The Wireless Innovation Forum Presents:
Static Compliance Testing with R-Check™ SCA
Static Analysis for SCA Developers

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Static Compliance Testing with R-Check™ SCA

Outline

Introduction to Static Analysis
- What is Static Analysis?
- Capabilities of Static Analysis
- Successes from the State of the Art

Static Analysis and the SCA
- Relating the Specification to Testing
- Unique Challenges of the SCA

R-Check SCA
- Modern Static Analysis Customized to the SCA
- Looking ahead to SCA Next
- What is Possible ...
Introduction to Static Analysis

Static Analysis seeks to find bugs through inspection of source code rather than through the execution of the program

- Analyzes all possible program paths without bias
- Can be run on code in an intermediate state
- Integrates with development environments

What can it do?

- Provide reproducible, automated tests
- Explain specifications, answer “what ifs”
- Generate counter-examples

What are the limitations?

- Depending on how specifications are written, some problems are very hard

What infrastructure is needed?

- Works best within a tool that can break code down into data-structures
Foundations of Static Analysis

G. Kildall – Dataflow Analysis (1973)
- Equations for deriving facts that hold at each program point
- Solution reduces to finding a fixed point over a lattice
- Foundation of modern compiler-driven optimization (e.g., live variable analysis, use-before-def detection)

M. Sharir & A. Pnueli – Interprocedural Analysis (1978)
- Extended the equations to support flow through procedures
- Added a level of abstraction to support calling contexts

- Logical sentences (CTL, LTL, etc.) over abstract labeled transition systems (Kripke Structures)
- 2007 ACM Turing Award

Field has a deep history with a solid mathematical foundation – not just a bag of tricks!

Kripke Structure
Successes from the State of the Art

Locks over the Linux Kernel (SATURN, Stanford)

- Precise checking of lock/unlock sequencing
- Use constraints to model conditional branches
- Found hundreds of previously unknown errors, low false positives

Counter-Example Guided Abstraction Refinement (CMU)

- Automate the abstraction process for a program
- Finds faults in programs using model checking techniques
- Big leap forward in proving properties about real systems

Proving Termination (MS Research)

- Provides usable results for an impossible problem!
- Applicable to liveness properties – what must happen
- Proving Program Termination, CACM, May 2011

The Halting Problem:
There is always a record that breaks the player
Static Analysis for the SCA

JTEL SCA 2.2.2 Applications Requirement List

<table>
<thead>
<tr>
<th>Requirement Tag</th>
<th>Criterion Tag</th>
<th>Requirement/Criterion Text</th>
<th>Section Number</th>
<th>Test Method</th>
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<td>AP0603</td>
<td></td>
<td>Applications shall be limited to using the OS services that are designated as mandatory in the SCA Application Environment Profile (Appendix B).</td>
<td>3.2.1.1</td>
<td>Manual</td>
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Simple – Can be performed with search and inspect
- Benefits from a context aware parsing – preprocessor, syntax, library awareness

Deceptive – Simple statement, but non-trivial to test
- Requires an enumeration of what is not allowed – domain & language expertise

Holy grail – Reducible to the locking or termination problems
- Simple and intuitive statement – really hard to get right
- Balance between eliminating false-negatives, limiting false-positives, speed
- Opens the door to the deepest types of analysis available today
Why Memory Leaks are Hard

Lessons from Examples

Memory leaks cannot be found by simply inspecting the memory allocation / deallocation lines

• Context, sequencing matter
• Semantics matter

These errors occur in real code

• Linux kernel (c.2005)
  Open source –
  thousands of sets of eyeballs –
  hundreds of undiscovered lock bugs

A safe, conservative analysis requires
deeper analysis tools

Example 1: Memory Leaks through Pointer Reassignment
Component::method_a() {
    p = malloc(...);
    ...
    p = malloc(...);
}
Component::releaseObject() {
    free(p);
}
Second malloc() leaks memory allocated by first malloc()

Example 2: Memory Leaks through Control Flow
Component::method_a() {
    if (A) {
        p = malloc(...);
    }
}
Component::releaseObject() {
    if (B) {
        free(p);
    }
}
If “A” evaluates to true, but “B” does not, then memory allocated by malloc() will be leaked
Static Analysis for the SCA

Static Analysis isn't limited to just C/C++ source code

SCA 2.2.2 also puts requirements on XML domain profile files ...

<table>
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<th>AP0613</th>
<th>C174</th>
<th>D.6.1.5.1.1.6</th>
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May also want to analyze CORBA IDL files ...

- These files define implementation contracts with the source code

And check consistency requirements across file types ...

- Profile matches interface description matches implementation

Or check non-SCA-specific properties

- Memory leaks, memory/pointer usage
- API usage requirements
R-Check SCA

Goal: Draw from the most successful ideas in static analysis to develop a solution customized to the SCA

Version 1.0

- Structure and context aware
- C and C++, POSIX and CORBA support
- Intermediate representation that supports advanced analysis techniques
  - Type system
  - Control-flow abstraction
- Support for XML, CORBA IDL
- Scales to enterprise code
- Push-button support for SCA tests
R-Check SCA Workflow

With GNU Make Enabled Scripting:

Source Compiler Replacement  Linker Replacement  Build Targets
Looking Ahead to SCA Next

*We expect static testing to become an even more integral component in SCA Next certification*

New Challenges making Dynamic Analysis Harder

- More flexibility in interface (e.g., CORBA vs. no-CORBA)
- More flexibility in capability supported
- Data hiding – component interfaces behind Domain Manager

Opportunities

- Static testing tool can be used to “teach” the specification with each compile operation

Providing meaningful guarantees requires an accord among

- **Specification authors**: What the specification says
- **Testers**: Tools available (time vs. precision), what can be tested
- **Developers**: How code is written
What is Possible

SCA Next
• R-Check SCA architecture extends to SCA Next
• SCA Profiles
• Support for Platform Specific Model
• Retain push-button functionality

Deeper Analyses
• Add flow and path-sensitivity, more precision
• Have the necessary platform

Direct Query Interface
• Write new analyses using structured natural-language syntax
• Motivated by model-checking ideas (logic sentences)
• Ask questions about what the radio might do

Static Analysis:
Find & eliminate bugs earlier in the process
About Reservoir Labs

Privately owned, Reservoir Labs has been providing leading-edge consulting and contract R&D to the computer industry, business, end-users, and the US Government since 1990

Expertise

- Custom verification solutions
- Applied compiler research for emerging high-performance and embedded architectures
- Reasoning, constraint solving, and mathematics
- Cyber-security, deep network content inspection

Technologies

- R–Check Static Analysis Platform
- R–Stream Mapping Compiler
- R–Solve Reasoning and Planning Technology
- R–Scope Network Security Technology

Reservoir Labs’ offices in New York, NY and Portland, OR