Software Testing: Introduction

Mohammad Mousavi

Halmstad University, Sweden

http://bit.ly/TAV16

Testing and Verification,
January 22, 2016

Contact information

Courses Web Pages

`http://bit.ly/TAV16`

Check for news, updates, course material and much more!

Mohammad Mousavi

Office	Halmstad University, E 305 Fridays: Jupiter, 428
E-mail	M.R.Mousavi@hh.se
Telephone	(035 16) 7122
WWW	http://ceres.hh.se/mediawiki/Mohammad_Mousavi

Objectives and assessment

Learning objectives: Knowledge

1. describe the distinction between software verification and software validation name and
2. describe the basic concepts on testing, as well as different testing techniques and approaches
3. describe the connection between software development phases and kinds of testing, and
4. exemplify and describe a number of different test methods.

Objectives and assessment

Learning objectives: Skills

1. write models in timed automata
2. construct appropriate and meaningful test cases, and interpret and explain
3. plan and produce appropriate documentation for testing

Objectives and assessment

Learning objectives: Judgment

1. exemplify and describe tools used for testing software, and
2. exemplify and describe the area of formal verification, including model checking, and
3. identify and hypothesize about sources of program failures

Objectives and assessment

- Practical assignments (U, G, or VG):
  VG only if you have VG in 2 out of 3 assignments,
  G if you have G or VG in all 3 assignments (and the above rule does not apply),
  U otherwise
- Written exams (U, G, or VG):
  VG if you score 80 or higher,
  G if you score 60 to 79, and
  U otherwise.

The final mark (U, G, or VG):
VG if you score VG in both parts,
G if you score G or VG in both part (but not VG in both),
U otherwise.

Project: GUCar Protocol

General Description

A USB-based communication protocol between the Aduino and the Odroid process-boards,

- test-driven development in Java using jUnit,
- integration testing using Mockito,
- Visual UI testing using Sikuli, and
- model-checking using UPPAAL.

Project: GUCar Protocol

General Description: Phase 1

TDD of the Arduino module with the following interfaces:

- Send Sensor Data (torque, ultra_distance and ir_distance),
- Read speed and torque,
- Write to input buffer, and
- Read from output buffer

Test design, TDD and self-evaluation.

Project: GUCar Protocol

Schedule and Deadlines

- Forming Groups of 4: Jan. 29 at 17:00
- Phase 1: TDD of a Unit: Feb. 5,
- Phase 2: Integration Testing (Mocking): Feb. 19
- Phase 3: UI Testing and Model Checking: Mar. 5

Final exam: March 15.

Project: GUCar Protocol

Schedule and Deadlines

By the deadline:

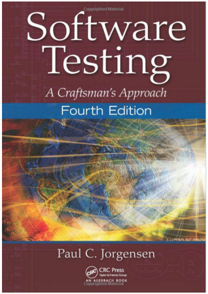
- Deliverable to be presented by all group members to the lecturer.

Our Order of Business

- Terminology and Functional Testing
- Test-Driven Development and jUnit
- Coverage Criteria
- Model Checking
- GUI Testing
- Slicing and Debugging
- Reviewing Model Examination
- Guest Lectures

General Information

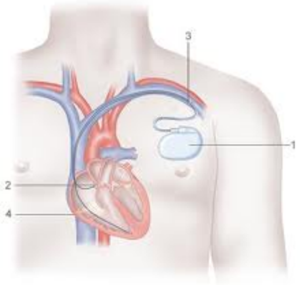
- Text book: P.C. Jorgensen. Software Testing: A Craftsmans Approach. Auerbach Publications, 4th edition, 2013.
- Recommended: P. Ammann and J. Offutt, Introduction to Software Testing, Cambridge University Press, 2008.
- Papers and other recommended books posted on the course page.



Software at Your Heart. . .

Software glitches in pacemakers

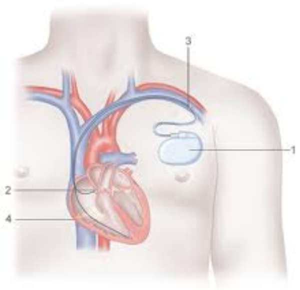
Company said it has not received any reports of deaths or clinical complications resulting from the glitch, which appears in about 53 out of every 199,100 cases.



Software at Your Heart. . .

At least 212 deaths from device failure in five different brands of implantable cardioverter-defibrillator (ICD) according to a study reported to the FDA . . . .

[Killed by Code, 2010]



Why?

“Bugs”

- Facts of life! (correct by construction: not always possible / affordable)
- Serious consequences (Pentium bug, OV Chipcard, etc.)

Why?

A Classic Bug

- Ariane 5 explosion report:

> *This loss of information was due to specification and design errors in the software ... caused during execution of a data conversion from 64-bit floating point to 16-bit signed integer value. The floating point number which was converted had a value greater than what could be represented ...*

Why?

The NorthWest Blackout "Bug"

- Widespread blackouts in 2003
- Affecting 8 US states and a part of Canada
- Traced back to a race condition bug
- Surfaced after 3 million hours of operation

Moral of the Story

If it can go wrong, it will go wrong.

Why?

"Bugs"

- 2002 Costs: 60 Billion USD (only USA).
- *Coders introduce bugs at the rate of 4.2 defects per hour of programming. If you crack the whip and force people to move more quickly, things get even worse. [Watts Humphreys]*

Why?

Quest for Quality

- *Software quality will become the dominant success criterion in the software industry. [ACM Workshop on Strategic Directions in Software Quality]*
- Testing:
  - a way to achieve better quality
  - >50% of the development costs

Why?

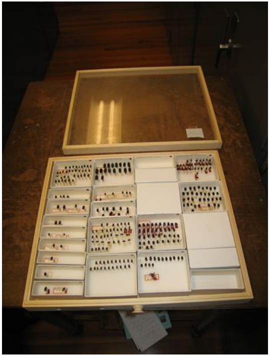
Bezier's Testing Levels

- L0 debugging (ad hoc, few input/outputs)
- L1 showing that software works (validating some behavior)
- L2 showing that software does not work (scrutinizing corner cases)
- L3 reducing risks (organizing and prioritizing test goals)
- L4 mental discipline for quality (central to development)

What?

Sorts of "Bug"

- Fault: incorrect implementation
  - commission: implement the wrong specification
  - omission: forget to implement a specification
    (the more difficult one to find and resolve)
- Error: incorrect system state (e.g., incorrect value for a variable)
- Failure (anomaly, incident) : visible error in the behavior



How?

Spec: A program that inputs an integer, and outputs $2 * i^3$.

```
int i;
i << cin;
i = 2 * i;
i = exp(i,3);
cout << i;
```

How?

Spec: A program that inputs an integer, and outputs $2 * i^3$.

```
1: int i;
2: i << cin;
3: i = 2 * i;
4: i = exp(i,3);
5: cout << i;
```

- Conceptual mistake: confusing the binding power of operators
- Fault: Statements 3 and 4 are in the wrong order
- Failure:
  Test-case: on input 1, the program must output 2.
  input 1 ... output 8!

What?

Validation vs. Verification

- Validation: Have we made the right product; compliance with the intended usage
  often: user-centered, manual process, on the end product
- Verification: Have we made the product right; compliance between artifacts of different phases
  often: artifact-driven, formalizable and mechanizable process among all phases

What?

Testing

- Planned experiments to:
  1. reveal bugs (turn faults into failures, test to fail),

     Testing can show the presence of bugs, but not the absence. *[Dijkstra]*

  2. gain confidence in software quality (test to pass)

What?

RIP Process

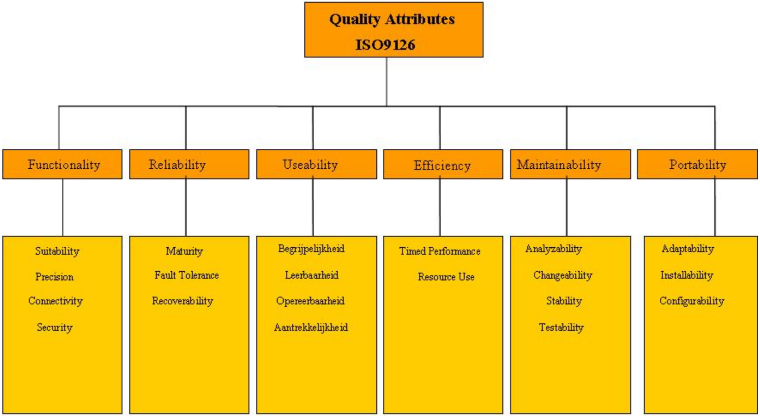
- Reachability: triggering the statements containing the fault,
- Infection: triggering the fault to produce incorrect state
- Propagation: carrying the fault to the visible behavior (output)

What?

- Test case (the plan):
  input (execution condition / behavior) and output (pass / fail conditions)
- Testing: planning and executing test-cases (how?).

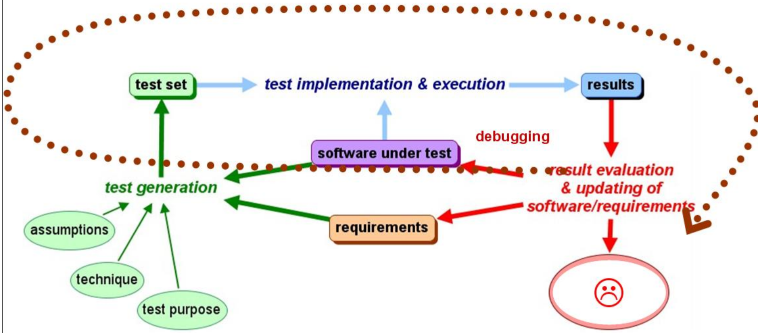
What?

Quality Attributes



How?

Testing


test set
test implementation & execution
results
software under test
debugging
result evaluation & updating of software/requirements
test generation
requirements
assumptions
technique
test purpose
☹

How?

Testing


Test Policy
Test Management
Test Method
Test Tooling and Utilities

How?

- Testing: planning and executing test-cases.
  1. designing test-cases (manual, automatic: models, formal specs),
  2. executing them (manual or automatic: scaffolding, fixture),
  3. distinguishing failures or correct executions (manual: experts, automatic: oracles, models)
  4. giving feed back for debugging / changing specification

How?

Moral of the Story

Testing aims at covering some (abstract) artifacts; examples:

- Functional testing: requirements (logical partitions, formulae, graphs, trees)
- Structural testing: program (control or data flow graphs)

How?

Coverage Criterion

A set of predicates on test cases (formalization of a test requirement)

Examples:

1. For a software with an integer input x:
   $C = \{x < 0, x = 0, 0 \leq x \leq 10, x = 10, x > 10\}$
2. For a program with a set of statements S $C = \{s \text{ is executed at least once} \mid s \in S\}$.

How?

Coverage

A test suite T satisfies a coverage criterion C, if for each $c \in C$, there exists a $t \in T$ such that t satisfies C.

Examples:

1. The set of (x, y) input-output $\{(-1,-1),(0,0),(10,100),(11,-1)\}$ satisfies $C = \{x < 0, x = 0, 0 < x < 10, x = 10, x > 10\}$
2. A test suite that runs every control-flow simple path satisfies $C = \{s \text{ is executed at least once} \mid s \in S\}$.

How?

Aspects of Testing

- Functional testing:
  assumption: software is a function from inputs to outputs
  coverage criterion defined based onspecification
  suitable for black-box testing (but can be enhanced with information from the code)
  - + program independent: tests can be planned early
  - + tests are re-usable
  - - gaps: untested pieces of software
  - - redundancies: the same statements may be tested several times

Functional Testing: Mortgage Example

Spec. Write a program that takes
three inputs: gender (boolean), age([18-55]), salary ([0-10000])
and output the total mortgage for one person

Mortgage = salary * factor,
where factor is given by the following table.

Category	**Male**	**Female**
Young	(18-35 years) 75	(18-30 years) 70
Middle	(36-45 years) 55	(31-40 years) 50
Old	(46-55 years) 30	(41-50 years) 35

From: P.C. Jorgensen. Software Testing: A Craftsmans Approach.

An Implementation

Mortgage (male:Boolean, age:Integer, salary:Integer): Integer
if male **then**
return $((18 \leq age < 35)?(75 * salary) : (31 \leq age < 40)?(55 * salary) : (30 * salary))$
else {female}
return $((18 \leq age < 30)?(75 * salary) : (31 \leq age < 40)?(50 * salary) : (35 * salary))$
end if

Is this implementation correct? No way, 12 bugs!

Functional Testing

Mortgage (male:Boolean, age:Integer, salary:Integer): Integer
if male **then**
return $((18 \leq age < 35)?(75 * salary) : (31 \leq age < 40)?(55 * salary) : (30 * salary))$
else {female}
return $((18 \leq age < 30)?(75 * salary) : (31 \leq age < 40)?(50 * salary) : (35 * salary))$
end if

Possible coverage:
for each age range and for each gender and salary 1, the input combination is in this range
output: factors as given by the table
(similar to equivalence testing; wait till next sessions!)

How?

Aspects of Testing

- Structural testing:
  coverage criterion based on abstraction of program
  examples: code coverage, branch coverage
  - \+ giving insight to the effectiveness of test
  - \- more complicated than functional testing
  - \- incapable of detecting errors of omission

Structural Testing

Spec.: input: an integer x $[1..2^{16}]$
output: x incremented by two, if x is less than 50, x decremented by one, if x is greater than 50, and 50, otherwise.

```
if x < 50 then
   x = x + 1;
end if
if x > 50 then
   x = x - 1;
end if
return x
```

Structural Testing

```
if x < 50 then
   x = x + 1;
end if
if x > 50 then
   x = x - 1;
end if
return x
```

Coverage criterion: all statements are at least executed once, manually check the outputs with the spec.

Input	Output	Pass/Fail
1540	1539	P
2783	2782	P
3222	3221	P
30	31	F

Structural Testing

First "Debugged" Version:

```
if x < 50 then
  x = x + 2;
end if
if x > 50 then
  x = x - 1;
end if
return x
```

Input	Output	Pass/Fail
1540	1539	P
2783	2999	P
3222	3221	P
30	32	P

Have we tested enough?

Structural Testing

```
if x < 50 then
   x = x + 2;
end if
if x > 50 then
   x = x - 1;
end if
return x
```

Input	Output	Pass/Fail
49	50	F

Pesticide paradox: debugging old faults may produce new bugs (or "wake" old bugs up).

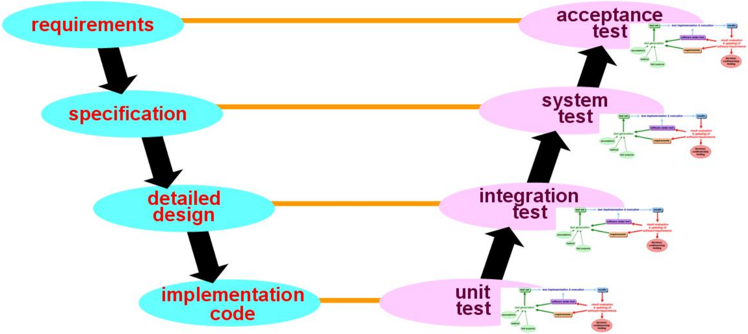
How?

Ideal Mix

- Functional and structural testing at various levels (unit, integration, system)
- Structural measures for the effectiveness of functional test-cases

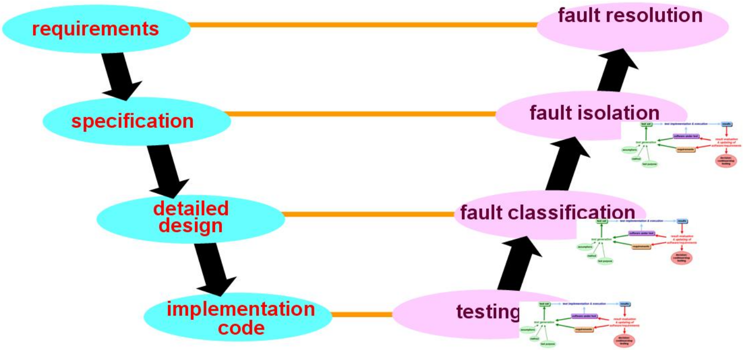
When?

V Model


requirements
specification
detailed design
implementation code
acceptance test
system test
integration test
unit test

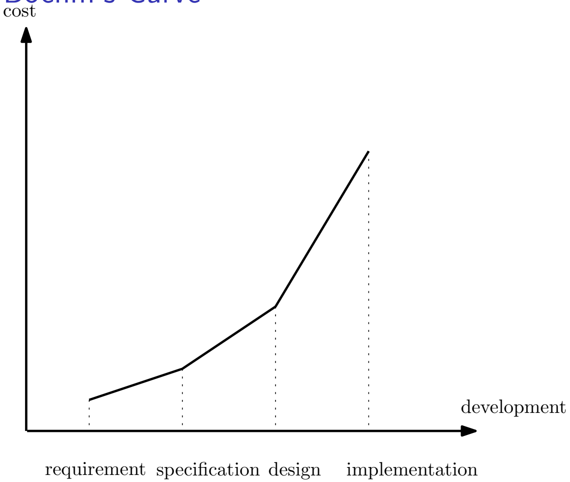
When?

V Model


requirements
specification
detailed design
implementation code
testing
fault classification
fault isolation
fault resolution

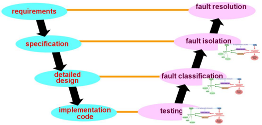
When?

Boehm's Curve



When?

Dealing with Bugs



1-4 Putting errors in (producing bugs),

5-7 finding bugs:
- testing
- fault classification
- fault isolation

8 removing bugs

What Else?

Alternatives

- Static Analysis:
  test abstract properties without running the program,
  e.g., uninitialized/unused variables, empty/unspecified cases, coding standards, checking for design (anti)patterns.
  + automatic and scalable for generic and abstract properties;
  + existing powerful tools;
  - involves approximation (true negatives and false positives); complicated (may involve theorem proving) for concrete and specific properties (proving the abstraction function to be "correct")

What Else?

Alternatives

- Model Checking:
  test the state-space for formally specified properties.
  - + rigorous analysis, push-button technology;
  - - not (yet) applicable to many industrial cases (state-space explosion)