L3 Mention Informatique
Parcours Informatique et MIAGE

Génie Logiciel Avancé

Part IV : Test Introduction

Burkhart Wolff
wolff@lri.fr

Validation and Verification

- Validation :
  - Does the system meet the clients requirements ?
  - Will the performance be sufficient ?
  - Will the usability be sufficient ?

Validation and Verification

- Validation :
  - Does the system meet the clients requirements ?
  - Will the performance be sufficient ?
  - Will the usability be sufficient ?

Do we build the right system ?

Validation and Verification

- Validation :
  - Does the system meet the clients requirements ?
  - Will the performance be sufficient ?
  - Will the usability be sufficient ?

Do we build the right system ?

- Verification: Does the system meet the specification ?

Validation and Verification

- Validation :
  - Does the system meet the clients requirements ?
  - Will the performance be sufficient ?
  - Will the usability be sufficient ?

Do we build the right system ?

- Verification: Does the system meet the specification ?

Do we build the system right ?

Is it « correct » ?

How to do Validation ?

- Mesuring customer satisfaction ...
  (well, that's afterwards, and its difficult)

- Interviews, inspections (again post-hoc)

- How to validate a system early?
  - early prototypes, including performance analysis ...
  - mock-ups (fonctionnality, ergonomics,…)

  - Test and Animation on the basis of formal specifications
    (e.g., à la OCL !)

How to do Verification ?

- Test and Proof on the basis of formal specifications (e.g., à la OCL !) against programs ...

How to do Verification ?

- Test and Proof on the basis of formal specifications (e.g., à la OCL !) against programs ...

  In the sequel, we concentrate on Testing and Proof Techniques ...

A Philosophical Position Statement : Test vs. Proof

- **Note**:

  Some researcher consider test as opposite to formal proof! Reasons:

  - “A test can only reveal the presence of bugs, but not their absence” (Dijkstra, v. Dalen)

  - ... these researchers referred to unsystematic tests ... (which are, addmittedly, still quite common in SE practice)

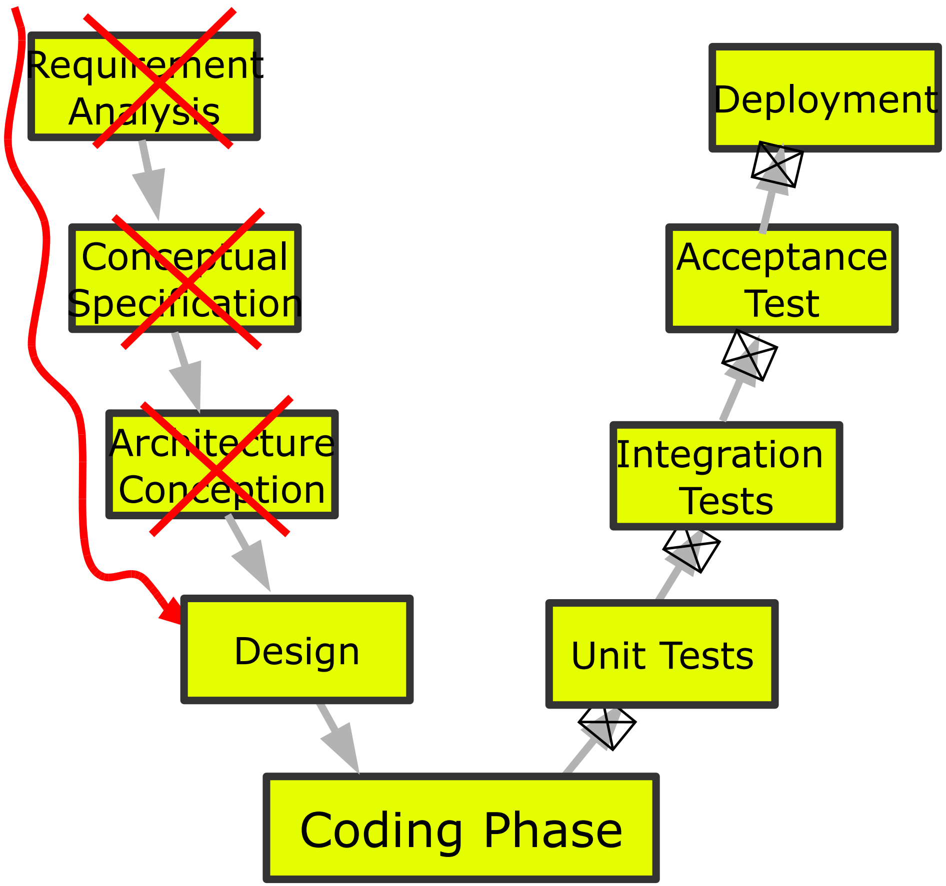
A Philosophical Position Statement : Test vs. Proof

- **Note**:

  We consider (systematic!) test more as an approximation to formal proof. Reasons:

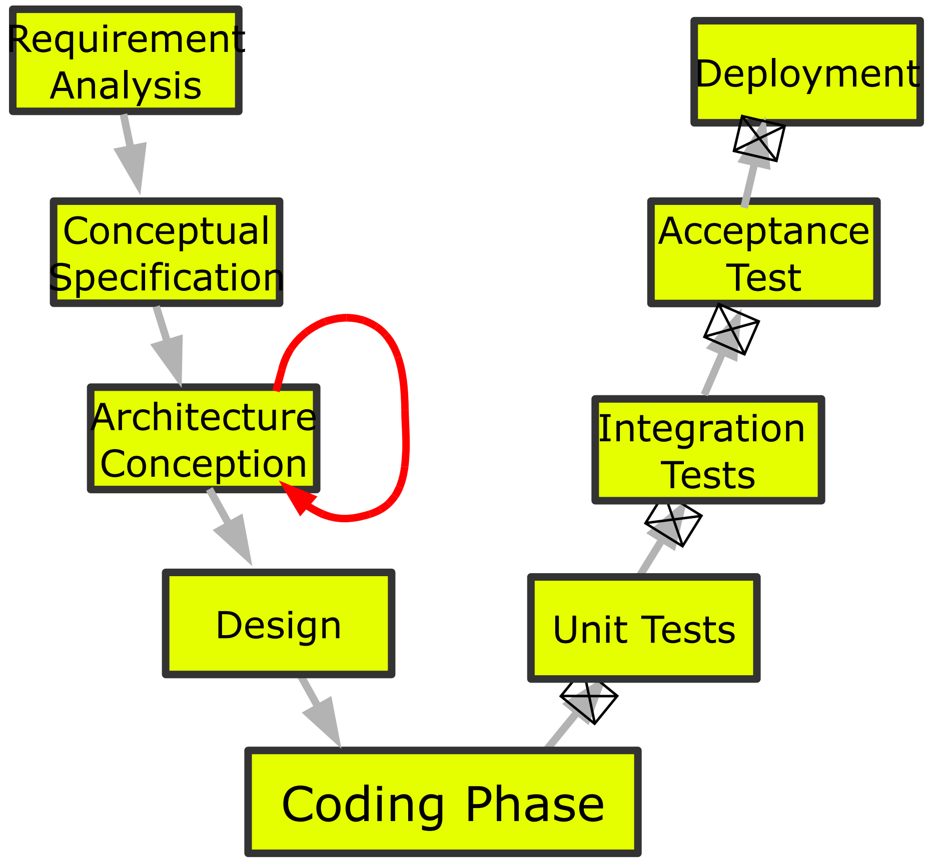
  - The nature of the approximation can be made formally precise (via explicit test-hypothesis ...)
  - both techniques, model-based tests and formal verification, share a lot of technologies ...
  - even full-blown proof attempts may profit from testing, since it can help to debug specs early and cost-effectively

Test in the SE Process



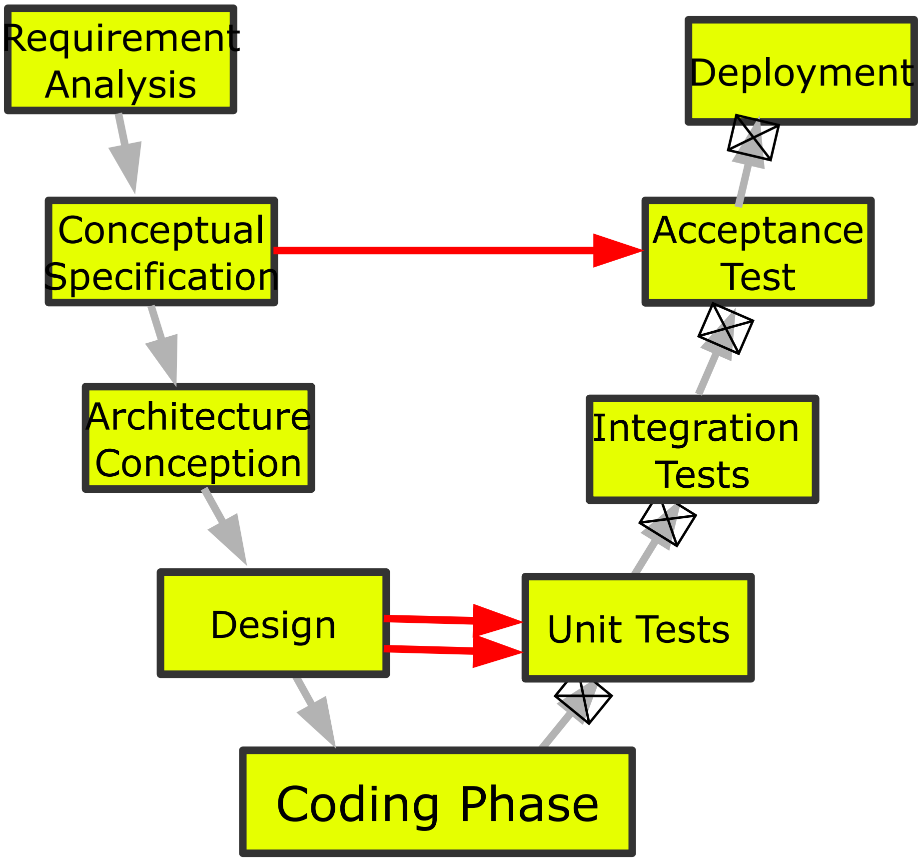
- Where to integrate Tests in the SE-Process:
  - On the methodological level, à la "Extreme Programming" (XP) ?
    No specs, instead writing test scenarios and test cases from the beginning ...

Test in the SE Process



- Where to integrate Tests in the SE-Process:
  - On the methodological level, à la "Extreme Programming" (XP) ?
    No specs, instead writing test scenarios and test cases from the beginning ...
  - On the specification level for validation ...

Test in the SE Process



- Where to integrate Tests in the SE-Process:
  - On the methodological level, à la "Extreme Programming" (XP) ?
    No specs, instead writing test scenarios and test cases from the beginning ...
  - On the specification level for validation ...
  - On the specification level against code

Test in the SE Process

- General questions for verification in a process:
  - How to select test-data ? To which purpose ?>
  - How to focus verification activities?
    Where to verify formally, and
    where to test, and when did we test enough?

    Note: The quality of a test does not increase necessarily by the number of test-cases !
  - Automation ? Tools ?

Some empirical data ...

- Size of Software ?
  - Peugeot 607 : 2 Mb embedded software
  - Windows 90: 10 Mb. LOC source, Win2000: 30 Mb.
  - Kernel Hyper V: 50000 LOC. (Highly complex, concurrent C)
  - Noyau RedHat 7.1 (2002) : ~2.4 M. LOC, XWindow ~1.8, Mozilla ~2.1 M.
  - Space Shuttle (and its environment) : ~50 MLOC

- Reminder: Development Cost ?
  - Percentage of «Coding» ? 15 - 20 %

    Trend: Code is more and more generated (*CASE Tools*)
  - Proportion of Validation et Verification ? ~20% / ~20%

Verification Costs

- costs ? *35 - 50 % of the global effort ?*
- all “real” (large) software has remaining bugs …
- The cost of bug ?
  - the cost to reveal and fix it …
    or:
    the cost of a legal battle it may cause...
    or the potential damage to the image
    (difficult to evaluate, but veeeery real)
    or costs as a result to come later on the market
  - *on the other side – you can't test infinitely, and verification is again 10 times more costly than thoroughly testing !*

Verification Costs

- Conclusion:
  - verification is vitally important,
    and also critical in the development
  - to do it cost-effectively, it requires
    - a lot of expertise on products and process
    - a lot of knowledge over methods,
      tools, and tool chains ...

Overview on the part on « Test »

- WHAT IS TESTING ?
- A taxonomy on types of tests
  - Static Test / Dynamic (*Runtime*) Test
  - Structural Test / Functional Test
  - Statistic Tests
- Functional Test; Link to UML/OCL
  - Dynamic Unit Tests, Static Unit Tests,
  - Coverage Criteria
- Structural Tests
  - Control Flow and Data Flow Graphs
  - Tests and executed paths. Undecidability.
  - Coverage Criteria

What is testing ?

- It is an approximation to full verification (for ex. by proof)
- Main emphasis: finding bugs early,
  - either in the model
  - or in the program
  - or in both

- A systematic test is:
  - process programs and specifications and to compute a set of test-cases under controlled conditions.

  - *ideally*: testing is complete if a certain criteria, the adequacy criteria is reached.

Limits of testing ?

- We said, test is an approximation to verification, usually easier (and less expensive)

- Note: Sometimes it is easier to verify than to test. In particular:

  - low-level OS implementations:
    memory allocation, garbage collection
    memory virtualization, ...
    crypt-algorithms, ...

  - non-deterministic programs with
    no control over the non-determinism.

Taxomomy: Static / Dynamic Tests

- **static**: running a program before deployment on data carefully constructed by the analyst (in a test environment)
  - analyse the result on the basis of all components
  - working on some classes of executions symbolically
    = representing infinitely many executions

- **dynamic**: running the programme (or component) after deployment, on "real data" as imposed by the application domain
  - experiment with the real behaviour
  - essentially used for post-hoc ananalysis and debugging

Taxonomy: Unit / Sequence / Reactive Tests

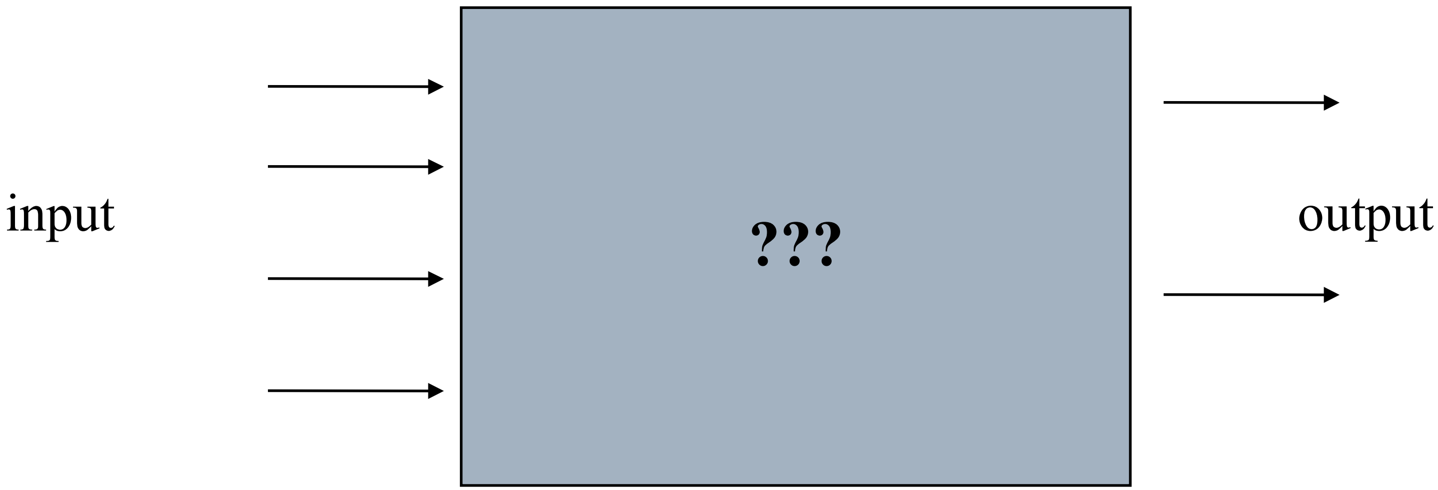
- **unit**: testing of a local component (function, module), typically only one step of the underlying state.
  (In functional programs, thats essentially all what you have to do!)
- **sequence**: testing of a local component (function, module), but typicallY sequences of executions, which typically depend on internal state
- **reactive sequence**: testing components by sequences of steps, but these sequences represent communication where later parts in the seqience depend on what has been earlier cummunicated

Taxonomy: Functional / Structural Test

- **functional**: (also: black-box tests). Tests were generated on a specification of the component, the test focusses on input output behaviour.
- **structural**: (also: white-box tests). Tests were generated on the basis of the structure or the program, i.e. using control-flow, data-flow paths or by using symbolic executions.
- **both**: (also: grey-box testing).

Functional Dynamic Unit Test

- We got the spec, but not the program, which is considered a black box:



we focus on what the program *should* do !!!

Functional Dynamic Unit Test : an example

The (informal) specification:

Read a "Triangle Object" (with three sides of integral type), and test if it is isoscele, equilateral, or (default) arbitrary.

Each length should be strictly positive.

Give a specification, and develop a test set ...

Functional Dynamic Unit Test : an example

The specification in UML/OCL (Classes in USE Notation):

```
class Triangles inherits_from Shapes
   attributes
      a : Integer
      b : Integer
      c : Integer


   operations
      mk(Integer,Integer,Integer):Triangle
      is_Triangle(): triangle
   end
```

Functional Dynamic Unit Test : an example

The specification in UML/OCL (Classes in USE Notation):

```
context Triangles:
inv def      : a.oclIsDefined() and b.oclIsDefined()...
inv pos      : 0<a and 0<b and 0<c
inv triangle : a+b>c  and  b+c>a  and  c+a>b

context Triangle::isTriangle()
post equi : a=b and b=c implies result=equilateral
post iso  :((a<>b or b<>c) and
            (a=b or b=c or a=c))implies result=isosceles
post default: (a<>b or b<>c) and
              (a<>b and b<>c and a<>c)
              implies result=arbitrary
```

Functional Dynamic Unit Test : an example

The specification in UML/OCL (Classes in USE Notation):
Recall implicit consequences due to strictness of all operations

```
context Triangle::isTriangle()
...
post res_strict: self.oclIsUndefined implies
                             result.oclIsUndefined
post res_total: result.oclIsDefined implies
                             self.oclIsDefined
```

Functional Dynamic Unit Test : an example

How to perform Runtime-Test?

Well, compile:

context X:

inv $l_1 : C_1$, ...,

inv $l_n : C_n$

to some checking code (with assert as in Junit, VCC, Boogie, ...)

```
check_X() = assert(C1);  ... ; assert(Cn)
```

Functional Dynamic Unit Test : an example

How to perform Runtime-Test?

Moreover, compile:

context $C::m(a_1:C_1,...,a_n:C_n)$

pre : $P(self,a_1,...,a_n)$

post : $Q(self,a_1,...,a_n,result)$

to some checking code (with assert as in Junit, VCC, Boogie, ...)

check_C(); check_C_1(); ... ; check_C_n();

assert($P(self,a_1,...,a_n)$);

result=run_m($self,a_1,...,a_n$);

assert($Q(self,a_1,...,a_n,result)$);

Functional Dynamic Unit Test : Problems

- Thus, any violation of an invariant, a pre-condition or a post-condition is detected.

- If a violation occurs within an execution of a method, the error is precisely reported.

- On the other hand – it is post-hoc. Only when a problem occured, we know where. And we need complete program.

- Inefficiencies can be partly overcome by optimized compilations.