



State-of-the-Art in Java Verification

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Dagstuhl in a Nutshell





Verification in Modern Software Development



- verification is not always necessary
- verification is rarely necessary
- your problem domain, team, customer, CEO/CTO matter more than technology
- when your systems have to have high quality, then various verfication techniques can have a role
- modern verification software has dramatically improved over the past ten years and is widely used in certain industries and in many universities

Some Personal Examples



• use in teaching and research in top universities (e.g., Caltech, MIT, CMU)

 but also use in teaching and research in universities not chock-full of geniuses :)

CAD systems for VLSI

financial systems on smart cards

Dutch KOA and Irish Votáil tally systems

Best-practices in (Realistic) Modern Software Engineering



- modern, most-often-used best-practices in writing high-quality software
 - write documentation (at some point)
 - write unit tests (by hand), preferably prior to implementing functionality
 - focus on the code, write simple-but-good code, and refactor often
 - talk to your customer frequently
 - but... most developers are embarrased by, and not confident in, their code



```
public class Purse {
  int balance;

public int debit(int amount)
  throws PurseException;
}
```

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```
public class Purse {
 // The balance of this purse.
  int balance;
 // Decrease the balance of this account by
  // "amount".
  public int debit(int amount)
    throws PurseException;
```



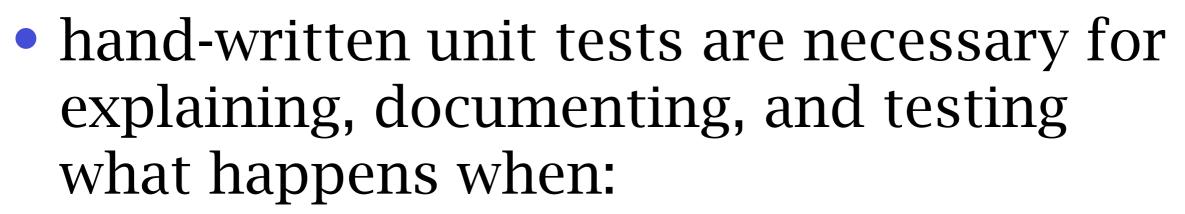
```
public class Purse {
 // The (non-negative) balance of this purse.
  private int balance;
 // Decrease the balance of this account by
 // "amount". Return the new balance of the
 // purse. Throw an exception if something
 // went wrong.
  public int debit(int amount)
    throws PurseException;
```



```
public class Purse {
 // The (non-negative) balance of this purse.
  private int balance;
  /** Decrease the balance of this account by
   * "amount". Return the new balance of the
   * purse. Throw an exception if something
   * went wrong. */
  public int debit(int amount)
    throws PurseException;
```

```
public class Purse {
  // The (non-negative) balance of this purse.
  private int balance;
  /** Decrease the balance of this account.
   * @param amount the non-negative amount
   * of funds of the debit.
   * @return the new balance of the purse.
   * @exception PurseException is thrown if
   * something went wrong.
  public int debit(int amount)
    throws PurseException;
```

Unit Tests for Purse





- the field balance is non-negative
- the field balance is negative
- the amount passed is positive
- the amount passed is negative
- the amount passed is zero
- one or more situations when an exception is thrown
- this results in about 2 pages of test code

Ambiguity and Evolvability of this Trivial Method





- but every time you refactor the method you must rewrite all unit tests that mention it
- as the method's purpose and meaning evolves, then so must its documentation
 - but there is very little connection between the English documetation and the method
- and there are still many open questions
 - e.g., what happens to balance when an exception is thrown? can more than the balance of the object be modified? what is the maximum balance possible?



```
// The (non-negative) balance of this purse.
private int balance;
/** Decrease the balance of this account.
 * @param amount the non-negative amount
 * of funds of the debit.
 * @return the new balance of the purse.
 * @exception PurseException is thrown if
 * something went wrong. */
public int debit(int amount)
  throws PurseException;
```

```
final int MAX_BALANCE;
/*@ invariant 0 <= balance &</pre>
              balance <= MAX_BALANCE; */</pre>
private int balance;
/** Decrease the balance of this account.
 * @param amount the non-negative amount
 * of funds of the debit.
 * @return the new balance of the purse.
 * @exception PurseException is thrown if
 * something went wrong. */
public int debit(int amount)
  throws PurseException;
```



```
final int MAX_BALANCE;
/*@ invariant 0 <= balance &
              balance <= MAX_BALANCE; */</pre>
private int balance;
/** Decrease the balance of this account.
 * @return the new balance of the purse.
 * @exception PurseException is thrown if
 * something went wrong. */
//@ requires amount >= 0;
public int debit(int amount)
  throws PurseException;
```

```
final int MAX_BALANCE;
/*@ invariant 0 <= balance &
              balance <= MAX_BALANCE; */</pre>
private int balance;
/** Decrease the balance of this account.
 * @return the new balance of the purse.
 * @exception PurseException is thrown if
 * something went wrong. */
//@ requires amount >= 0;
//@ assignable balance;
public int debit(int amount)
  throws PurseException;
```



```
final int MAX_BALANCE;
/*@ invariant 0 <= balance &
              balance <= MAX_BALANCE; */</pre>
private int balance;
/** Decrease the balance of this account.
 * @exception PurseException is thrown if
 * something went wrong. */
//@ requires amount >= 0;
//@ assignable balance;
//@ ensures balance == \old(balance-amount);
//@ ensures \result == balance;
public int debit(int amount)
  throws PurseException;
```



```
/** Decrease the balance of this account. */
//@ requires amount >= 0;
//@ assignable balance;
//@ ensures balance == \old(balance-amount);
//@ ensures \result == balance;
//@ signals (PurseException)
            balance == \old(balance);
//@
public int debit(int amount)
  throws PurseException;
```

What Does This "Gentle" Use of JML Buy You?



- write less English documentation
- less need to keep English documentation in-sync with code as it evolves
- eliminate defensive programming boilerplate in method implementation
 - parameter validity checking & exceptions
- write no inline assertions
- write and babysit no unit tests
- statically check that code fulfills spec automatically with several tools



Demonstration