Université Concordia University

Intelligent System
Logging and Monitoring
ISyLM Research Lab

Software Maintenance At Commit-Time

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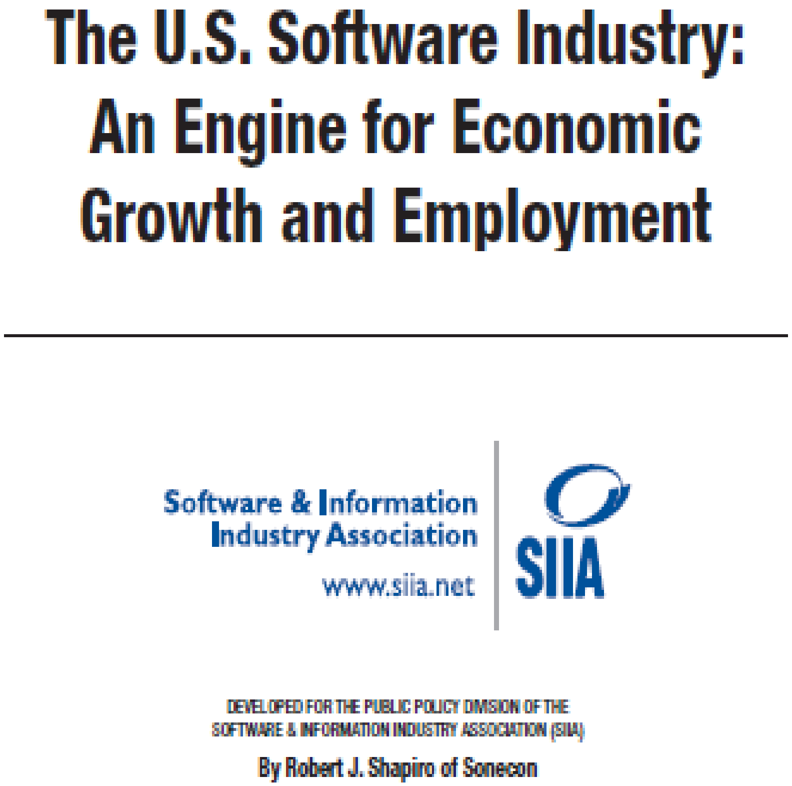
Motivations

- From 1997 to 2012, software industry production grew from $149 billion to $425 billion.
- The software industry's direct share of U.S. GDP went from 1.7% to 2.6%.
- Software accounted for 12.1% percent of all U.S. labor productivity gains from 1995 to 2004 and 15.4% from 2004 to 2012.



The U.S. Software Industry: An Engine for Economic Growth and Employment

Software & Information Industry Association

www.siia.net

SIIA

DEVELOPED FOR THE PUBLIC POLICY DIVISION OF THE SOFTWARE & INFORMATION INDUSTRY ASSOCIATION (SIIA)

By Robert J. Shapiro of Sonecon

Motivations

- Maintenance of Software Systems can reach up **to 70% of the overall cost.**
- Up to **50%** of the overall maintenance cost can be spent **on identifying and correcting defects.**
- Defects in software cost the U.S. economy **$56 billion annually**.

NIST

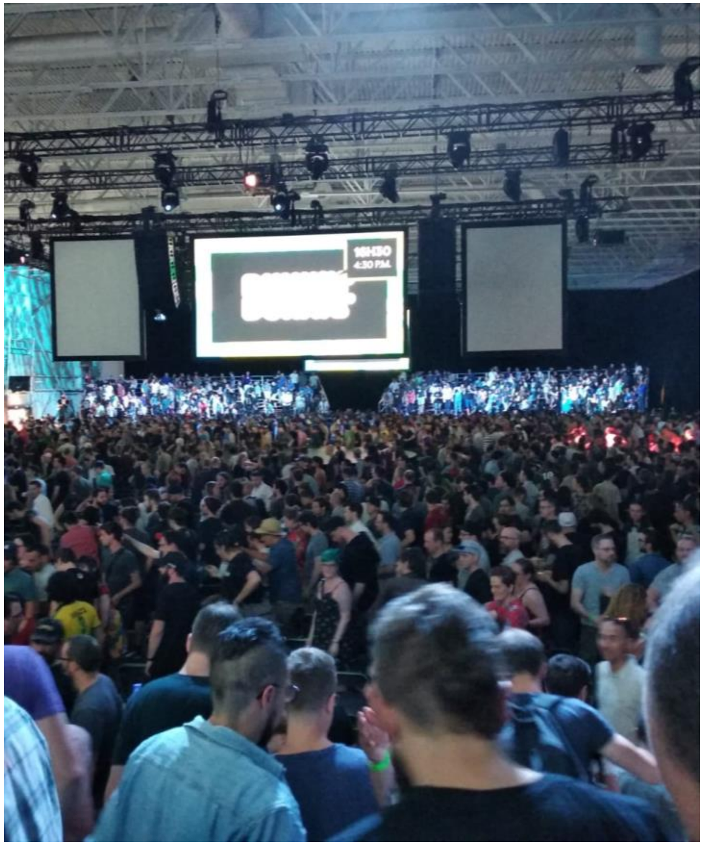
U.S Department of Commerce

Technology Administration

Source: Health, Social and Research, E. 2002. The Economic Impacts of Inadequate Infrastructure for Software Testing

Motivations

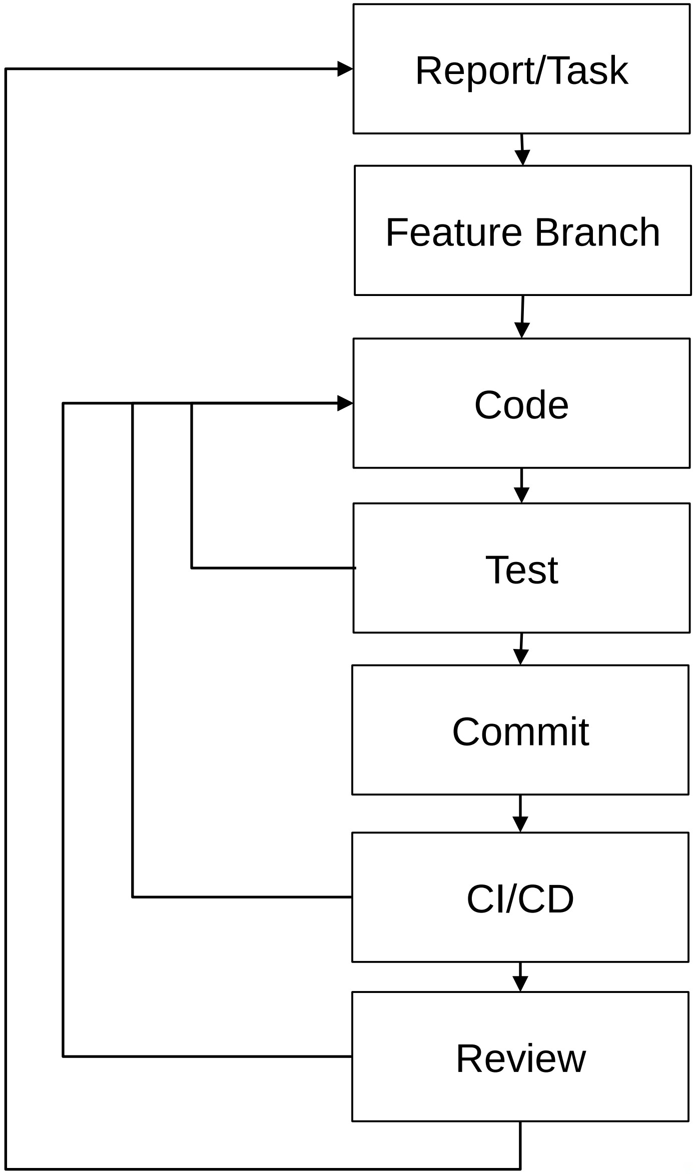
- Offline.
- Little integration with dev.
- No or unclear call to actions.
- Extensive setup.
- False positives.



Source: Ubisoft Montreal Employees during the annual assembly

Classical Workflow & Challenges

- Increased complexity.
- High cost.
- Heavy reliance on people.
- Lack of automated tools.
- Time to market pressure.
- Maintaining quality.



Goal

To empower software developers with intelligent tools that detects defects as they write code, help reproduce on-field crashes and propose fixes without altering their workflows.

UNIVERSITÉ Concordia UNIVERSITY

ERICSSON

UBISOFT MONTREAL

NSERC CRSNG

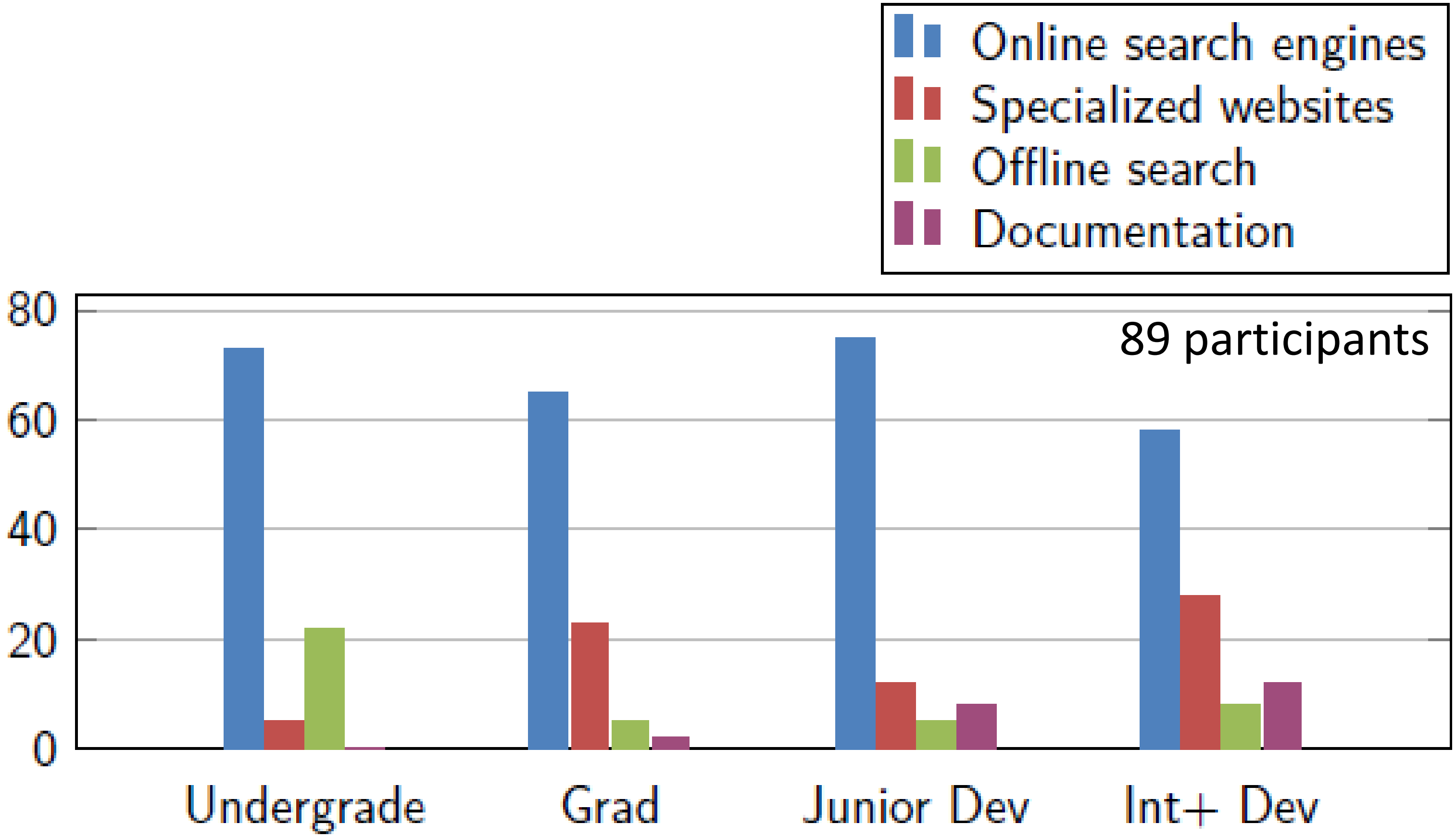
Mitacs

Results

Contributions

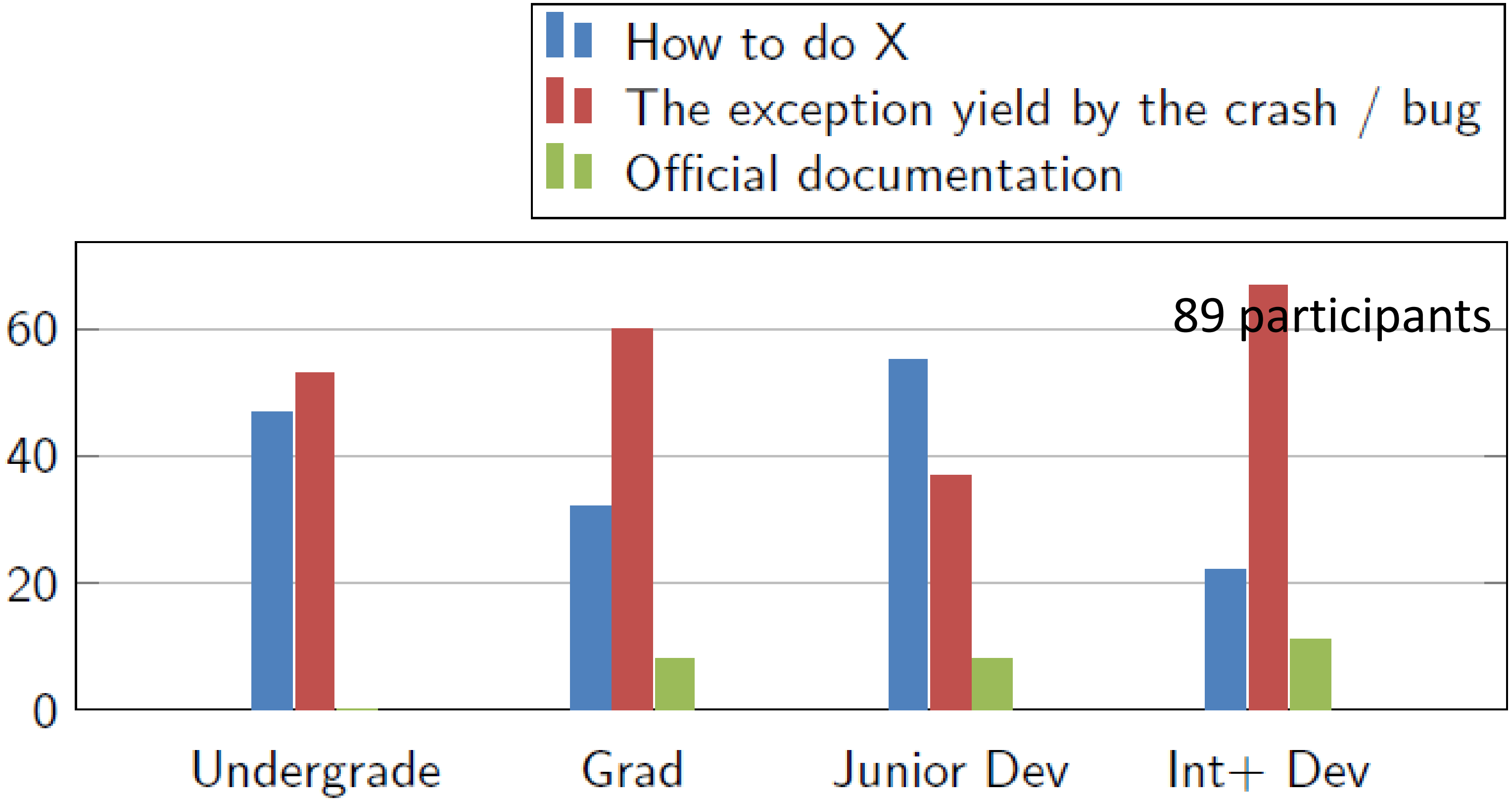
- BUMPER: A Tool for Coping with Natural Language Searches of Millions of Bugs and Fixes.
- PRECINCT: An Approach for Preventing Clone Insertion at Commit-Time.
- BIANCA: Preventing Bug Insertion at Commit-Time Using Dependency Analysis and Clone Detection.
- CLEVER: Combining Code Metrics with Clone Detection for Just-In-Time Fault Prevention and Resolution in Large Industrial Projects.
- JCHARMING: A bug reproduction approach using crash traces and directed model checking.
- Towards a Classification of Bugs to Facilitate Software Maintainability Tasks.

Where do developers look for information when facing an unknown bug/crash?



89 participants

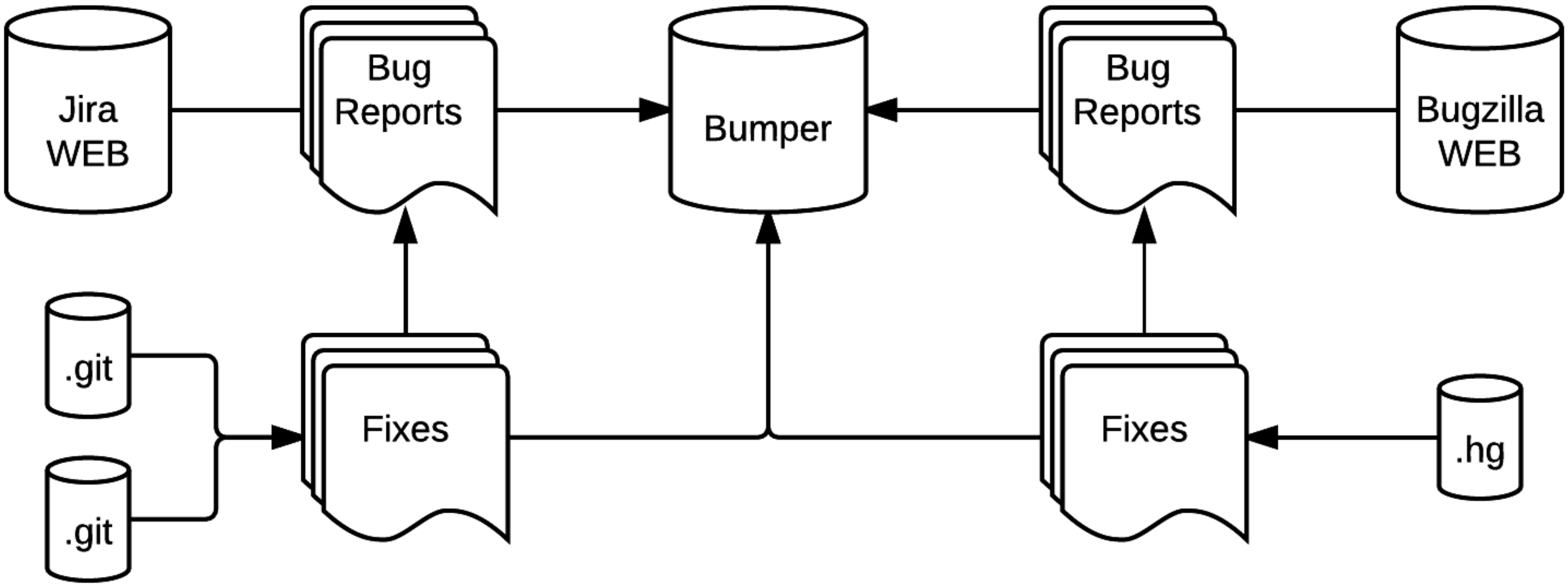
What do developers search for when facing an unknown bug/crash?



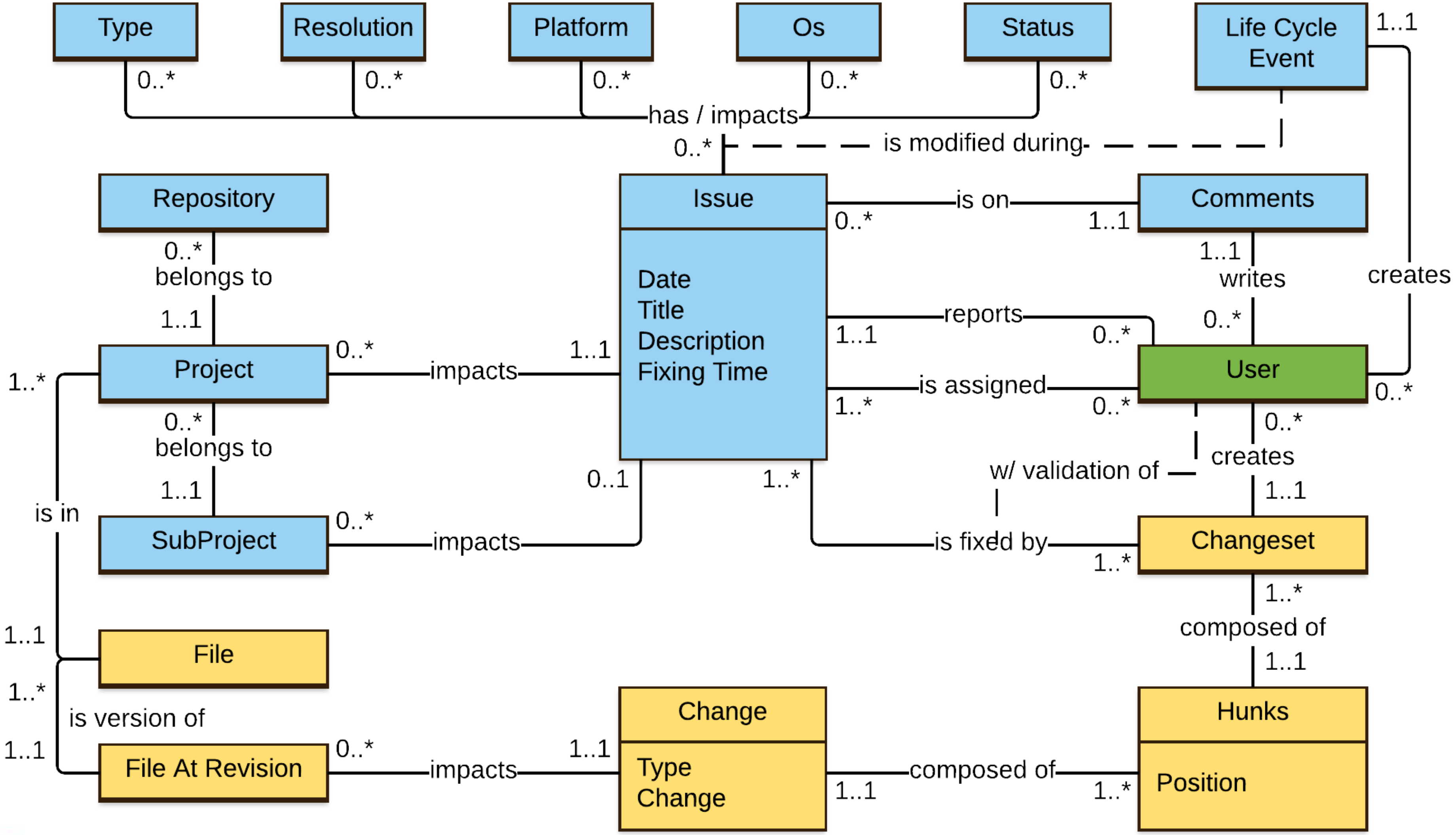
89 participants

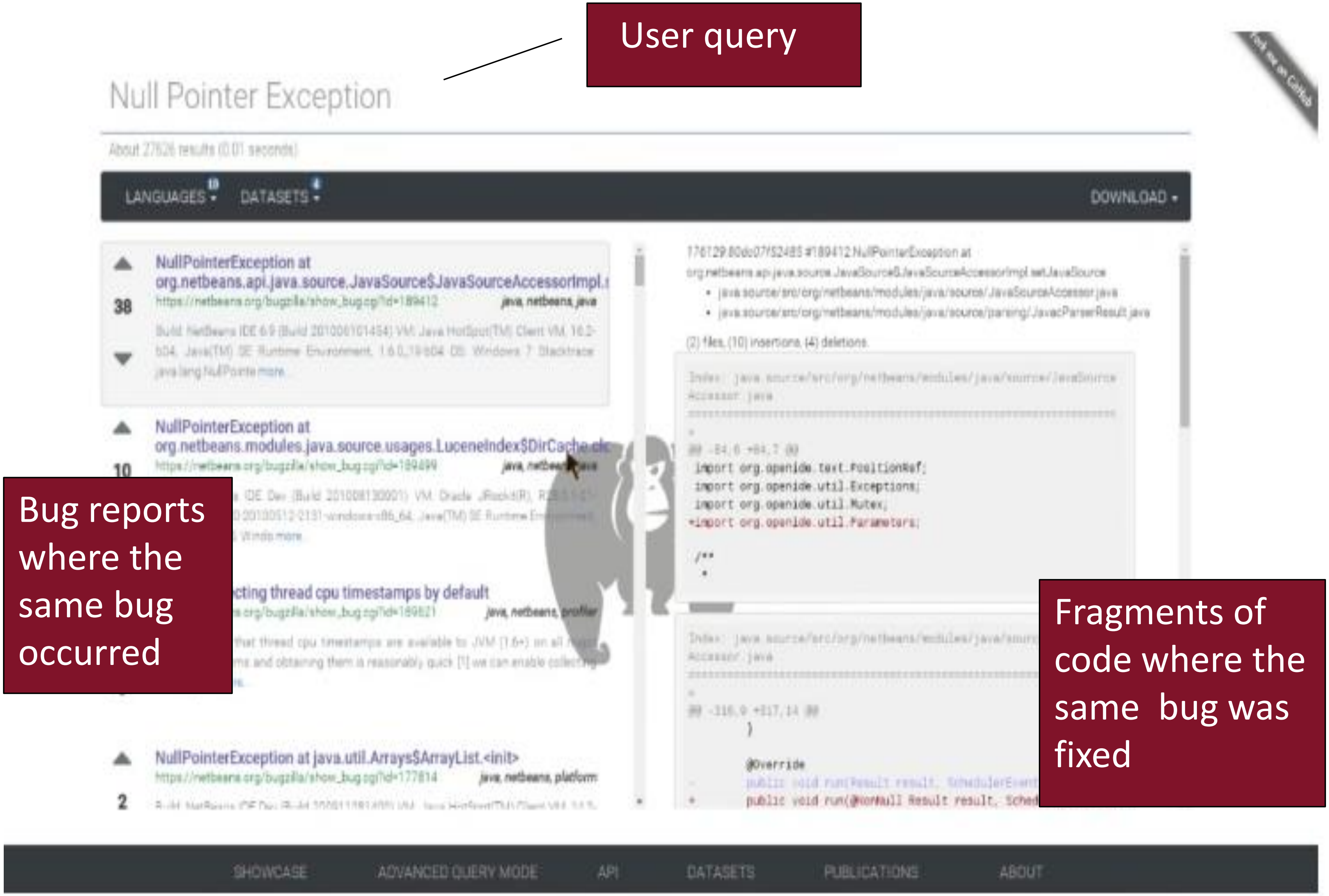
BUMPER

- Aggregate millions of bugs / fixes.



BUMPER


Type
Resolution
Platform
Os
Status
Life Cycle Event
0..*
0..*
0..*
0..*
0..*
1..1
has / impacts
0..*
is modified during
Repository
Issue
Comments
0..*
belongs to
1..1
Date
Title
Description
Fixing Time
is on
0..*
1..1
1..1
writes
0..*
creates
Project
1..*
0..*
impacts
1..1
reports
1..1
0..*
User
0..*
is assigned
1..*
0..*
0..*
belongs to
1..1
creates
1..1
w/ validation of
0..1
1..*
is in
SubProject
0..*
impacts
is fixed by
1..*
Changeset
1..*
composed of
1..1
1..1
File
1..*
is version of
1..1
File At Revision
0..*
impacts
1..1
Change
Type
Change
composed of
1..1
1..*
Hunks
Position



Null Pointer Exception

About 27626 results (0.01 seconds)

38
NullPointerException at org.netbeans.api.java.source.JavaSource$JavaSourceAccessorImpl.s
https://netbeans.org/bugzilla/show_bug.cgi?id=189412 java, netbeans, java
Build: NetBeans IDE 6.9 (Build 201006101454) VM: Java HotSpot(TM) Client VM, 16.2-b04, Java(TM) SE Runtime Environment, 1.6.0_19-b04 OS: Windows 7 Stacktrace: java.lang.NullPointe more

10
NullPointerException at org.netbeans.modules.java.source.usages.LuceneIndex$DirCache.clc
https://netbeans.org/bugzilla/show_bug.cgi?id=189499 java, netbeans, java
IDE Dev (Build 201008130001) VM: Oracle JRockit(R), R28.0.1 ... 20100512-2131-windows-x86_64, Java(TM) SE Runtime Environment ... Windo more

...cting thread cpu timestamps by default
...s.org/bugzilla/show_bug.cgi?id=189521 java, netbeans, profiler
... that thread cpu timestamps are available to JVM (1.6+) on all major ... ms and obtaining them is reasonably quick [1] we can enable collecting ...

2
NullPointerException at java.util.Arrays$ArrayList.<init>
https://netbeans.org/bugzilla/show_bug.cgi?id=177814 java, netbeans, platform

176129.80dc07f52485 #189412 NullPointerException at org.netbeans.api.java.source.JavaSource$JavaSourceAccessorImpl.setJavaSource

- java.source/src/org/netbeans/modules/java/source/JavaSourceAccessor.java
- java.source/src/org/netbeans/modules/java/source/parsing/JavacParserResult.java

(2) files, (10) insertions, (4) deletions.

```
Index: java.source/src/org/netbeans/modules/java/source/JavaSource
Accessor.java
===================================================================
=
@@ -84,6 +84,7 @@
 import org.openide.text.PositionRef;
 import org.openide.util.Exceptions;
 import org.openide.util.Mutex;
+import org.openide.util.Parameters;

 /**
  *
```

```
Index: java.source/src/org/netbeans/modules/java/sourc
Accessor.java
===================================================
=
@@ -116,9 +117,14 @@
         }

         @Override
-        public void run(Result result, SchedulerEvent
+        public void run(@NonNull Result result, Sched
```

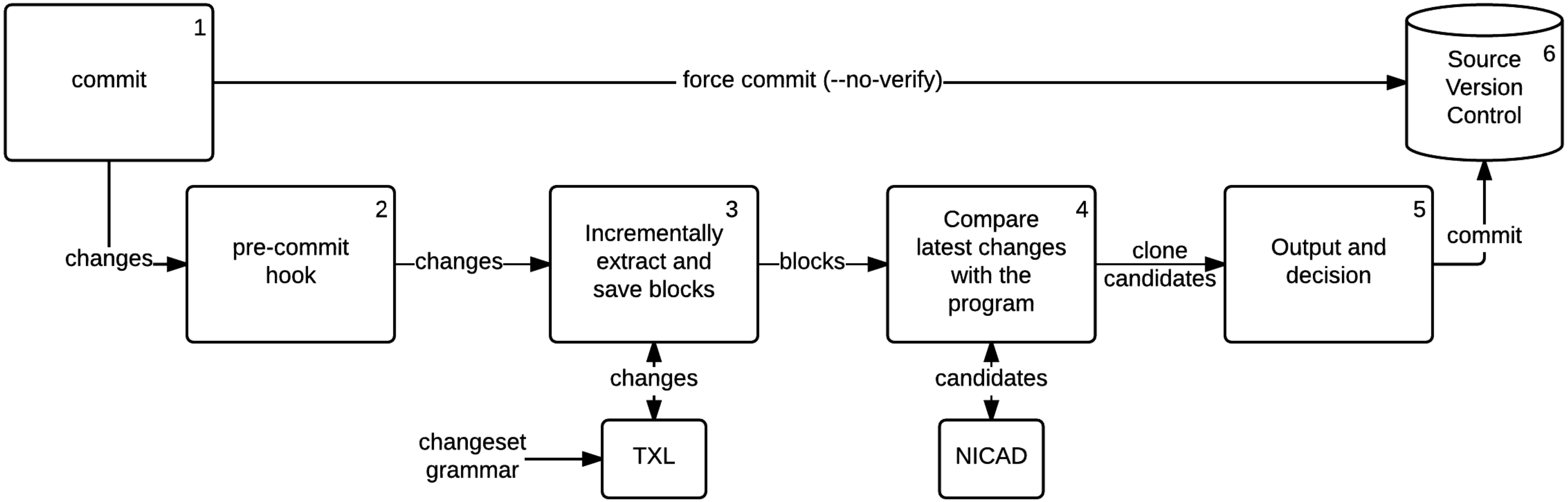
User query

Bug reports where the same bug occurred

Fragments of code where the same bug was fixed

PRECINCT

- Detect Near Miss Clones At Commit-Time



PRECINCT

```
+ using System;

+ public class Test
+ {
+ public static void Main()
+ {
+ Console.WriteLine("Hello Concordia; let's sort...");
+ int[] array = new int[]{1, 5, 6, 2, 3};
+ for(int i=0; i<array.Length; i++){
+    for(int j=0; j<array.Length - 1; j++){
+        if(array[j] > array[j+1]){
+            int tmp = array[j+1];
+            array[j+1] = array[j];
+            array[j] = tmp;
+        }
+    }
+ }
+
+ Console.WriteLine(string.Join(",", array));
+ }
+ }
```

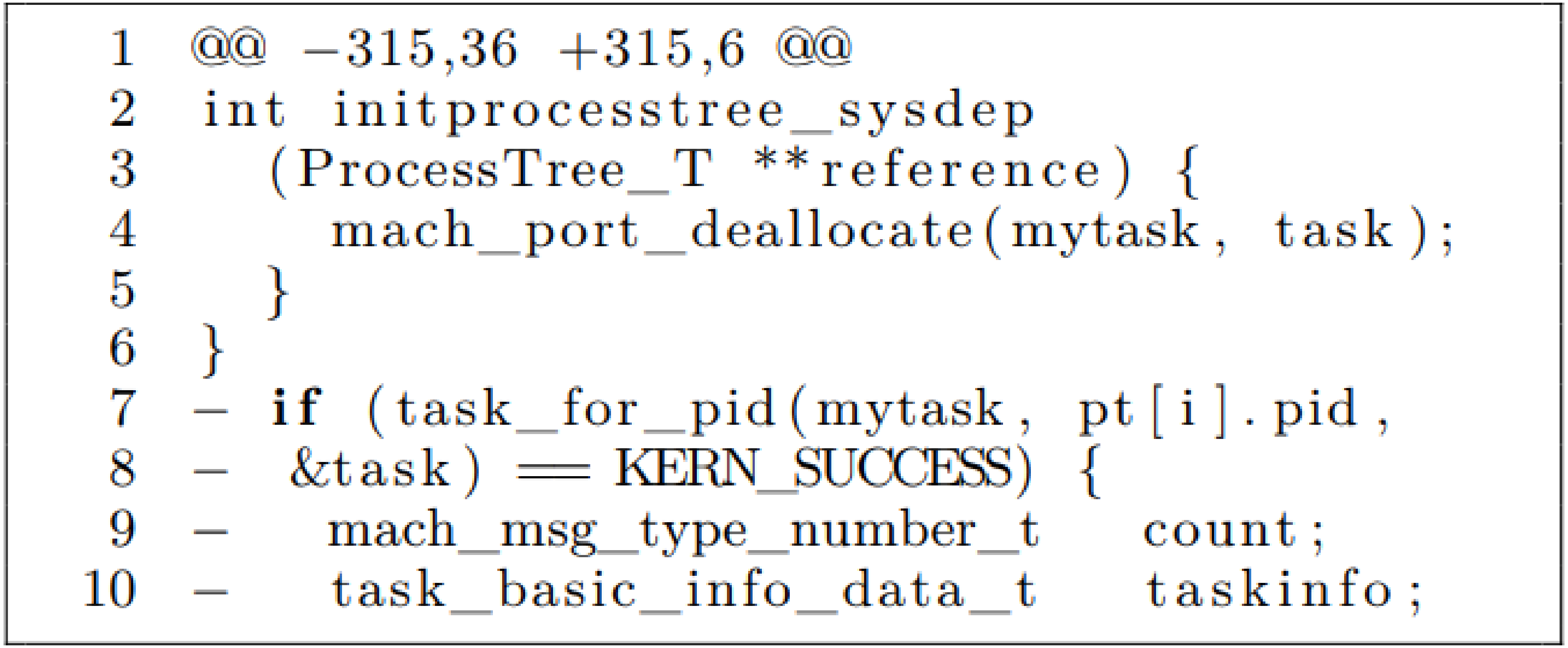
```
A[] = A[]
for(
B=0
B<A.Length
B++
){
for(
C=0
C<A.Length
C++
){
if(
A[C] >
A[C+1]
){
D = A[C+1]
A[C+1] = A[C]
A[C] = D
}
}
}
```

PRECINCT

```
for(
C=A.Length
C<A.Length
C++
){
if(
A[C] >
A[C+1]
){
D = A[C+1]
A[C+1] = A[C]
A[C] = D
}
}
```

```
for(
C=B
C<A.Length
C++
){
if(
A[C] >
A[C+1]
){
D = A[C+1]
A[C+1] = A[C]
A[C] = D
}
}
```

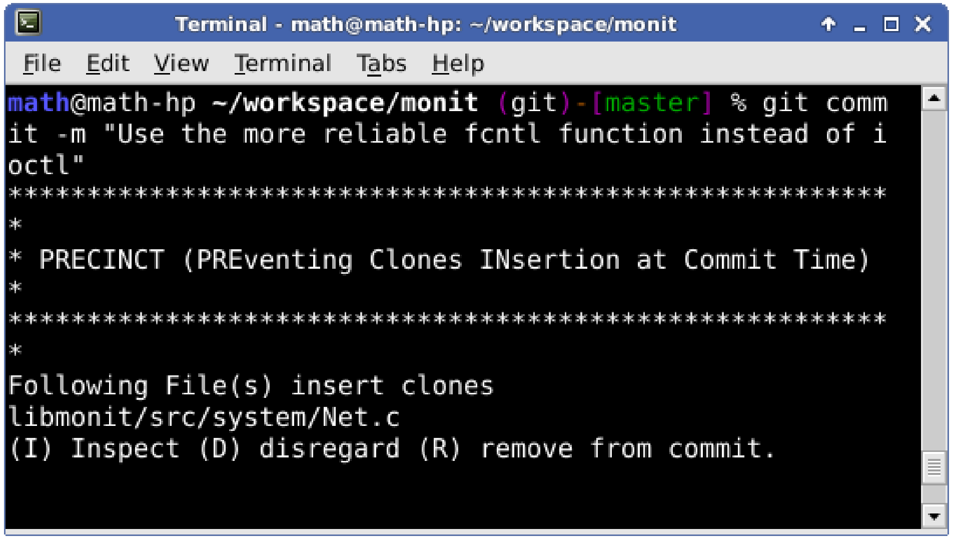
PRECINCT



```
@@ -315,36 +315,6 @@
 int initprocesstree_sysdep
    (ProcessTree_T **reference) {
       mach_port_deallocate(mytask, task);
    }
 }
- if (task_for_pid(mytask, pt[i].pid,
-  &task) == KERN_SUCCESS) {
-     mach_msg_type_number_t   count;
-     task_basic_info_data_t   taskinfo;
```

PRECINCT

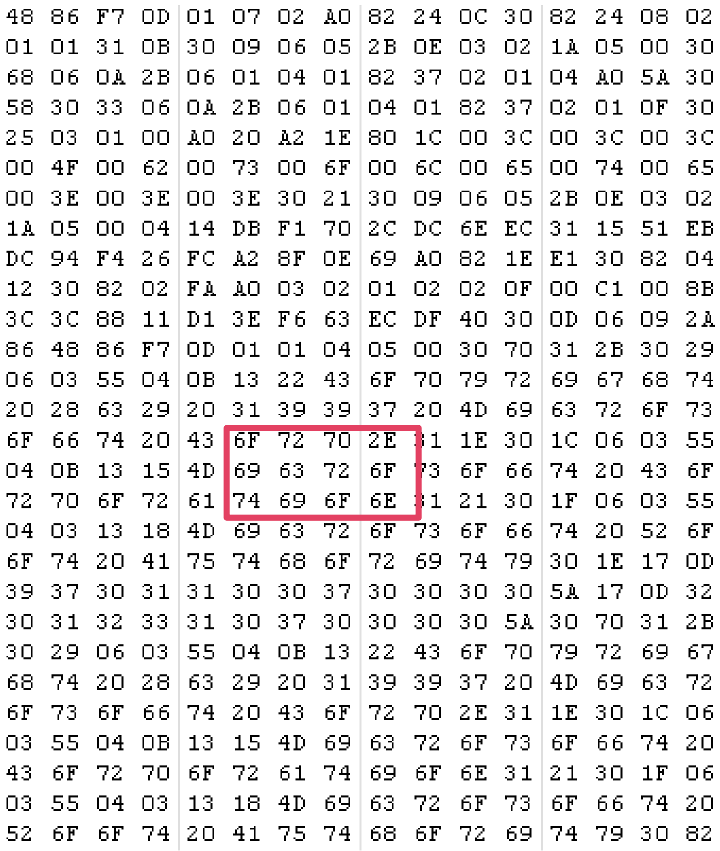
- Tested on 3 OSS
- 97.7% Precision
- 100% Recall
- 98.8% F1-Measure
- 6839 Clones
- 2.5x faster
- Workflow Compliant



```
math@math-hp ~/workspace/monit (git)-[master] % git comm
it -m "Use the more reliable fcntl function instead of i
octl"
********************************************************
*
* PRECINCT (PREventing Clones INsertion at Commit Time)
*
********************************************************
*
Following File(s) insert clones
libmonit/src/system/Net.c
(I) Inspect (D) disregard (R) remove from commit.
```

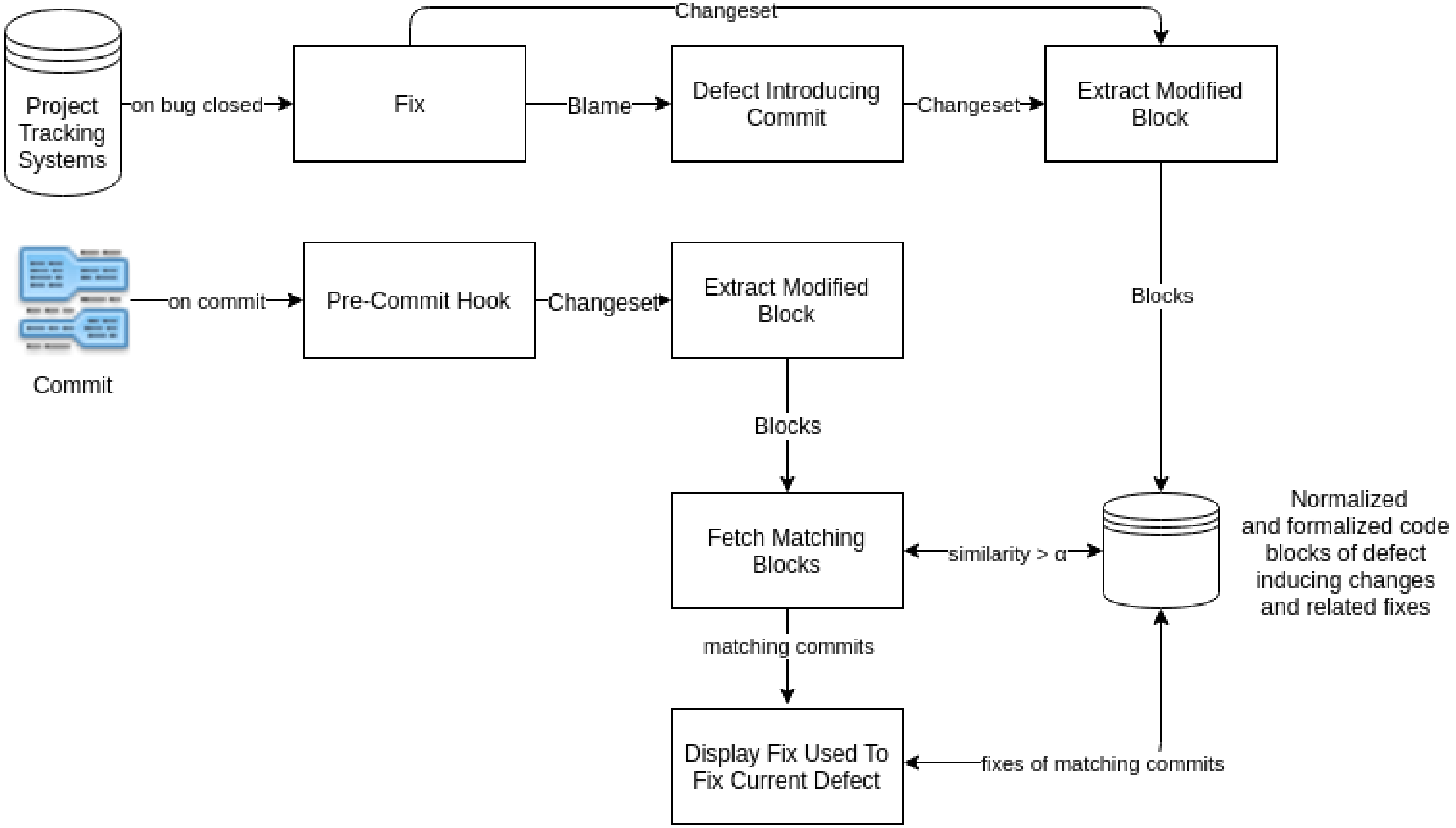
BIANCA: Preventing Bug Insertion at Commit-Time Using Clone Detection

- BIANCA learns known defects by mining BUMPER-indexed systems.
- It intercepts developer’s code and compares it to signatures of known defects.
- If a match exists, a flag is raised and a fix is proposed.



```
48 86 F7 0D | 01 07 02 A0 | 82 24 0C 30 | 82 24 08 02
01 01 31 0B | 30 09 06 05 | 2B 0E 03 02 | 1A 05 00 30
68 06 0A 2B | 06 01 04 01 | 82 37 02 01 | 04 A0 5A 30
58 30 33 06 | 0A 2B 06 01 | 04 01 82 37 | 02 01 0F 30
25 03 01 00 | A0 20 A2 1E | 80 1C 00 3C | 00 3C 00 3C
00 4F 00 62 | 00 73 00 6F | 00 6C 00 65 | 00 74 00 65
00 3E 00 3E | 00 3E 30 21 | 30 09 06 05 | 2B 0E 03 02
1A 05 00 04 | 14 DB F1 70 | 2C DC 6E EC | 31 15 51 EB
DC 94 F4 26 | FC A2 8F 0E | 69 A0 82 1E | E1 30 82 04
12 30 82 02 | FA A0 03 02 | 01 02 02 0F | 00 C1 00 8B
3C 3C 88 11 | D1 3E F6 63 | EC DF 40 30 | 0D 06 09 2A
86 48 86 F7 | 0D 01 01 04 | 05 00 30 70 | 31 2B 30 29
06 03 55 04 | 0B 13 22 43 | 6F 70 79 72 | 69 67 68 74
20 28 63 29 | 20 31 39 39 | 37 20 4D 69 | 63 72 6F 73
6F 66 74 20 | 43 6F 72 70 | 2E 31 1E 30 | 1C 06 03 55
04 0B 13 15 | 4D 69 63 72 | 6F 73 6F 66 | 74 20 43 6F
72 70 6F 72 | 61 74 69 6F | 6E 31 21 30 | 1F 06 03 55
04 03 13 18 | 4D 69 63 72 | 6F 73 6F 66 | 74 20 52 6F
6F 74 20 41 | 75 74 68 6F | 72 69 74 79 | 30 1E 17 0D
39 37 30 31 | 31 30 30 37 | 30 30 30 30 | 5A 17 0D 32
30 31 32 33 | 31 30 37 30 | 30 30 30 5A | 30 70 31 2B
30 29 06 03 | 55 04 0B 13 | 22 43 6F 70 | 79 72 69 67
68 74 20 28 | 63 29 20 31 | 39 39 37 20 | 4D 69 63 72
6F 73 6F 66 | 74 20 43 6F | 72 70 2E 31 | 1E 30 1C 06
03 55 04 0B | 13 15 4D 69 | 63 72 6F 73 | 6F 66 74 20
43 6F 72 70 | 6F 72 61 74 | 69 6F 6E 31 | 21 30 1F 06
03 55 04 03 | 13 18 4D 69 | 63 72 6F 73 | 6F 66 74 20
52 6F 6F 74 | 20 41 75 74 | 68 6F 72 69 | 74 79 30 82
```

BIANCA


Project Tracking Systems

on bug closed

Fix

Blame

Defect Introducing Commit

Changeset

Extract Modified Block

Changeset

Blocks

Commit

on commit

Pre-Commit Hook

Changeset

Extract Modified Block

Blocks

Fetch Matching Blocks

similarity > α

Normalized and formalized code blocks of defect inducing changes and related fixes

matching commits

Display Fix Used To Fix Current Defect

fixes of matching commits

BIANCA

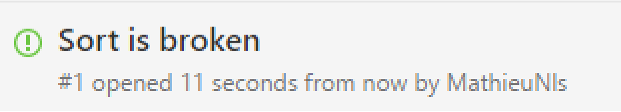
```
+ using System;

+ public class Test
+ {
+ public static void Main()
+ {
+ Console.WriteLine("Hello Concordia; let's sort...");
+ int[] array = new int[]{1, 5, 6, 2, 3};
+ for(int i=0; i<array.Length; i++){
+    for(int j=0; j<array.Length - 1; j++){
+        if(array[j] > array[j+1]){
+            int tmp = array[j+1];
+            array[j+1] = array[j];
+            array[j] = tmp;
+        }
+    }
+ }
+
+ Console.WriteLine(string.Join(",", array));
+ }
+ }
```

```
A[] = A[]
for(
B=0
B<A.Length
B++
){
for(
C=0
C<A.Length
C++
){
if(
A[C] >
A[C+1]
){
D = A[C+1]
A[C+1] = A[C]
A[C] = D
}
}
}
```

BIANCA

```
public class Test
{
public static void Main()
{
Console.WriteLine("Hello Concordia; let's sort...");
int[] array = new int[]{1, 5, 6, 2, 3};
for(int i=0; i<array.Length; i++){
-    for(int j=array.Length; j<array.Length - 1; j++){
+                        for(int j=i; j<array.Length - 1; j++){
         if(array[j] > array[j+1]){
           int tmp = array[j+1];
           array[j+1] = array[j];
           array[j] = tmp;
       }
   }
}
Console.WriteLine(string.Join(",", array));
}
}
```



Sort is broken

#1 opened 11 seconds from now by MathieuNls

```
for(
C=A.Length
C<A.Length
C++
){
if(
A[C] >
A[C+1]
){
D = A[C+1]
A[C+1] = A[C]
A[C] = D
}
}
```

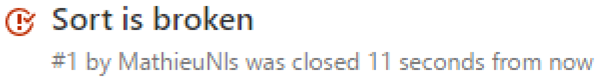
STABLE

```
for(
C=B
C<A.Length
C++
){
if(
A[C] >
A[C+1]
){
D = A[C+1]
A[C+1] = A[C]
A[C] = D
}
}
```

BUGGY

BIANCA

```
public class Test
{
public static void Main()
{
Console.WriteLine("Hello Ubi; let's sort...");
int[] array = new int[]{1, 5, 6, 2, 3};
for(int i=0; i<array.Length; i++){
-    for(int j=i; j<array.Length - 1; j++){
+    for(int j=array.Length; j<array.Length - 1;
j++){
        if(array[j] > array[j+1]){
          int tmp = array[j+1];
          array[j+1] = array[j];
          array[j] = tmp;
       }
   }
}
Console.WriteLine(string.Join(",", array));
}
}
```



Sort is broken

#1 by MathieuNls was closed 11 seconds from now

```
for(
C=0
C<A.Length
C++
){
if(
A[C] >
A[C+1]
){
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A[C+1] = A[C]
A[C] = D
}
}
```

BUGGY

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for(
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```

STABLE

BIANCA

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STABLE

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}
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```

BUGGY

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for(
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C++
){
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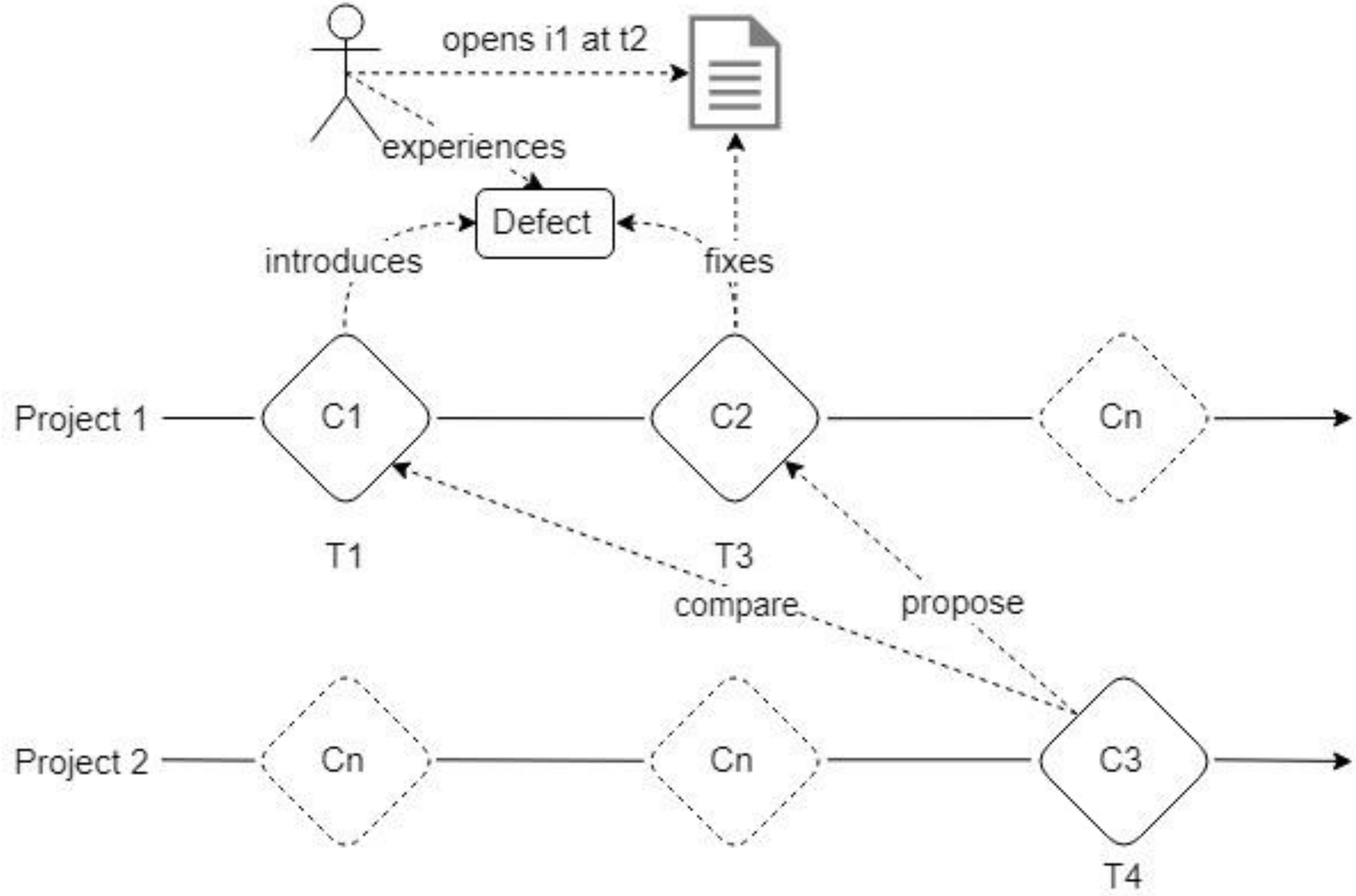
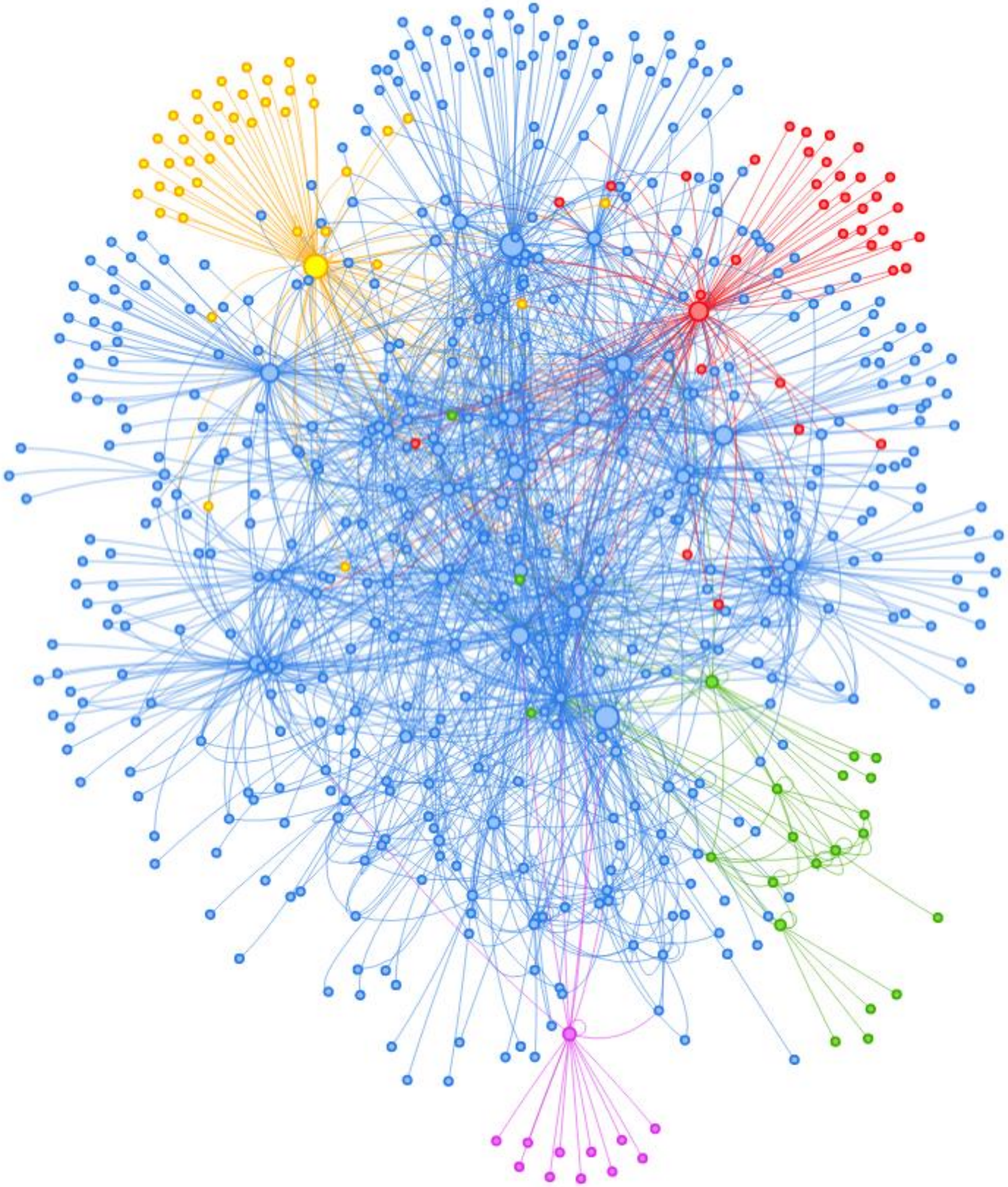
A[C] >
A[C+1]
){
D = A[C+1]
A[C+1] = A[C]
A[C] = D
}
}
```

STABLE

BIANCA

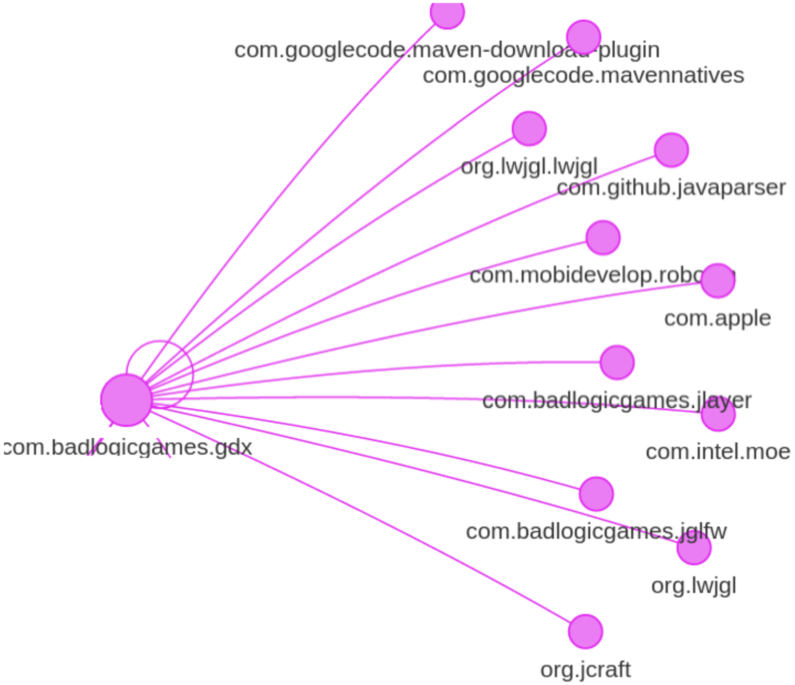

opens i1 at t2
experiences
Defect
introduces
fixes
Project 1
C1
C2
Cn
T1
T3
compare
propose
Project 2
Cn
Cn
C3
T4

BIANCA



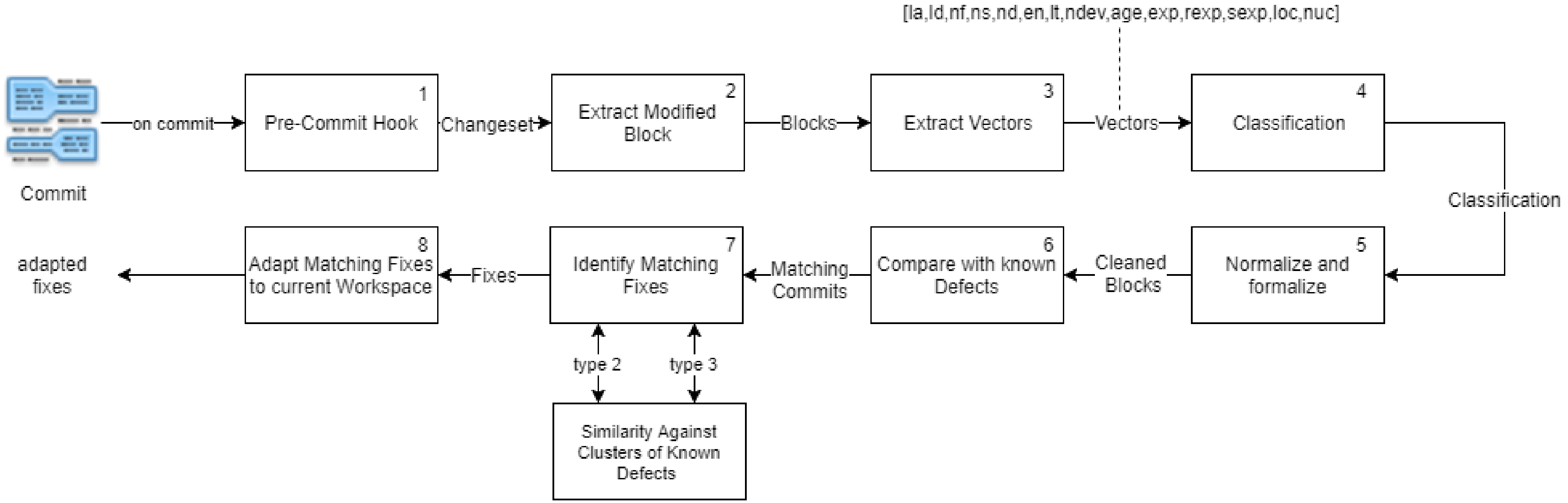
BIANCA

- Tested on 42 OSS
- 90.75% Precision
- 37.15% Recall
- 52.72% F1-Measure
- 41,225 defects
- 8.6% self-fixes
- 78% valid fix proposition
- Workflow Compliant

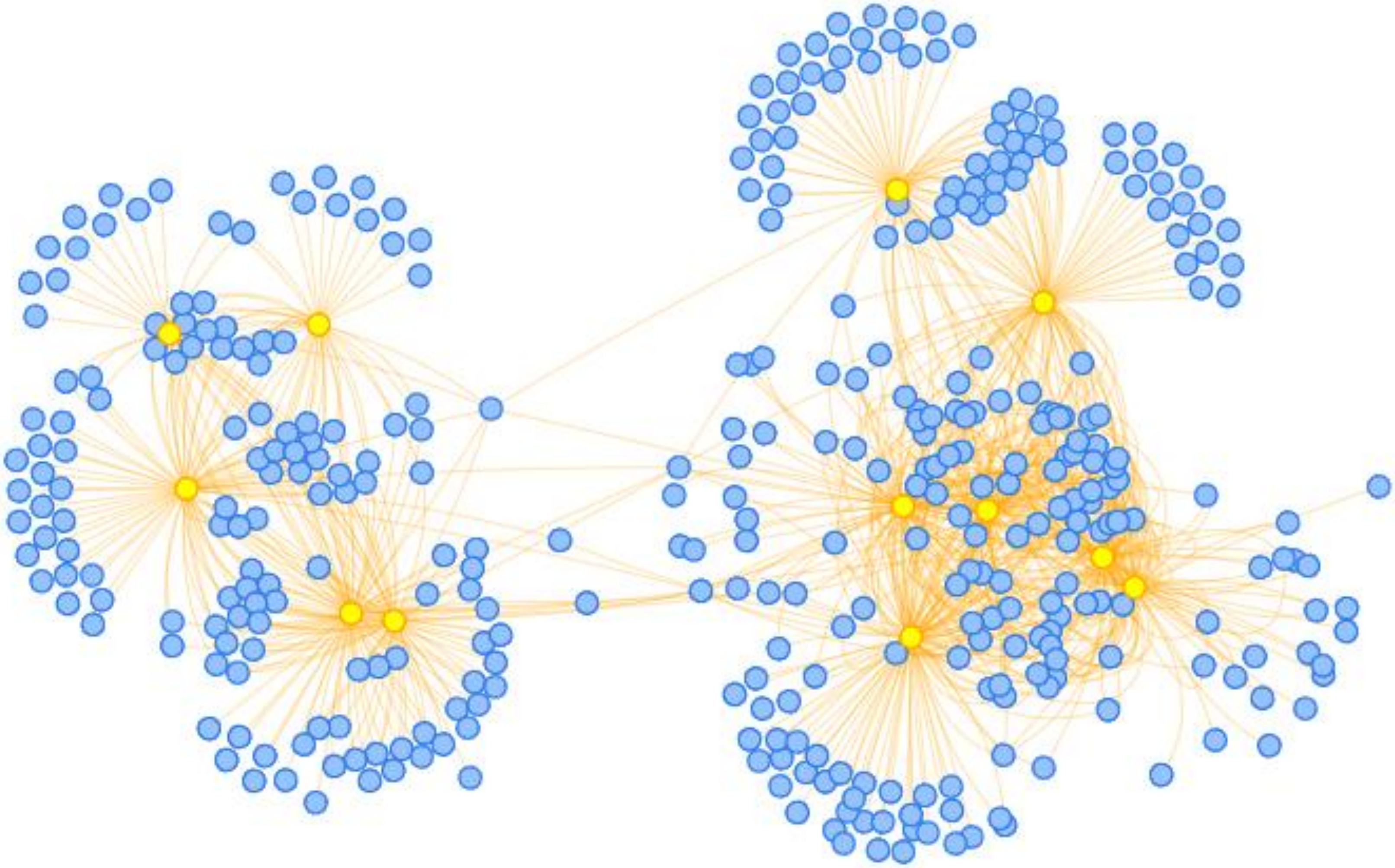


CLEVER

- Detect Bug Introduction At-Commit Time Using Clone Analysis And Code Metrics

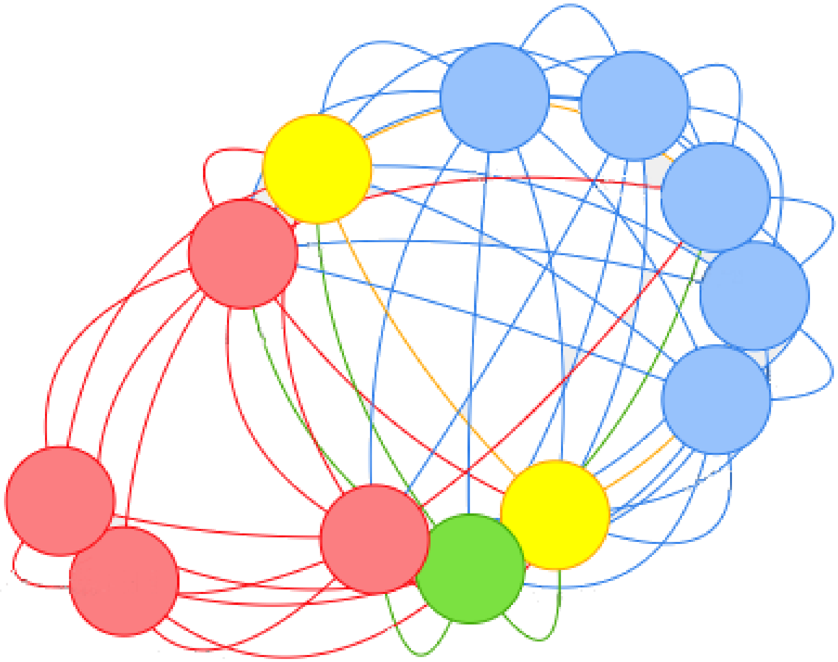


CLEVER



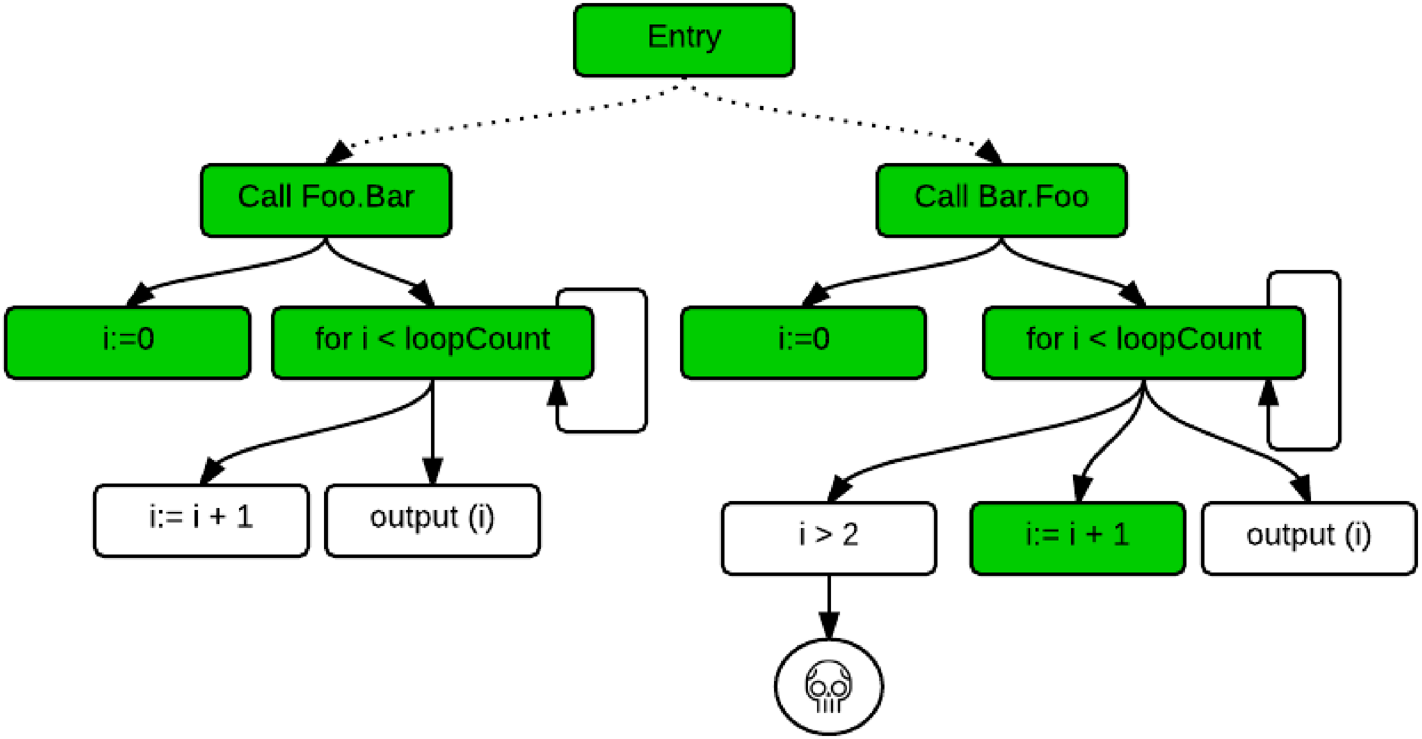
CLEVER

- Tested on 12 CSS
- 79% Precision
- 65% Recall
- 66% valid fix proposition
- Workflow Compliant
- ~2 seconds to ~25 seconds

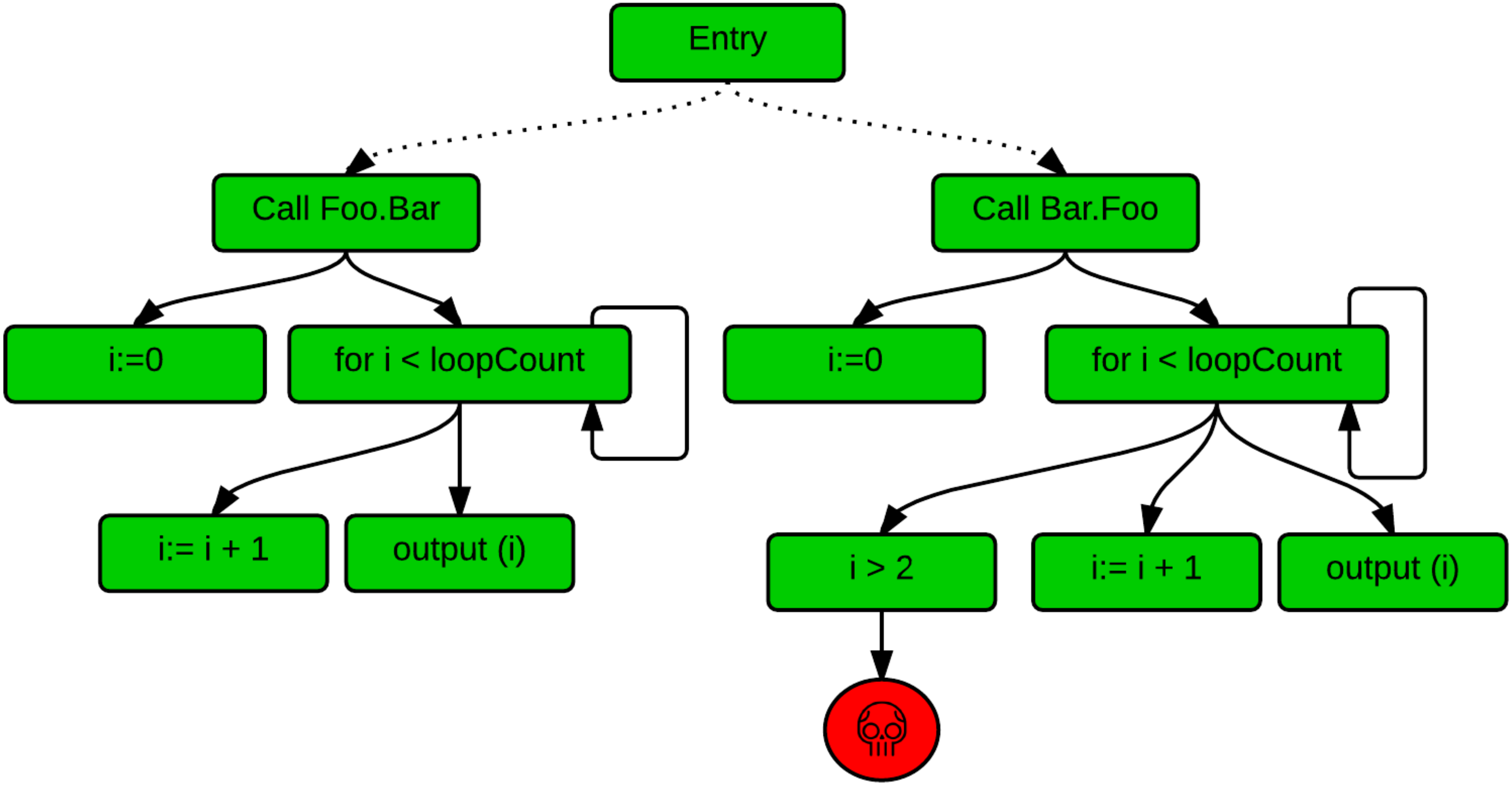


JCHARMING

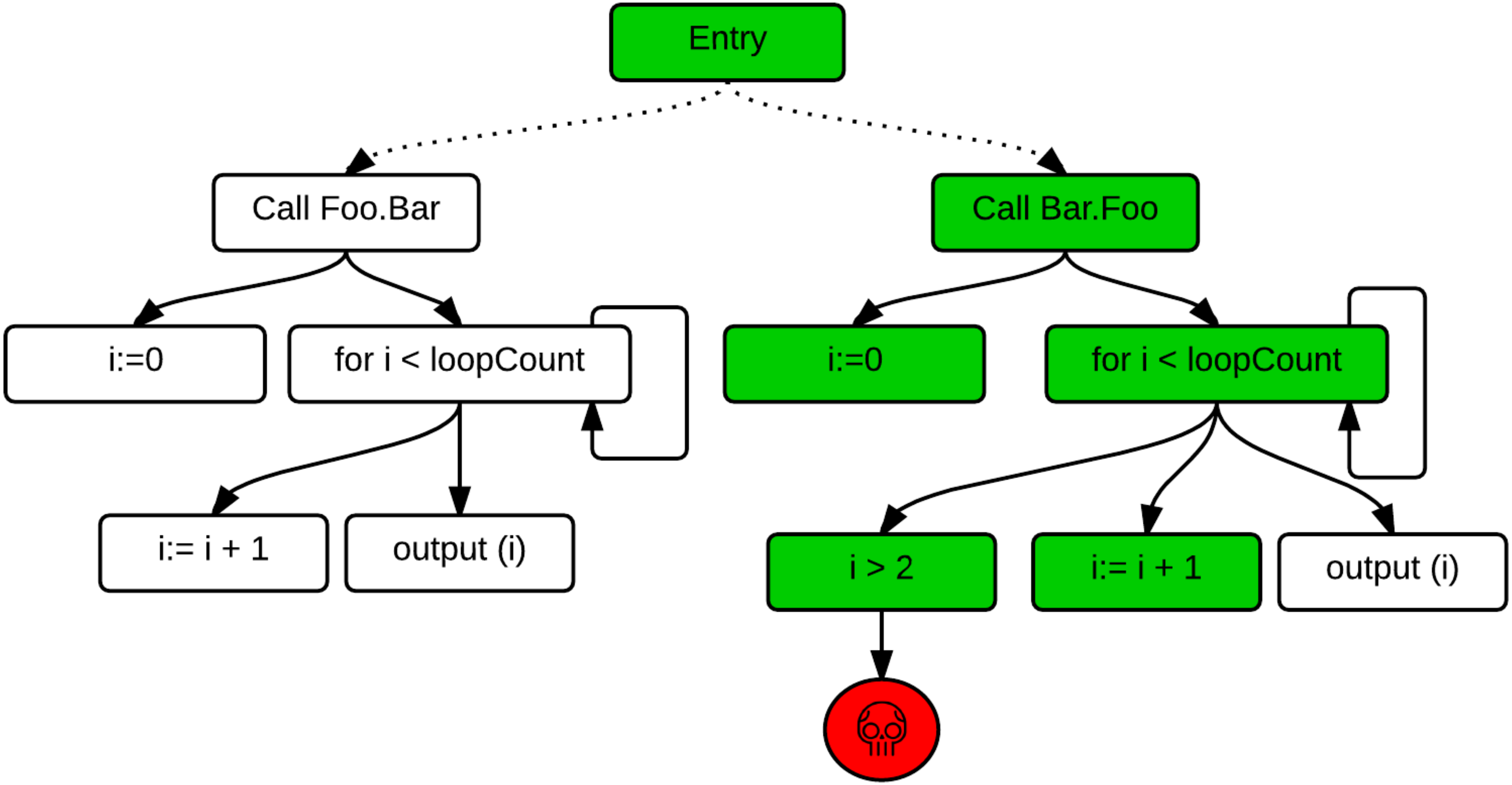
- Reproduce on-field crashes using stack traces and directed model checking



JCHARMING


Entry
Call Foo.Bar
Call Bar.Foo
i:=0
for i < loopCount
i:=0
for i < loopCount
i:= i + 1
output (i)
i > 2
i:= i + 1
output (i)

JCHARMING



Entry
Call Foo.Bar
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i:=0
for i < loopCount
i:=0
for i < loopCount
i:= i + 1
output (i)
i > 2
i:= i + 1
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JCHARMING

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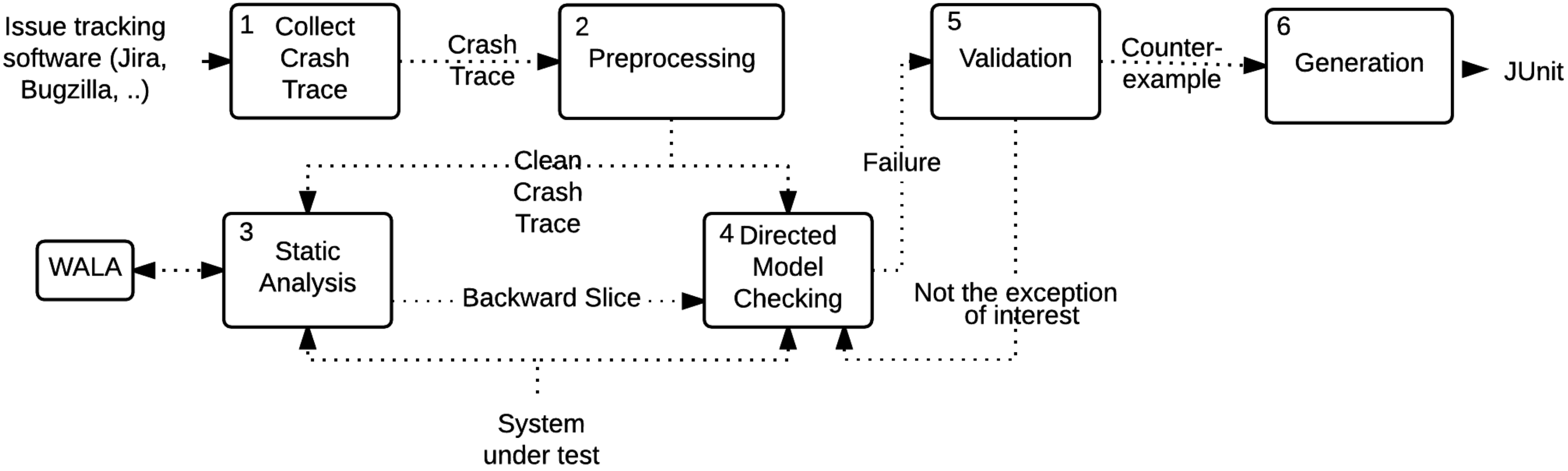
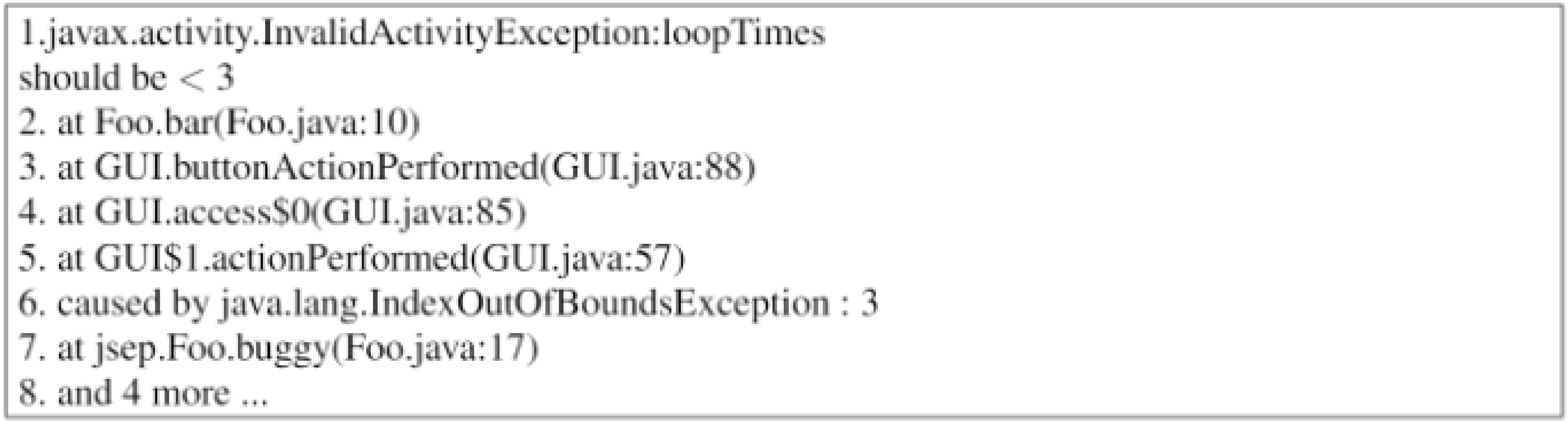
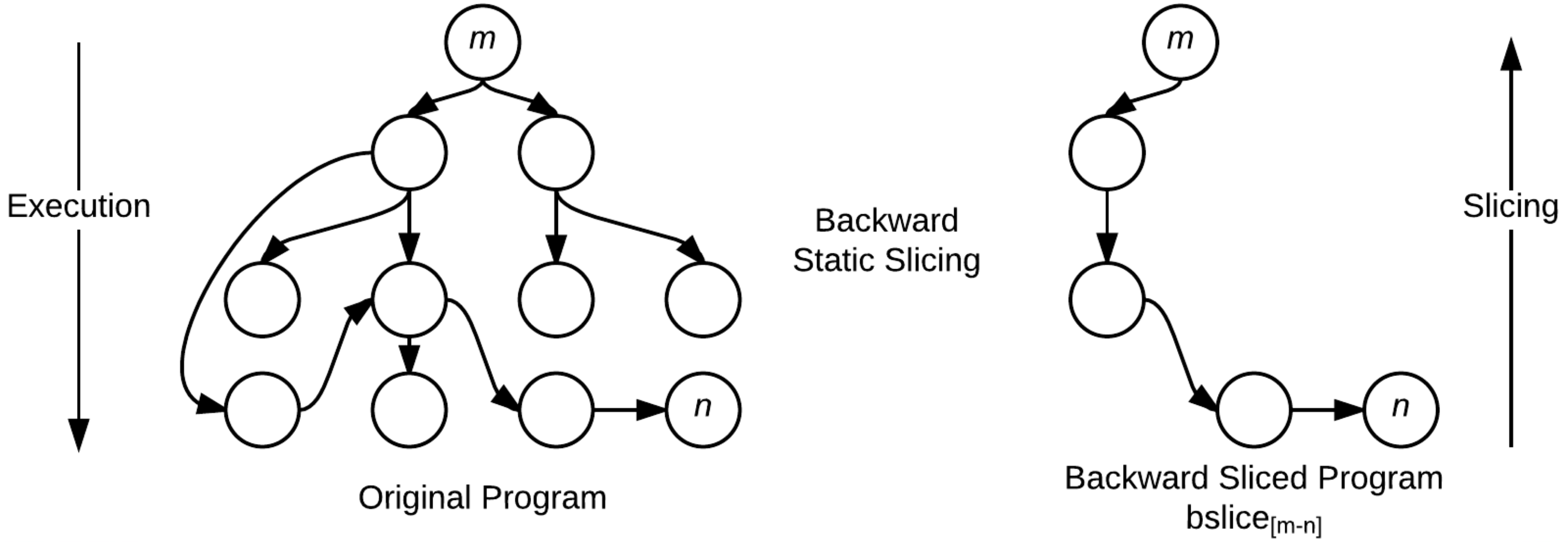


JCHARMING



```
1.javax.activity.InvalidActivityException:loopTimes
should be < 3
2. at Foo.bar(Foo.java:10)
3. at GUI.buttonActionPerformed(GUI.java:88)
4. at GUI.access$0(GUI.java:85)
5. at GUI$1.actionPerformed(GUI.java:57)
6. caused by java.lang.IndexOutOfBoundsException : 3
7. at jsep.Foo.buggy(Foo.java:17)
8. and 4 more ...
```



Execution

Original Program

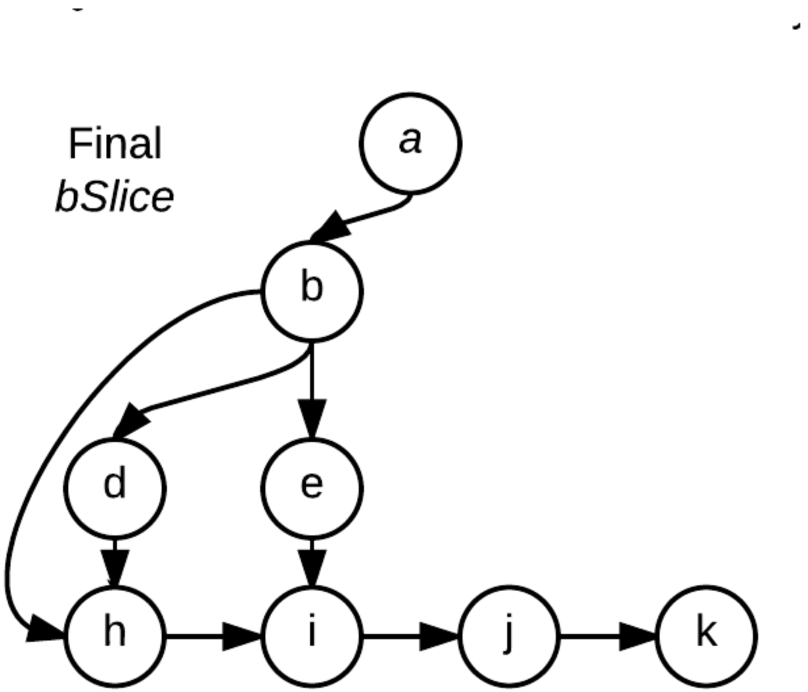
Backward Static Slicing

Slicing

Backward Sliced Program $\text{bslice}_{[m\text{-}n]}$

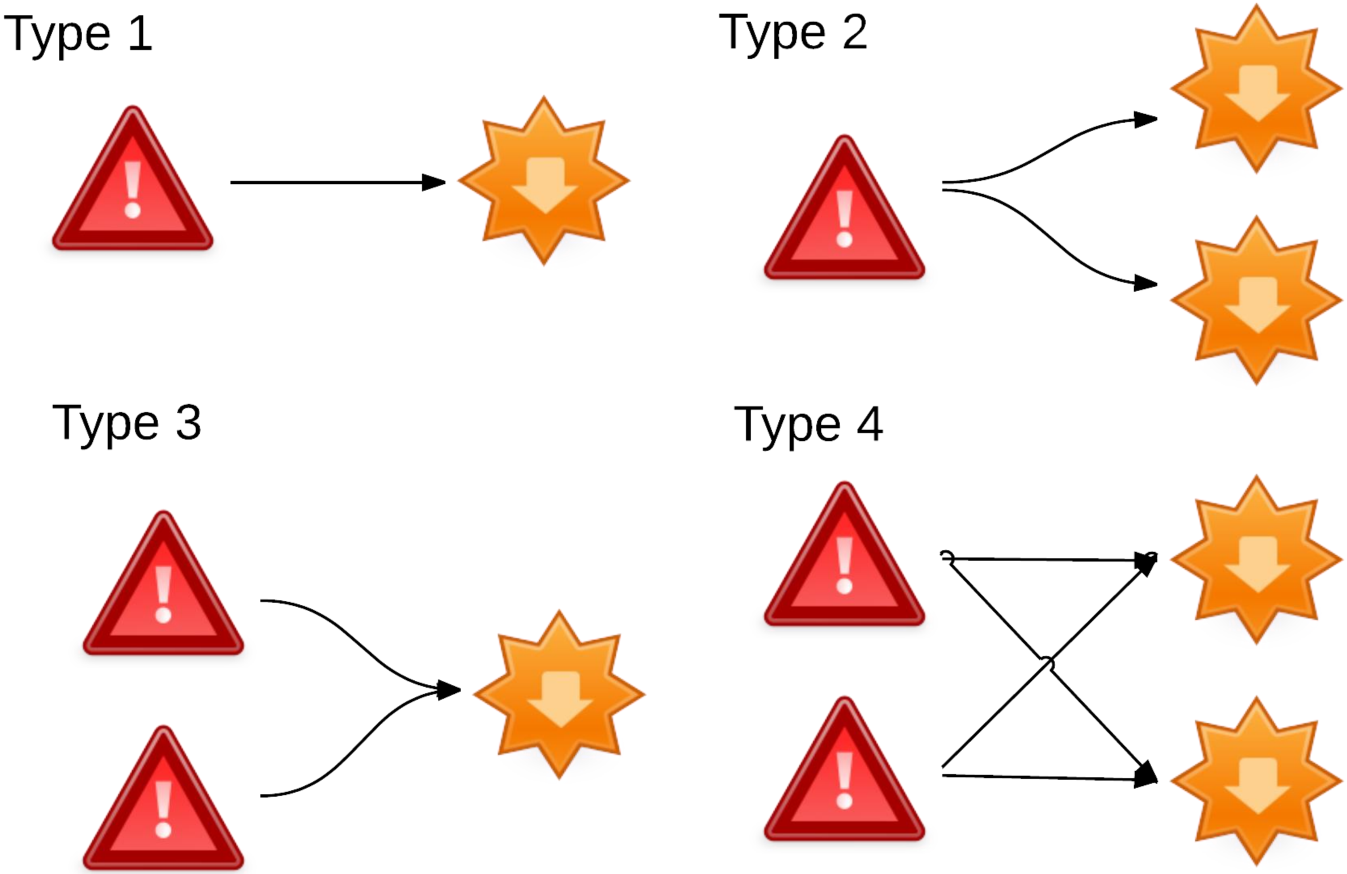
JCHARMING

- Tested on 10 OSS
- 80% success ratio.
- 32 defects.
- Produce unit test that exercise the crash.
- 19 minutes per crash.



Bug Taxonomy

- Categorizing Defects by their fix location and predicting defects type



Type 1

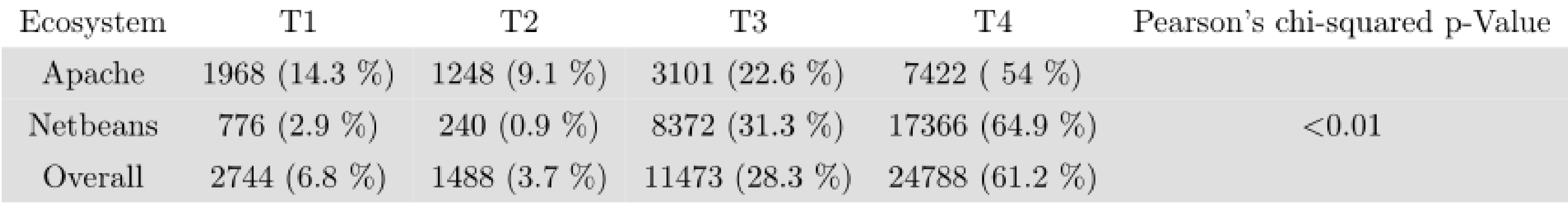
Type 2

Type 3

Type 4

Bug Taxonomy

- Type 4 are predominant
- Type 4 are the most complex
  - duplicate, time to fix, comments, reopening, files changed, severity, changesets, churns



Ecosystem	T1	T2	T3	T4	Pearson's chi-squared p-Value
Apache	1968 (14.3 %)	1248 (9.1 %)	3101 (22.6 %)	7422 (54 %)	<0.01
Netbeans	776 (2.9 %)	240 (0.9 %)	8372 (31.3 %)	17366 (64.9 %)	
Overall	2744 (6.8 %)	1488 (3.7 %)	11473 (28.3 %)	24788 (61.2 %)	

Bug Taxonomy

- Tested on 2 OSE (388 OSS).
- Predict Type 4 defects using SVM on the report words.
- 65.40% precision.
- 94.16% recall.
- 77.19% F1-measure.

Conclusion

- We proposed approaches that fit into the workflow of developers to:
  - Improve coding productivity (BUMPER).
  - Prevent Clone Insertion At Commit-Time (PRECINCT).
  - Prevent Bug Insertion At Commit-Time (BIANCA+CLEVER).
  - Reproduce On-Field Crashes At Report Time (JCHARMING).
  - Propose a new taxonomy of bugs based on their fixes.
- Validated on 455 OSS and CSS.

Publications

- Abdelwahab Hamou-Lhadj, Mathieu Nayrolles: A Project on Software Defect Prevention at Commit-Time: A Success Story of University-Industry Research Collaboration. *(SER&IP 2018, Co-located with the International Conference on Software Engineering 2018).*

- Mathieu Nayrolles, Abdelwahab Hamou-Lhadj: CLEVER: Combining Code Metrics with Clone Detection for Just-In-Time Fault Prevention and Resolution in Large Industrial Projects. *(MSR 2018, Co-located with the International Conference on Software Engineering 2018).*

- Mathieu Nayrolles, Abdelwahab Hamou-Lhadj: Towards a Classification of Bugs to Facilitate Software Maintainability Tasks. *(SQUADE 2018, Co- located with the International Conference on Software Engineering 2018).*

Publications

- Mathieu Nayrolles, Abdelwahab Hamou-Lhadj, Sofiene Tahar, Alf Larsson: A bug reproduction approach based on directed model checking and crash traces. *Journal of Software: Evolution and Process 29(3) (2017).*

- Mathieu Nayrolles, Abdelwahab Hamou-Lhadj: BUMPER: A Tool for Coping with Natural Language Searches of Millions of Bugs and Fixes. *International Conference on Software Analysis, Evolution and Reengineering 2016: 649-652.*

- Mathieu Nayrolles, Abdelwahab Hamou-Lhadj, Sofiene Tahar, Alf Larsson: JCHARMING: A bug reproduction approach using crash traces and directed model checking. *International Conference on Software Analysis, Evolution and Reengineering 2015: 101-110.* ***Best Paper Award***

Publications

- Abdou Maiga, Abdelwahab Hamou-Lhadj, Mathieu Nayrolles, Korosh Koochekian Sabor, Alf Larsson: An empirical study on the handling of crash reports in a large software company: An experience report. *International Conference on Software Maintenance and Evolution 2015: 342-351*

- Mathieu Nayrolles, Eric Beaudry, Naouel Moha, Petko Valtchev, Abdelwahab Hamou-Lhadj: Towards Quality-Driven SOA Systems Refactoring Through Planning. *International Multidisciplinary Conference on e-Technologies 2015: 269-284.*

Publications

THE GLOBE AND MAIL

L'actualité

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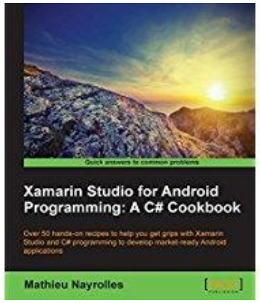
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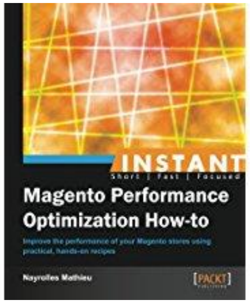
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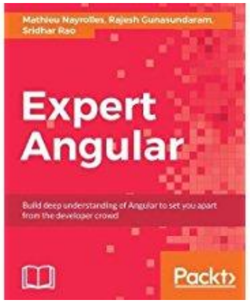
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Closing Remarks

- The *truth* is a moving target

- When is the right *time* for JIT Software Maintenance

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