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

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# 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.

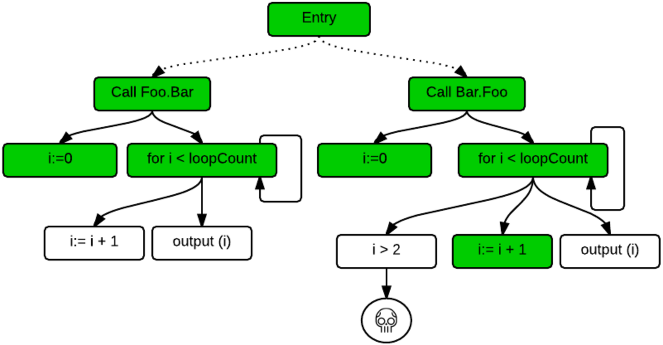
- Yield average results.
- NP-Compex Problem
- Exponential learning curve.
- Privacy concerns.

- 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.

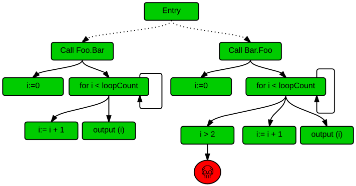
# Prelimenaries: **Testing**, Model Checking and Directed Model Checking




- 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]

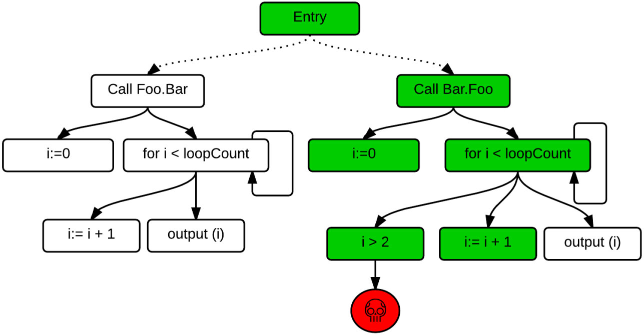



- Ensures that $p$ is reached at some point and not that $p$ holds nor $\forall x, p$ is satisfiable.
- We aim to verify that $\forall$ states the program does not crash:

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

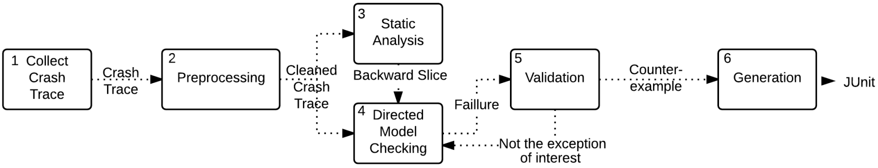
- Explores each and every state of the program, hence it is complete.
- Impractical for real-world and large systems

# 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



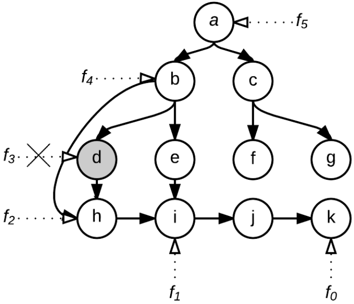

- **Step 1: Collect the crash trace**

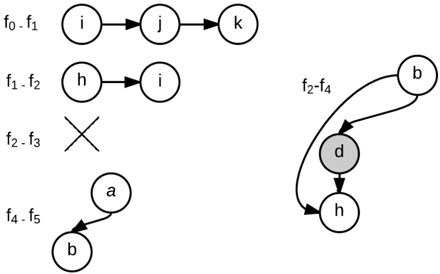
```
1.javax.activity.IAE:loopTimes should be < 3
2.   at Foo.bar(Foo.java:10)
3.   at GUI.buttonActionPerformed(GUI.java:88)
4.   at GUI.access$0(GUI.java:85)
5.   at GUI$1.actionPerformed(GUI.java:57)
6.   caused by java.lang.IndexOutOfBoundsException :  3
7.   at saner.Foo.buggy(Foo.java:17)
8.   and 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 $\{a, b, d, h, i, j, k\}$.



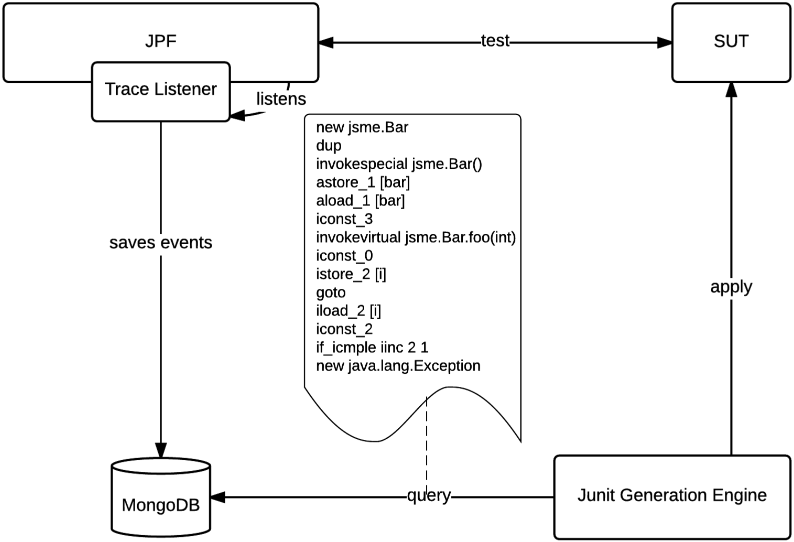
# Step 4: Directed Model Checking

- 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

- 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.
- Only 6% (2/30) of the bugs could have been reproduced using undirected model checking.

# Conclusion

- JCHARMING (Java CrasH Automatic Reproduction by directed Model checking)
- Automatic bug reproduction technique that combines crash traces and directed model checking
- Direct the model checking engine with a backward static slice
- Was able to reproduce fully or partially 80% of the bugs

- Stress JCHARMING with more bugs
  - Fine tune the approach
  - Assess the scalability on larger / proprietary systems
- Test the performances of JCHARMING with multi-threading related bugs

# QUESTIONS?