Programs that test themselves

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Introduction

- Modern engineering products continuously test themselves
- They are designed for testability
- Software design pays little attention to testing needs

Idea: Design software for testability

Autotest

- Autotest is a set of components that
  - automates testing process
  - relies on programs with contracts
  - is integrated into the EiffelStudio

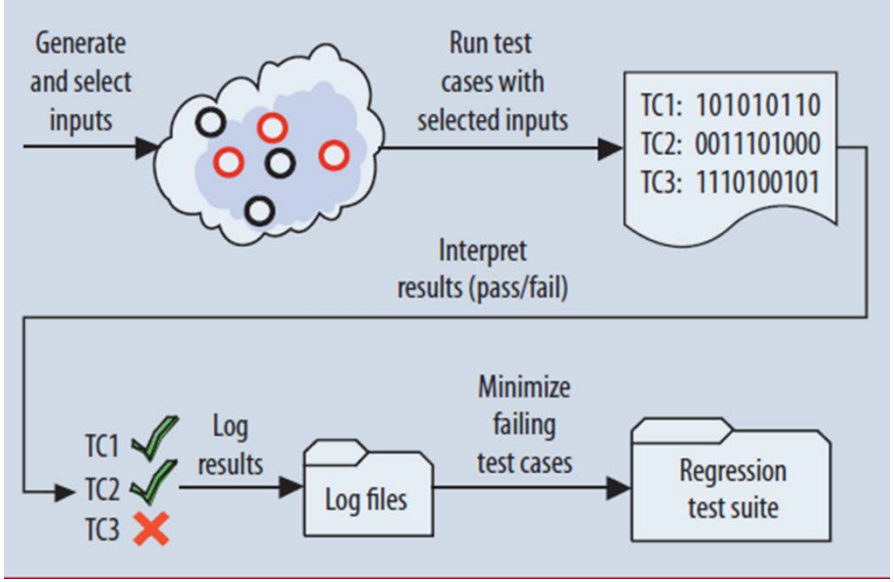
- Components
  - test generation
  - test extraction
  - integration of manual tests

Automated testing

- Levels of automation:
  - test execution (JUnit, PHPunit …)
  - regression testing
  - resilience
  - test case generation
  - test oracles
  - minimization
- Most frameworks support only the first three
- Autotest innovates also on the last three

Test generation

- The unit of a generated test is a failed routine call
- Each routine is exercised with different targets and arguments
- Use contracts as oracles
- Log results
- Create minimized tests for the failed routines



Exercising a routine (1)

- Objects are needed for target and possibly for arguments
- When an object T is needed, Autotest decides:
  - to create a new one
  - to use an existing one
- To create a new object Autotest
  - selects a constructor
  - makes sure invariant holds

Exercising a routine(2)

- The arguments of a routine might be of primitive types. Autotest decides:
  - random selection from the domain
  - selection from preset values for each type

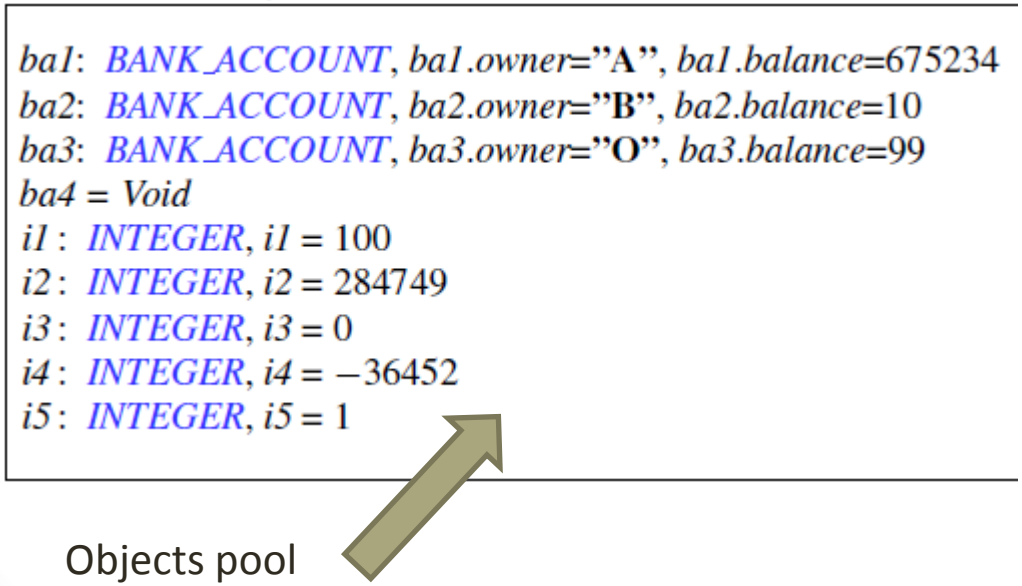
- Random but still powerful

Contracts as oracles

- Contracts in the code serve as oracles
- A contract violation signals a flaw either in:
  - the caller of a routine or
  - in the routine itself
- Benefits
  - software is tested as it is
  - no further programming skills needed

Optimizations

- Adaptive random testing
  - use values equally spaced out across a domain
  - introduction of a distance metric for objects
  - complements rather than replaces the random algorithm



Routine exercising using ART

ba3.transfer(ba1, i5)
ba1.transfer(ba4, i2)
ba2.transfer(ba2, i4)
…

Minimization

- Keeping the whole failed test is impractical
- Keep only the instructions that involve the target and the arguments of the failing routine
  - statically analyze the failed test
  - calculate backward slice
  - use the slice as the failed test

```
    ...
 67 v_61. forget_right
 68 create {PRIMES} v_62
 69 v_63 := v_62.lower_prime ({INTEGER_32} 2)
 70 create {STRING_8} v_64.make_from_c (itp_default_pointer
    )
    ...
146 create {ARRAY2 [ANY]} v_134.make ({INTEGER_32} 7, {
    INTEGER_32} 6)
147 v_134.enter (v_45, v_131)
148 create {RANDOM} v_135.set_seed (v_63)
149 v_136 := v_135.real_item
```

Initial test

```
 68 create {PRIMES} v_62
 69 v_63 := v_62.lower_prime ({INTEGER_32} 2)
148 create {RANDOM} v_135.set_seed (v_63)
149 v_136 := v_135.real_item
```

Minimized test

Test generation results

- Autotest was experimented on classes with different semantics and sizes

Tested library	Faults	Percent failing routines	Percent failed tests
EiffelBase	127	6.4 (127/1984)	3.8 (1513/39615)
Gobo libraries	26	4.4 (26/585)	3.7 (2.928/79886)
Specification library	72	14.1 (72/510)	49.6 (12860/25946)

Test extraction

- Failed runs are candidate test cases

- Autotest can turn a failure into a test by
  1. creating a trace abstraction of the debugger (a called_by tree with <invocation,context> nodes)
  2. selecting the invocation that received the failure
  3. extracting a snapshot of the state that is required for this invocation

Demo

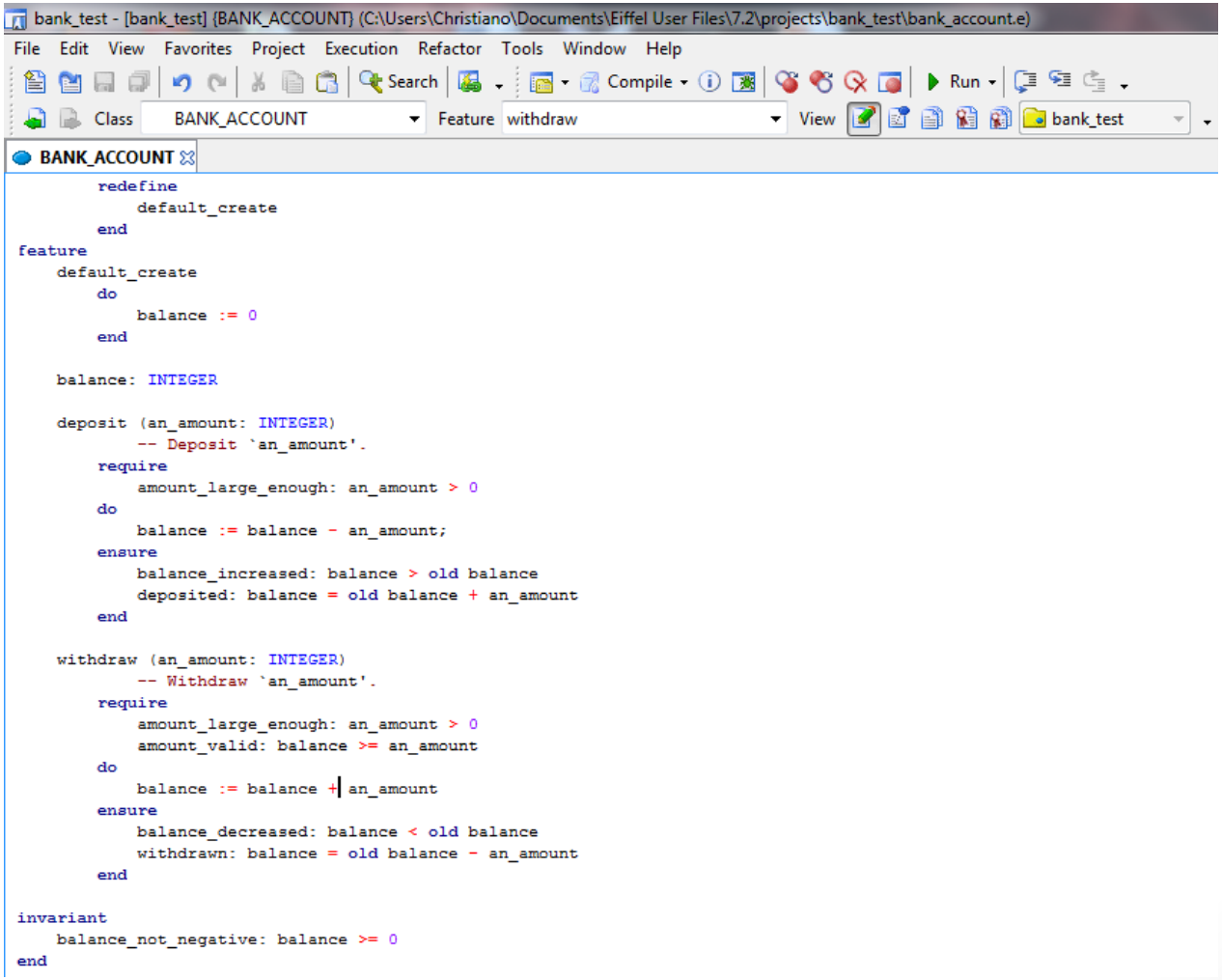
Conclusions

- Advantages
  - nice features on automatized testing
  - discovers unfound software failures
  - helps investigate questions
  - does not require extra knowledge
  - all tests are treated the same regardless of their origin
- Disadvantages
  - cannot guarantee absence of faults
  - not suitable for integration testing
  - generated and extracted tests less robust and readable

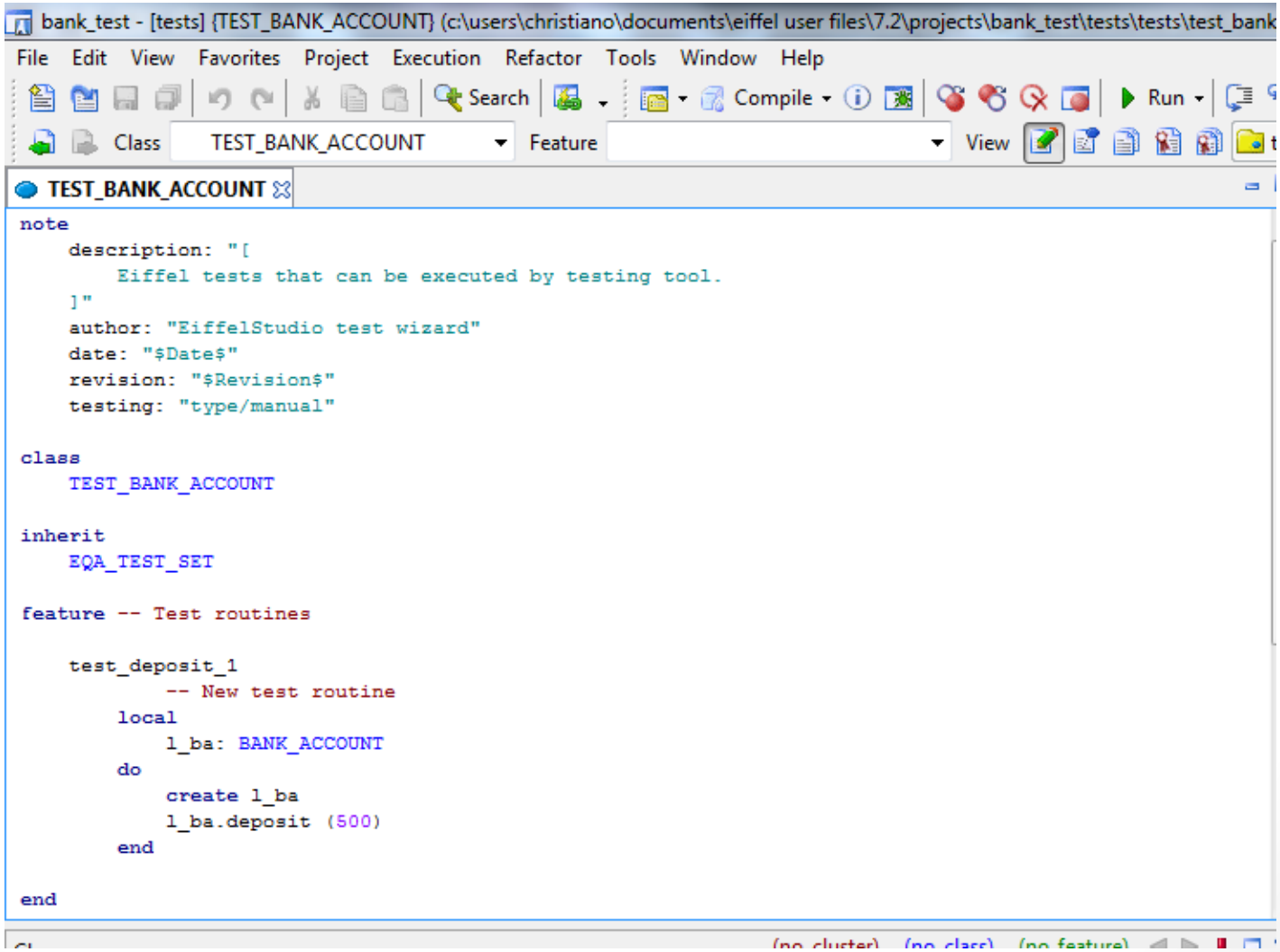
Manual tests should still form the majority of your testing suite!

Questions?

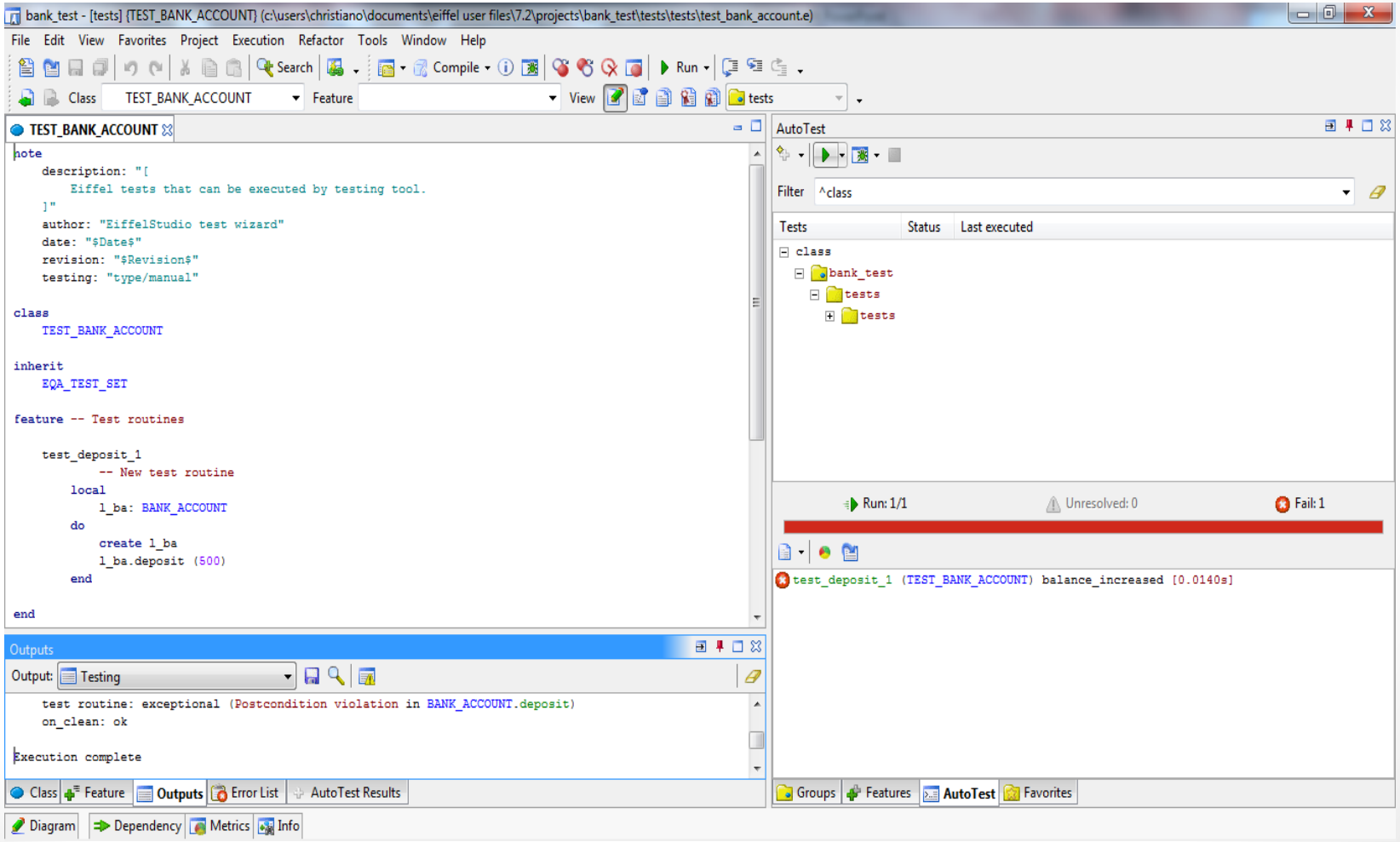
Demo – Bank Account Class



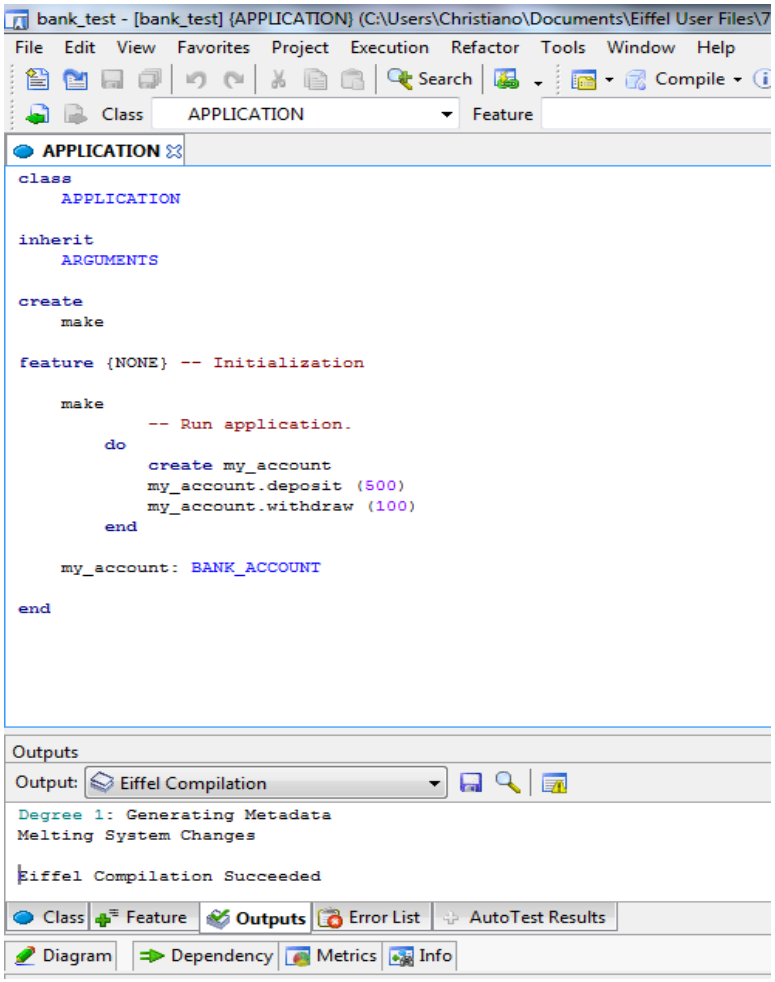
Demo – Manual Test Case



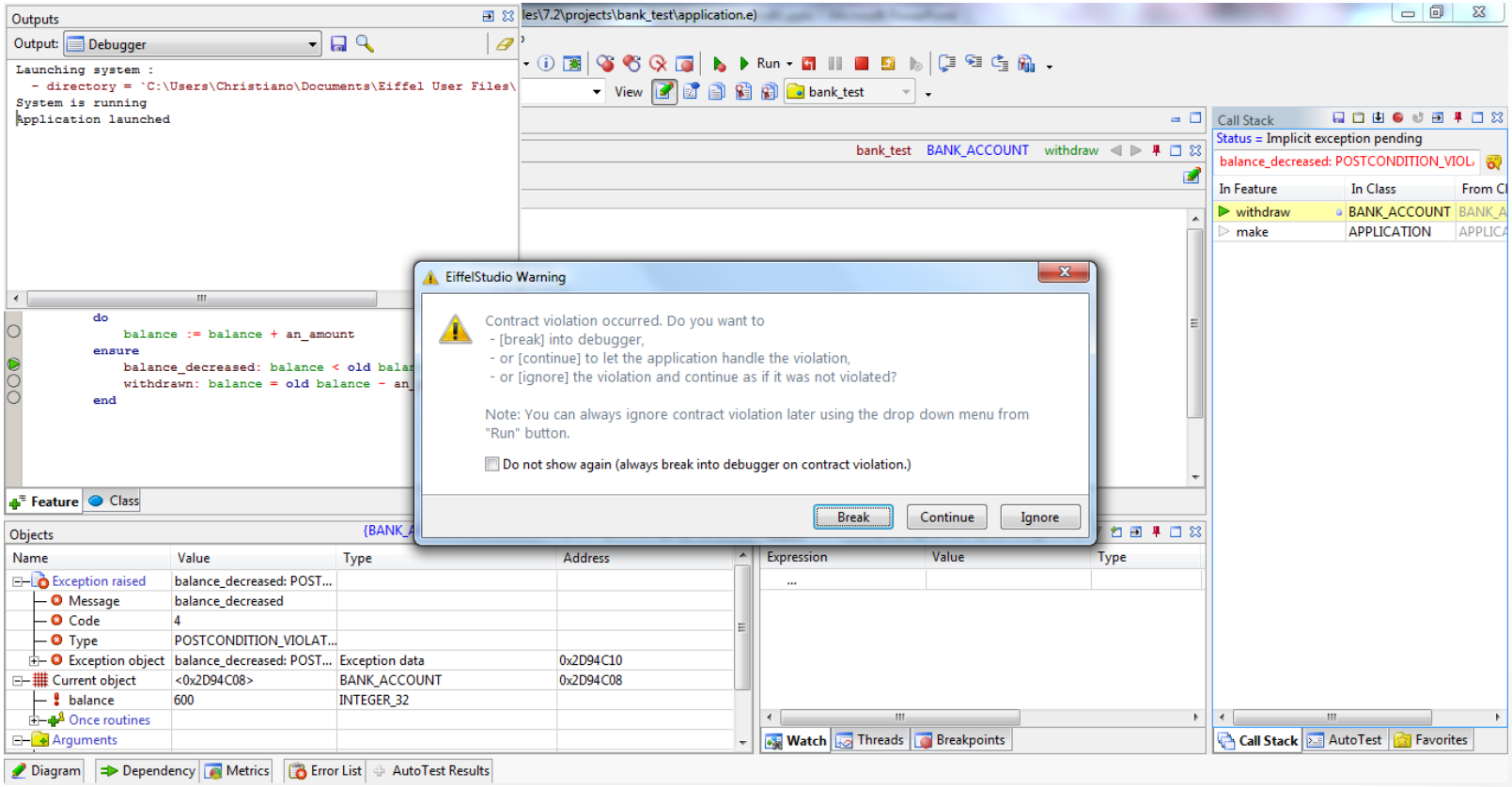
Demo – Test Execution



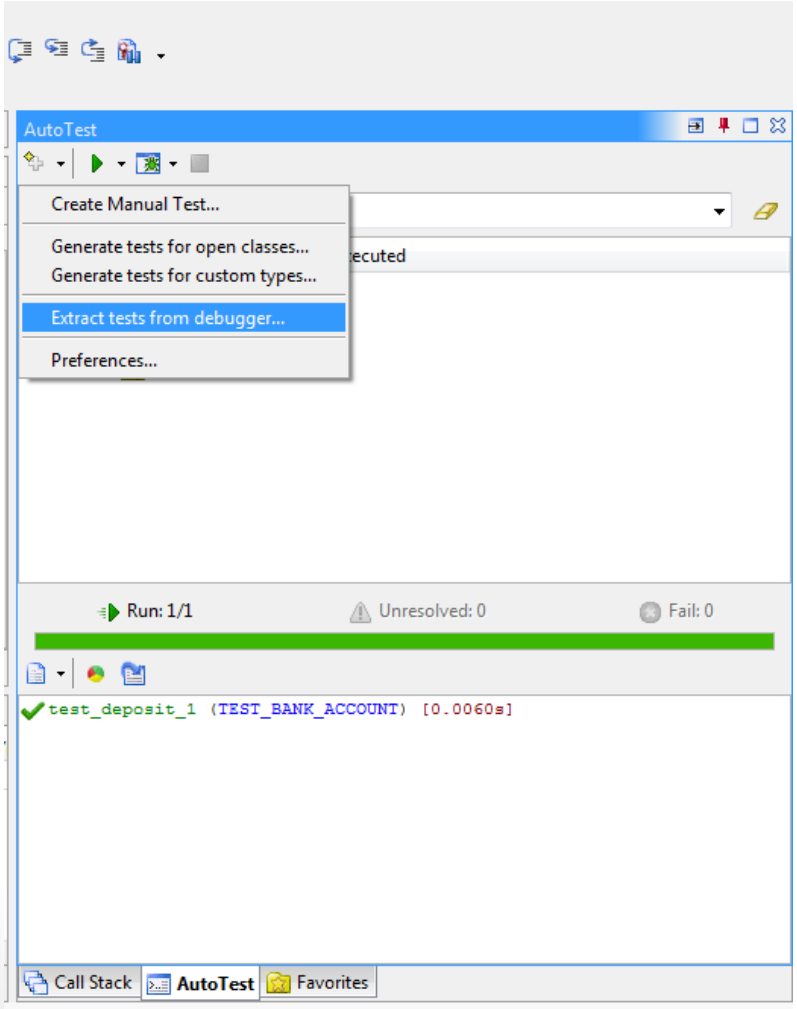
Demo – Application Class

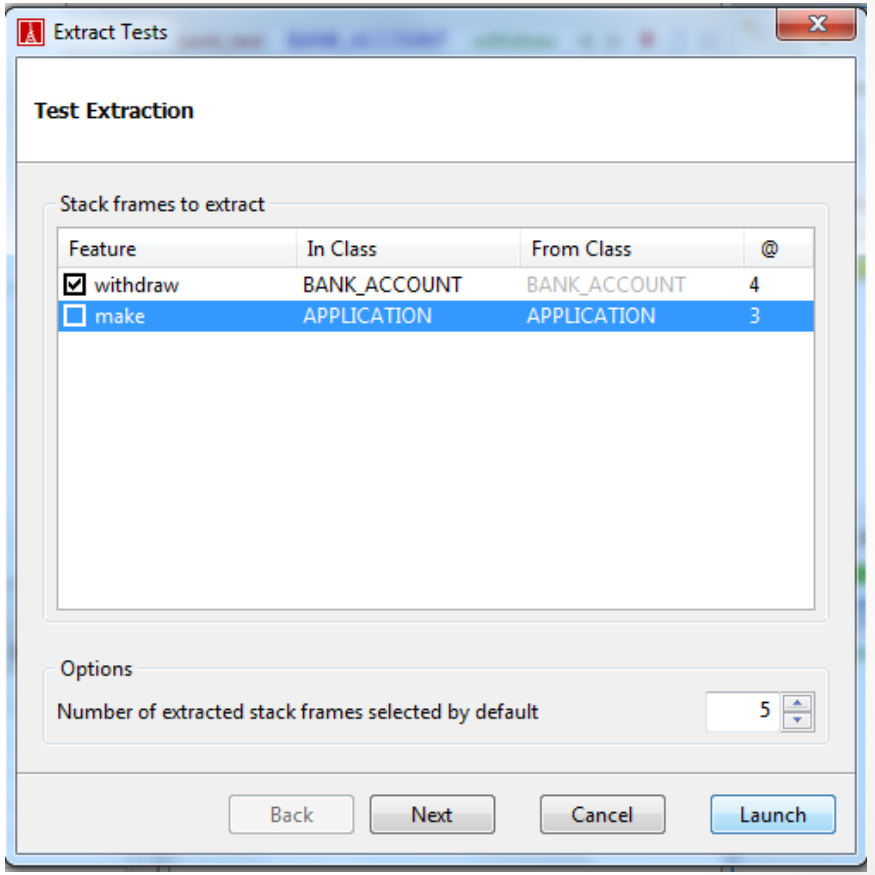


Demo – Failed Execution

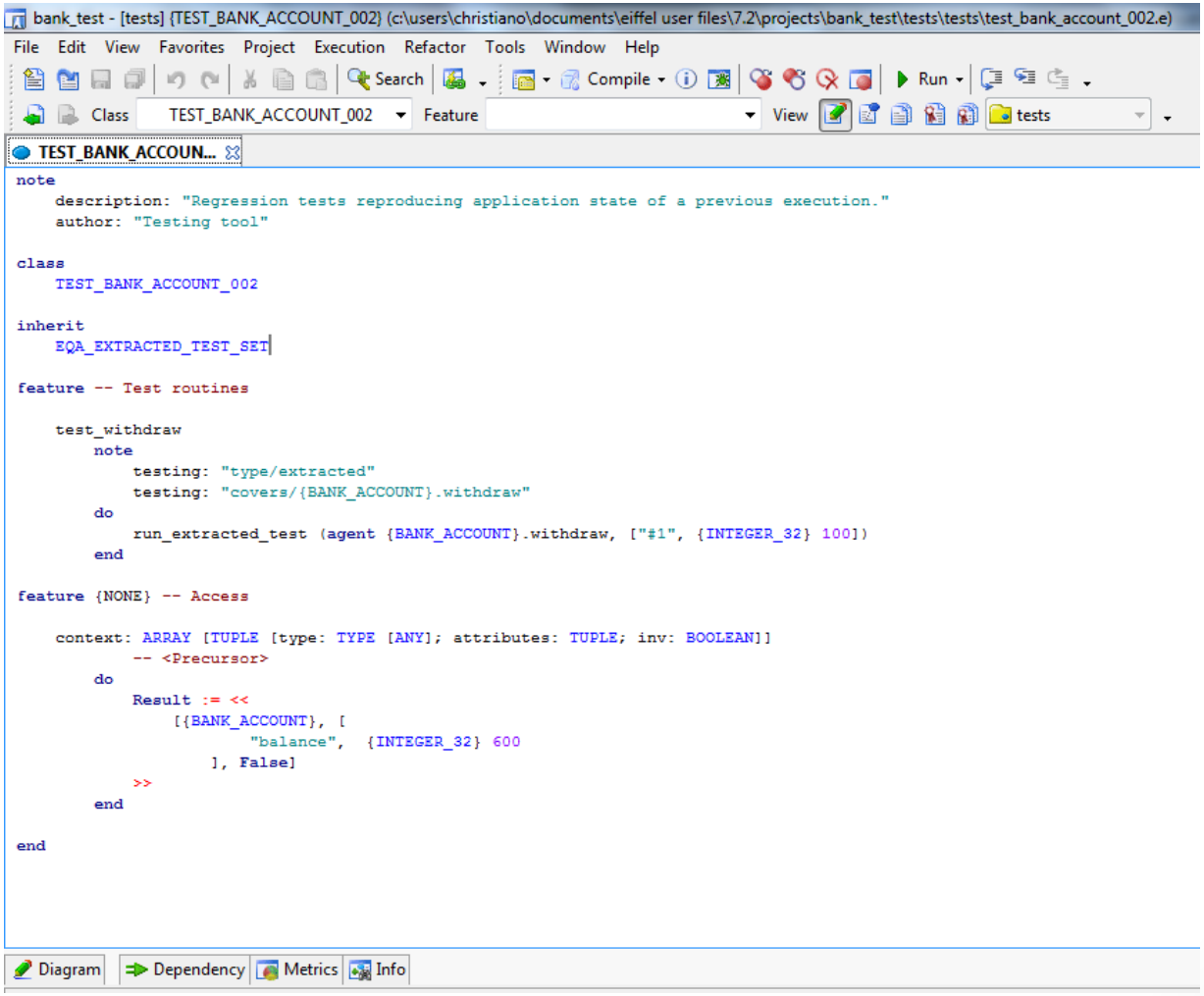


Demo – Test Extraction

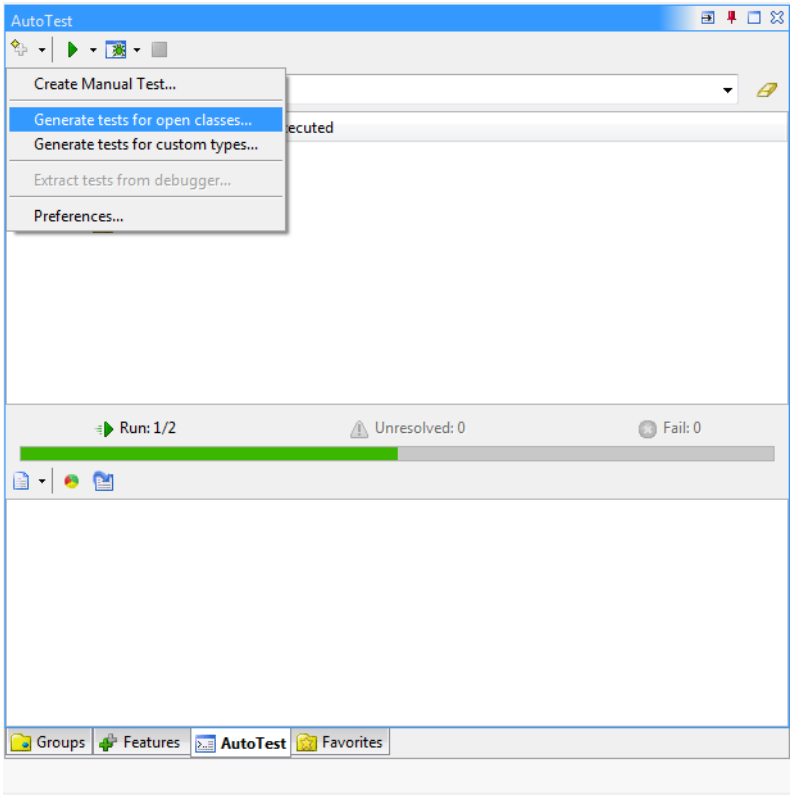


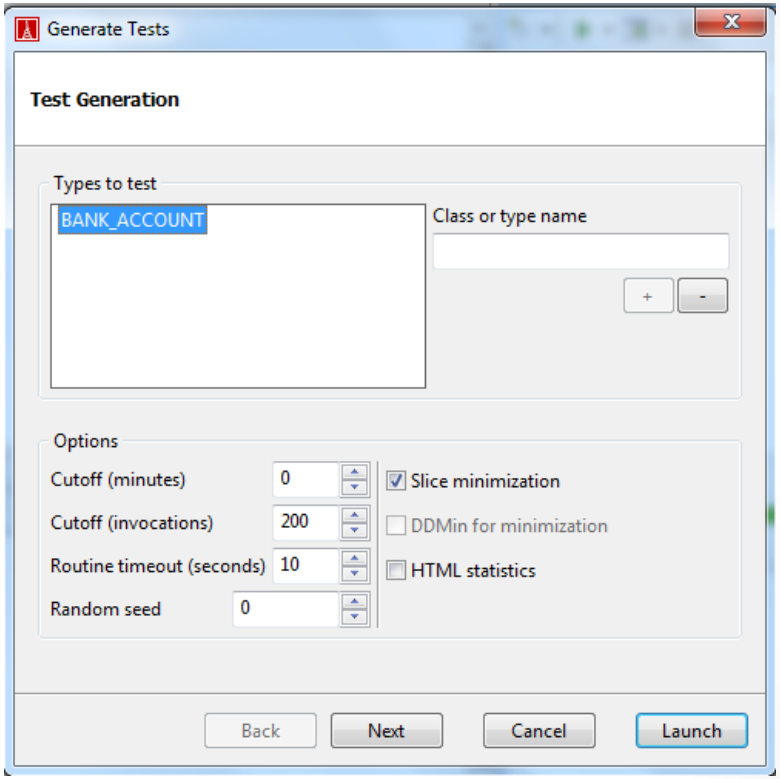


Demo – Extracted Test

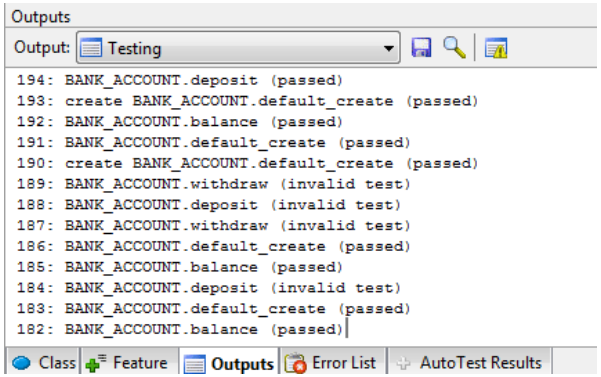


Demo – Test Generation





Demo – Generated Test



TEST_BANK_ACCOUN...

```
inherit
    EQA_GENERATED_TEST_SET

feature -- Test routines

    generated_test_1
        note
            testing: "type/generated"
            testing: "covers/{BANK_ACCOUNT}.withdraw"
        local
            v_22: BANK_ACCOUNT
            v_23: INTEGER_32
            v_27: detachable ANY
            v_40: INTEGER_32
            v_75: detachable ANY
            v_106: INTEGER_32
        do
            execute_safe (agent: BANK_ACCOUNT
                do
                    create {BANK_ACCOUNT} Result
                end)
            check attached {BANK_ACCOUNT} last_object as l_ot1 then
                v_22 := l_ot1
            end
            v_23 := {INTEGER_32} 5
            execute_safe (agent v_22.deposit (v_23))
            execute_safe (agent v_22.balance)
            v_27 := last_object
            v_40 := {INTEGER_32} 9
            execute_safe (agent v_22.deposit (v_40))
            execute_safe (agent v_22.balance)
            v_75 := last_object
            v_106 := {INTEGER_32} 6

                -- Final routine call
            set_is_recovery_enabled (False)
            execute_safe (agent v_22.withdraw (v_106))
```