An Empirical Framework for Comparing Effectiveness of Testing and Property-Based Formal Analysis

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Background

- There is an increase in the practicality of formal analysis.
  - e.g. automatic, scalable tools that can directly analyze source code
- In the next few years applications will need to be concurrent to fully exploit CPU throughput gains [Sut05].
- Formal analysis can often succeed at debugging concurrent systems while testing can be insufficient or impractical.

[Sut05] H. Sutter. The free lunch is over: A fundamental turn toward concurrency in software. *Dr. Dobb's Journal*, 30(3), Mar. 2005.

Goals of Proposed Study

- Development of a quantitative assessment framework to empirically evaluate the following open problems:
  - How good is property-based formal analysis at finding bugs in source code?
  - How efficient is a formal analysis technique at finding bugs in comparison to testing or in comparison to another formal analysis technique?
  - Can a hybrid approach that combines formal analysis and testing ever find more bugs or be more efficient than either approach used in isolation?
  - …

Experimental Setup

- **Quantity of bugs detected**
  - Mutant score = percentage of non-equivalent mutants detected (*killed*) by a test suite or property set

Selection of Metrics

Experimental Setup

- **Quantity of bugs detected**
  - Mutant score = percentage of non-equivalent mutants detected (*killed*) by a test suite or property set
- **Efficiency of bug detection**
  - Execution cost = the time to run each test case or test suite
  - Verification cost = the time to verify each property or property set
  - Cost to kill a mutant = the time to run a test case or verify a property that kills the mutant averaged over the number of mutants killed by the test case/property

Selection of Metrics

Experimental Setup

- Testing approaches
  - Test suites developed using standard coverage technique – e.g. branch coverage.
- Formal analysis approaches
  - Static analysis – Path Inspector
  - Model checking – Bogor

Selection of Metrics

Selection of Testing and Formal Analysis Techniques

Experimental Setup

- We have tried to find industrial example programs that have
  - a mature test suite
  - an existing property specification
- To start, we will use the Siemens programs used in testing community
  - a pattern replace program
  - priority schedulers
  - lexical analyzers
  - …

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Selection of Testing and Formal Analysis Techniques

Selection of Example Programs, Test Suites, and Property Sets

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← Difficult!

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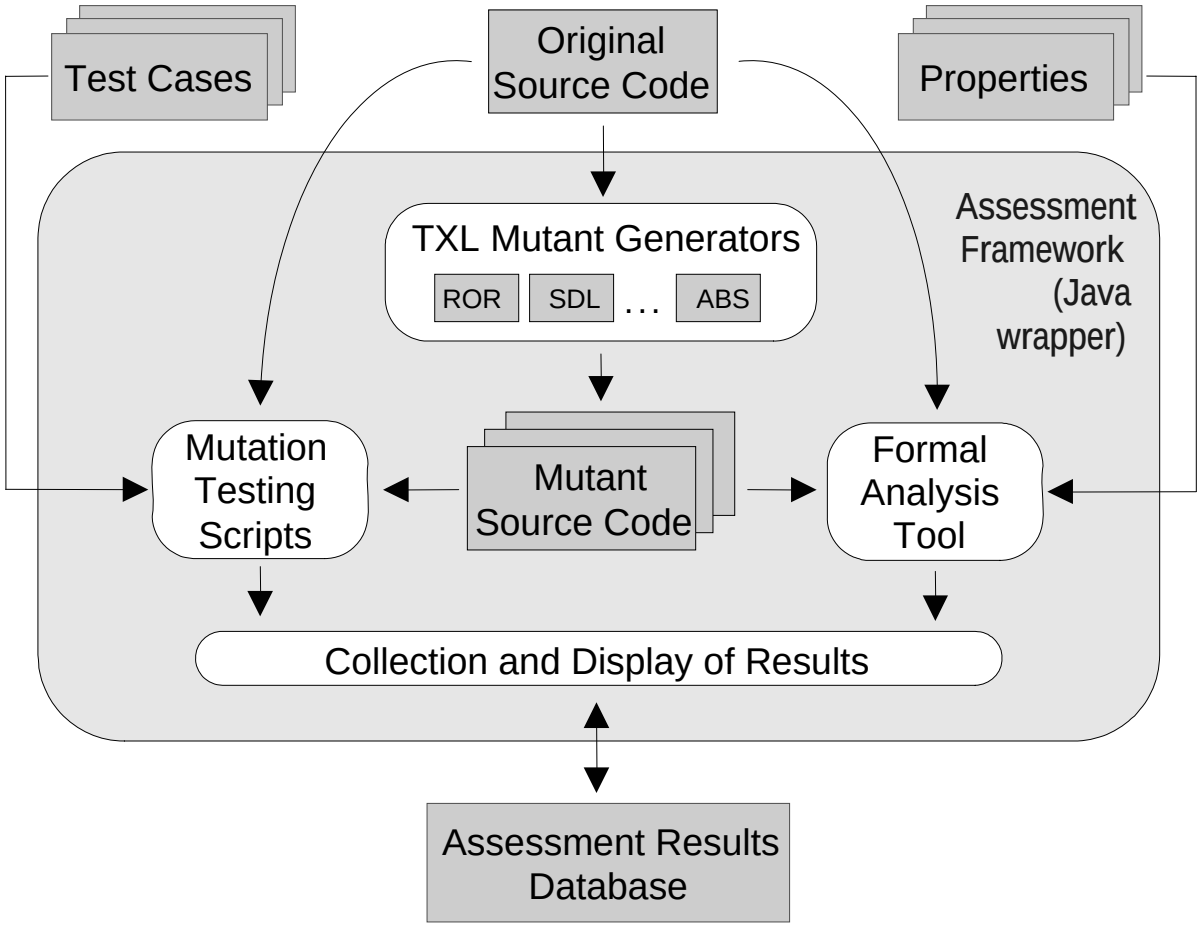
Selection of Metrics

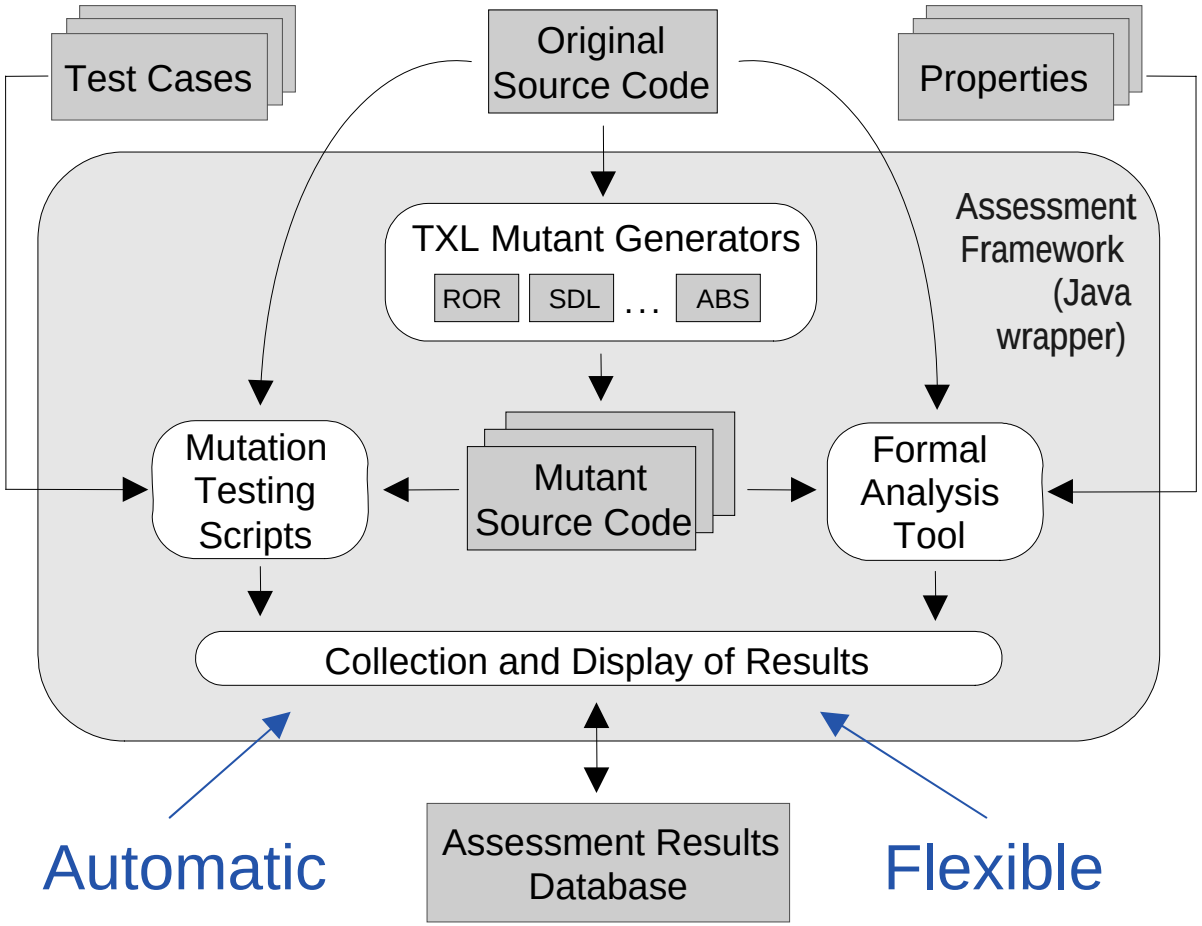
Selection of Testing and Formal Analysis Techniques

Selection of Example Programs, Test Suites, and Property Sets

Experimental Procedure



Experimental Procedure



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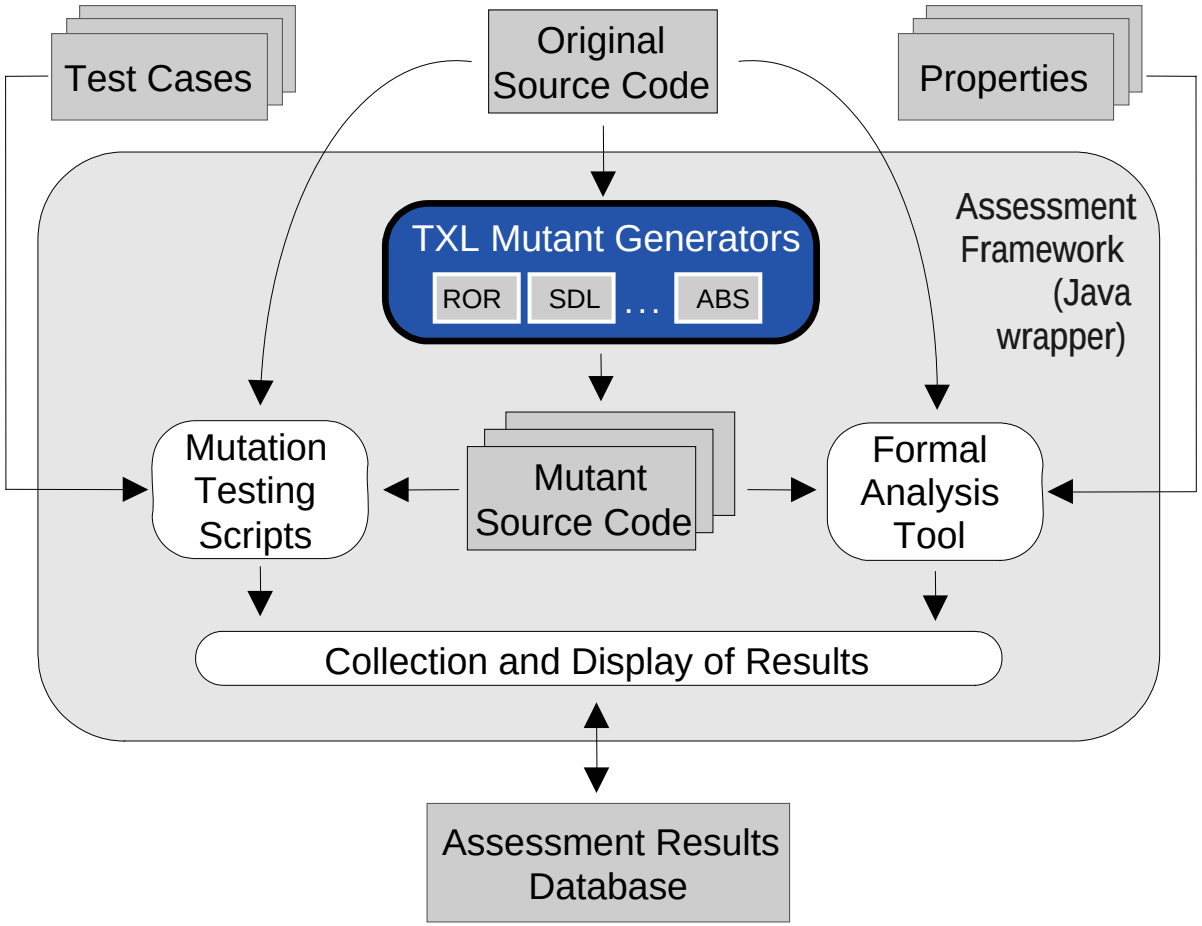
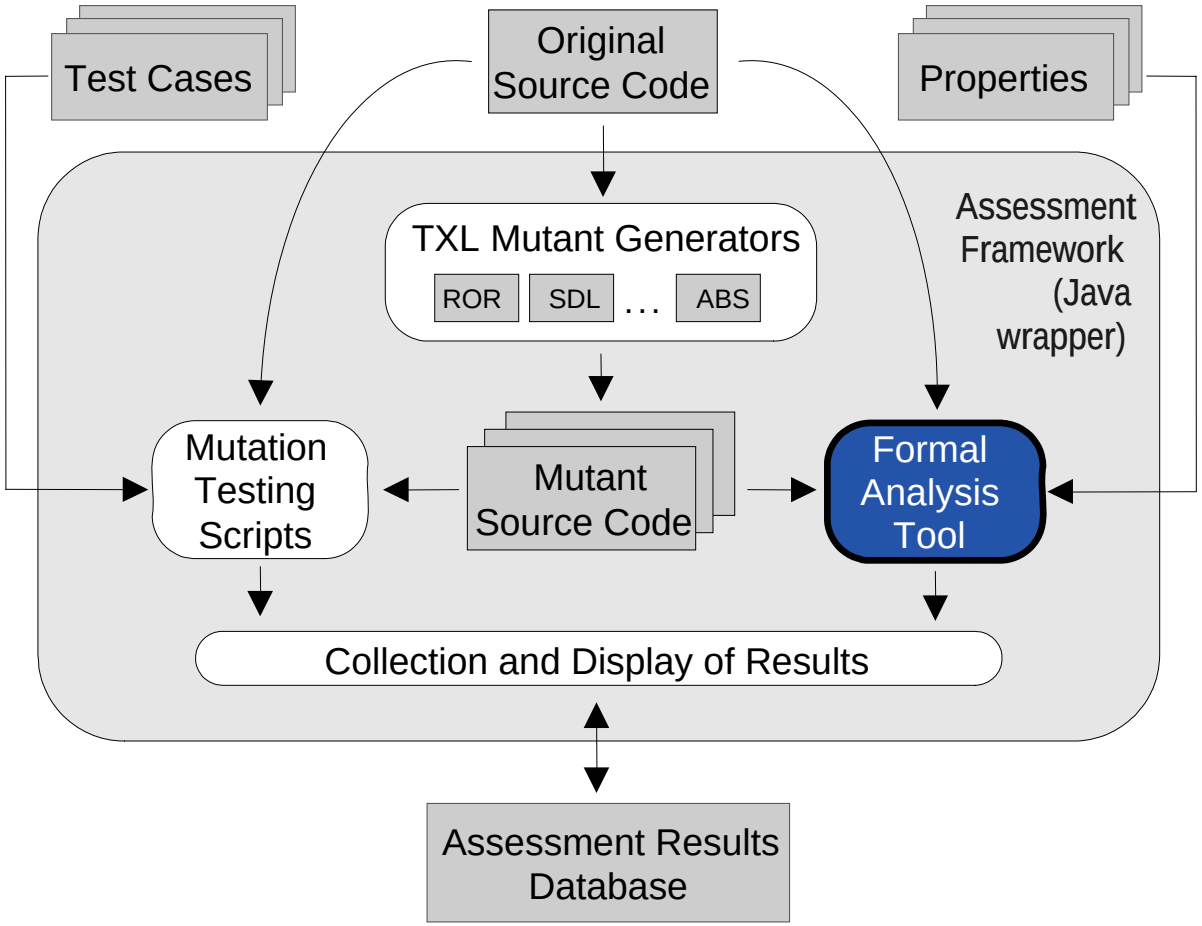


Mutation generation

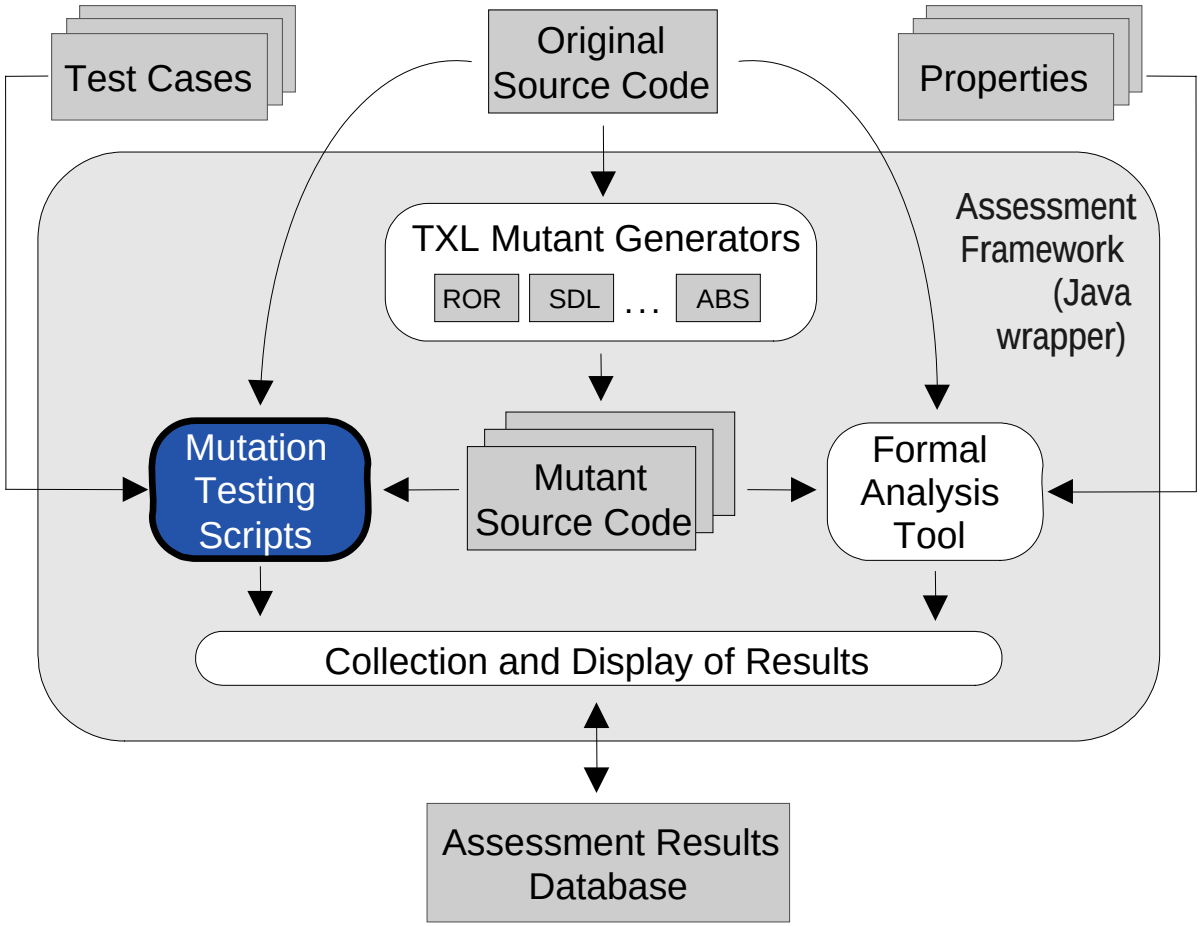
Experimental Procedure



Mutation generation

Formal Analysis

Experimental Procedure

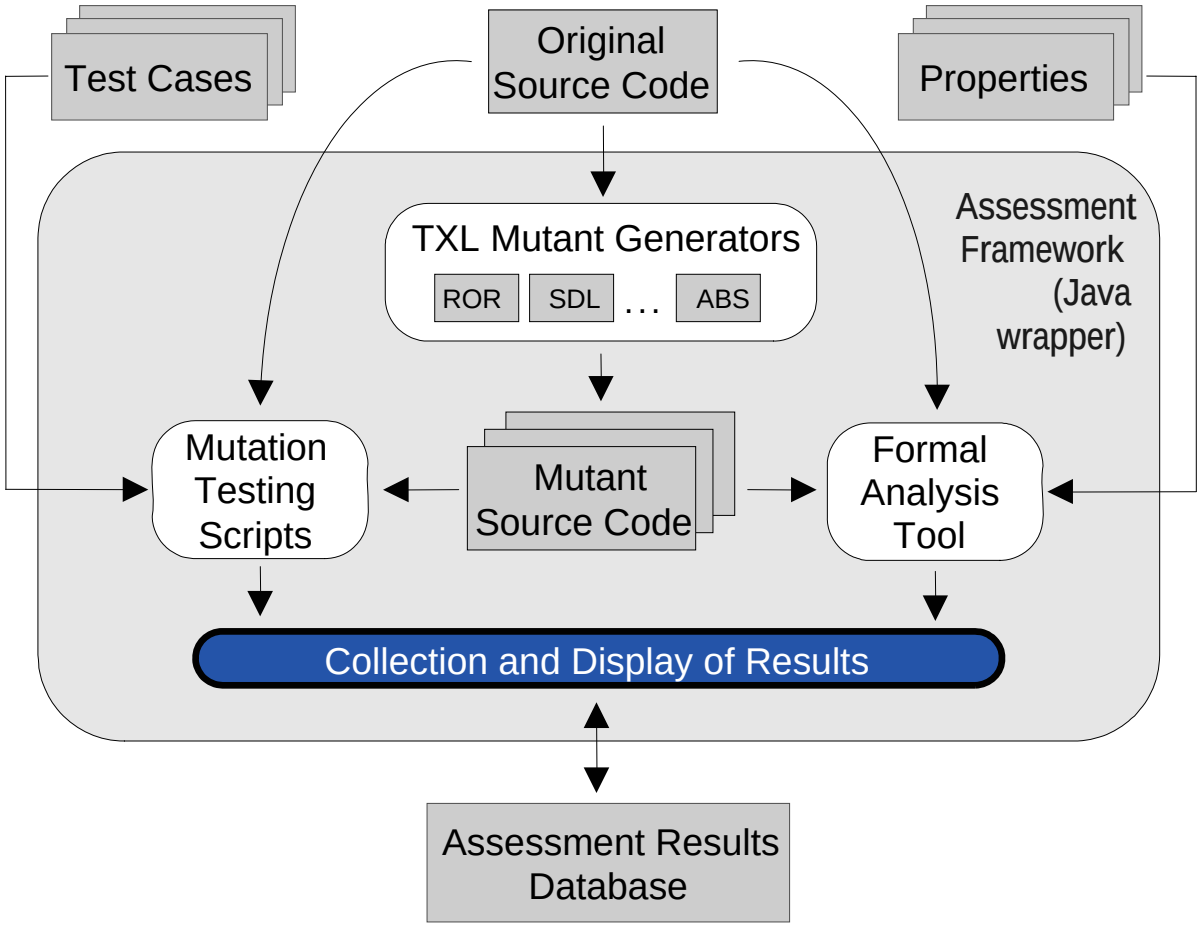


Mutation generation

Formal Analysis

Testing

Experimental Procedure



Mutation generation

Formal Analysis

Testing

Collection and display of results

Experimental Procedure

- For properties we report:
  - mutant score, verification cost, number of properties that kill each mutant.
  - the relationship between mutants killed vs. property patterns.

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  - the relationship between mutants killed vs. property patterns.
- For tests we report:
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- For hybrid approaches we examine sets of tests and properties with:
  - highest mutant score
  - lowest execution cost (or smallest set) given a mutant score.

Mutation generation

Formal Analysis

Testing

Collection and display of results

Contributions

- A mutation-based method for quantitatively evaluating bug detection with respect to:
  - property-based analysis and testing
  - different property-based analysis techniques
  - different sets of properties
  - different types of properties (assertions vs. LTL)
  - …
- Automatic experimental assessment framework
- Empirical data *(expected)*

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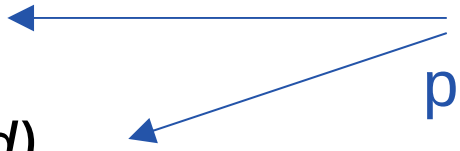

Will be made publicly available

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