MSR for Vulnerability Prediction

Mining Vulnerability-Contributing Commits

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Master Course "Cybersecurity Data Science"

Winter Semester 22/23

Vulnerability-contributing commit (VCC)

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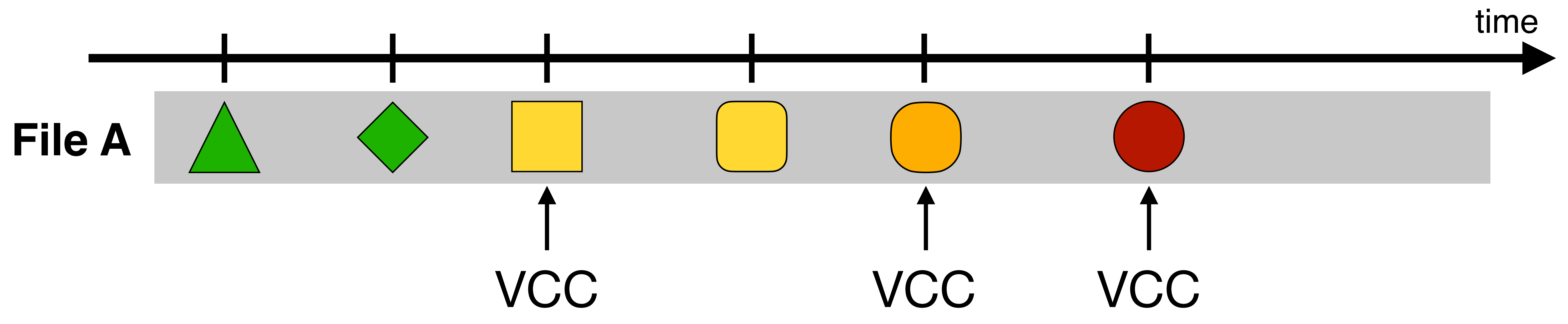

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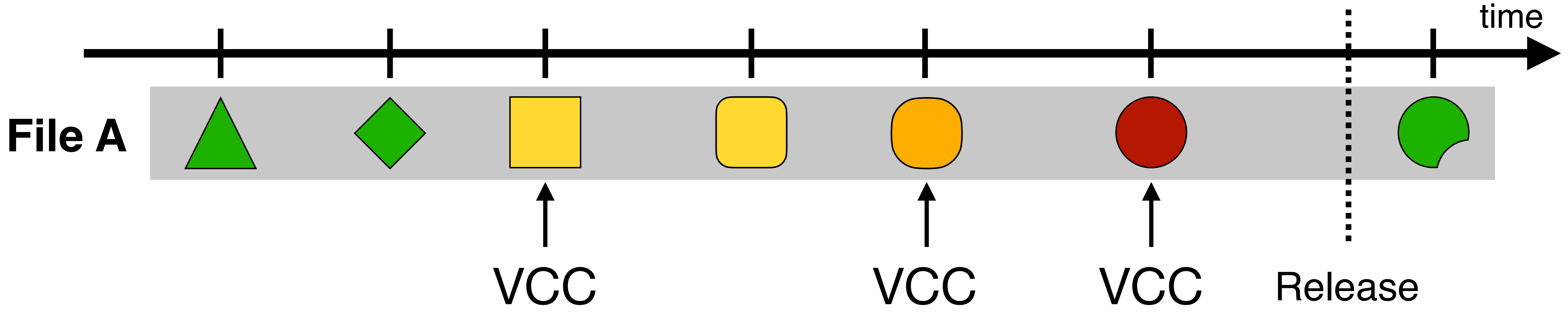

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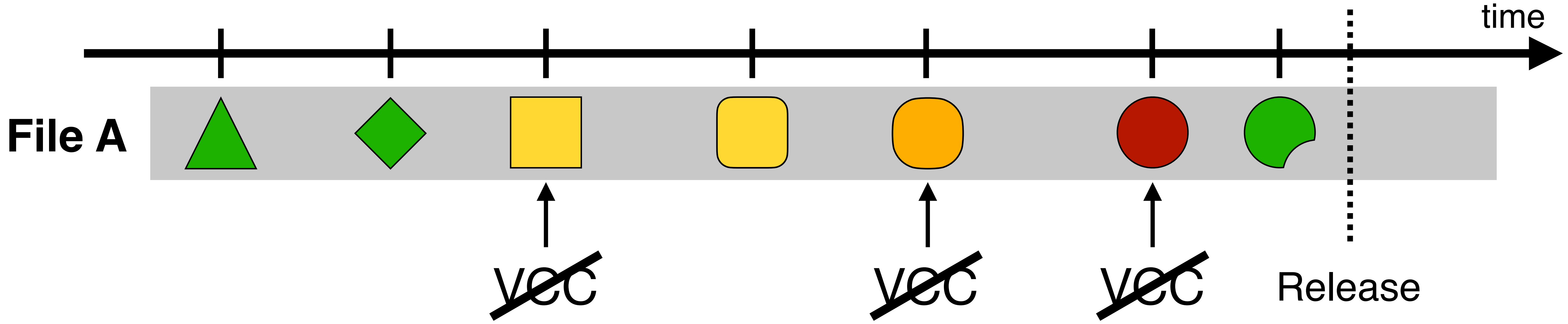

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Example of a VCC

CVE-2019-11274

"Cloud Foundry UAA, versions prior to 74.0.0, is vulnerable to an XSS attack. A remote unauthenticated malicious attacker could craft a URL that contains a SCIM filter that contains malicious JavaScript, which older browsers may execute."

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CWE-79: Improper Neutralization of Input During Web Page Generation ('Cross-site Scripting')

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CWE-79: Improper Neutralization of Input During Web Page Generation ('Cross-site Scripting')

We expect unescaped or unvalidated data supplied from the user via URL parameters that end up directly in the response.

Example of a VCC

CVE-2019-11274

Fix a34f55fc

```
@RequestMapping(value = {"/Groups"}, method = RequestMethod.GET)
@ResponseBody
public SearchResults<?> listGroups(
  @RequestParam(value = "attributes", required = false) String attributesCommaSeparated,
  @RequestParam(required = false, defaultValue = "id pr") String filter,
  @RequestParam(required = false, defaultValue = "created") String sortBy,
  @RequestParam(required = false, defaultValue = "ascending") String sortOrder,
  @RequestParam(required = false, defaultValue = "1") int startIndex,
  @RequestParam(required = false, defaultValue = "100") int count) {
  if (count > groupMaxCount) {
    count = groupMaxCount;
  }
  List<ScimGroup> result;
  try {
    result = dao.query(filter, sortBy, "ascending".equalsIgnoreCase(sortOrder),
      identityZoneManager.getCurrentIdentityZoneId());
  } catch (IllegalArgumentException e) {
    throw new ScimException("Invalid filter expression: [" + filter + "]",
      HttpStatus.BAD_REQUEST);
    throw new ScimException("Invalid filter expression: [" + HtmlUtils.htmlEscape(filter) + "]",
      HttpStatus.BAD_REQUEST);
  }
  [...]
```

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    result = dao.q
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+   throw new ScimException("Invalid filter expression: [" + HtmlUtils.htmlEscape(filter) + "]",
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  }
  [...]
```

Essentially, **the** `filter` **parameter is not sanitized and is placed directly in this** `ScimException`**.** Then, this exeption message is placed verbatim on an error page.

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  }
  [...]
```

Let’s go back in time to find the commit that contributed to this problem!

Example of a VCC

CVE-2019-11274

VCC
bb8ff8f4

```
@RequestMapping(value = { "/Groups/External/list" }, method = RequestMethod.GET)
@ResponseBody
public SearchResults<?> listExternalGroups(
  @RequestParam(required = false, defaultValue = "1") int startIndex,
  @RequestParam(required = false, defaultValue = "100") int count) {
  String filter = "";
  List<ScimGroupExternalMember> result;
  try {
    result = externalMembershipManager.query(filter);
  } catch (IllegalArgumentException e) {
    throw new ScimException("Invalid filter expression: [" + filter + "]",
      HttpStatus.BAD_REQUEST);
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  [...]
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```

This was the first revision where the `filter` parameters was put inside the exception message: the vulnerability was there since the method (with a different name) was born.

Terminology

2013 ACM / IEEE International Symposium on Empirical Software Engineering and Measurement

When a Patch Goes Bad: Exploring the Properties of Vulnerability-Contributing Commits

Andrew Meneely, Harshavardhan Srinivasan, Ayemi Musa,
Alberto Rodriguez Tejeda, Matthew Mokary, Brian Spates
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Rochester Institute of Technology
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***Abstract*—Security is a harsh reality for software teams today. Developers must engineer secure software by preventing vulnerabilities, which are design and coding mistakes that have security consequences. Even in open source projects, vulnerable source code can remain unnoticed for years. In this paper, we traced 68 vulnerabilities in the Apache HTTP server back to the version control commits that contributed the vulnerable code originally. We manually found 124 Vulnerability-Contributing Commits (VCCs), spanning 17 years. In this exploratory study, we analyzed these VCCs quantitatively and qualitatively with the over-arching question: "What could developers have looked for to identify security concerns in this commit?" Specifically, we examined the size of the commit via code churn metrics, the amount developers overwrite each others' code via interactive churn metrics, exposure time between VCC and fix, and dissemination of the VCC to the development community via release notes and voting mechanisms. Our results show that VCCs are large: more than twice as much code churn on average than non-VCCs, even when normalized against lines of code. Furthermore, a commit was twice as likely to be a VCC when the author was a new developer to the source code. The insight from this study can help developers understand how vulnerabilities originate in a system so that security-related mistakes can be prevented or caught in the future.**

***Index Terms*— vulnerability, churn, socio-technical, empirical.**

I. Introduction

Security is a harsh reality for software teams today. Insecure software is not only expensive to maintain, but can cause immeasurable damage to a brand, or worse, to the livelihood of customers, patients, and citizens.

To software developers, the key to secure software lies in preventing vulnerabilities. Software vulnerabilities are special types of "faults that violate an [implicit or explicit] security policy" [1]. If developers want to find and fix vulnerabilities they must focus beyond making the system work as specified and prevent the system's functionality from being abused. According to security experts [2]–[4], finding vulnerabilities requires expertise in both the specific product and in software security in general.

The field of engineering secure software has a plethora of security practices for finding vulnerabilities, such as threat modeling, penetration testing, code inspections, misuse and abuse cases [5], and automated static analysis [2]–[4]. While these practices have been shown to be effective, they can also be inefficient. Development teams are then faced with the challenge of prioritizing their fortification efforts within the entire development process. Developers might know what is possible, but lack a firm grip on what is probable. As a result, an uninformed development team can easily focus on the wrong areas for fortification.

Fortunately, an historical, longitudinal analysis of how vulnerabilities originated in professional products can inform fortification prioritization. Understanding the specific trends of how vulnerabilities can arise in a software development product can help developers understand where to look and what to look for in their own product. Some of these trends have been quantified in vulnerability prediction [6]–[10] studies using metrics aggregated at the file level, but little has been done to explore the original coding mistakes that contributed the vulnerabilities in the first place. In this study, we have identified and analyzed original coding mistakes as Vulnerability-Contributing Commits (VCCs), or commits in the version control repository that contributed to the introduction of a post-release vulnerability.

A myriad of factors can lead to the introduction and lack of detection of vulnerabilities. A developer may make a single massive change to the system, leaving his peers with an overwhelmingly large review. Furthermore, a developer may make small, incremental changes, but his work might be affecting the work of many other developers. Or, a developer may forget to disseminate her work in the change notes and so the code may miss out on be reviewed entirely.

The objective of this research is to improve software security by analyzing the size, interactive churn, and community dissemination of VCCs. We conducted an empirical case study of the Apache HTTP Server project (HTTPD). Using a multi-researcher, cross-validating, semi-automated, semi-manual process, we identified the VCCs for each known post-release vulnerability in HTTPD. To explore **commit size**, we analyzed three code churn metrics. **Interactive churn** is a suite of five recently-developed [6] socio-technical variants of code churn metrics that measure the degree to which developers' changes overwrite each others' code at the line level. To explore **community dissemination,** we analyzed the

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The core idea behind VCCs is not new to the MSR world, and stems the from research on traditional bugs.

Fix-inducing Change

Bug-introducing Change

Bug-injecting Change

Bug-inducing Change

Meneely et al. argued about the term "fix-inducing", which can be translated into "persuade to fix (the bug)". In their view, a VCC does not persuade developers to fix the vulnerability… the vulnerability is fixed after its discovery, not because of a flawed commit!

Long story short: as long as we all agree, it makes no (real) difference.

Main Uses of VCCs

Train Vulnerability Prediction Models

We can build a **just-in-time vulnerability prediction model** if the dataset is made of VCCs and non-VCCs.

Recover Vulnerable Versions/Releases

VCCs can help understand which project releases are affected by the vulnerability.

Expand the Knowledge on Vulnerabilities

Understand how vulnerabilities are progressively introduced in the code, drawing out interesting facts.

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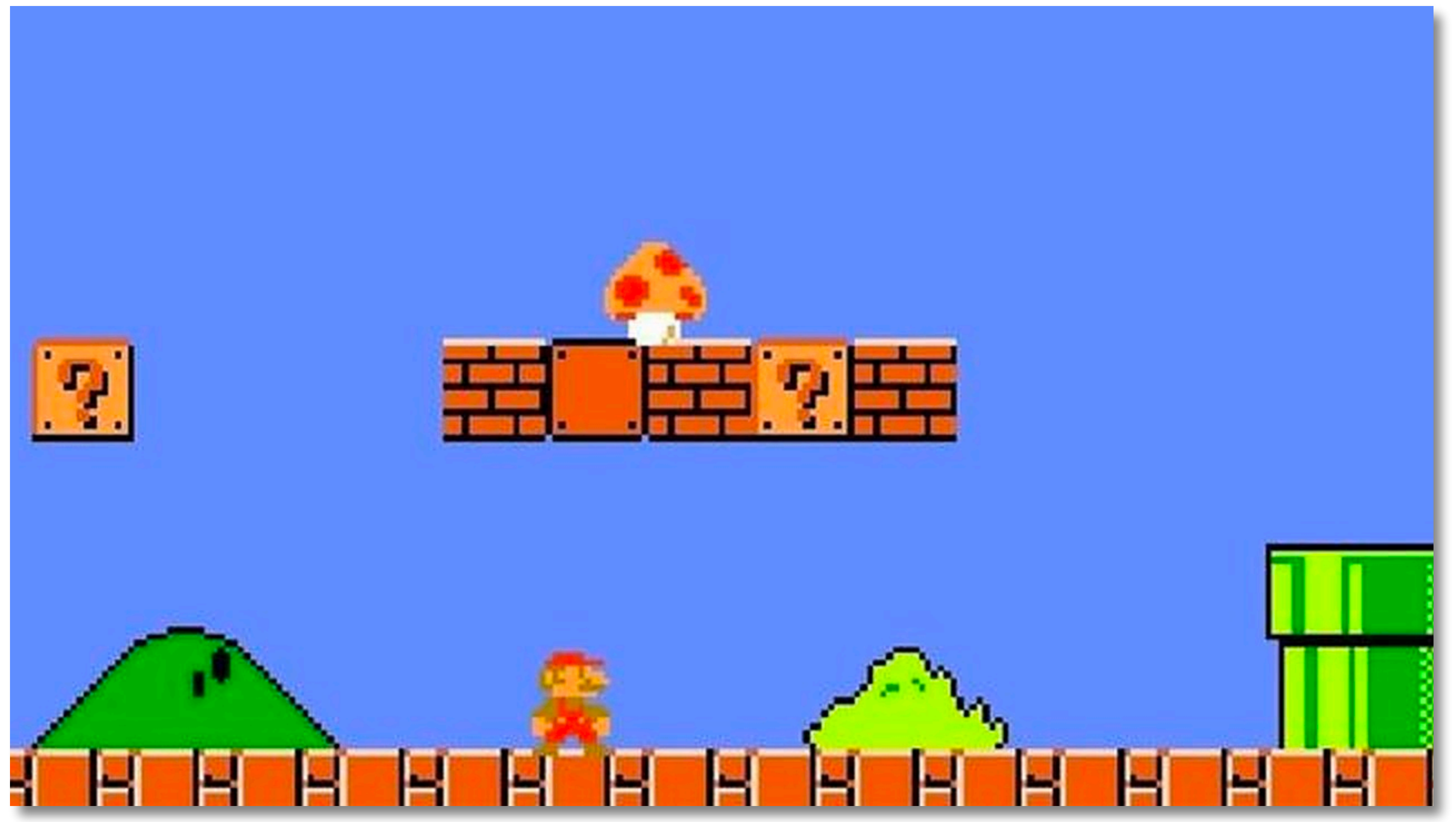

Size matters

VCCs change **x10 more lines of code** than non-VCCs.

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Size matters

Don't step on someone's toes

VCCs are made by **new authors in 15% more cases** than non-VCCs.

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Don't step on someone's toes

A leopard CAN change its spots

VCCs affect **existing files in 87% of the cases** rather than new files.

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Large commits might increase the chance of contributing to a vulnerability.

Changing **other developers' code** might increase the chance of contributing to a vulnerability.

Vulnerabilities are more likely to be added when **modifying existing files** rather than creating new files.

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Yeah, cool. How can we mine them?

Mining VCCs: A First Approach

Now let's see how we can retrieve VCCs from project histories.

Unnamed Technique by Meneely et al.

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Post-release vulnerability

Can be a known vulnerability from NVD or another source, it is the same.

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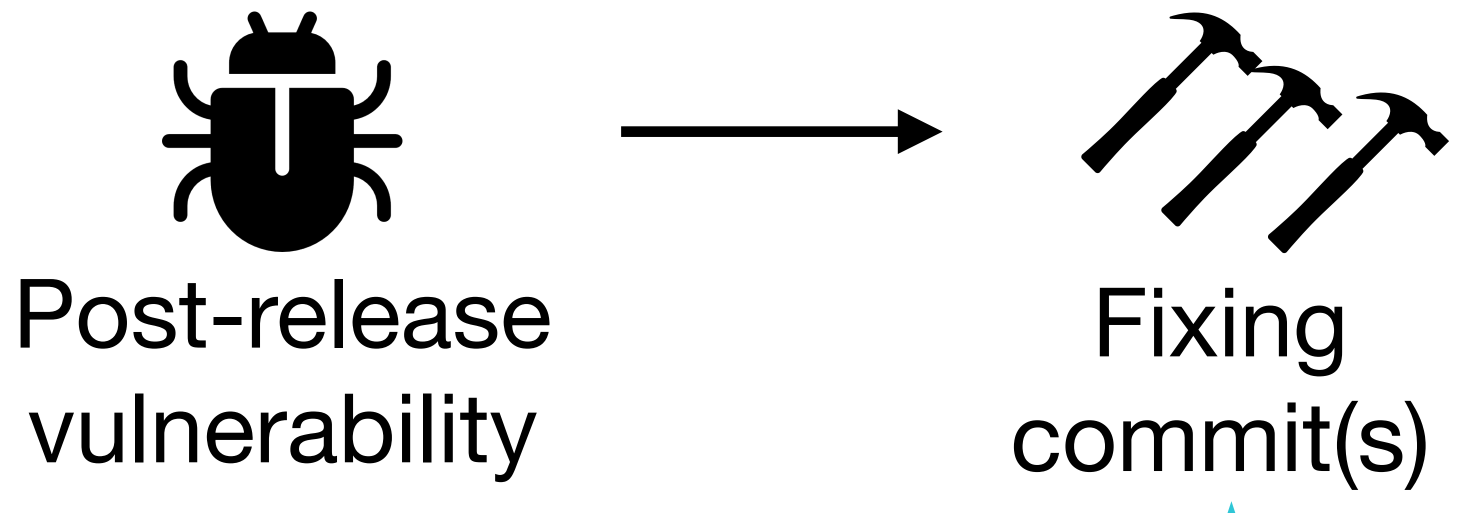

We assume the vulnerability is already mapped to its fixing commits.

Mining VCCs: A First Approach

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Unnamed Technique by Meneely et al.

One (or more) inspectors examine(s) the patch and its context to find the **vulnerable code elements** (statements). All the fixing commits are analyzed as one single big commit.

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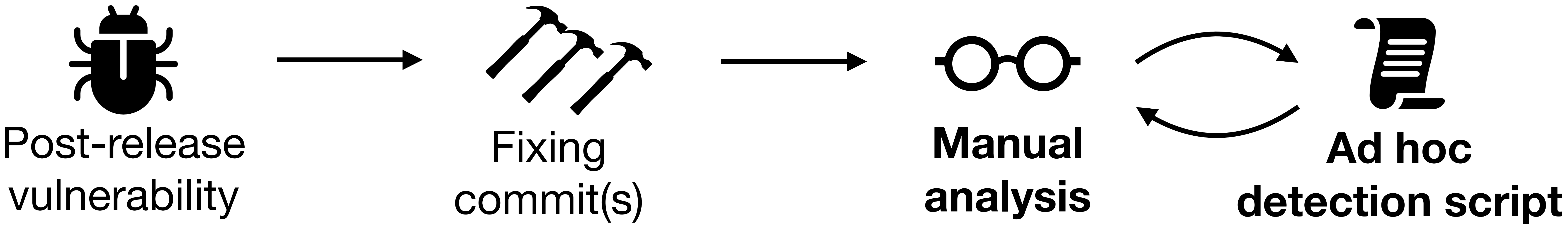

Detecting the vulnerable code elements is supported by a **regex-based string search** crafted by the inspector(s). This script is continuously updated until the vulnerability is fully understood.

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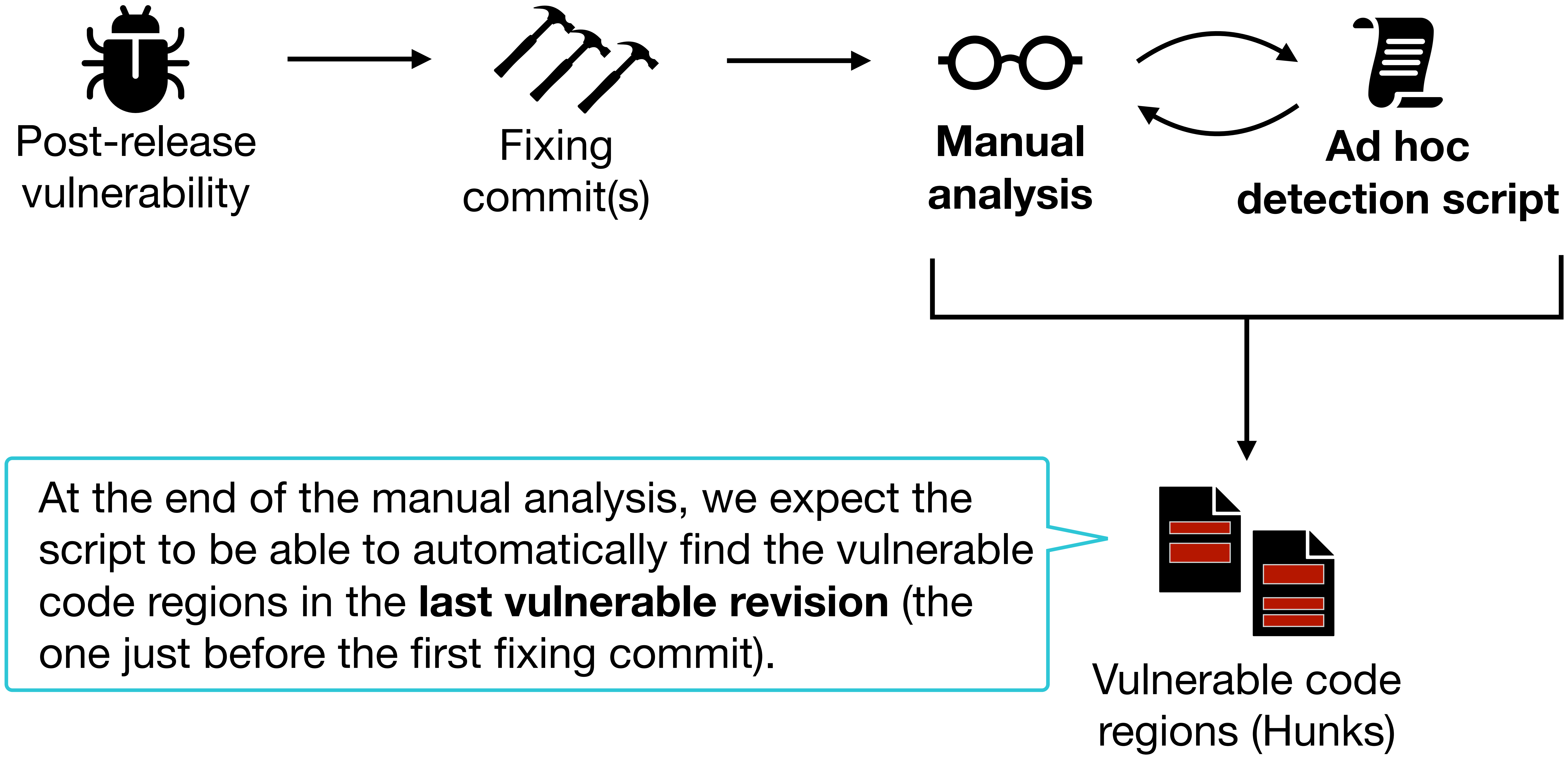

At the end of the manual analysis, we expect the script to be able to automatically find the vulnerable code regions in the **last vulnerable revision** (the one just before the first fixing commit).

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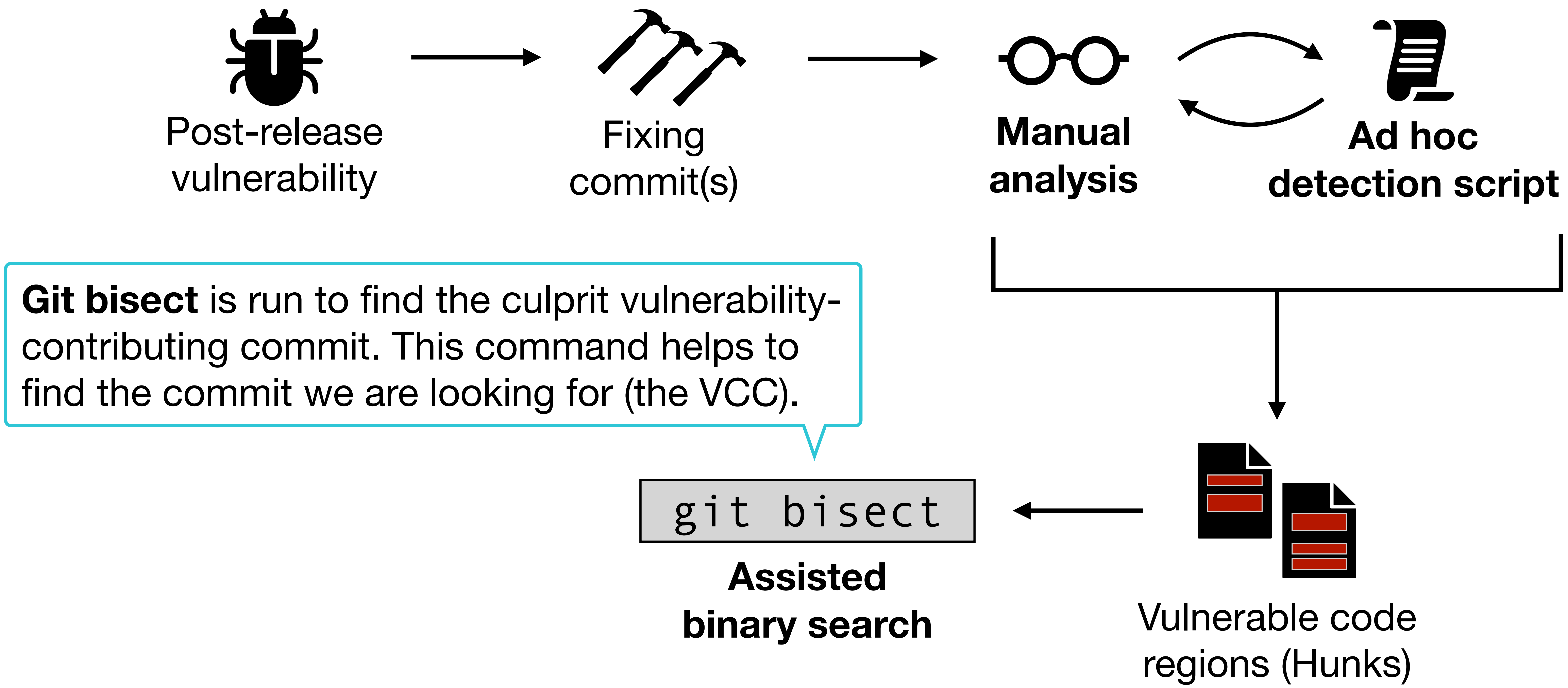

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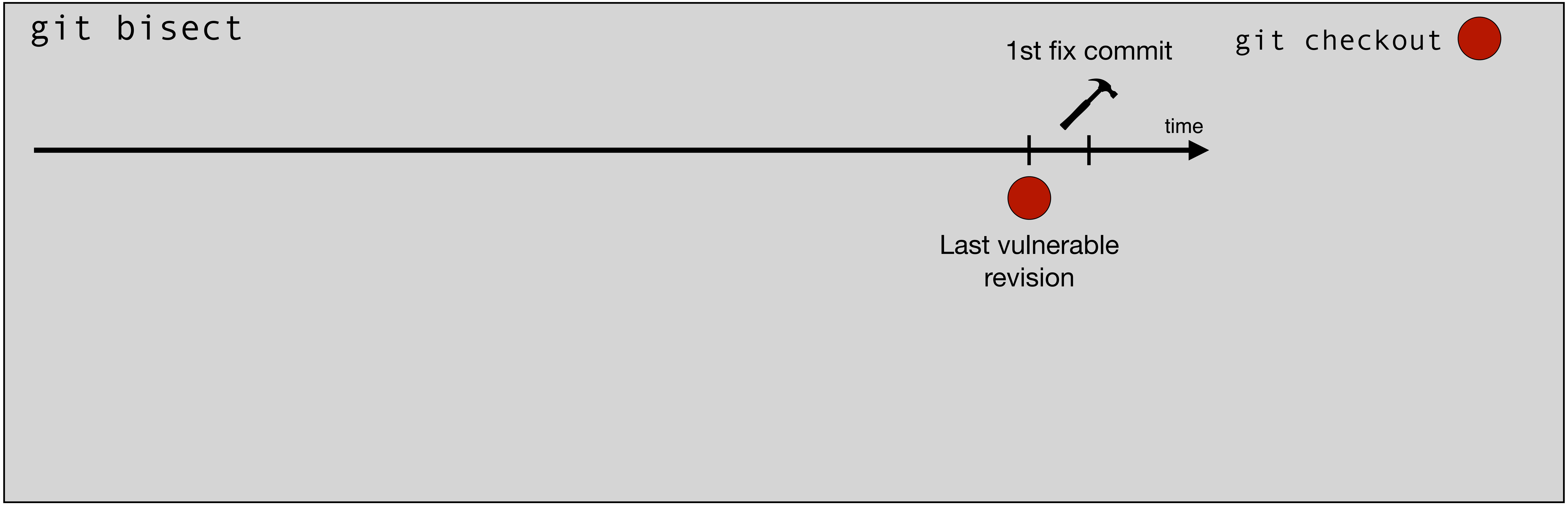

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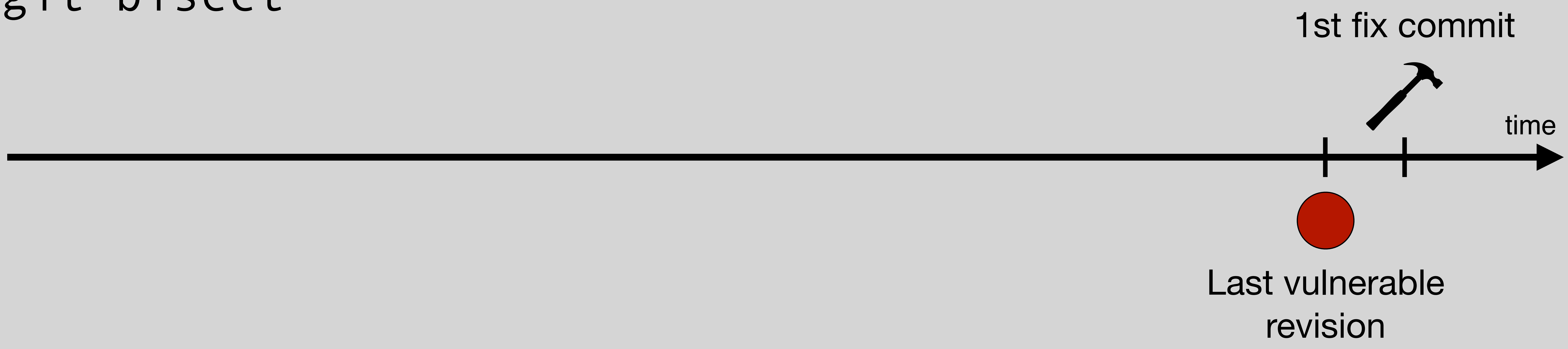

`git checkout` ●

`git bisect start`

This will start our procedure. The first thing we must do is flag a commit that **we are sure is vulnerable.** That is, this one!

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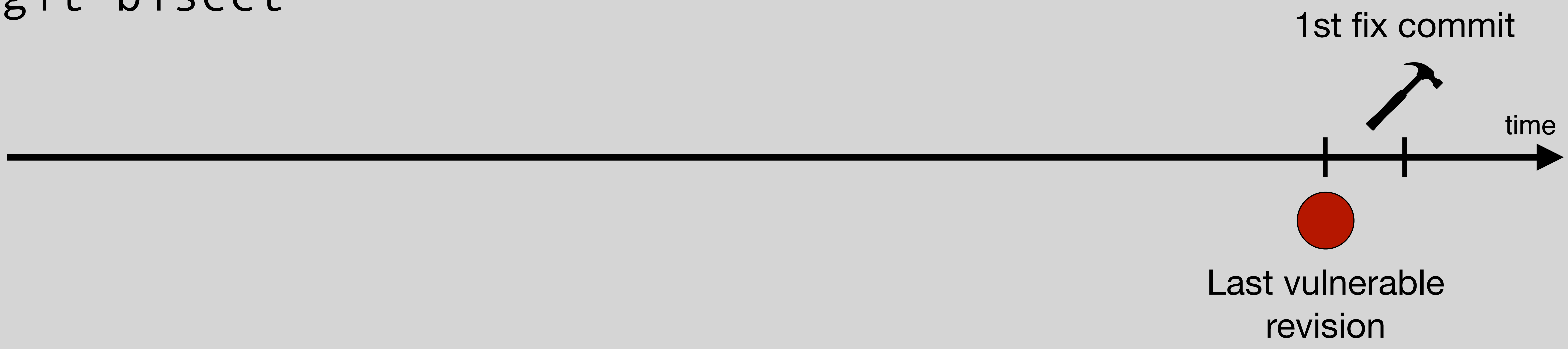


```
git checkout
git bisect start
git bisect bad
```

This will set the last vulnerable version as the "upper bound" of the process. Now, we have to look for the "lower bound". The **project start** can be a good candidate.

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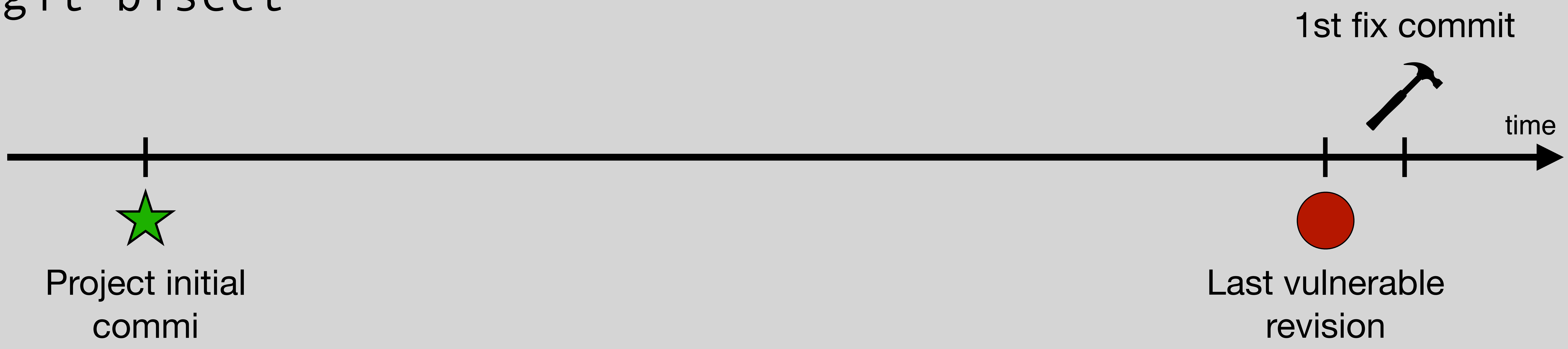
Unnamed Technique by Meneely et al.

`git bisect`




```
git checkout
git bisect start
git bisect bad
git bisect good
```

The main process starts now. Git will **select a commit in the middle**, on which we are automatically checked out so that we can inspect it.

Mining VCCs: A First Approach

Now let's see how we can retrieve VCCs from project histories.

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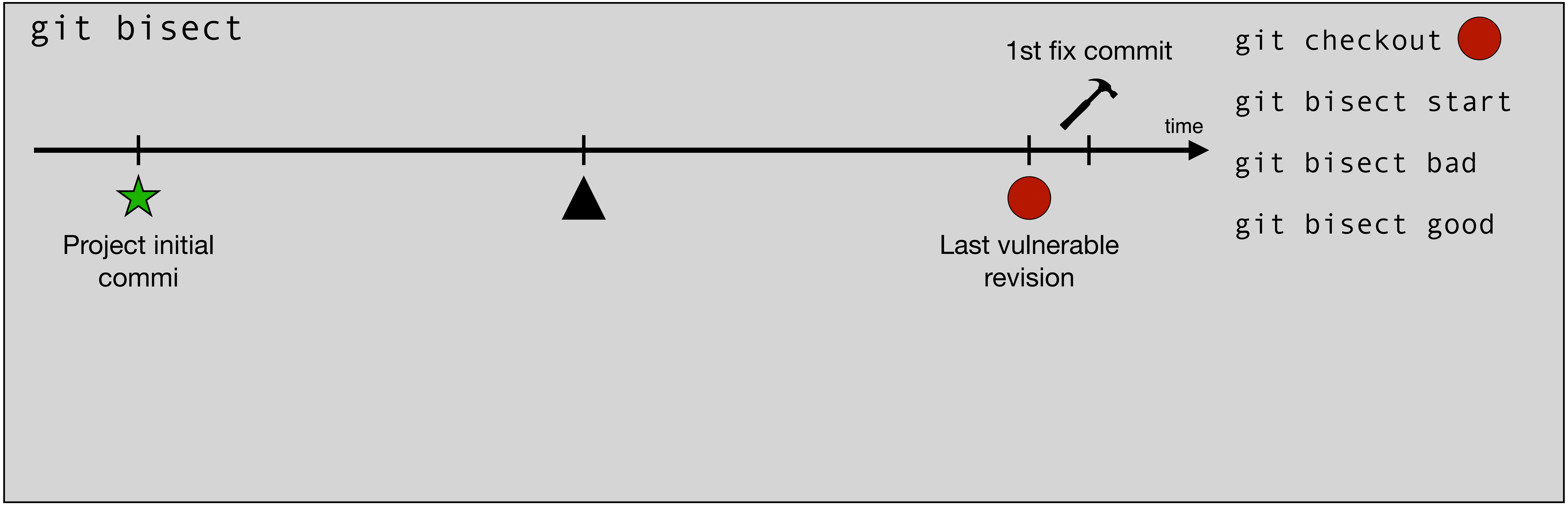

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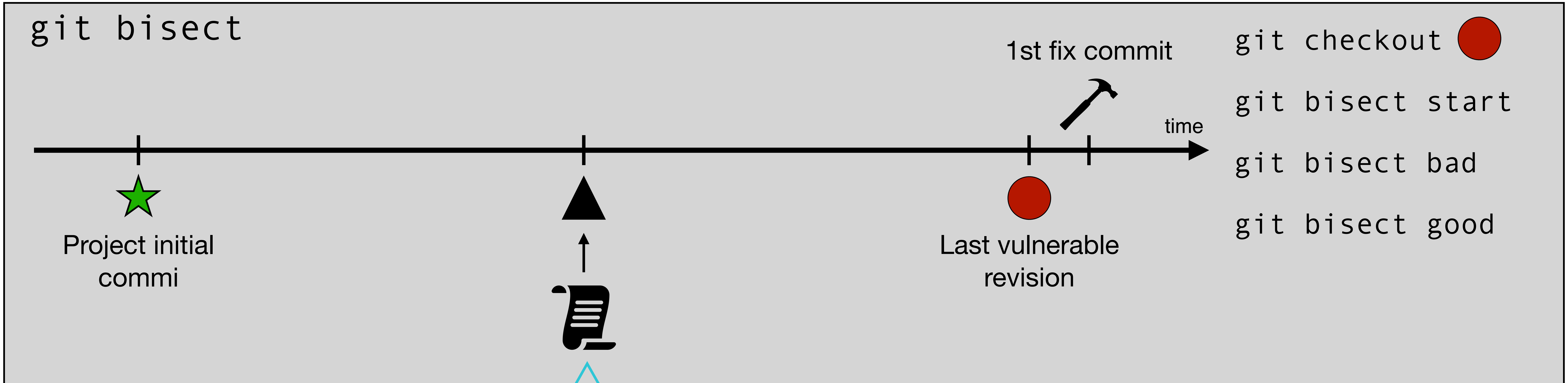

Instead of doing another manual inspection, we just ran the detection script prepared before.

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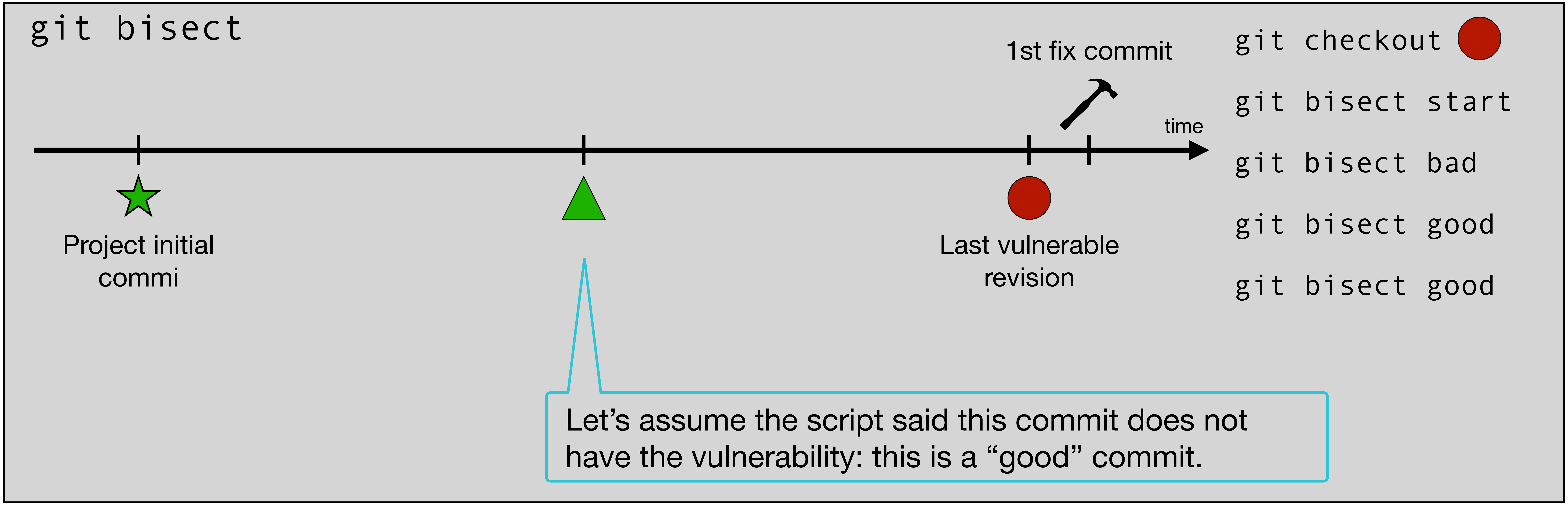

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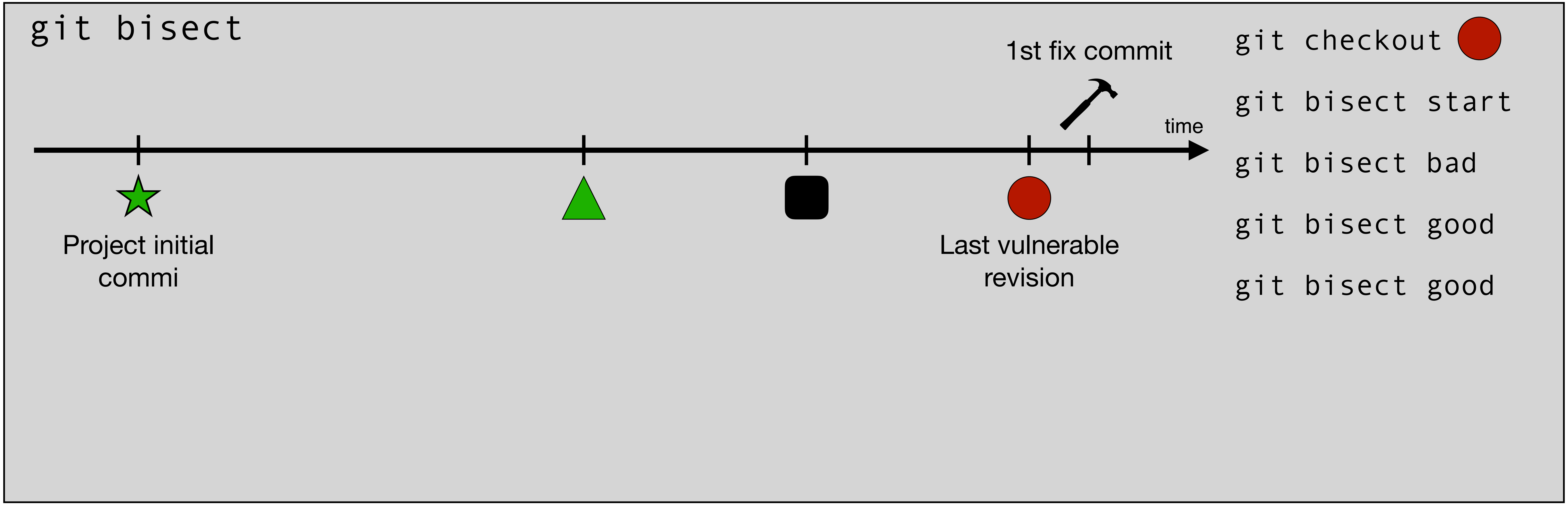

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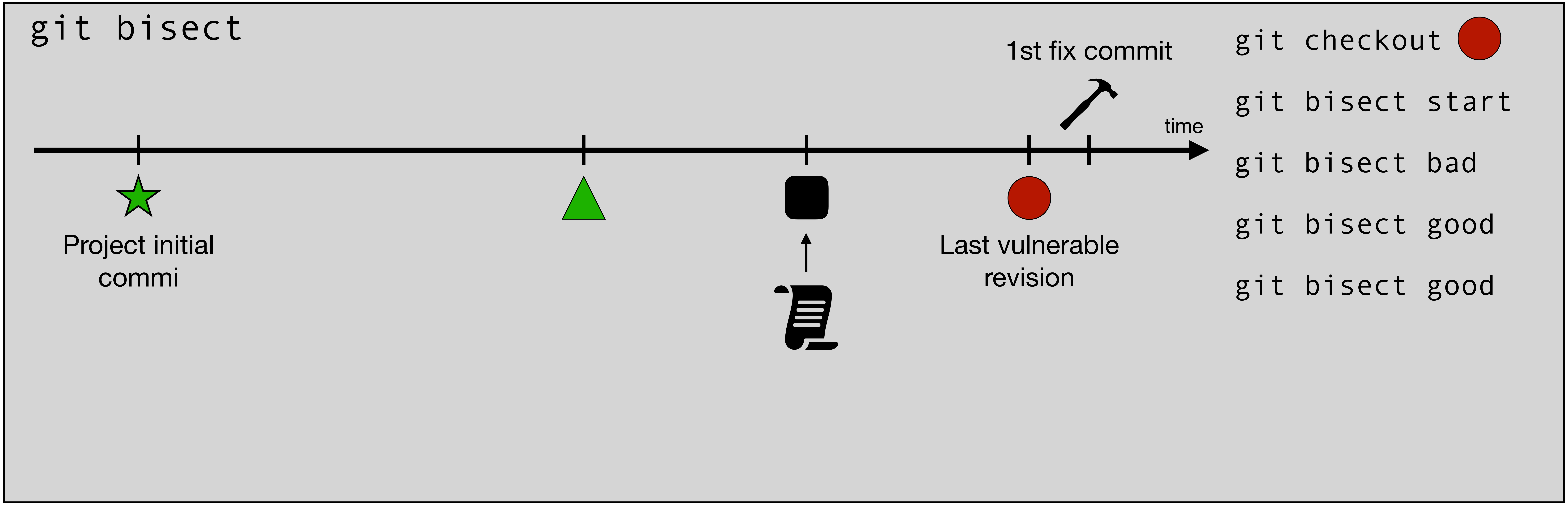

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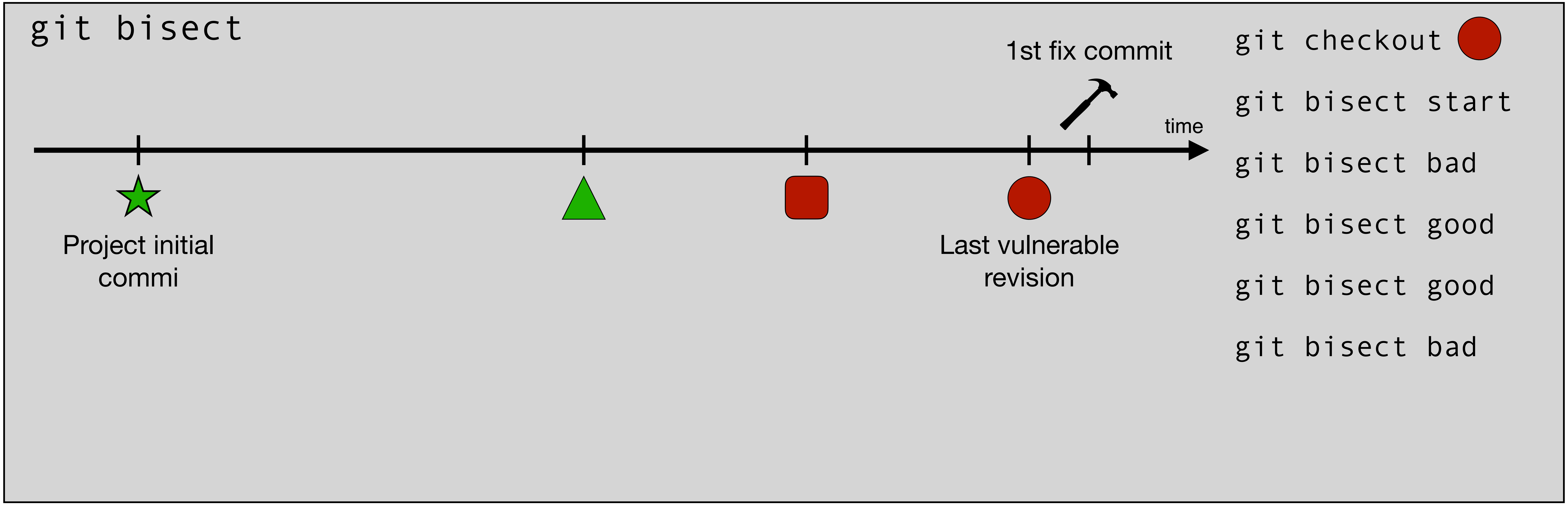

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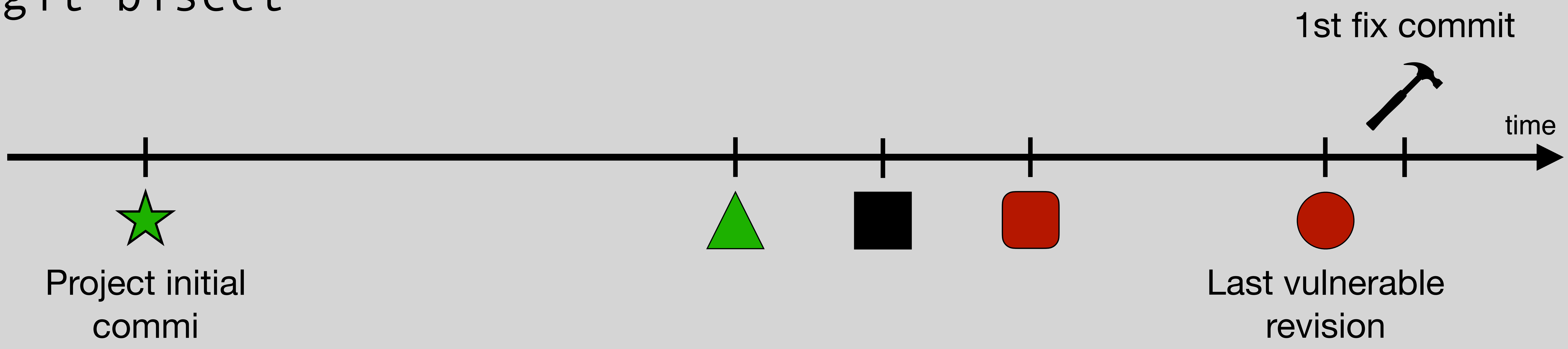


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```

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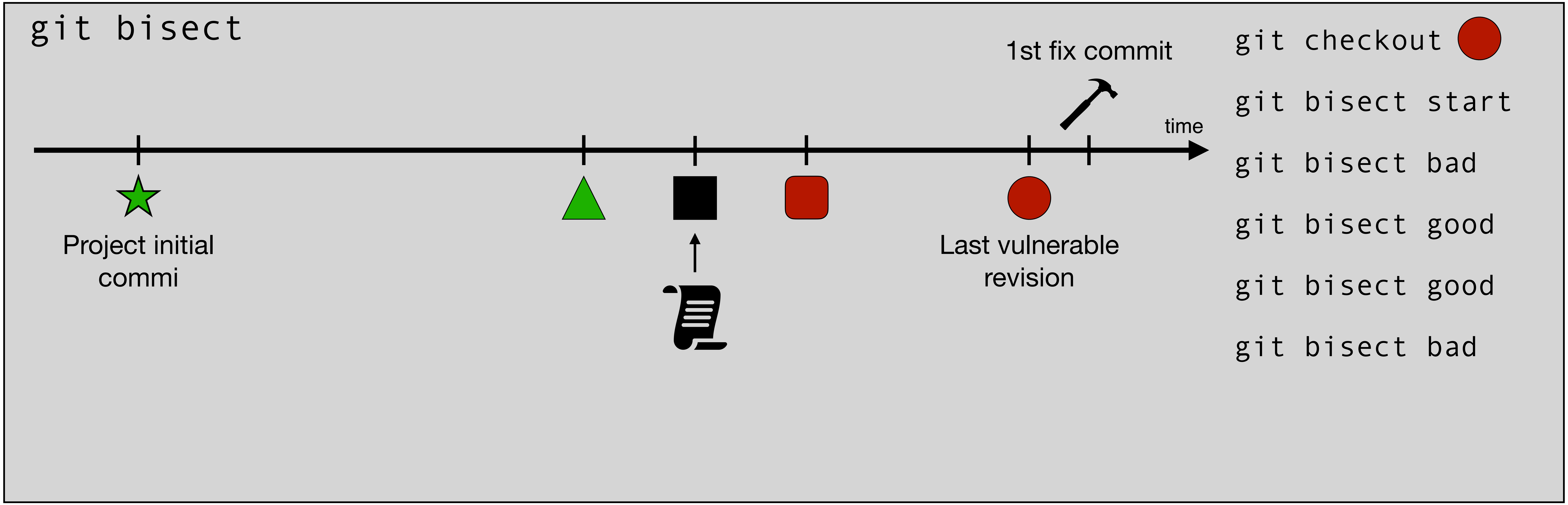

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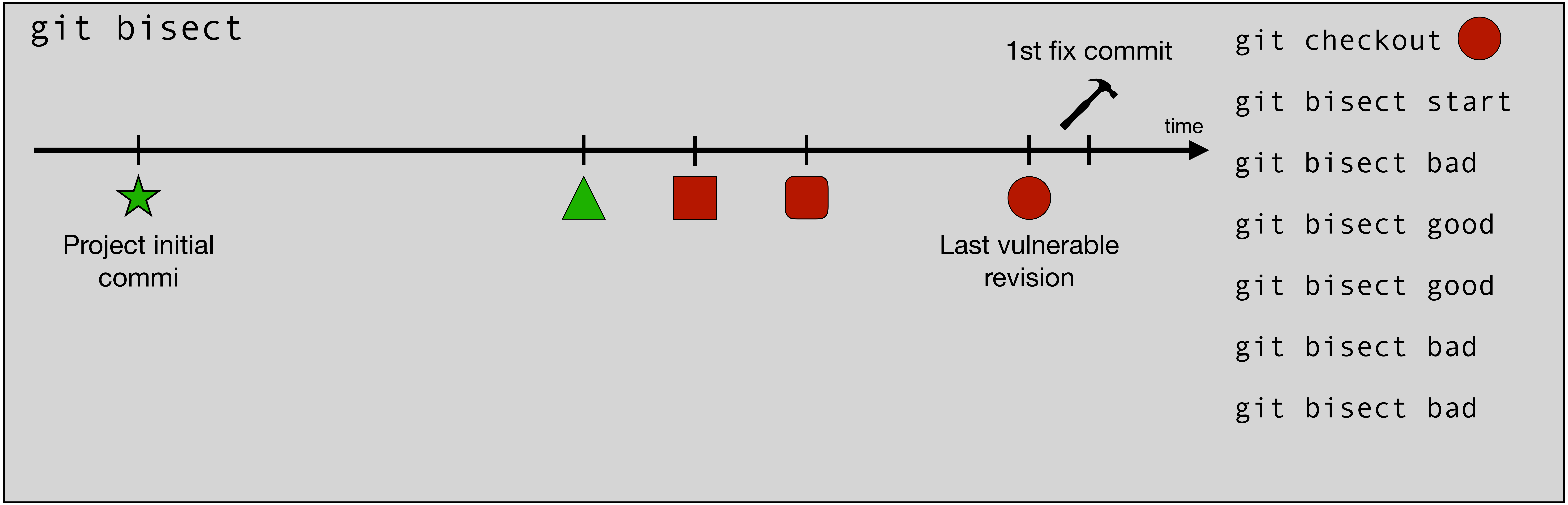

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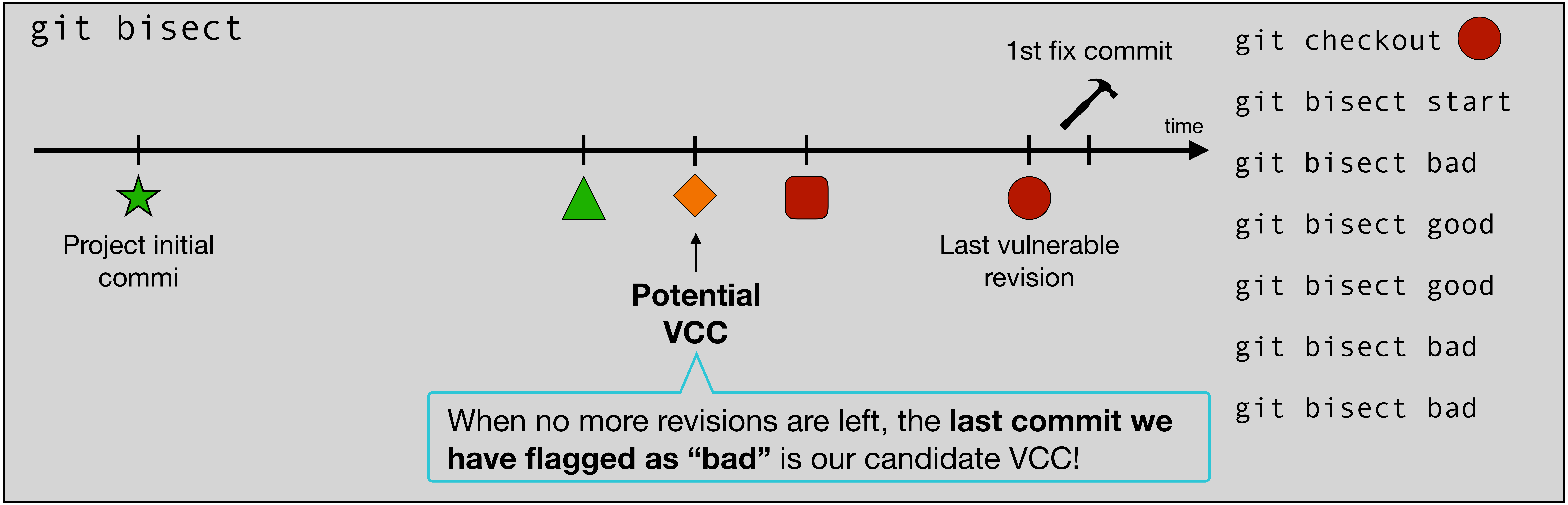

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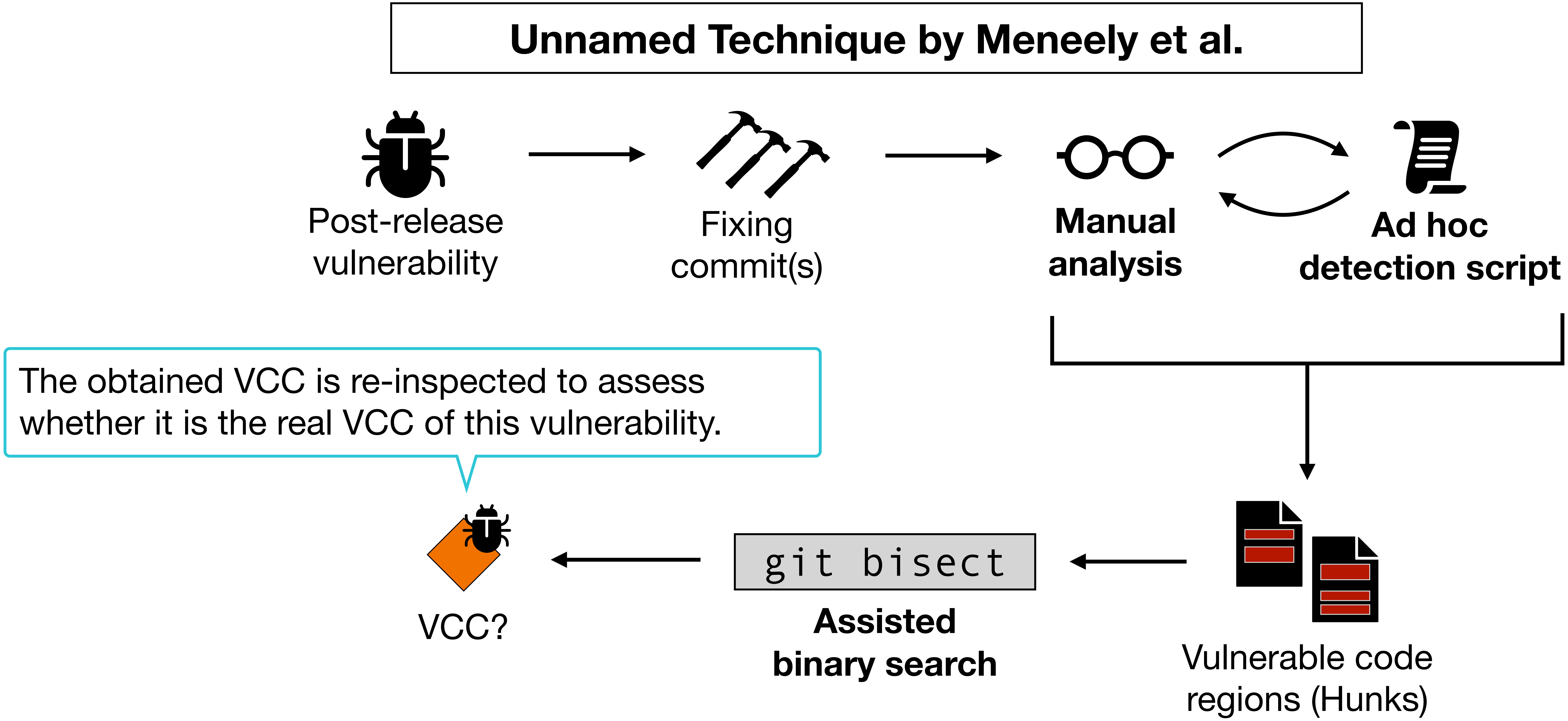

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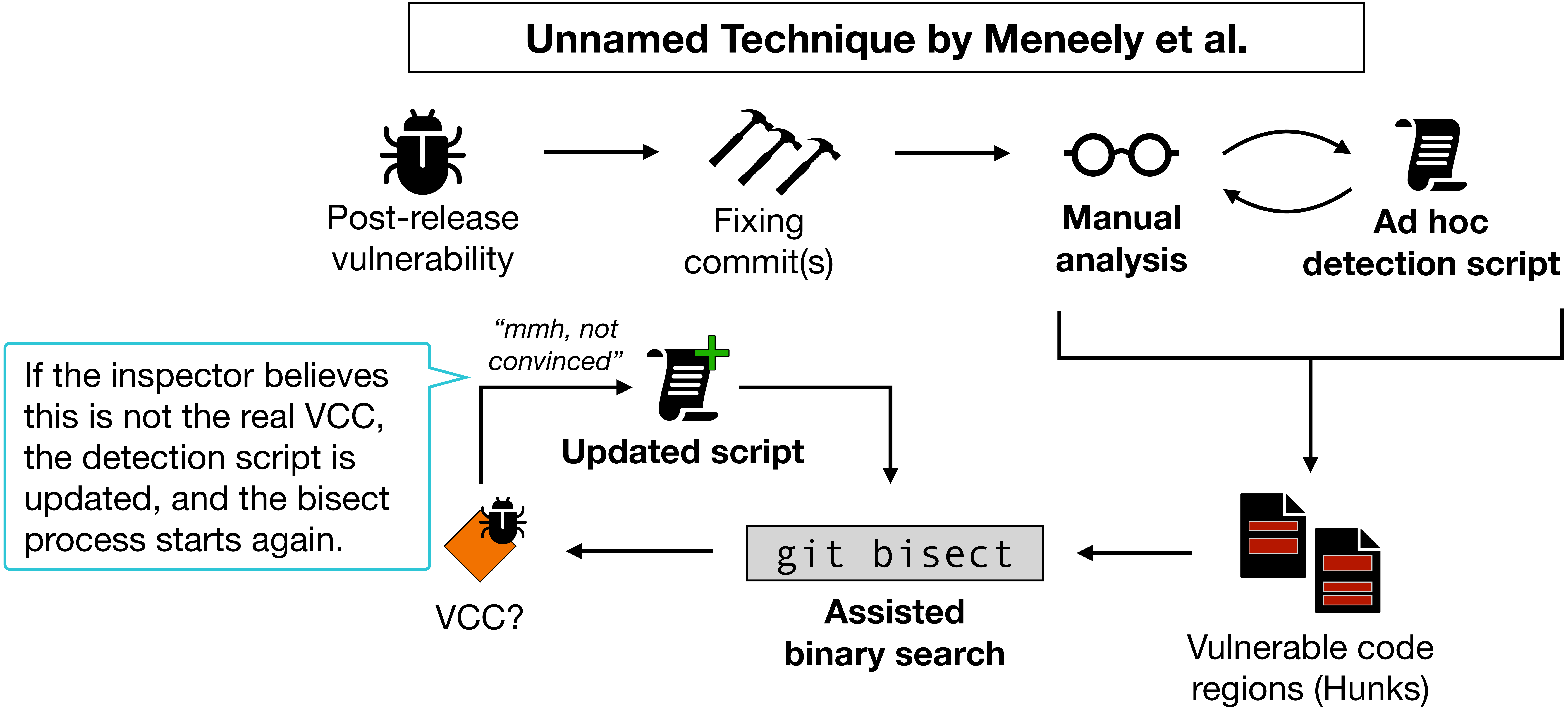

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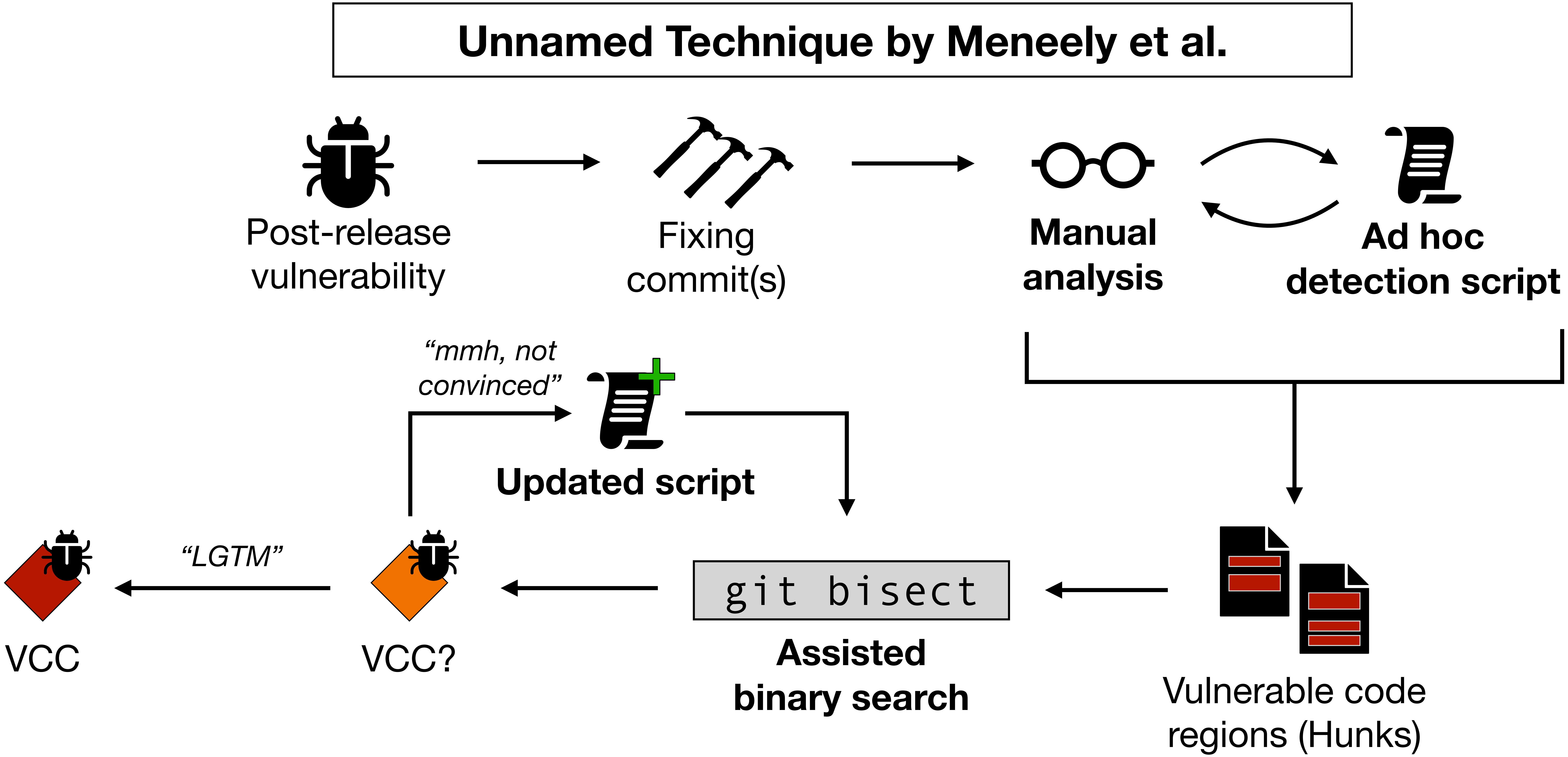

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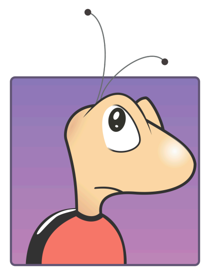

Project Bug Tracker

The original approach relies on *Bugzilla*, but we can mine any bug tracker or similar database.

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Śliwerski, Zimmermann, Zeller (SZZ)

Project Bug Tracker

Project History

The original approach relies on *CVS (Concurrent Versioning System)*, but here we consider *git*.

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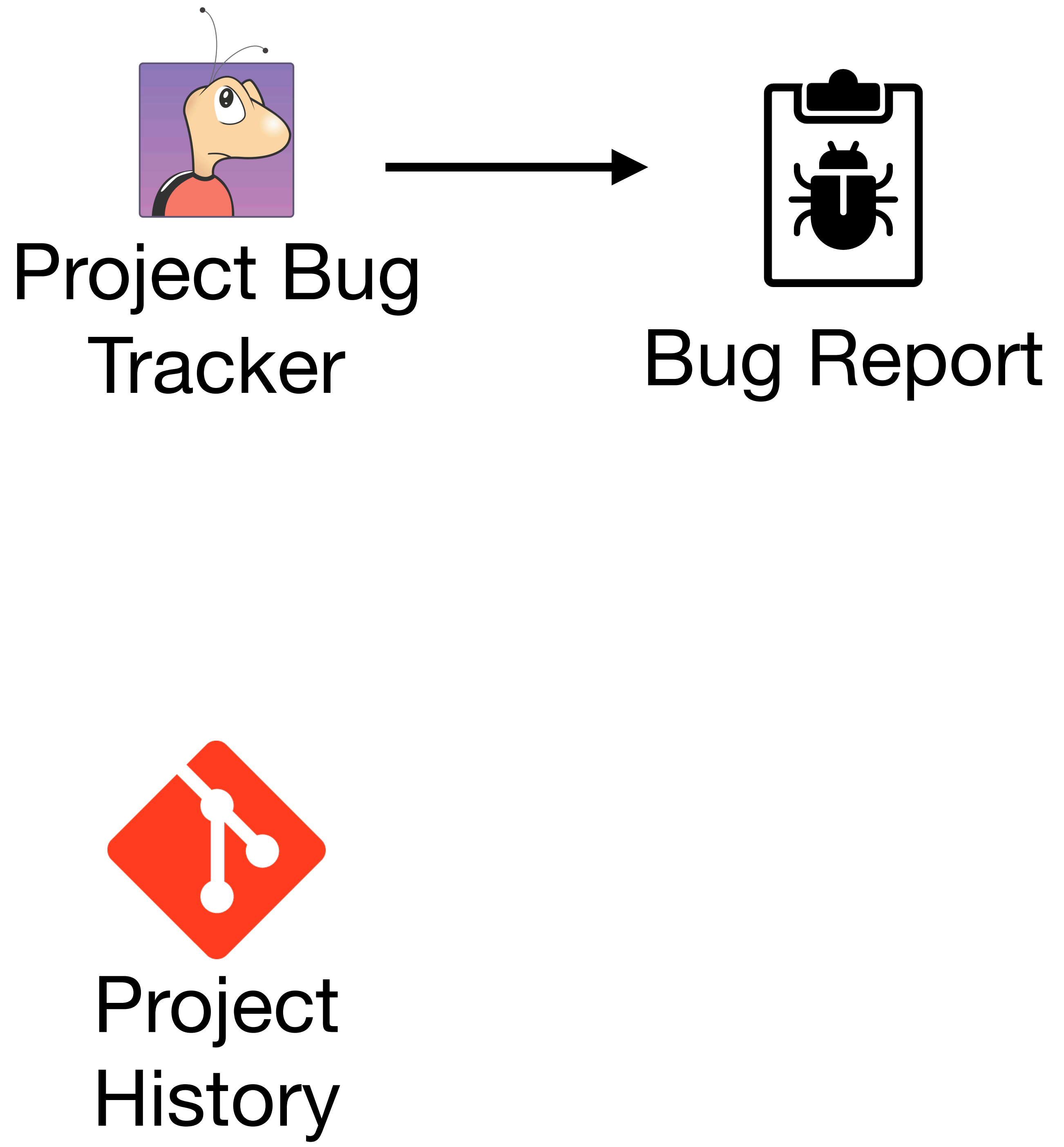

We pick a bug report for which we want to know its *bug-inducing commits* (BICs).

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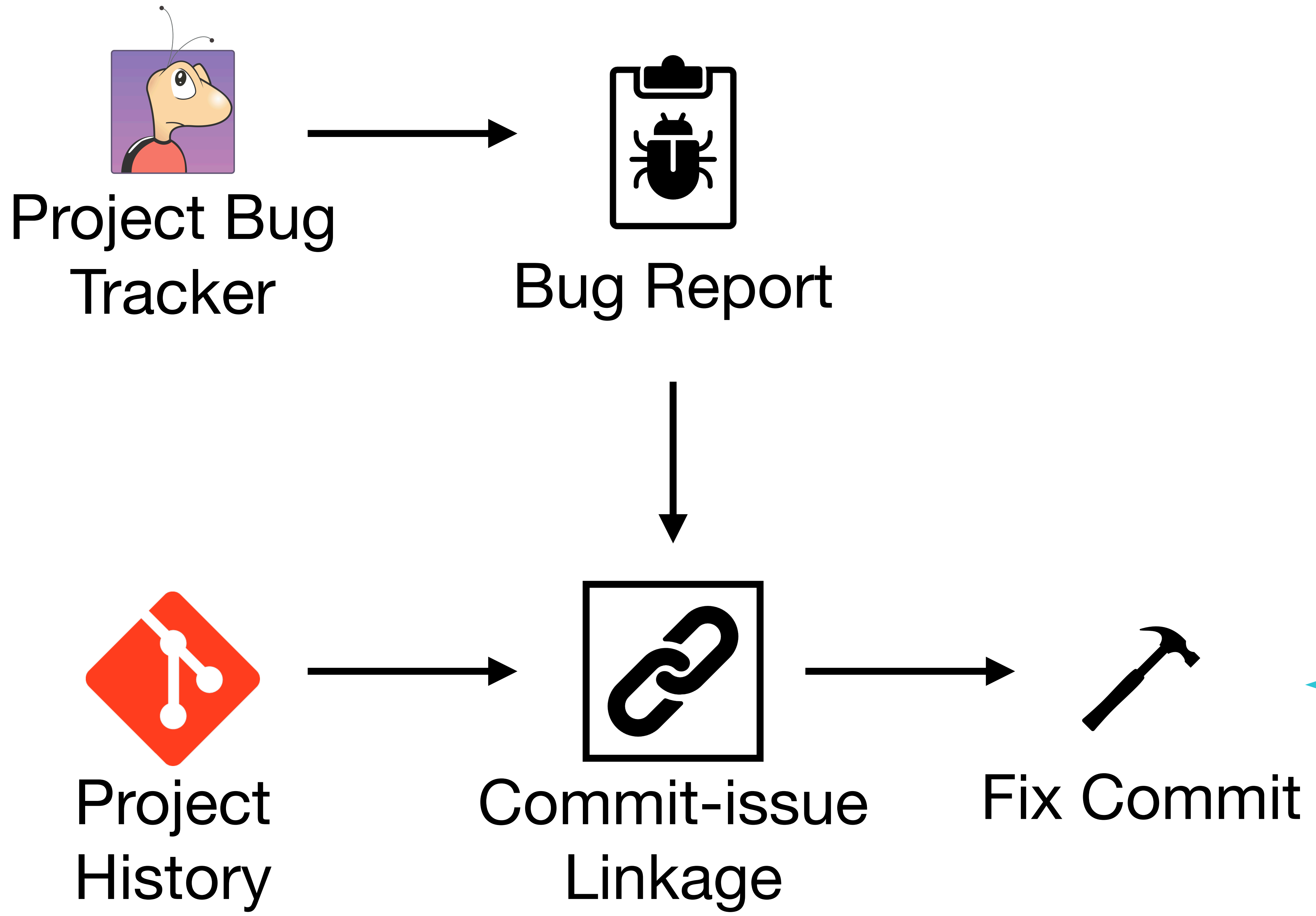

We can run any commit-issue link algorithm we want. The original approach uses a **pattern-based search**, looking for the bug ID (a number) inside the commit messages. In any case, we just want the *bug-fixing commit*.

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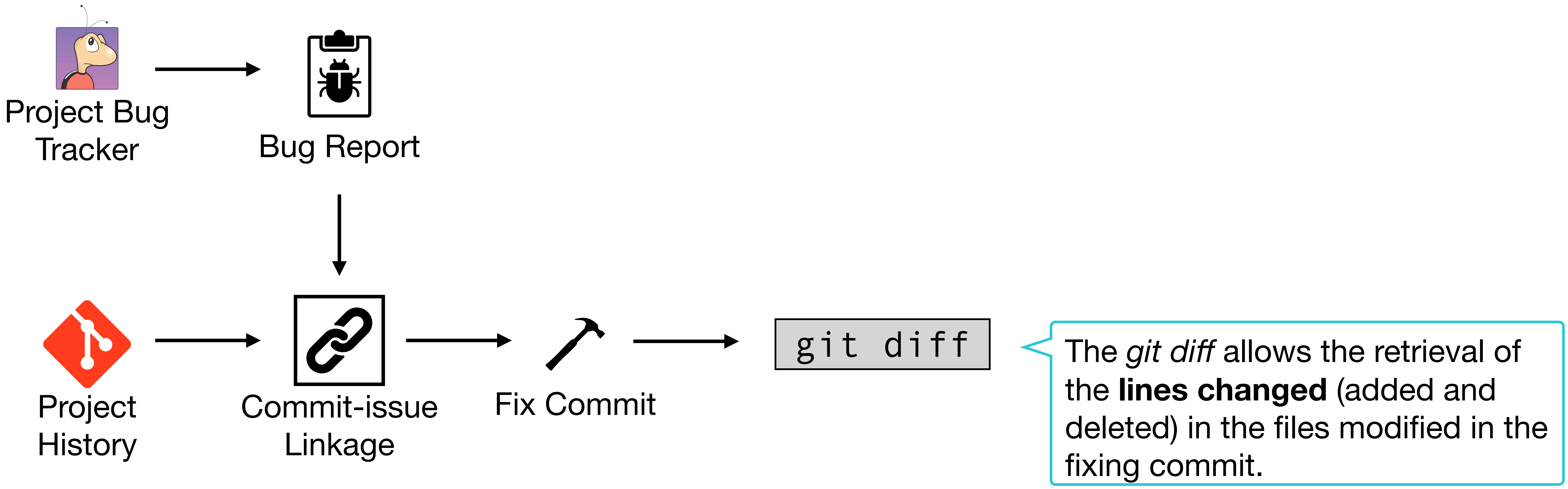

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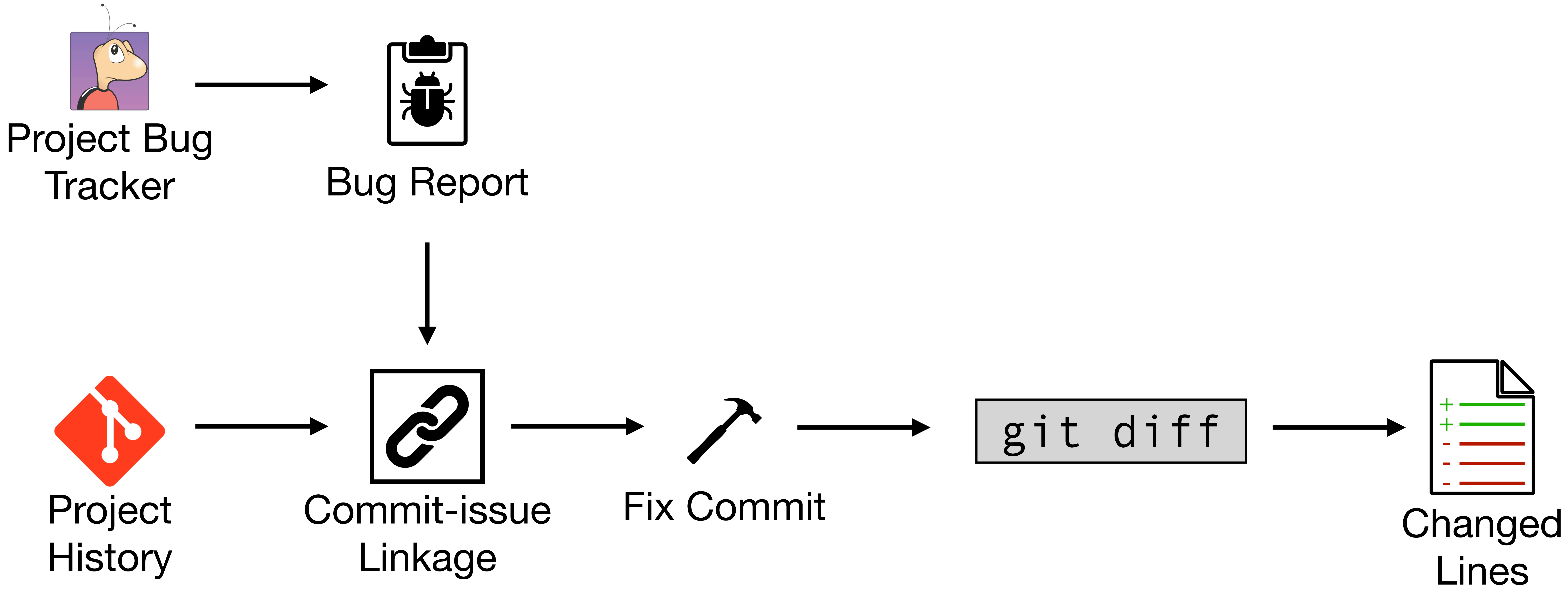

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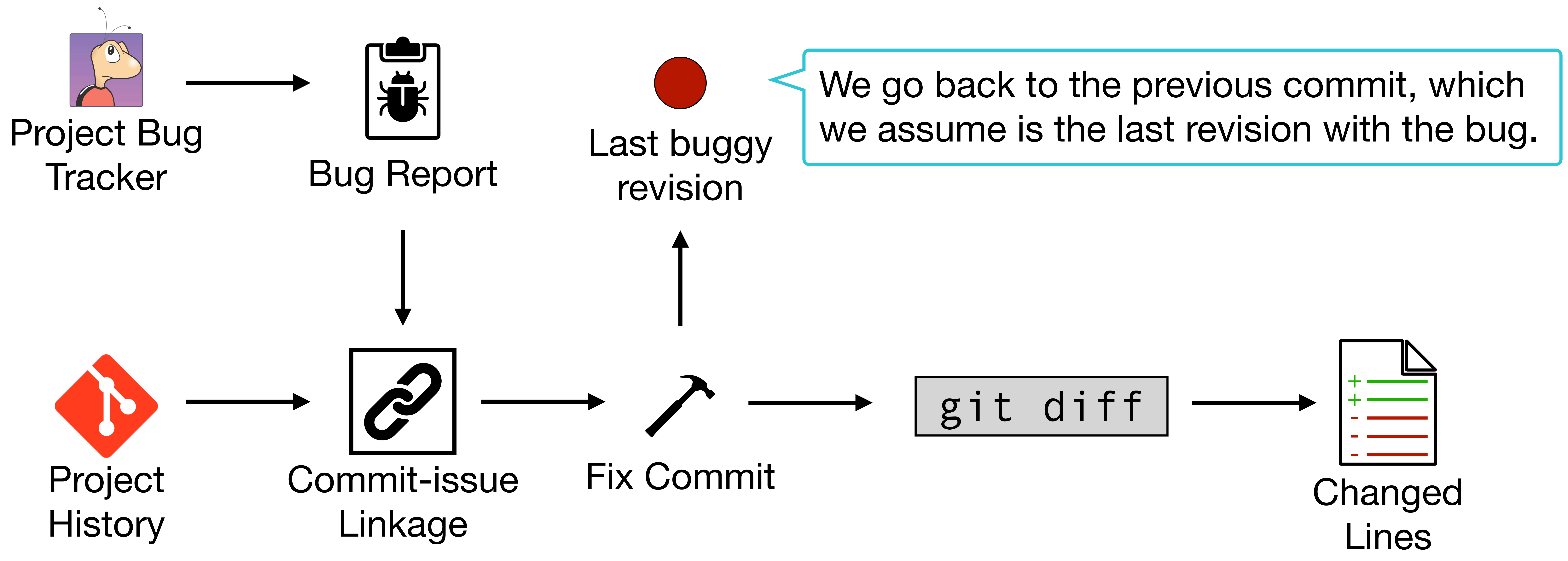

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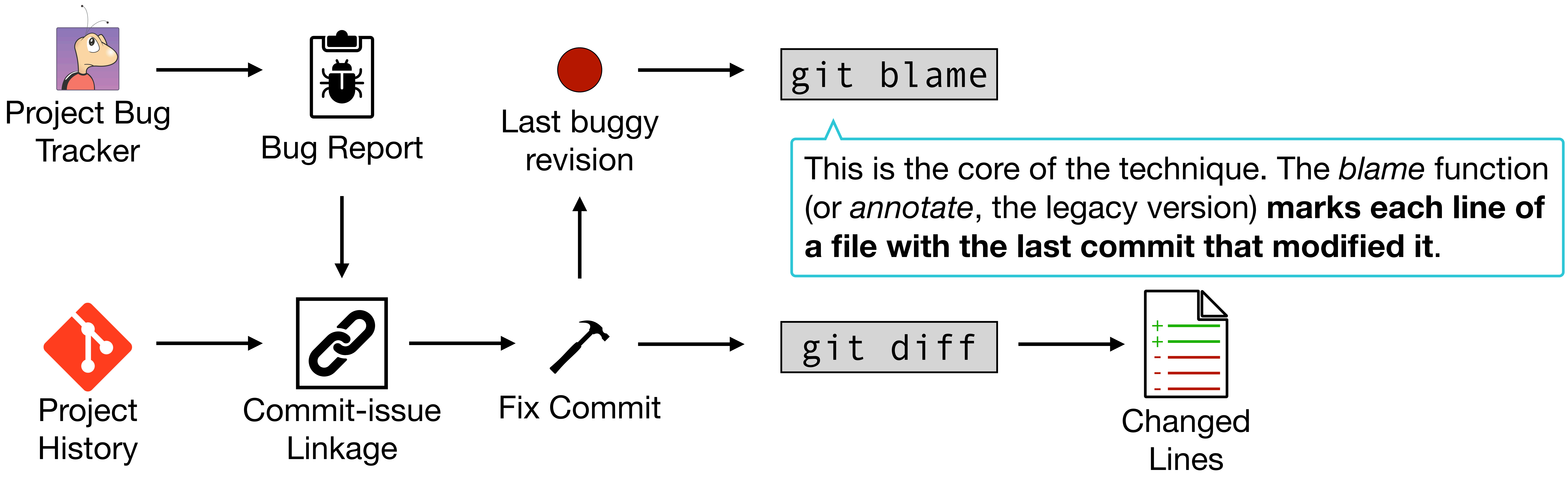

MSR for Vulnerability Prediction — Mining VCCs

commons-csv / src / main / java / org / apache / commons / csv / CSVParser.java

Top

Code | Blame | 823 lines (759 loc) · 29.2 KB

Raw

Older ■■■■■■■■■■ Newer

Contributors 10

4 years ago	[CSV-239] Add CSVRecord.ge...
4 years ago	[CSV-239] Cannot get headers ...
4 years ago	[CSV-239] Add CSVRecord.ge...
4 years ago	[CSV-239] Cannot get headers ...
4 years ago	[CSV-239] Cannot get headers ...
4 years ago	[CSV-239] Cannot get headers ...
8 months ago	[CSV-304] Accessors for hea...
4 years ago	[CSV-239] Cannot get headers ...
8 months ago	Guard against NPE in createH...
4 years ago	[CSV-239] Cannot get headers ...

```java
    private Headers createHeaders() throws IOException {
        Map<String, Integer> hdrMap = null;
        List<String> headerNames = null;
        final String[] formatHeader = this.format.getHeader();
        if (formatHeader != null) {
            hdrMap = createEmptyHeaderMap();
            String[] headerRecord = null;
            if (formatHeader.length == 0) {
                // read the header from the first line of the file
                final CSVRecord nextRecord = this.nextRecord();
                if (nextRecord != null) {
                    headerRecord = nextRecord.values();
                    headerComment = nextRecord.getComment();
                }
            } else {
                if (this.format.getSkipHeaderRecord()) {
                    final CSVRecord nextRecord = this.nextRecord();
                    if (nextRecord != null) {
                        headerComment = nextRecord.getComment();
                    }
                }
                headerRecord = formatHeader;
            }
            // build the name to index mappings
            if (headerRecord != null) {
```

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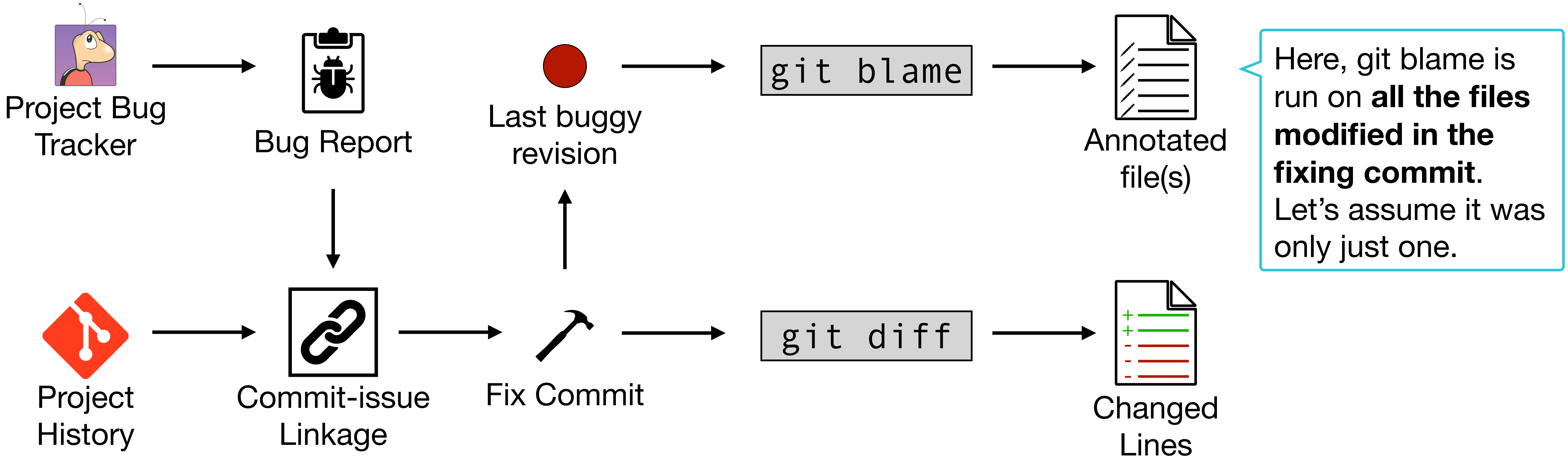

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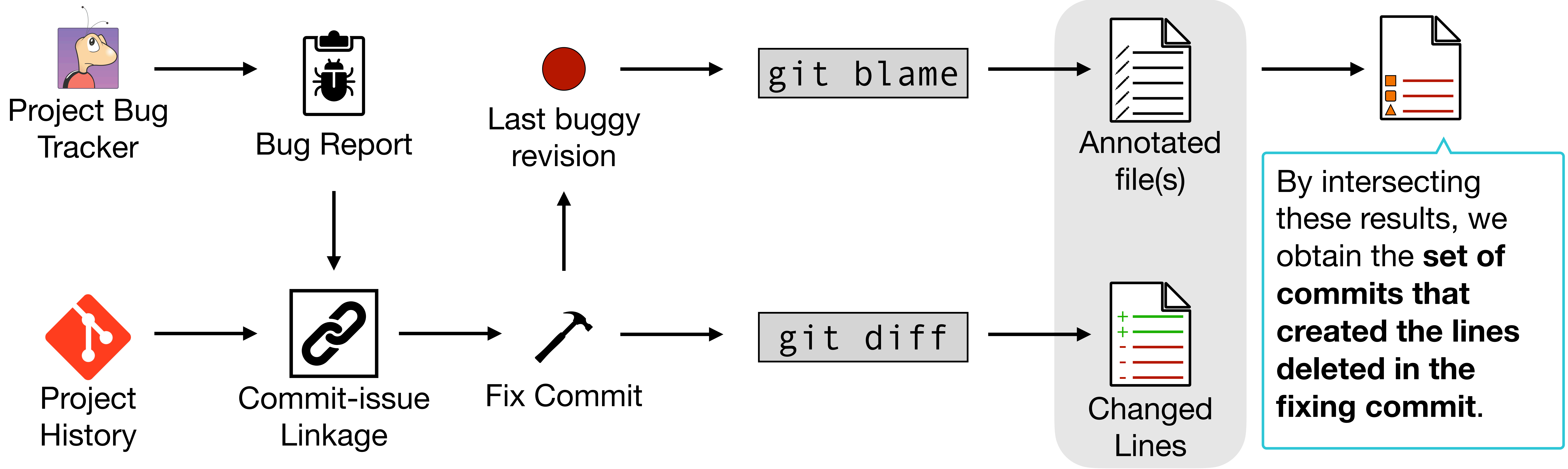

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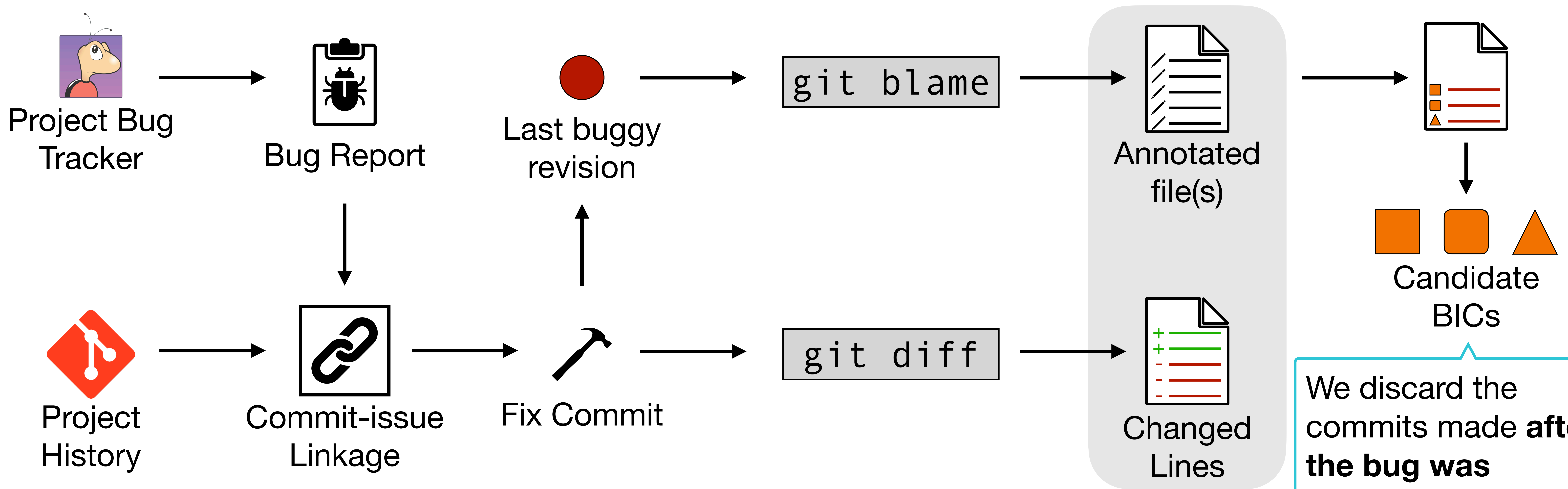

We discard the commits made **after the bug was reported**.

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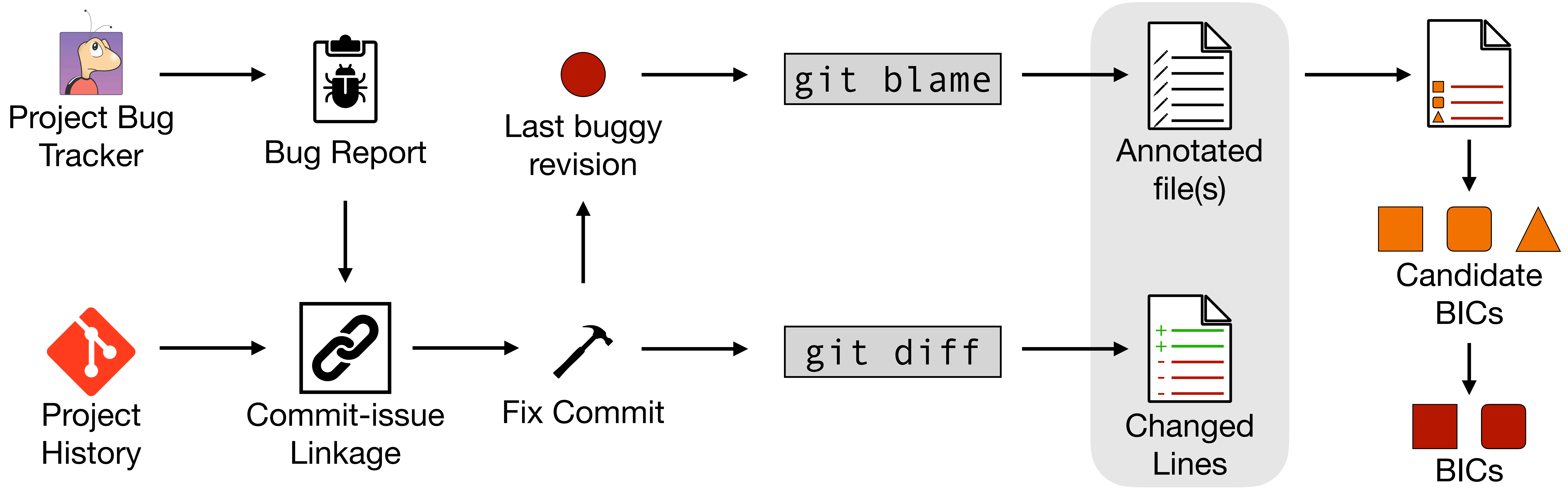

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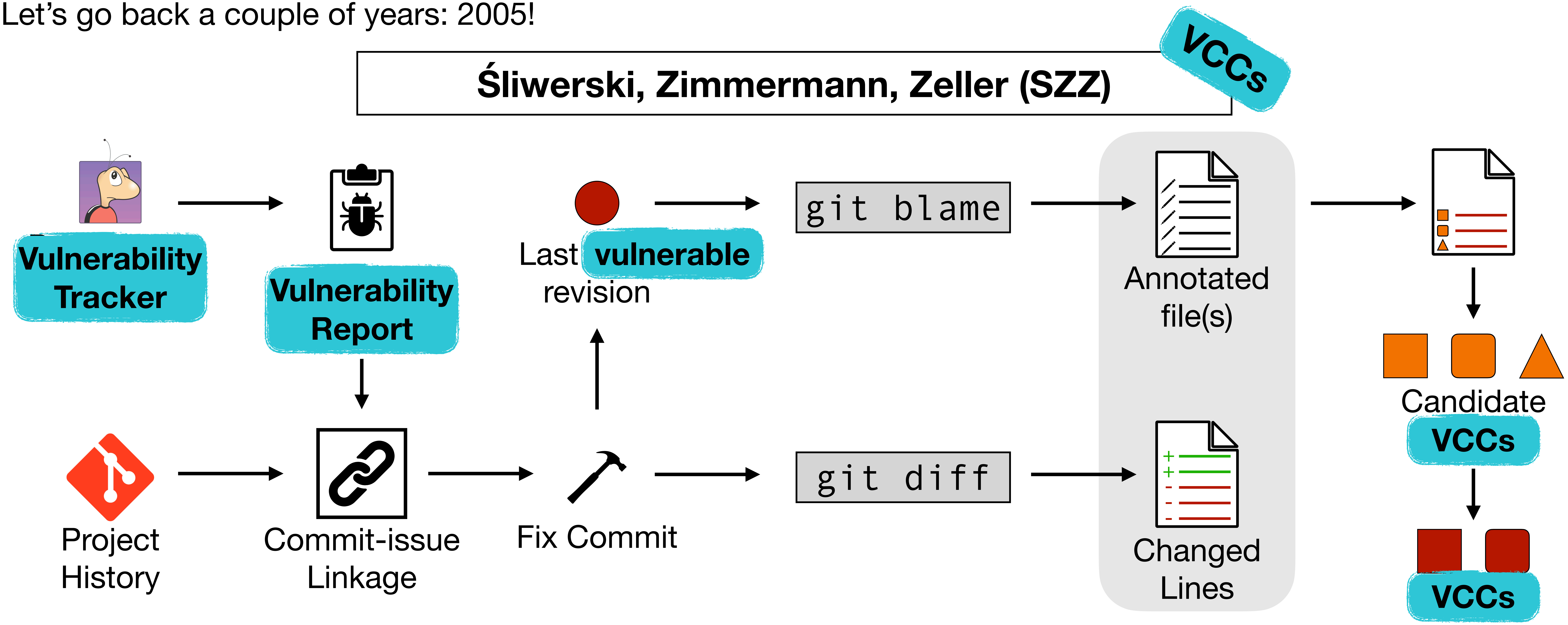

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The SZZ algorithm is quite intuitive, but, despite its simplicity, it has been a revolution in the MSR world. Yet, all that glitters is not gold: it has some problems.

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Comments and Blank Lines

If the fixing commit also **modified an existing comment** or **removed a blank line**, the BICs (or VCCs) resulting from blaming these lines would be false positives: they made no real contribution to the bug.

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Last buggy/vulnerable

```
1: public void foo() {
2:   // print report
3:   if (report == null)
4:   {
5:     println(report);
6:
7:   }
```

Fixed Revision

```
1: public void foo() {
2:   // print out report
3:   if (report != null)
4:   {
5:     println(report);
6:   }
```

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Comments and Blank Lines

If the fixing commit also **modified an existing comment** or **removed a blank line**, the BICs (or VCCs) resulting from blaming these lines would be false positives: they made no real contribution to the bug.

Two lines changed, one was just deleted.

Last buggy/vulnerable

```
public void foo() {
  // print report
  if (report == null)
  {
    println(report);

  }
```

Fixed Revision

```
public void foo() {
  // print out report
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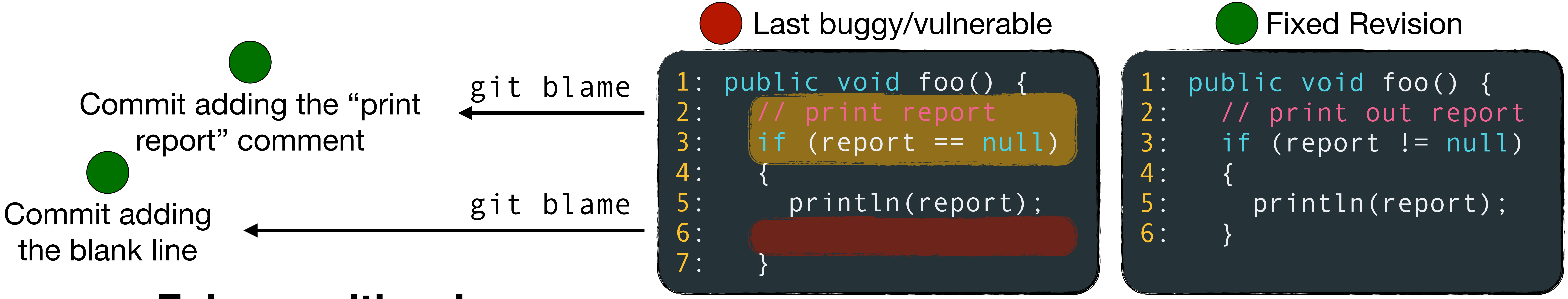

False positives!

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Format/Aesthetic Changes

If the fixing commit **modified a line that underwent at least one format change after the bug was introduced**, the BICs (or VCCs) resulting from blaming these lines would be false positives, and the real BICs (VCCs) will be false negatives.

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Last buggy/vulnerable

```
public void foo() {
  if (folder == null)
    return;
```

Fixed Revision

```
public void foo() {
  if (folder != null)
    return;
```

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Revision A

```
public void foo() {
  if (folder != null) return;
```

Revision B

```
public void foo() {
  if (folder == null) return;
```

Revision C

```
public void foo() {
  if (folder == null)
    return;
```

Last buggy/vulnerable

```
public void foo() {
  if (folder == null)
    return;
```

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If the fixing commit **modified a line that underwent at least one format change after the bug was introduced**, the BICs (or VCCs) resulting from blaming these lines would be false positives, and the real BICs (VCCs) will be false negatives.

The commit that brought A to B is adding the bug/ vulnerability!

Revision A

```
public void foo() {
  if (folder != null) return;
```

Revision B

```
public void foo() {
  if (folder == null) return;
```

Revision C

```
public void foo() {
  if (folder == null)
    return;
```

Last buggy/vulnerable

```
public void foo() {
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If the fixing commit **modified a line that underwent at least one format change after the bug was introduced**, the BICs (or VCCs) resulting from blaming these lines would be false positives, and the real BICs (VCCs) will be false negatives.

C is the last commit that changed line 2 (false positive), shadowing B (false negative)!

Revision B

```
1: public void foo() {
2:   if (folder == null) return;
```

Last buggy/vulnerable

```
1: public void foo() {
2:   if (folder == null)
3:     return;
```

Revision C

```
1: public void foo() {
2:   if (folder == null)
3:     return;
```

git blame

Revision A

```
1: public void foo() {
2:   if (folder != null) return;
```

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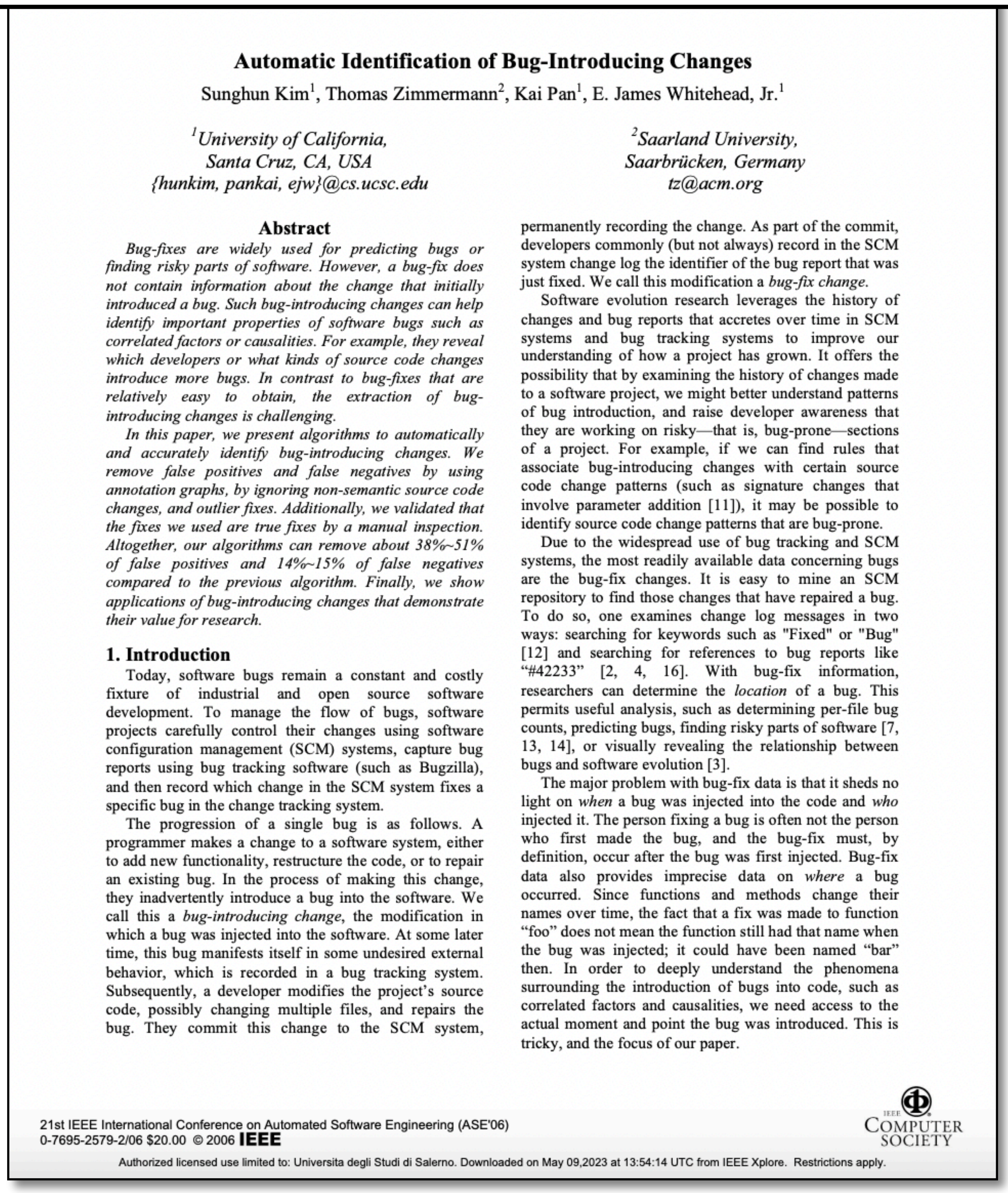
SZZ by Kim et al.



Automatic Identification of Bug-Introducing Changes

Sunghun Kim[1], Thomas Zimmermann[2], Kai Pan[1], E. James Whitehead, Jr.[1]

[1] *University of California, Santa Cruz, CA, USA*
{hunkim, pankai, ejw}@cs.ucsc.edu

[2] *Saarland University, Saarbrücken, Germany*
tz@acm.org

Abstract

Bug-fixes are widely used for predicting bugs or finding risky parts of software. However, a bug-fix does not contain information about the change that initially introduced a bug. Such bug-introducing changes can help identify important properties of software bugs such as correlated factors or causalities. For example, they reveal which developers or what kinds of source code changes introduce more bugs. In contrast to bug-fixes that are relatively easy to obtain, the extraction of bug-introducing changes is challenging.

In this paper, we present algorithms to automatically and accurately identify bug-introducing changes. We remove false positives and false negatives by using annotation graphs, by ignoring non-semantic source code changes, and outlier fixes. Additionally, we validated that the fixes we used are true fixes by a manual inspection. Altogether, our algorithms can remove about 38%~51% of false positives and 14%~15% of false negatives compared to the previous algorithm. Finally, we show applications of bug-introducing changes that demonstrate their value for research.

1. Introduction

Today, software bugs remain a constant and costly fixture of industrial and open source software development. To manage the flow of bugs, software projects carefully control their changes using software configuration management (SCM) systems, capture bug reports using bug tracking software (such as Bugzilla), and then record which change in the SCM system fixes a specific bug in the change tracking system.

The progression of a single bug is as follows. A programmer makes a change to a software system, either to add new functionality, restructure the code, or to repair an existing bug. In the process of making this change, they inadvertently introduce a bug into the software. We call this a *bug-introducing change*, the modification in which a bug was injected into the software. At some later time, this bug manifests itself in some undesired external behavior, which is recorded in a bug tracking system. Subsequently, a developer modifies the project's source code, possibly changing multiple files, and repairs the bug. They commit this change to the SCM system, permanently recording the change. As part of the commit, developers commonly (but not always) record in the SCM system change log the identifier of the bug report that was just fixed. We call this modification a *bug-fix change*.

Software evolution research leverages the history of changes and bug reports that accretes over time in SCM systems and bug tracking systems to improve our understanding of how a project has grown. It offers the possibility that by examining the history of changes made to a software project, we might better understand patterns of bug introduction, and raise developer awareness that they are working on risky—that is, bug-prone—sections of a project. For example, if we can find rules that associate bug-introducing changes with certain source code change patterns (such as signature changes that involve parameter addition [11]), it may be possible to identify source code change patterns that are bug-prone.

Due to the widespread use of bug tracking and SCM systems, the most readily available data concerning bugs are the bug-fix changes. It is easy to mine an SCM repository to find those changes that have repaired a bug. To do so, one examines change log messages in two ways: searching for keywords such as "Fixed" or "Bug" [12] and searching for references to bug reports like "#42233" [2, 4, 16]. With bug-fix information, researchers can determine the *location* of a bug. This permits useful analysis, such as determining per-file bug counts, predicting bugs, finding risky parts of software [7, 13, 14], or visually revealing the relationship between bugs and software evolution [3].

The major problem with bug-fix data is that it sheds no light on *when* a bug was injected into the code and *who* injected it. The person fixing a bug is often not the person who first made the bug, and the bug-fix must, by definition, occur after the bug was first injected. Bug-fix data also provides imprecise data on *where* a bug occurred. Since functions and methods change their names over time, the fact that a fix was made to function "foo" does not mean the function still had that name when the bug was injected; it could have been named "bar" then. In order to deeply understand the phenomena surrounding the introduction of bugs into code, such as correlated factors and causalities, we need access to the actual moment and point the bug was introduced. This is tricky, and the focus of our paper.

21st IEEE International Conference on Automated Software Engineering (ASE'06)
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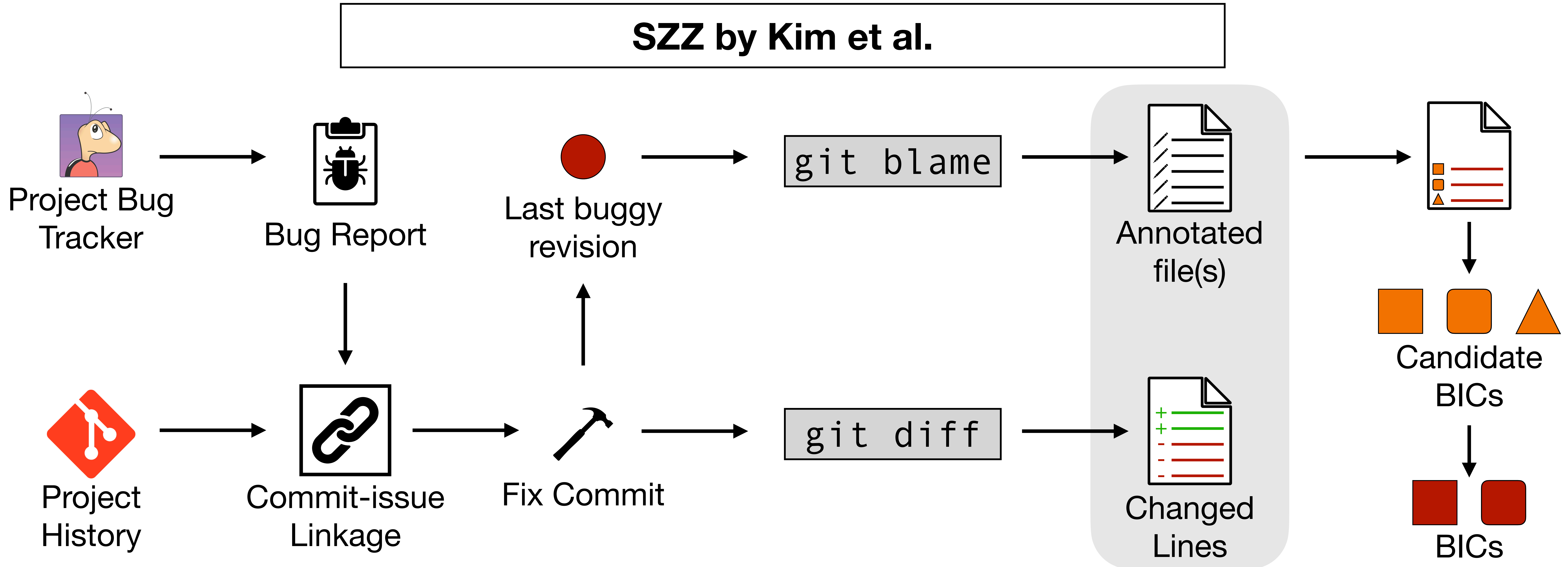
S. Kim, T. Zimmermann, K. Pan and E. J. Jr. Whitehead, "Automatic Identification of Bug-Introducing Changes," *21st IEEE/ACM International Conference on Automated Software Engineering (ASE'06)*, Tokyo, Japan, 2006, pp. 81-90, doi: 10.1109/ASE.2006.23.

Mining VCCs: Borrowing from the Bug World

The SZZ algorithm is quite intuitive, but, despite its simplicity, it has been a revolution in the MSR world. Yet, all that glitters is not gold: it has some problems.



Let's go back to the original SZZ…

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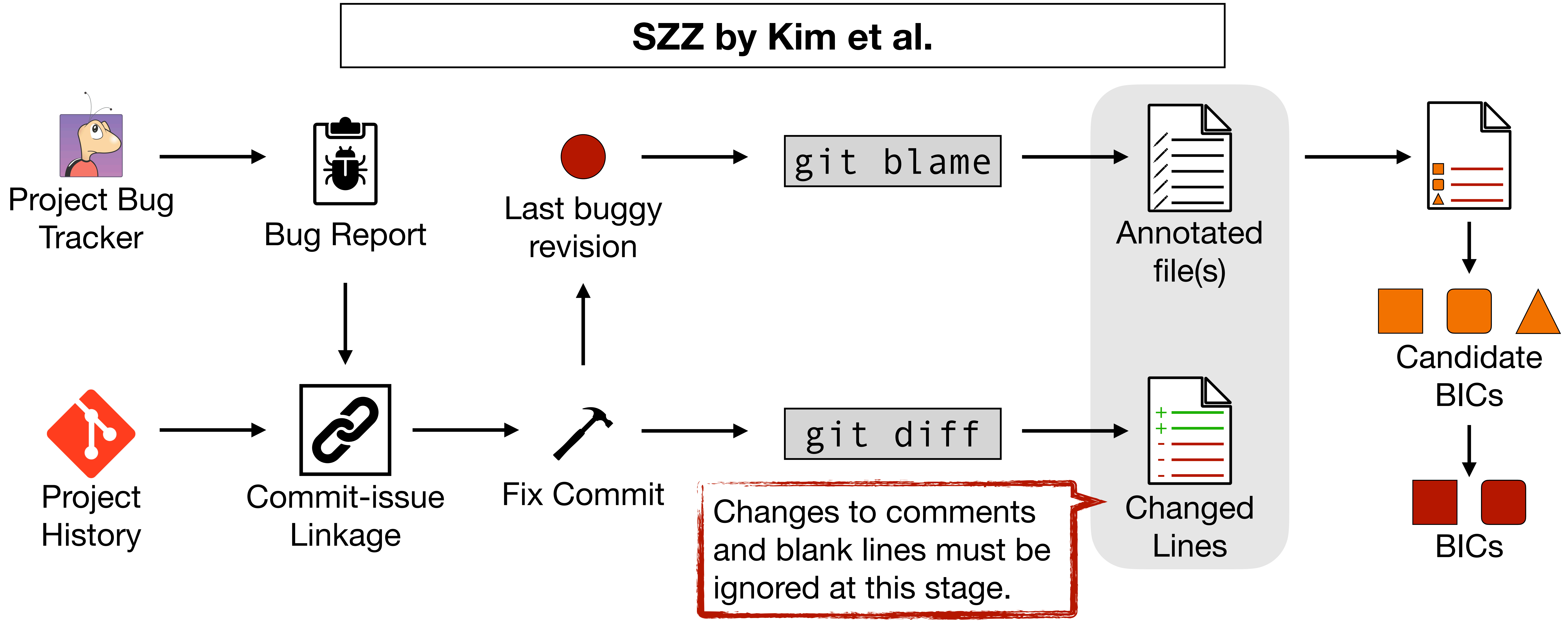

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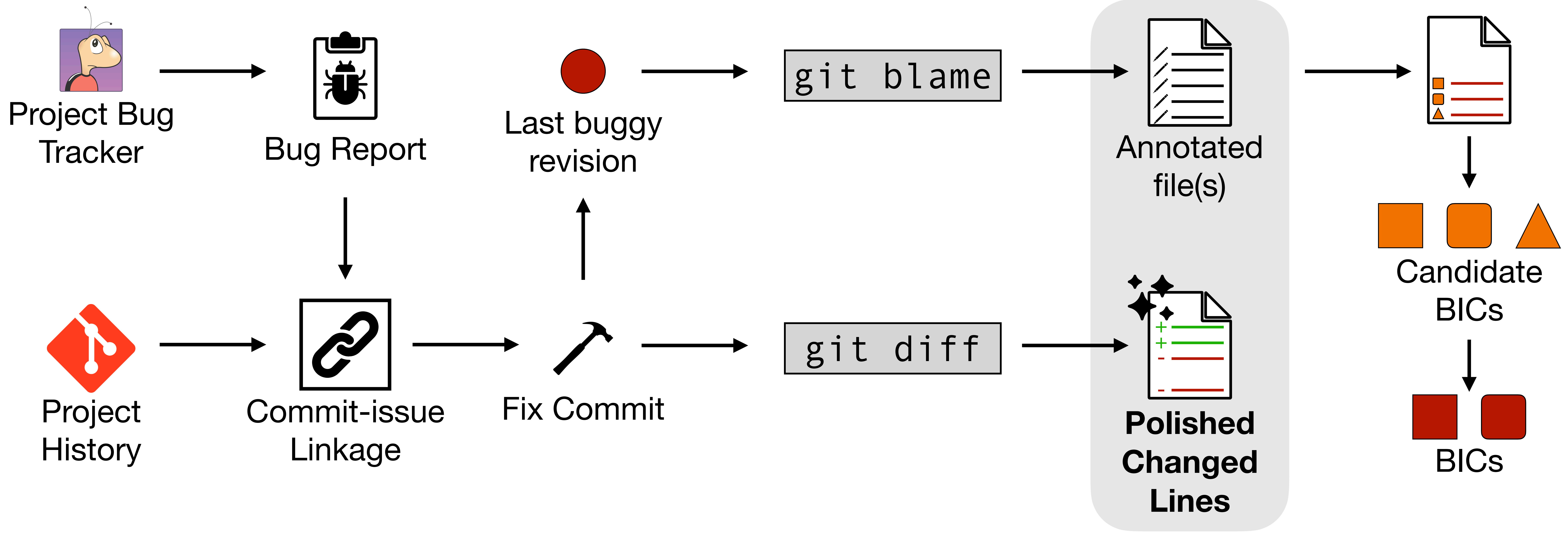

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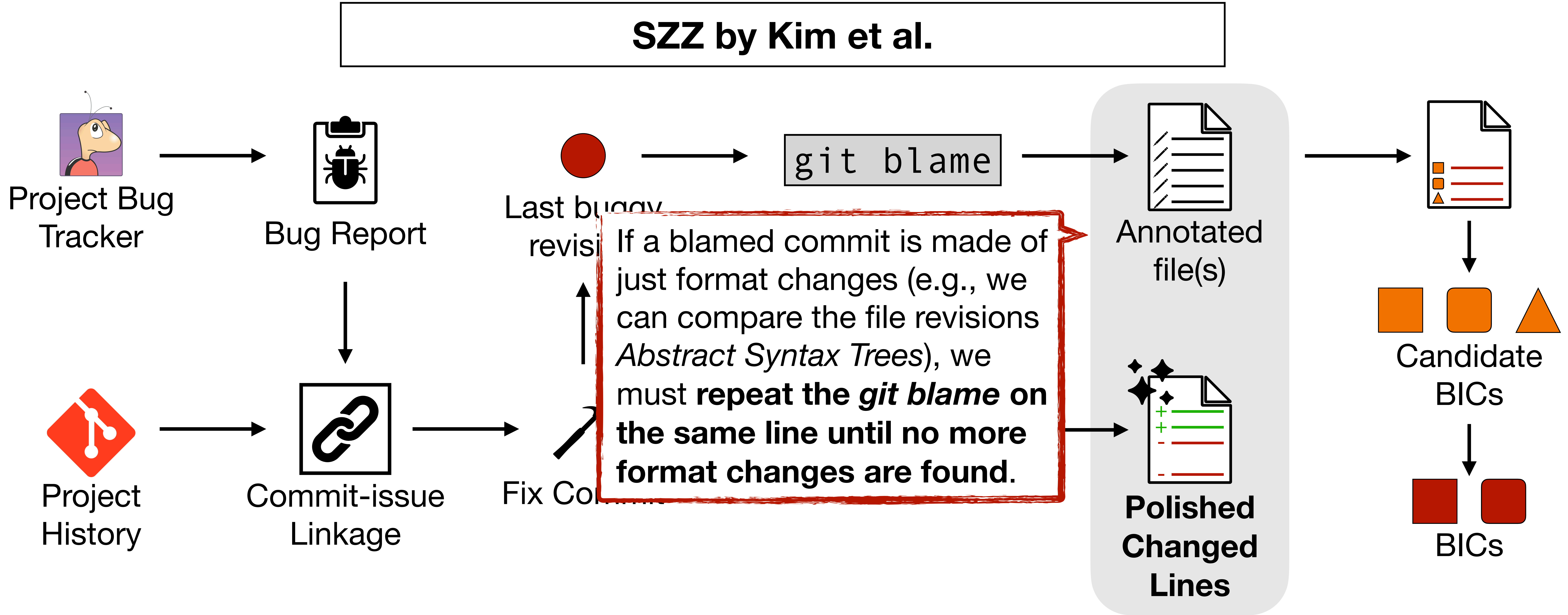

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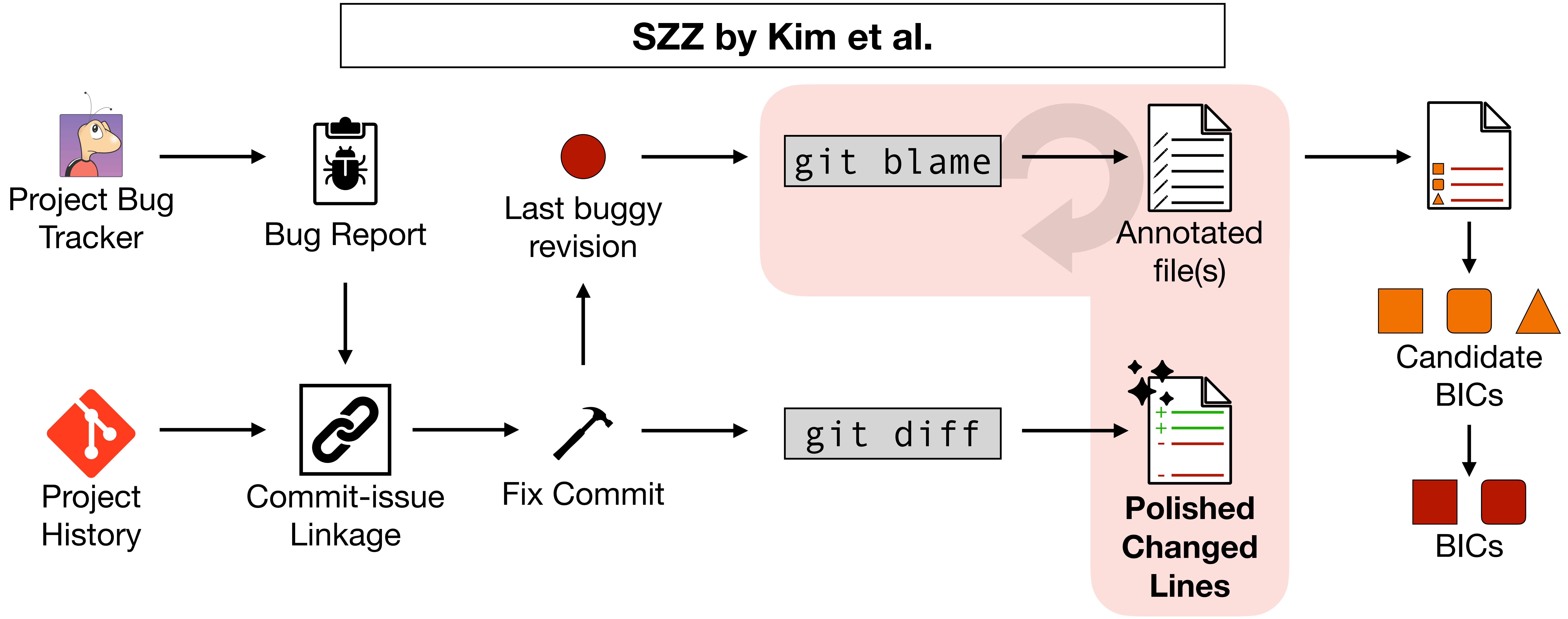


Mining VCCs: Borrowing from the Bug World

This is surely a good improvement, but there are still some more problems…

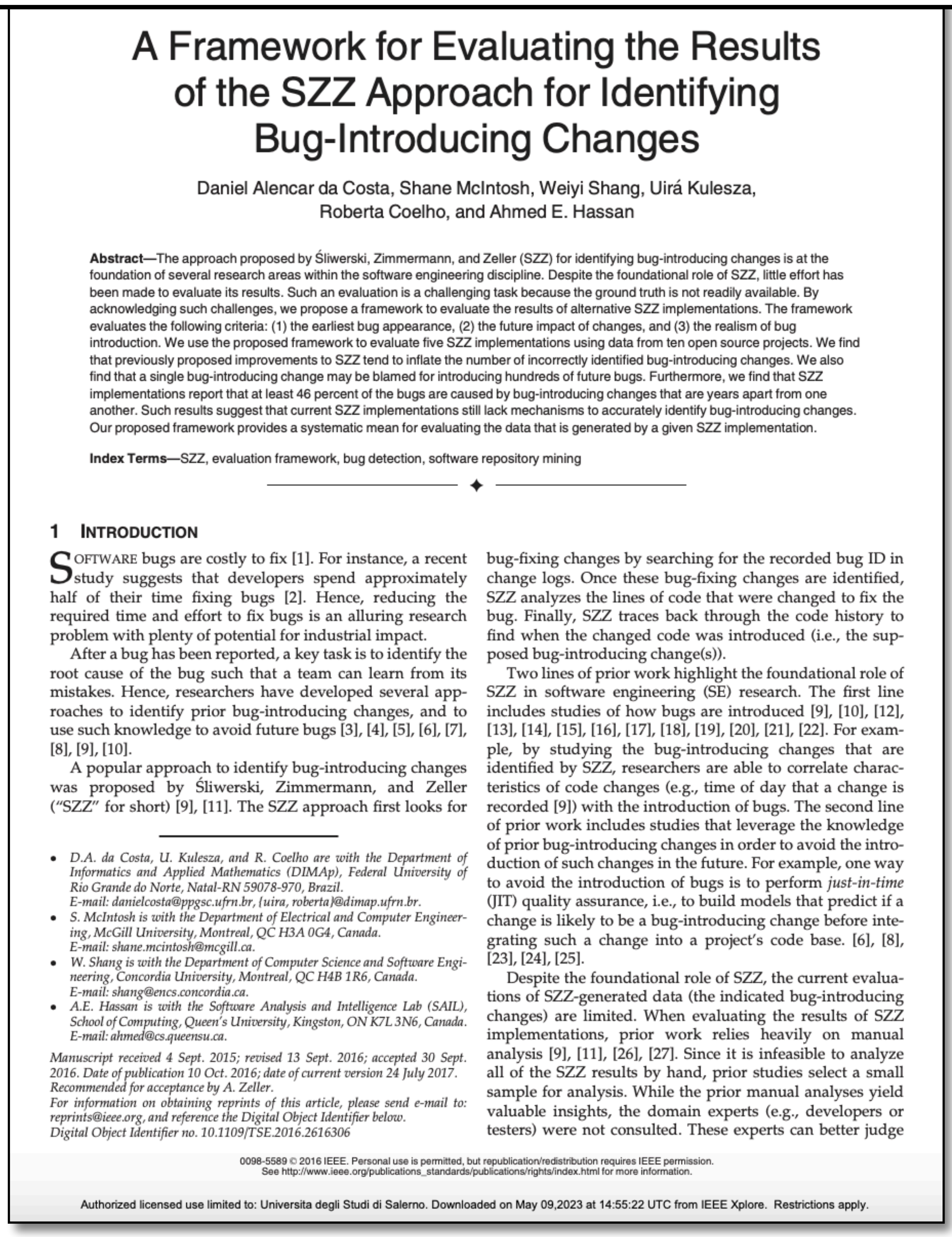
Mining VCCs: Borrowing from the Bug World

This is surely a good improvement, but there are still some more problems…

Meta-changes

The set of candidate BICs/VCCs might be made of commits that do not really modify the source code, e.g., **merge commits**, which incorporate commits from one branch into another.

SZZ by da Costa et al.



A Framework for Evaluating the Results of the SZZ Approach for Identifying Bug-Introducing Changes

Daniel Alencar da Costa, Shane McIntosh, Weiyi Shang, Uirá Kulesza, Roberta Coelho, and Ahmed E. Hassan

Abstract—The approach proposed by Śliwerski, Zimmermann, and Zeller (SZZ) for identifying bug-introducing changes is at the foundation of several research areas within the software engineering discipline. Despite the foundational role of SZZ, little effort has been made to evaluate its results. Such an evaluation is a challenging task because the ground truth is not readily available. By acknowledging such challenges, we propose a framework to evaluate the results of alternative SZZ implementations. The framework evaluates the following criteria: (1) the earliest bug appearance, (2) the future impact of changes, and (3) the realism of bug introduction. We use the proposed framework to evaluate five SZZ implementations using data from ten open source projects. We find that previously proposed improvements to SZZ tend to inflate the number of incorrectly identified bug-introducing changes. We also find that a single bug-introducing change may be blamed for introducing hundreds of future bugs. Furthermore, we find that SZZ implementations report that at least 46 percent of the bugs are caused by bug-introducing changes that are years apart from one another. Such results suggest that current SZZ implementations still lack mechanisms to accurately identify bug-introducing changes. Our proposed framework provides a systematic mean for evaluating the data that is generated by a given SZZ implementation.

Index Terms—SZZ, evaluation framework, bug detection, software repository mining

1 INTRODUCTION

SOFTWARE bugs are costly to fix [1]. For instance, a recent study suggests that developers spend approximately half of their time fixing bugs [2]. Hence, reducing the required time and effort to fix bugs is an alluring research problem with plenty of potential for industrial impact.

After a bug has been reported, a key task is to identify the root cause of the bug such that a team can learn from its mistakes. Hence, researchers have developed several approaches to identify prior bug-introducing changes, and to use such knowledge to avoid future bugs [3], [4], [5], [6], [7], [8], [9], [10].

A popular approach to identify bug-introducing changes was proposed by Śliwerski, Zimmermann, and Zeller ("SZZ" for short) [9], [11]. The SZZ approach first looks for bug-fixing changes by searching for the recorded bug ID in change logs. Once these bug-fixing changes are identified, SZZ analyzes the lines of code that were changed to fix the bug. Finally, SZZ traces back through the code history to find when the changed code was introduced (i.e., the supposed bug-introducing change(s)).

Two lines of prior work highlight the foundational role of SZZ in software engineering (SE) research. The first line includes studies of how bugs are introduced [9], [10], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21], [22]. For example, by studying the bug-introducing changes that are identified by SZZ, researchers are able to correlate characteristics of code changes (e.g., time of day that a change is recorded [9]) with the introduction of bugs. The second line of prior work includes studies that leverage the knowledge of prior bug-introducing changes in order to avoid the introduction of such changes in the future. For example, one way to avoid the introduction of bugs is to perform *just-in-time* (JIT) quality assurance, i.e., to build models that predict if a change is likely to be a bug-introducing change before integrating such a change into a project's code base. [6], [8], [23], [24], [25].

Despite the foundational role of SZZ, the current evaluations of SZZ-generated data (the indicated bug-introducing changes) are limited. When evaluating the results of SZZ implementations, prior work relies heavily on manual analysis [9], [11], [26], [27]. Since it is infeasible to analyze all of the SZZ results by hand, prior studies select a small sample for analysis. While the prior manual analyses yield valuable insights, the domain experts (e.g., developers or testers) were not consulted. These experts can better judge

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- *S. McIntosh is with the Department of Electrical and Computer Engineering, McGill University, Montreal, QC H3A 0G4, Canada. E-mail: shane.mcintosh@mcgill.ca.*
- *W. Shang is with the Department of Computer Science and Software Engineering, Concordia University, Montreal, QC H4B 1R6, Canada. E-mail: shang@encs.concordia.ca.*
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Manuscript received 4 Sept. 2015; revised 13 Sept. 2016; accepted 30 Sept. 2016. Date of publication 10 Oct. 2016; date of current version 24 July 2017. Recommended for acceptance by A. Zeller.
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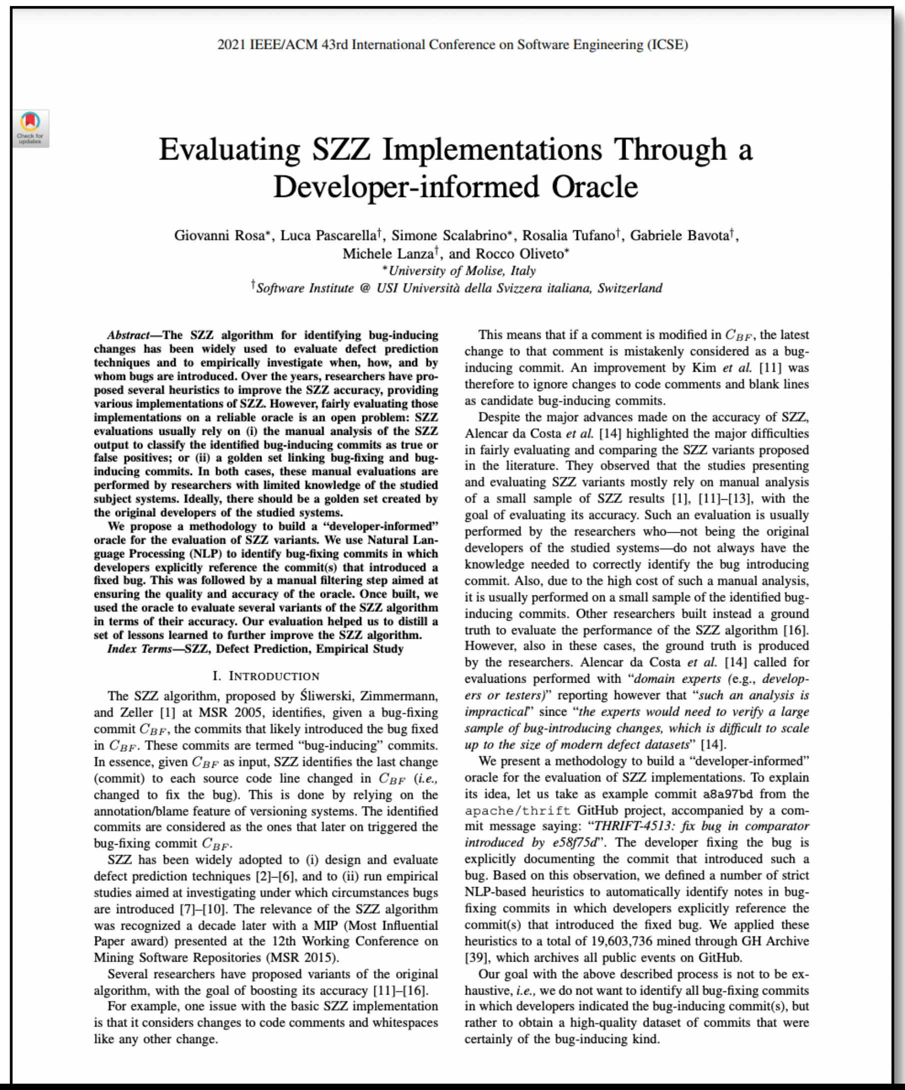
Authorized licensed use limited to: Universita degli Studi di Salerno. Downloaded on May 09,2023 at 14:55:22 UTC from IEEE Xplore. Restrictions apply.

Basically, it's a variant of the SZZ by Kim et al. that **ignores merge commits while traversing the history with the repeated *git blames*.**

D. A. da Costa, S. McIntosh, W. Shang, U. Kulesza, R. Coelho and A. E. Hassan, "A Framework for Evaluating the Results of the SZZ Approach for Identifying Bug-Introducing Changes," in IEEE Transactions on Software Engineering, vol. 43, no. 7, pp. 641-657, 1 July 2017, doi: 10.1109/TSE.2016.2616306.

Mining VCCs: Borrowing from the Bug World

Many SZZ variants have been proposed over the years. It is difficult to remember them all or understand which is better. Luckily, some studies put things in order.

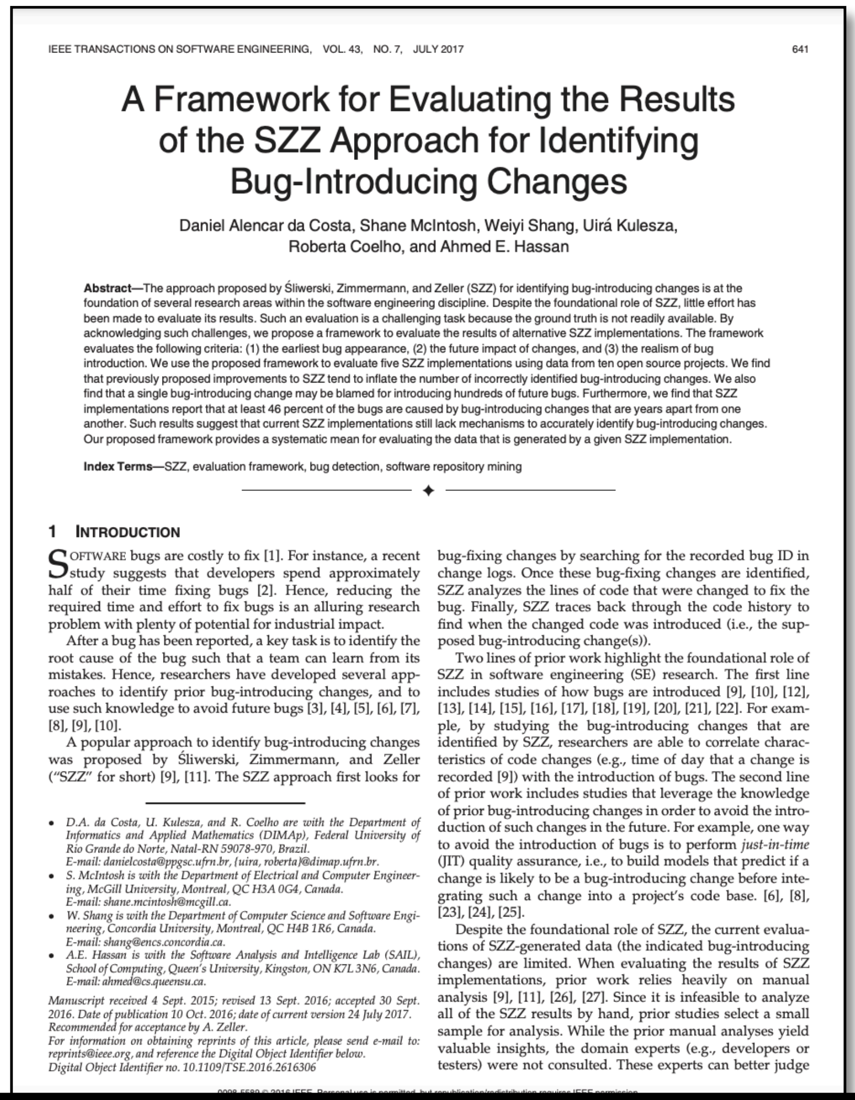

2021 IEEE/ACM 43rd International Conference on Software Engineering (ICSE)

Evaluating SZZ Implementations Through a Developer-informed Oracle

Giovanni Rosa, Luca Pascarella, Simone Scalabrino, Rosalia Tufano, Gabriele Bavota, Michele Lanza, and Rocco Oliveto

Rosa et al.

Comparison of nine SZZ variants on 123 OSS projects.


IEEE TRANSACTIONS ON SOFTWARE ENGINEERING, VOL. 43, NO. 7, JULY 2017

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da Costa et al.

Comparison of five SZZ variants on ten OSS projects.


Empirical Software Engineering (2020) 25:1294–1340

https://doi.org/10.1007/s10664-019-09781-y

How bugs are born: a model to identify how bugs are introduced in software components

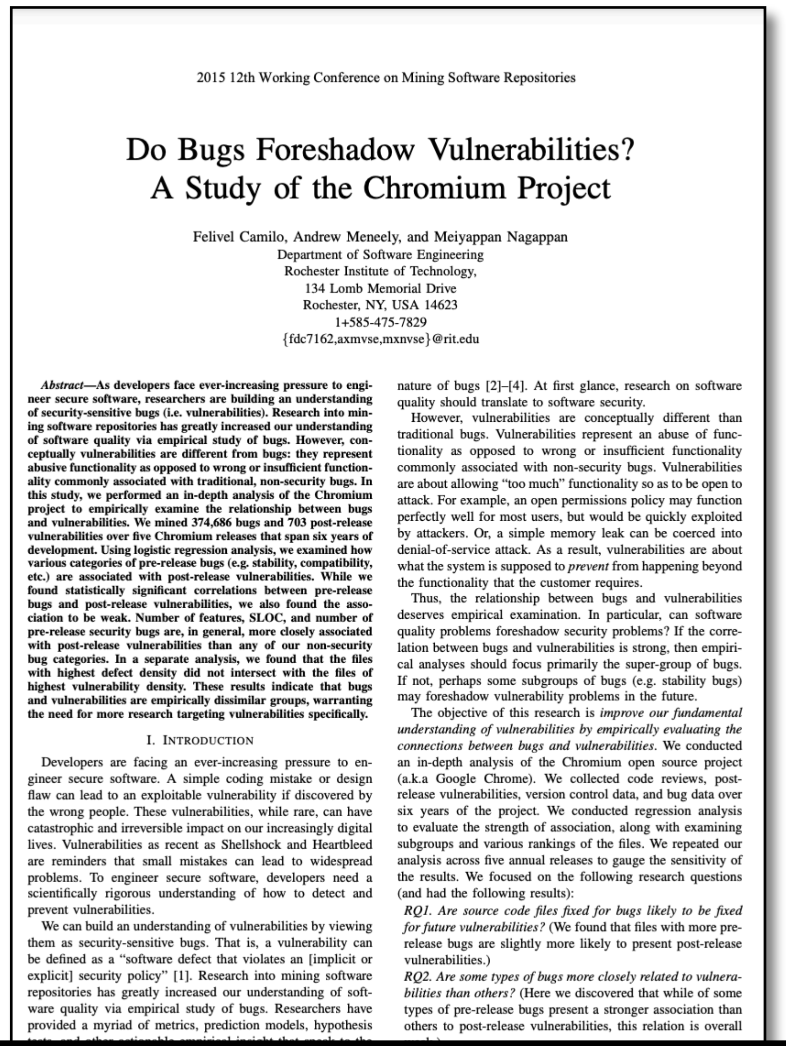
Gema Rodríguez-Pérez · Gregorio Robles · Alexander Serebrenik · Andy Zaidman · Daniel M. Germán · Jesus M. Gonzalez-Barahona

Rodríguez-Pérez et al.

Comparison of four SZZ variants on two OSS projects.

Mining VCCs: Ad hoc Approaches

Okay but reusing the algorithms meant for bugs does not work well for VCCs.
Indeed, there are studies explaining how bugs and vulnerabilities differ.

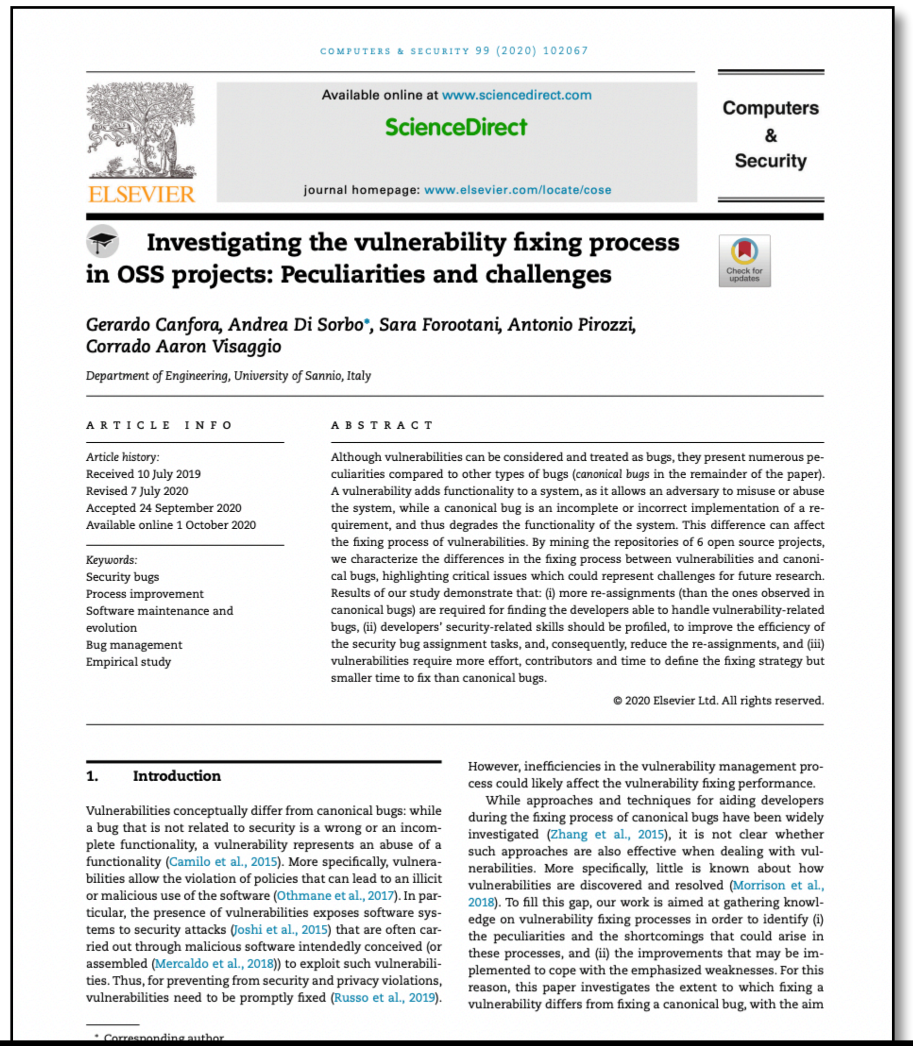

2015 12th Working Conference on Mining Software Repositories

Do Bugs Foreshadow Vulnerabilities? A Study of the Chromium Project

Felivel Camilo, Andrew Meneely, and Meiyappan Nagappan

Camilo et al.

Comparison of pre-release bugs and post-release vulnerabilities in Chromium.

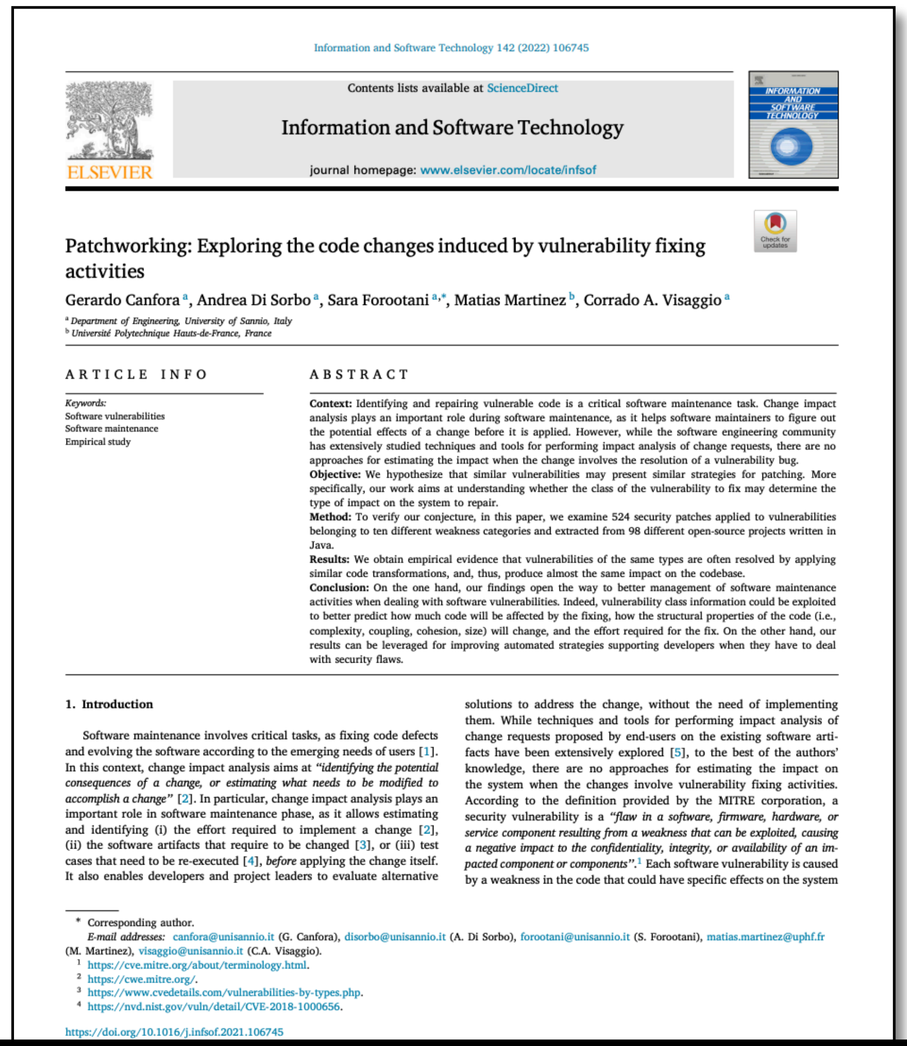

Computers & Security

Investigating the vulnerability fixing process in OSS projects: Peculiarities and challenges

Gerardo Canfora, Andrea Di Sorbo, Sara Forootani, Antonio Pirozzi, Corrado Aaron Visaggio

Canfora et al.

Comparison of bug and vulnerability fixing commits in six OSS projects.


Information and Software Technology

Patchworking: Exploring the code changes induced by vulnerability fixing activities

Gerardo Canfora, Andrea Di Sorbo, Sara Forootani, Matias Martinez, Corrado A. Visaggio

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In-depth analysis of the changes made in vulnerability fixing commits in 98 Java projects.

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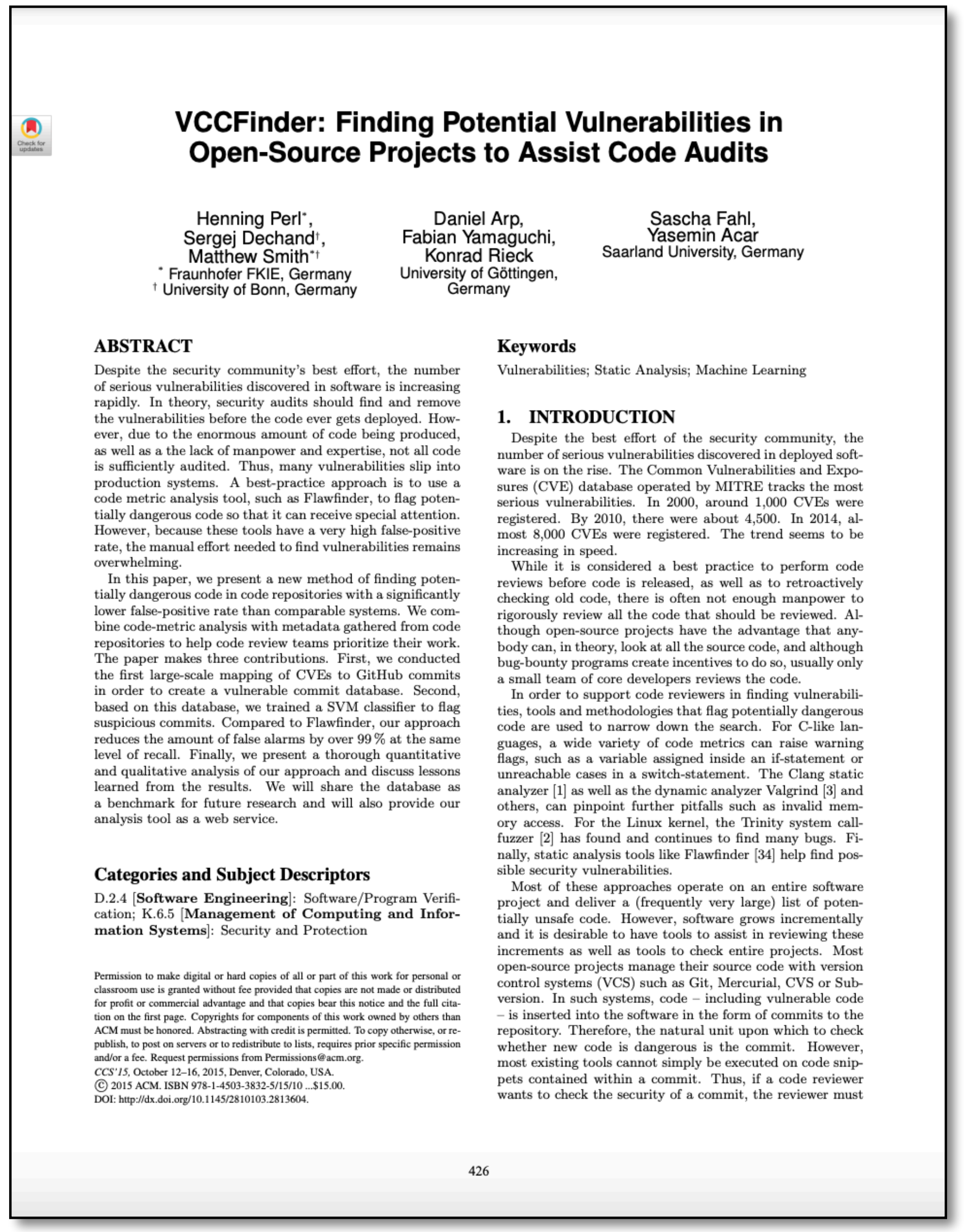

VCCFinder: Finding Potential Vulnerabilities in Open-Source Projects to Assist Code Audits

Henning Perl*, Sergej Dechand†, Matthew Smith*†
* Fraunhofer FKIE, Germany
† University of Bonn, Germany

Daniel Arp, Fabian Yamaguchi, Konrad Rieck
University of Göttingen, Germany

Sascha Fahl, Yasemin Acar
Saarland University, Germany

ABSTRACT

Despite the security community's best effort, the number of serious vulnerabilities discovered in software is increasing rapidly. In theory, security audits should find and remove the vulnerabilities before the code ever gets deployed. However, due to the enormous amount of code being produced, as well as a the lack of manpower and expertise, not all code is sufficiently audited. Thus, many vulnerabilities slip into production systems. A best-practice approach is to use a code metric analysis tool, such as Flawfinder, to flag potentially dangerous code so that it can receive special attention. However, because these tools have a very high false-positive rate, the manual effort needed to find vulnerabilities remains overwhelming.

In this paper, we present a new method of finding potentially dangerous code in code repositories with a significantly lower false-positive rate than comparable systems. We combine code-metric analysis with metadata gathered from code repositories to help code review teams prioritize their work. The paper makes three contributions. First, we conducted the first large-scale mapping of CVEs to GitHub commits in order to create a vulnerable commit database. Second, based on this database, we trained a SVM classifier to flag suspicious commits. Compared to Flawfinder, our approach reduces the amount of false alarms by over 99 % at the same level of recall. Finally, we present a thorough quantitative and qualitative analysis of our approach and discuss lessons learned from the results. We will share the database as a benchmark for future research and will also provide our analysis tool as a web service.

Categories and Subject Descriptors

D.2.4 [**Software Engineering**]: Software/Program Verification; K.6.5 [**Management of Computing and Information Systems**]: Security and Protection

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DOI: http://dx.doi.org/10.1145/2810103.2813604.

Keywords

Vulnerabilities; Static Analysis; Machine Learning

1. INTRODUCTION

Despite the best effort of the security community, the number of serious vulnerabilities discovered in deployed software is on the rise. The Common Vulnerabilities and Exposures (CVE) database operated by MITRE tracks the most serious vulnerabilities. In 2000, around 1,000 CVEs were registered. By 2010, there were about 4,500. In 2014, almost 8,000 CVEs were registered. The trend seems to be increasing in speed.

While it is considered a best practice to perform code reviews before code is released, as well as to retroactively checking old code, there is often not enough manpower to rigorously review all the code that should be reviewed. Although open-source projects have the advantage that anybody can, in theory, look at all the source code, and although bug-bounty programs create incentives to do so, usually only a small team of core developers reviews the code.

In order to support code reviewers in finding vulnerabilities, tools and methodologies that flag potentially dangerous code are used to narrow down the search. For C-like languages, a wide variety of code metrics can raise warning flags, such as a variable assigned inside an if-statement or unreachable cases in a switch-statement. The Clang static analyzer [1] as well as the dynamic analyzer Valgrind [3] and others, can pinpoint further pitfalls such as invalid memory access. For the Linux kernel, the Trinity system call-fuzzer [2] has found and continues to find many bugs. Finally, static analysis tools like Flawfinder [34] help find possible security vulnerabilities.

Most of these approaches operate on an entire software project and deliver a (frequently very large) list of potentially unsafe code. However, software grows incrementally and it is desirable to have tools to assist in reviewing these increments as well as tools to check entire projects. Most open-source projects manage their source code with version control systems (VCS) such as Git, Mercurial, CVS or Subversion. In such systems, code – including vulnerable code – is inserted into the software in the form of commits to the repository. Therefore, the natural unit upon which to check whether new code is dangerous is the commit. However, most existing tools cannot simply be executed on code snippets contained within a commit. Thus, if a code reviewer wants to check the security of a commit, the reviewer must

426

A modified version of the **original SZZ** but:

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- In addition to the blames on the deleted lines, this variant also considers the blames on **the lines around the block of new lines.**

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Mining VCCs: Ad hoc Approaches

Let us consider a commit that fixes a vulnerability by adding this line:

```c
int main(int argc, char* argv[]) {
    char buff[65], *temp;
    temp = argv[1] ? argv[1] : "";          ← Blamed
    if (argc > 0 && strlen(argv[1]) > 64)
      strcpy(buff, temp);                   ← Blamed
    printf("%s", "bye");
}
```

Rationale

Some vulnerabilities are fixed by adding missing checks, e.g., an *if* added before reading from a buffer. Hence, the **context** around the new code blocks might be responsible for the vulnerability.

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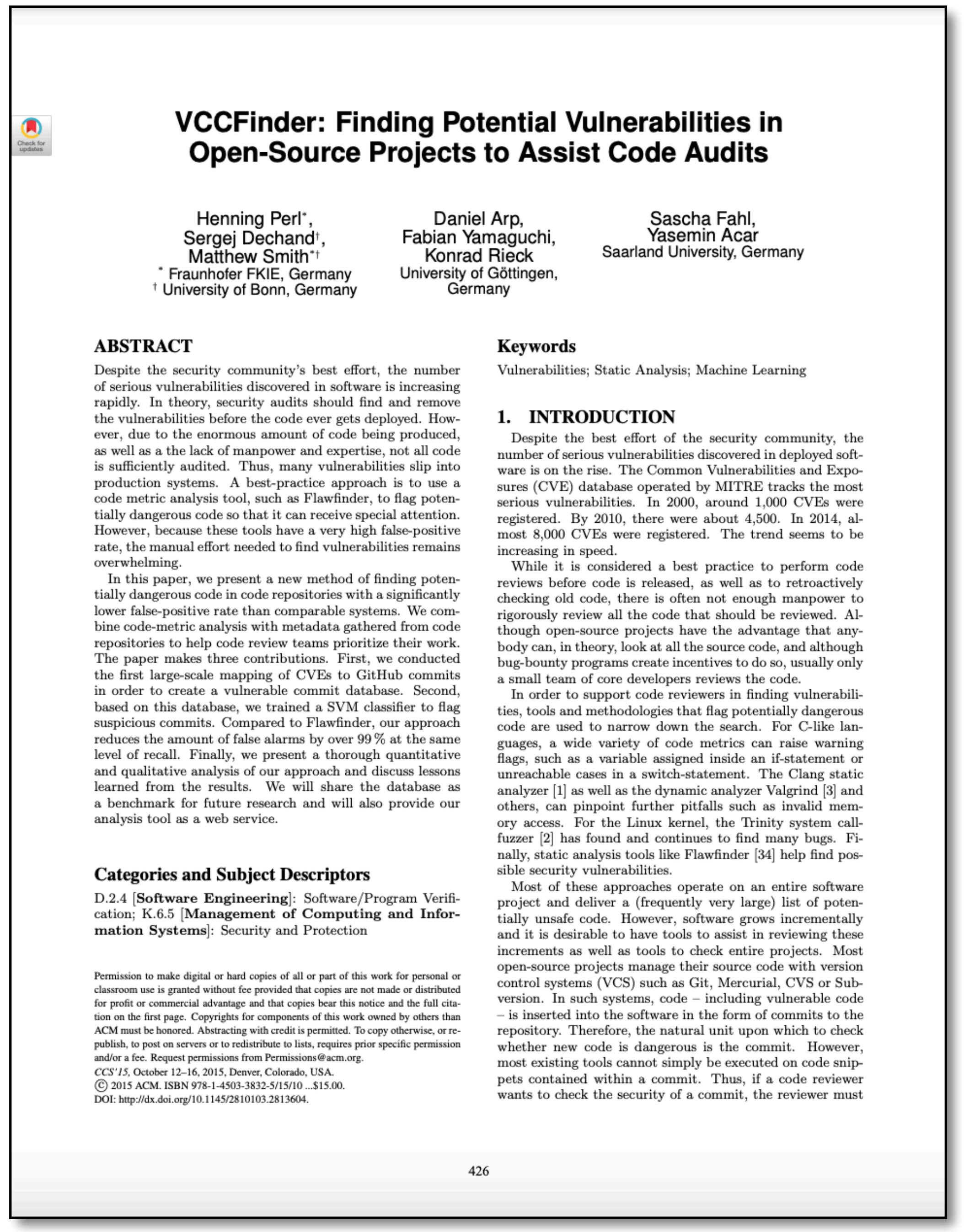

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- It returns **only the most blamed commit.** In case of a tie, all the commits with the top score are returned (ex aequo).

H. Perl, S. Dechand, M. Smith, D. Arp, F. Yamaguchi, K. Rieck, S. Fahl, and Y. Acar. 2015. VCCFinder: Finding Potential Vulnerabilities in Open-Source Projects to Assist Code Audits. In Proceedings of the 22nd ACM SIGSAC Conference on Computer and Communications Security (CCS '15). https://doi.org/10.1145/2810103.2813604

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Okay but reusing the algorithms meant for bugs does not work well for VCCs. Indeed, there are studies explaining how bugs and vulnerabilities differ. → **We need other VCC-specific techniques!**

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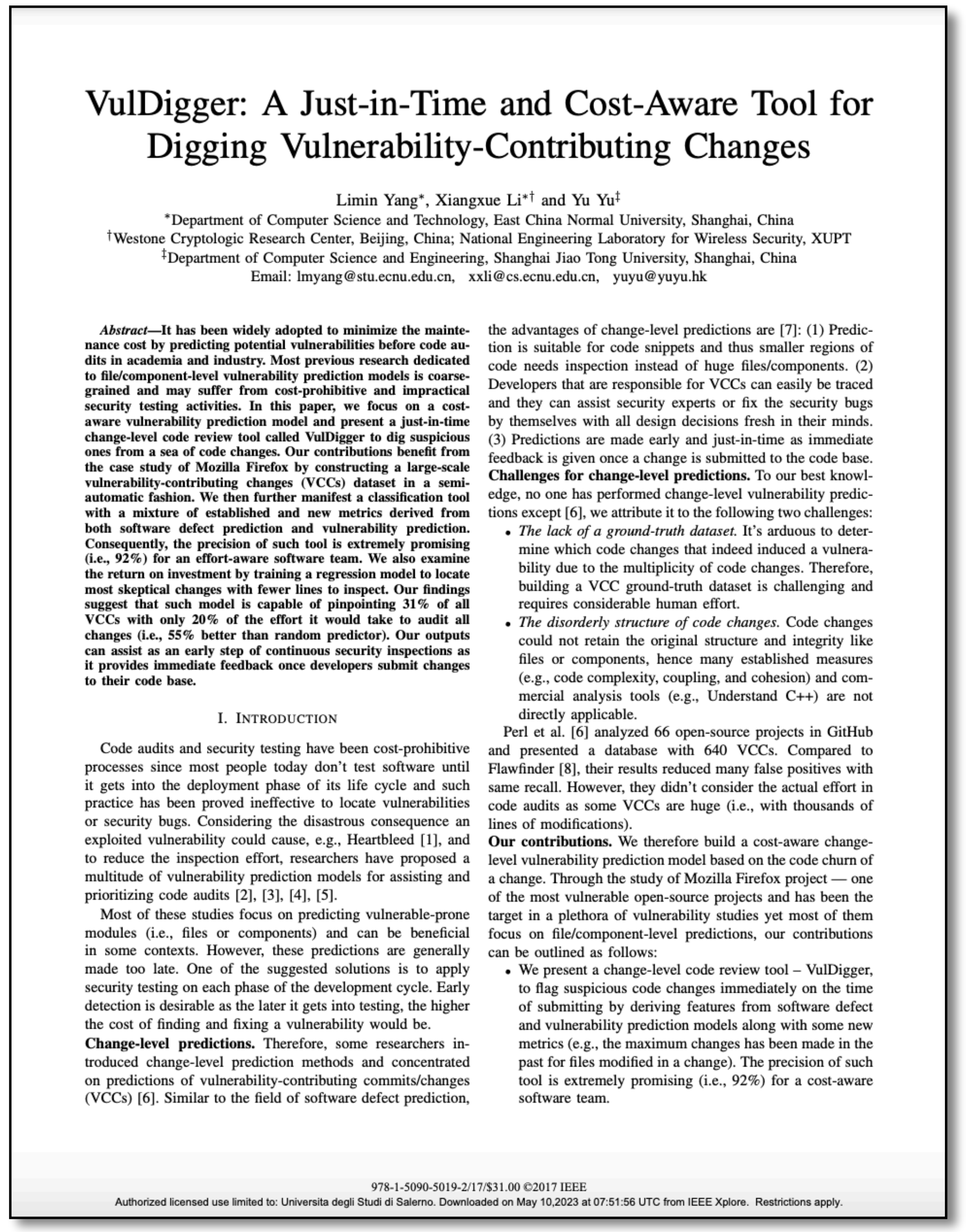
- V-SZZ by Bao et al.



VulDigger: A Just-in-Time and Cost-Aware Tool for Digging Vulnerability-Contributing Changes

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***Abstract*—It has been widely adopted to minimize the maintenance cost by predicting potential vulnerabilities before code audits in academia and industry. Most previous research dedicated to file/component-level vulnerability prediction models is coarse-grained and may suffer from cost-prohibitive and impractical security testing activities. In this paper, we focus on a cost-aware vulnerability prediction model and present a just-in-time change-level code review tool called VulDigger to dig suspicious ones from a sea of code changes. Our contributions benefit from the case study of Mozilla Firefox by constructing a large-scale vulnerability-contributing changes (VCCs) dataset in a semi-automatic fashion. We then further manifest a classification tool with a mixture of established and new metrics derived from both software defect prediction and vulnerability prediction. Consequently, the precision of such tool is extremely promising (i.e., 92%) for an effort-aware software team. We also examine the return on investment by training a regression model to locate most skeptical changes with fewer lines to inspect. Our findings suggest that such model is capable of pinpointing 31% of all VCCs with only 20% of the effort it would take to audit all changes (i.e., 55% better than random predictor). Our outputs can assist as an early step of continuous security inspections as it provides immediate feedback once developers submit changes to their code base.**

I. Introduction

Code audits and security testing have been cost-prohibitive processes since most people today don't test software until it gets into the deployment phase of its life cycle and such practice has been proved ineffective to locate vulnerabilities or security bugs. Considering the disastrous consequence an exploited vulnerability could cause, e.g., Heartbleed [1], and to reduce the inspection effort, researchers have proposed a multitude of vulnerability prediction models for assisting and prioritizing code audits [2], [3], [4], [5].

Most of these studies focus on predicting vulnerable-prone modules (i.e., files or components) and can be beneficial in some contexts. However, these predictions are generally made too late. One of the suggested solutions is to apply security testing on each phase of the development cycle. Early detection is desirable as the later it gets into testing, the higher the cost of finding and fixing a vulnerability would be.

Change-level predictions. Therefore, some researchers introduced change-level prediction methods and concentrated on predictions of vulnerability-contributing commits/changes (VCCs) [6]. Similar to the field of software defect prediction, the advantages of change-level predictions are [7]: (1) Prediction is suitable for code snippets and thus smaller regions of code needs inspection instead of huge files/components. (2) Developers that are responsible for VCCs can easily be traced and they can assist security experts or fix the security bugs by themselves with all design decisions fresh in their minds. (3) Predictions are made early and just-in-time as immediate feedback is given once a change is submitted to the code base.

Challenges for change-level predictions. To our best knowledge, no one has performed change-level vulnerability predictions except [6], we attribute it to the following two challenges:

- *The lack of a ground-truth dataset.* It's arduous to determine which code changes that indeed induced a vulnerability due to the multiplicity of code changes. Therefore, building a VCC ground-truth dataset is challenging and requires considerable human effort.
- *The disorderly structure of code changes.* Code changes could not retain the original structure and integrity like files or components, hence many established measures (e.g., code complexity, coupling, and cohesion) and commercial analysis tools (e.g., Understand C++) are not directly applicable.

Perl et al. [6] analyzed 66 open-source projects in GitHub and presented a database with 640 VCCs. Compared to Flawfinder [8], their results reduced many false positives with same recall. However, they didn't consider the actual effort in code audits as some VCCs are huge (i.e., with thousands of lines of modifications).

Our contributions. We therefore build a cost-aware change-level vulnerability prediction model based on the code churn of a change. Through the study of Mozilla Firefox project — one of the most vulnerable open-source projects and has been the target in a plethora of vulnerability studies yet most of them focus on file/component-level predictions, our contributions can be outlined as follows:

- We present a change-level code review tool – VulDigger, to flag suspicious code changes immediately on the time of submitting by deriving features from software defect and vulnerability prediction models along with some new metrics (e.g., the maximum changes has been made in the past for files modified in a change). The precision of such tool is extremely promising (i.e., 92%) for a cost-aware software team.

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A modified version of the **SZZ by Perl et al.** but:

- Test and non-C/C++ files are ignored. Changes to comments, empty lines, and whitespaces are ignored as well.
- For each new line added, the blame around this line is considered **only if it contains a C/C++ keyword or a function call**.
- Unlike the Perl et al. variant, it considers the blames around blocks of new lines **only if they do not contain new functions**.

L. Yang, X. Li and Y. Yu, "VulDigger: A Just-in-Time and Cost-Aware Tool for Digging Vulnerability-Contributing Changes," GLOBECOM 2017 - 2017 IEEE Global Communications Conference, Singapore, 2017, pp. 1-7, doi: 10.1109/GLOCOM.2017.8254428.

Mining VCCs: Ad hoc Approaches

Let us consider a commit that fixes a vulnerability by adding this line and a new function:

```
int main(int argc, char* argv[]) {
    char buff[65], *temp;
    temp = argv[1] ? argv[1] : "";        <- Blamed
    if (argc > 0 && my_len(argv[1]) > 64)
      strcpy(buff, temp);                 <- Blamed
    printf("%s", "bye");
}                                         <- NOT blamed
int my_len(char* buff) {
  return strlen(buff);
}
```

Rationale

Functions can be added anywhere in the file. Hence, the local context does not always involve meaningful parts.

L. Yang, X. Li and Y. Yu, "VulDigger: A Just-in-Time and Cost-Aware Tool for Digging Vulnerability-Contributing Changes," GLOBECOM 2017 - 2017 IEEE Global Communications Conference, Singapore, 2017, pp. 1-7, doi: 10.1109/GLOCOM.2017.8254428.

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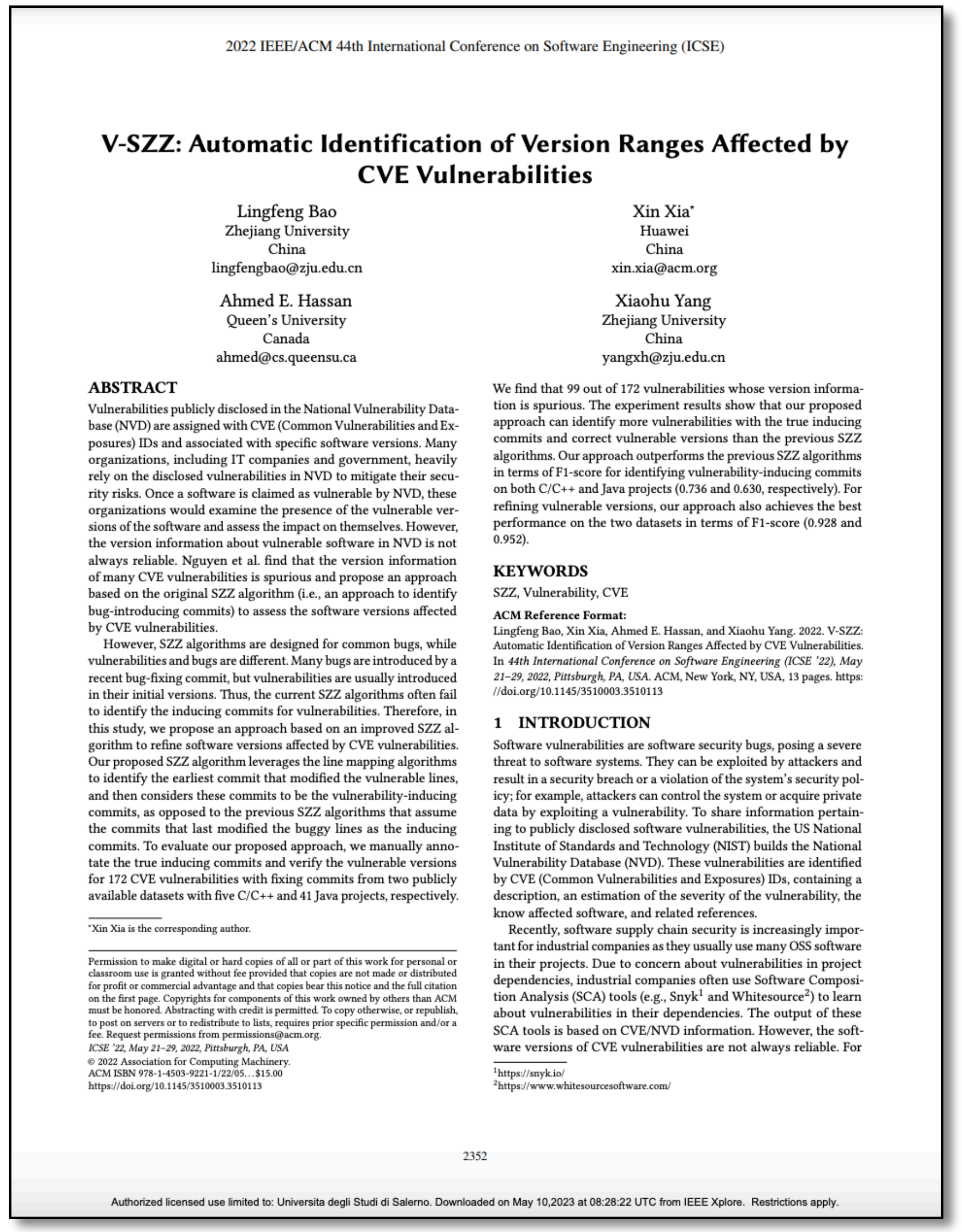

2022 IEEE/ACM 44th International Conference on Software Engineering (ICSE)

V-SZZ: Automatic Identification of Version Ranges Affected by CVE Vulnerabilities

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ABSTRACT

Vulnerabilities publicly disclosed in the National Vulnerability Database (NVD) are assigned with CVE (Common Vulnerabilities and Exposures) IDs and associated with specific software versions. Many organizations, including IT companies and government, heavily rely on the disclosed vulnerabilities in NVD to mitigate their security risks. Once a software is claimed as vulnerable by NVD, these organizations would examine the presence of the vulnerable versions of the software and assess the impact on themselves. However, the version information about vulnerable software in NVD is not always reliable. Nguyen et al. find that the version information of many CVE vulnerabilities is spurious and propose an approach based on the original SZZ algorithm (i.e., an approach to identify bug-introducing commits) to assess the software versions affected by CVE vulnerabilities.

However, SZZ algorithms are designed for common bugs, while vulnerabilities and bugs are different. Many bugs are introduced by a recent bug-fixing commit, but vulnerabilities are usually introduced in their initial versions. Thus, the current SZZ algorithms often fail to identify the inducing commits for vulnerabilities. Therefore, in this study, we propose an approach based on an improved SZZ algorithm to refine software versions affected by CVE vulnerabilities. Our proposed SZZ algorithm leverages the line mapping algorithms to identify the earliest commit that modified the vulnerable lines, and then considers these commits to be the vulnerability-inducing commits, as opposed to the previous SZZ algorithms that assume the commits that last modified the buggy lines as the inducing commits. To evaluate our proposed approach, we manually annotate the true inducing commits and verify the vulnerable versions for 172 CVE vulnerabilities with fixing commits from two publicly available datasets with five C/C++ and 41 Java projects, respectively. We find that 99 out of 172 vulnerabilities whose version information is spurious. The experiment results show that our proposed approach can identify more vulnerabilities with the true inducing commits and correct vulnerable versions than the previous SZZ algorithms. Our approach outperforms the previous SZZ algorithms in terms of F1-score for identifying vulnerability-inducing commits on both C/C++ and Java projects (0.736 and 0.630, respectively). For refining vulnerable versions, our approach also achieves the best performance on the two datasets in terms of F1-score (0.928 and 0.952).

KEYWORDS

SZZ, Vulnerability, CVE

ACM Reference Format:
Lingfeng Bao, Xin Xia, Ahmed E. Hassan, and Xiaohu Yang. 2022. V-SZZ: Automatic Identification of Version Ranges Affected by CVE Vulnerabilities. In *44th International Conference on Software Engineering (ICSE '22), May 21–29, 2022, Pittsburgh, PA, USA*. ACM, New York, NY, USA, 13 pages. https://doi.org/10.1145/3510003.3510113

1 INTRODUCTION

Software vulnerabilities are software security bugs, posing a severe threat to software systems. They can be exploited by attackers and result in a security breach or a violation of the system's security policy; for example, attackers can control the system or acquire private data by exploiting a vulnerability. To share information pertaining to publicly disclosed software vulnerabilities, the US National Institute of Standards and Technology (NIST) builds the National Vulnerability Database (NVD). These vulnerabilities are identified by CVE (Common Vulnerabilities and Exposures) IDs, containing a description, an estimation of the severity of the vulnerability, the know affected software, and related references.

Recently, software supply chain security is increasingly important for industrial companies as they usually use many OSS software in their projects. Due to concern about vulnerabilities in project dependencies, industrial companies often use Software Composition Analysis (SCA) tools (e.g., Snyk[1] and Whitesource[2]) to learn about vulnerabilities in their dependencies. The output of these SCA tools is based on CVE/NVD information. However, the software versions of CVE vulnerabilities are not always reliable. For

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[1] https://snyk.io/
[2] https://www.whitesourcesoftware.com/

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ICSE '22, May 21–29, 2022, Pittsburgh, PA, USA
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ACM ISBN 978-1-4503-9221-1/22/05...$15.00
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A modified version of the **SZZ by Kim et al.** but:

- The git blame is **repeated beyond format changes** until reaching the commits that created the blamed lines. This approach is supported by both AST and string similarity matching.

Rationale

According to certain studies, many vulnerabilities are *foundational*, i.e., introduced early in the project, even before the first release.

L. Bao, X. Xia, A. E. Hassan and X. Yang, "V-SZZ: Automatic Identification of Version Ranges Affected by CVE Vulnerabilities," 2022 IEEE/ACM 44th International Conference on Software Engineering (ICSE), Pittsburgh, PA, USA, 2022, pp. 2352-2364, doi: 10.1145/3510003.3510113.

Are we sure they work?

Performance Indicators

How can we be sure VCC mining algorithms work as expected? We want our algorithm to minimize:

False Positives The algorithm returned a commit that was not a real VCC.

False Negatives The algorithm did not return one (or more) real VCC.

From the *Information Retrieval* world, we commonly use these metrics to evaluate such approaches:

$$Precision = \frac{|correct \cap identified|}{|identified|}$$

"Among the found VCCs, how many are correct?"

$$Recall = \frac{|correct \cap identified|}{|correct|}$$

"Among the correct VCCs, how many did I find?"

$$F - measure = \frac{2}{\frac{1}{Precision} + \frac{1}{Recall}}$$

"Trade-off between precision and recall"

Performance Indicators

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$$Recall = \frac{|correct \cap identified|}{|correct|}$$

$$F - measure = \frac{2}{\frac{1}{Precision} + \frac{1}{Recall}}$$

But how do we determine this "correct" set?

Building the Ground Truth

We need to build a **ground truth** (a.k.a. *golden set*) that is the “standard” for evaluating the algorithms. In other words, a dataset of true VCCs and non-VCCs. We can employ some methods:

- **Exhaustive Labeling**
- **Bisect-driven Labeling**
- **Precision Assessment**
- **Developer-informed Oracle**

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Exhaustive Labeling | Bisect-driven Labeling | Precision Assessment | Developer-informed Oracle

For each vulnerability, we manually inspect all the commits in the project and assess whether it is a VCC. Complete but time-consuming.

Recommended when… we want to be exhaustive (!) or just want to analyze a few vulnerabilities.

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Exhaustive Labeling | **Bisect-driven Labeling** | Precision Assessment | Developer-informed Oracle

For each vulnerability, we run git bisect until we find at least one VCC. Inspired by the Meneely et al. mining technique. Less complete but faster, reducing the workload by a logarithmic factor.

Recommended when… we don’t need a complete *correct* set, and we have time to inspect.

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Exhaustive Labeling	Bisect-driven Labeling	**Precision Assessment**	Developer-informed Oracle

For each commit flagged as VCC by the algorithm, we inspect it to assess whether it is a real VCC. This will not produce the *correct* set, but only *correct* $\cap$ *identified*. Hence, we are not aware of the “missed” VCCs.

Recommended when… we are only interested in assessing the precision.

Building the Ground Truth

We need to build a **ground truth** (a.k.a. *golden set*) that is the “standard” for evaluating the algorithms. In other words, a dataset of true VCCs and non-VCCs. We can employ some methods:

Exhaustive Labeling | Bisect-driven Labeling | Precision Assessment | **Developer-informed Oracle**

For each vulnerability, we process the fixing commit message to retrieve mentions of the culprit commit(s). Developers sometimes explicitly indicate the commit where the vulnerability was introduced. This method has a fully automated part based on NLP/text mining and an (optional) manual assessment part.

Recommended when… we don’t need a complete *correct* set and, we want developers’ experience.

G. Rosa, L. Pascarella, S. Scalabrino, R. Tufano, G. Bavota, M. Lanza, and R. Oliveto. 2021. Evaluating SZZ Implementations Through a Developer-informed Oracle. In Proceedings of the 43rd International Conference on Software Engineering (ICSE '21). IEEE Press, 436–447. https://doi.org/10.1109/ICSE43902.2021.00049

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EXAMPLE

CVE-2011-5321 (NULL pointer dereference) in Linux Kernel was fixed in commit *c290f835* by just adding a single line of code.

> "
> *TTY: drop driver reference in tty_open fail path*
> *When tty_driver_lookup_tty fails in tty_open, we forget to drop a reference to the tty driver. This was added by commit 4a2b5fd (Move tty lookup/reopen to caller). […]*

```
if (!tty) {
  /* check whether we're reopening an existing tty */
  tty = tty_driver_lookup_tty(driver, inode, index);
  if (IS_ERR(tty)) {
    tty_unlock();
    mutex_unlock(&tty_mutex);
    tty_driver_kref_put(driver);
    return PTR_ERR(tty);
  }
}
```

G. Rosa, L. Pascarella, S. Scalabrino, R. Tufano, G. Bavota, M. Lanza, and R. Oliveto. 2021. Evaluating SZZ Implementations Through a Developer-informed Oracle. In Proceedings of the 43rd International Conference on Software Engineering (ICSE '21). IEEE Press, 436–447. https://doi.org/10.1109/ICSE43902.2021.00049

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According to the developer who fixed this vulnerability, this is a VCC (which involuntarily introduced the vulnerability while refactoring some code)**.**

G. Rosa, L. Pascarella, S. Scalabrino, R. Tufano, G. Bavota, M. Lanza, and R. Oliveto. 2021. Evaluating SZZ Implementations Through a Developer-informed Oracle. In Proceedings of the 43rd International Conference on Software Engineering (ICSE '21). IEEE Press, 436–447. https://doi.org/10.1109/ICSE43902.2021.00049

How can I use them?

Available Tools

OpenSZZ

Command-line tool written in Java implementing the **standard SZZ**, analyzing GitHub repositories and Jira issues.

SZZUnleashed

Collection of Python and Java scripts implementing the **SZZ by Williams and Spacco** (not seen).

PyDriller

Python library for repository mining, including an implementation of **SZZ by Kim et al.**

Archeogit

Command-line tool written in Python implementing the **SZZ by Perl et al.**

V-SZZ

Collection of Python scripts replicating **V-SZZ by Bao et al.**

PySZZ

Collection of Python scripts implementing **several SZZ variants** with a uniform interface.

Isn't there something ready to use?

Available Datasets

Curated

Vulnerability History Project

Database of curated histories of 2,677 vulnerabilities of eight open-source projects. Built by **class assignments in a Master's degree course held at RIT.**

Java VCC Dataset

Dataset of 100 VCCs of 71 known vulnerabilities affecting popular Java projects. Built by **manually analyzing the history aided by blames on fixing commits**.

Mined

Secret Life Dataset

Dataset of 12,256 VCCs of 3,663 vulnerabilities affecting 1,096 open-source projects. Built by **running an SZZ variant by Iannone et al.** (not seen).

FrontEndART Dataset

Dataset of ~700 VCCs of 564 vulnerabilities affecting 198 Java projects. Built by **running an SZZ variant by Aladics et al.**

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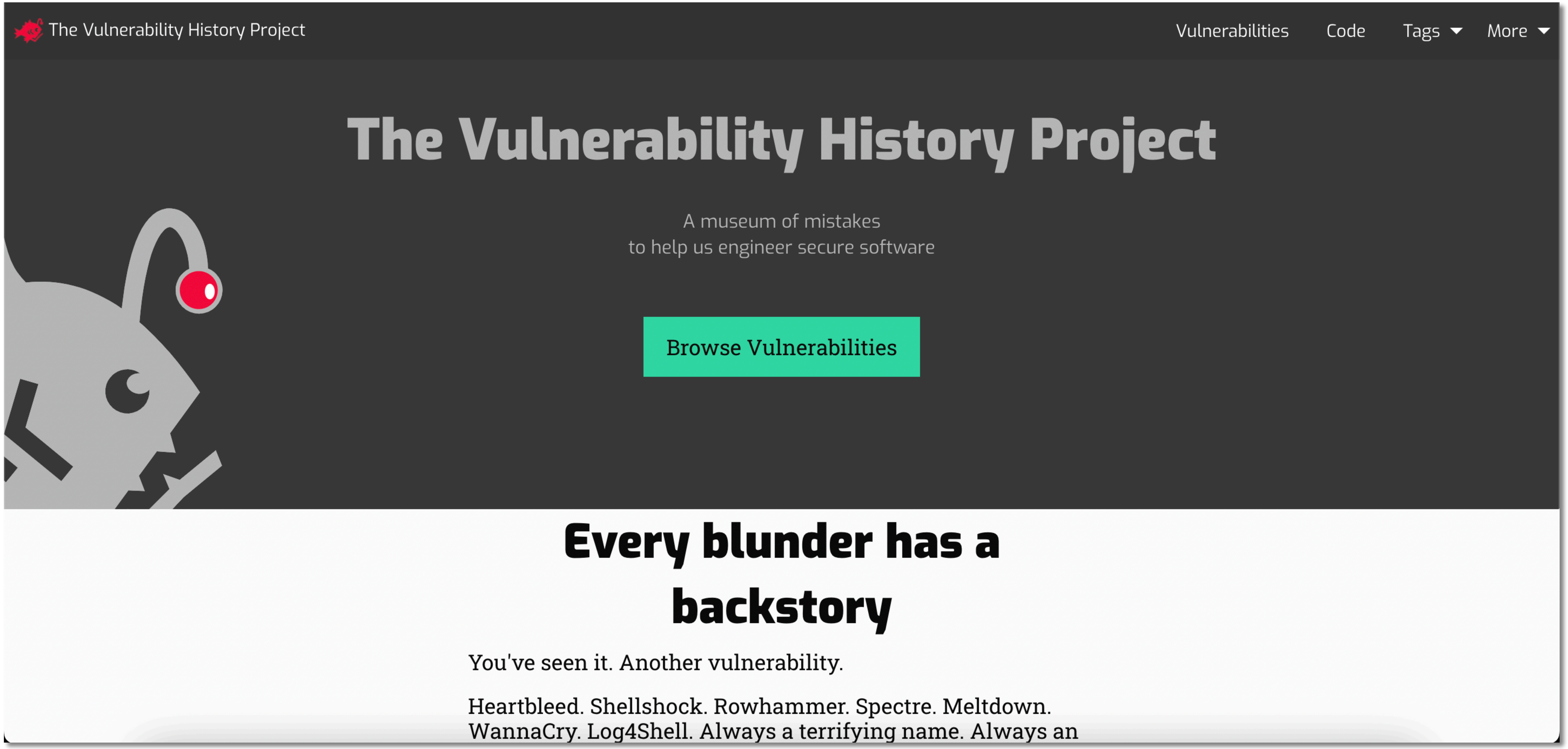

Available Datasets

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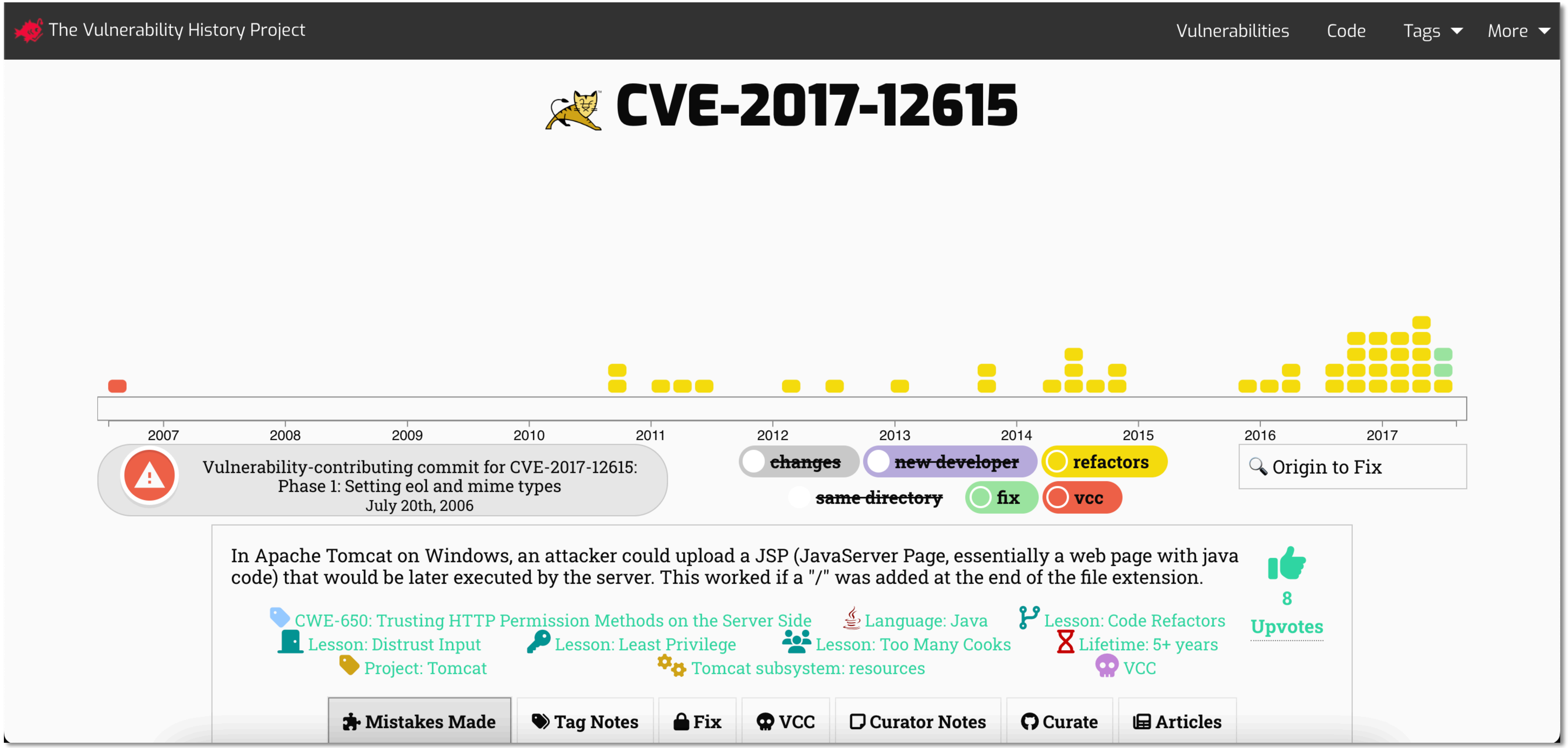

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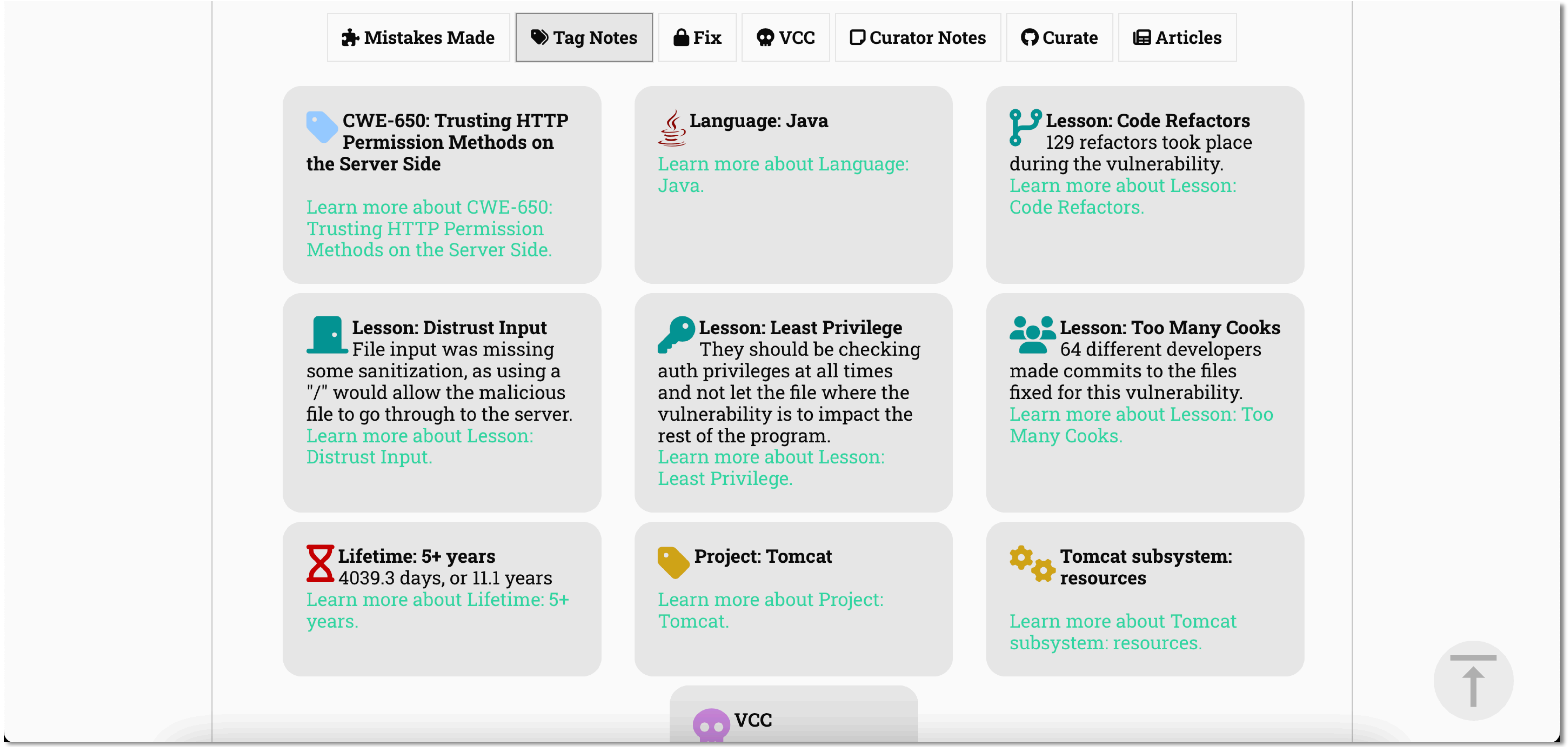


Built by running a SZZ variant by Aladics et al.

Available Datasets

Vulnerability History Project

VHP can be mined in several ways

RESTFul API

Retrieving data with simple HTTP requests.

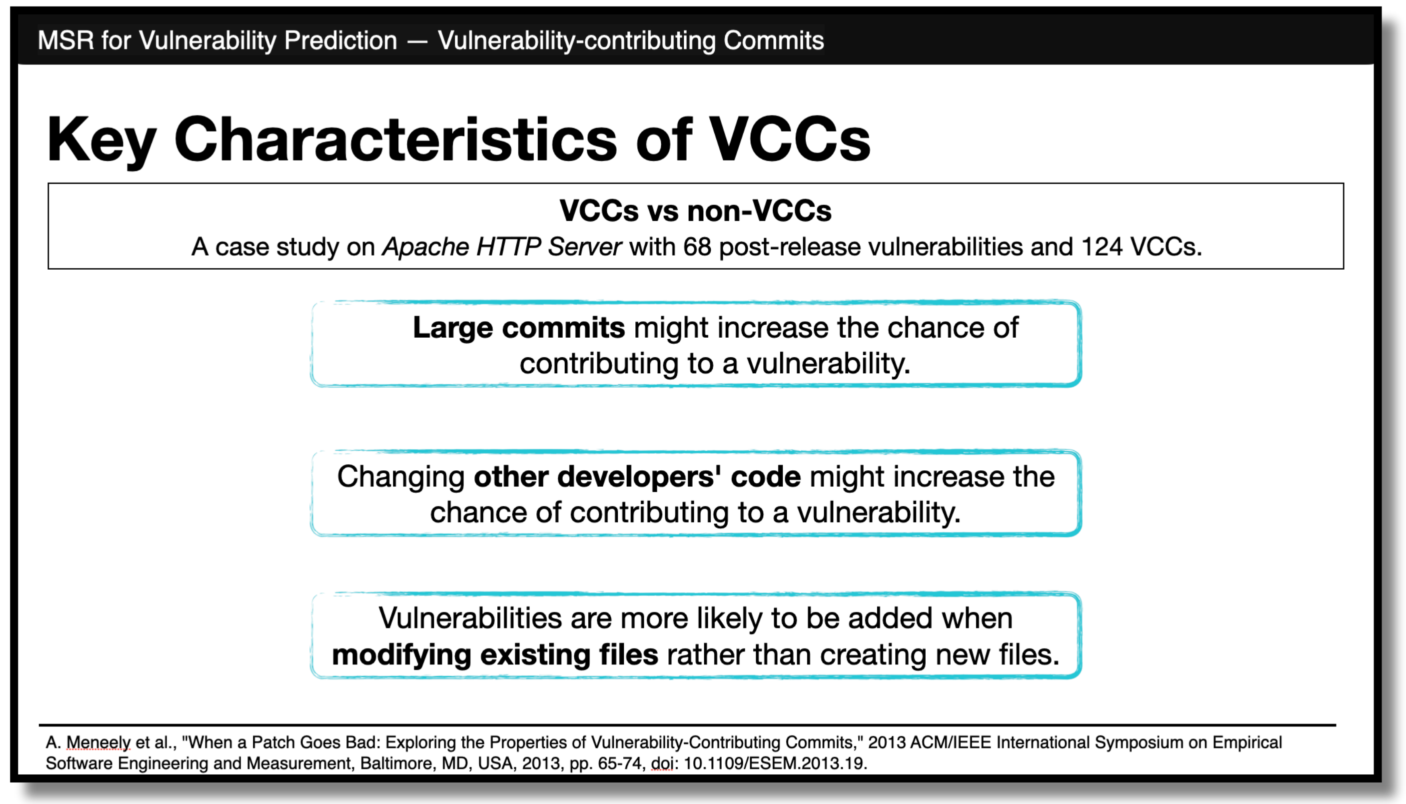
Raw Data

The list of vulnerabilities is available in a repository of its organization in GitHub.

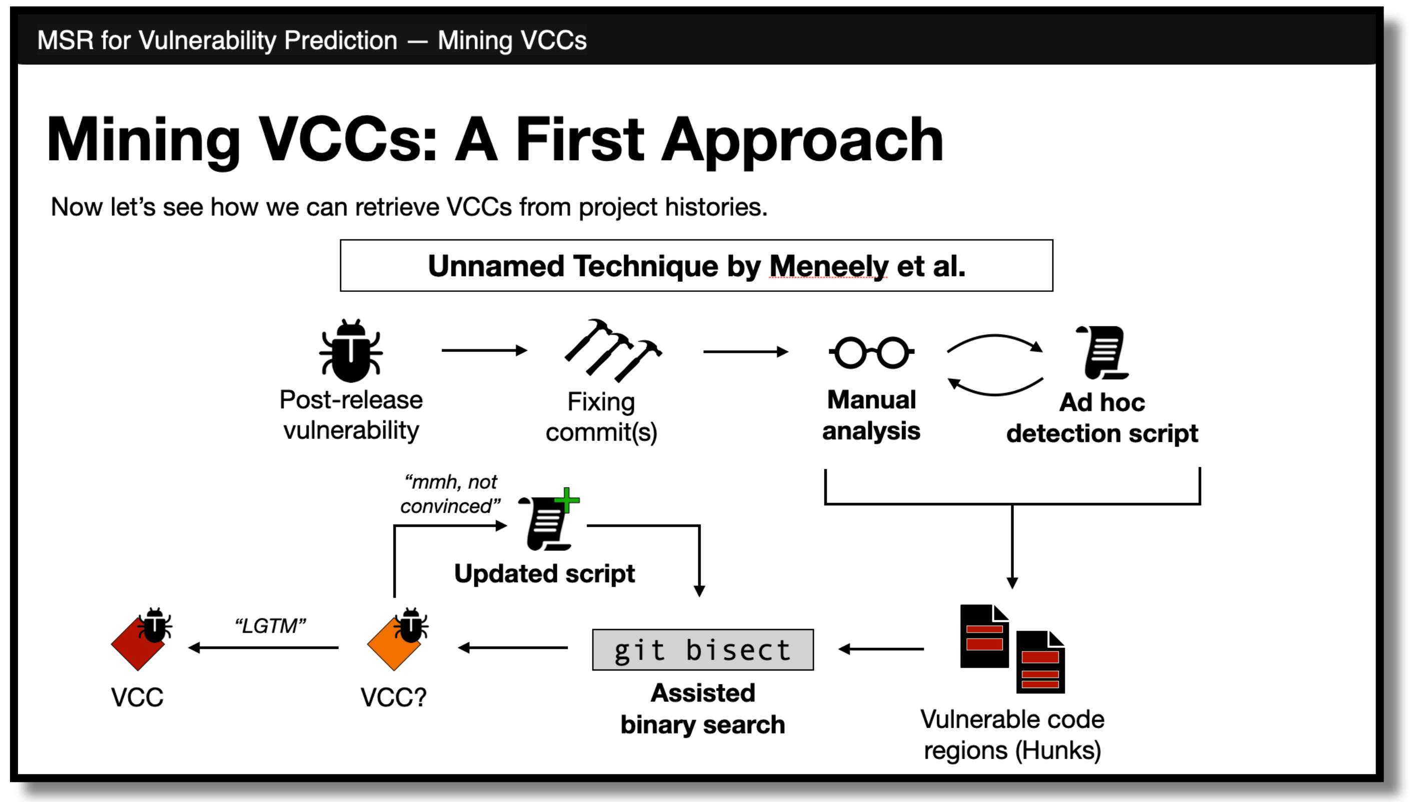
Ad Hoc Tool

The organization in GitHub offers a dedicated command-line tool.

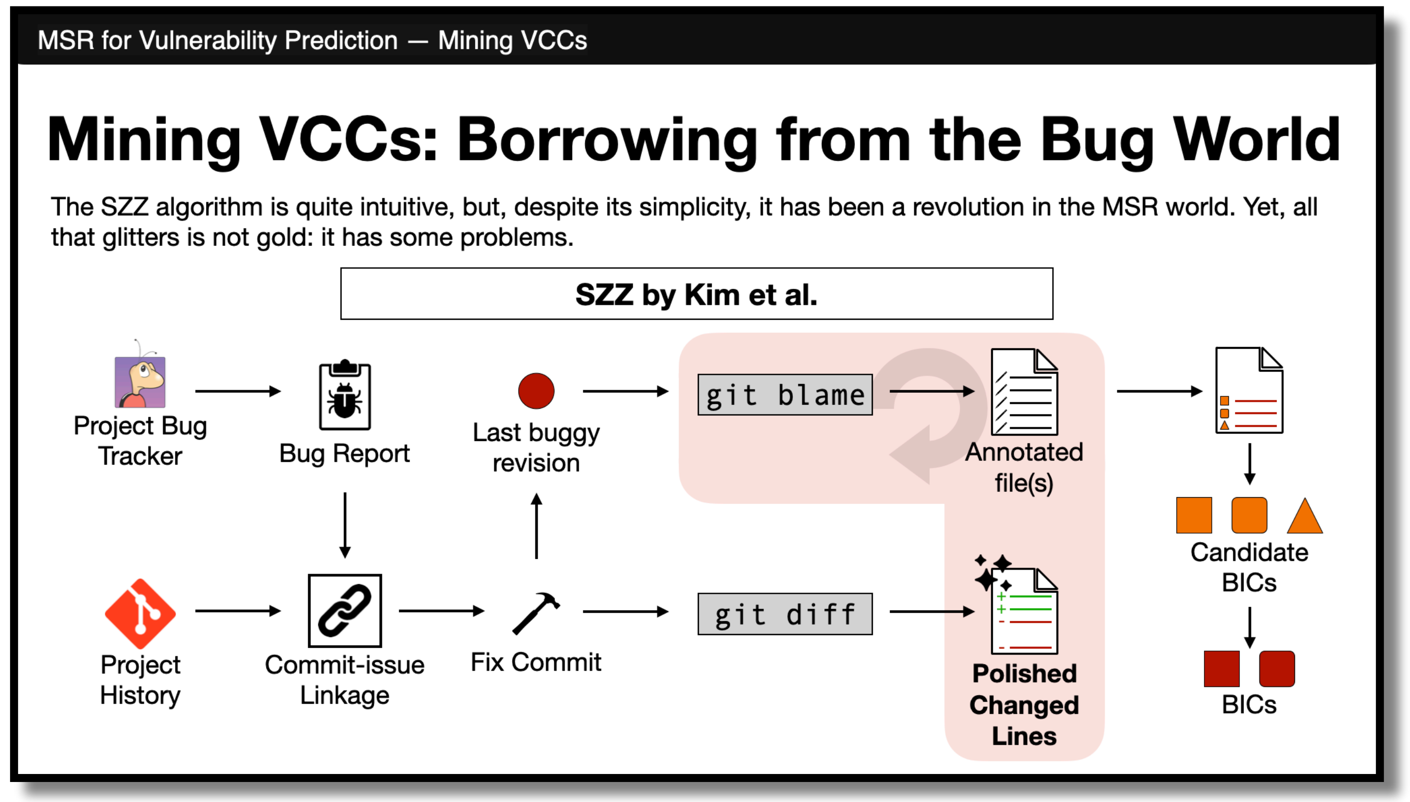
Wrap up



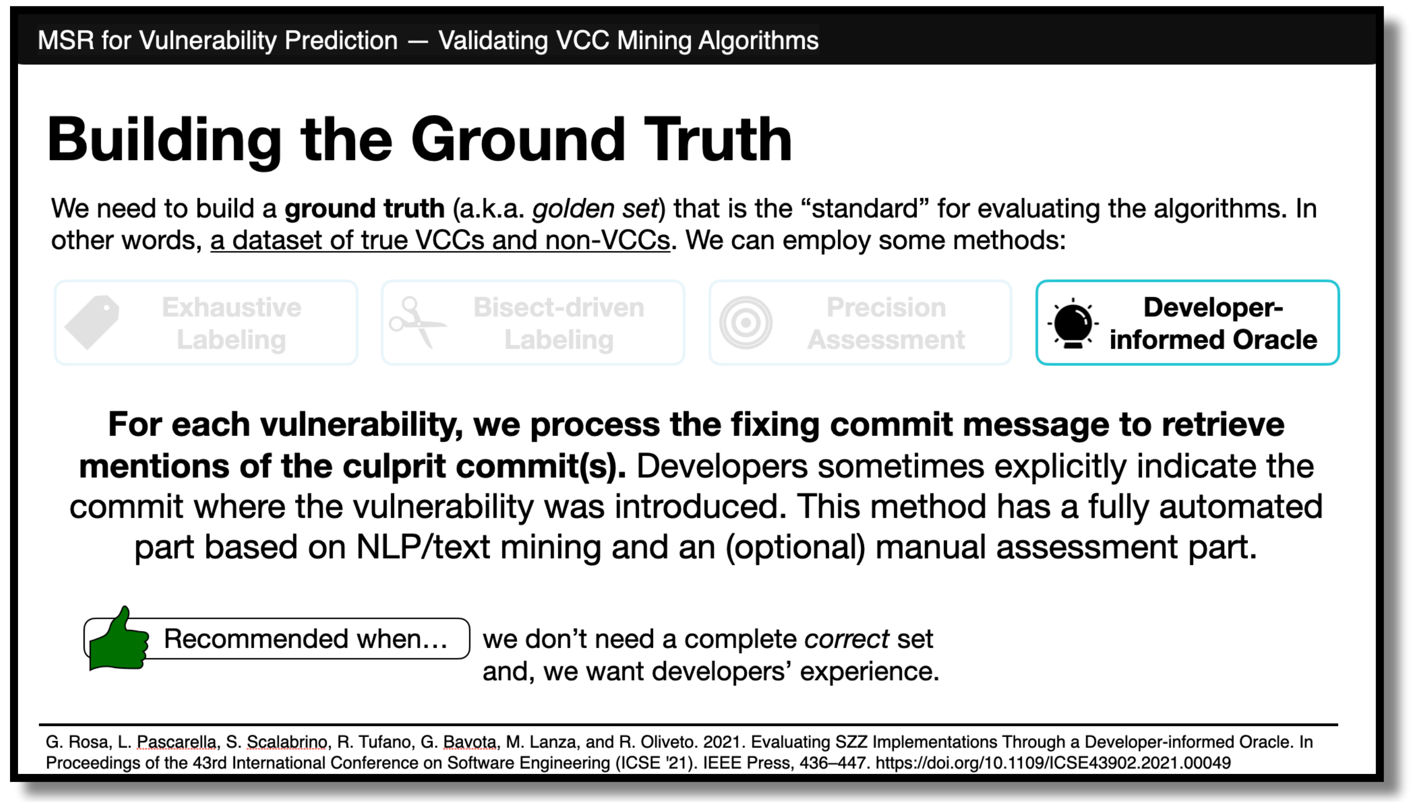
Definition & Characteristics of VCCs



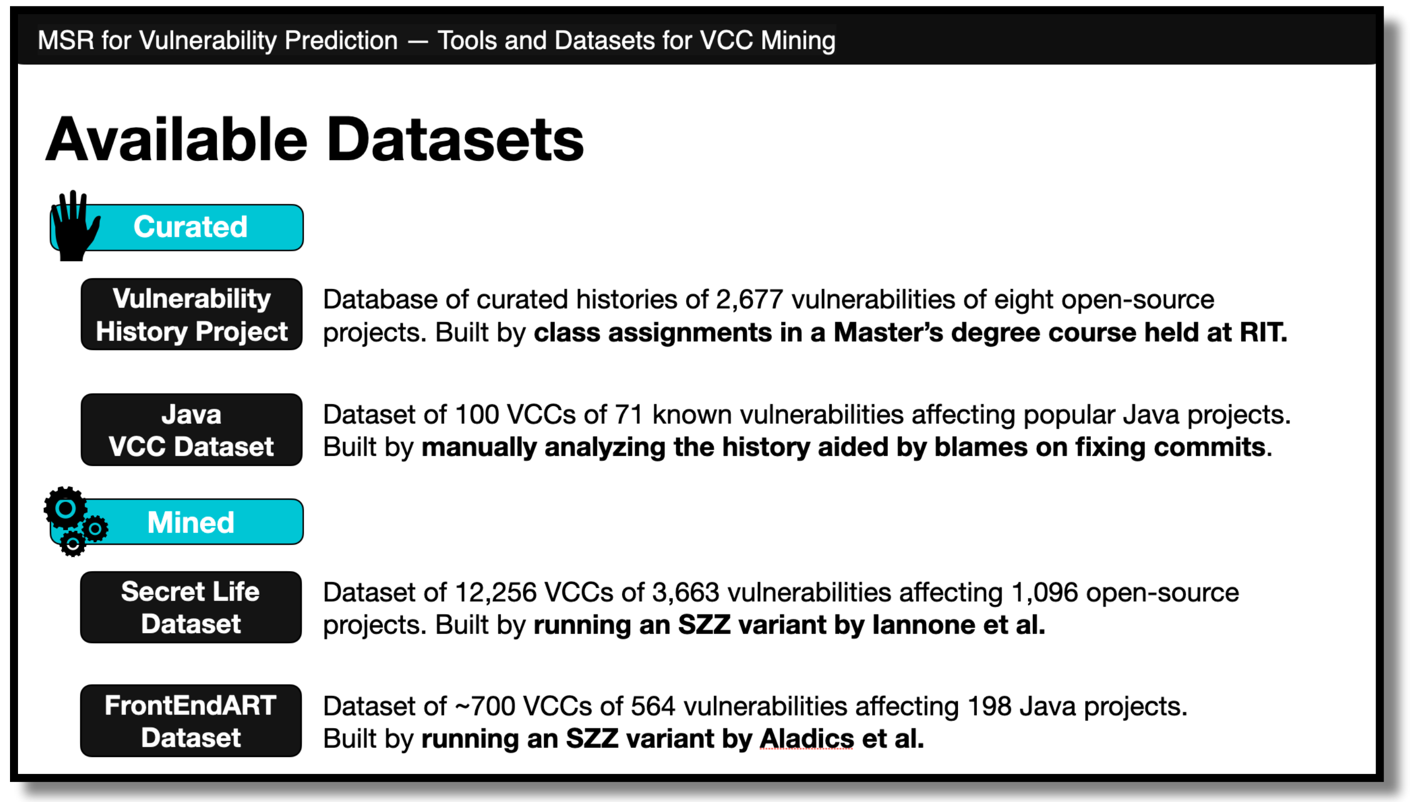
Meneely et al. technique (git bisect)



SZZ algorithm and variants (git blame)



Performance Metrics & Ground Truth



Available Tools & Datasets

(Some) Open Challenges

Non-code-related Vulnerabilities

Not all vulnerabilities are caused by coding mistakes. Some of them are caused by improper configurations or, even worse, design issues.

Tangled Changes

Not all fixing commits are focused on fixing the vulnerability: other collateral activities may be done.

Irrelevant Changes

Not all lines changed are directly related to the vulnerability, e.g., addition/removal of import statements, parameters reordering, etc.

Migrated Repositories

Many “old” projects were migrated from another VCS (e.g., svn to git), so their history might be incomplete (e.g., the initial commit is enormous).

MSR for Vulnerability Prediction

Mining Vulnerability-Contributing Commits

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Winter Semester 22/23

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SoftSEC Institute of Software Security

TUHH Hamburg University of Technology

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[Perl et al.] **VCCFinder: Finding Potential Vulnerabilities in Open-Source Projects to Assist Code Audits**: https://dl.acm.org/doi/10.1145/2810103.2813604

[Yang et al.] **VulDigger: A Just-in-Time and Cost-Aware Tool for Digging Vulnerability-Contributing Changes**: https://ieeexplore.ieee.org/document/8254428

[Iannone et al.] **The Secret Life of Software Vulnerabilities: A Large-Scale Empirical Study**: https://ieeexplore.ieee.org/document/9672730

[Bao et al.] **V-SZZ: Automatic Identification of Version Ranges Affected by CVE Vulnerabilities**: https://ieeexplore.ieee.org/document/9794006

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Tools & Datasets

OpenSZZ: https://github.com/clowee/OpenSZZ

SZZUnleashed: https://github.com/wogscpar/SZZUnleashed

PyDriller: https://github.com/ishepard/pydriller

Archeogit: https://github.com/samaritan/archeogit

V-SZZ: https://github.com/baolingfeng/V-SZZ

PySZZ: https://github.com/grosa1/pyszz

VHP: https://vulnerabilityhistory.org/

Java VCC Dataset: https://tinyurl.com/java-vccs

Secret Life Dataset: https://github.com/sesalab/OnlineAppendices/tree/main/TSE21-VulnerabilityLifecycle

FrontEndART Dataset: https://zenodo.org/record/5785254#.ZGIw9uxBzDK

VHP API: https://vulnerabilityhistory.org/api

VHP Raw data: https://github.com/VulnerabilityHistoryProject/vulnerabilities

VHP command-line tool: https://github.com/VulnerabilityHistoryProject/shepherd-tools