

Test Generation with JML

Part I – JMLUnitNG

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Overview

Part I

- ▶ JML as test oracle

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Part II

- ▶ Provide even better test data with KeY

The Basic Idea

Use JML specs to check I/O behaviour of methods

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- ▶ After the execution of the method evaluate the postcondition
 - ▶ if true – test passed
 - ▶ if false – test fail, quote the values of the input data

Running Example

```
/*@ public normal_behavior
    requires param >= 0;
    ensures \result >= 10;

    also public normal_behavior
        requires param < 0;
        ensures \result < -10;
@*/
public int makeHole(int param) {
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- ▶ **What inputs?!**

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 - ▶ **Collect objects after successful tests of constructors**
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- ▶ Runtime Assertion Checker (RAC) compiler:
 - ▶ Embed JML checks into the compiled Java code
 - ▶ Report results of evaluating JML expressions to the testing framework
- ▶ Result: a standalone test suite based on the TestNG engine – <http://testng.org>
- ▶ Very efficient (compared to the older, non-NG version)

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5. Compile the test suite with **regular** Java compiler
6. Run the test suite

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- ▶ I used OpenJDK ver. 6 on Ubuntu

Example Again – Demo

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Consequence

Try to have the overall precondition *wide*, ideally the disjunction (n number of spec cases):

$$\text{pre}_1 \ || \ \text{pre}_2 \ || \ \dots \ || \ \text{pre}_n$$

should be equivalent to **true**.

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Observation II

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Observation IIa

The tested code may contain more information for data partitioning (e.g. **if** branches), KeY can help here, see Part II

Specifications for Testing

Observation III

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Simple **true** is not a good postcondition, trivial test case. . .

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Observation IIIa

Not all JML expressions are RAC checkable, e.g. some quantifications.

Such specifications are quite accepted as true!

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Solution

It is always possible to combine multiple spec cases into one:

```
public normal_behavior
  requires pre1;
  ensures post1;
also public behavior
  requires pre2;
  ensures post2;
  signals (Exception e)
    expost2;
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```
public behavior
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```
  requires pre1 || pre2;
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```
  ensures \old(pre1) ==> post1;
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    (\old(pre2) ==> expost2)
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    && !\old(pre1);
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Examples to Play With

- ▶ Binary search algorithm:
 - ▶ Specify two cases, element found and not found, hint:

```
requires array != null;  
requires Array is sorted;  
requires (\forall int i;  
    i >= 0 && i < array.length; array[i] != target);  
ensures \result == -1;
```

- ▶ Create and run the tests, find the bug in the code
- ▶ File `BinSearch.java`, then

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$ make TESTCLASS=BinSearch testgen
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Reference Material – My Makefile

```
OPENJMLBOOT=lib/openjmlboot.jar
JMLUNITNG=lib/jmlunitng.jar
JML4C=lib/jml4c.jar
JML4RT=lib/jml4rt.jar

TESTCLASS?=Example

all: testgen run

clean:
    rm -rf tests test-output
    find src/ -name "*.class" -exec rm \{\} \;

testgen: clean
    mkdir -p tests
    java -Xbootclasspath/p:${OPENJMLBOOT} -jar $(JMLUNITNG) --dest tests --reflection src/

compile:
    java -jar $(JML4C) -cp $(JML4C):$(JMLUNITNG) src/
    javac -cp $(JML4RT):$(JMLUNITNG):src/ `find tests/ -name "*.java"`

run: compile
    java -cp $(JMLUNITNG):$(JML4RT):./tests:./src/ org.charter.jmlunitng.$(TESTCLASS)_JML_Test

report: compile
    java -cp $(JMLUNITNG):$(JML4RT):./tests:./src/ com.beust.testng.TestNG test_$(TESTCLASS).xml
```

References

Yoonsik Cheon and Gary Leavens. *A simple and practical approach to unit testing: The JML and JUnit way*. ECOOP'02 Proceedings, Springer LNCS 2374.

Daniel M. Zimmerman and Rinkesh Nagmoti. *JMLUnit: The Next Generation*, FoVeOOS 2010 Conference Proceedings, Springer LNCS 6528.

Software & Libraries

- ▶ OpenJML

<http://jmlspecs.sourceforge.net/openjml.tar.gz>

- ▶ JML4C

<http://www.cs.utep.edu/cheon/download/jml4c/download.php>

- ▶ JMLUnitNG

<http://formalmethods.insttech.washington.edu/software/jmlunitng/>