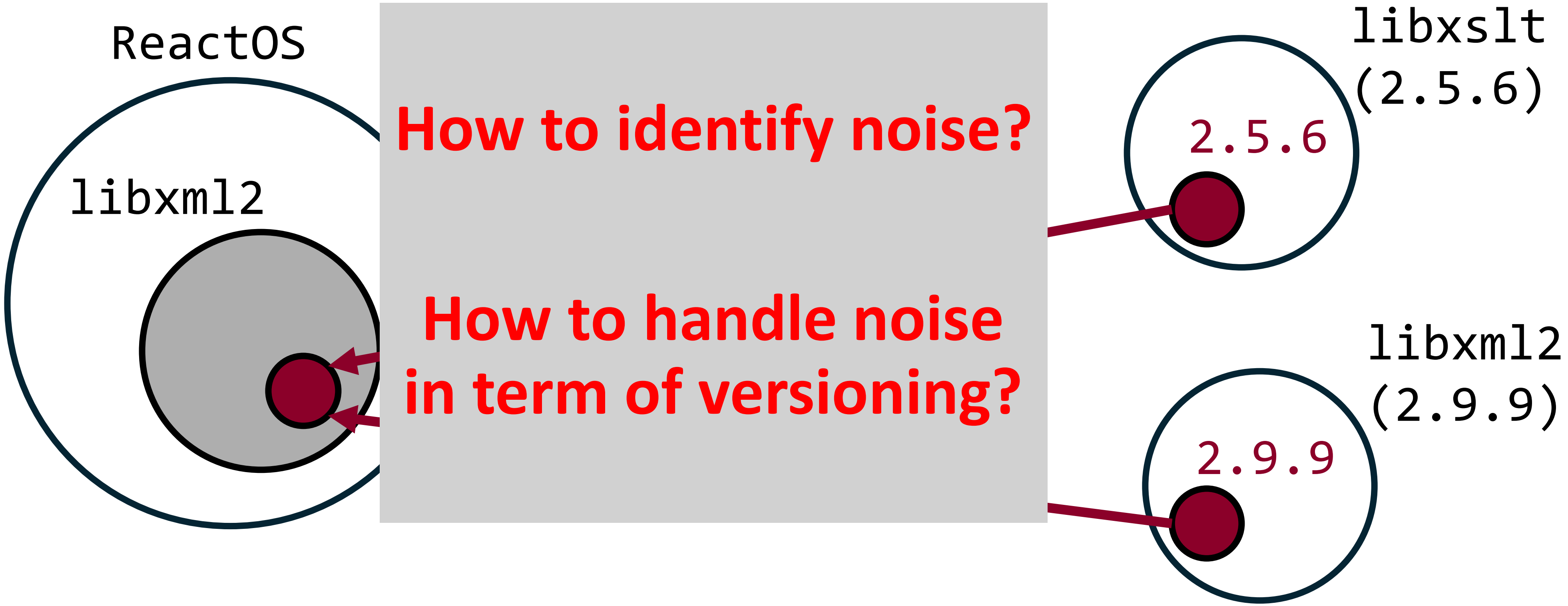


How to identify noise?

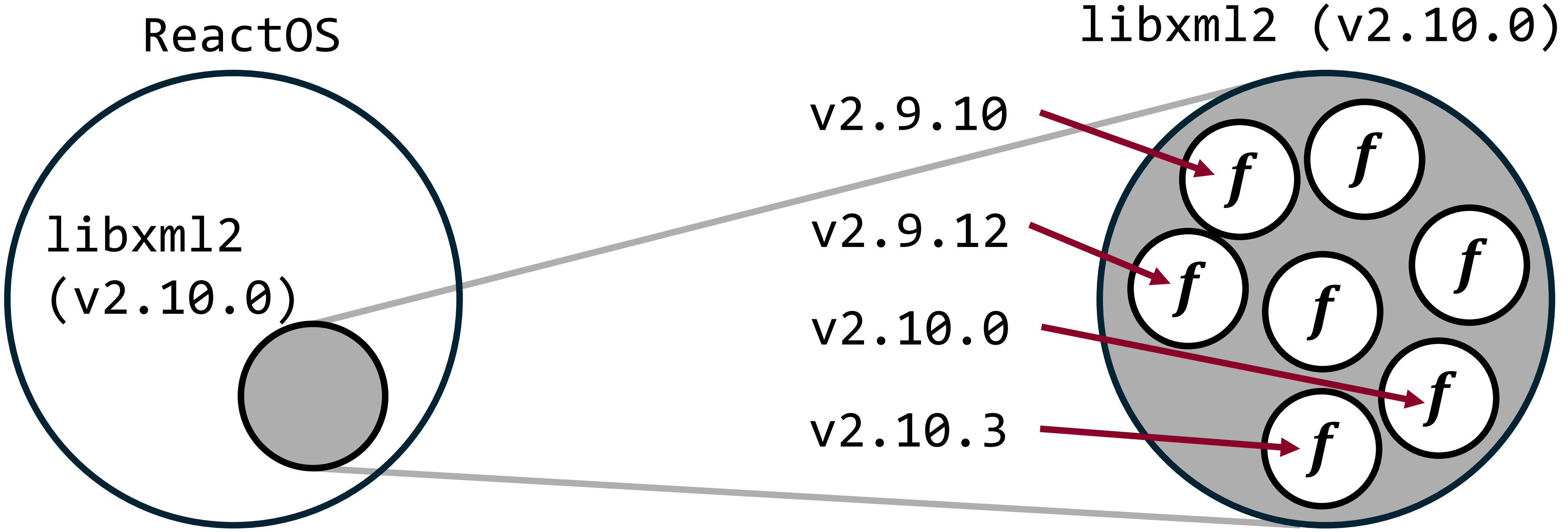
How to handle noise in term of versioning?

TIVER 🧸

- adap**TI**ve **V**ersion analyz**ER**
  - Novel approach to identify ***adaptive version*** of OSS components
  - Key techniques to overcome challenges
    - Function-level versioning
    - Code clustering

TIVER: Function-level versioning

- **Existing single-version approaches**



TIVER: Function-level versioning

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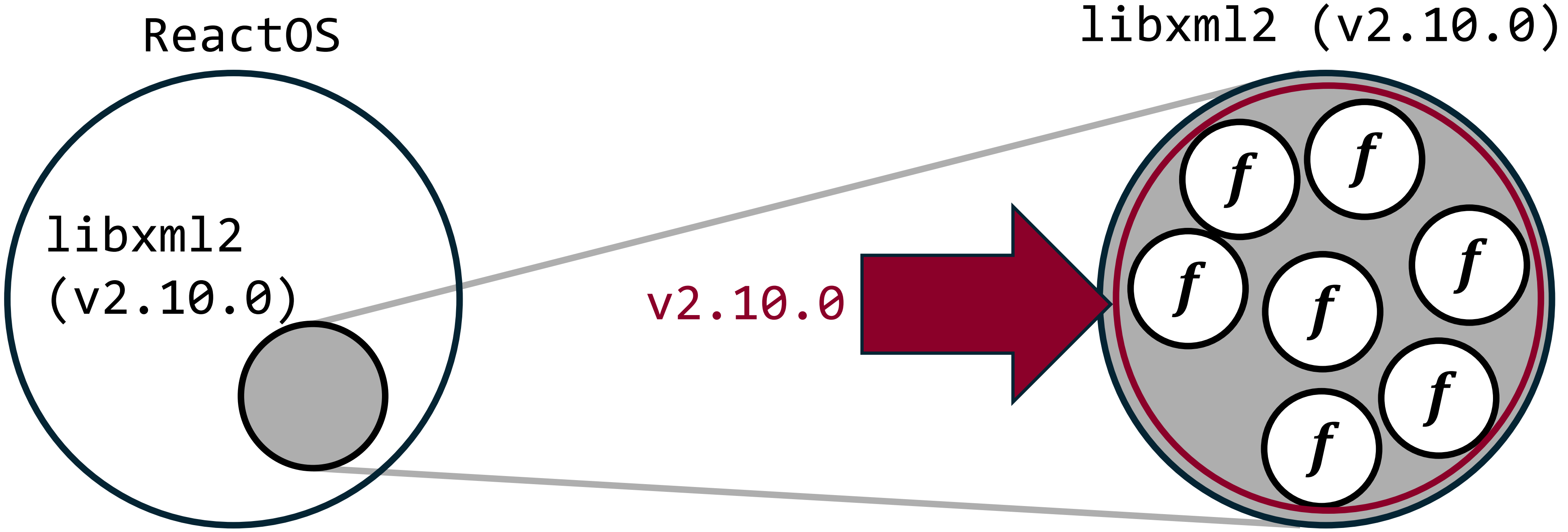

TIVER: Function-level versioning

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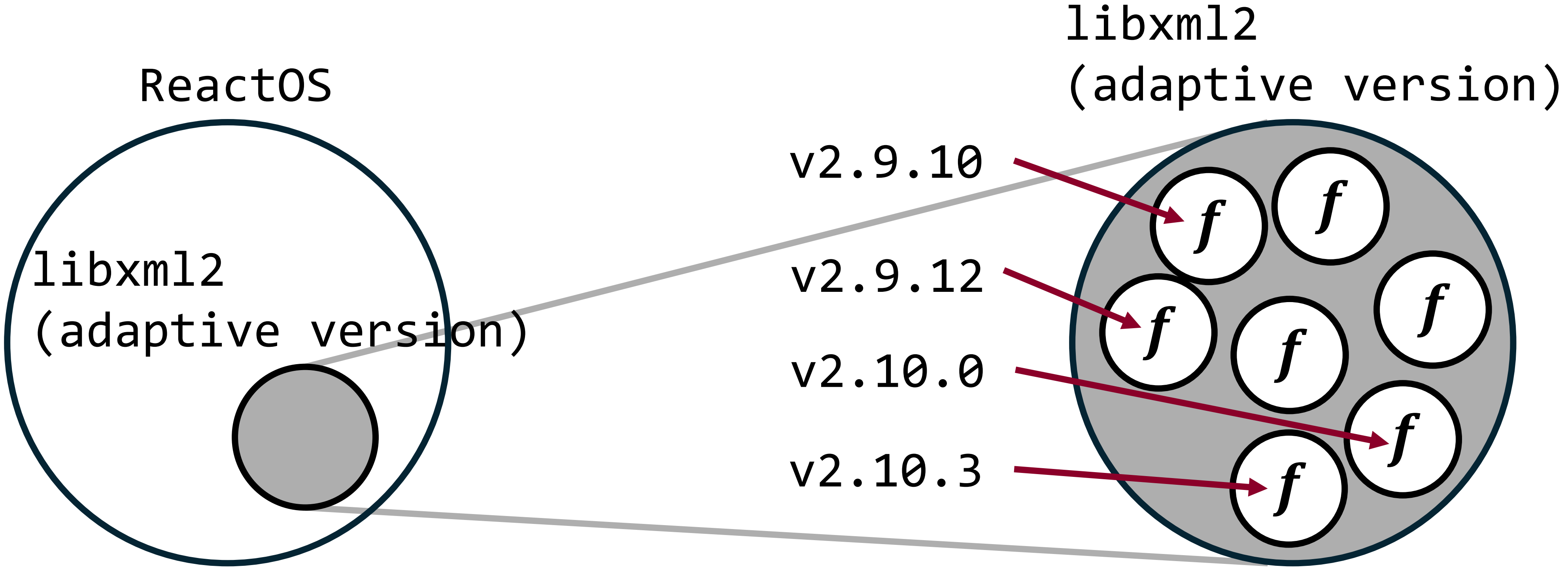


TIVER: Code Clustering

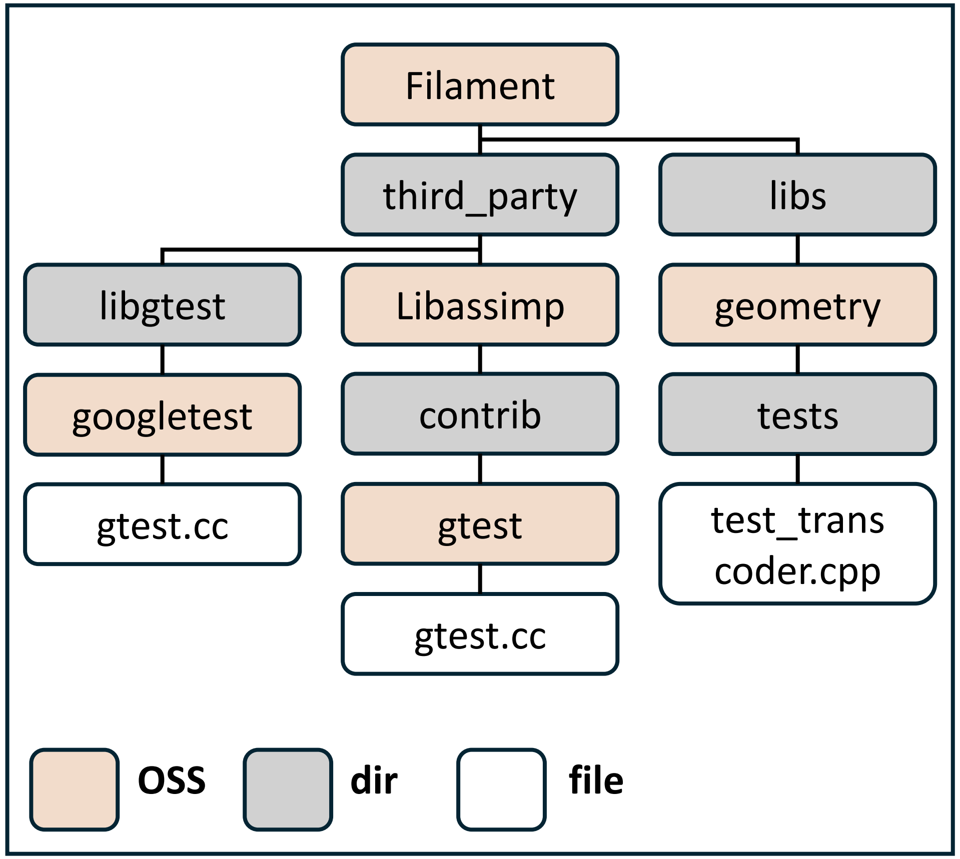
Directory hierarchy of OSS (GoogleTest)

- **TIVER uses filename as indicator**
- ***known duplicates***
  - Examine ***known duplicates*** before clustering process
  - Same filename coexist in target software

    -> Redundant OSS reuse

    OR

    -> Already exist in original OSS



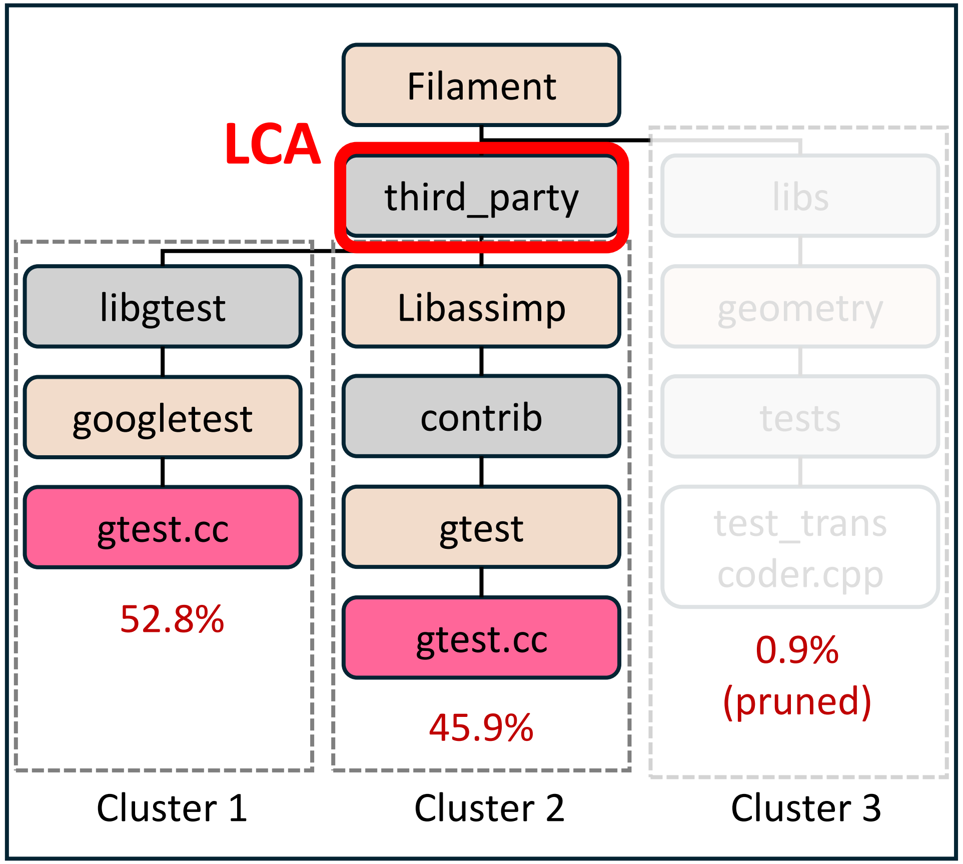
Known duplicates: NONE

TIVER: Code Clustering

- **Code Clustering**
  - Use LCA (Lowest Common Ancestor)
  - Distinguish duplicate components

- **Cluster pruning**
  - Eliminate noise
  - th = 3%

Directory hierarchy of OSS (GoogleTest)



Known duplicates: NONE

TIVER: Adaptive version

```
          {1.2.0} -> 1.2.0
{1.2.0, invalid_ver†} -> +1.2.0
{3.2.0, 2.2.5, 1.2.0} -> *1.2.0
{1.2.0, 1.2.5, 1.3.2} -> ^1.2.0
{1.2.0, 1.2.5, 1.2.7} -> ~1.2.0
```

Per cluster

†Invalid version: not following semantic versioning

Evaluation

- **Dataset**

Functions

Functions present in all versions of **10,417 OSS projects**

- 4,720,744 version strings

Repositories

Popular **2,025 repositories** in GitHub (C/C++)

- Ranked by the number of stars
- 570 million lines of code

Evaluation

- **Accuracy**

- **# Duplicate component distinction**
  - 88% Precision & 92% Recall
  - 230/273 components were TP
- **# Noise elimination**
  - 86% Precision & 87% Recall
  - 264/307 clusters were TP

Evaluation

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VS. CNEPS (ICSE 2024)

	TIVER	**CNEPS**
TP	46	20
FN	6	28
Recall	0.88	0.42

Evaluation

- **Effectiveness**
    - VS. V1SCAN (Single version based vulnerability detector)
    - USENIX SECURITY 2023
    - On average,

V1SCAN covers 1 version per component

TIVER covers **3.49** versions per component

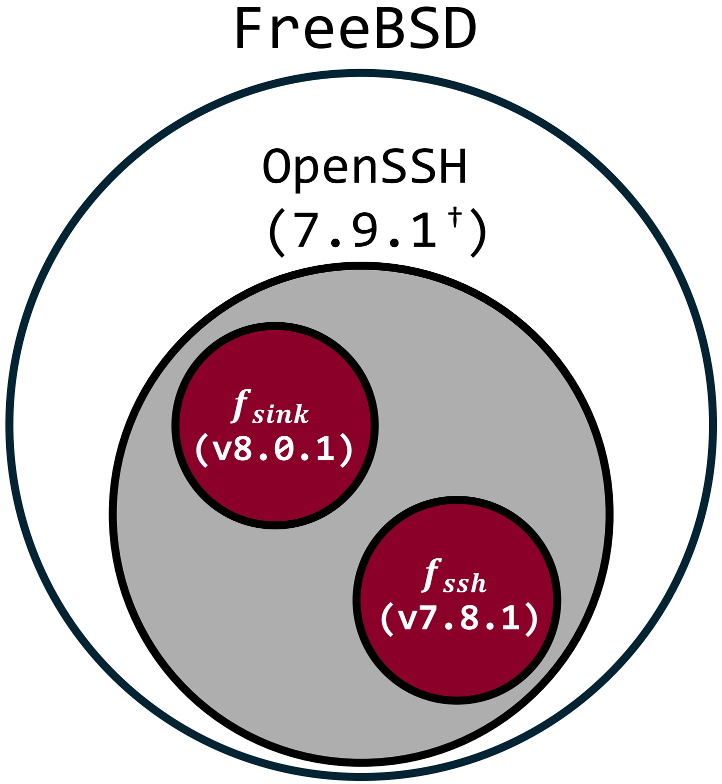
V1SCAN cleanses 0 noisy region per component

TIVER cleanses **3.31** noisy clusters per component

† By previous single-version approach

Implication

- **Value of TIVER**
  - Enhances supply chain security through precise version tracking



CVE-id	vulnerable func	reused version	previous	TIVER
CVE-2018-20685	f_{sink}(~7.9.1)	8.0.1	Vulnerable (FP)	Safe
CVE-2018-15919	f_{ssh}(~7.8.1)	7.8.1	Safe (FN)	Vulnerable

Conclusion

- **TIVER**: novel approach for identifying adaptive versions of C/C++ OSS components
  - Function-level versioning
  - OSS code clustering

- TIVER can be used to
  - Perform effective OSS management
    - Covers 3.49 versions & Cleanses 3.31 noisy clusters per component
  - Enhance supply chain security
    - Eliminated 81% of FPs from functions flagged as vulnerable by single-version approach

Q & A

Thank you for your attention!

- TIVER repository (https://github.com/Genius-Choi/TIVER-public)
- Dataset (https://zenodo.org/records/14862460)

Contact

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  - SSP LAB (https://ssp.korea.ac.kr)

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Appendix

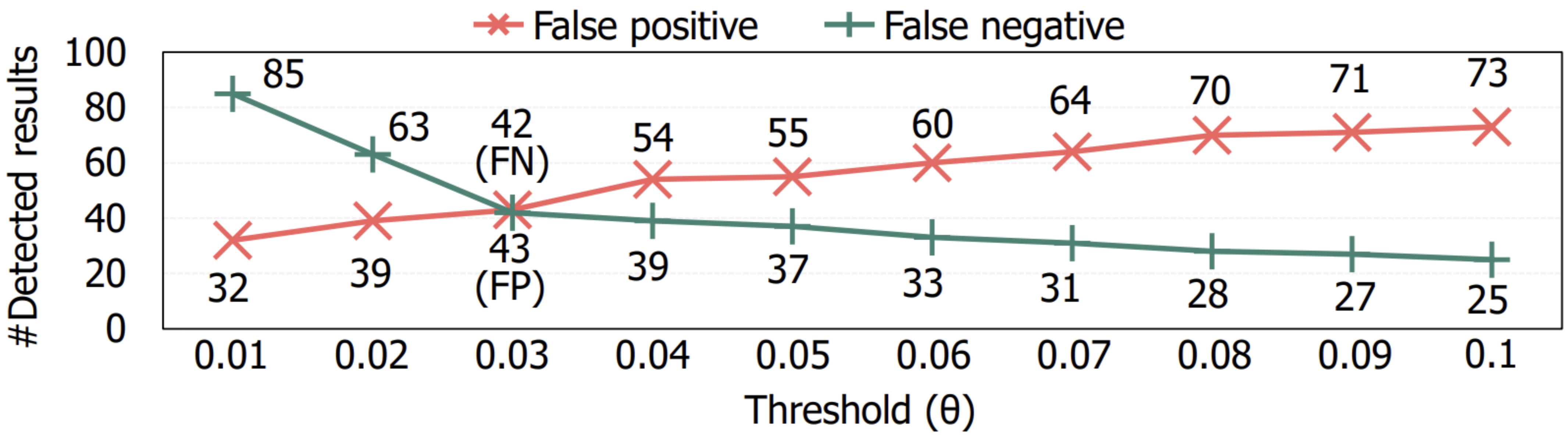
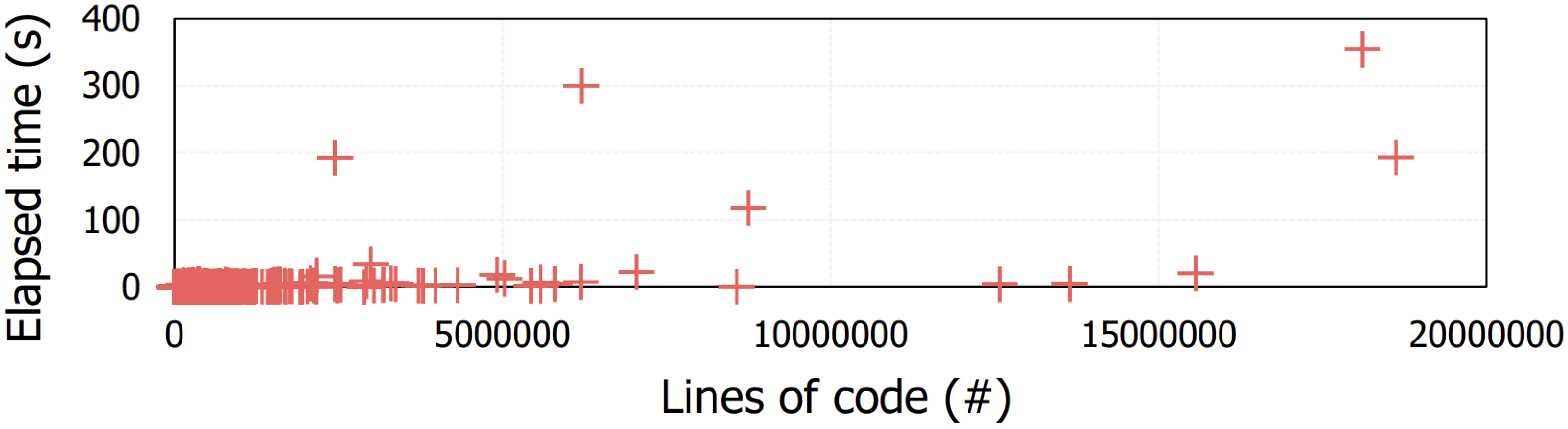


Fig. 3: Experimental results for measuring sensitivity of θ.

Appendix

Avg: 1.67s


Elapsed time (s)
Lines of code (#)