DD2459

Software Reliability

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Lecture 1: Introduction.

Course Material

- This course is mainly about software testing
- We cover the whole testing activity
- We emphasize test design as a practical skill
- We consider classical and modern approaches to testing
- We don’t have time to cover everything!

Course Format

- 7 lectures – fundamental theory + math
- 7 exercise classes: alternate weeks
  - 1 week practical instructions
  - 1 week practical lab work
- Labs are mini projects (3 points)
  - Work in pairs
  - Build or use existing tools
- Short take-home exam (4.5 points)

Course Book

Main Book

Amman and Offut, *Introduction to Software Testing*, Cambridge University Press, 2nd edition, 2016.

… you can also look at …

R. Bierig et al., *Essentials of Software Testing*, Cambridge University Press, 2022.

Today's class

1. What is testing?
2. Why do we need to test?
3. What are the basic concepts?

Who hasn’t heard of testing?

Black-box testing	Load Testing
Regression testing	Security testing
Functional testing	Mutation testing
Random testing	Unit testing
Alpha/Beta testing	Integration testing
Acceptance testing	System testing
Performance testing	Usability testing

Varieties of System Under Test

- Procedural (C code, FORTRAN, etc)
  - Precondition and postcondition
- Reactive (ATM machine, fly-by-wire)
  - “always on” - event driven behaviour
- Real-time (soft/hard)
- Communications protocol
- Numerical (approximately correct)
- Object-oriented (class and method invariants)
- Distributed system (non-deterministic)
- GUI, user event generation must be simulated

Some Views on Testing …

- "*Testing can show the presence of bugs but not their absence*" (Dijkstra).

- *"Testing is an infinite process of comparing the invisible to the ambiguous in order to avoid the unthinkable happening to the anonymous"*
- (*James Bach [3]*)

… and Definitions

- Testing concerns the design, execution and subsequent analysis of individual test cases to evaluate a system.
- Testing concerns dynamic code execution (in situ) rather than static analysis
- Testing has different goals according to one's level of test maturity.

IEEE SWEBOK 2004

- Testing is an activity performed for evaluating product quality, and for improving it, by identifying defects and problems …

- Software testing consists of the *dynamic* verification of the behavior of a program on a *finite* set of test cases, suitably *selected* from the usually infinite executions domain, against the *expected* behavior.
- www.swebok.org

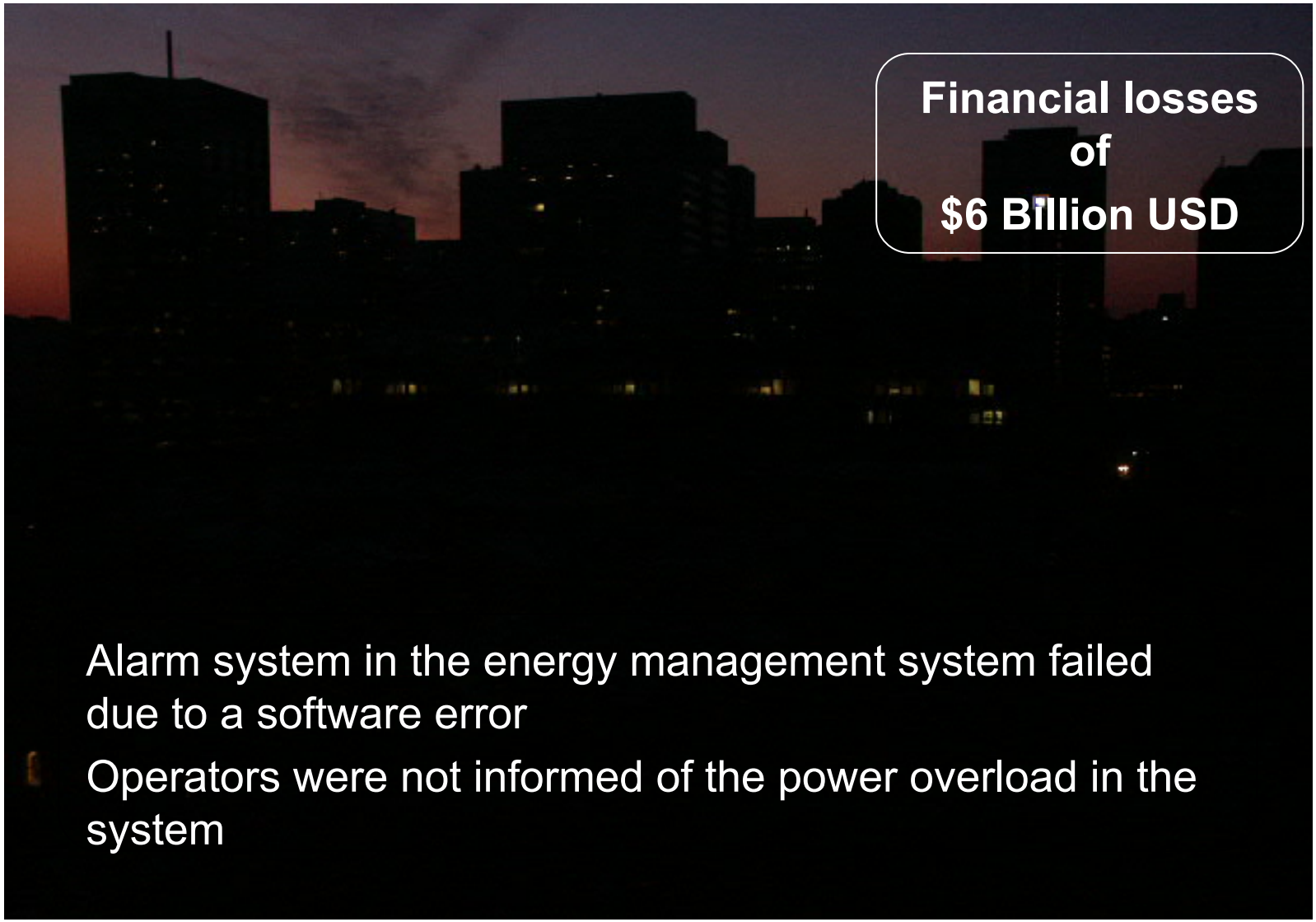
How to study?

- Bewildering variety of themes
- Try to find similarities of approach
- Reusable concepts and techniques
  - E.g. graph models and coverage models
- Focus on functional (behavioural) testing
- Focus on test design
- Use lab work to focus our studies

Why do we test?:
The Price of Failure

- NIST report (2002) – inadequate testing costs USA alone $22 - $59 billion dollars annually
- Improved testing could half this cost

- **USA Northeast Blackout 2003**



FT Magazine Health + Add to myFT

How one patient found errors in the algorithm making transplant decisions

Sarah Meredith was in urgent need of a liver when she found out an algorithm would be making the life-or-death decision

Financial Times 2023-11-09

CrowdStrike July 2024

CNN Business Markets Tech Media Calculators Videos Wa

We finally know what caused the global tech outage - and how much it cost

By Brian Fung, CNN

4 minute read · Updated 7:30 PM EDT, Wed July 24, 2024

a bug in CrowdStrike's **cloud-based testing system** — ended up allowing the software to be pushed out "despite containing problematic content data."

the largest IT outage in history will cost Fortune 500 companies alone more than **$5 billion in direct losses**

Conclusions

- *Software is a skin that surrounds our civilisation* (Amman and Offut)
- We need software to be reliable
- Testing is main method to assess reliability
- Testing is becoming more important
- Resources (manpower) for testing increases linearly
- Complexity of software increases exponentially
- Automated testing is inevitable

Basic Testing Concepts

- Activities
- Technical Definitions

(Traditional) Test Activities – 4 Types

- Test design
  - Criteria based
  - Human based
- Test automation
- Test execution
- Test evaluation
- Need different skills, background knowledge, education and training.

1.a. Test Design – Criteria based

- Design test values to satisfy coverage criteria or other engineering goal
- Testing is a search problem, coverage measures search effort
- Most technical and demanding job of all
- Needs skills in
  - Discrete math
  - Programming
  - Testing
- Traditional Computer Science Degree

1.b. Test Design – Human based

- Design test values based on domain knowledge of program and human knowledge of testing
- Criteria based approaches can be blind to situations
- Requires knowledge of domain, testing and user interfaces
- No traditional CS required

Human-based (cont)

- Background in the software domain is essential
- Empirical background is helpful (biology, psychology etc)
- A logic background is helpful (law, philosophy, math)
- Work is experimental and intellectually stimulating.

2. Test Automation

- Embed test values into executable scripts
- Straightforward programming
  - Small pieces, simple algorithms
  - Junit, JBehaviour
- Needs little theory
- Who determines and embeds the expected outputs?
- What if system is non-deterministic?

3. Test Execution

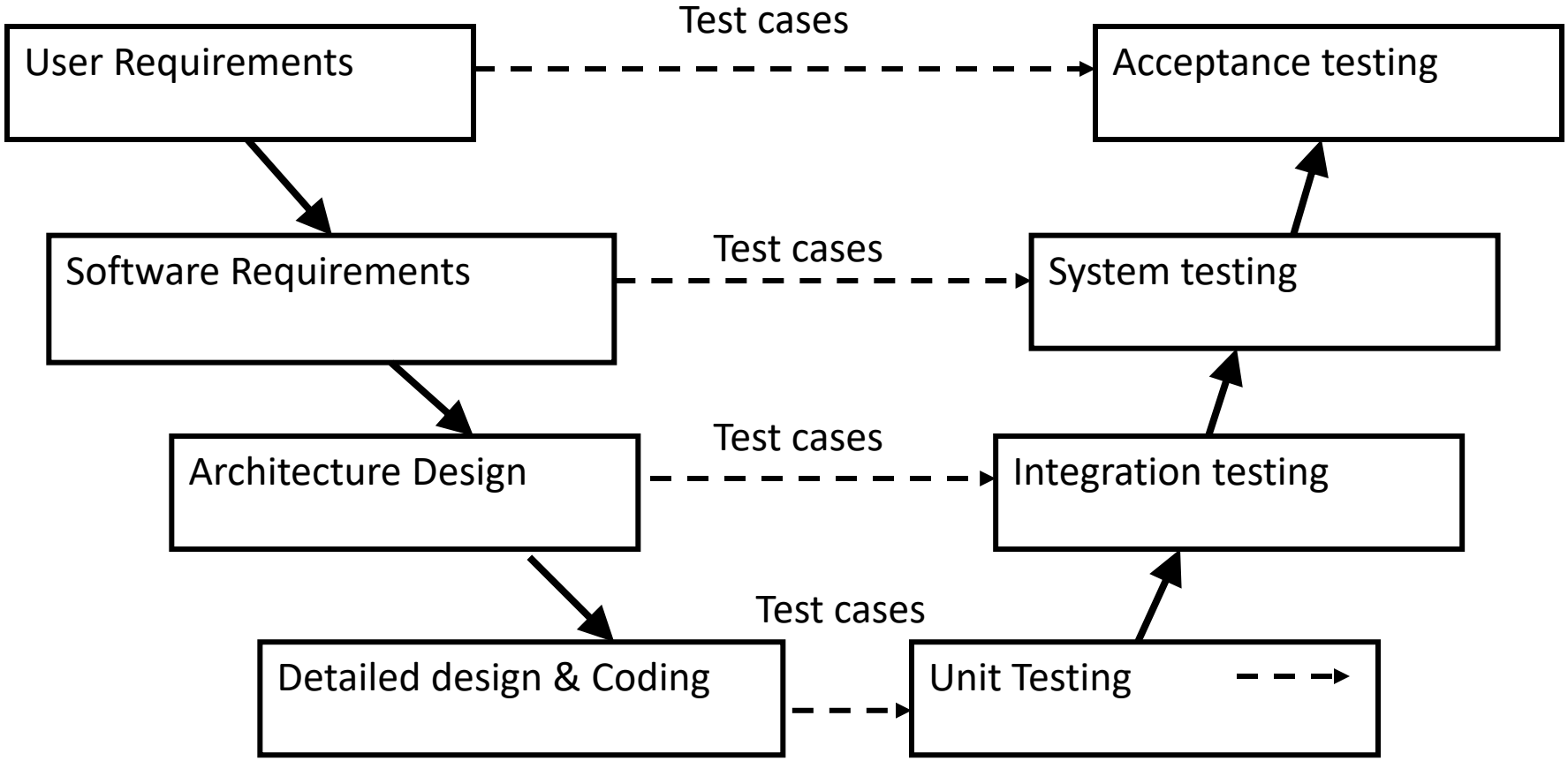
- Run tests on the SUT and record results
- Easy and trivial if tests automated
- Very junior personnel
- Test executors must be careful and meticulous with book-keeping (e.g. time of day error?)
- A test is an experiment in the real world.

4. Test Evaluation

- Evaluate outcome of testing and report to developers
- Test report
- Psychological problems – blame etc
- Test goals must be clear to assist debugging

Other Activities

- Test management: policy, group structure, integration with development, budget, scheduling.
- Test maintenance: test reuse, repositories, continuous integration, historical data, statistics, regression testing.
- Test documentation:
  - Document “why” criteria
  - Ensure traceability to requirements or architectural models.
  - Evolve with the product.



The ”V” model of Testing

Integrates testing with waterfall lifecycle

Time

Test Maturity Model (TMM)

- Level 0: no difference between testing and debugging
- Level 1: purpose is to show software works
- Level 2: purpose is to show software fails
- Level 3: purpose is to reduce risk of use
- Level 4: purpose is a mental discipline for quality.

Technical Definitions

1. Software Fault: *a static defect in software*
2. Software Error: *an incorrect internal state manifesting a fault*
3. Software Failure: *External incorrect behaviour wrt requirements.*

Patient has a symptom of thirst (3), doctor finds high blood glucose (2), doctor diagnoses diabetes (1)

- Test Failure: *execution resulting in failure*
- Debugging: *process of locating and fixing a fault from a test failure*
- Test case values: *input values needed to complete execution of the SUT*
- Expected results: *results that should be produced iff SUT meets its requirements*

- Prefix (setup) values: *input necessary to bring SUT to an appropriate state to receive test case values*
- Postfix (teardown) values: *input needed to be sent after the test case values*
  - Verification values: *needed to recover the results*
  - Exit values: *needed to terminate or return to a stable state*.

Def^{n}: Test Case

- Test Case: *the test case values, setup values, teardown values and expected values needed for one observation of the SUT.*

  ***Note**: a test case should ideally bring a program to termination if possible.*

- Test Suite: *a set of test cases*.
- Dead Code: code which can never be executed by any test case (aka. unreachable code).

Coverage

- Test requirement: *A specific (structural) element r of an SUT that a test case must cover.*
- Eg: *lines, paths, branches, variable values*.
- Coverage Criterion: *a set of rules that impose test requirements on a test suite*, e.g. node coverage
- Coverage: *Given a set R of test requirements coming from a criterion C, a test suite T satisfies C iff for each* $r \in R$ *there exists at least one* $t \in T$ *which satisfies r.*