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# LCT: An Open Source Concolic Testing Tool for Java Programs

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# Overview

- Concolic Testing
- Tool Overview
- Experiments
- Tool Demonstration

# Concolic Testing

- Concolic testing (dynamic symbolic execution) is an automated testing method
  - Generate test inputs
  - Execute program with these inputs
  - Catch runtime errors (uncaught exceptions, assertion violations)
- Can we cover all the reachable statements with the tests?
  - E.g., random testing can have a very low probability on reaching certain statements
  - Concolic testing: Attempt to explore all feasible execution paths

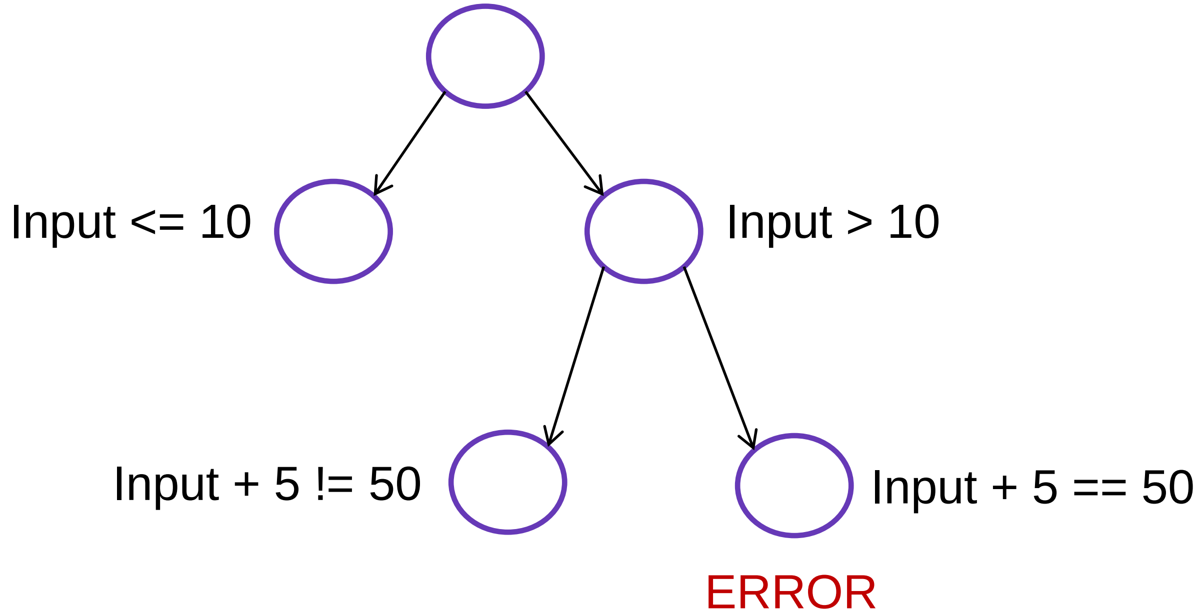
# Concolic Testing

- Concolic testing combines concrete and symbolic execution
  - Program is instrumented with additional statements to enable symbolic execution
  - Concrete execution guarantees that all the found bugs are real
- Symbolic execution collects path constraints that can be used to compute new test inputs that explore previously unexplored execution paths
- Path constraint are typically solved using SMT-solvers

# Example

```
int x = input();

if (x > 10) {
  x = x + 5;
  if (x == 50)
    error;
}
```

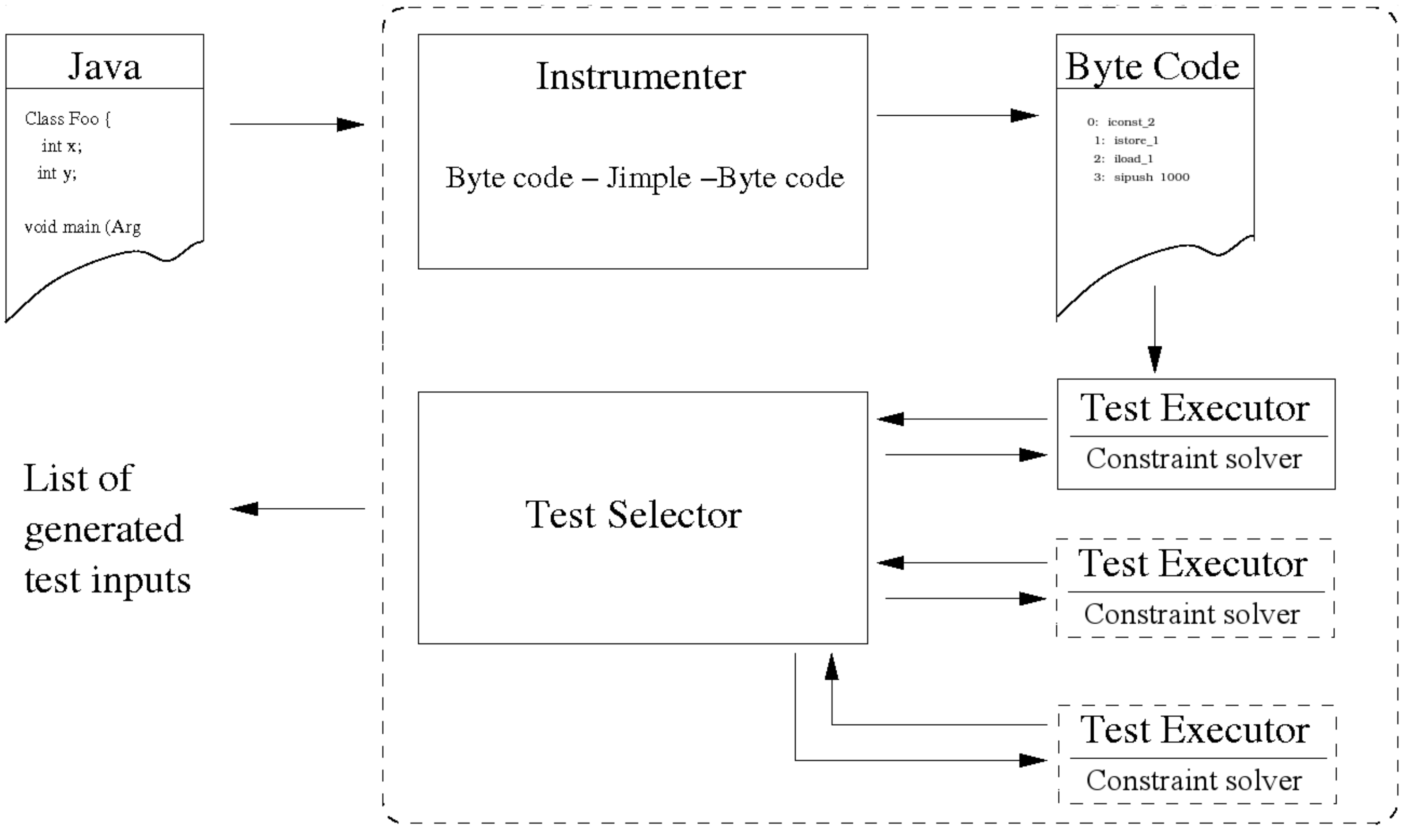



Path constraint is a conjunction of constraints along a path from root of the tree to a leaf node

# LCT – LIME Concolic Tester

- An open source concolic testing tool for sequential Java programs
- Instruments the program under test using Soot
- Uses Boolector for bit-precise constraint solving
  - For example, overflows and modulo-operator are handled precisely
- Supports distributed testing by allowing several tests to be executed in parallel
- Reports uncaught exceptions as errors
- Several related tools exists: CUTE/jCUTE, Pex, Klee,…

# Tool Architecture



# Distributed Testing

- Concolic testing suffers from path explosion problem
- Testing separate execution paths can be done independently
  - Keep track of all the unexplored branched in the execution tree
  - Distribute the path constraints related to these branches to test executors
  - Solving path constraints centrally could cause a performance bottleneck
- Distributed testing allows taking advantage of multicore architectures and networks of computers

# Limitations

- Java core classes can be problematic to instrument directly
  - LCT replaces some of the core classes with custom implemented counterparts that can be instrumented
- If the program under test contains un-instrumented classes, full path coverage cannot be guaranteed
- Floating point input values are not supported as the constraint solver does not support floating points
- LCT makes a non-alising assumption
  - A[i] = 0; A[j] = 1; if (A[i] != 0) ERROR;

# Experiments

| Benchmark | Paths | 1 executor | 10 executors | 20 executors |
|---|---|---|---|---|
| AVL tree | 3840 | 16m 57s | 2m 6s / 8.1 | 1m 8s / 15.0 |
| Quicksort (5) | 514 | 3m 11s | 21s / 5.2 | 13s / 8.4 |
| Quicksort (6) | 4683 | 28m 22s | 3m 29s / 8.1 | 1m 39s / 17.2 |
| GCD | 2070 | 11m 12s | 1m 13s / 9.2 | 38s / 17.7 |

- The distributed nature of LCT has been evaluated by testing Java programs with varying number of test executors running concurrently

# Experiments

| Approach | 1-bounded | 2-bounded | 3-bounded |
|---|---|---|---|
| Decoupled | 121 (54.50%) | 185 (83.33%) | 221 (99.95%) |
| Coupled | 123 (55.41%) | 187 (84.23%) | 221 (99.95%) |
| Random | 95 (42.79%) | 151 (68.02%) | 184 (82.88%) |

- LCT has been used in a case study to compare random testing and concolic testing (SPIN 2010)
- Here LCT was used on a large number of mutants of a Java Card application to discover if the mutations changed the behavior of the program

# Future Work

- We are currently extending LCT to support testing of multi-threaded Java programs
  - Support for multi-threaded programs will be released soon in LCT 2.0
- Support for C language based on the LLVM compiler infrastructure is also in development
- We are investigating how to support incremental testing by exploring only execution paths affected by recent changes

# Availability

- LCT is open source and available from http://www.tcs.hut.fi/Software/lime