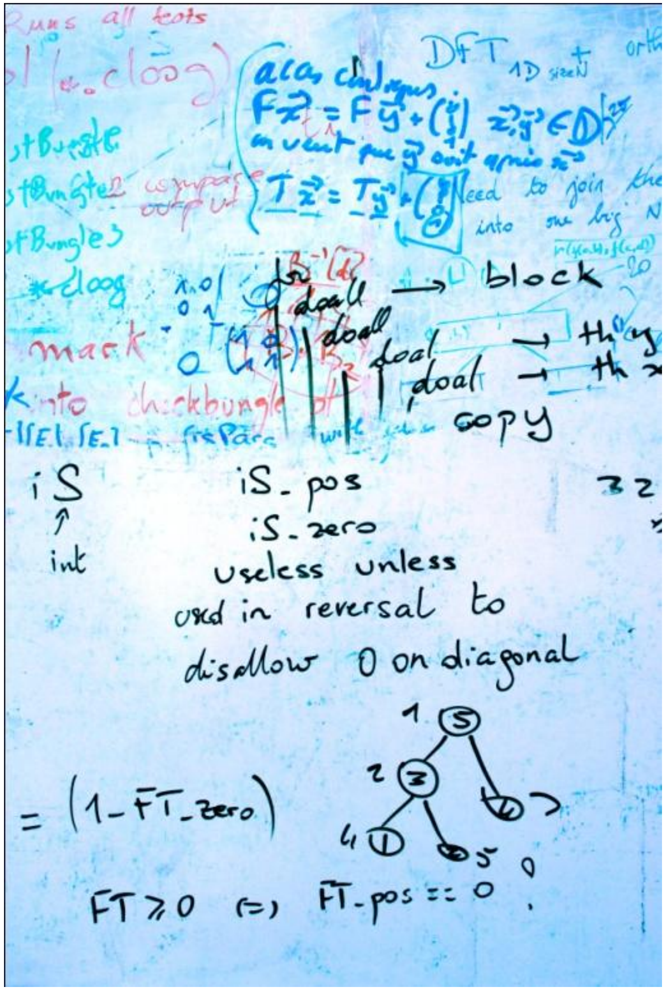
The Wireless Innovation Forum Presents:
Static Compliance Testing with R-Check™ SCA
Static Analysis for SCA Developers

James Ezick
Jonathan Springer

Reservoir Labs, Inc.
New York, NY



The Software
Communications Architecture
Winn Forum Webinar Series

26 May 2011

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

Static Analysis:
Finding bugs through inspection of source code

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)

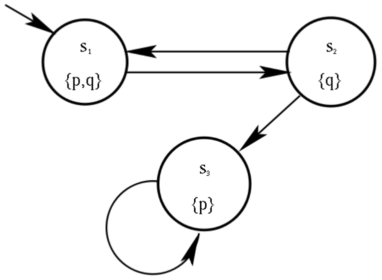
M. Sharir & A. Pnueli – Interprocedural Analysis (1978)

- Extended the equations to support flow through procedures
- Added a level of abstraction to support calling contexts

E. Clarke, A. Emerson & J. Sifakis – Model Checking (~1981)

- 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

Requirement Tag	Criterion Tag	Requirement/Criterion Text	Section Number	Test Method
AP0603		Applications shall be limited to using the OS services that are designated as mandatory in the SCA Application Environment Profile (Appendix B).	3.2.1.1	Manual

Simple – Can be performed with search and inspect

- Benefits from a context aware parsing – preprocessor, syntax, library awareness

AP0604		Applications shall perform file access through the CF File interfaces.	3.2.1.1	Manual

Deceptive – Simple statement, but non-trivial to test

- Requires an enumeration of what is not allowed – domain & language expertise

AP0075		The releaseObject operation shall release all internal memory allocated by the component during the life of the component.	3.1.3.1.2.5.2.3	Manual

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 …

AP0613	C174	The devicethatloadedthiscomponentref element refers to a specific component found in the assembly, which is used to obtain the logical CF Device that was used to load the referenced component from the CF ApplicationFactory.	D.6.1.5.1.1.6	Manual

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

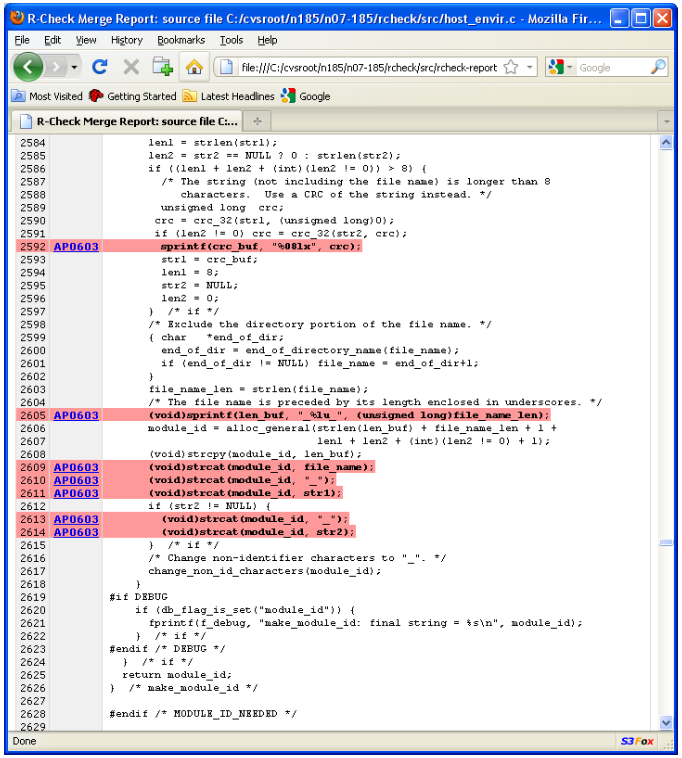
- Memory leaks, memory/pointer usage
- API usage requirements

R-Check SCA

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

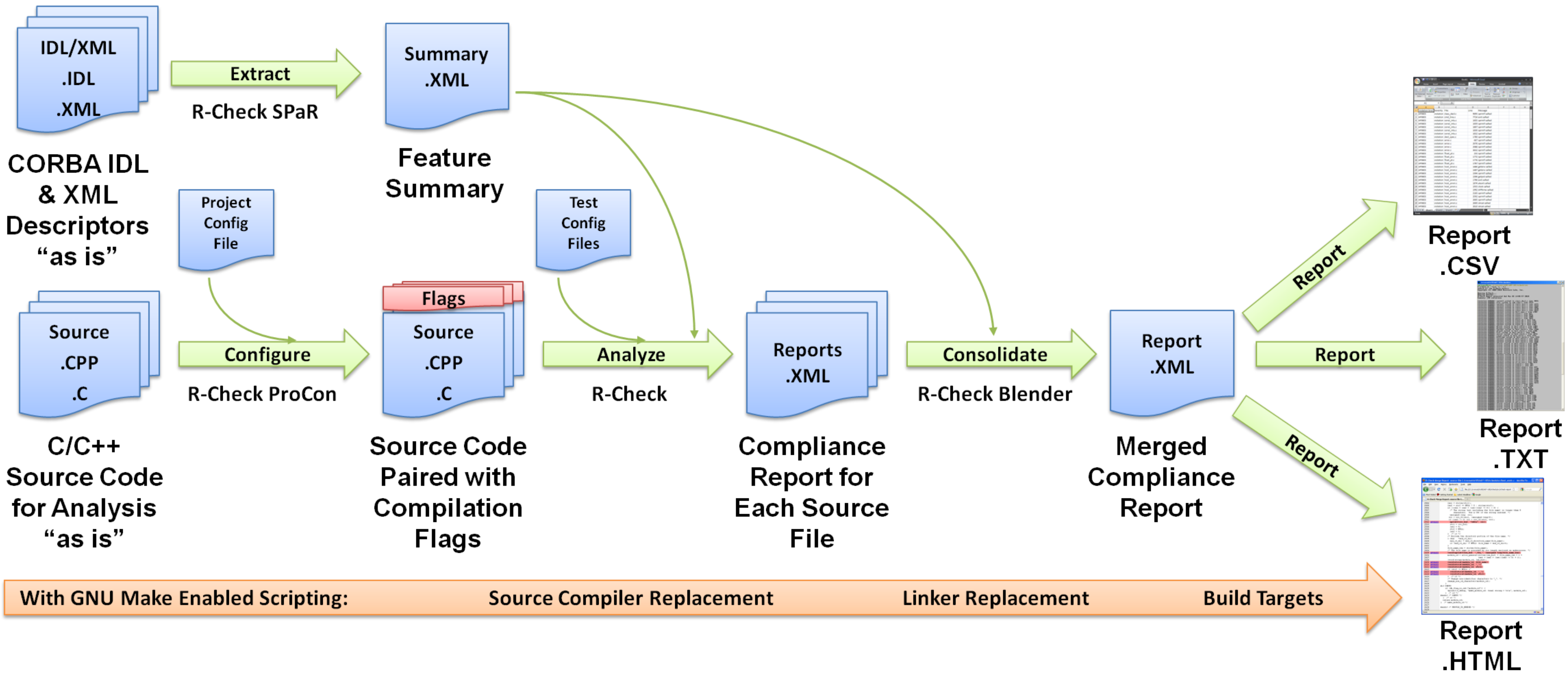
Version 1.0

- 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 HTML report for the SCA AP0603 core POSIX requirement (SCA 2.2.2. App B)

R-Check SCA Workflow



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

Static Analysis:
Find & eliminate bugs earlier in the process

Deeper Analyses

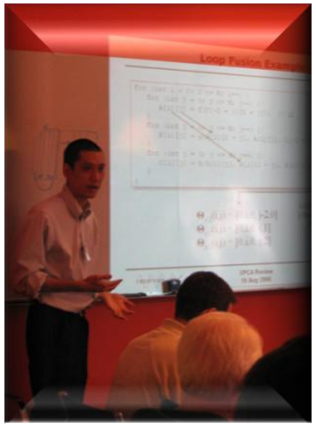
- Add flow and path-sensitivity, more precision
- Have the necessary platform

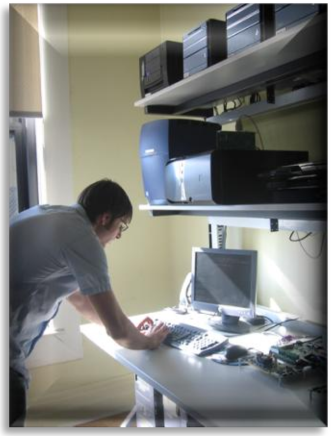
Direct Query Interface

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

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





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

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