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May 2, 2016

The Mission of the Software Behaviour Analysis Research Lab

To investigate techniques and tools **to help software (and system) analysts understand and analyze the behaviour of complex software systems** with the primary goal of enhancing maintenance, security, and addressing performance problems

Topics of interest

- Tracing, logging, and runtime monitoring
- Big data analytics of log and trace data
- Log management and engineering
- Cloud-based logging and tracing infrastructures
- System diagnosis and observability
- Dynamic analysis for program comprehension
- Model-driven software tracing and debugging
- Online system observation and surveillance
- Software healing and adaptation
- Visualization and classification of program behaviour

Current Projects

- AHLS - Advanced Host-Level Surveillance
- D2K - From Data 2 Knowledge for Better System Maintenance
- OpenSim - An Open Architecture for Aircraft Simulation Integration and Monitoring Methods Using the HLA Standard
- AVIO 508 - Diagnostics for Real Time Distributed Multi-core Architecture in Avionics

HQP

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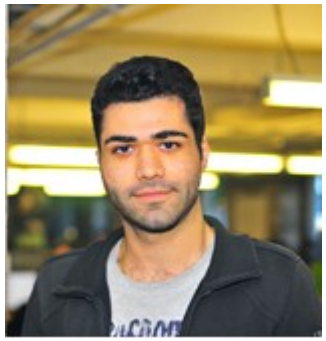

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A Bug Reproduction Approach Based on Directed Model Checking and Crash Traces

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May 2nd, 2016

Context: Software are released with bugs.

- Despite testing and verification, softwares are pledged to be released with latent bugs.
- Latent bugs will cause field crashes / faillures.
- Patching field faillures is challenging:
  - We have to know about them.
  - Information is scarce and inconsistent
  - Most valuable information are the one that help to reproduce a bug [Bettenburg, 2008].

Related Works: Current ways to reproduce a crash.

Record and replay

- Instrumentation of source code
- Record on-field execution
- Replay in-house

- Cheap & easy to implement
- Yield good results
- Overhead (1% to 1066%) and privacy concerns

- JRapture'00, BugNet'05, ReCrash'08

In house crash reproduction

- Core dump.
- Forward Symbolic Execution.
- Backward Symbolic Execution.

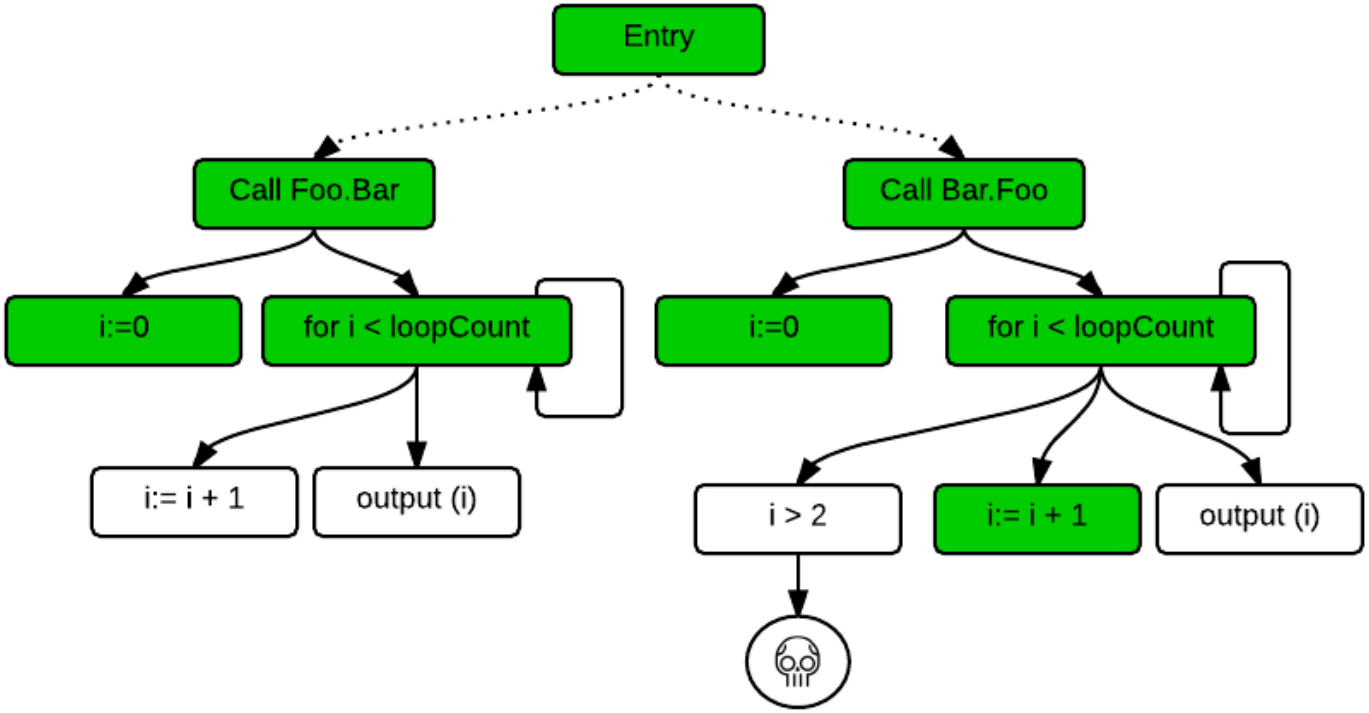
- Yield average results.
- NP-Compex Problem
- Exponential learning curve.
- Privacy concerns.

- BugRedux'12, RECORE'13, STAR'13

JCHARMING: A different direction

- Avoid code instrumentation
  - 0% overhead
- Do no yield privacy concerns
  - Scalable to real-world and industrial/proprietary software systems
- Leverage the stack traces resulting from a crash
  - More and more often present in bug reports
- JCHARMING uses directed model checking and backward slicing.

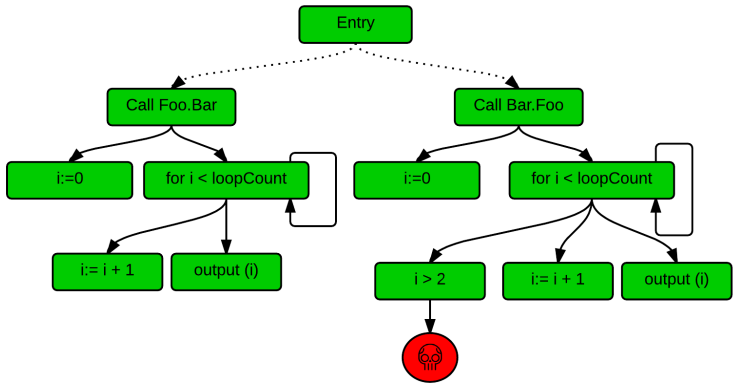
Prelimenaries: **Testing**, Model Checking and Directed Model Checking



- Depends on the tester understanding of the SUT.
- Ineficient because it is not exhaustive.

Prelimenaries: Model Checking

- Checks if a given system under test (SUT) meets a specification p by exhaustively testing every states. [Visser, 2003], [Kropf, 1999]

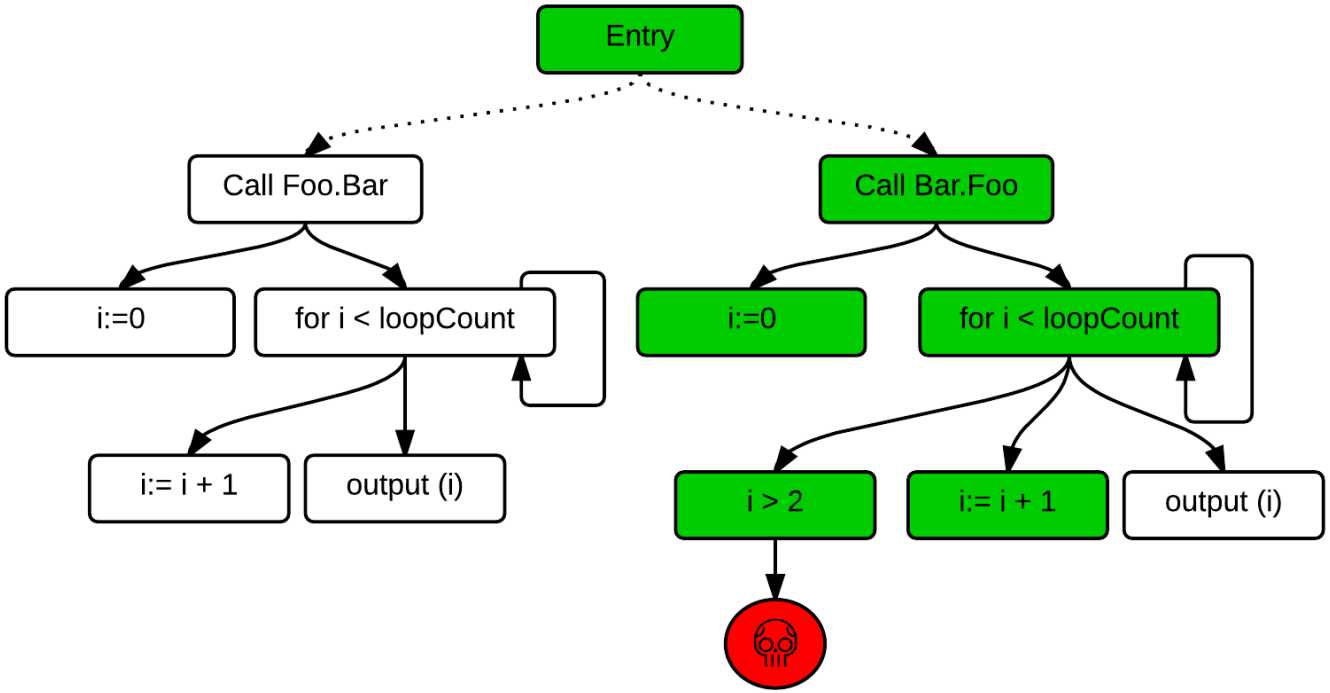


- Ensures that p is reached at some point and not that p holds nor $\forall x, p$ is satisfiable.
- We aim to verify that $\forall$ states the program does not crash:

$$\forall x.(SUT, x) \models \neg c$$

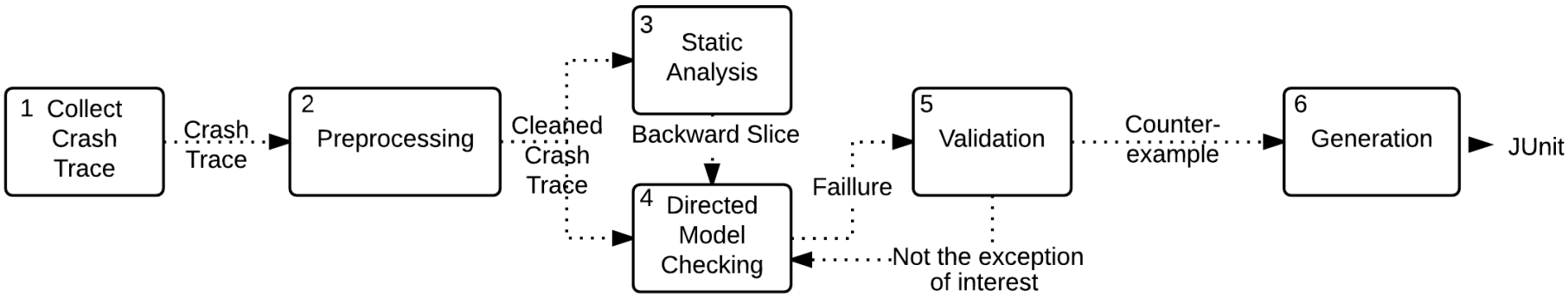
- Explores each and every state of the program, hence it is complete.
- Impractical for real-world and large systems

Prelimenaries: Testing, Model Checking and **Directed Model Checking**



- Explores only the states that may lead to a specific location. [Rungta, 2009]
- Use insights — generally heuristics — about the SUT to prune states.

The JCHARMING approach



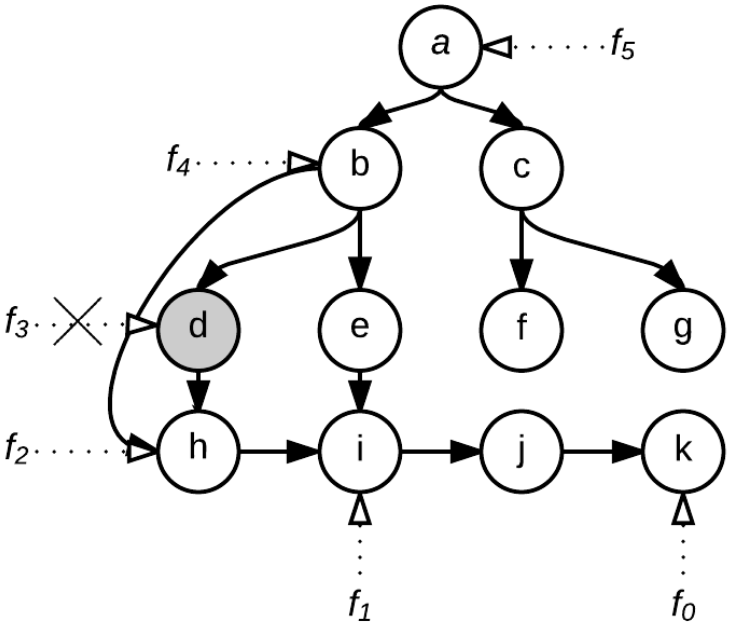
- **Step 1: Collect the crash trace**

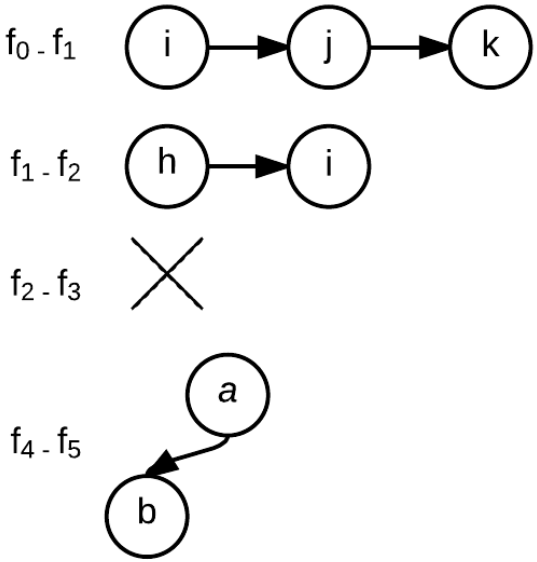
```
1.javax.activity.IAE:loopTimes should be < 3
2.   at Foo.bar(Foo.java:10)
3.   at GUI.buttonActionPerformed(GUI.java:88)
4.   at GUI.access$0(GUI.java:85)
5.   at GUI$1.actionPerformed(GUI.java:57)
6.   caused by java.lang.IndexOutOfBoundsException :  3
7.   at saner.Foo.buggy(Foo.java:17)
8.   and 4 more ...
```

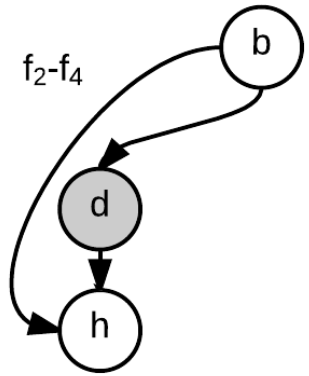
- **Step 2: Preprocessing**

Step 3: Building the Backward Static Slice (Cont'd)

- A backward slice contains all possible branches that may lead to a point n from a point m as well as the definition of the variables that control these branches
- Let's assume we have $T = \{k, i, f, d, b, c\}$
- Without using T the backward slice is $\{a, b, d, e, h, u, j, k\}$.
- With T, and frame by frame it is $\{a, b, d, h, i, j, k\}$.







Step 4: Directed Model Checking

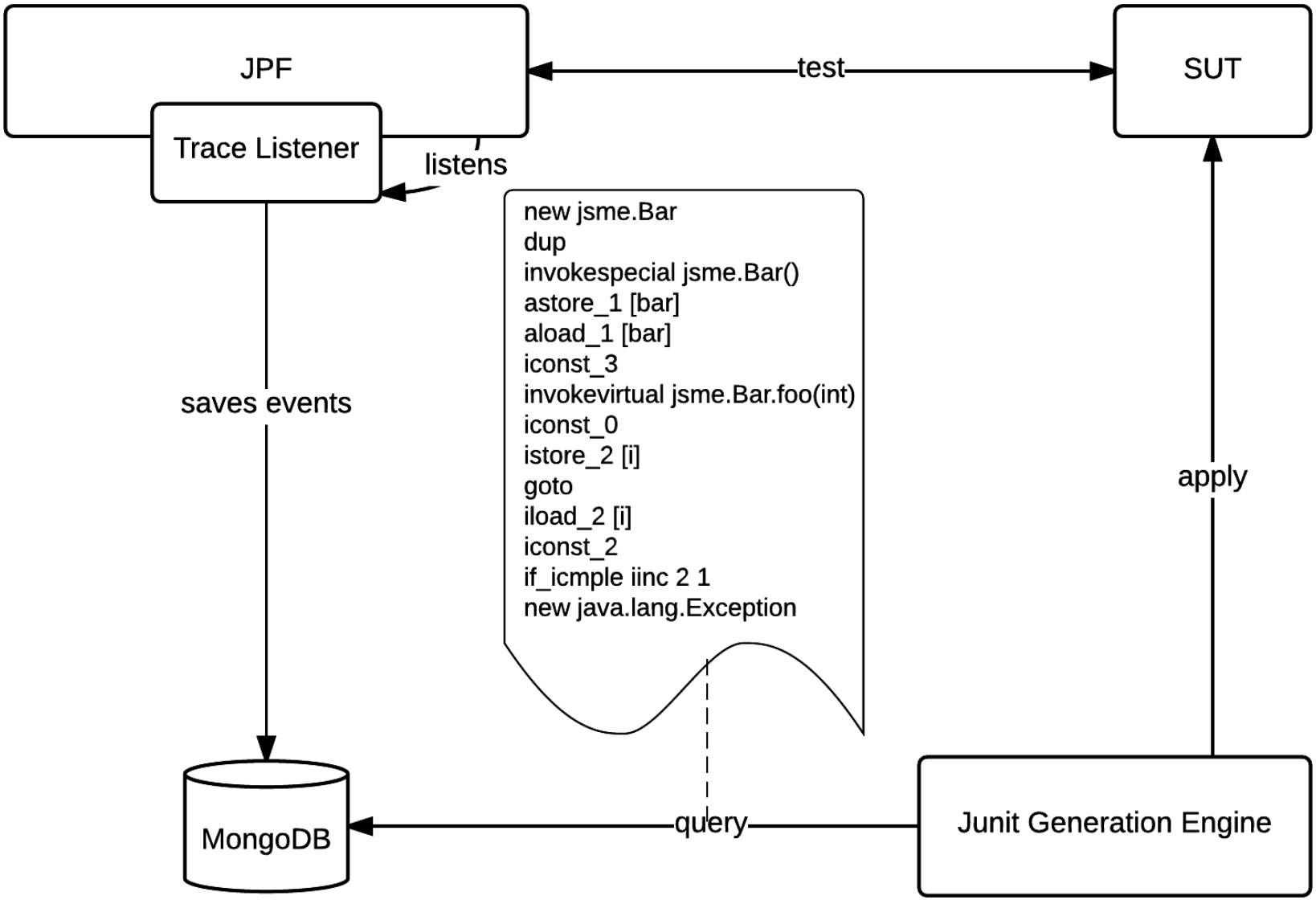
- We use Java PathFinder (JPF)
  - JVM for Java bytecode verification.
  - Front-end for the SPIN model checker.
  - Developped and maintained by NASA.
- Generate states
- Forward
  - Generates the next state S_{t+1} and add it to the backtrack table
- Backward
- Backtrack
  - Restore the last state of the backtrack table.
- Restore state
- Check properties
  - Is triggered after each forward, backward and restore operations.

Step 4: Directed Model Checking (Cont'd)

- We modified the *generate states* and the *forward steps*.
- The *generate states* is populated with: $\bigcup_{i=0}^{entry} bslice_{[f_{i+1} \leftarrow f_i]} \subset SUT$
- The *foward step* can explore a state if s_{i+1} and the transition x from s_i to s_{i+1} are in $\bigcup_{i=0}^{entry} bslice_{[f_{i+1} \leftarrow f_i]} \subset SUT$
- The *check properties* step of JPF:
  - If the current states transitions x yield an exception
  - We execute x and compare the stack trace to the original
  - If the two exceptions match, the bug is *reproduced*.

- JPF is now directed and explores only a sub-system of the SUT.

Step 6: Generating Test Cases for Bug Reproduction



Experiments And Conclusion

- 30 bugs belonging to 10 open sources systems (Ant, ArgoUML, DnsJava, jFreeChart, Log4j, MCT, PDFBox, Mahout, Hadoop, ActiveMQ).
- 80% success ratio (24/30).
- Average success time is 19 minutes.
- Average fail time is 11 minutes.
- Average JUNIT length is 5 java statements.

- Stress JCHARMING with more bugs
- Test the performances of JCHARMING with multi-threading related bugs

QUESTIONS?