Semantic Mutation Testing

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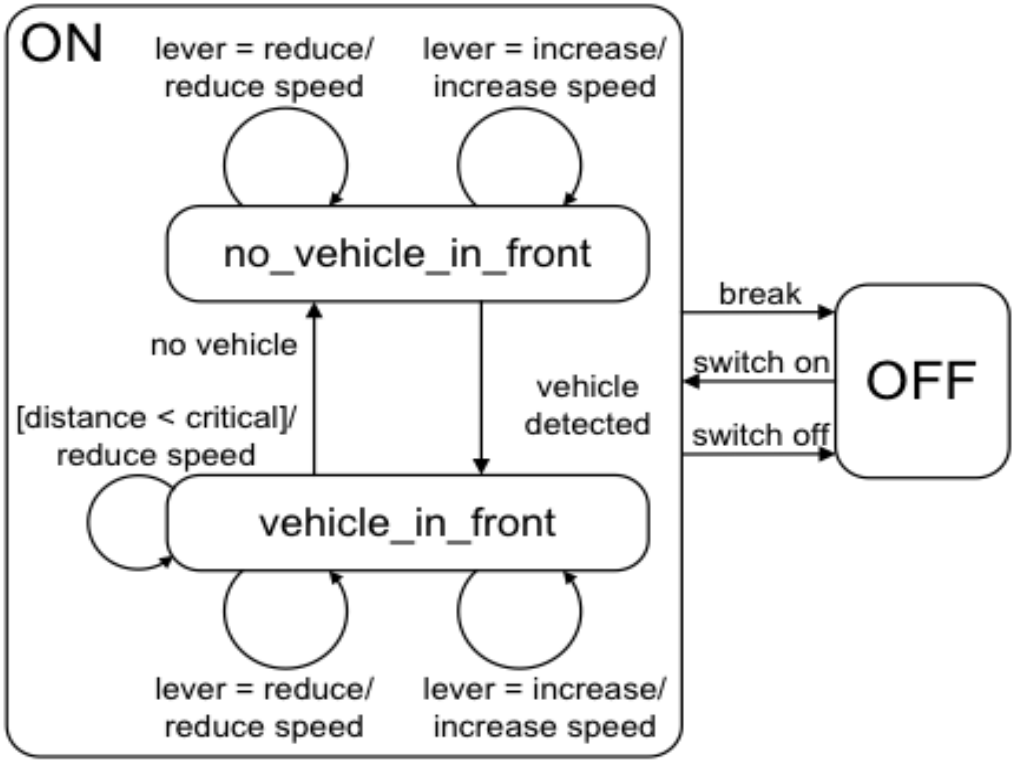
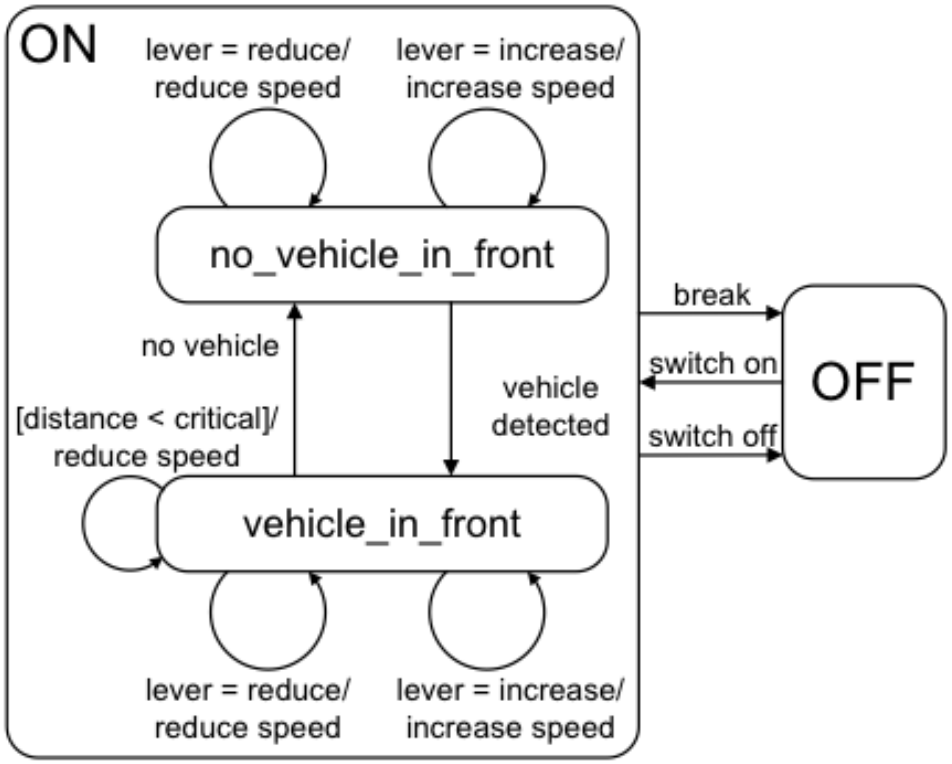
An example: cruise control



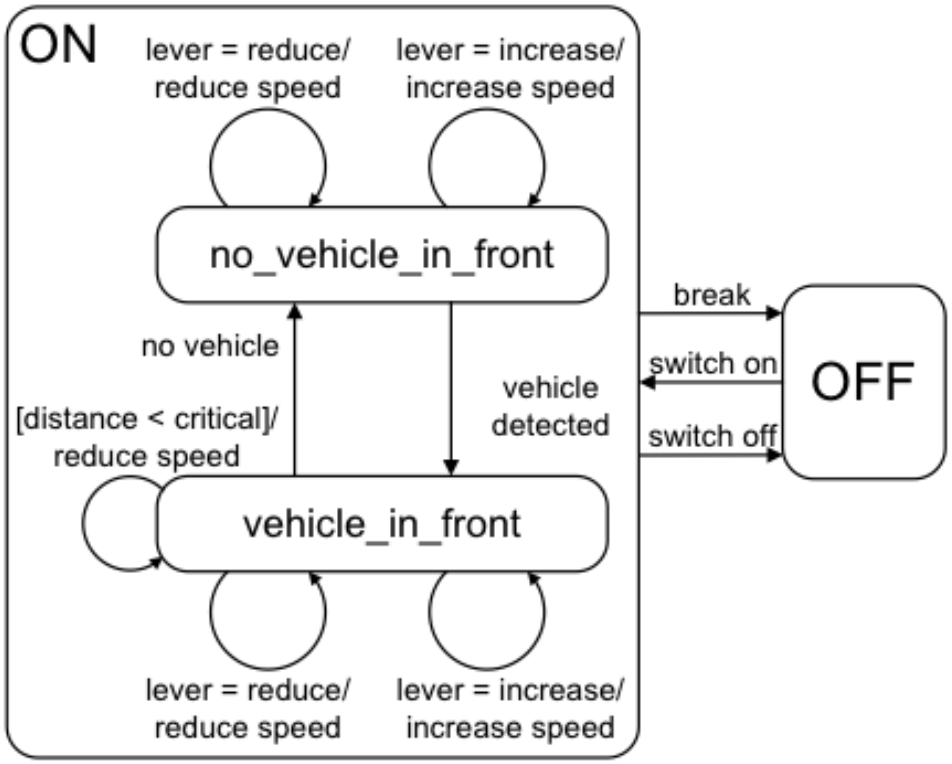
Question

- What happens in no_vehicle_in_front if brake and level=increase?



Another question

- What happens in no_vehicle_in_front if a vehicle is detected and level=increase?



The problem

- Traditional mutation operators introduce changes similar to ‘slips’.

- Sometimes a developer/user will make semantic mistakes:
  - They will misunderstand the semantics of part of the language they are using

Semantic Mutation

- A developer has been using language X with semantics L and moves to X with semantics L'.

- How do we find test data to find resultant faults?

An alternative: switching between programming languages

- Developer moves between two languages at the same level of abstraction that have different semantics for a common construct.
- Example:
  - Logical connectives in C and Ada.
    - C uses short-circuit evaluation;
    - Ada has alternatives (with and without short-circuit evaluation)

Scenario: refinement/retrenchment

- Similar constructs can have different semantics.
- Examples:
  - integer division in Z and Ada
  - retrenching infinite types (issues with precision, bounds on the types)

A simple framework

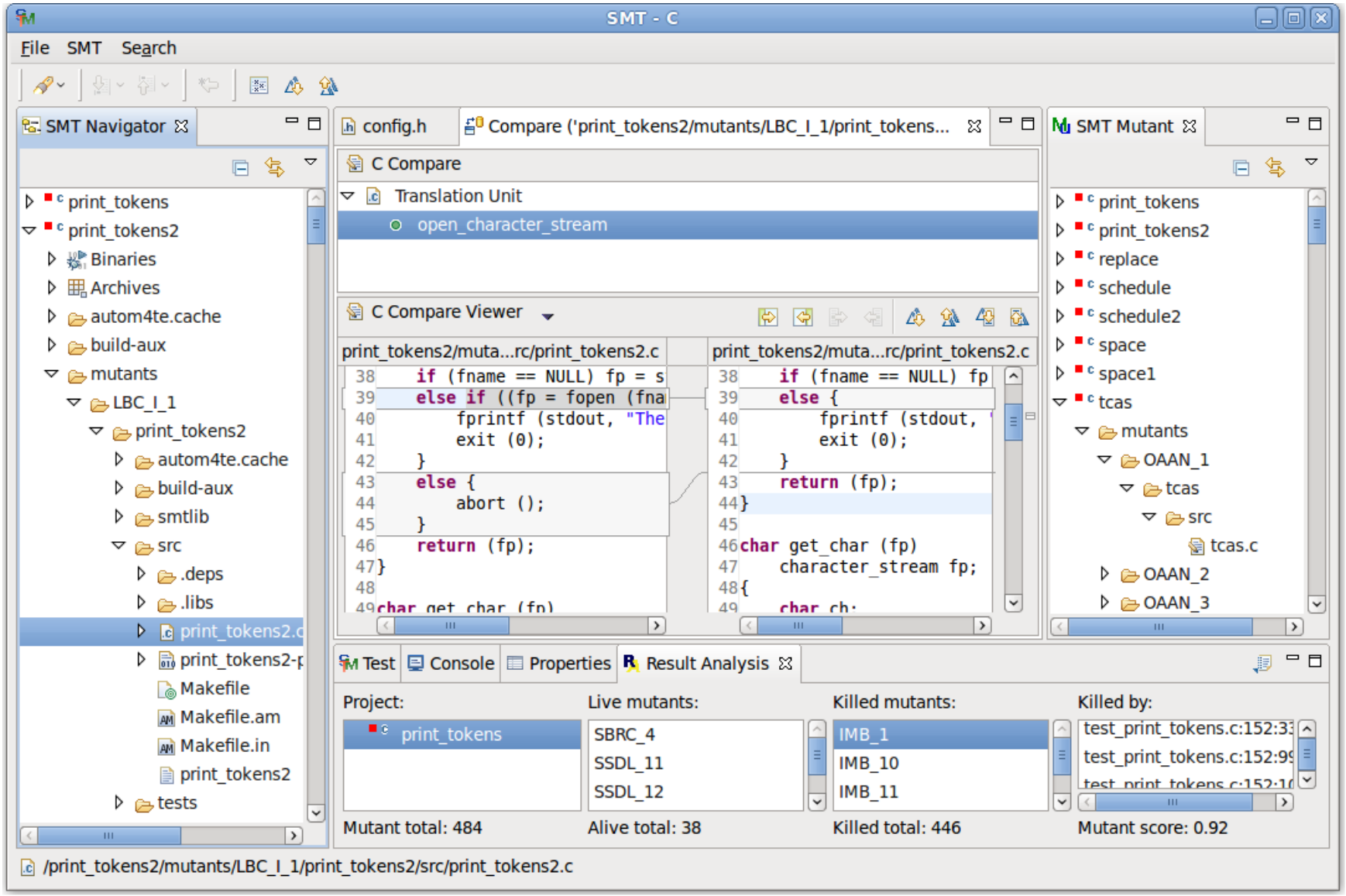
- We have a syntactic entity N in a language with semantics L.
- Traditional mutation operators transform (N,L) to some (N’,L)
- Semantic mutation operators transform (N,L) to some (N,L’) [or maybe even (N’,L’)]
- They aim to find a different type of mistake.

Current status and future work

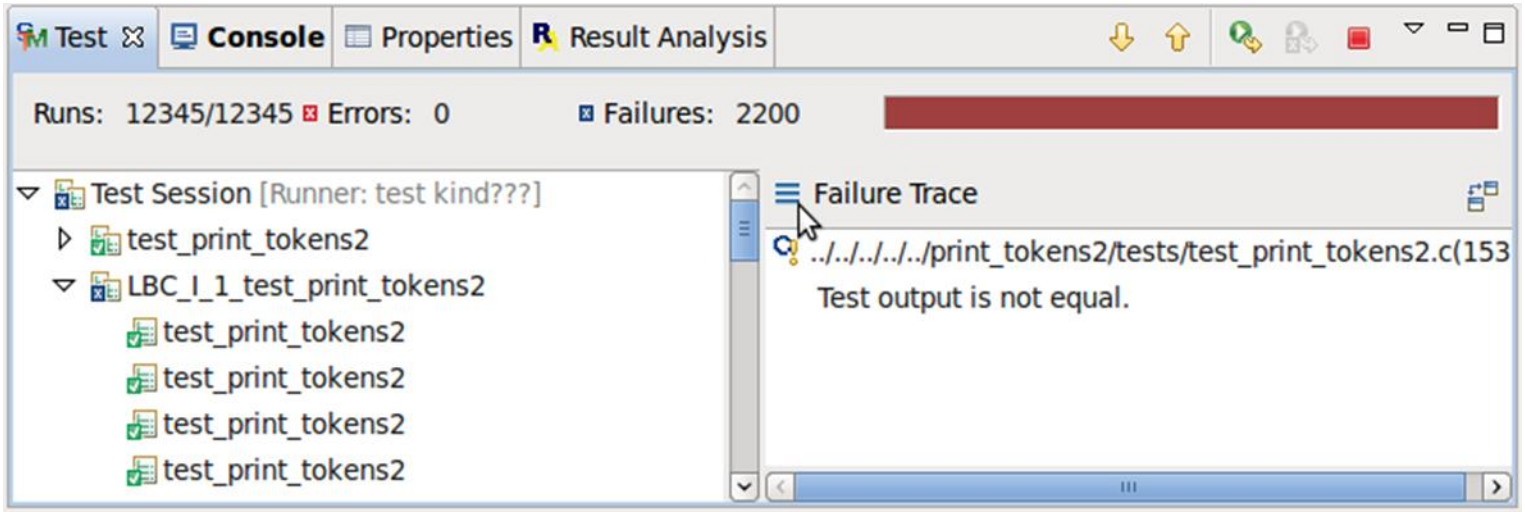
- Prototype tool being developed for C
- Some experiments being conducted to explore nature of semantic mutants:
  - How many are produced?
  - How do they relate to traditional syntactic mutants?
  - What are good operators?
  - Are there many trivial or equivalent mutants?
- More experiments

A Semantic Mutation Tool for C

GUI of SMT-C*

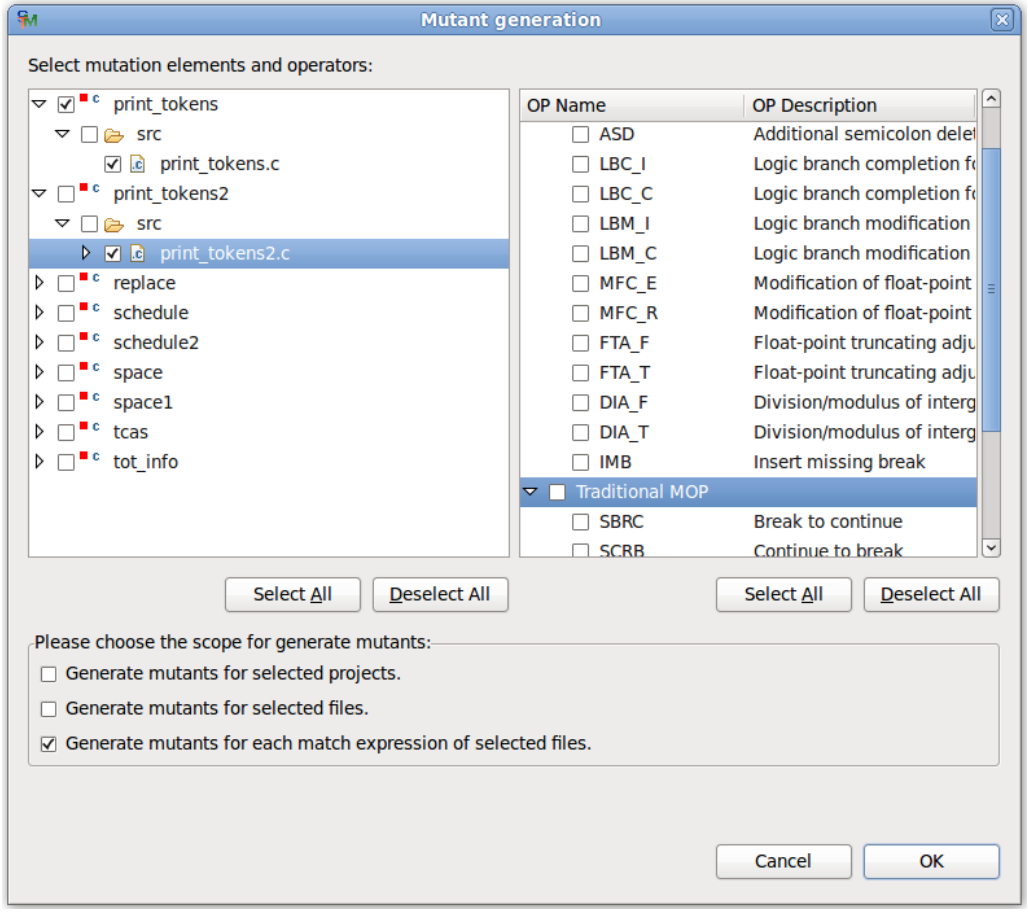

SMT - C
File SMT Search
SMT Navigator
print_tokens
print_tokens2
Binaries
Archives
autom4te.cache
build-aux
mutants
LBC_I_1
print_tokens2
autom4te.cache
build-aux
smtlib
src
.deps
.libs
print_tokens2.c
print_tokens2-p
Makefile
Makefile.am
Makefile.in
print_tokens2
tests
config.h
Compare ('print_tokens2/mutants/LBC_I_1/print_tokens...
C Compare
Translation Unit
open_character_stream
C Compare Viewer
print_tokens2/muta...rc/print_tokens2.c
print_tokens2/muta...rc/print_tokens2.c
SMT Mutant
print_tokens
print_tokens2
replace
schedule
schedule2
space
space1
tcas
mutants
OAAN_1
tcas
src
tcas.c
OAAN_2
OAAN_3
Test
Console
Properties
Result Analysis
Project:
print_tokens
Live mutants:
SBRC_4
SSDL_11
SSDL_12
Killed mutants:
IMB_1
IMB_10
IMB_11
Killed by:
test_print_tokens.c:152:33
test_print_tokens.c:152:99
Mutant total: 484
Alive total: 38
Killed total: 446
Mutant score: 0.92
/print_tokens2/mutants/LBC_I_1/print_tokens2/src/print_tokens2.c

GUI of Test Runner*



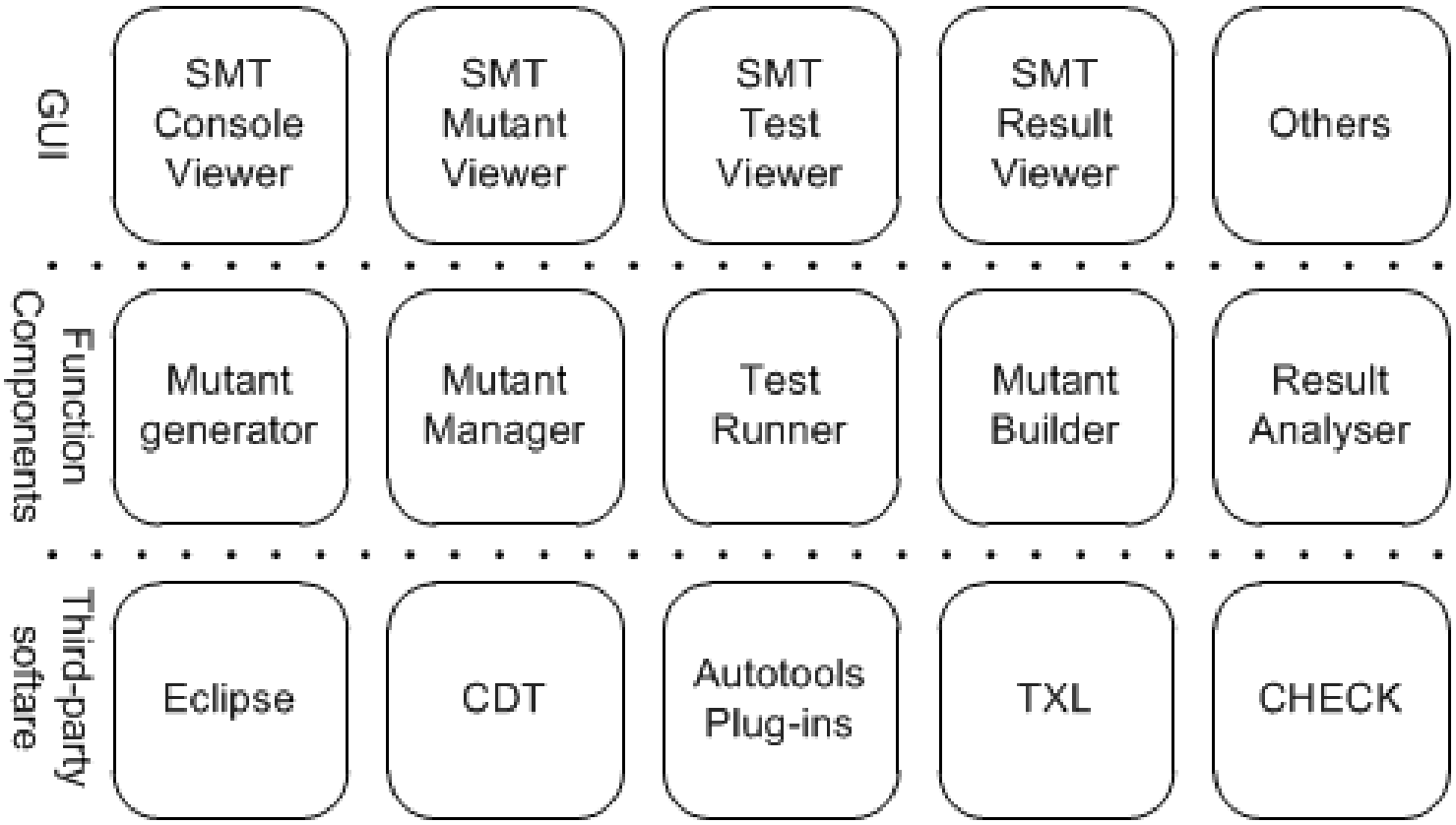
- Running results of test suites and testcases: statistics and the result for each test suite and testcase with graphical highlight;
- Progress bar;
- Test error traces.

Mutant generation*



Mutant generation -- support three different scopes

Tool Architecture



Implementation Overview

- The tool is developed using Java and as Eclipse plug-ins.
- It also can be published as an independent testing tool based on Rich Client Platform (RCP) of Eclipse.
- For current version, TXL is used to drive the semantic mutation and Check is used to support mutant compilation and running tests.

TXL – as a prototyping mutation engine

- It is a generalized source-to-source translation system.
- It takes as input an piece of source code, and a set of transformation.
- It produces as output the transformed source code.
- Example:
  - txl source1.c tranform_rule.txl

Semantic Mutation Operators

- Thirteen semantic mutation operators have been implemented.
  - ASD, MFC_R, FTA_F…
- 6 traditional mutation operators were also implemented for conducting experiments to compare traditional and semantic mutation operators.
  - SCRB, SSWM, SSDL …

CHECK

- A unit testing framework for C.
- Check is based on Autotools.
- Many advanced features: run in fork mode (allow signal and early exit), test fixture, multiple suites in one runner, looping tests, test timeouts, determining test coverage, xml logging etc.

Future work of SMT-C

- Implement more semantic mutation operators.
- Improve the GUI, better integration with C development process.
- Enhance mutant generation function: mutant management, function scope mutation and efficiency.
- Accelerate the mutation generation and testing processes.

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