香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

THE DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING
計算機科學及工程學系

Locus: Locating Bugs from Software Changes



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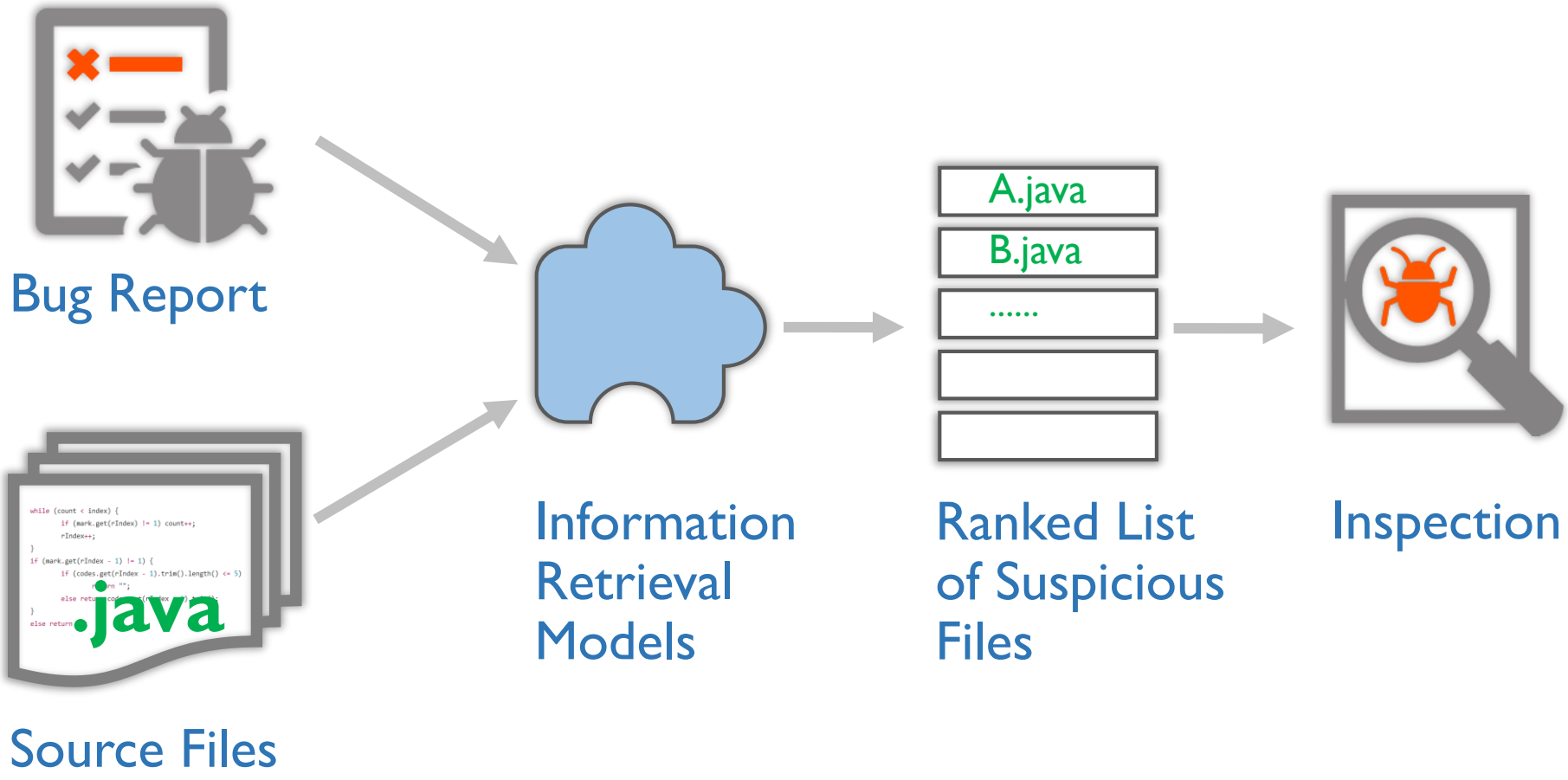
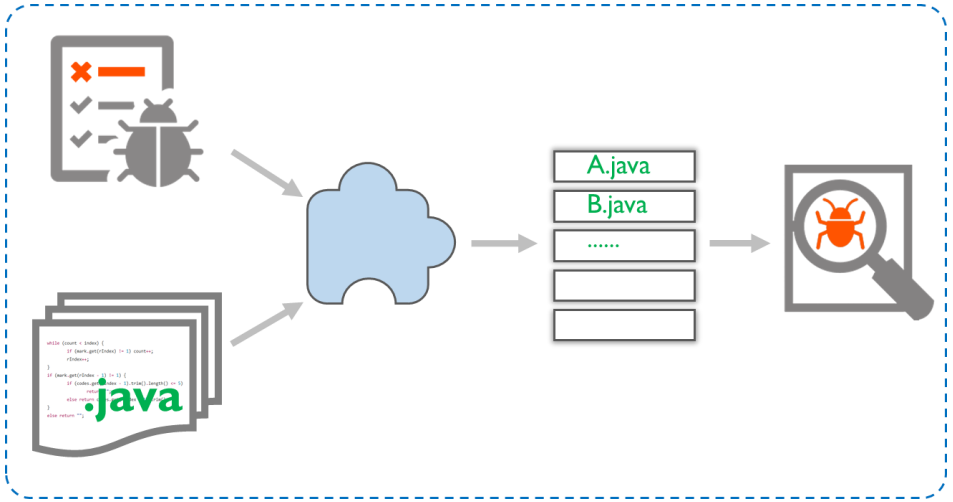
ASE 2016, 6th Sept, Singapore

Debugging is Painful!!

IR-Based Fault Localization



Limitations



- **Limit#1 Granularity**
  Source file results are coarse-grained [Wang et al. ISSTA'15].
- **Limit#2 Context**
  Lack of contextual clues [Parnin et al. ISSTA'11].

Comments of Bug Report

Konstantin Kolinko 2014-09-01 09:15:22 UTC Comment 1

Created attachment 31958 [details]
2014-09-01_tc8_56905_v1.patch

Patch (v1) for current trunk at r1621698
I have not tested it yet.

Mark Thomas 2014-09-03 13:41:40 UTC Comment 2

Patch looks sensible to me. Applied to 8.0.x for 8.0.13 onwards and to 7.0.x got 7.0.56 onwards.

Réda Housni Alaoui 2016-05-03 20:55:14 UTC Comment 3

Hello,

Running on tomcat 8.0.33, we are having this issue.

Here is the trace:

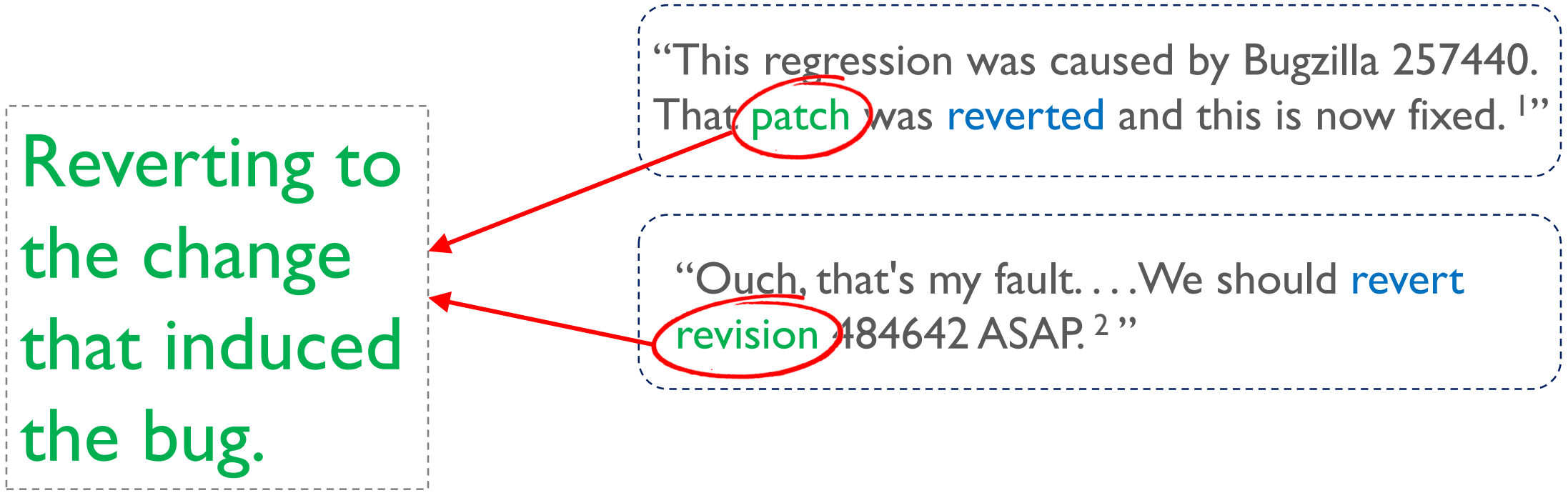
03-May-2016 22:09:13.405 WARNING [http-nio-8002-exec-150]
org.apache.tomcat.websocket.server.WsServerContainer.destroy Unable to destroy
WebSocket thread group [WebSocketServer-localhost-/0
********] as [1] threads were still running when the web application was stopped.
The thread group will be destroyed once the threads terminate.

The application that we tried to stop does not restart.
I will add the thread dump in attachment asap.

Mark Thomas 2016-05-04 13:07:28 UTC Comment 4

(In reply to Réda Housni Alaoui from comment #3)

Comments of Bug Report



[1] https://bugs.eclipse.org/bugs/show_bug.cgi?id=262975
[2] https://bz.apache.org/bugzilla/show_bug.cgi?id=41551

Developers' Feedback

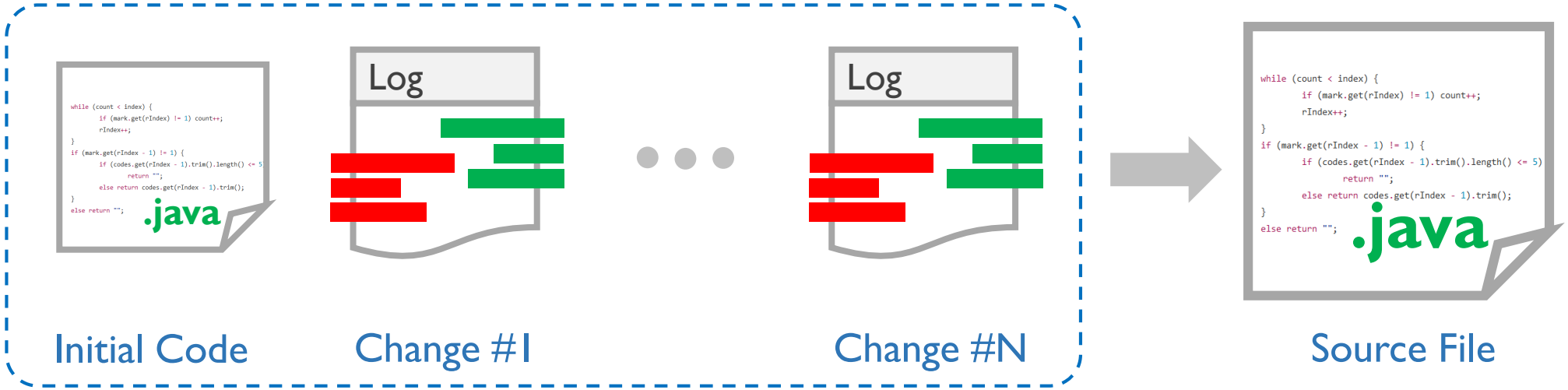
Is the information of inducing changes useful?

"It can be a eureka moment for the developer, where they see the inducing change and say 'I know exactly why this is happening', thus resulting in a fix typically in a matter of days, even hours. It really is a critical piece of the puzzle."

What actions will be taken if inducing change is available?

"The action taken is usually getting the responsible developer to either A) back out the change or B) code and land a follow-up fix as soon as possible."

Bug Inducing Change



- Changes are committed to fix bugs, introduce new features or refactor.
- Changes can induce new bugs, and those changes are regarded as **bug-inducing changes**.

Change A(#2653cea) of Tomcat
WsServerContainer.java

```
Commit   #2653cea
Author : Mark Emlyn David Thomas <markt@apache.org>
Date :   Tue Apr 22 08:31:56 2014 +0000
Log: Refactor server container shutdown into the destroy
method. Destroy the thread group on shutdown. Log a warning if
the thread group can't be destroyed
@@ -270,6 +275,21 @@ public void addEndpoint(Class<?> pojo)
+        shutdownExecutor();
+        super.destroy();
+        try {
+            threadGroup.destroy();
+        } catch (IllegalThreadStateException itse) {
...
    boolean areEndpointsRegistered() {
        return endpointsRegistered;
    }

@@ -550,11 +563,18 @@ public void toString()
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Developer Log Message

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    boolean areEndpointsRegistered() {
        return endpointsRegistered;
    }
```

```
@@ -550,11 +563,18 @@ public void toString()
```

Hunk

A group of continuous lines that are changed along with contextual unchanged lines.
A change may contain multiple hunks.

Bug #56905

Summary: Unable to destroy WebSocket thread group when reloading webapp …… generally there might be threads that are still running,…,threadGroup.enumerate() have not returned

```
Commit   #2653cea  (inducing change)
Author : Mark Emlyn David Thomas
Date :   Tue Apr 22 08:31:56 2014 +0000
Log: Refactor server container shutdown into the destroy
method. Destroy the thread group on shutdown. Log a warning if
the thread group can't be destroyed
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...
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         return endpointsR
     }

@@ -550,11 +563,18 @@ public void toString()
```

Bug-Inducing Change

```
Commit   #a027afd (fixing change)
Author : Mark Emlyn David Thomas
Date :   Wed Sep 03 13:36:43 2014 +0000
Log: Fix https://issues.apache.org/bugzilla/show_bug.cgi?id=56905
@@ -273,14 +273,42 @@ public void addEndpoint(Class<?> pojo)
+         int threadCount = threadGroup.activeCount();
+         boolean success = false;
          try {
-             threadGroup.destroy();
-         } catch (IllegalThreadStateException itse) {

+             while (true) {
+                 int oldThreadCount = threadCount;
+                 synchronized (threadGroup) {
```

Bug Report #56905 of Tomcat

Change A (#2653cea)

WsServerContainer.java

Refactoring and adding new features

Bug #56905 is reported

Change B (#a027afd)

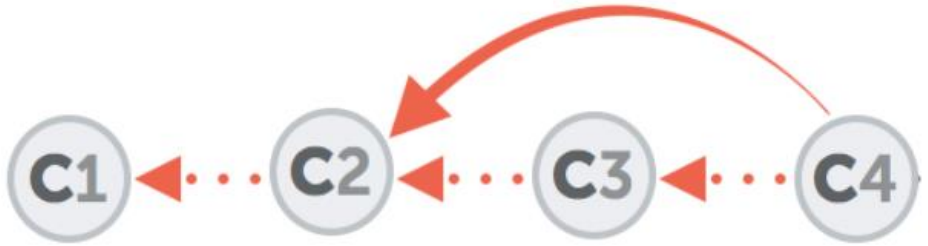
WsServerContainer.java

Fixing Change

by the **same developer** of the inducing change

Changes are Useful

- Reverting Bug Inducing Change
  - Limit#2 Context
- Facilitating Bug Triaging
  - Limit#2 Context
- Fine Granularity
  - Limit#1 Granularity



Inspected many bug reports.

THE APACHE SOFTWARE FOUNDATION : #761

eclipse : #1733

Changes are Useful

- Reverting Bug Inducing Change
  - Limit#2 Context
- **Facilitating Bug Triaging**
  - **Limit#2 Context**
- Fine Granularity
  - Limit#1 Granularity

Triaging bugs to the committer of the inducing change.

Subject	#Dev	#Bugs	#Same	Ratio (%)
SWT 3.1	86	97	65	67.00%
JDT 4.5	95	94	67	71.30%
Tomcat 8.0	29	193	167	86.50%

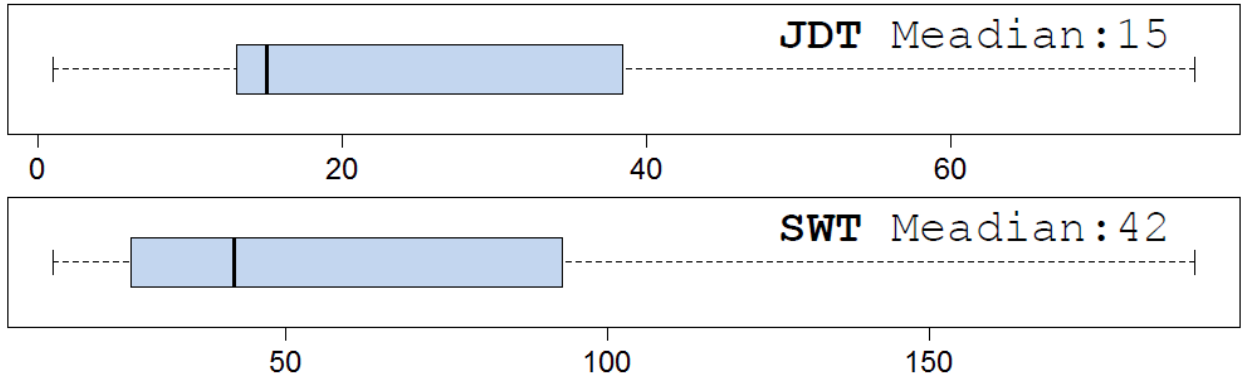
Ratio of Bug Reports Whose Fixing Developer is the Same as the Developer of the Bug Inducing Change

77.86% of the bugs are fixed by the committer of the inducing change.

Changes are Useful

- Reverting Bug Inducing Change
  - Limit#2 Context
- **Facilitating Bug Triaging**
  - **Limit#2 Context**
- Fine Granularity
  - Limit#1 Granularity

Triaging bugs to the committer of the inducing change.



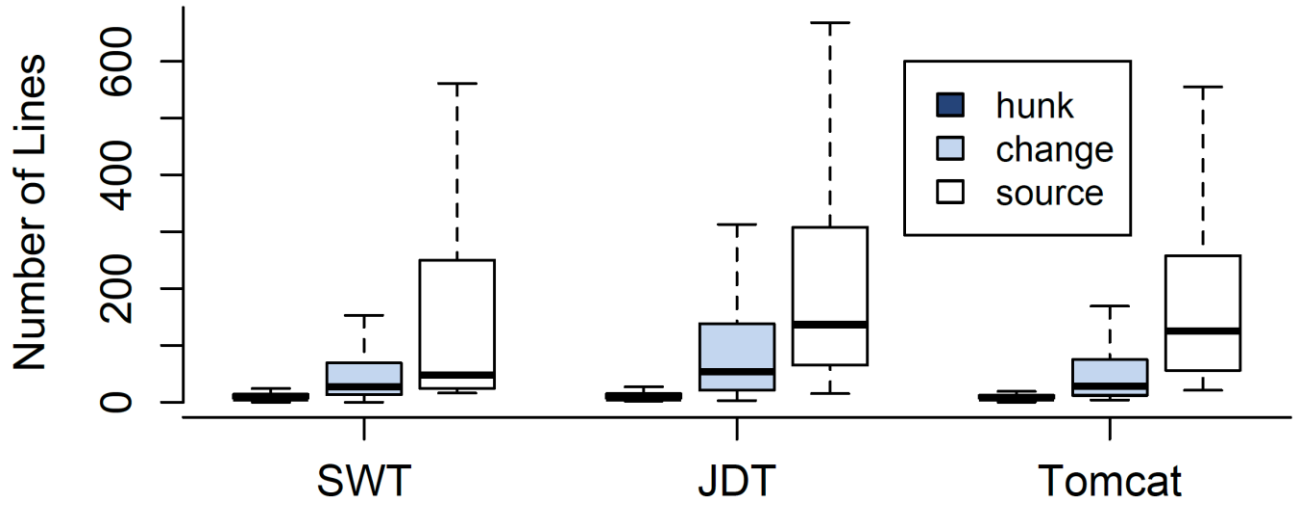
Bug Triage Time for JDT and SWT (days)

Many manual efforts are required to triage bugs.

Changes are Useful

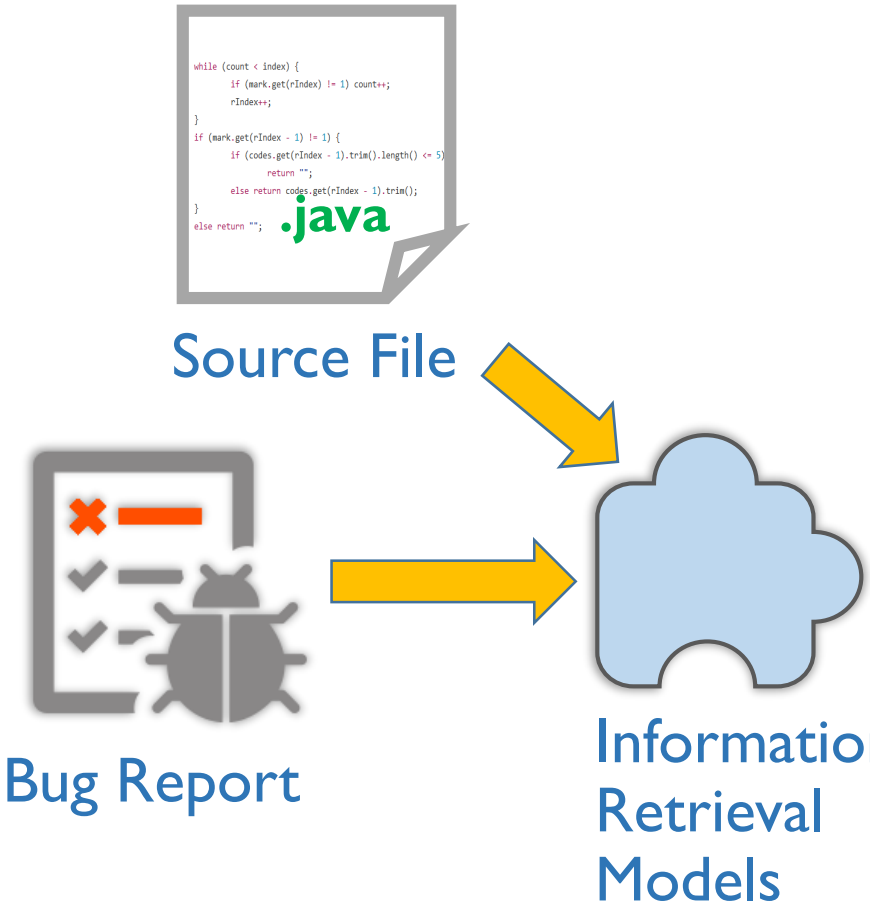
- Reverting Bug Inducing Change
  - Limit#2 Context
- Facilitating Bug Triaging
  - Limit#2 Context
- Fine Granularity
  - Limit#1 Granularity

Debugging at the change level can significantly save effort when compared with source level [Kamei et al. TSE'13].

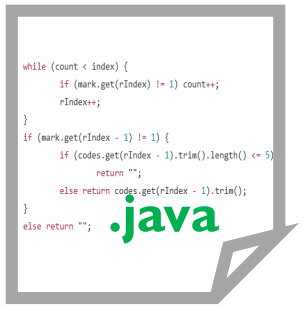


Comparison of Lines of Codes among Hunks, Changes and Source Files

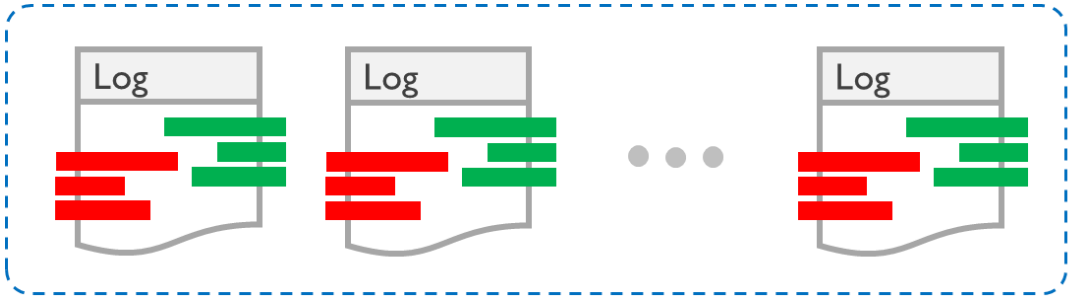
Using Software Changes in IR-Based Fault Localization



Using Software Changes in IR-Based Fault Localization

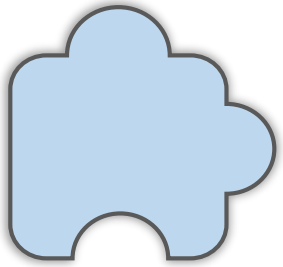


Source File



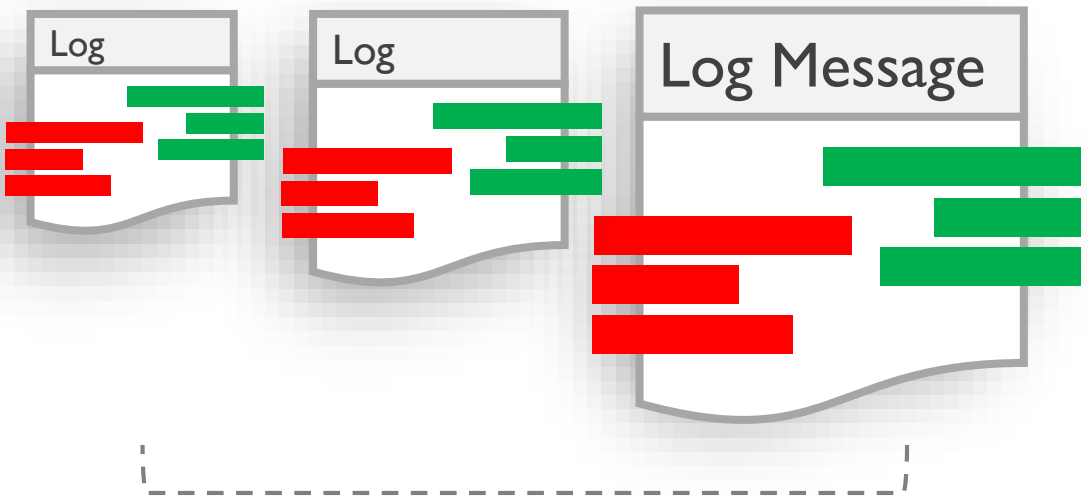
Software Changes

Bug Report



Information Retrieval Models

Benefits of Using Software Changes



1. Informative Change Logs
2. Highly Correlated Contents
3. Change Histories

Bug #56905

Summary: Unable to destroy WebSocket thread group when reloading webapp …… generally there might be threads that are still running,…,threadGroup.enumerate() have not returned

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Author : Mark Emlyn David Thomas <markt@apache.org>
Date :   Tue Apr 22 08:31:56 2014 +0000
Log: Refactor server container shutdown into the destroy
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+            while (true) {
+                int oldThreadCount = threadCount;
+                synchronized (threadGroup) {
```

Bug Report #56905 of Tomcat

Inducing Change

Refactoring and adding new features
Inducing bug #56905

Fixing Change

by the same developer of the inducing change

Bug #56905

Summary: Unable to **destroy** WebSocket **thread group** when reloading webapp …… generally there might be **threads** that are still running,…,**threadGroup**.enumerate() have not

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Bug Report #56905 of Tomcat

Inducing Change

Refactoring and adding new features

Inducing bug #56905

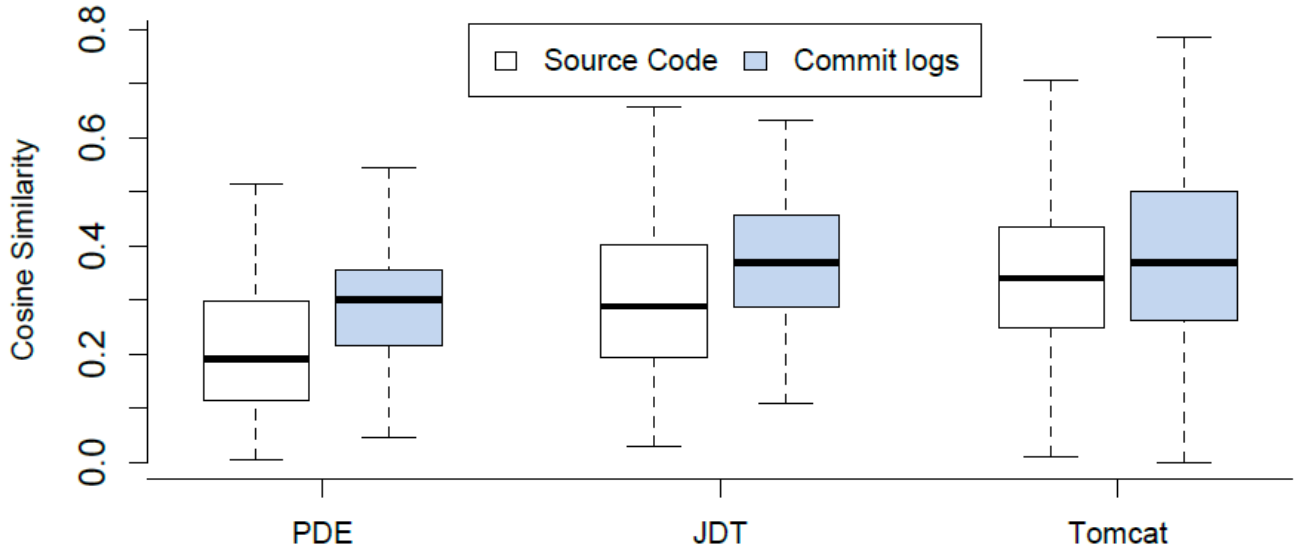
Lots of common tokens are shared between the bug report and the log messages of the change.

Fixing Change

by the same developer of the inducing change

Benefits of Using Software Changes

- Informative Change Logs
- Highly Correlated Contents
- Change History



Text Similarities between Bug Reports and the Buggy Files as well as the Change Logs

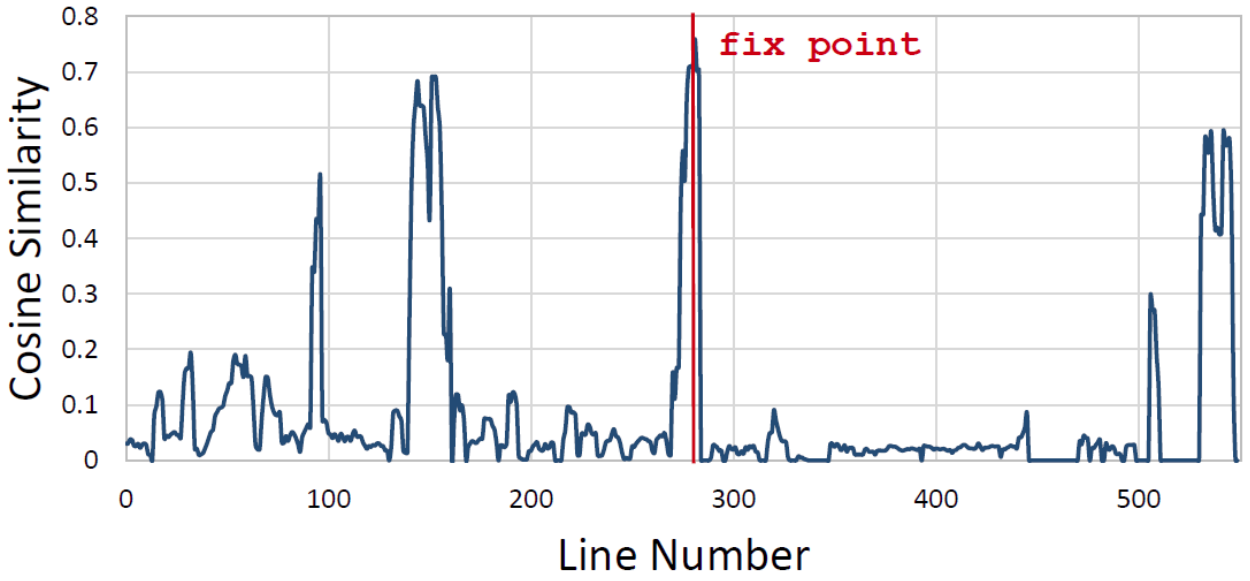
Change logs share a substantial number of common tokens with bug reports.

Benefits of Using Software Changes

- Informative Change Logs
- **Highly Correlated Contents**
- Change History

- Large source files are susceptive to noise due to the fuzziness arising from information retrieval [Wong et al. ICSME'14, Ye et al. FSE'14].

Bug Report #56905 and its Cosine Similarity of Source File *WsServerContainer.java*



Benefits of Using Software Changes

- Informative Change Logs
- Highly Correlated Contents
- Change History

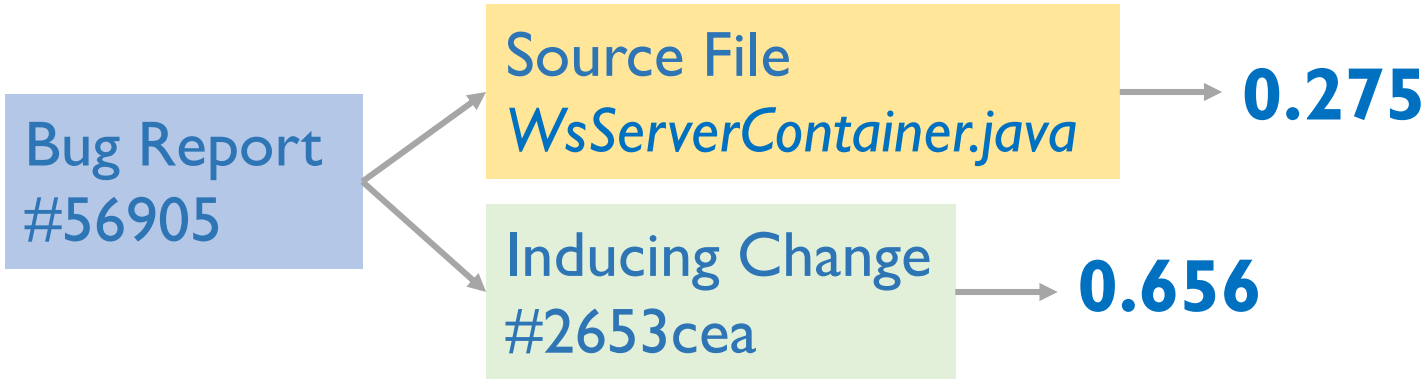
- Segmenting source files into equal-sized segments [Wong et al. ICSME'14].
- Segmenting source files into methods [Ye et al. FSE'14].

Benefits of Using Software Changes

- Informative Change Logs
- Highly Correlated Contents
- Change History

Highly correlated and small pieces of code are desired in retrieval models.

Change hunks are intrinsically small in size and correlated in contents.[Alali et al. ICPC'08].



Benefits of Using Software Changes

- Informative Change Logs
- Highly Correlated Contents
- **Change History**

Software changes capture the history of source files (e.g. ownership, fixing history), which indicate the proneness of source files to contain faults.

- Defect prediction [Moser ICSE'08, Rahman FSE'11]
- Fault Localization [Ye. FSE'14, Wang ICPC'14]
- Google[1]

[1] http://google-engtools.blogspot.hk/2011/12/bug-prediction-at-google.html. Accessed: 2015-03-22.

Locus

Locus: Locating Bugs from Change Hunks

Locus

Bug #56905

Summary: Unable to **destroy** WebSocket **thread group** when reloading webapp …… generally there might be **threads** that are still running,…,threadGroup.enumerate() have not returned

Bug Report: Summary + Description

Commit #2653cea

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    boolean areEndpointsRegistered() {
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```

Hunk: Log Message + Changed Lines + Contextual Lines

- Index **N**atural **L**anguage Tokens (**NL**)

  e.g. destroy, web, socket, group, thread,…

Locus

Bug #56905

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Hunk: Log Message + Changed Lines + Contextual Lines

- Index **N**atural **L**anguage Tokens (**NL**)

  e.g. destroy, web, socket, group, thread,…

- Index **C**ode **E**ntity Names (**CE**)

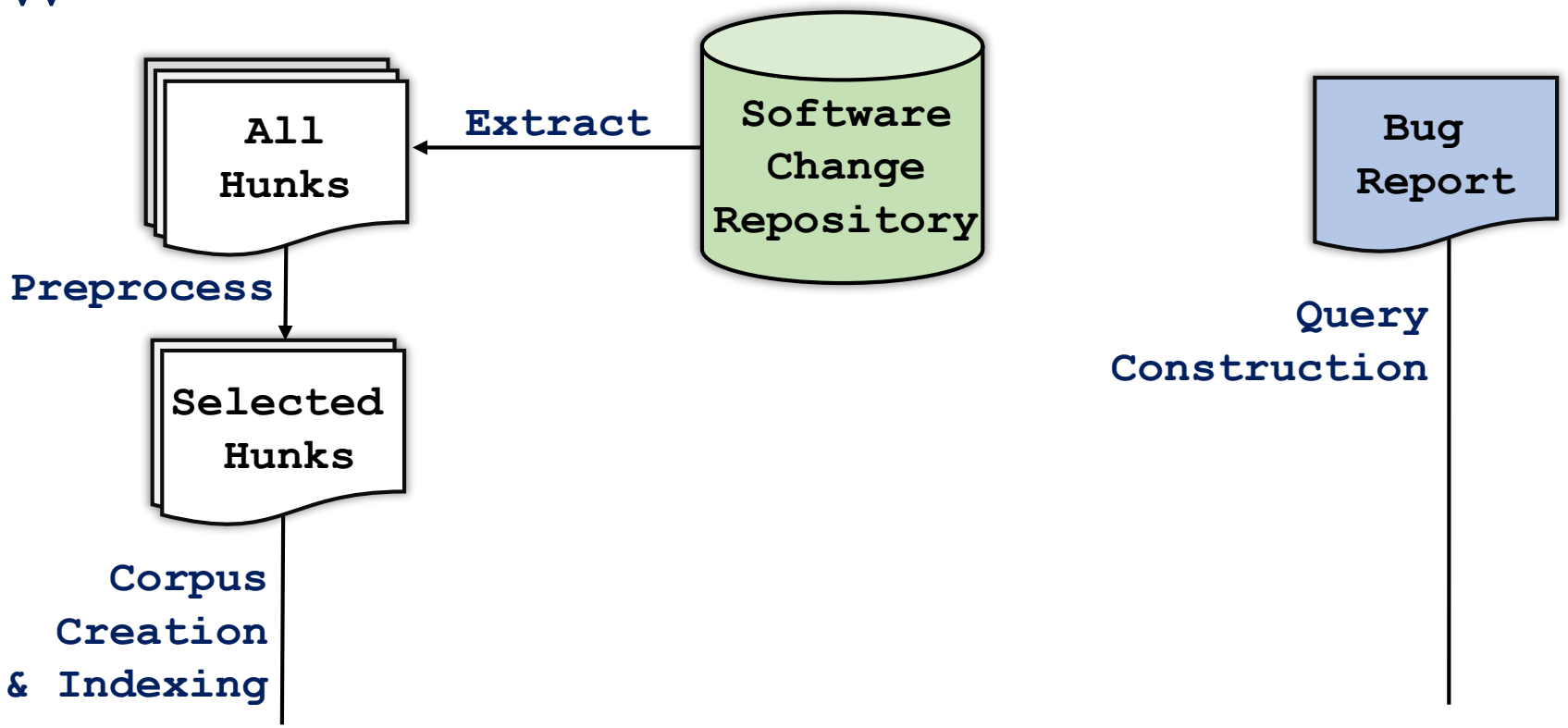
  e.g. addEndpoint, threadGroup, …

- Leverage Change History (**Boosting**)

  e.g. fixing history, change time

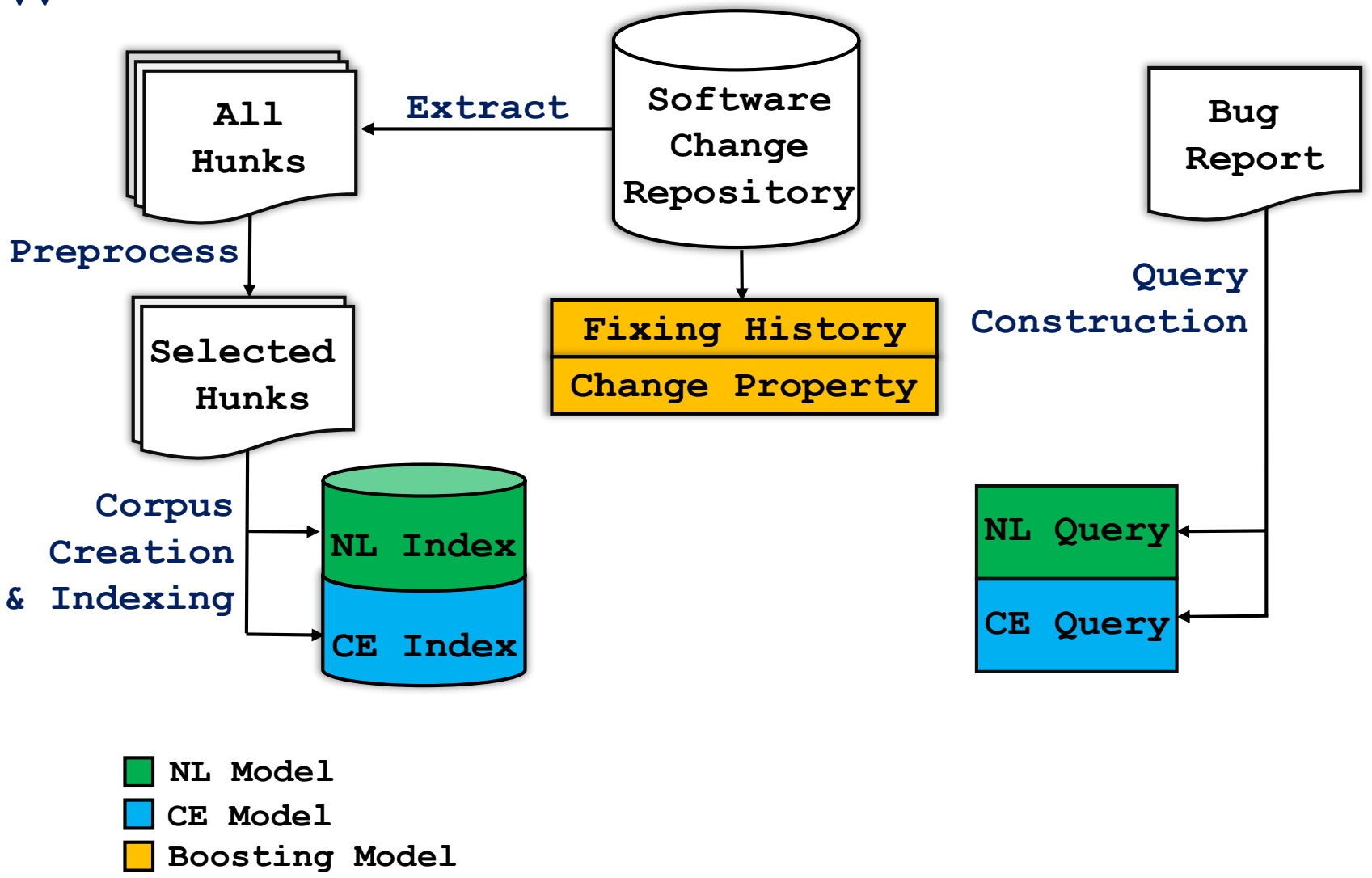
Locus Overview

- Vector Space Model



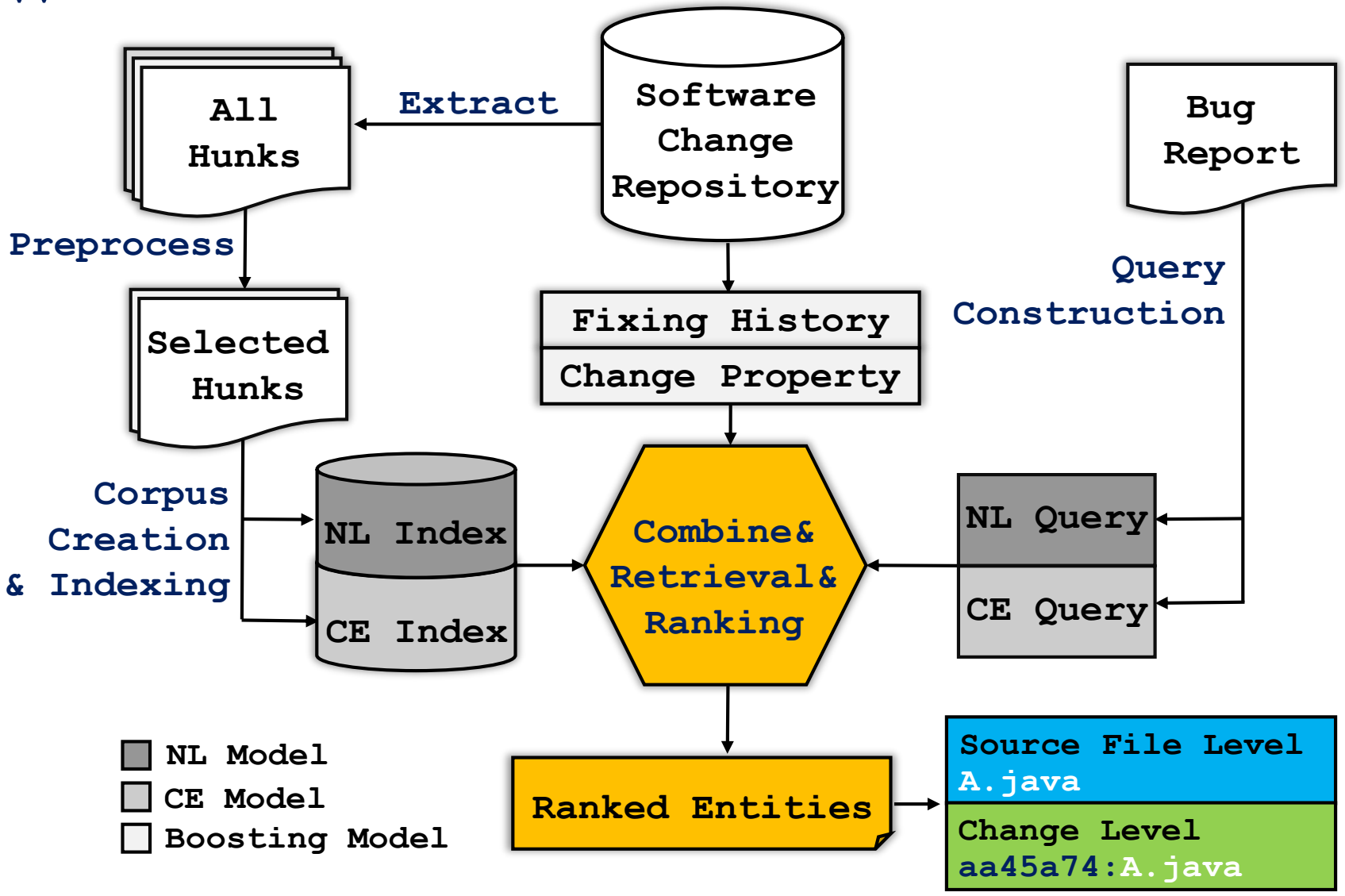
Locus Overview

- Vector Space Model
- Three Models
  NL / **CE** / **Boosting**



Locus Overview

- Vector Space Model
- Three Models NL / CE / Boosting
- Combing Results
  - Source Leve
  - Change Level



Experiment Setup

➢ Dataset

Subject	Num Bugs	Num Files	K Loc	K Changes
ZXing	20	391	49.6	3.14
SWT 3.1	98	484	141.9	11.9
AspectJ	244	6,485	511.9	7.7
PDE 4.4	60	5,273	565.2	11.3
JDT 4.5	94	6,775	1,675.30	21.7
Tomcat 8.0	193	2,042	485.7	16.1

Benchmark dataset from BugLocator

Collected by us

All the bugs with valid links to fix changes

Tomcat

SWT, PDE, JDT, AspectJ

ZXing

Experiment Setup

- Evaluation Metrics
  - Top@N (N = 1, 5, 10…)

    The percentage of bugs whose relevant files can be listed in the top N of the ranked list.
  - (MRR) Mean Reciprocal Rank

    How well the first relevant files are ranked, the higher the better.
  - (MAP) Mean Average Precision

    How well all relevant files are ranked, the higher the better

Research Questions

- **[RQ1] Software Changes VS. Source Files**

  Can the text tokens extracted from software changes effectively locate bugs in IR-based techniques?

- **[RQ2] Locus VS. Baselines**

  How is the performance of Locus compared with state-of-the-art approaches.

- **[RQ3] Contributions of Each Model**

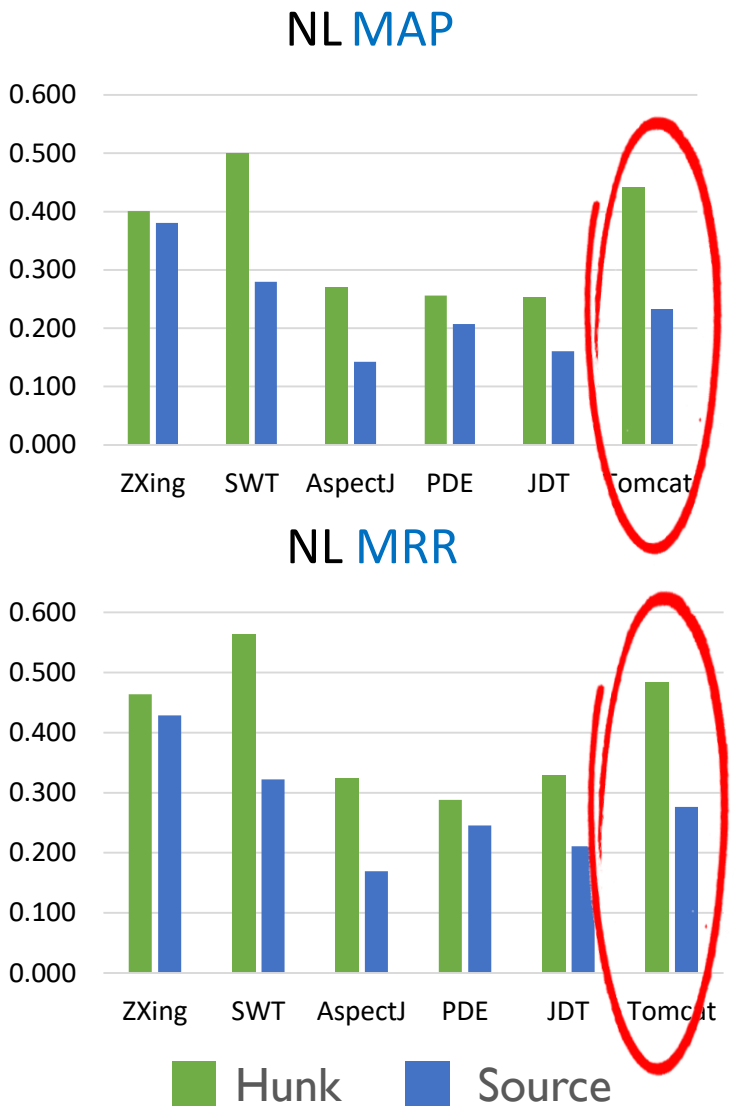
  Can each model we proposed improves the final performance?

[RQ1] Software Changes VS. Source Files

- Compare the localization results using the text tokens extracted from software changes with those from source files.

- Keeping only the natural language tokens.
- Keeping only the tokens of code entity names.
- Using both of them.

[RQ1] Software Changes VS. Source Files

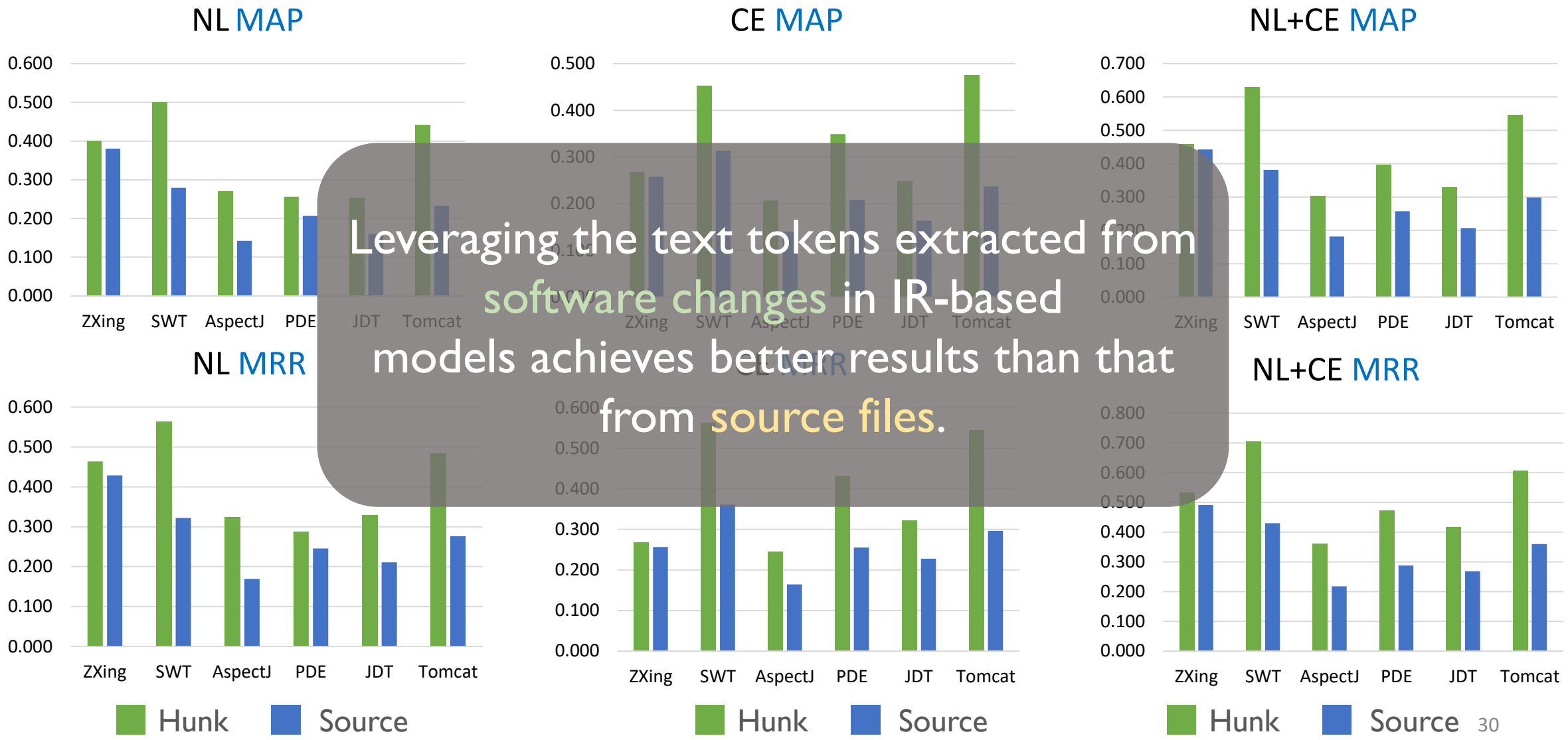


Tomcat

The MAP has been improved by 89.43%.

The MRR has been improved by 75.20%.

[RQ1] Software Changes VS. Source Files



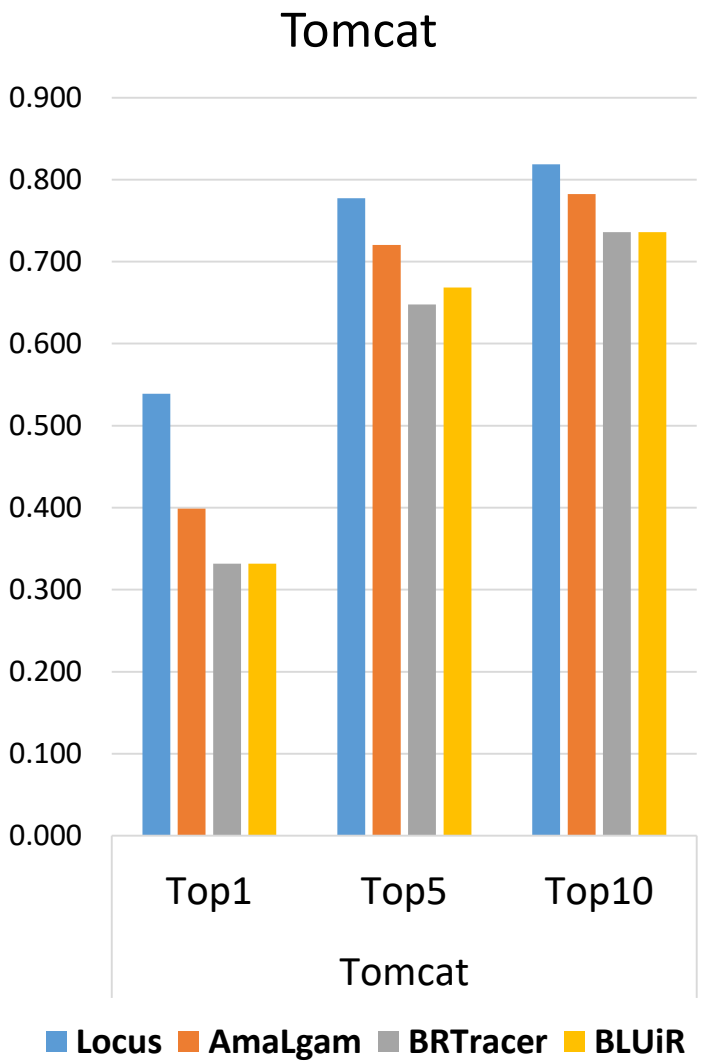
Leveraging the text tokens extracted from software changes in IR-based models achieves better results than that from source files.

[RQ2] Locus VS. Baselines

Three state-of-the-art **IR-based** approaches:

- BRTracer [Wong et al. ICSME'2014]
  Leveraging stack traces and segmenting source files
- BLUiR [Saha et al. ASE'2013]
  Leveraging code structures information
- AmaLgam [Wang et al. ICPC'2014]
  Combining similar bugs, code structures and fixing histories together.

[RQ2] Locus VS. Baselines



Tomcat

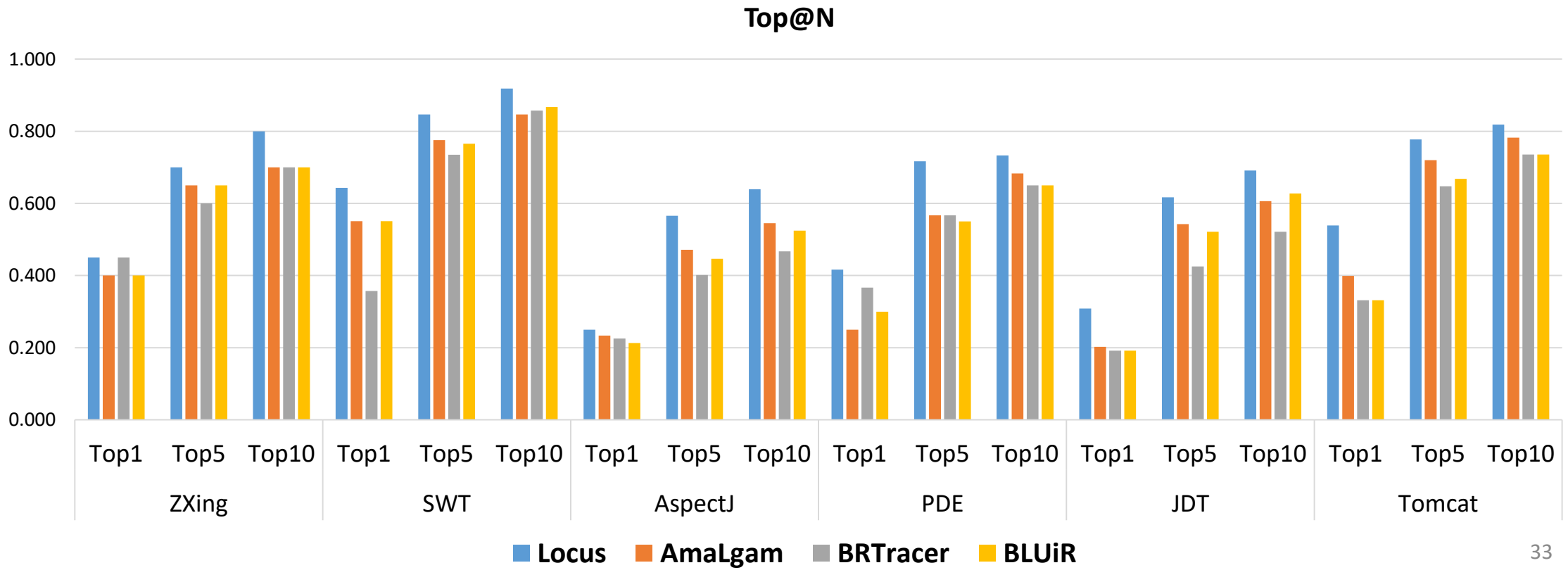
Locates 56.6% of the bugs and rank them at Top 1. **27 more bugs**

Locates 77.7% of the bugs and rank them at Top 5. **11 more bugs**

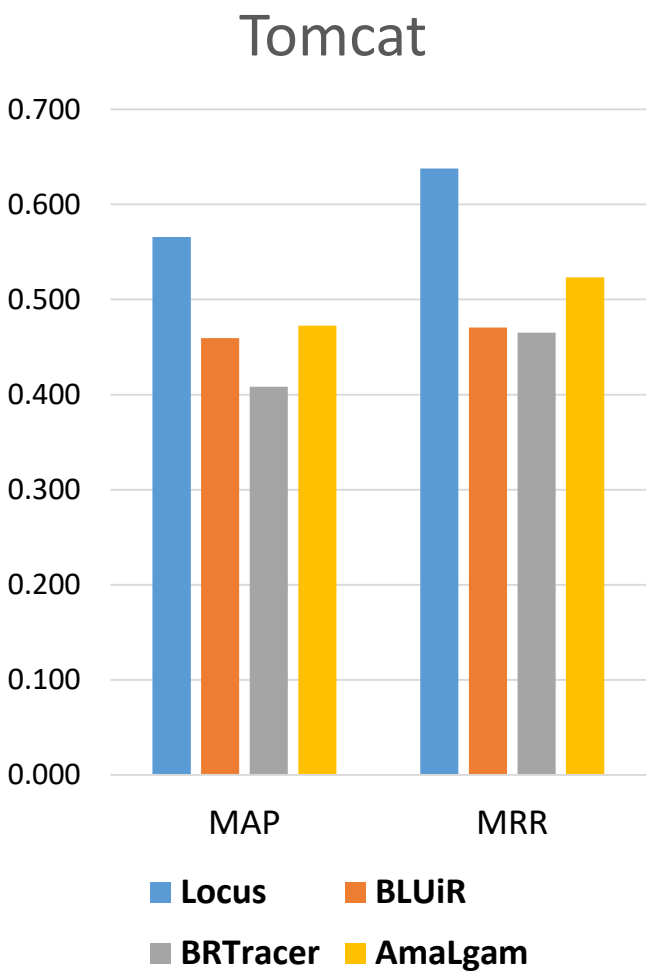
Locates 81.9% of the bugs and rank them at Top 10. **7 more bugs**

[RQ2] Locus VS. Baselines

- Locus locates the buggy files and rank them as top 1 for 41.0% of the bugs.
- Locus outperforms the three baselines works for all subjects under all Top@N metrics.



[RQ2] Locus VS. Baselines

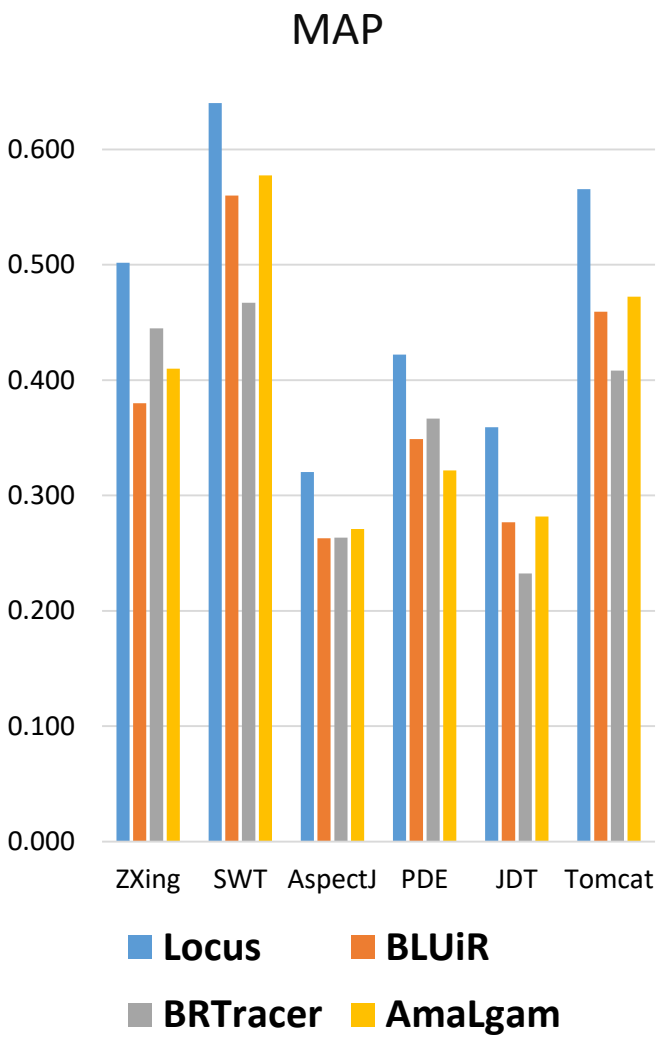


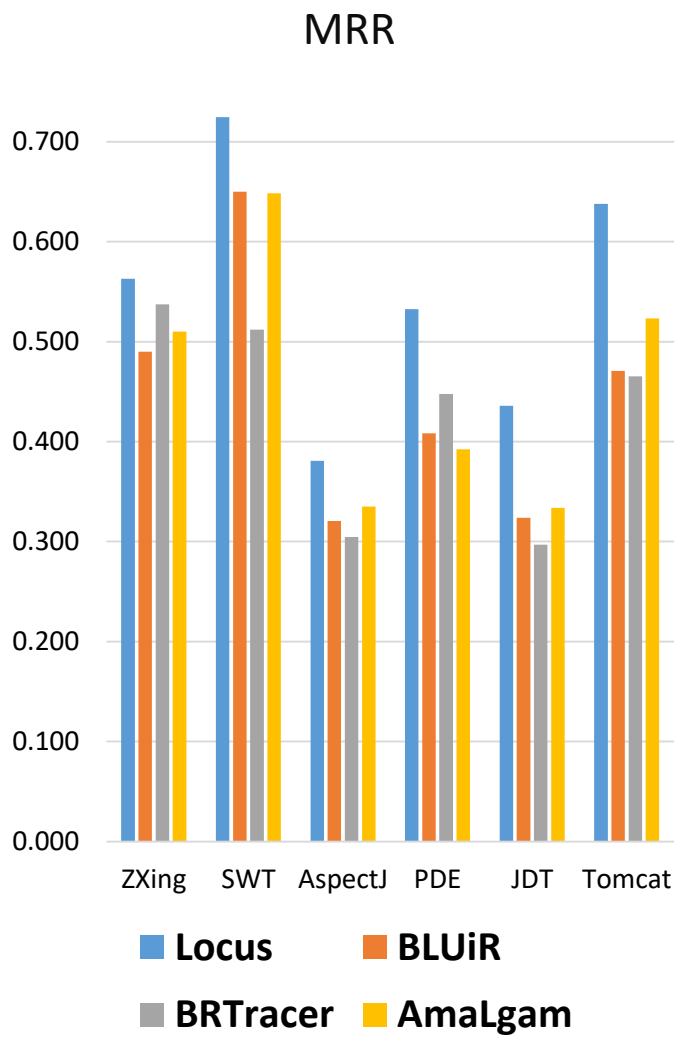
Tomcat

Achieves an MAP and MRR of 0.566 and 0.638.

The MAP and MRR have outperform the best baseline for 19.7% and 21.9% respectively.

[RQ2] Locus VS. Baselines





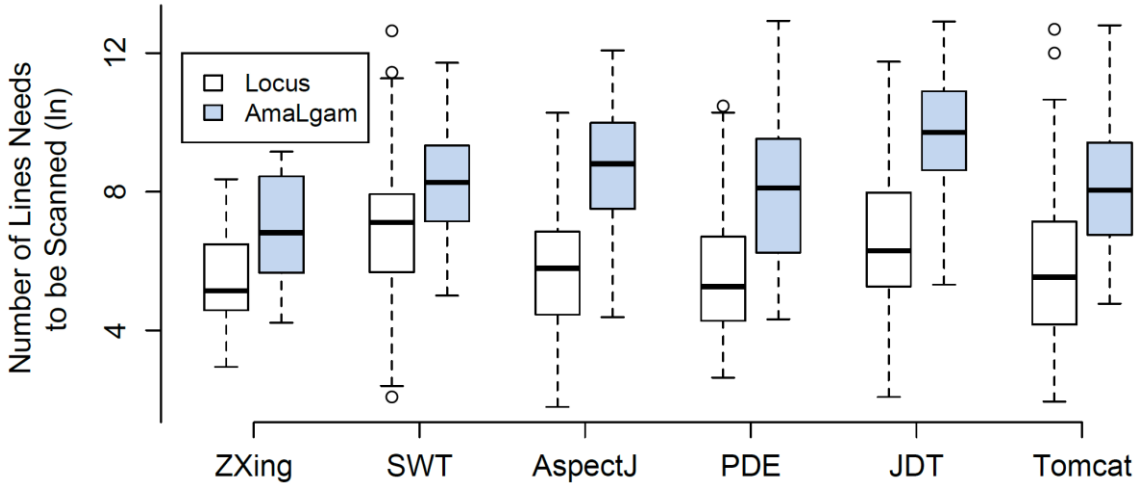
- Locus achieves an average MAP of 0.468 and MRR of 0.546.
- The average improvements

	MAP	MRR
AmaLgam	20.1%	20.5%
BLUiR	22.4%	25.3%
BRTracer	31.9%	32.4%

[RQ2] Change Level Results

Results of MAP, MRR and Top@N at the Change Level

Subject	MAP	MRR	Top@1	Top@5	Top@10	Top@20
ZXing	0.262	0.333	0.200	0.400	0.500	0.900
SWT	0.14	0.224	0.141	0.308	0.436	0.551
AspectJ	0.217	0.315	0.228	0.406	0.506	0.628
PDE	0.219	0.33	0.208	0.479	0.604	0.667
JDT	0.103	0.223	0.162	0.275	0.385	0.474
Tomcat	0.268	0.390	0.276	0.511	0.598	0.701



Comparison between Locus and Amalgam, in terms of the Effort-Based Evaluation.

- Locus achieves an average MAP of 0.205 and MRR of 0.256.
- Locus locates the inducing changes and rank them within top5 for 41.0% of the bugs.
- The lines of codes needing to be inspected has been reduced by an order of magnitude.
- The debugging efforts can be **significantly** saved.

[RQ2] Change Level Results – Case Study

Bug #56905 of Tomcat

Locus : ranked the inducing change at **1st**
58 lines including contextual lines
AmaLgam : ranked the buggy file as **21st**

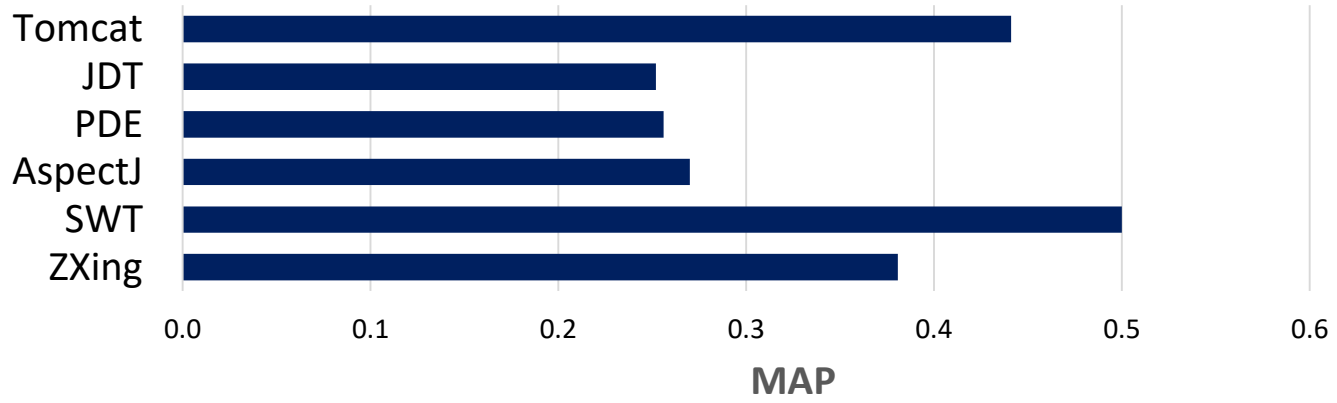
Bug #56199 of Tomcat

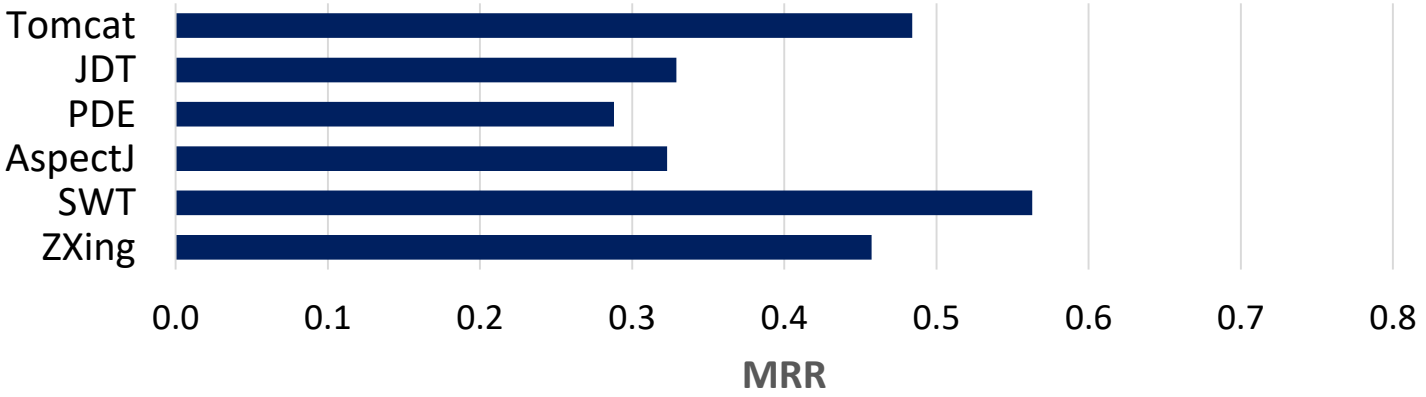
```
@@ -119,6 +124,20 @@ public JspDocumentParser(
119 124         this.isTagFile = isTagFile;
120 125         this.directivesOnly = directivesOnly;
121 126         this.isTop = true;
    127 +
    128 +       String blockExternalString = ctxt.getServletContext().getInitParameter(
    129 +               Constants.XML_BLOCK_EXTERNAL_INIT_PARAM);
    130 +       boolean blockExternal;
    131 +       if (blockExternalString == null) {
    132 +           blockExternal = Constants.IS_SECURITY_ENABLED;
    133 +       } else {
    134 +           blockExternal = Boolean.parseBoolean(blockExternalString);
    135 +       }
    136 +
    137 +       this.entityResolver = new LocalResolver(
    138 +               DigesterFactory.SERVLET_API_PUBLIC_IDS,
    139 +               DigesterFactory.SERVLET_API_SYSTEM_IDS,
```

Both Locus and AmaLgam ranked as Top 1

The inducing change contains **32** lines of code while the whole file contains **864** lines.

[RQ3] Contributions of Each Model



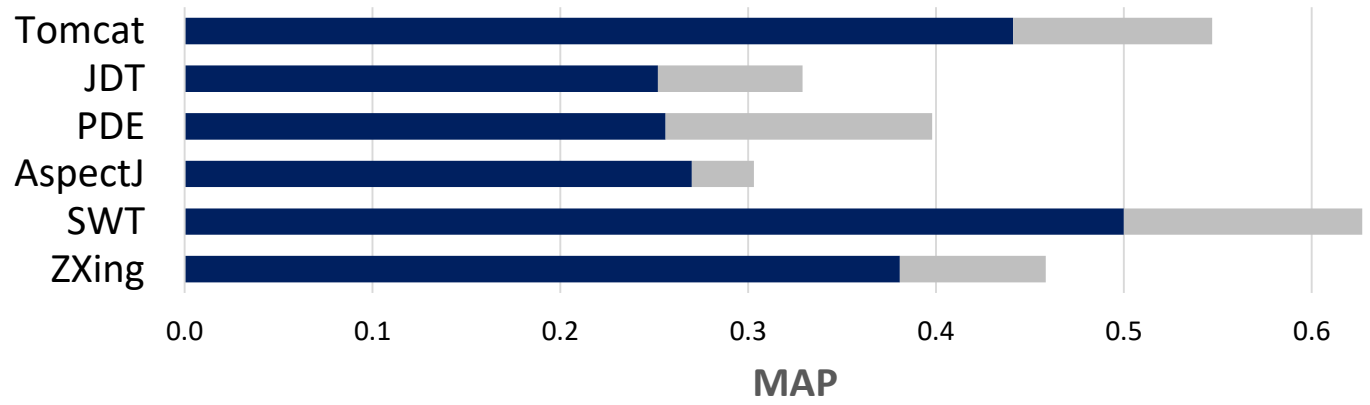


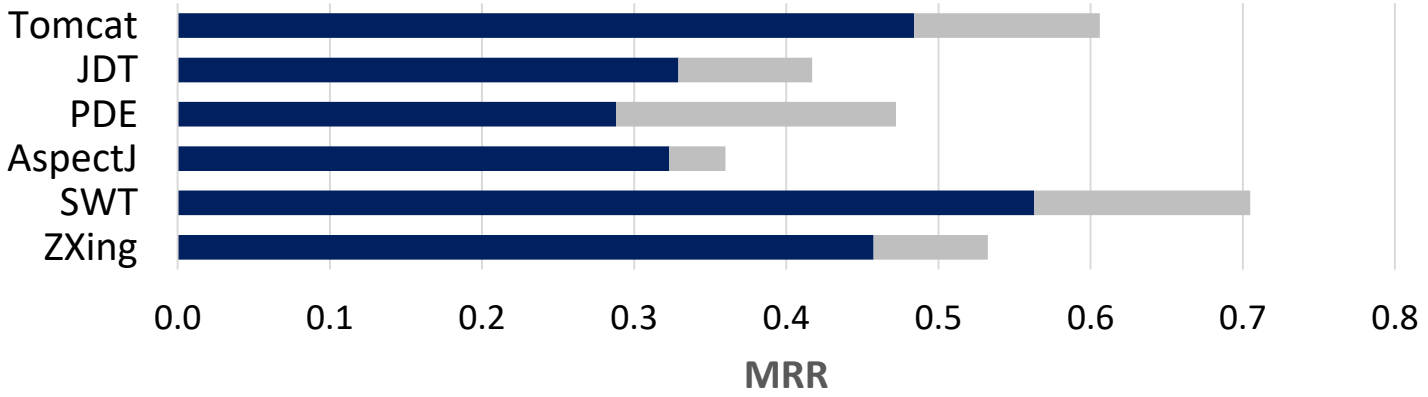
MAP	MRR
0.348	0.402

- NL Model

Contributions of Each Model at Source Level

[RQ3] Contributions of Each Model





MAP	MRR

- NL Model

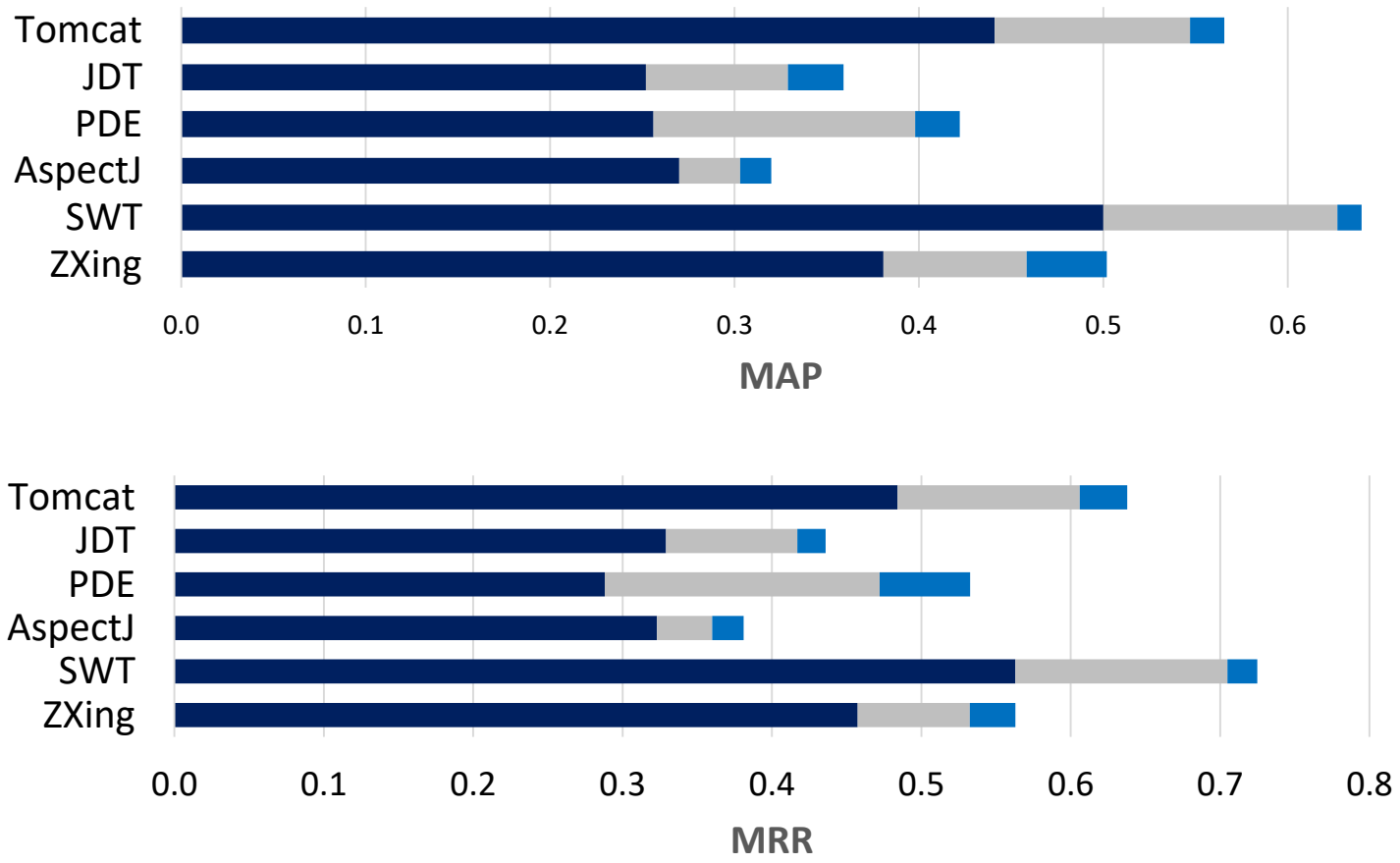
0.348	0.402

- NL + CE

↑23.6%	↑23.7%

Contributions of Each Model at Source Level

[RQ3] Contributions of Each Model



	MAP	MRR
NL Model	0.348	0.402
NL + CE	↑23.6%	↑23.7%
NL + CE + Boosting	↑5.1%	↑5.7%

Contributions of Each Model at Source Level

Conclusions

- Bug inducing changes can help developers in debugging.
- Software changes can benefit IR-based bug localization techniques.
- We propose **Locus** based on our observations, the evaluation results show that Locus outperforms the state-of-the-art approaches.

Future Work

- We plan to leverage more **properties** of software changes (e.g. ownership, change patterns) to improve the performance at the change level.

- We plan to conduct **user studies** to evaluate the practical usefulness.

Q & A