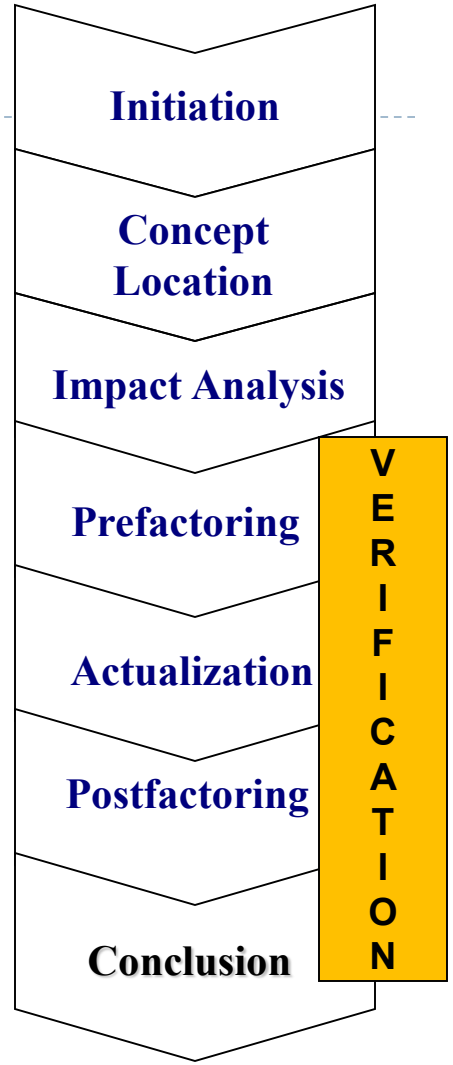
Software Testing and Verification

Roberto A. Bittencourt
Based on Rajlich's slides

Verification

- All changes in the code have to be verified
  - refactoring
  - actualization
- Essential difficulties
  - programmers very often produce imperfect work
  - defects (bugs) usually arise
- Verification finds bugs



Verification techniques

- Many techniques of software verification have been researched and proposed
- Current practice
  - testing
  - code inspection

Testing

- Tests execute the program or its parts
  - specific input to the execution
  - compare the outputs of the execution with the previously specified outputs
  - report if there is a deviation
- Tests are usually organized into a *test suite*
  - several, often many, tests.

Incompleteness of the testing

- *"Testing can demonstrate the presence of the bugs, but not their absence."*
- No matter how much testing has been done, residual bugs still can hide in the code
  - they have not been reached and revealed by any tests.
  - no test suite can guarantee that the program runs without errors

Turing's *halting problem*

- Theoretical reasons for testing incompleteness
- It is theoretically impossible to create a perfect test suite
- The programmers have been trying to do the best under the circumstances
  - techniques of the testing cannot guarantee a complete correctness of software
  - well designed tests come close to be adequate

New vs. old code tests

- Tests of the new code
  - new tests must be written with the new code
- Testing of the old code
  - the tests make sure the old code is not broken by the change
  - regression tests
  - prevent regression of what was already functioning in the software.
    - Merriam Webster: "regression" = "a trend or shift toward a lower or less perfect state"

Variety of software testing

- Setting
  - programmer's workspace
  - team's configuration management
- Strategy
  - structural
  - unit
  - functional
- Functionality
  - old (regression testing)
  - new
  - combined

Acceptance tests

- Final functional test
  - both the new and the old
- done during the phase of change conclusion
  - test the complete functionality of the software
  - software stakeholders are able to assess the progress of the software project

Composition of the test suite

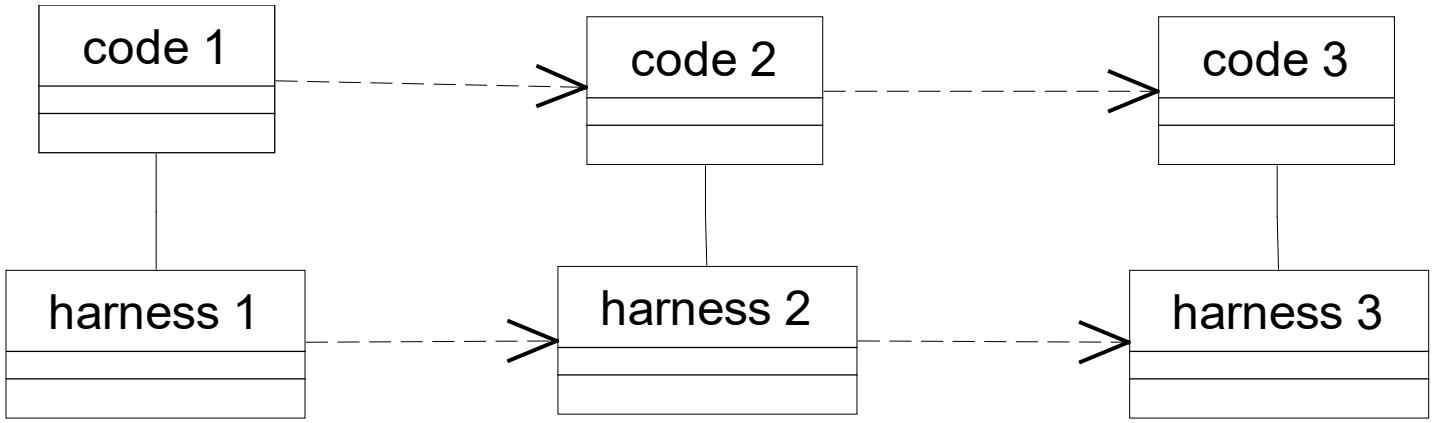
- Unit tests
  - test for a specific class
- Functional tests
  - test a specific functionality of the whole program
    - user manual or graphics user interface guide the creation of the functional tests.
    - all features that are available to the user should be tested
- Structural tests

Harness (scaffolding)

- Test drivers
  - implement the support for the tests
- Stubs
  - implement the replacement for missing classes and subsystems
- Environment simulation
- Harness = drivers + stubs + simulators
  - production code vs. harness
  - developers vs. testers

Harness and production code

- Production code goes to the user
- Harness stays within the programming group
- Parallel evolution of both



Coverage

- We cannot guarantee a complete correctness of the code by testing
- We are going to guarantee that each unit of the tested code is executed at least once
  - this guarantees that at least some of the bugs are discovered
    - in particular, the bugs that are brought up by this single execution of the unit.

Granularity of methods

- calcSubTotal(), calcTotal(), getPrice(), setPrice(double)
  - each of them executed at least once
- Seems like a crude approach
  - systematic
  - guarantees correctness better than random selection of tests

Statement coverage

- Guarantees that every statement of the program is executes at least once
- *Minimal test suite* does not have any redundant tests
  - tests that cover only statements that are already covered by other tests
- Minimal test suite efficiently accomplishes the coverage
  - preferred approach

Example

```
read (x); read (y);
if x > 0 then write ("1");
else     write ("2");
end if;
if y > 0 then write ("3");
else write ("4");
end if;
```

{<x = 2, y = 3>}

- not complete coverage
- does not cover write("2)

{<x =2, y =3>,<x=9,y=1>, <x=-1,y=-1>}

- complete coverage
- not minimal
- <x =9, y=1> is redundant

{<x =2, y =3>, <x=-1,y=-1>}

- complete and minimal

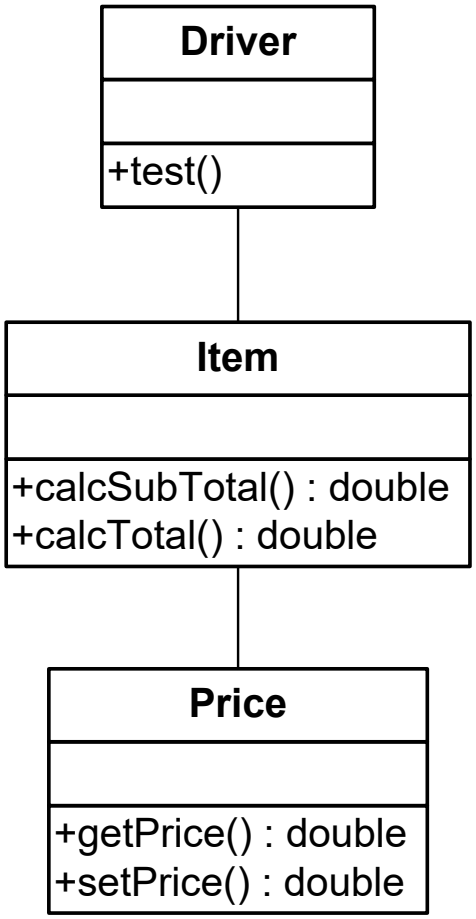
Minimal complete test suite

- Easy to write the first test
  - no matter what it covers, it adds to the test suite coverage
- Increased number of tests
  - the statements not covered are fewer
  - it is increasingly hard to aim new tests at these remaining uncovered statements
  - increased coverage is not economic
- 70% coverage is considered to be good

Unit testing

- Testing of individual modules
  - testing classes and methods
- Testing of the composite functionality
  - the class is being tested together will all classes that support it
- Testing local functionality

Testing driver



Testing driver example

```
public class TestItem {
   Item testItem;
   public void testCalcSubTotal() {
      assert(testItem.calcSubTotal(2, 3) == 6);
      assert(testItem.calcSubTotal(10, 20) ==30);
   }
   public void testCalcTotal() {
      assert(testItem.calcTotal(0, 5) == 5);
      assert(testItem.calcTotal(15, 25) == 40);
   }
} ;
```

Testing local responsibility

- Driver + stub
  - stub simulates suppliers
    - part of harness
- Reasons: supplier classes
  - are not available
  - have not been tested
    - the confidence in them is low
  - support a limited contract (limited precondition)
    - the tested class planned for a wider use with other suppliers

Stubbing techniques

- Less effective algorithm
  - easier to implement
  - test becomes less efficient
    - developers do testing, acceptable impact
- Limited precondition of the stub
  - simplifies the code of the stub substantially
    - convert the date into a day of the week
      - the stub does that only for a selected month
    - inappropriate if the stubbing is to broaden the contract

Stubbing techniques, cont.

- User intervention
  - interrupts the test, the user provides the correct answer
    - practical only in if the stub is executed only few times during the test
    - human user may input incorrect values
- Replacement contract
  - quick but incorrect postcondition
  - the most controversial stubbing technique
  - still may provide valuable results

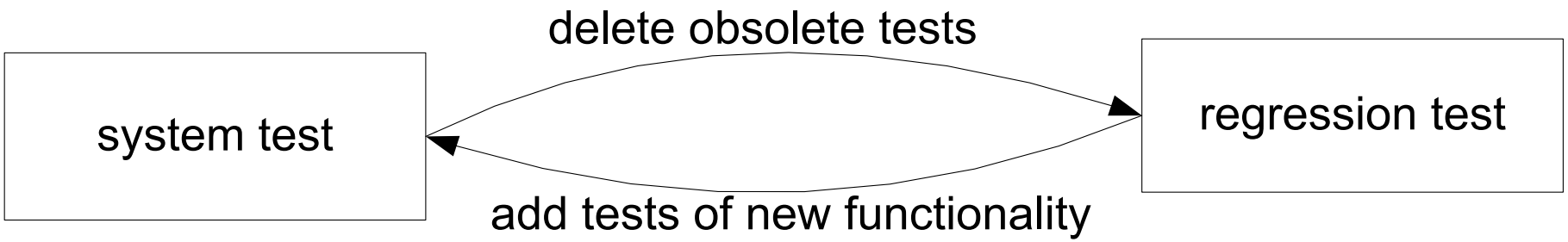
Functional testing

- Tests the functionality of the complete program
- Program with GUI: test every function
  - "tape recording" for future tests
- Coverage
  - percentage of the requirements tested

Regression Testing

- After a change, programmers retest the code
  - reestablish the confidence that the former functionalities of the software still work
  - change may have inadvertently introduced stray bugs into the intact parts
- Tests from the past constitute the bulk of the regression test suite
  - test suite often grows
  - testing is done overnight

Test suite evolution



Obsolete tests

- Broken test cases that cannot run
  - They do not interface with the software any more
- Tests that do not fulfill their purpose
  - a test case testing the limits of a range becomes obsolete when the range is changed.
- Tests that no longer provide a deterministic result
  - a test case which may now impacted by the mouse

Code inspection

- Somebody else than the author reads the code
  - checks its correctness
  - reports bugs
- Code inspection does not require execution of a system
  - can be applied to incomplete code or to other artifacts
    - Models
    - Documentation

Effectiveness of code inspection

- "Habituation"
  - people become blind to their own mistakes
- After reading the code several times
  - programmers no longer read the code
    - recall from the memory what the code should contain
    - some errors repeatedly escape their attention
  - a different reader spots these errors easily and right away.

Inspections and testing are complementary

- Some bugs are easily found by testing
  - they appear in each test
    - they are sometimes hard to spot by humans
    - example: misspellings of long identifiers
- Some bugs are hard to find by testing
  - it is hard to create a test that finds them
    - human readers can find them easily
    - example: a division by zero
    - to create a test that causes such situation can be hard

Inspection of different artifacts

- Inspections can also check whether different artifacts agree with each other
  - does the code correspond to the change request?
  - does the UML model correspond to the actual code?
- Inspections cannot check non-functional characteristics
  - performance and usability.