An overview of JML tools and applications

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Overview

1. The JML language

3. Tools for JML

5. Applications

7. Conclusions
1. The JML language
Java Modeling Language

- Initiative of Gary Leavens [Iowa State Univ.]

- Behavioural Interface Specification Language for Java: annotations added to Java programs, expressing pre-, postconditions, invariants...

- Inspired by Eiffel (Design-by-Contract) & Larch

- Main design goal: easy to learn
  - simple extension of Java’s syntax
JML example

private int balance;
final static int MAX_BALANCE;

/*@ invariant 0 <= balance &&
    balance < MAX_BALANCE; */
JML example

/*@ requires amount >= 0;
 assignable balance;
 ensures balance == \old(balance) - amount;
 signals (PurseException)
     balance == \old(balance);
 @*/

public void debit(int amount) {
    ....
}

Erik Poll  JML tools & applications  6
JML example

private byte[] pin;
private byte appletState;

/*@ invariant
   appletState == PERSONALIZED
->
   pin != null &&
   pin.length == 4 &&
   (\forall int i; 0 <= i && i < 4
    ; 0 <= pin[i] && pin[i] <= 9); */
2. Tools for JML
Tools for JML

- tools for reading & writing specs
- tools for generating specs
- tools for checking implementation against specs
Tools for reading & writing specs

- parsing & typechecking (as part of other tools)
- jmldoc: javadoc for JML
Tools for generating specs

- Invariant detection using Daikon
  [Michael Ernst, MIT]

  Daikon observes execution of code to detect likely invariants
Tools for checking specs (I)

- **Runtime assertion checker**
  [Gary Leavens et al., Iowa State Univ.]
  tests if specs are violated at runtime
  - not so exciting for academia, but appealing to industry
  - well-specified code is easy to test!
    - runtime checker handles `forall` and `old`
  - **jmlunit**: tool combining runtime checking with unit testing
Tools for checking specs (II)

- Extended static checker ESC/Java
  [Rustan Leino et al., ex-Compaq]
  automatic verification of simple properties
  - not sound, not complete, but finds lots of bugs quickly
  - eg. can “prove” absence of NullPointer- and ArrayIndexOutOfBoundsException

- Chase tool [Nestor Cataño, INRIA] remedies one important source of unsoundness
Tools for checking specs (III)

“Real” program verification

- **JACK** tool [Gemplus]
  automatic verification of JML-annotated code
  Inspired by ESC/Java, integrated with Eclipse

- **LOOP** tool [Nijmegen]
  interactive verification of JML-annotated code

- **Krakatoa** tool [INRIA/Orsay] for interactive verification now also supports JML
Tools for checking specs

There is a range of tools offering different levels of assurance at different costs (ie. time & effort):

- runtime assertion checking
- extended static checking using ESC/Java
- automatic verification using JACK
- interactive verification using LOOP, Krakatoa
3. Applications
JavaCard

- **Subset of a superset** of Java for programming smart cards
  - no floats, no threads, limited API, optional gc, ...
  + support for allocation in EEPROM or RAM
- **Ideal target for formal methods**
  - small programs, written in simple language, using small API, whose correctness is critical
  - highest levels of security evaluation standards require use of formal methods (**Common Criteria**)
Applications of JML to JavaCard as part of VeriCard project

- Writing JML specs of JavaCard API [Cardis'00]
- Checking applets using ESC/Java [FME'02]
  - 1000's of lines of code
- Verifying applets using LOOP [AMAST'02]
  - 100's of lines of code
- Runtime checking part of smartcard OS [Cardis'02]
4. Conclusions
Assertion-based languages promising way to use formal methods in industry

- Familiar syntax and semantics
- No need for formal model (code is formal model)
- Easy to introduce use incrementally

NB: JML does not provide or impose any design methodology
What to specify?

- Detailed functional specs often too difficult

- Just establishing weak specs, e.g.
  
  ```java
  requires ....
  ensures true;
  signals (NullPointerException) false;
  often suffices to expose most invariants
  ```

- Invariants make explicit many design decisions that are typically undocumented
Using JML for JavaCard applets

• For smartcard applets, verifying simple “safety” properties (eg. absence of certain exceptions) with JACK or ESC/Java has good return-on-investment

• Verification has found errors not found during testing

• Using JML tools to help manual code reviews when certifying code?
JML

- Lots of ongoing work and open issues about JML, eg.
  - tricky questions about semantics
  - concurrency?
  - alias control & ownership models?
- Agreeing on common syntax & semantics is hard work! (witnessed by upcoming patch of ESC/Java)
- Most tools just support subsets of JML
- JML as standard or as vehicle for research?
JML

• Having a common specification language supported by different tools important benefit
  - for individual tool builders, and
  - for users

• JML is an open collaborative effort, and we welcome cooperation with others
More info:

www.jmlspecs.org