Better Tests and Better Code with Mutation Testing

Hands-On Coding
SoCraTes 2017

Beyond Code Coverage

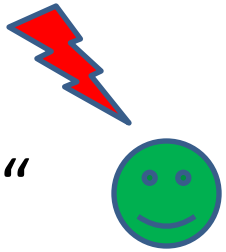
- Our tests are checking our code
- How do we check our tests?

- High code coverage => High quality of tests?
- 100% code coverage, but no assertions …

Mutation Testing

Basic idea is as simple as that:

- <code>**SOLID**</code> original
- All tests are green is a prerequisite
- <code>**SOLD**</code> with mutation
- Still all tests are green => Mutation „survived“
- At least one test is red => Mutation was „killed“
- Quality of tests = Killed mutation count / total mutation count



Examples of Mutators

- Replacing relational operators
  - With different boundaries — if (a **>=** b) => if (a **>** b)
  - With the opposite — if (a **>=** b) => if (a **<** b)
  - With constants — if (a **>=** b) => if (**true**)
- Replacing arithmetic operators
  - a = b **+** c => a = b **-** c
- Changing return values
  - return **x** => return **x != null ? null : throw new RuntimeException()**
- Removing statements
  - ~~**doSomething()**~~

Challenges

- All tests have to be green for original code
  - Not self-evident everywhere
- Terminating mutation inducted infinite loops
  - Timeout criteria for each test
- Limiting total runtime of tests
  - Executing only distinctive tests
  - Restricting classes that are being mutated
- Detecting semantically equivalent mutations
  - Hard problem!

Choice of tools

Java - PIT http://pitest.org

JavaScript – Stryker https://stryker-mutator.github.io

C# - Visual Mutator https://visualmutator.github.io/web

Ruby – Mutant https://github.com/mbj/mutant

PHP – Humbug https://github.com/humbug/humbug

Python – Cosmic Ray http://cosmic-ray.readthedocs.io

Hands-On

Exercise project

- Domain: Payment authorisation

Either

- Language: Java
- Tool: PIT

https://github.com/thbrunzendorf/mutation-testing-sample

Or

- Language: JavaScript
- Tool: Stryker

https://github.com/thbrunzendorf/mutation-testing-js

Hands-On PIT

- Base code coverage 100%

Coverage PaymentAuthorisationCheckerTest

100% classes, 100% lines covered in 'all classes in scope'

Element	Class, %	Method, %	Line, %
de.thbrunzendorf.payment.authorisation	100% (2/2)	100% (6/6)	100% (25/25)
de.thbrunzendorf.payment.value	100% (3/3)	100% (13/13)	100% (24/24)

- mvn clean install
- mvn org.pitest:pitest-maven:mutationCoverage
- Report at target/pit-reports/…

Hands-On PIT

Pit Test Coverage Report

Package Summary

de.thbrunzendorf.payment.authorisation

Number of Classes	Line Coverage		Mutation Coverage	
2	100%	27/27	56%	9/16

Breakdown by Class

Name	Line Coverage		Mutation Coverage	
PaymentAuthorisation.java	100%	7/7	100%	2/2
PaymentAuthorisationChecker.java	100%	20/20	50%	7/14

Report generated by PIT 1.2.0

Hands-On PIT

```
10  public class PaymentAuthorisationChecker {
11
12      public PaymentAuthorisation checkFor(Payment payment) {
13          PaymentAuthorisation paymentAuthorisation = new PaymentAuthorisation();
14          User initiator = payment.getInitiator();
15          Money amount = payment.getAmount();
16          Money limit = initiator.getLimit();
17 2        if (amount.compareTo(limit) <= 0) {
18 1            paymentAuthorisation.setApprovalNeeded(false);
19          }
20 2        if (amount.compareTo(limit) > 0) {
21 1            paymentAuthorisation.setApprovalNeeded(true);
22              User approver = getPrimaryApprover(initiator, amount);
23 1            paymentAuthorisation.setPrimaryApprover(approver);
24          }
25 1        return paymentAuthorisation;
26      }
27
28      private User getPrimaryApprover(User initiator, Money amount) {
29          User supervisor = initiator.getSupervisor();
30          Money limit = supervisor.getLimit();
31          int maxIterations = 10; // preventing infinite loops
32 3        for (int i = 0; i < maxIterations; i++) {
33 2            if (amount.compareTo(limit) > 0) {
34                  supervisor = supervisor.getSupervisor();
35                  limit = supervisor.getLimit();
36              }
37          }
38 1        return supervisor;
39      }
40  }
```

Mutations

```
17  1. changed conditional boundary → SURVIVED
    2. negated conditional → SURVIVED
18  1. removed call to de/thbrunzendorf/payment/authorisation/PaymentAuthorisation::setApprovalNeeded → SURVIVED
20  1. changed conditional boundary → SURVIVED
    2. negated conditional → KILLED
21  1. removed call to de/thbrunzendorf/payment/authorisation/PaymentAuthorisation::setApprovalNeeded → KILLED
23  1. removed call to de/thbrunzendorf/payment/authorisation/PaymentAuthorisation::setPrimaryApprover → KILLED
25  1. mutated return of Object value for de/thbrunzendorf/payment/authorisation/PaymentAuthorisationChecker::checkFor to ( if (x != null) null else throw new RuntimeException ) → KILLED
    1. changed conditional boundary → SURVIVED
32  2. Changed increment from 1 to -1 → TIMED_OUT
    3. negated conditional → SURVIVED
33  1. changed conditional boundary → SURVIVED
    2. negated conditional → KILLED
38  1. mutated return of Object value for de/thbrunzendorf/payment/authorisation/PaymentAuthorisationChecker::getPrimaryApprover to ( if (x != null) null else throw new RuntimeException ) → KILLED
```

Hands-On Stryker

- Basic code coverage 100%

File	% Stmts	% Branch	% Funcs	% Lines	Uncovered Lines
All files	100	100	100	100	
money.js	100	100	100	100	
payment.js	100	100	100	100	
paymentAuthorisation.js	100	100	100	100	
paymentAuthorisationChecker.js	100	100	100	100	
user.js	100	100	100	100	

- npm run-script stryker
- Report at reports/mutation/…

Hands-On Stryker

\D\IntelliJ Workspace\mutation-testing-js\src - Stryker report

Totals

File	Mutation score		# Killed	# Survived	# Timeout	# No coverage	# Errors	Total detected	Total undetected	Total mutants
\D\IntelliJ Workspace\mutation-testing-js\src	48%	17/35	16	18	1	0	0	17	18	35

Finegrained

File	Mutation score		# Killed	# Survived	# Timeout	# No coverage	# Errors	Total detected	Total undetected	Total mutants
money.js	57%	4/7	4	3	0	0	0	4	3	7
payment.js	100%	1/1	1	0	0	0	0	1	0	1
paymentAuthorisation.js	0%	0/2	0	2	0	0	0	0	2	2
paymentAuthorisationChecker.js	45%	11/24	10	13	1	0	0	11	13	24
user.js	100%	1/1	1	0	0	0	0	1	0	1

Generated with stryker-html-reporter generator. Visit the Stryker website

Hands-On Stryker

```
var Payment = require('../src/payment.js');
var PaymentAuthorisation = require('../src/paymentAuthorisation.js');
function checkFor(payment) 0 {
    paymentAuthorisation = new PaymentAuthorisation();
    initiator = payment.initiator;
    amount = payment.amount;
    limit = initiator.limit;
    if ( 1 2 3 4 amount.compareTo(limit) <= 0) 5 {
        paymentAuthorisation.approvalNeeded = 6 false;
    }
    if ( 7 8 9 10 amount.compareTo(limit) > 0) 11 {
        paymentAuthorisation.approvalNeeded = 12 true;
        approver = getPrimaryApprover(initiator, amount);
        paymentAuthorisation.primaryApprover = approver;
    }
    return paymentAuthorisation;
}
function getPrimaryApprover(initiator, amount) 13 {
    supervisor = initiator.supervisor;
    limit = supervisor.limit;
    maxIterations = 10; // preventing infinite loops
    for (i = 0; 14 15 16 i < maxIterations; 17 i++) 18 {
        if ( 19 20 21 22 amount.compareTo(limit) > 0) 23 {
            supervisor = supervisor.supervisor;
            limit = supervisor.limit;
        }
    }
    return supervisor;
}
module.exports = checkFor;
```

Hands-On

Kill the mutants!

Discussion

!?

Mutation Testing?

- High code coverage is necessary but not sufficient for high quality tests
- Mutation Testing helps finding missing test cases
  - Additional test data, e.g. boundary values
  - Additional assertions
- Mutation Testing helps finding dead code
  - If we can not think of any test case that would kill a given survived mutation, then the mutated code is probably redundant
- Hint: Test-driven development will drastically reduce the chances of survival for mutants

Questions?

Thorsten Brunzendorf

@thbrunzendorf

Thank you!