FindBugs

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http://findbugs.sourceforge.net/

ITA Software &
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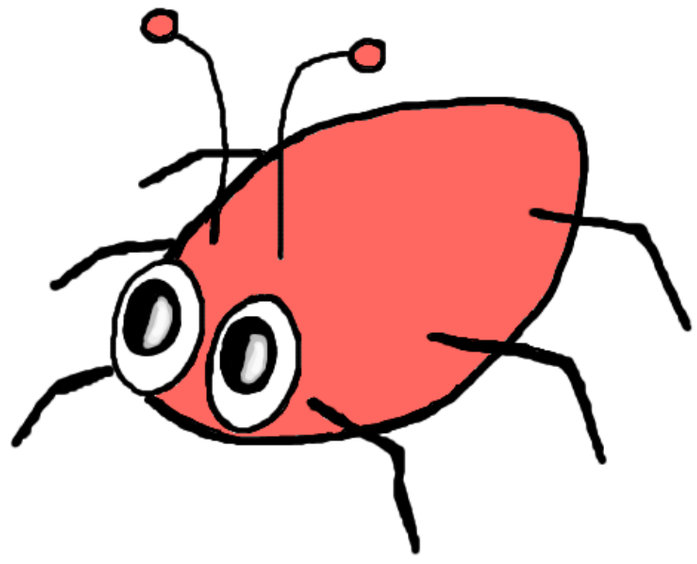


FindBugs

- Open source static analysis tool for finding defects in Java programs
- Analyzes classfiles
- Generates XML or text output
  - can run in Netbeans/Swing/Eclipse/Ant/SCA
- Total downloads from SourceForge: 274,291+

What is FindBugs?

- Static analysis tool to find defects in Java code
  - not a style checker
- Can find hundreds of defects in each of large apps such as Bea WebLogic, IBM Websphere, Sun's JDK
  - real defects, stuff that should be fixed
  - hundreds is conservative, probably *thousands*
- Doesn't focus on security
  - lower tolerance for false positives

Common Wisdom about Bugs

- Programmers are smart
- Smart people don't make dumb mistakes
- We have good techniques (e.g., unit testing, pair programming, code inspections) for finding bugs early
- So, bugs remaining in production code must be subtle, and require sophisticated techniques to find

Would You Write Code Like This?

```
if (in == null)
    try {
        in.close();
```

. . .

- Oops
- This code is from Eclipse (versions 3.0 - 3.2)
  - You may be surprised what is lurking in your code

Why Do Bugs Occur?

- Nobody is perfect
- Common types of errors:
  - Misunderstood language features, API methods
  - Typos (using wrong boolean operator, forgetting parentheses or brackets, etc.)
  - Misunderstood class or method invariants
- Everyone makes syntax errors, but the compiler catches them
  - What about bugs one step removed from a syntax error?

Bug Patterns

Infinite recursive loop

- Student came to office hours, was having trouble with his constructor:

```
/** Construct a WebSpider */
public WebSpider() {
    WebSpider w = new WebSpider();

    }
```

- A second student had the same bug
- Wrote a detector, found 3 other students with same bug

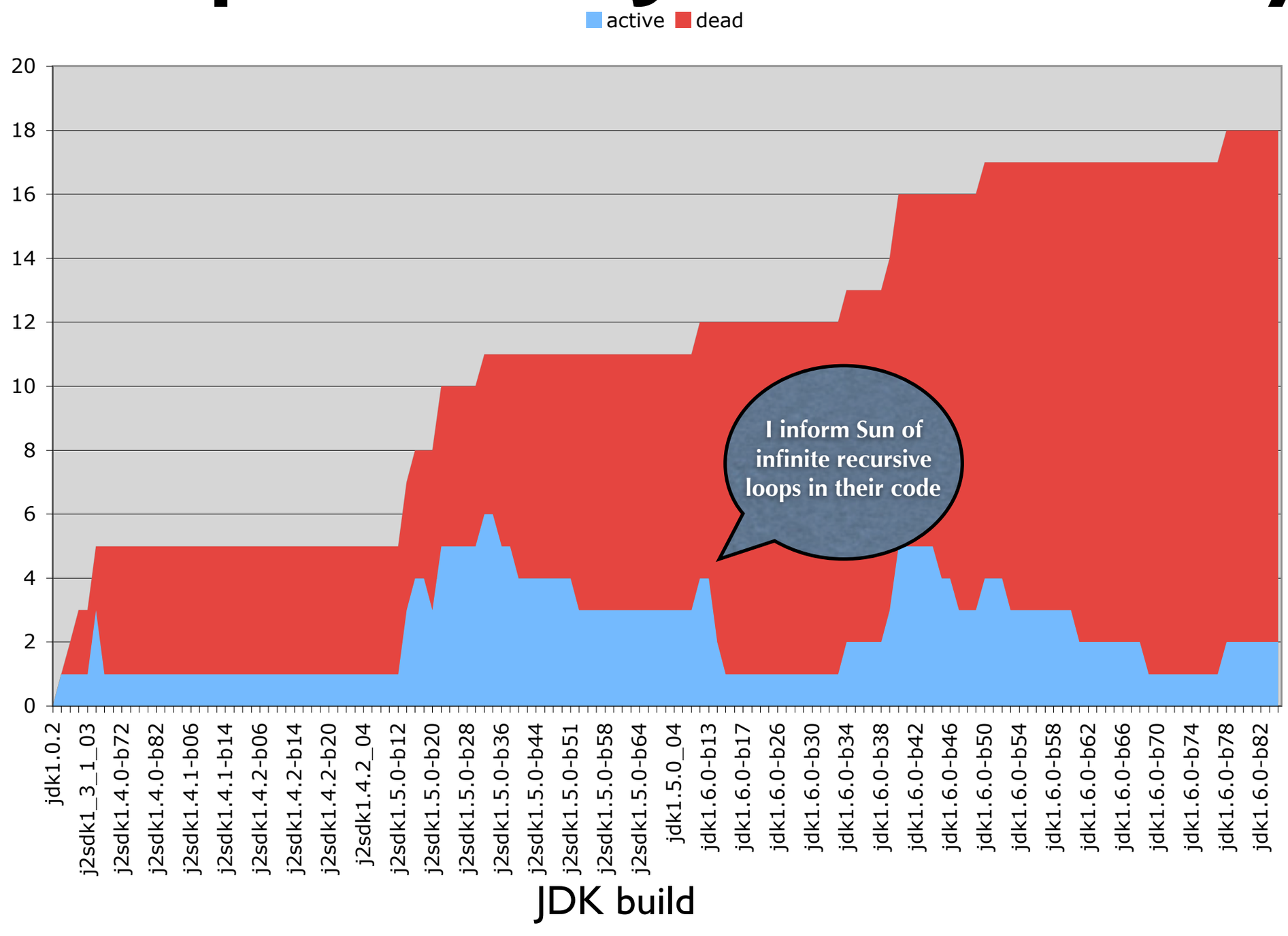
Double check against JDK

- Found 4 infinite recursive loops
- Including one written by Joshua Bloch

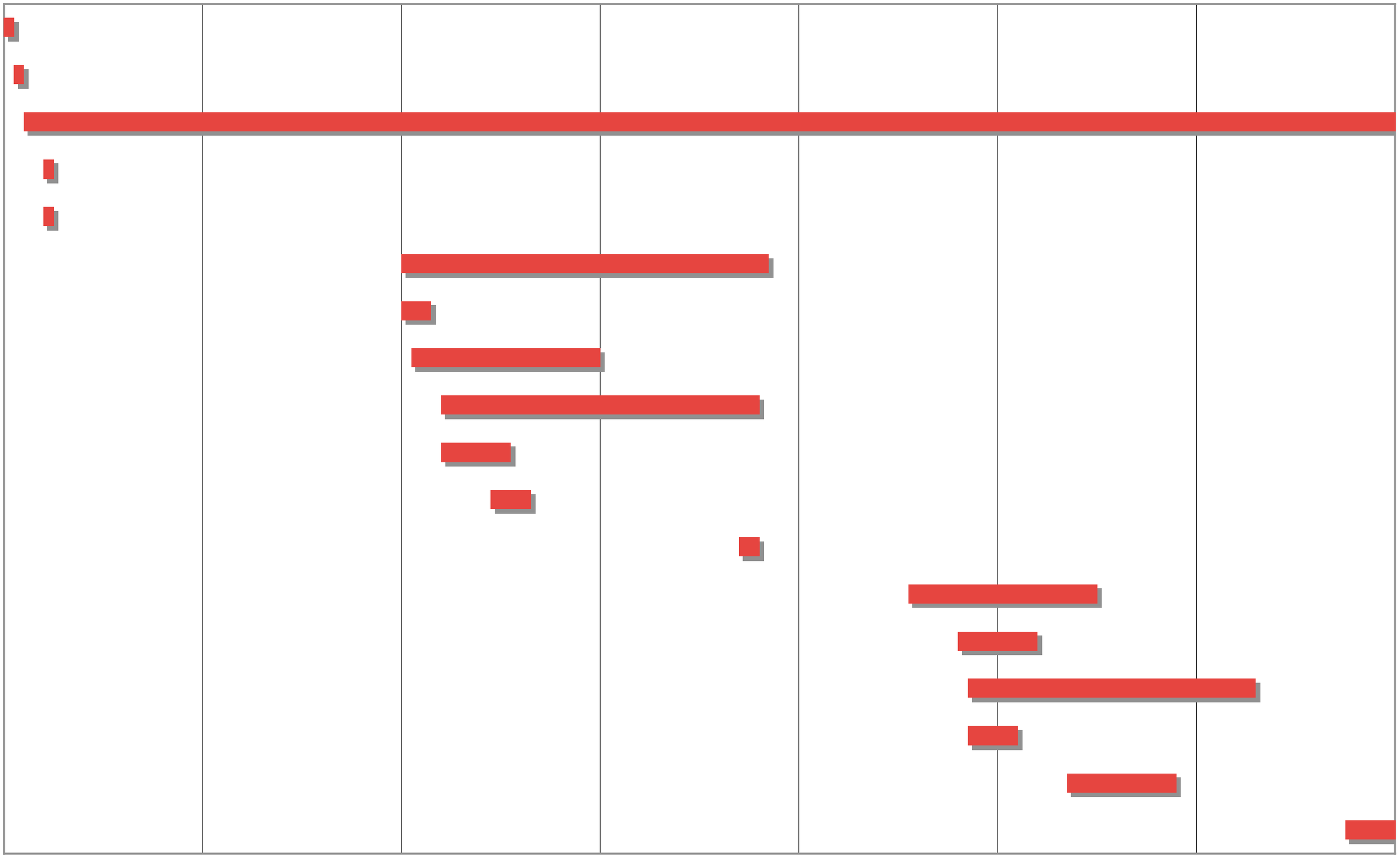
```
public String foundType() {
   return this.foundType();
}
```

- Smart people make dumb mistakes
- Embrace and fix your dumb mistakes

Infinite Recursive Loops: Sun JDK history



Duration of infinite recursive loop bugs in JDK



Hashcode/Equals

- Equal objects must have equal hash codes
  - Programmers sometimes override equals() but not hashCode()
    - Or, override hashCode() but not equals()
  - Objects violating the contract won't work in hash tables, maps, sets
- Examples (53 bugs in 1.6.0-b29)
  - javax.management.Attribute
  - java.awt.geom.Area

Fixing hashCode

- What if you want to define equals, but don't think your objects will ever get put into a HashTable?
- Suggestion:

```
public int hashCode() {
  assert false : "hashCode method not designed";
  return 42;
  }
```

Null Pointer Dereference

- Dereferencing a null value results in NullPointerException
  - Warn if there is a statement or branch that if executed, guarantees a NPE
- Example:

```
// Eclipse 3.0.0M8
Control c = getControl();
if (c == null && c.isDisposed())
    return;
```

Bad Binary operations

```
if ((f.getStyle () & Font.BOLD) == 1) {
      sbuf.append ("<b>");
      isBold = true;
      }

if ((f.getStyle () & Font.ITALIC) == 1) {
      sbuf.append ("<i>");
      isItalic = true;
      }
```

Doomed Equals

```
public static final ASDDVersion
    getASDDVersion(BigDecimal version) {
  if(SUN_APPSERVER_7_0.toString()
        .equals(version))
    return SUN_APPSERVER_7_0;
```

Unintended regular expression

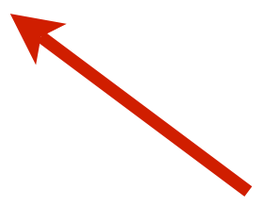
```
String[] valueSegments
  = value.split("."); // NOI18N
```

Field Self Assignment

```
public TagHelpItem(String name, String file,
                   String startText, int startOffset,
                   String endText, int endOffset,
                   String textBefore, String textAfter){
        this.name = name;
        this.file = file;
        this.startText = startText;
        this.startTextOffset = startTextOffset;
        this.endText = endText;
        this.endTextOffset = endTextOffset;
        this.textBefore = textBefore;
        this.textAfter = textAfter;
        this.identical = null;
    }
```

Bad Naming

```
package org.eclipse.jface.dialogs;
public abstract class Dialog extends Window {
   protected Button getOKButton() {
      return getButton(IDialogConstants.OK_ID);
      };
   }
public class InputDialog extends Dialog {
   protected Button getOkButton() {
      return okButton;
      };
}
```



Wrong capitalization

Confusing/bad naming

- Methods with identical names and signatures
  - but different capitalization of names
  - could mean you don't override method in superclass
  - confusing in general
- Method name same as class name
  - gets confused with constructor

Bad naming in BCEL (shipped in jdk1.6.0-b29)

```
/** @return a hash code value
  *for the object.
  */
public int hashcode() {
   return basic_type.hashCode()
          ^ dimensions; }
```

Ignored return values

- Lots of methods for which return value always should be checked
  - E.g., operations on immutable objects

```
// Eclipse 3.0.0M8
String name= workingCopy.getName();
name.replace('/', '.');
```

Ignored Exception Creation

```
/**
 * javax.management.ObjectInstance
 * reference impl., version 1.2.1
 **/
    public ObjectInstance(ObjectName objectName,
                          String className) {
      if (objectName.isPattern()) {
        new RuntimeOperationsException(
          new IllegalArgumentException(
           "Invalid name->"+ objectName.toString()));
      }
      this.name = objectName;
      this.className = className;
  }
```

Inconsistent Synchronization

- Common idiom for thread safe classes is to synchronize on the receiver object ("this")
- We look for field accesses
  - Find classes where lock on "this" is sometimes, but not always, held
  - Unsynchronized accesses, if reachable from multiple threads, constitute a race condition

Inconsistent Synchronization Example

- GNU Classpath 0.08, java.util.Vector

```
public int lastIndexOf(Object elem)
{
  return lastIndexOf(elem, elementCount - 1);
}

public synchronized int lastIndexOf(
  Object e, int index)
{
  ...
}
```

Unconditional Wait

- Before waiting on a monitor, the condition should be almost always be checked
  - Waiting unconditionally almost always a bug
  - If condition checked without lock held, could miss the notification
- Example (JBoss 4.0.0DR3):

```
if (!enabled) {
   try {
     log.debug(...);
     synchronized (lock) {
       lock.wait();
     }
```

condition can become true after it is checked

but before the wait occurs

Bug Categories

- Correctness
- Bad Practice
  - equals without hashCode, bad serialization, comparing Strings with ==, equals should handle null argument
- Dodgy
  - Dead store to local variable, load of known null value, overbroad catch
- Performance
- Multithreaded correctness
- Malicious code vulnerability

Demo

- Live code review
- Available as Java Webstart from
  - http://findbugs.cs.umd.edu/demo/
  - http://findbugs.sourceforge.net/demo.html

Warning Density

Warning density

- Density of high and medium priority correctness warnings

Warnings/KNCSS	Software
0.1	SleepyCat DB
0.3	Eclipse 3.2
0.6	JDK 1.5.0_03
0.6	JDK 1.6.0 b51
0.9	IBM WebSphere 6.0.3

How we do it

Some detectors are simple

- But specific
- Looking for ignored return values is easy
  - once you know what methods to look at
- value.split(“.”) also pretty easy
- Experience, taste, and access to lots of bugs is what you need

Some are harder

- Finding uses of .equals to compare two objects of different types
  - requires a type analysis
- We do fairly simple analysis: very little interprocedural code analysis

Null pointer analysis

- Where we do a lot of work
- Want to avoid false positives
- Big issue: infeasible paths

An infeasible path?

```
private int f(Object x, boolean b) {
   int result = 0;
   if (x == null) result++;
   else result--;
   // at this point, we know x is null on a simple path
   if (b) {
     // at this point, x is only null on a complex path
     // we don't know if the path in which x is null
     //    and b is true is feasible
     return result + x.hashCode();
     }
 return result;
}
```

First attempt

- Don't worry about infeasible paths
- Only report null pointer exceptions that would occur if every statement and branch is covered

- This finds a lot of bugs!
  - with a very low false positive rate

The primary lesson

- You don't have to be clever to find stupid mistakes
  - being stupid works pretty well

A “false” positive

```
XMLEvent getXMLEvent(XMLStreamReader reader){
      EventBase event = null;
      switch(reader.getEventType()){
        case XMLEvent.START_ELEMENT:
          event = ...;
          break;
       case XMLEvent.END_ELEMENT:
          event = ...;
          break;
       }
event.setLocation(reader.getLocation());
return event ;
}
```

Missing default

Null pointer exception

But clever can find more

- We wanted to find more null pointer bugs
  - wanted to do better than commercial tools that cost $250K
- So we look for situations where a value is known to be null at some statement or branch
- and the value is guaranteed to be dereferenced on all paths to exit

A Guaranteed Dereference

```
public int f(Object x, boolean b) {
  int result = 0;
  if (x == null) result++;
  else result--;
  // at this point, we know x is null on a simple path
  if (b) {
    // at this point, x is only null on a complex path
    // we don't know if the path in which x is null
    //    and b is true is feasible
    return result + x.hashCode();
    }
 else {
    // at this point, x is only null on a complex path
    // we don't know if the path in which x is null
    //    and b is false is feasible
    return result - x.hashCode();
    }
}
```

Advantages of not being too clever

- If your analysis tries to be very clever, and do context sensitive alias resolution and interprocedural analysis
  - any developer is going to have to duplicate that analysis to understand your bug report
- they need to be able to understand it in order to fix it

Overall improvements

- We put a lot of effort into improving our null pointer analysis
  - field tracking
  - guaranteed dereferences

- FindBugs 1.1 finds about twice as many null pointer bugs as FindBugs 1.0
  - without an increase in false positives

The questions I want to answer

What is the fruit distribution?

- FindBugs looks for low hanging fruit
- Where is the best place to expend effort to find more bugs?
  - Use more sophisticated analysis to find more subtle errors
  - Build more shallow and general bug detectors
  - Write application-specific bug detectors

What kinds of errors can be detected by static analysis?

- I never would have thought to look for recursive infinite loops
- Or doing an integer division, converting the result to a double, and passing the result to Math.ceil
- Easy to measure false positives, hard to measure false negatives:
  - defects that could be detected by static analysis but aren't

Turning bug instances into bug patterns

- We need to change our software development process so that we learn from our mistakes
- Evaluate bugs, see if they can be turned into bug patterns
  - many bug patterns manifest themselves over and over again
- Example: the flaw identified in most binary search implementations

Examples of turning bugs into bug patterns

- I read through all the bugs fixed in each build of Sun's JDK
  - Example: In build 89, they fixed a serialization bug in ArrayBlockingQueue
- In 5 hours of work, I wrote and tuned a bug detector for that bug pattern
  - Found 17 other erroneous classes in the JDK

Specific details of bug

- Class was serializable, but had a transient field
- that wasn't reset by a readObject or readResolve method
- Had to tweak priorities for detector
  - raise priority if set to non-default value in constructor, or if set in multiple places

How can we make it easy to write bug detectors?

- We want to allow as many developers as possible to write their own bug detectors
  - some will be generally applicable, some specific to particular projects
- What tools/analysis/pattern languages do we need?
  - now starting to have enough samples to think about this

How can we make static analysis pervasive?

- State of the art static analysis has a lot to offer, more than many people suspected
- What are the practical and cultural issues that need to be surmounted to make it pervasive?
  - false positive suppression: no one wants to review a false positive more than once
  - other points of pain?

My Other Cool Project

Marmoset: an advanced project testing framework

Marmoset

- A total rethinking of how student programming projects are submitted and tested
- designed to provide students, instructors and researchers with lots of feedback, including feedback before submission deadline
- Collecting large data sets of student efforts, starting to learn lots of stuff about how students learn to program

Previous Practice

- Everyone agrees we can't just distribute all the test cases to students
- Instructor has secret test cases
  - sometimes not made up until time to grade the project
- Student code run against secret tests by TA after project deadline

Release Testing

- If a submission passing all of the public tests, students are given the option to release test their submission
  - given limited information from a release test
  - limited opportunities for release tests

Marmoset

- Students are told # of release tests passed and failed
  - and names of first two release tests that failed
- For example, on Poker project, might be told that they "fail FourOfAKind, FullHouse, and 2 other tests"
- Release testing consumes a token
  - students receive 2-3 tokens
  - tokens regenerate 24 hours after used

Advantages of release testing

- Encourages students to think, develop their own tests
- Gives students an indication of where they are, whether that are having trouble
- Gives students an incentive to start working early
- Instructors get live feedback about student progress before project deadline

Marmoset Research Study

- Students asked consent to participate in research study
- Eclipse plugin captures each save as students work on their projects
- Research database of more than 200,000 snapshots, each of which is run against all the test cases
  - ask questions such as what leads to null pointer exceptions in student code

Marmoset data

- From 4 semesters of a CS 2 course
  - 147,595 snapshots of student work
  - 2,171,812 unit test runs
- Exceptions include:
  - 31,454 null pointer exceptions
  - 8,122 class cast exceptions
  - 5,453 index out of bounds
  - 4,996 array index out of bounds
  - 3,754 stack overflows

Questions?