Empirical Software Engineering

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Most slides are taken from **Tao Xie and Miryung Kim**

New Era…Software itself is changing…

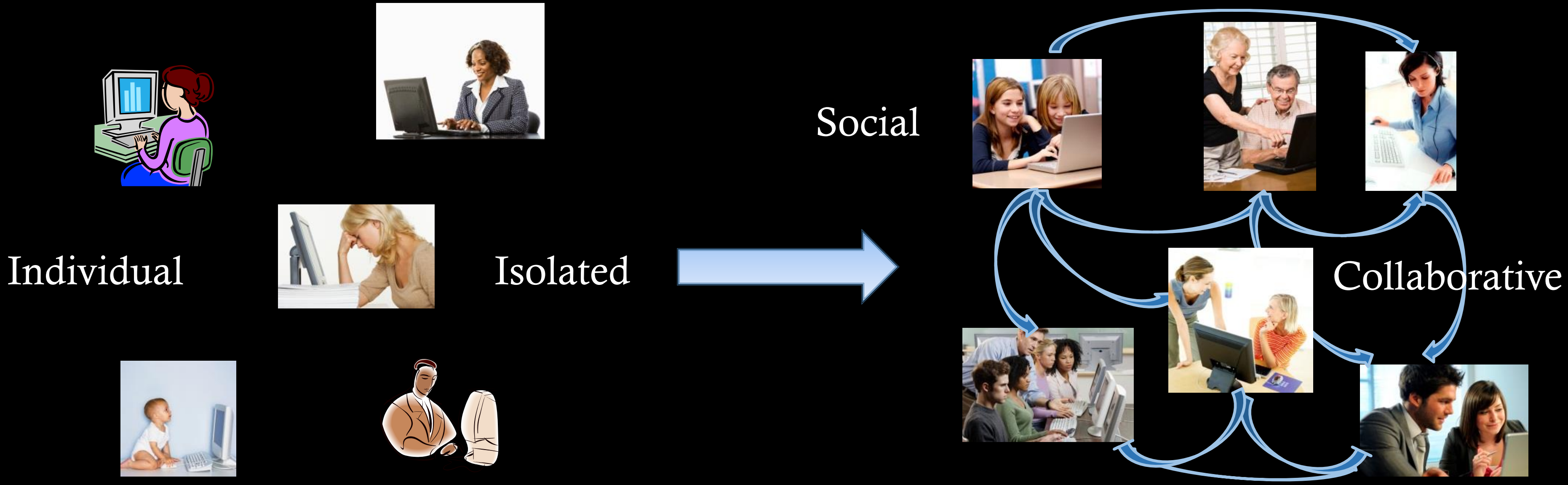
bing
MS Beta 0
facebook
skype
amazon
ebay
Microsoft
Office 365
twitter
salesforce

Facebook helps you connect and share with the people in your life.

Software

Services

How people use software is changing…



Individual

Isolated

Social

Collaborative

Not much content generation

Huge amount of artifacts generated anywhere anytime

How software is built & operated is changing…

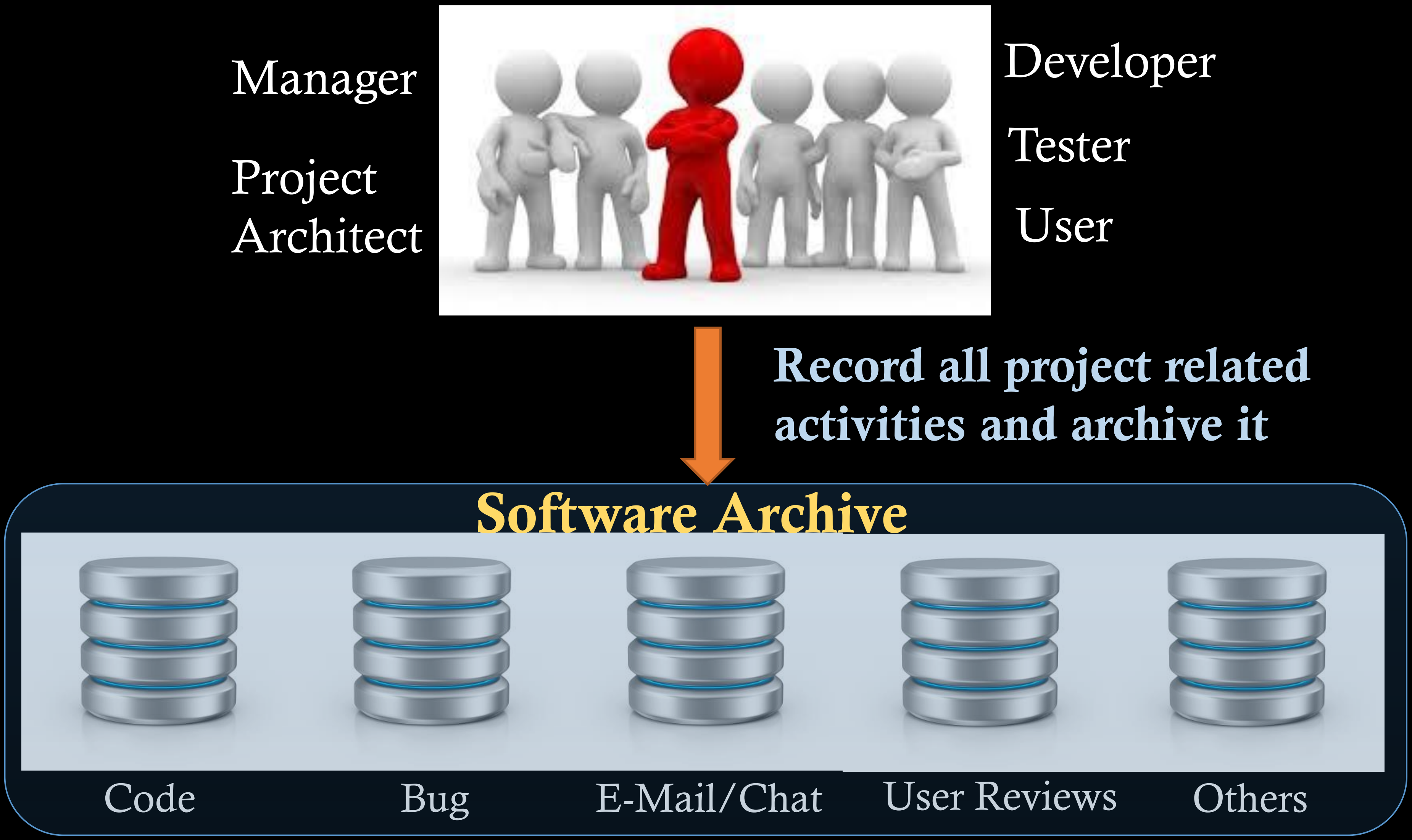
Code centric	Data pervasive
In-lab testing	Debugging in the large
Experience & gut-feeling	Informed decision making
Centralized development	Distributed development
Long product cycle	Continuous release
…	…

The Secret for Software Decision Making

- Which software or its property to use?
- How to improve your software?
- How to write better code?
- How to efficiently debug your code?
- Which code we should test?
- Which project to join?
- Whom to recruit?
- …

'Big' Software Data!!
Use Data Science to find the answers

Data Science in Software Engineering



Manager

Project Architect

Developer

Tester

User

Record all project related activities and archive it

Software Archive

Code

Bug

E-Mail/Chat

User Reviews

Others

Data Science in Software Engineering

Manager

Project Architect

Developer

Tester

User

Record all project related activities and archive it

stackoverflow

GitHub

Bugzilla

Bitbucket

App Store

Google play

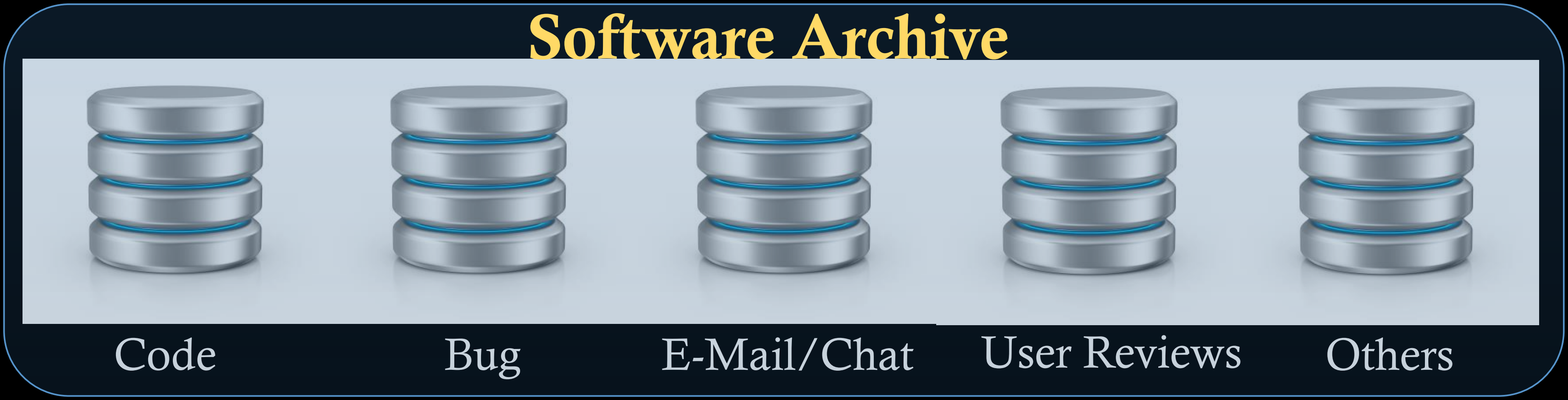
Apache SOFTWARE FOUNDATION

Data Science in Software Engineering

Analyze software data

Make informed data-driven decisions

Supporting decision making using facts instead of fortune tellers!



Software Archive

Code

Bug

E-Mail/Chat

User Reviews

Others

Data sources

Runtime traces

Program logs

System events

Performance counters

…

Usage log

User surveys

Online forum posts

Blog & Twitter

…

Source code

Bug history

Check-in history

Test cases

…

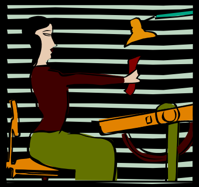
Target audience – software practitioners

Program Manager

Developer

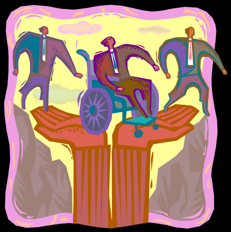
Management personnel

Designer



Tester

Support engineer



Operation engineer

Usability engineer

Output – insightful information

- Conveys *meaningful* and *useful* understanding or knowledge towards completing the target task
- Not easily attainable via directly investigating raw data without aid of *analytics technologies*
- Example
  - It is easy to count the number of re-opened bugs, but how to find out the primary reasons for these re-opened bugs?

Output – actionable information

- Enables software practitioners to come up with *concrete solutions* towards completing the target task
- Examples
  - Why bugs were re-opened?
    - A list of bug groups each with the same reason of re-opening
  - Which part of my code should be refactored?
    - A list of cloned code snippets easily explored from different perspectives

Few Examples!!

Leveraging Software Data to

Improve Software Quality

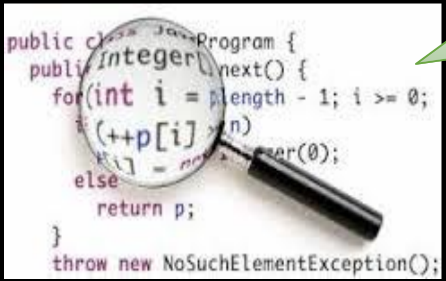
PL/SE research effort to reduce bugs

Languages

Type System,
Memory Management

Assertions (invariant checking), Code reuse

Best Coding Practices



```
public c[illegible]Program {
  publi[illegible]Integer[illegible]next() {
    for(int i = p.length - 1; i >= 0;
      [illegible](++p[i] [illegible]n)
        [illegible]er(0);
        [illegible]
      else
        return p;
    }
    throw new NoSuchElementException();
```

Automatic Bug Finding Tools

Program Analysis,
Testing

Code Reviews
Development
Processes

Team Process

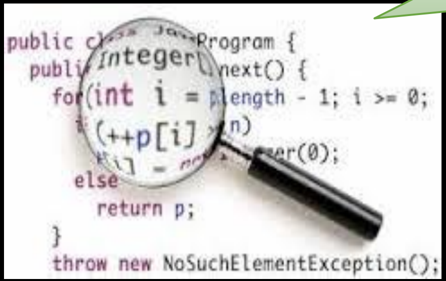
Do we know the answers ?

Languages

Does a choice of language affect code quality?

What kinds of bugs are caused by copy-paste?

Best Coding Practices



```
public class JavaProgram {
  public Integer next() {
    for(int i = p.length - 1; i >= 0;
      if (++p[i] > n)
        p[i] = ...er(0);
      else
        return p;
    }
    throw new NoSuchElementException();
```

Do automatically generated unit tests find real faults?

Automatic Bug Finding Tools

How does API evolution affect code quality?

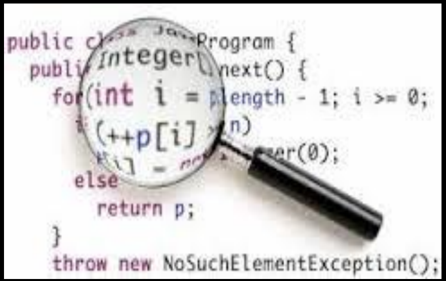
Team Process

`Big' Software Data

Languages

Use data science to find the answers

Best Coding Practices



```
public class JavaProgram {
  publi Integer next() {
    for(int i = p.length - 1; i >= 0;
      (++p[i]   n)
               er(0);
    else
      return p;
  }
  throw new NoSuchElementException();
```

Automatic Bug Finding Tools

Get Insights for future directions

Team Process

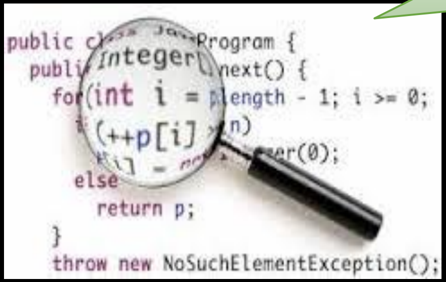
Empirical Findings

Languages

A choice of language matters more for specific error categories than it does for overall defects [FSE’14]

Incorrect adaptation of copied code introduces bugs [ASE’13]

Best Coding Practices



```
public class JavaProgram {
  public Integer[] next() {
    for(int i = p.length - 1; i >= 0;
      if (++p[i] > n)
        p[i] = new Integer(0);
      else
        return p;
    }
    throw new NoSuchElementException();
```

Automatically generated tests effectively find real faults [ASE’15]

Automatic Bug Finding Tools

Aggressive API update leads to bugs and delayed adoption in client code [ICSM’2013]

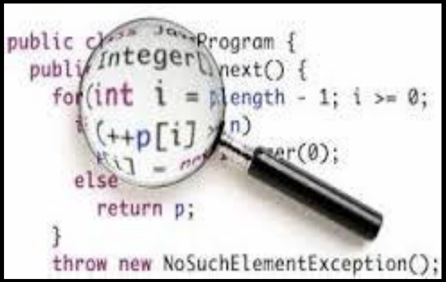
Team Process

Develop new techniques based on Empirical Findings

Languages

Design new algorithms and build tools (e.g. Static analysis tools, bug prediction tools, testing strategies) that can address the empirically found problems.

Best Coding Practices



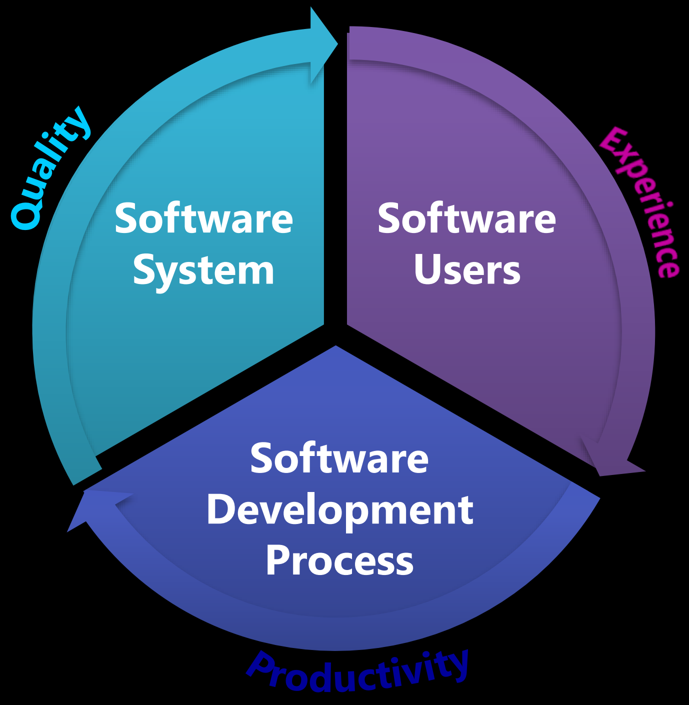
```
public c    Program {
  publi Integer next() {
    for(int i = p.length - 1; i >= 0;
      (++p[i]   n)
        [i] -   er(0);
      else
        return p;
    }
    throw new NoSuchElementException();
```

Automatic Bug Finding Tools

Team Process

Research Topics

Research topics

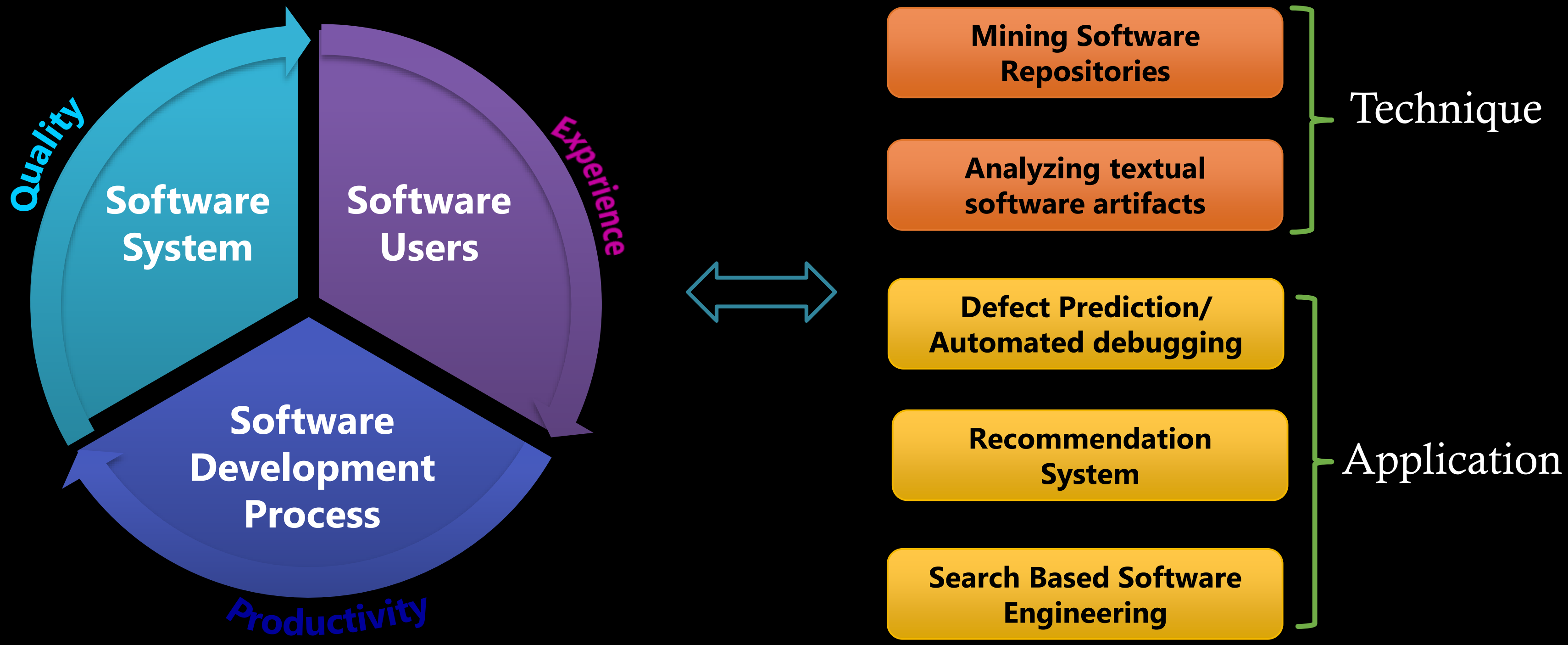


- Covering different areas of software domain

- Throughout entire development cycle

- Enabling practitioners to obtain insights

Research topics



Quality

Software System

Experience

Software Users

Software Development Process

Productivity

Mining Software Repositories

Analyzing textual software artifacts

Technique

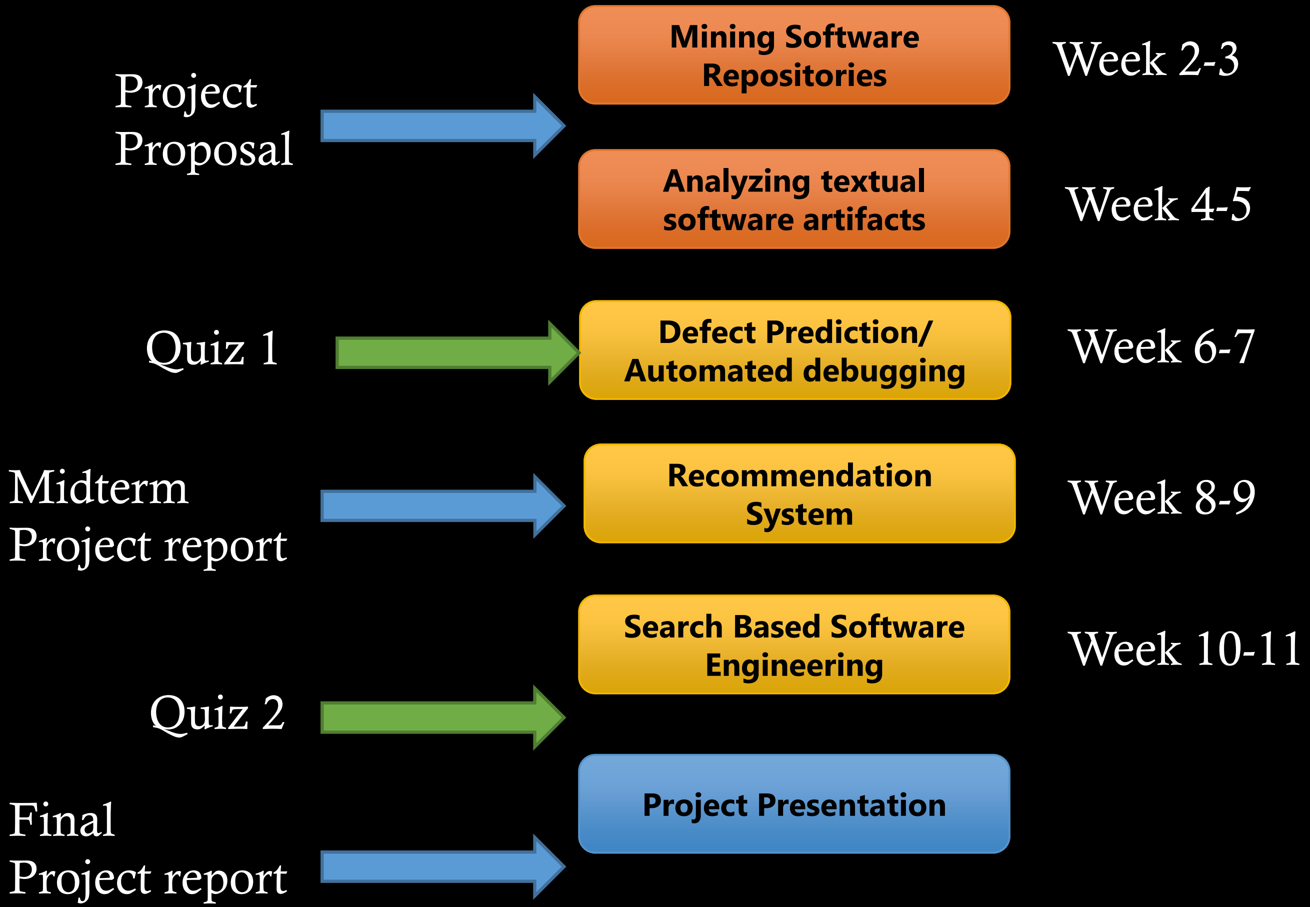
Defect Prediction/ Automated debugging

Recommendation System

Search Based Software Engineering

Application

Tentative Course Layout



Mining Software Repositories — Week 2-3

Project Proposal

Analyzing textual software artifacts — Week 4-5

Quiz 1

Defect Prediction/ Automated debugging — Week 6-7

Midterm Project report

Recommendation System — Week 8-9

Search Based Software Engineering — Week 10-11

Quiz 2

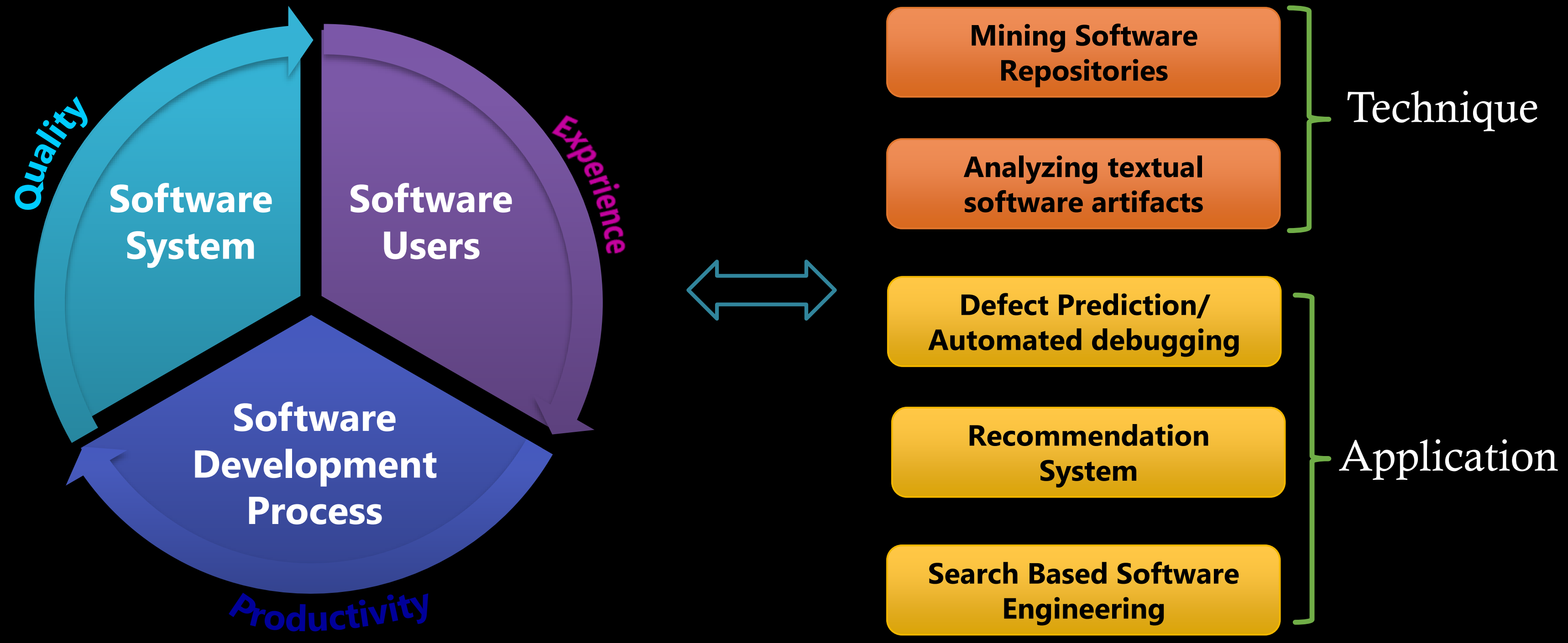
Project Presentation

Final Project report

Grading Policy

- Group Project (2-3 students) – 60%
  - Project Proposal – 5%
  - Mid-term report/presentation : 15%
  - End of semester presentation : 20%
  - End of semester project report – 20%
- Quiz – 25%
- Class Participation – 15%
  - Paper presentation – 8%
  - Reviews/questions – 7%

Research topics



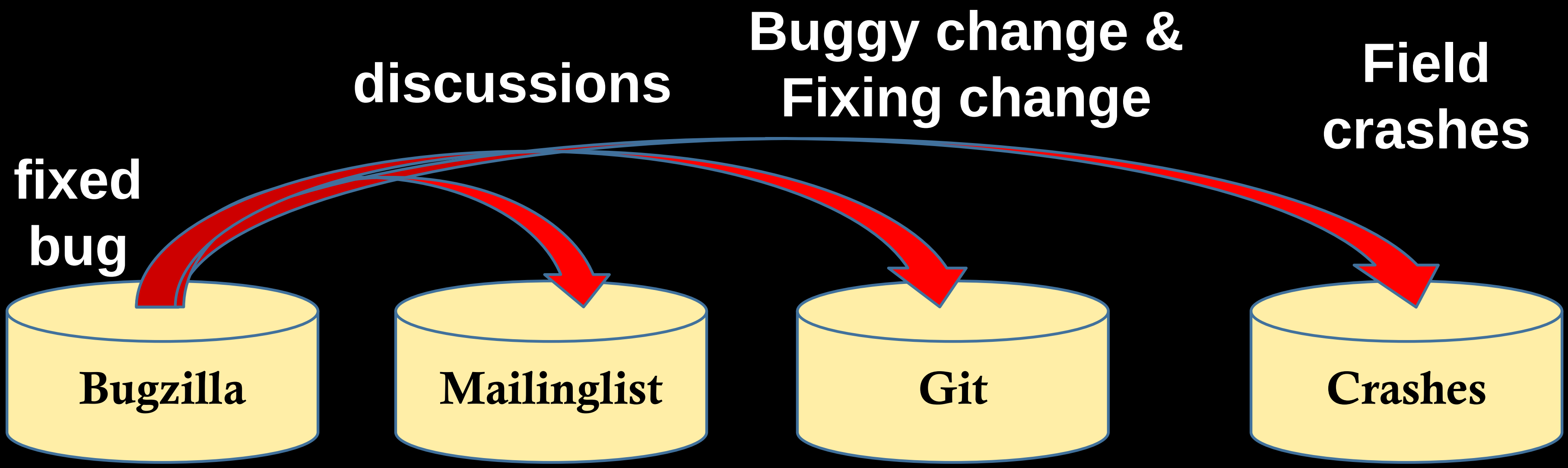
- Mining Software Repositories
- Analyzing textual software artifacts

Technique

- Defect Prediction/ Automated debugging
- Recommendation System
- Search Based Software Engineering

Application

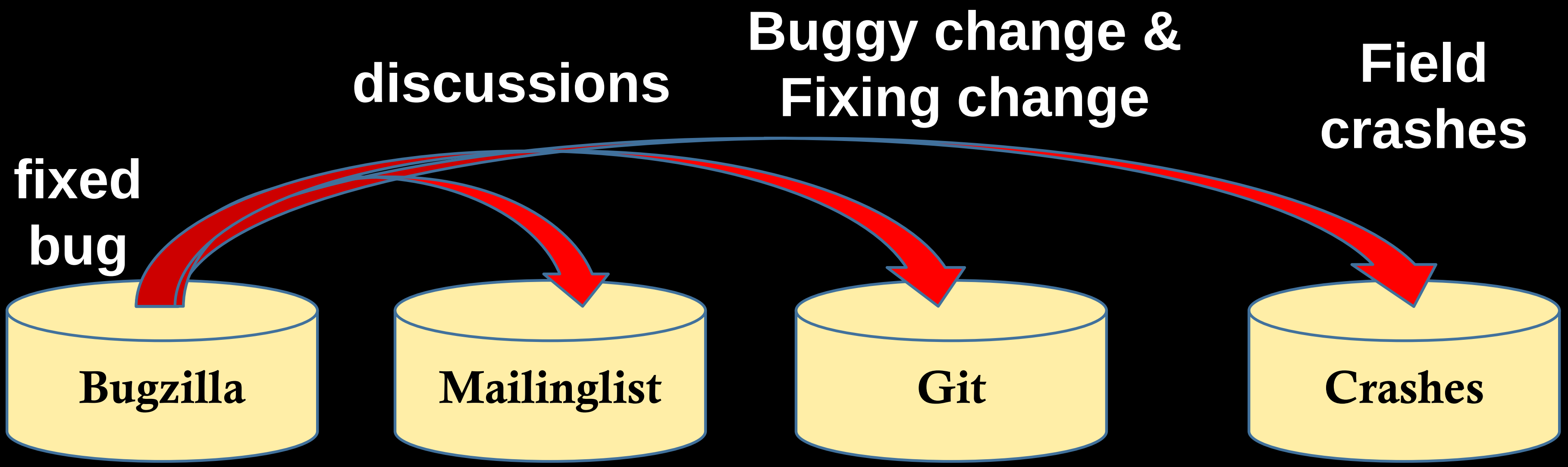
Example: Mining Software Repositories



When a new bug is reported

- Estimate fix effort
- Mark duplicates
- Suggest experts and fix!

Example: Mining Software Repositories



When code is changed

- Suggest APIs
- Warn about risky code or bugs
- Suggest locations to co-change

Example: Analyzing Textual Software Artifacts

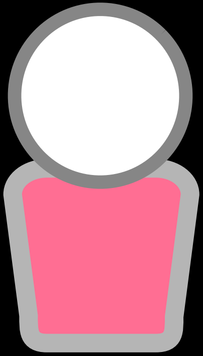
Types of Textual Software Artifacts

- requirement documents
- code comments
- identifier names
- commit logs
- release notes
- bug reports
- …

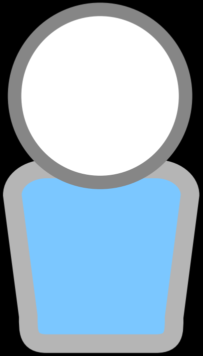
- emails discussing bugs, designs, etc.
- mailing list discussions
- test plans
- project websites & wikis
- Question answer cites (hybrid)

Text data contains useful information, much of which is not in structured data.

Example: code comment contains *Specification*



```
linux/drivers/scsi/in2000.c:
/* Caller must hold instance
lock! */
static int reset_hardware(…)
{…}
```



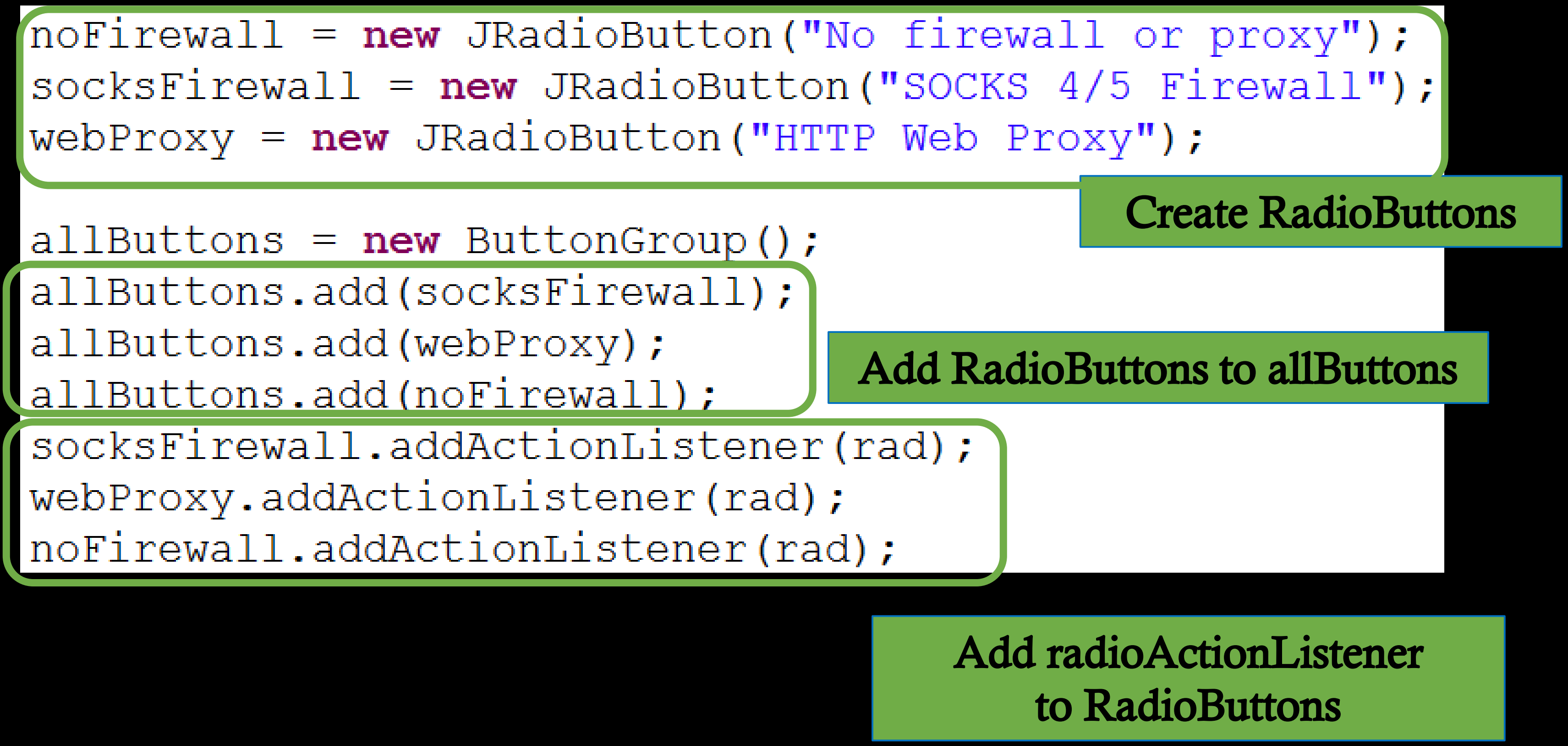
```
linux/drivers/scsi/in2000.c:
static int in2000_bus_reset(…){    …

    reset_hardware(…);
    …
}
```

No lock acquisition ⇒ A bug!

Tan et al. “/*iComment: Bugs or Bad Comments?*/”, SOSP’07

Example: contains *semantics of identifiers*



```
noFirewall = new JRadioButton("No firewall or proxy");
socksFirewall = new JRadioButton("SOCKS 4/5 Firewall");
webProxy = new JRadioButton("HTTP Web Proxy");

allButtons = new ButtonGroup();
allButtons.add(socksFirewall);
allButtons.add(webProxy);
allButtons.add(noFirewall);
socksFirewall.addActionListener(rad);
webProxy.addActionListener(rad);
noFirewall.addActionListener(rad);
```

Create RadioButtons

Add RadioButtons to allButtons

Add radioActionListener
to RadioButtons

Sridhara, Pollock, Vijay-Shanker. Automatically Detecting and Describing High Level Actions within Methods. ICSE 2011

Challenges in Analyzing Textual Data

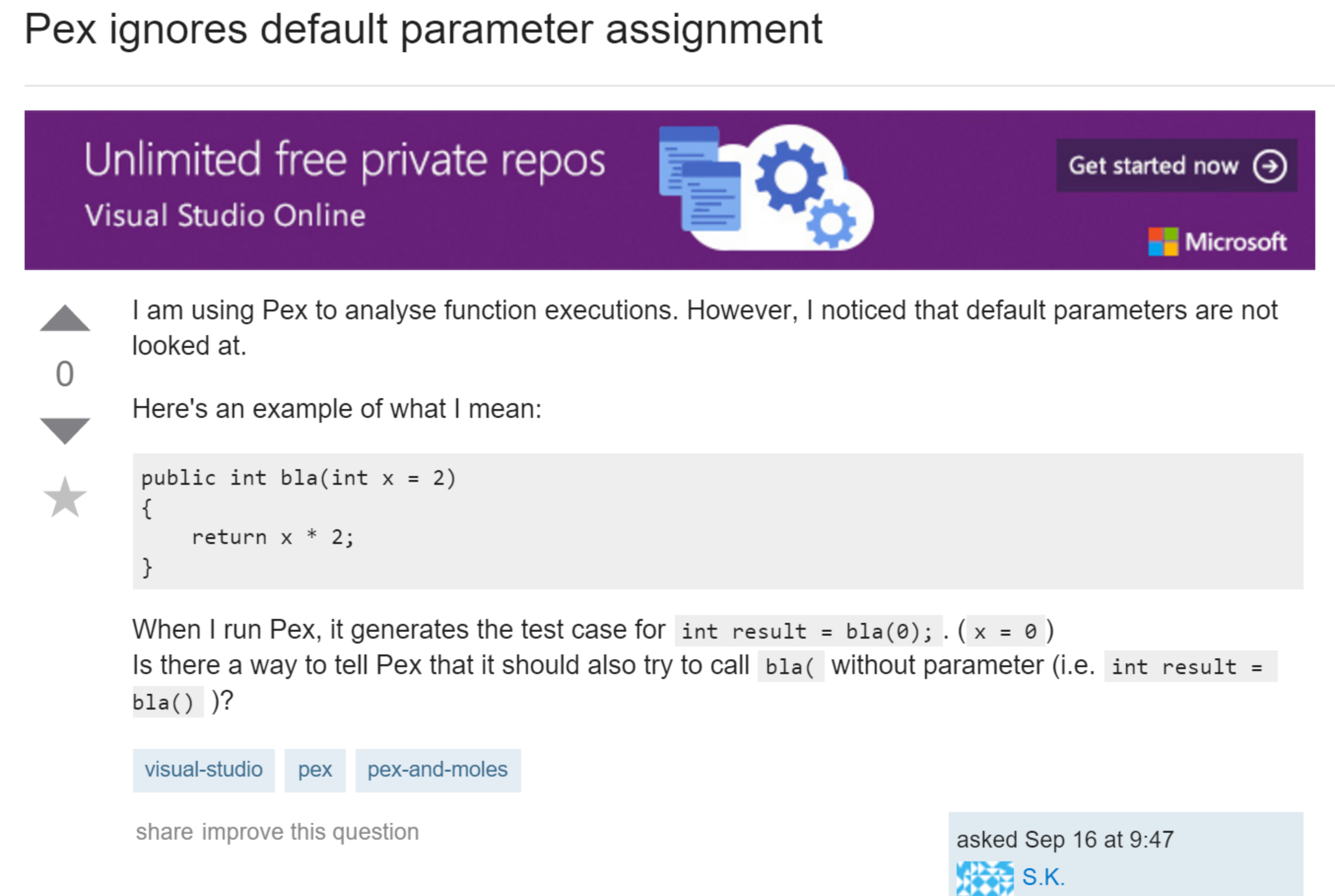
- Unstructured
  - Hard to parse, sometimes wrong grammar
- Ambiguous: often has no defined or precise semantics (as opposed to source code)
  - Hard to understand
- Many ways to represent similar concepts
  - Hard to extract information from

```
/* We need to acquire the write IRQ lock before calling ep_unlink(). */
/* Lock must be acquired on entry to this function. */
/* Caller must hold instance lock! */
```

Why Analyzing Textual Data is Easy(?)

- Redundant data
- Many techniques to borrow from text analytics: NLP, Machine Learning (ML), Information Retrieval (IR), etc.

Stackoverflow Question



Pex ignores default parameter assignment

I am using Pex to analyse function executions. However, I noticed that default parameters are not looked at.

Here's an example of what I mean:

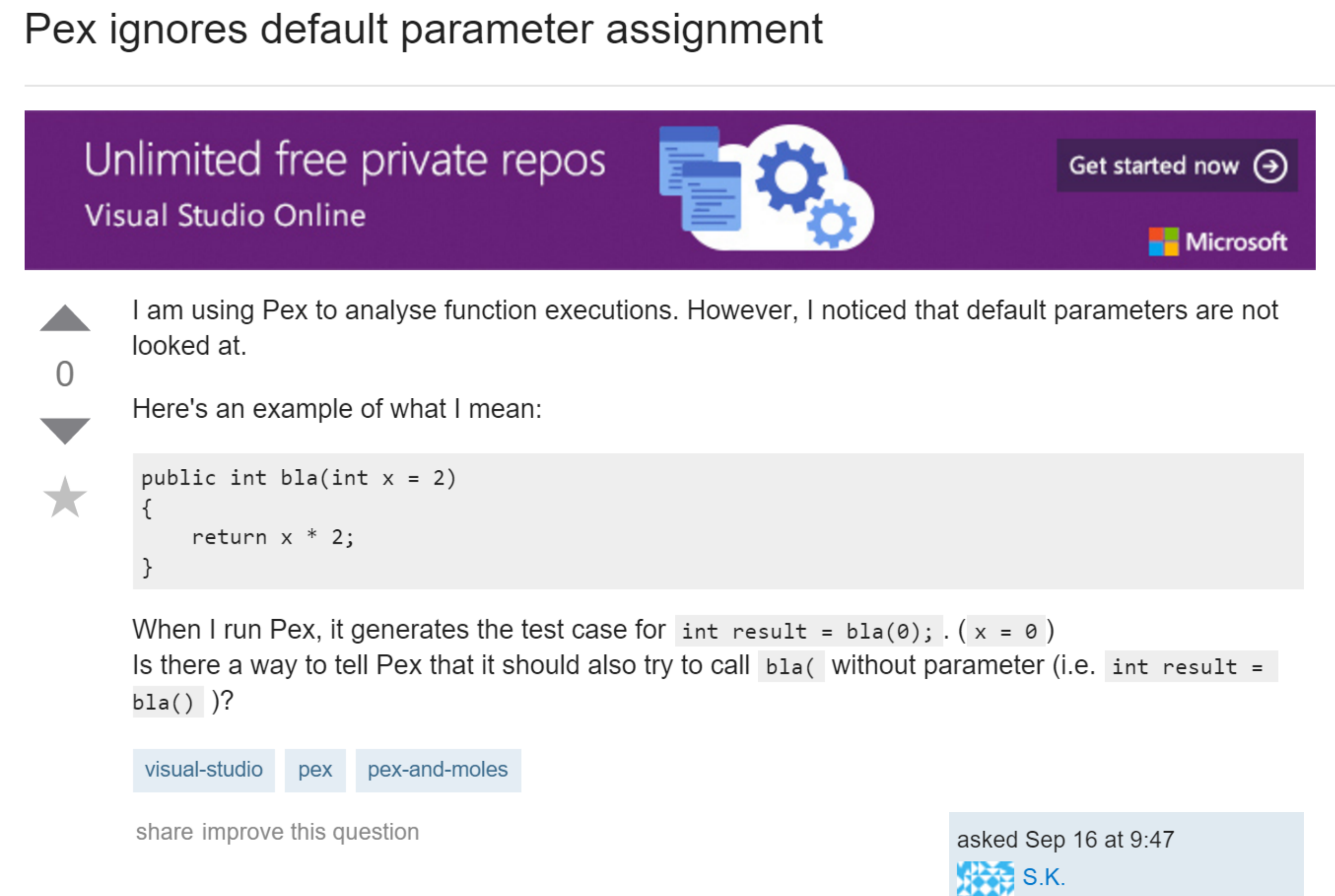
```
public int bla(int x = 2)
{
    return x * 2;
}
```

When I run Pex, it generates the test case for `int result = bla(0);`. (`x = 0`)
Is there a way to tell Pex that it should also try to call `bla(` without parameter (i.e. `int result = bla()`)?

asked Sep 16 at 9:47
S.K.

Challenge: Detect Duplicate Post

stackoverflow



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visual-studio pex pex-and-moles

share improve this question

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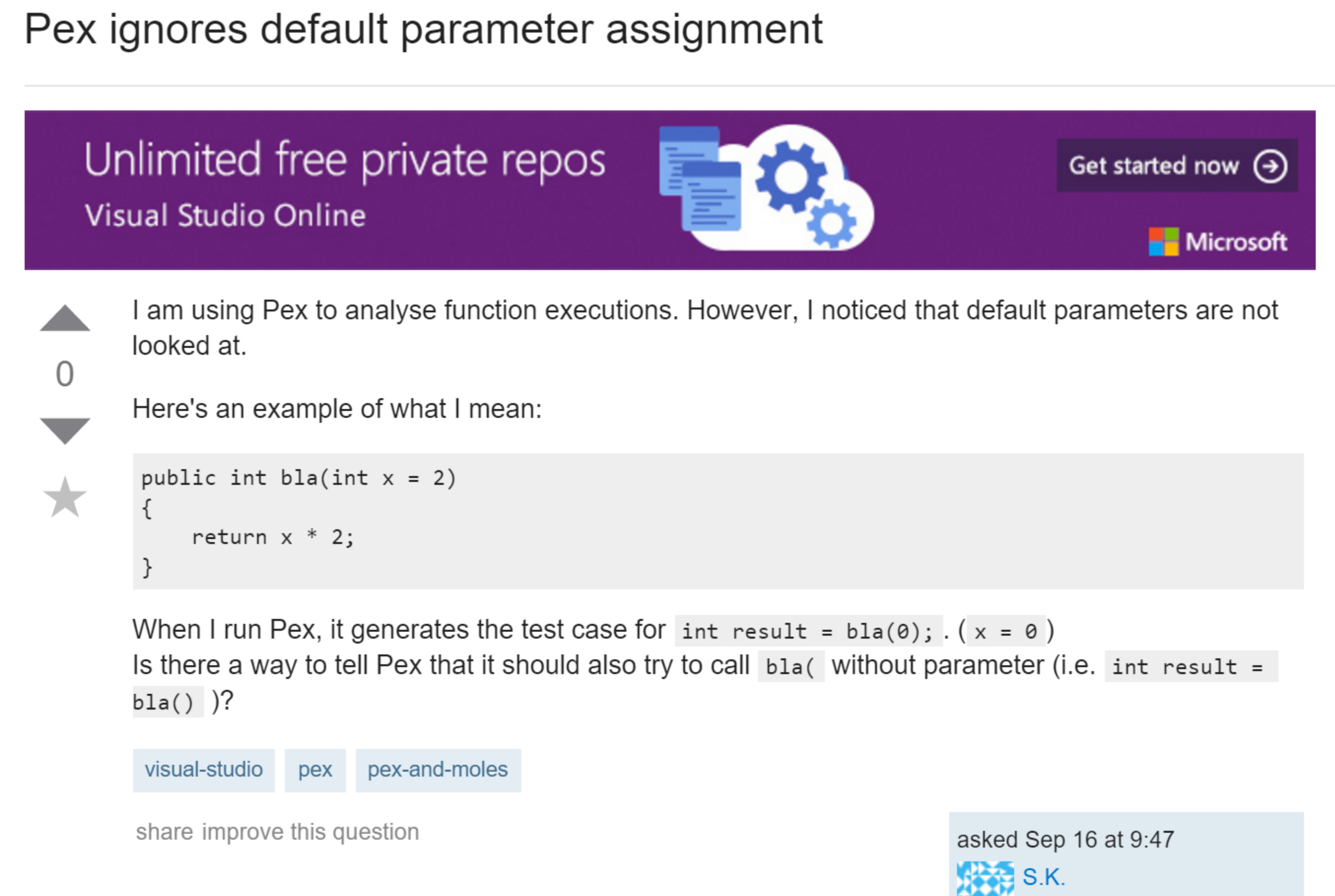
S.K.

Challenge: Assign Post to Whom?

stack overflow



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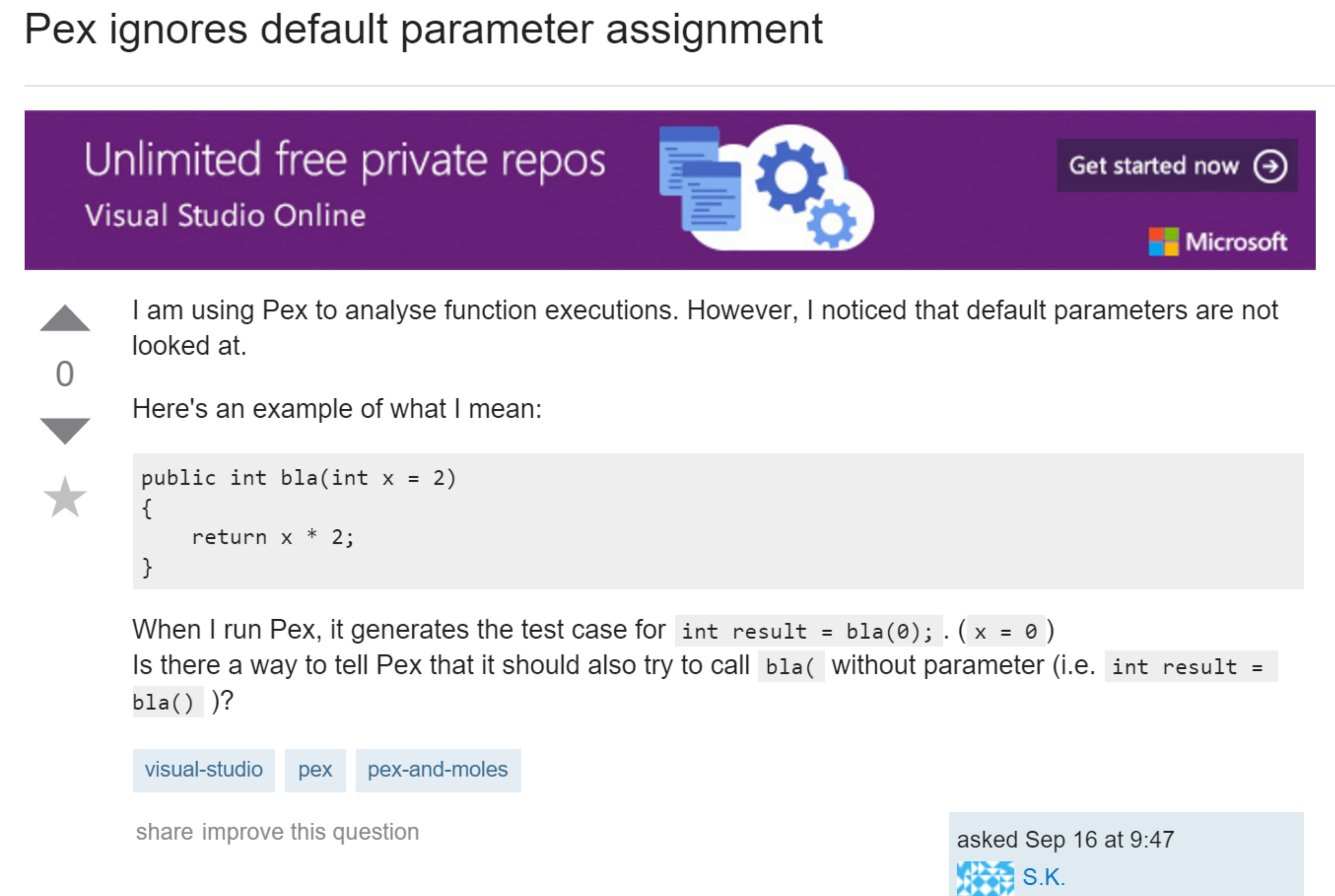
Challenge: Identify High Severity Post

stackoverflow



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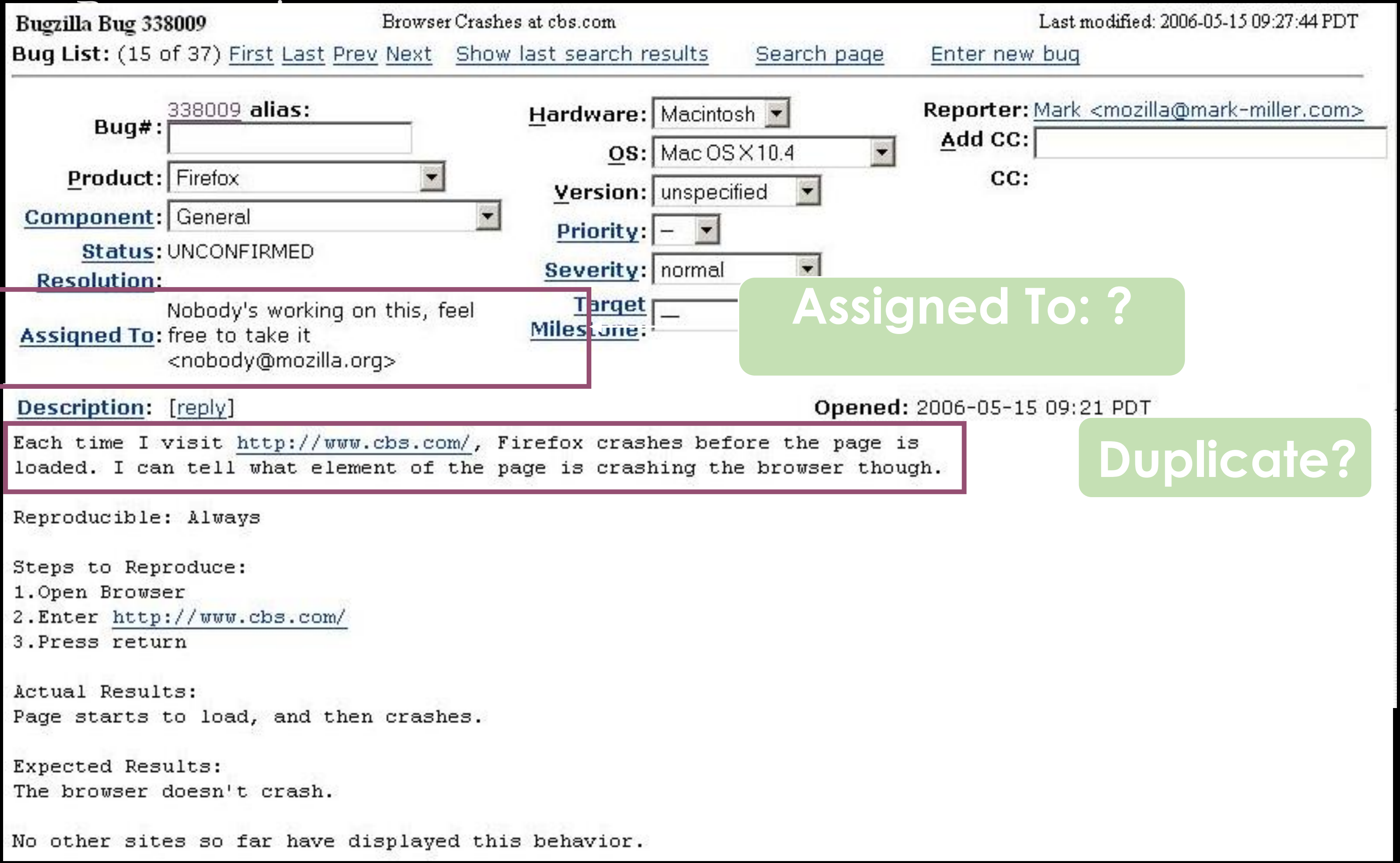
Example Bugzilla Bug Report



Bugzilla Bug 338009 Browser Crashes at cbs.com Last modified: 2006-05-15 09:27:44 PDT

Bug List: (15 of 37) First Last Prev Next Show last search results Search page Enter new bug

Bug#: 338009 **alias:**

Product: Firefox

Component: General

Status: UNCONFIRMED

Resolution:

Assigned To: Nobody's working on this, feel free to take it <nobody@mozilla.org>

Hardware: Macintosh

OS: Mac OS X 10.4

Version: unspecified

Priority: --

Severity: normal

Target Milestone: ---

Reporter: Mark <mozilla@mark-miller.com>

Add CC:

CC:

Description: [reply] **Opened:** 2006-05-15 09:21 PDT

```
Each time I visit http://www.cbs.com/, Firefox crashes before the page is
loaded. I can tell what element of the page is crashing the browser though.

Reproducible: Always

Steps to Reproduce:
1.Open Browser
2.Enter http://www.cbs.com/
3.Press return

Actual Results:
Page starts to load, and then crashes.

Expected Results:
The browser doesn't crash.

No other sites so far have displayed this behavior.
```

Assigned To: ?

Duplicate?

Anvik, Hiew, Murphy. Who should fix this bug? ICSE 2006.
Wang, Zhang, Xie, Anvik, Sun. An Approach to Detecting Duplicate Bug Reports using Natural Language and Execution Information. ICSE 2008.

From Requirement Text to Formal Security Policy

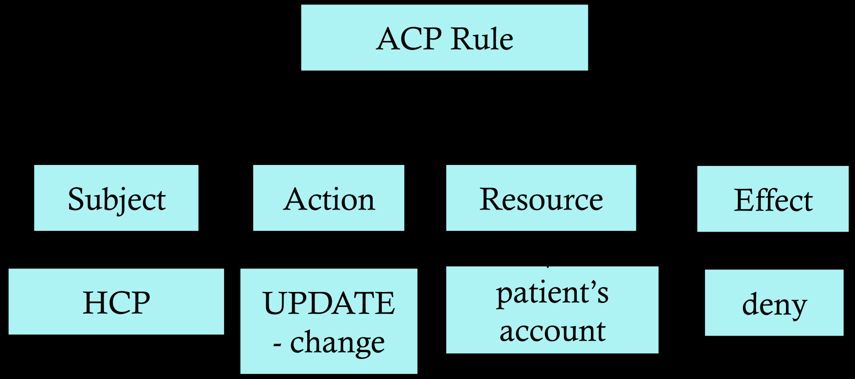
Linguistic Analysis

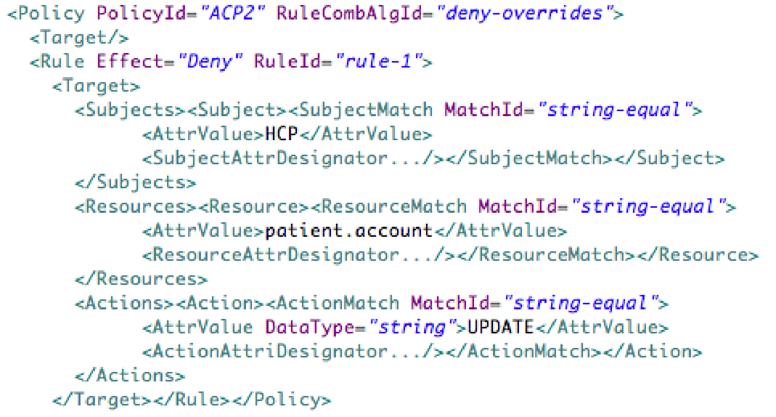
A HCP should not change patient's account.

→

An [*subject*: HCP] should not [*action*: change] [*resource*: patient's account].

Model-Instance Construction





```
<Policy PolicyId="ACP2" RuleCombAlgId="deny-overrides">
  <Target/>
  <Rule Effect="Deny" RuleId="rule-1">
    <Target>
      <Subjects><Subject><SubjectMatch MatchId="string-equal">
            <AttrValue>HCP</AttrValue>
            <SubjectAttrDesignator.../></SubjectMatch></Subject>
      </Subjects>
      <Resources><Resource><ResourceMatch MatchId="string-equal">
            <AttrValue>patient.account</AttrValue>
            <ResourceAttrDesignator.../></ResourceMatch></Resource>
      </Resources>
      <Actions><Action><ActionMatch MatchId="string-equal">
            <AttrValue DataType="string">UPDATE</AttrValue>
            <ActionAttriDesignator.../></ActionMatch></Action>
      </Actions>
    </Target></Rule></Policy>
```

Transformation

Xiao, Paradkar, Thummalapenta, Xie. Automated Extraction of Security Policies from Natural-Language Software Documents. FSE 201

You might be surprised!!

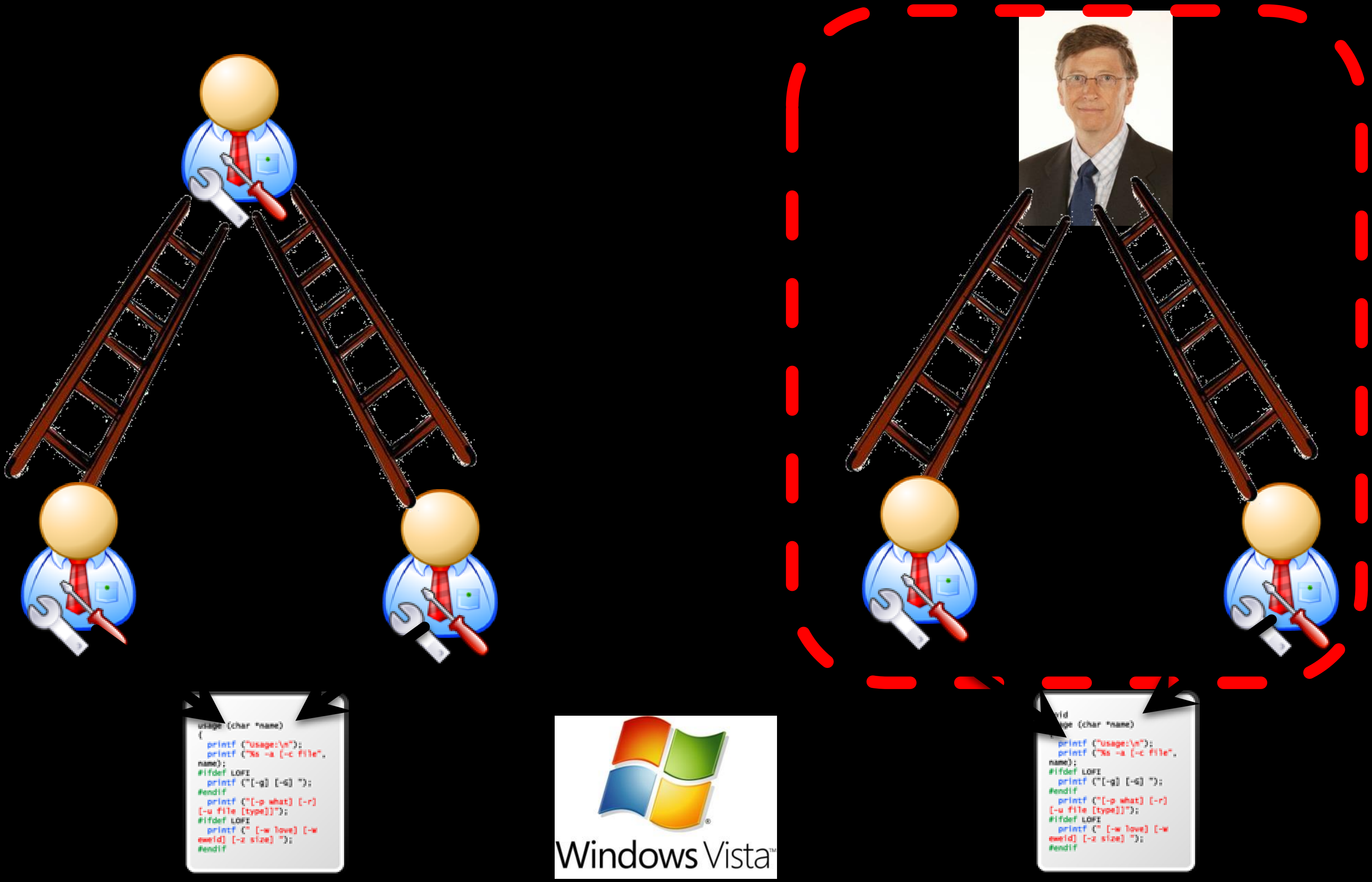
Should I test\review my?

A. Ten *most-complex* functions

B. Ten *largest* functions

[✓ **C. Ten *most-fixed* functions**]

Distance in corporate ladder has a much larger impact



```
usage (char *name)
{
  printf ("usage:\n");
  printf ("%s -a [-c file",
name);
#ifdef LOFI
  printf ("[-g] [-G] ");
#endif
  printf ("[-p what] [-r]
[-u file [type]]");
#ifdef LOFI
  printf (" [-w love] [-w
weird] [-z size] ");
#endif
```

```
id
ge (char *name)

  printf ("usage:\n");
  printf ("%s -a [-c file",
name);
#ifdef LOFI
  printf ("[-g] [-G] ");
#endif
  printf ("[-p what] [-r]
[-u file [type]]");
#ifdef LOFI
  printf (" [-w love] [-w
weird] [-z size] ");
#endif
```

Who produces more buggy code?

A. Junior Developer [✓ B. Senior Developer]

Adoption Challenges for Software Mining

Must show value before data quality improves

Correlation vs. Causation

Integration into daily pratice

Domain Knowledge + Close(r) Inspection

- Make sure you manually examine the repositories. Do not fully automate the process!

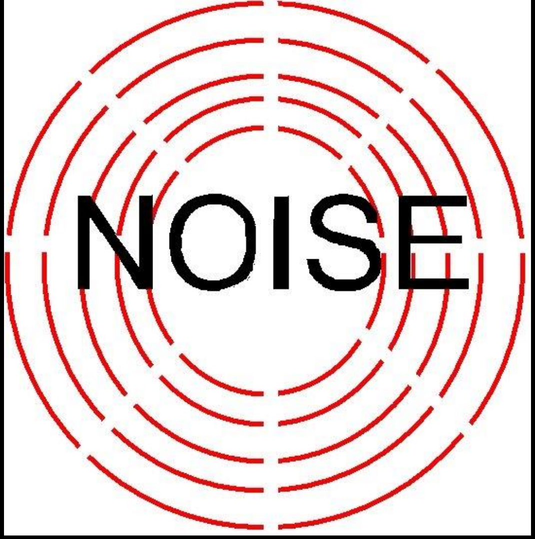
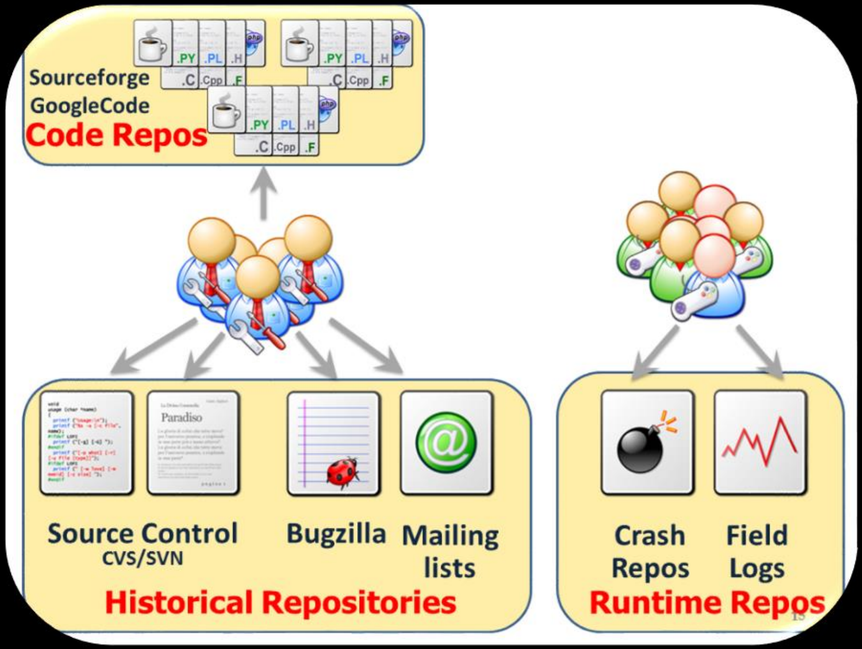


Image from http://www.quincyma.gov/Government/OCS/neighborhoodtips.cfm

The Secret for Software Decision Making



Sourceforge
GoogleCode
Code Repos

Source Control
CVS/SVN

Bugzilla

Mailing lists

Historical Repositories

Crash Repos

Field Logs

Runtime Repos

Adoption Challenges for Software Intelligence

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