CAS Static Analysis Tool Study Overview

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Agenda

- Study Purpose
- Test Cases
  - Scope
  - Statistics
- Analysis Metrics
- 2010 Study Conclusions
- 2011 Study Plans

Study Purpose

- Study capabilities of commercial and open source static analysis tools for C/C++ and Java
  - Identify areas in which individual tools are strong
  - Determine how tools can be combined to use strong tool(s) in each area
- Study does NOT:
  - Attempt to choose a “best” tool
  - Cover anything other than results
    - Cost, performance, ease of use, customization, etc.

2010 Study – Tools

Tool	License Model	C/C++	Java
Tool 1	Commercial	✓	✓
Tool 2	Commercial	✓	✓
Tool 3	Commercial	✓	✓
Tool 4	Commercial	✓	✓
Tool 5	Commercial	✓	✓
Tool 6	Commercial	✓	
Tool 7	Open Source	✓	
Tool 8	Open Source		✓
Tool 9	Open Source		✓

Study Methodology Overview

- Analyze test cases with a tool in default configuration
- Convert the results into a CAS-defined, common CSV format
- Score results
  - Mark results relevant to test case as True Positives or False Positives
  - Add False Negatives
- Group test cases into “weakness classes”
- Calculate statistics for each weakness class

Differences from SATE/SAMATE

- We run each tool, not the tool vendor
- We use synthetic test cases instead of natural code
- We know where all the flawed and non-flawed constructs are
- We know exactly what type of flaw and non-flaw each construct represents

Test Cases

CAS Test Cases

- Test cases are artificial pieces of code for testing software analysis tools
- Each test case contains:
  - One flawed construct – “bad”
  - One or more non-flawed constructs that “fix” the flawed construct – “good”
    - As much as possible, performs the same function as the flawed construct
- Test cases cover:
  - C/C++
  - Java

Advantages of Test Cases

- Control over the breadth of flaws and non-flaws covered
  - Study full range of tools' capabilities
- Control over where flaws and non-flaws occur
  - Allows for automated scoring of results
- Control over data and control flows used
  - Study depth of tools' analysis
  - Test cases for many flaw types cover
    - Simplest form of flaw
    - 18 different control flow patterns
    - 22 different data flow patterns

Limitations of Test Cases

- Simpler than natural code
  - Tools may have “better” results on test cases than on natural code
- All flaws represented equally
  - Each flaw appears one time in test cases, regardless of how common the flaw is in natural code
- Ratio of flaws and non-flaws likely much different than in natural code
  - 1 or 2 non-flaw(s) for each flaw in the test cases
  - In natural code, non-flaws are likely much more common than flaws

Test Case Scope

- Test cases are currently focused on:
  - Functions available on the underlying platform
    - Not the use of third-party libraries or frameworks
  - Platform-neutral and Windows-specific functions
    - No test cases specific to Linux, Mac OS, etc.
  - C language vs. C++
    - C++ is only used for flaw types that require it (such as leaks of memory allocated with "new")
  - Java applications and Servlets
    - No Applets or Java Server Pages (JSPs)

2010 Test Case Statistics

	CWEs Covered	Flaw Types	Test Cases	Lines of Code
C/C++	116	1,432	45,324	6,338,548
Java	106	527	13,801	3,238,667
All Test Cases	**177**	**1,959**	**59,125**	**9,577,215**

Weakness Classes

Weakness Class	Example Weakness (CWE)	C/C++ Test Cases	Java Test Cases
Authentication and Access Control	CWE-620: Unverified Password Change	604	422
Buffer Handling	CWE-121: Stack-based Buffer Overflow	11,386	-
Code Quality	CWE-561: Dead Code	440	410
Control Flow Management	CWE-362: Race Condition	579	509
Encryption and Randomness	CWE-328: Reversible One-Way Hash	298	950
Error Handling	CWE-252: Unchecked Return Value	2,790	437
File Handling	CWE-23: Relative Path Traversal	2,520	718
Information Leaks	CWE-534: Information Leak Through Debug Log Files	283	468
Initialization and Shutdown	CWE-415: Double Free	9,894	450
Injection	CWE-89: SQL Injection	6,882	5,970
Miscellaneous	CWE-480: Use of Incorrect Operator	2,304	222
Number Handling	CWE-369: Divide by Zero	6,017	2,802
Pointer and Reference Handling	CWE-476: Null Pointer Dereference	1,308	425

Analysis Metrics

Precision, Recall, and F-Score

- CAS uses concepts from Information Retrieval in examination of static analysis tool results
- Precision
  - Fraction of flaw reports from tool that are actual flaws
  - Same as “True Positive Rate”
  - Complement of “False Positive Rate”
- Recall
  - Fraction of flaws in code that are correctly reported
  - Also known as “Sensitivity” or “Soundness”
- F-Score
  - Harmonic mean of Precision and Recall

Problem

- Precision, Recall, and F-Score on test cases don't tell whole story
- An unsophisticated "grep-like" tool can get:
  - Recall: 1
  - Precision: 0.5
  - F-Score: 0.67
  - Doesn't accurately reflect that tool is noisy
- This is a limitation of test cases
  - Only 1 or 2 non-flaws for each flaw

Discrimination

- A “Discrimination” is a test case where a tool:
  - Correctly reported the flaw
  - Did not incorrectly report any false positives
- Each tool gets 0 or 1 discrimination(s) for each test case

Discrimination Rate

- Discrimination Rate is the fraction of test cases where a tool reported discriminations

$$Discrimination\ Rate = \frac{\#\ Discriminations}{\#\ Flaws}$$

- Discrimination Rate ≤ Recall
  - Every Discrimination “counts” toward Discrimination Rate and Recall
  - Every True Positive “counts” toward Recall, but not necessarily toward Discrimination Rate

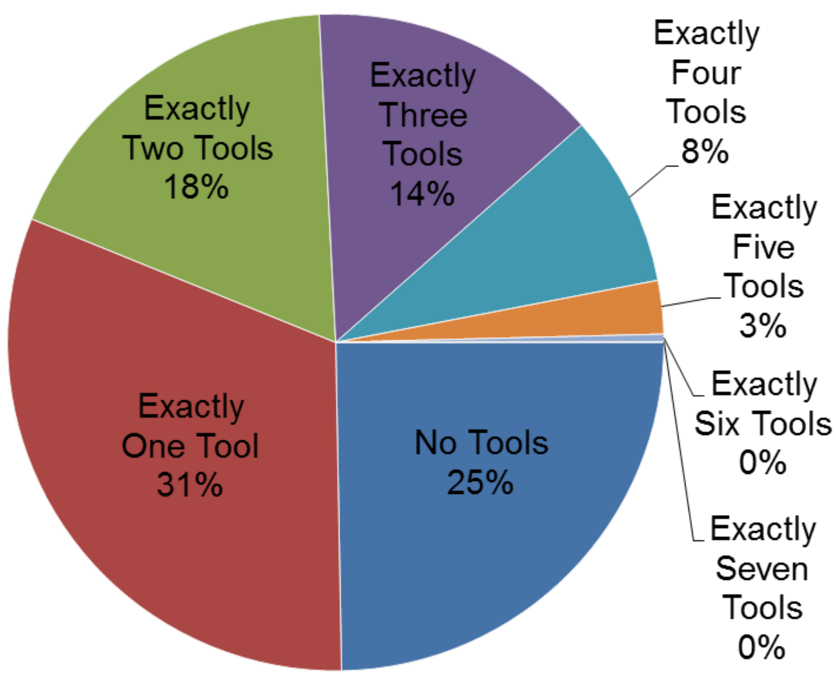
2010 Study Conclusions

2010 Study Conclusions

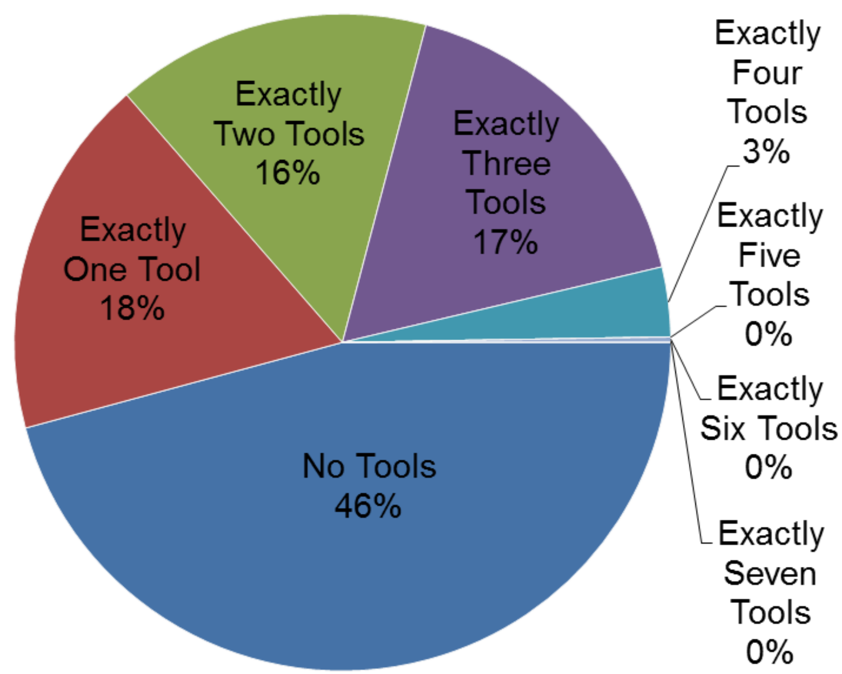
- Tools are not interchangeable
- Tools perform differently on different languages
- Complementary tools can be combined to achieve better results
- Each tool failed to report a significant portion of the flaws studied
  - Average tool covered 8 of 13 Weakness Classes
  - Average tool covered 22% of flaws in Weakness Classes covered

Flaws Reported – 2010

C/C++ Test Cases (2010)

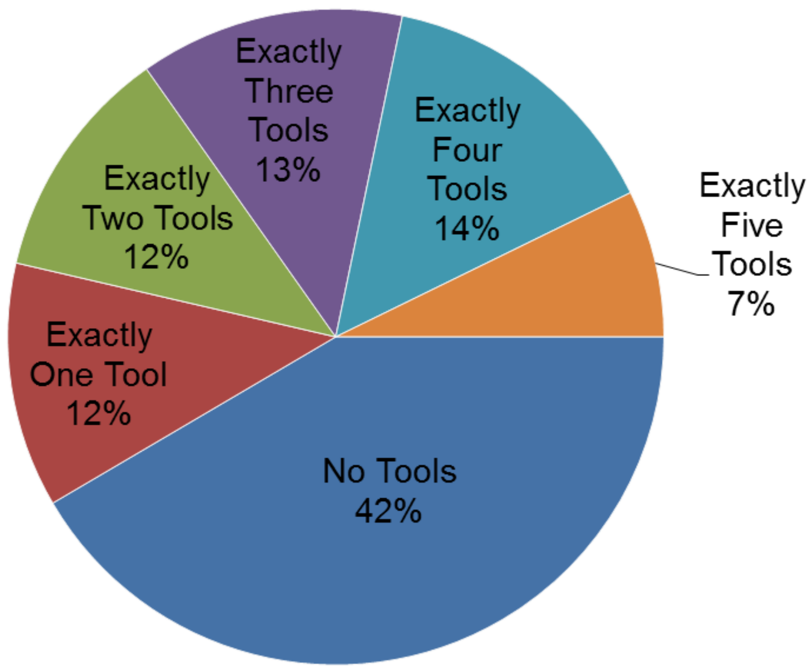


Java Test Cases (2010)



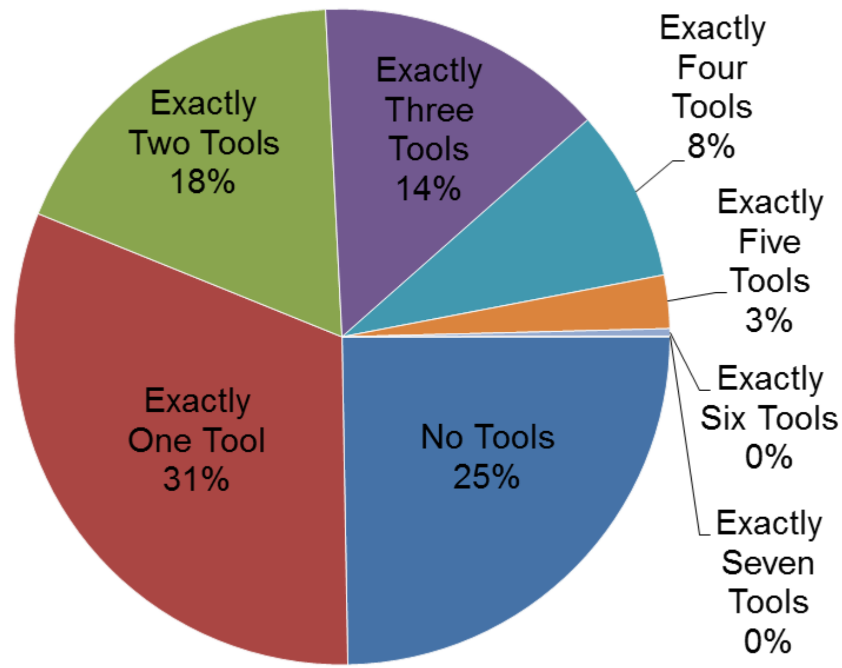
Flaws Reported – C/C++ 2009 vs. 2010

C/C++ Test Cases (2009)



- 207 Test Cases
- 207 Flaw Types
- No data or control flows

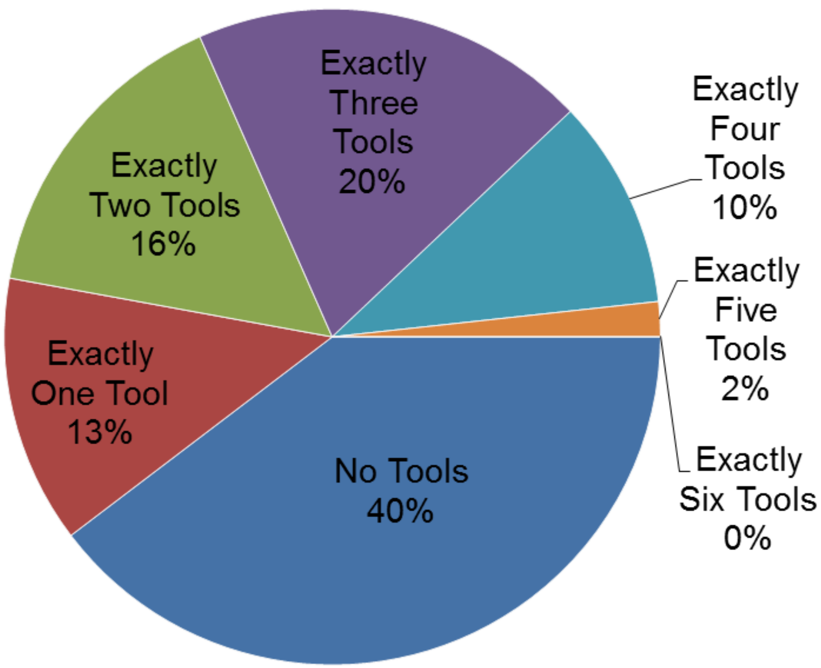
C/C++ Test Cases (2010)



- 45,286 Test Cases
- 1,432 Flaw Types
- Various data and control flows

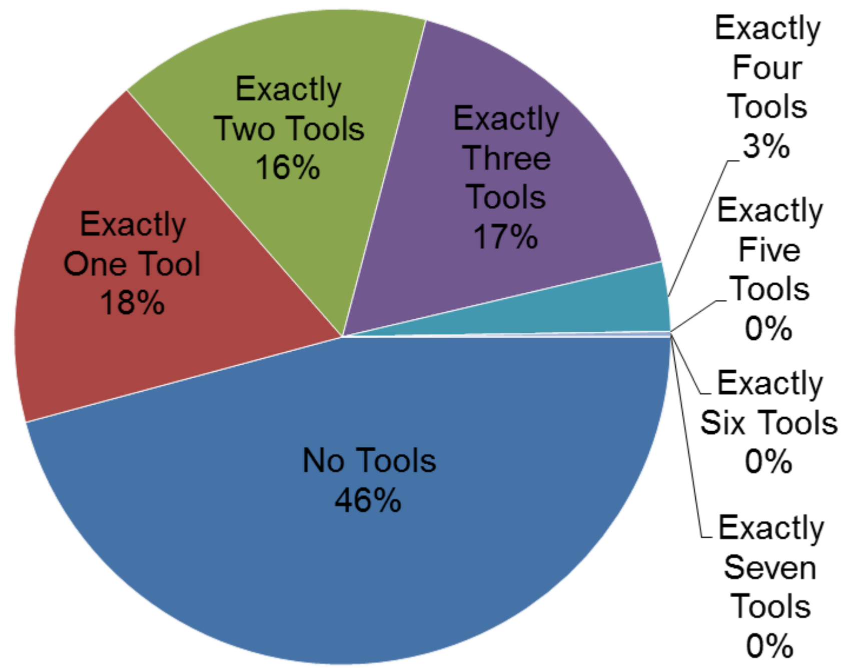
Flaws Reported – Java 2009 vs. 2010

Java Test Cases (2009)



- **174 Test Cases**
- **174 Flaw Types**
- **No data or control flows**

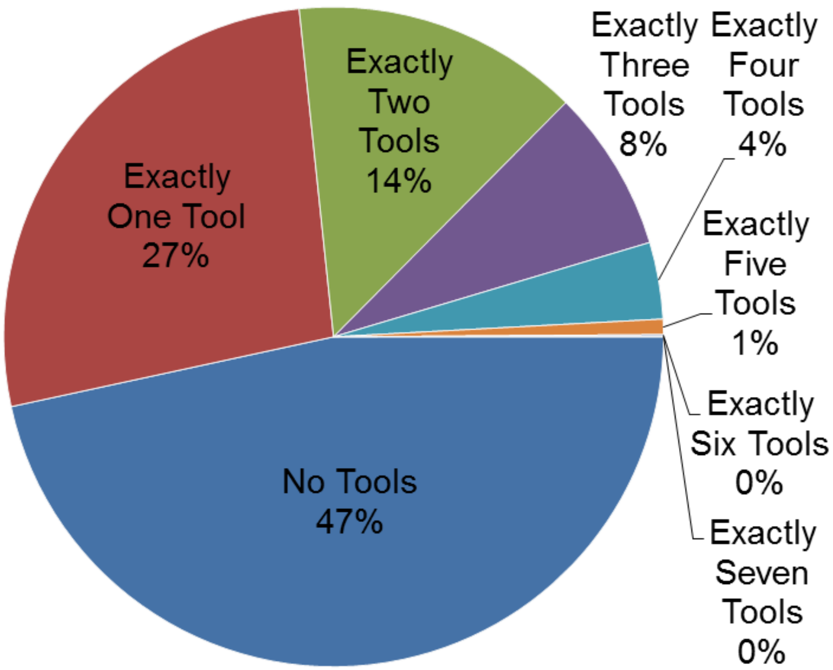
Java Test Cases (2010)



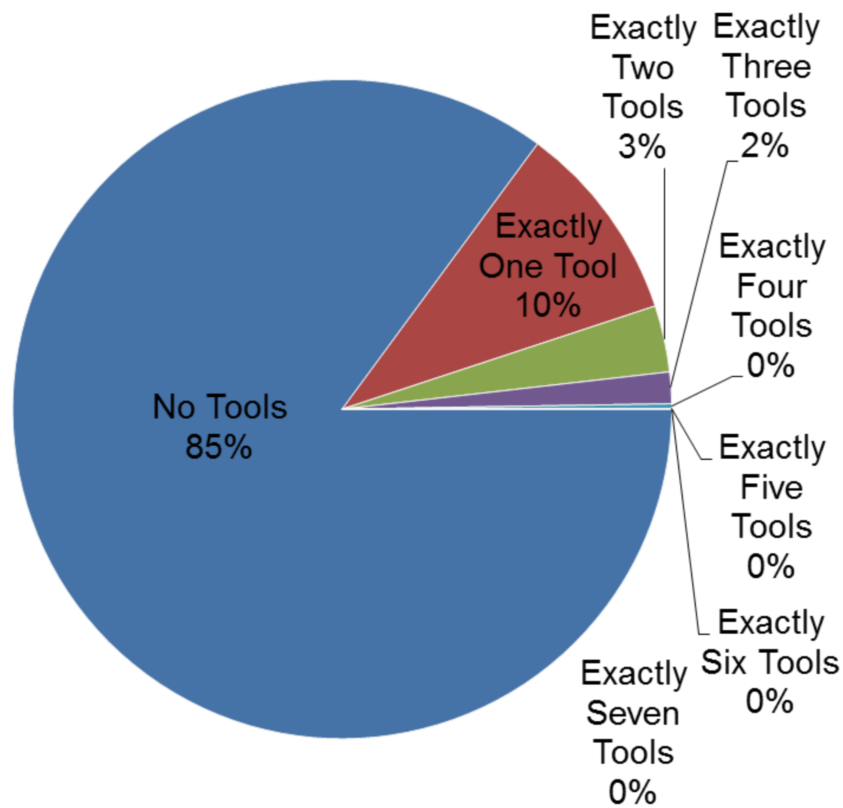
- **13,801 Test Cases**
- **527 Flaw Types**
- **Various data and control flows**

Flaws Discriminated – 2010

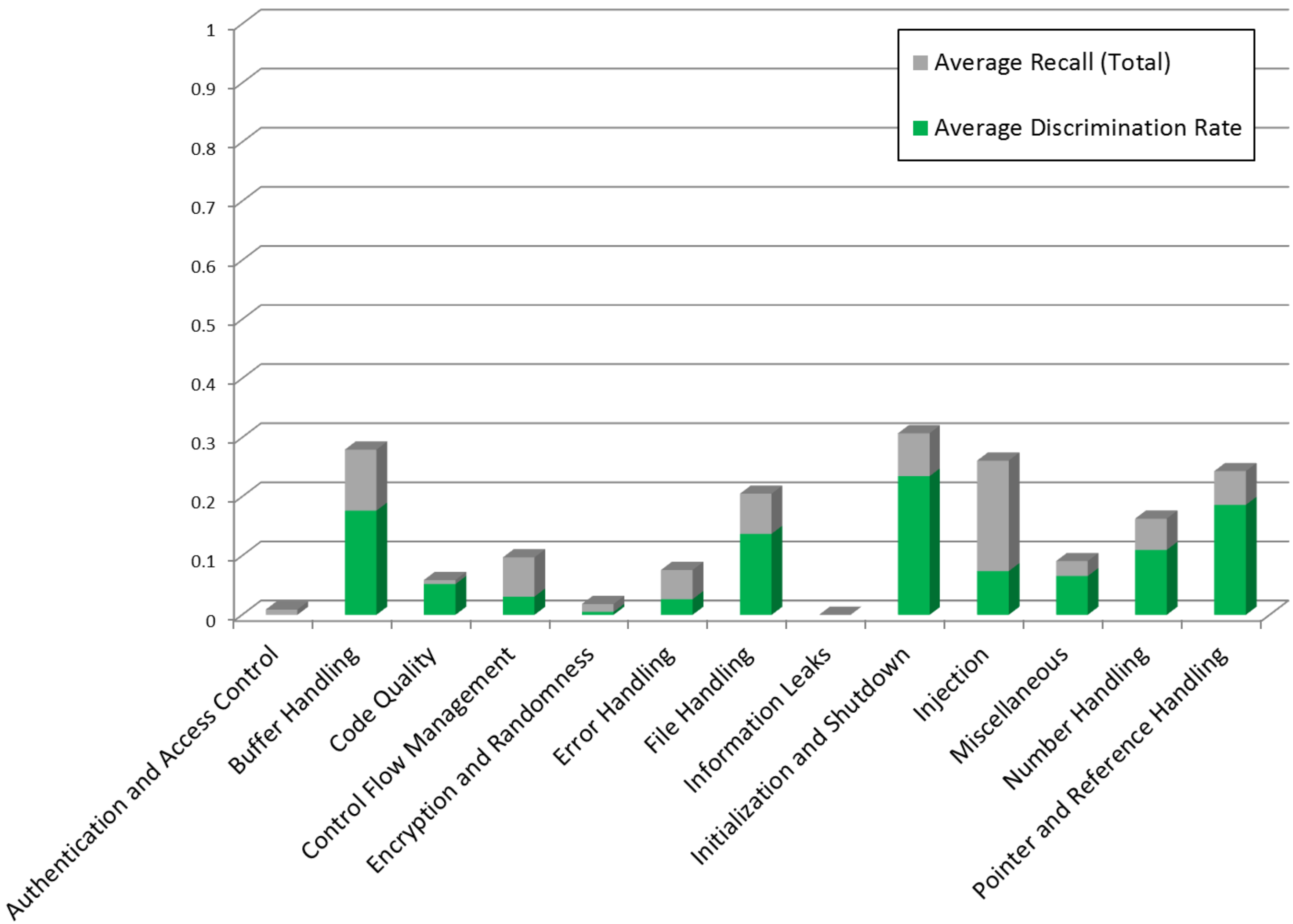
C/C++ Test Cases (2010)



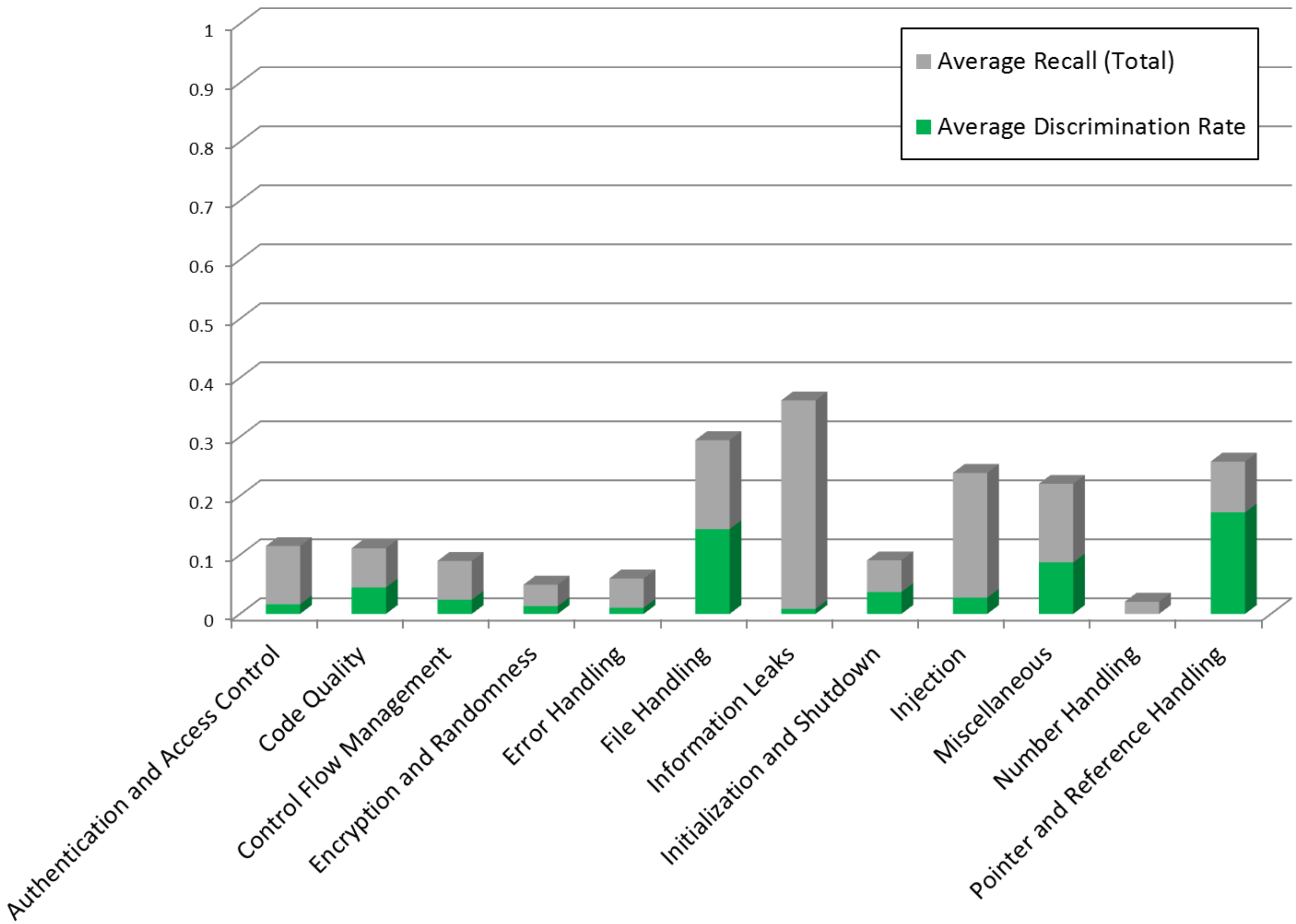
Java Test Cases (2010)



Flaws Reported and Disc. – C/C++ – 2010



Flaws Reported and Disc. – Java – 2010



Open Source vs. Commercial Tools

- Open source C/C++ tool was limited overall
  - Reported the flaws in a below-average fraction of the test cases in every Weakness Class it covered
  - Reported an above-average number of False Positives on five of the seven Weakness Classes it covered

Open Source vs. Commercial Tools

- Two open source Java tools studied had mixed results on the Weakness Classes they covered
  - In three Weakness Classes, an open source tool was the strongest of all tools (based on F-Score)
    - Control Flow Management
    - Code Quality
    - Error Handling
  - In four Weakness Classes, at least one open source tool was stronger than at least one commercial tool
    - Information Leaks
    - Initialization and Shutdown
    - Injection
    - Miscellaneous
  - In two Weakness Classes, the open source tools were the weakest tools
    - Auth. and Access Control
    - Pointer and Reference Handling

2011 Study Plans

Study Plans for 2011

- Update and expand Test Cases based on community feedback
- Soliciting input from vendors on configuration settings to use with their tools
- Considering additional tools
- Study scheduled to start in October 2011

Questions?

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