The Impact of Code Complexity on Static Analysis Results

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July 29, 2008

Outline

1. Research Objective
2. Test Cases
3. Metrics
4. Results
5. Analysis

Research Objective

Goal: Identify effects of code complexity on static analysis results.

Precision vs Scalability Tradeoff:

Increasing precision takes more time, decreasing size of code that can be analyzed in an acceptable amount of time.

Selected Prior Work:

- [Zitser, Lippmann, Leek 2004]
- [Kratkiewicz, Lippmann 2005]
- SAMATE

Study Needs

- A static analysis tool
  - Fortify Source Code Analyzer 4.5.0
- A vulnerability type that is reliably identified
  - Format string
- Metrics
  - Static analysis quality
  - Code complexity
- Test cases
  - Vulnerable and fixed source code samples

Metrics

- Static Analysis Metrics
  - Detection rate
  - False positive rate
- Code Metrics
  - Source Lines of Code (SLOC)
  - Cyclomatic Complexity

Test Cases

35 format string vulnerabilities
- Selected randomly from NVD.
- Open source C/C++ code that compiles on Linux.
- Each case has two versions of the code
  - One version has a format string vulnerability.
  - Other version is same program with vulnerability fixed.

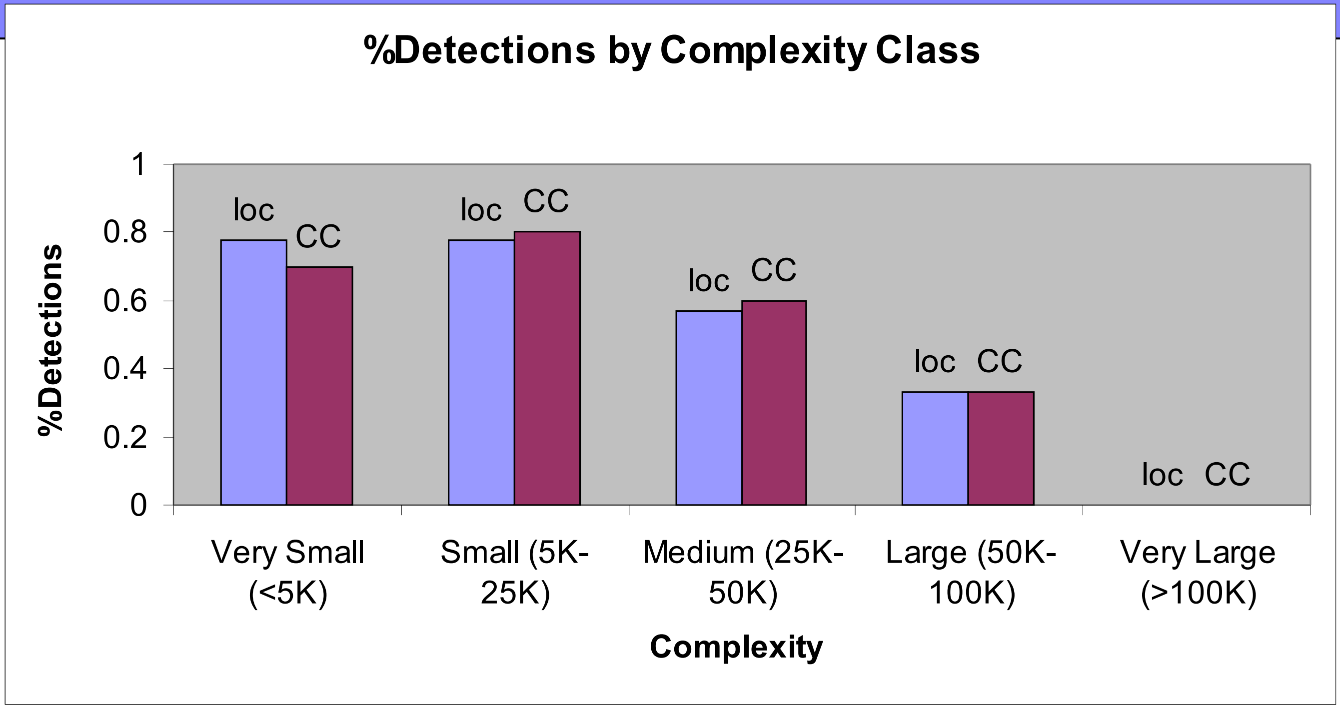
Examples

- wu-ftpd
- screen
- stunnel
- gpg
- hylafax
- exim
- dhcpd
- squid
- Kerberos 5
- cdrtools
- gnats
- cvs
- socat
- ethereal
- openvpn

Results

- Detections
  - 22 of 35 (63%) flaws detected by SCA 4.5.
- Detections by Complexity
  - Divided samples into 5 complexity bins.
  - No significant difference between SLOC and CC.
- Discrimination:
  - Measure of how often analyzer passes fixed test cases when it also passes vulnerable case.
  - Results almost identical to detection results since
  - Only one false positive from 35 fixed samples.

Detections by Complexity Class



Class	Lines of Code	Samples	Cyclomatic	Samples
Very Small	< 5000	9	< 1000	10
Small	5000 – 25,000	9	1000 – 5000	10
Medium	25,000 – 50,000	7	5000 – 10,000	5
Large	50,000 – 100,000	6	10,000 – 25,000	6
Very Large	> 100,000	4	> 25,000	4

Why do static analysis detection rates decrease with complexity?

Hypothesis 1: Tool designers make tradeoffs between precision and scalability, reducing the depth of analysis to handle larger programs in a reasonable amount of time.

Hypothesis 2: Software changes as it grows more complex, with increasing use of custom libraries such as the Apache Portable Runtime, which are not included in the rulesets of tools.

Problem: How do we measure the relative effect of each hypothesis? Are there alternative hypotheses?

Characteristics of Large Software

1. More complex control + data flow.
2. Participation of multiple developers.
3. Use of a broader set of language features.
4. Increased use of custom libraries.

Future Work

- How do static analysis results change with time? What happens after we remove all of the bugs that can be detected?
- How does code size affect the number of vulnerabilities in a program over time? How does churn affect this?