Interactivity in the generation of test cases with evolutionary computation

Aurora Ramírez (Univ. Córdoba, Spain)

Pedro Delgado-Pérez (Univ. Cádiz, Spain)

Kevin J. Valle-Gómez (Univ. Cádiz, Spain)

Inmaculada Medina-Bulo (Univ. Cádiz, Spain)

José Raúl Romero (Univ. Córdoba, Spain)

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Introduction and problem analysis

Motivation

Automated **test case/suite** generation

- Efficient alternative to a costly manual process
- Frequently solved with fully automated evolutionary algorithms (SBST)

Two main **limitations** remain:

Fault-detection effectiveness

Is coverage-based fitness enough?

Are realistic faults detected?

Lack of readability

Can the tester understand the code?

Is test code human-like written?

Introduction and problem analysis

Requirements

Requirement 1:
White-box testing requires a **broad knowledge of the source code** of the classes under test.

Requirement 2:
Testers should be able to **incorporate their knowledge and preferences** to the test generation process.

Requirement 3:
Search-based test generation tools should be able to **cope with two limitations:** *detection power* and *readability.*

Interactive optimization for the test generation problem

1 Type of interactive algorithm

- Human-based evaluation → Oriented to readability improvement (*subjective*)
- Human-guided search → Oriented to better fault-detection capability

2 Type of human actions

- *Evaluation*
  - Scores for detection capability / readability
  - Reward/penalize test code sequences
  - Weight objectives (*multi-objective approach*)
- *Modification*
  - Edit arguments in method calls
  - Add complex objects or data structures
  - Specify methods that should be combined
  - Add complex assertions
- *Selection*
  - Choose the best solution among those detecting the same mutant
  - Choose the best solution according to its readability

A. Ramírez, J.R. Romero, C. Simons. *A Systematic Review of Interaction in Search-Based Software Engineering*. IEEE Trans. Software Engineering, 45(8):760-781. 2019.

Interactive optimization for the test generation problem

3 Interaction mechanism

- *Time and frequency*
  - **Adaptive**: *n* trials without improvement, coverage threshold, detected mutant
  - **Fixed**: every *n* iterations
  - **On demand**: the tester pauses the search
- *Solution selection*
  - Best solution(s) according to the fitness value
  - All solutions detecting the same target mutant
  - Specific criterion, e.g., number of detected mutants
- *Level of detail*
  - Complete solution
  - Test case together with the lines affected by the mutation

4 Feedback integration

- *Information lifetime*
  - **Mutation-based**: applied to a *test case – mutant* pair
  - **Short-term**: evaluation and modifications are transferred to other solutions
  - **Long-term**: tester's preferences are saved for other executions
- *Information validity*
  - **Permanent**: tester's feedback remains unaltered
  - **Flexible**: tester's feedback can be revisited

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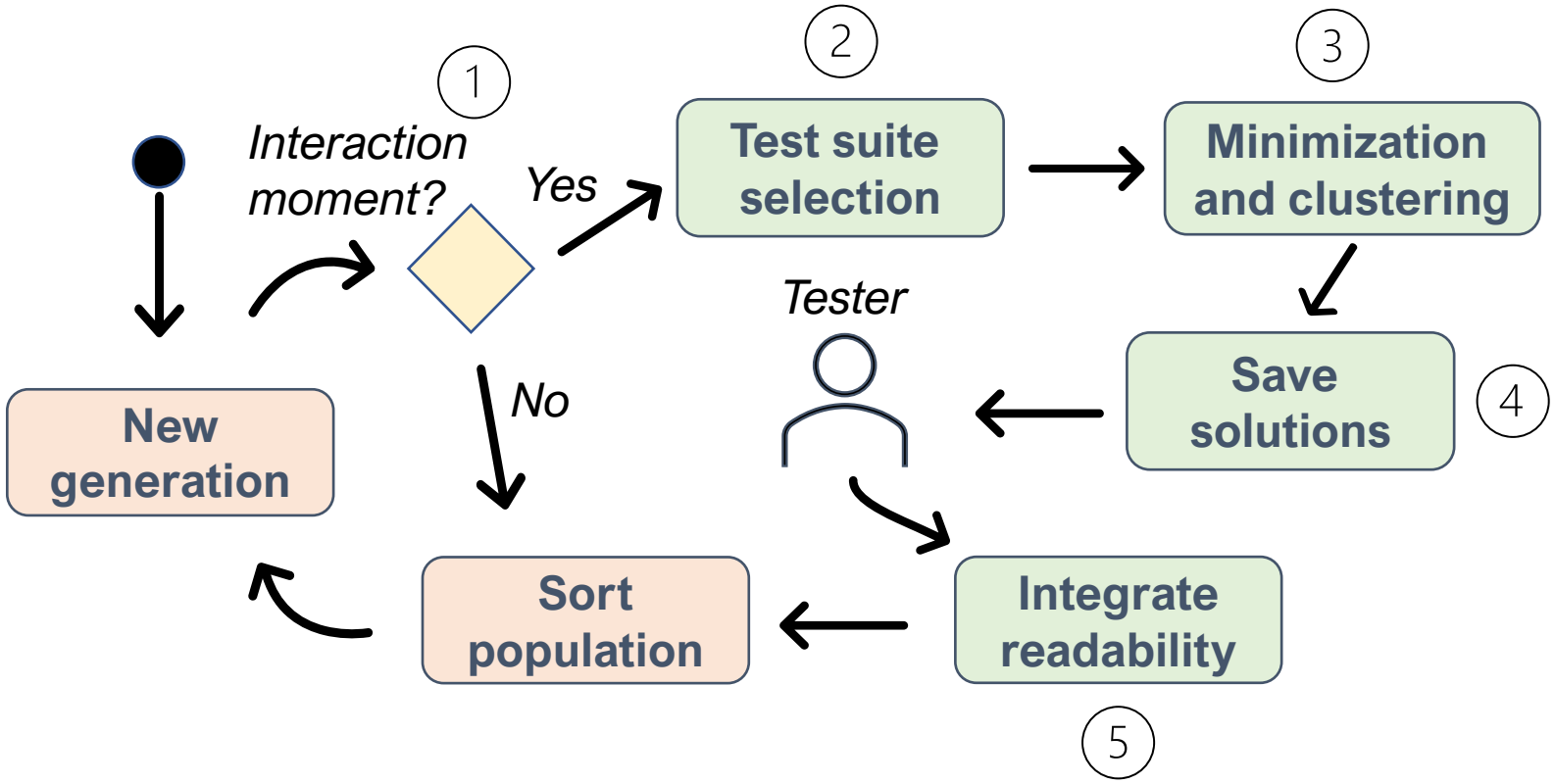
A proof of concept

Interactive options in EvoSuite

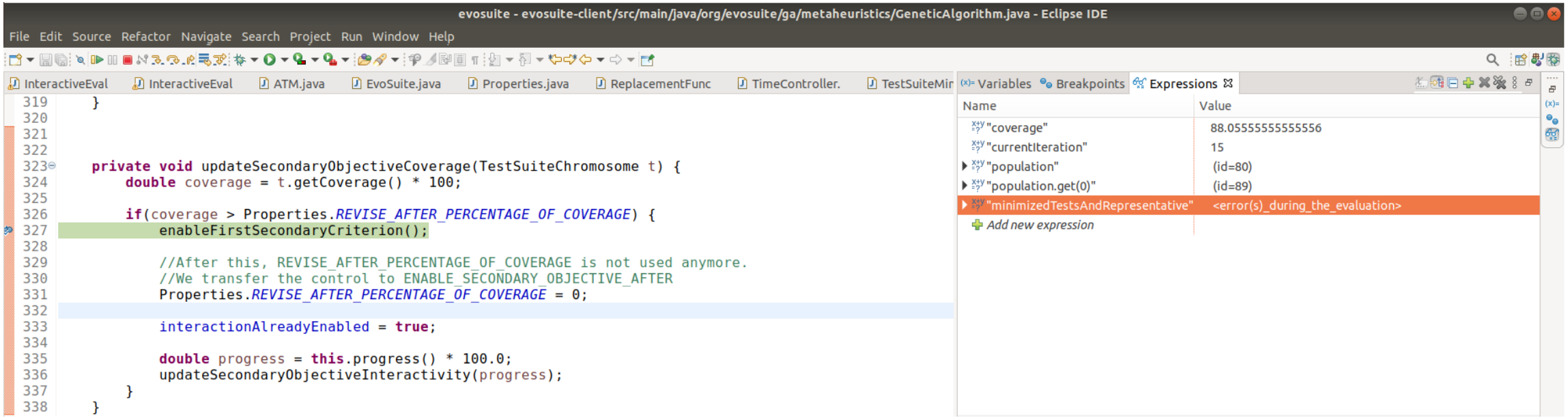


1. **Interactions happen when**:
   1. Best coverage > threshold (1st)
   2. Every N generations (after 1st)
   3. Max. Num. Interactions not reached
2. **Interaction to break ties**: choose the solutions with best fitness.
3. Apply EvoSuite **minimization procedure** and keep different test suites only.
4. **Save the candidate test suites** for subjective evaluation.
5. **Assign tester's readability score** as secondary objective.

A proof of concept
Illustrative example

(1) Search until first interaction

When the coverage of the best candidate is greater or equal to *Revise_after_percentage_of_coverage* (88%), the **secondary objective is enabled** (15th generation).

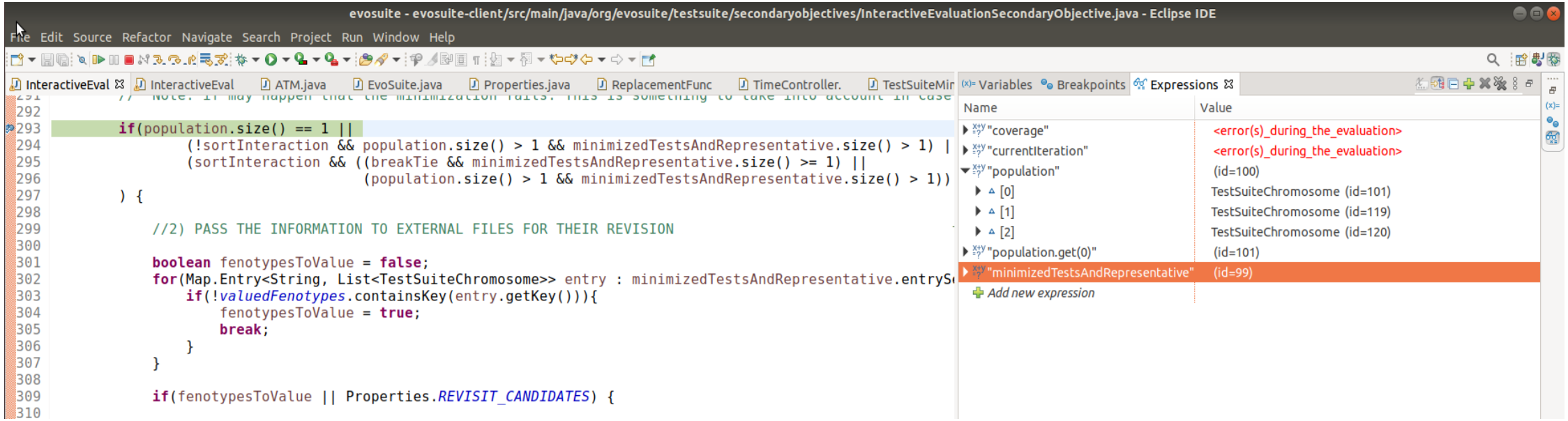


SUT: ATM class (EvoSuite tutorial)
https://www.uco.es/SEBASENet/CEC2021

A proof of concept
Illustrative example

(2) Selection of candidate solutions

26/30 candidate test suites have the same (best) fitness value, but only **3 will be presented to the tester for revision** (*Percentage_to_revise=10%*)



A proof of concept
Illustrative example

(3) Minimization
(4) Tester's evaluation

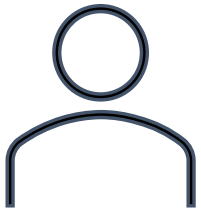
Only the different test suites after **minimization** are evaluated (2/3)

interaction1testsuite0.java

```
62  public void test4()  throws Throwable  {
63      Bank bank0 = new Bank();
64      ATM aTM0 = new ATM(bank0);
65      Person person0 = new Person("IouF+u0.!zQ", "%[8QRjSqhXNQMvm");
66      int[] intArray0 = new int[3];
67      CurrentAccount currentAccount0 = new CurrentAccount(person0, (-1563));
68      Company company0 = new Company("");
69      bank0.addAccount(currentAccount0);
70      int[] intArray1 = new int[2];
71      ATMCard aTMCard0 = new ATMCard(company0, currentAccount0, intArray1);
72      aTM0.insertCard(aTMCard0);
73      aTM0.enterPin(intArray0);
74  }
75
76  @Test(timeout = 4000)
77  public void test5()  throws Throwable  {
78      Bank bank0 = new Bank();
79      ATM aTM0 = new ATM(bank0);
80      Company company0 = new Company("");
81      CurrentAccount currentAccount0 = new CurrentAccount(company0, 0);
82      bank0.addAccount(currentAccount0);
83      int[] intArray0 = new int[1];
84      ATMCard aTMCard0 = new ATMCard(company0, currentAccount0, intArray0);
85      aTM0.insertCard(aTMCard0);
86      aTM0.enterPin(intArray0);
87  }
88
89  @Test(timeout = 4000)
90  public void test6()  throws Throwable  {
91      Bank bank0 = new Bank();
92      ATM aTM0 = new ATM(bank0);
93      aTM0.deposit((-827));
94  }
95
96  @Test(timeout = 4000)
97  public void test7()  throws Throwable  {
98      Bank bank0 = new Bank();
99      ATM aTM0 = new ATM(bank0);
100     aTM0.withdraw((-827));
101 }
```

7 test cases,
readability=6

Tester



6 test cases,
readability=8

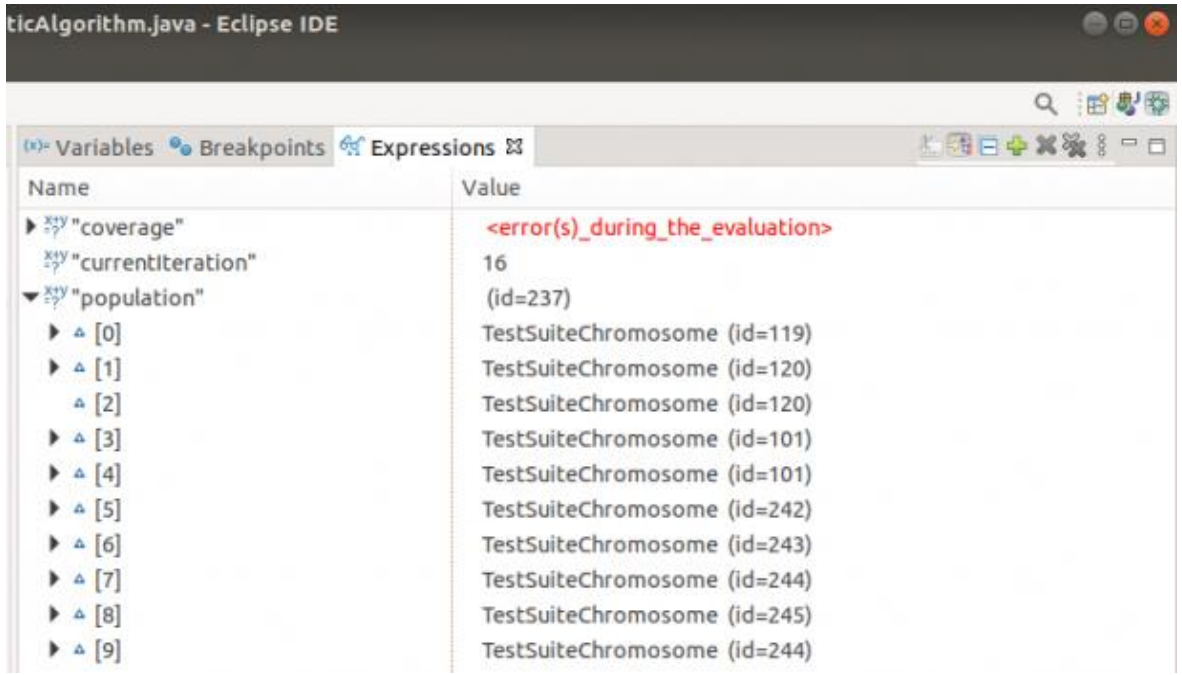
interaction1testsuite1.java

```
49      aTM0.insertCard(aTMCard0);
50  }
51
52  @Test(timeout = 4000)
53  public void test3()  throws Throwable  {
54      Bank bank0 = new Bank();
55      ATM aTM0 = new ATM(bank0);
56      int[] intArray0 = new int[0];
57      aTM0.enterPin(intArray0);
58  }
59
60  @Test(timeout = 4000)
61  public void test4()  throws Throwable  {
62      Bank bank0 = new Bank();
63      ATM aTM0 = new ATM(bank0);
64      Company company0 = new Company("");
65      CurrentAccount currentAccount0 = new CurrentAccount(company0, 0);
66      bank0.addAccount(currentAccount0);
67      int[] intArray0 = new int[19];
68      ATMCard aTMCard0 = new ATMCard(company0, currentAccount0, intArray0);
69      aTM0.insertCard(aTMCard0);
70      aTM0.enterPin(intArray0);
71  }
72
73  @Test(timeout = 4000)
74  public void test5()  throws Throwable  {
75      Bank bank0 = new Bank();
76      ATM aTM0 = new ATM(bank0);
77      aTM0.deposit((-827));
78  }
79
80  @Test(timeout = 4000)
81  public void test6()  throws Throwable  {
82      Bank bank0 = new Bank();
83      ATM aTM0 = new ATM(bank0);
84      aTM0.withdraw((-827));
85  }
86 }
```

A proof of concept
Illustrative example

(5) Integrate feedback
(6) Search continues...

Readability scores are assigned to the test suites, and **the population is sorted**



New interactions might be required **in next generations** (*Revise_frequency=10, Max_times_sort=3*)

```
IT IS TIME TO INTERACT! Go to the folder EvoSuite/CEC/InteractionSort-1.
After that, revise and provide a readability value for each test suite.

--------------------------------------------------------------------------------

Readability for test suite 0:
5
Readability for test suite 1:
7
Readability for test suite 2:
9


TARGET_CLASS: com.examples.with.different.packagename.interactive.ATM
criterion: LINE;BRANCH;EXCEPTION;WEAKMUTATION;OUTPUT;METHOD;METHODNOEXCEPTION;CBRANCH
Coverage: 0.9498263888888889
Total_Goals: 122
Covered_Goals: 111
TestSuite: 12
```

Conclusions and future work

- ✓ Complete definition of **interactive options** for the test generation problem
- ✓ Design of an interactive algorithm to **improve readability** of test suites
- ✓ A **running example** using EvoSuite with parameters to control the interaction

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- ❖ More experiments (SUT, parameters), including studies with testers
- ❖ Implementation of interaction options oriented to fault-detection
- ❖ Other test generation problems (GUI, integration testing)

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Aurora Ramírez (aramirez@uco.es)

Pedro Delgado-Pérez (pedro.delgado@uca.es)

Kevin J. Valle-Gómez (kevin.valle@uca.es)

Inmaculada Medina-Bulo (inmaculada.medina@uca.es)

José Raúl Romero (jrromero@uco.es)