1. A Framework for Test and Analysis

Angelo Gargantini

Testing e verifica del software

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Goals of Software Testing and Verification

- to assess software qualities

examples of sw qualities

- my program never crashes
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- my program is useful

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examples of sw qualities

- my program never crashes
- my program works
- my program is useful

- to make it possible to improve the software by finding defects

example of sw defects

- the pointer is not null
- when the user presses OK button, the application ....

Section 1

Validation and Verification

Validation & Verification

Validation

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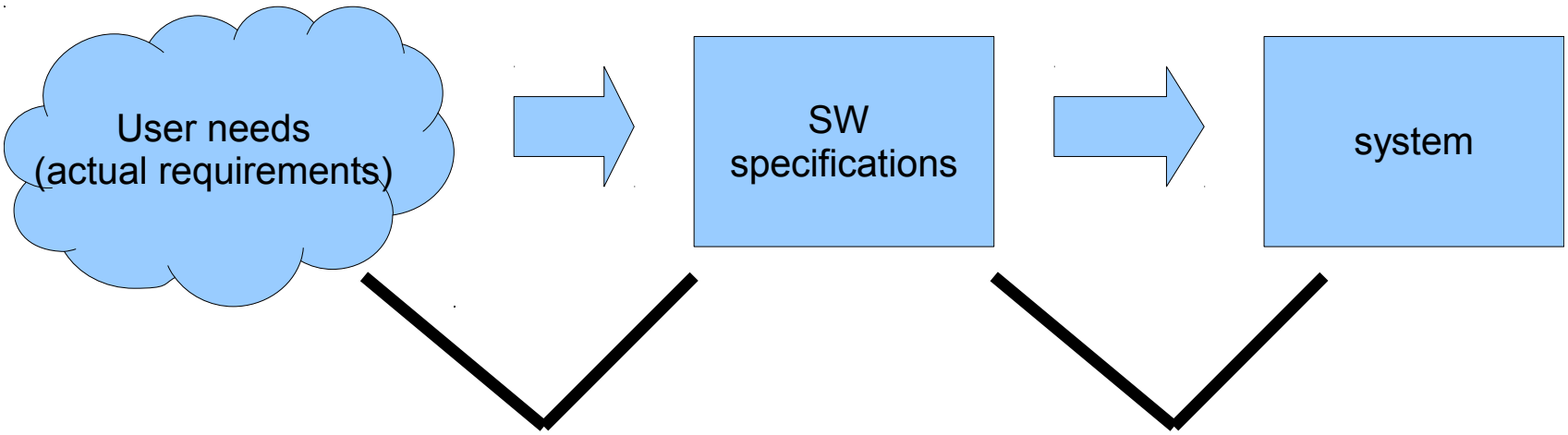
Verification

Does the software system meets the requirements specifications? are we building the software right?

Validation & Verification



Includes
usability testing,
user feedback

Includes testing,
inspections,
static analysis

Validation & Verification - standard definitions

IEEE standard in its 4th edition defines the two terms as follows:

Validation. The assurance that a product, service, or system meets the needs of the customer and other identified stakeholders. It often involves acceptance and suitability with external customers. Contrast with verification.

Verification. The evaluation of whether or not a product, service, or system complies with a regulation, requirement, specification, or imposed condition. It is often an internal process. Contrast with validation.

ISO 9001 standard defines them this way :

Verification is the conformation that a product meets identified specifications.

Validation is the conformation that a product appropriately meets its design function or the intended use.

Validation & Verification - standard definitions

Capability Maturity Model (CMMI-SW v1.1):

Software Verification: The process of evaluating software to determine whether the products of a given development phase satisfy the conditions imposed at the start of that phase.

Software Validation: The process of evaluating software during or at the end of the development process to determine whether it satisfies specified requirements.

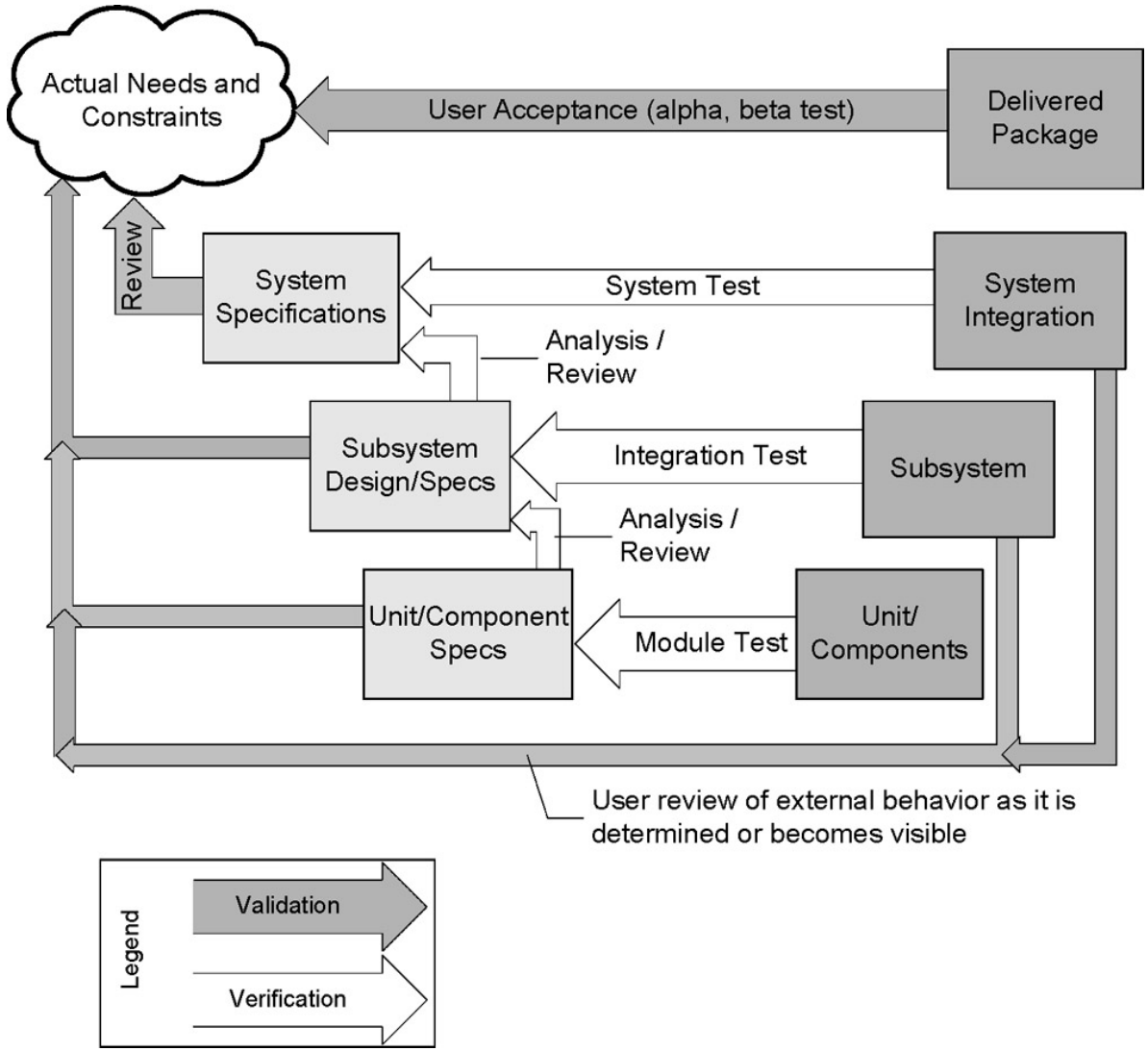
Boehm succinctly expressed the difference between:

Software Verification: Are we building the product right?

Software Validation: Are we building the right product?

Example

Validation & Verification



Verification

- Verification generally compares two or more artifacts
- Verification can consist in checking for *self-consistency* and well-formedness **one** artifact.
  - For example, we can certainly determine that some programs are "incorrect" because they are ill-formed.
  - We may likewise determine that a specification itself is ill-formed because it is inconsistent (requires two properties that cannot both be true) or ambiguous (can be interpreted to require some property or not),
  - or because it does not satisfy some other well-formedness constraint that we impose, such as adherence to a standard imposed by a regulatory agency.

Verification

- Validation against actual requirements necessarily involves human judgment
- Verification can be automatized

Section 2

Degrees of Freedom

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HALTING PROBLEM

Given the description of an arbitrary program and a finite input, decide whether the program finishes running or will run forever.

Exhaustive testing

```
static int sum(int a, int b) {return a+b;}
```

1. Exhaustive testing, that is, executing and checking every possible behavior of a program, would be a "proof by cases," which is a correct way to construct a logical proof. How long would this take?

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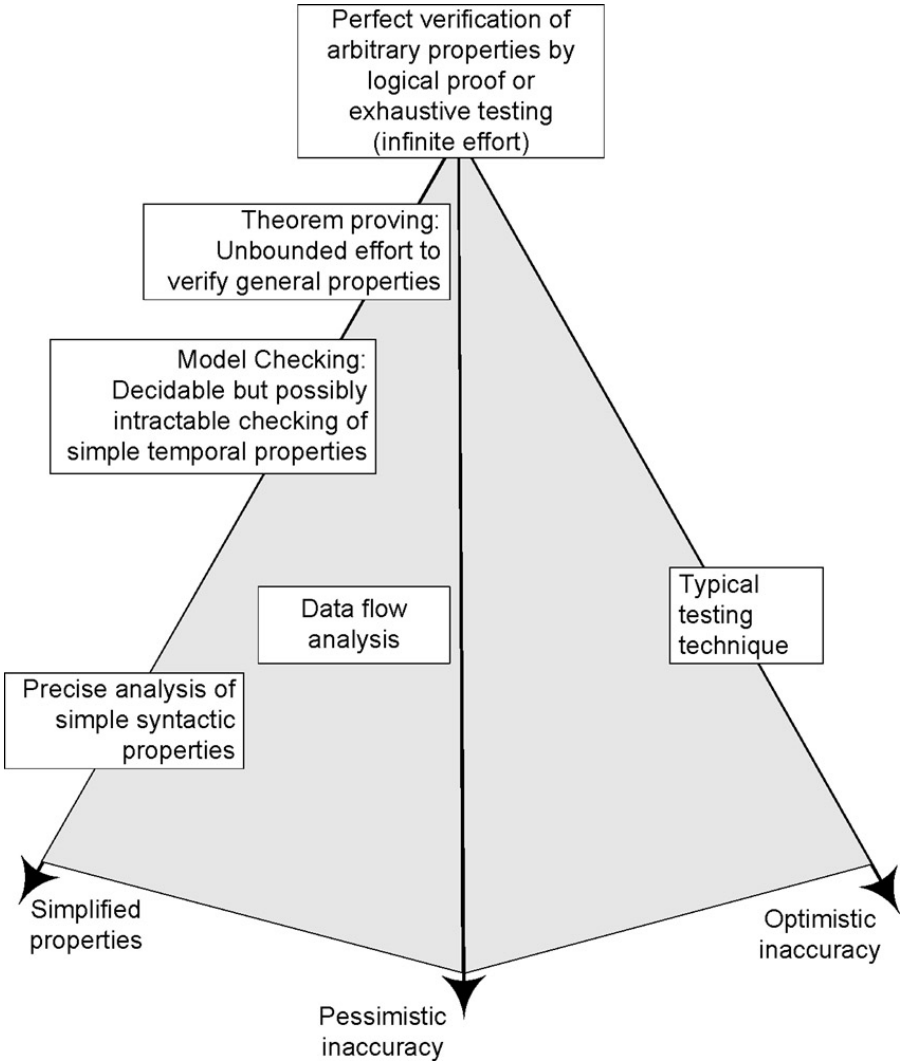
2. there are only $2^{32} \times 2^{32} = 2^{64} \approx 10^{21}$ different inputs on which the method Trivial.sum() need be tested to obtain a proof of its correctness. At one nanosecond (10^{-9} seconds) per test case, this will take approximately 10^{12} seconds, or about 30,000 years.

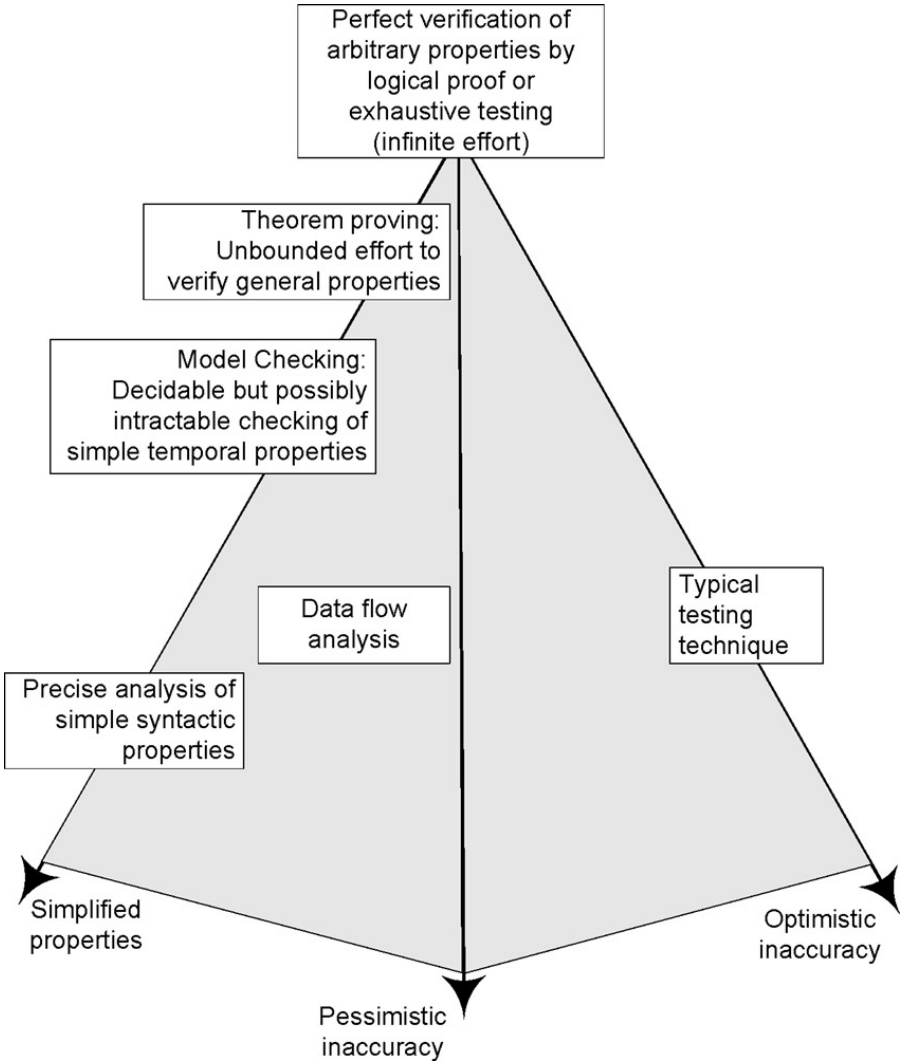
Pessimistic and Optimistic inaccuracy



A (testing/analysis) technique can be approximate:

1. pessimistic : it is not guaranteed to accept a program even if the program does possess the property being analyzed
2. optimistic : if it may accept some programs that do not possess the property (i.e., it may not detect all violations)

Simplification/abstraction



1. we want to verify a property S, but
   1. we cannot accept the optimistic inaccuracy of testing for S
   2. precise analysis is too difficult
2. a simpler property S' is a sufficient, but not necessary, condition for S
3. we check S' rather than S
4. we require S' to be satisfied

Simplification/abstraction Example

```
int i, sum;
int first=1;
for (i=0; i<10; ++i) {
  if (first) {
    sum=0; first=0;
  }
  sum += i;
}
```

Property: each variable should be initialized with a value before its value is used in an expression

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2. C ???
3. Java ???

Example of simplified property: Unmatched Semaphore Operations

Property: every semaphore it is eventually unlocked

```
if ( .... ) {
...     lock(S);
}
...
if ( ... ) {
    ...     unlock(S);
}
```

Static checking for match is necessarily inaccurate ...

Example of simplified property: Unmatched Semaphore Operations

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Java solution: synchronized statements specify the object that provides the intrinsic lock

```
synchronized(S) {
            ...
}
```

It is guarenteed that the lock S is released.

How to deal with undecideble problems

1. optimistic inaccuracy: we may accept some programs that do not possess the property (i.e., it may not detect all violations).
   - testing
2. pessimistic inaccuracy: it is not guaranteed to accept a program even if the program does possess the property being analyzed
   - automated program analysis techniques
3. simplified properties: reduce the degree of freedom for simplifying the property to check

Some Terminology

Safe (Sicuro): A **safe** analysis has no optimistic inaccuracy, i.e., it accepts only correct programs.

- if a program is "wrong" it is rejected.

Sound (Corretto): An analysis of a program P with respect to a formula F is sound if the analysis returns true only when the program does satisfy the formula.

- if a program is accepted, it is correct
- no wrong program is accepted
- there may be correct programs that are not accepted (conservative)
- testing is not sound.

Complete (completo): An analysis of a program P with respect to a formula F is complete if the analysis always returns true when the program actually does satisfy the formula.

- every correct program is accepted

Section 3

Varieties of Software

Section 4

Further Reading

Section 5

Exercises