The Impact of Code Complexity on Static Analysis Results

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

#### Graph

- **%Detections by Complexity Class**
  - **Very Small** (<5K): 4 detections
  - **Small (5K-25K)**: 4 detections
  - **Medium (25K-50K)**: 6 detections
  - **Large (50K-100K)**: 5 detections
  - **Very Large (>100K)**: 5 detections

#### Table

<table>
<thead>
<tr>
<th>Class</th>
<th>Lines of Code</th>
<th>Samples</th>
<th>Cyclomatic</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Small</td>
<td>&lt; 5000</td>
<td>9</td>
<td>&lt; 1000</td>
<td>10</td>
</tr>
<tr>
<td>Small</td>
<td>5000 – 25,000</td>
<td>9</td>
<td>1000 – 5000</td>
<td>10</td>
</tr>
<tr>
<td>Medium</td>
<td>25,000 – 50,000</td>
<td>7</td>
<td>5000 – 10,000</td>
<td>5</td>
</tr>
<tr>
<td>Large</td>
<td>50,000 – 100,000</td>
<td>6</td>
<td>10,000 – 25,000</td>
<td>6</td>
</tr>
<tr>
<td>Very Large</td>
<td>&gt; 100,000</td>
<td>4</td>
<td>&gt; 25,000</td>
<td>4</td>
</tr>
</tbody>
</table>
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?