Application programming in engineering;

Delivering quality

17.1.2019

Reading material for the basic lectures:

- Book: Ian Sommerville, Software Engineering, 10th edition, chapter 4 & 24.
- Slides of the book: http://iansommerville.com/software-engineering-book/slides/

Content

- Software quality
- Functional and non-functional requirements
- Requirements engineering processes
- Software testing and review

Quality is the degree of excellence of something. We measure the excellence of software via a set of attributes.

!= satisfying requirements – it is part of the software engineering process to get the "right" requirements

!= customer satisfaction – restaurant might be popular but is it quality?

Software quality

- IEEE
  1. *The degree to which a system, component, or process meets specified requirements.*
  2. *The degree to which a system, component, or process meets customer or user needs or expectations.*
- Pressman
  - *Conformance to explicitly stated functional and performance requirements, explicitly documented development standards, and implicit characteristics that are expected of all professionally developed software*

Why is software different?

- The actual product, code, is practically invisible to the user
- Limited opportunities to detect bugs or defects
- Often software is extraordinary highly complex piece of engineering
- Changes often lead to new demanding functionality
- Requirements are hard to specify
  - Tension between customer quality requirements and developer quality requirements
  - Software specifications are often incomplete and inconsistent

Software quality assurance

- IEEE
  1. *A planned and systematic pattern of all actions necessary to provide adequate confidence that an item or product conforms to established technical requirements.*
  2. *A set of activities designed to evaluate the process by which the products are developed or manufactured.*
- *Galin*
  - *A systematic, planned set of actions necessary to provide adequate confidence that the software development process or the maintenance process of a software system product conforms to established functional technical requirements as well as with the managerial requirements of keeping the schedule and operating within the budgetary confines.*

What is a requirement?

- It may range from a high-level abstract statement of a service or of a system constraint to a detailed mathematical functional specification.
- This is inevitable as requirements may serve a dual function
  - May be the basis for a bid for a contract - therefore must be open to interpretation;
  - May be the basis for the contract itself - therefore must be defined in detail;
  - Both these statements may be called requirements.

Type of requirement

- User requirements
  - Statements in natural language plus diagrams of the services the system provides and its operational constraints. Written for customers.
- System requirements
  - A structured document setting out detailed descriptions of the system's functions, services and operational constraints. Defines what should be implemented so may be part of a contract between client and contractor.

Type of requirement (another classification)

- Functional requirements
  - Statements of services the system should provide, how the system should react to particular inputs and how the system should behave in particular situations.
  - May state what the system should not do.
- Non-functional requirements
  - Constraints on the services or functions offered by the system such as timing constraints, constraints on the development process, standards, etc.
  - Often apply to the system as a whole rather than individual features or services.
- Domain requirements
  - Constraints on the system from the domain of operation

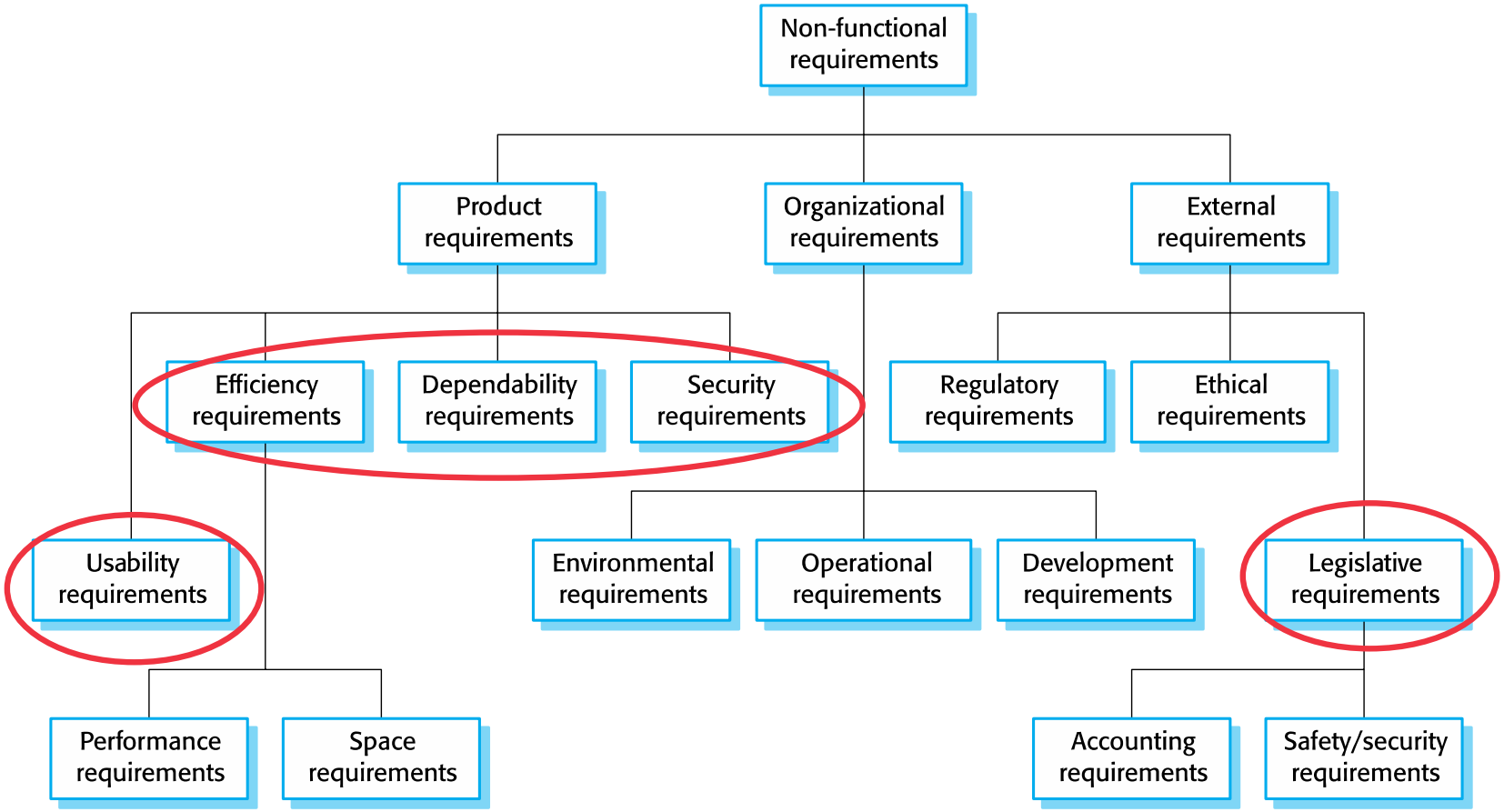
Requirements imprecision

- Problems arise when functional requirements are not precisely stated.
- Ambiguous requirements may be interpreted in different ways by developers and users.
  - What is used as input, what is the end result, what does each term used mean, inconsistent usage of terms…
- In principle, requirements should be both complete and consistent.
  - They should include descriptions of all facilities required.
  - There should be no conflicts or contradictions in the descriptions of the system facilities.
- In practice, because of system and environmental complexity, it is impossible to produce a complete and consistent requirements document.

Non-functional requirements

- These define system properties and constraints e.g. reliability, response time and storage requirements. Constraints are usable device resources, system representations, etc.
- Process requirements may also be specified mandating a particular IDE, programming language or development method.
- Non-functional requirements may be more critical than functional requirements. If these are not met, the system may be useless.

Types of non-functional requirements



Non-functional requirements implementation

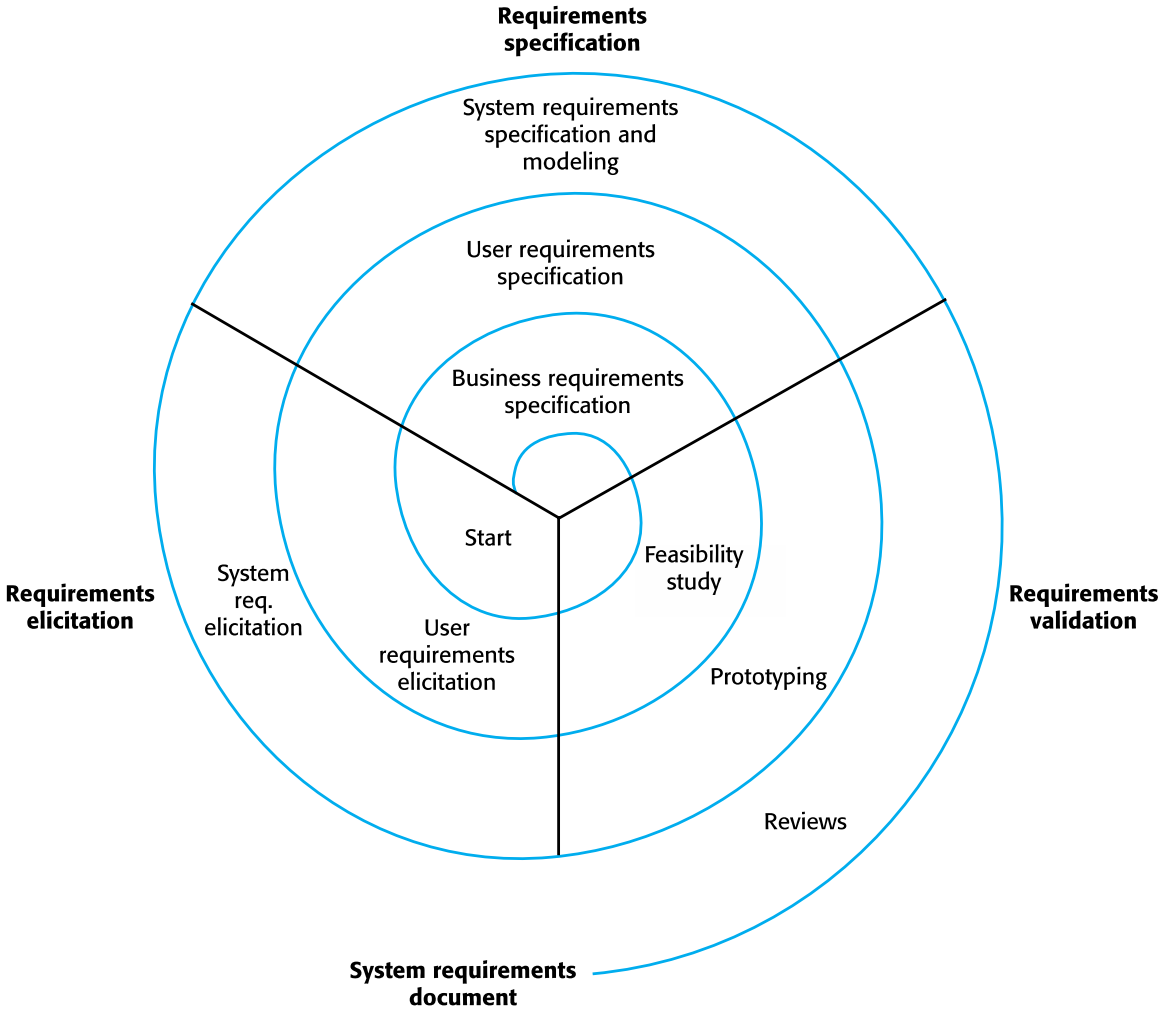
- Non-functional requirements may affect the overall architecture of a system rather than the individual components.
  - For example, to ensure that performance requirements are met, you may have to organize the system to minimize communications between components.
- A single non-functional requirement, such as a security requirement, may generate a number of related functional requirements that define system services that are required.
  - It may also generate requirements that restrict existing requirements.

Non-functional classifications

- Product requirements
  - Requirements which specify that the delivered product must behave in a particular way e.g. execution speed, reliability, etc.
- Organisational requirements
  - Requirements which are a consequence of organisational policies and procedures e.g. process standards used, implementation requirements, etc.
- External requirements
  - Requirements which arise from factors which are external to the system and its development process e.g. interoperability requirements, legislative requirements, etc.

What is a requirements engineering process?

- The processes used for RE vary widely depending on the application domain, the people involved and the organisation developing the requirements.
- However, there are a number of generic activities common to all processes
  - Requirements elicitation;
  - Requirements analysis;
  - Requirements validation;
  - Requirements management.
- In practice, RE is an iterative activity in which these processes are interleaved.


Requirements specification
System requirements specification and modeling
User requirements specification
Business requirements specification
Start
Feasibility study
Prototyping
Reviews
Requirements elicitation
System req. elicitation
User requirements elicitation
Requirements validation
System requirements document

Requirements elicitation

- Software engineers work with a range of system stakeholders to find out about the application domain, the services that the system should provide, the required system performance, hardware constraints, other systems, etc.
- Usually user stories and scenaries are the end result
- Challenges
  - Stakeholders don't know what they really want.
  - Stakeholders express requirements in their own terms.
  - Different stakeholders may have conflicting requirements.
  - Organisational and political factors may influence the system requirements.
  - The requirements change during the analysis process. New stakeholders may emerge and the business environment may change.

User stories and scenarios

- Scenarios and user stories are real-life examples of how a system can be used.
- Stories and scenarios are a description of how a system may be used for a particular task.
- Because they are based on a practical situation, stakeholders can relate to them and can comment on their situation with respect to the story.

Requirements specification

- The process of writing down the user and system requirements in a requirements document.
- User requirements have to be understandable by end-users and customers who do not have a technical background.
- System requirements are more detailed requirements and may include more technical information.
- The requirements may be part of a contract for the system development
  - It is therefore important that these are as complete as possible.

Requirements validation

- Concerned with demonstrating that the requirements define the system that the customer really wants.
- Requirements error costs are high so validation is very important
  - Fixing a requirements error after delivery may cost up to 100 times the cost of fixing an implementation error.

Requirements checking

- Validity. Does the system provide the functions which best support the customer's needs?
- Consistency. Are there any requirements conflicts?
- Completeness. Are all functions required by the customer included?
- Realism. Can the requirements be implemented given available budget and technology
- Verifiability. Can the requirements be checked?

Requirements validation techniques

- Requirements reviews
  - Systematic manual analysis of the requirements.
- Prototyping
  - Using an executable model of the system to check requirements.
- Test-case generation
  - Developing tests for requirements to check testability.

Changing requirements

- The business and technical environment of the system always changes after installation.
  - New hardware may be introduced, it may be necessary to interface the system with other systems, business priorities may change (with consequent changes in the system support required), and new legislation and regulations may be introduced that the system must necessarily abide by.
- The people who pay for a system and the users of that system are rarely the same people.
  - System customers impose requirements because of organizational and budgetary constraints. These may conflict with end-user requirements and, after delivery, new features may have to be added for user support if the system is to meet its goals.

Changing requirements

- Large systems usually have a diverse user community, with many users having different requirements and priorities that may be conflicting or contradictory.
  - The final system requirements are inevitably a compromise between them and, with experience, it is often discovered that the balance of support given to different users has to be changed.

Requirements management

- Requirements management is the process of managing changing requirements during the requirements engineering process and system development.
- New requirements emerge as a system is being developed and after it has gone into use.
- You need to keep track of individual requirements and maintain links between dependent requirements so that you can assess the impact of requirements changes. You need to establish a formal process for making change proposals and linking these to system requirements.

Verification and validation

Verification vs. validation

- Verification:
  "Are we building the product right".
  - The software should conform to its specification.
- Validation:
  "Are we building the right product".
  - The software should do what the user really requires.

V & V confidence

- Aim of V & V is to establish confidence that the system is 'fit for purpose'.
- Depends on system's purpose, user expectations and marketing environment
  - Software purpose
    - The level of confidence depends on how critical the software is to an organisation.
  - User expectations
    - Users may have low expectations of certain kinds of software.
  - Marketing environment
    - Getting a product to market early may be more important than finding defects in the program.

Program testing

- Testing is intended to show that a program does what it is intended to do and to discover program defects before it is put into use.
- When you test software, you execute a program using artificial data.
- You check the results of the test run for errors, anomalies or information about the program's non-functional attributes.
- Testing is part of a more general verification and validation process, which also includes static validation techniques, inspections and reviews
- Can reveal the presence of errors NOT their absence.

Program testing goals

- The ultimate (secret) goal of testing is to get the software fail
  - There are, however, different ways to do it

- To demonstrate to the developer and the customer that the software meets its requirements.
  - This means that there should be at least one test for every requirement in the requirements document.
- To discover situations in which the behavior of the software is incorrect, undesirable or does not conform to its specification.
  - Defect testing is concerned with rooting out undesirable system behavior such as system crashes, unwanted interactions with other systems, incorrect computations and data corruption

Validation and defect testing

- The first goal leads to validation testing
  - You expect the system to perform correctly using a given set of test cases that reflect the system's expected use.
- The second goal leads to defect testing
  - The test cases are designed to expose defects. The test cases in defect testing can be deliberately obscure and need not reflect how the system is normally used.

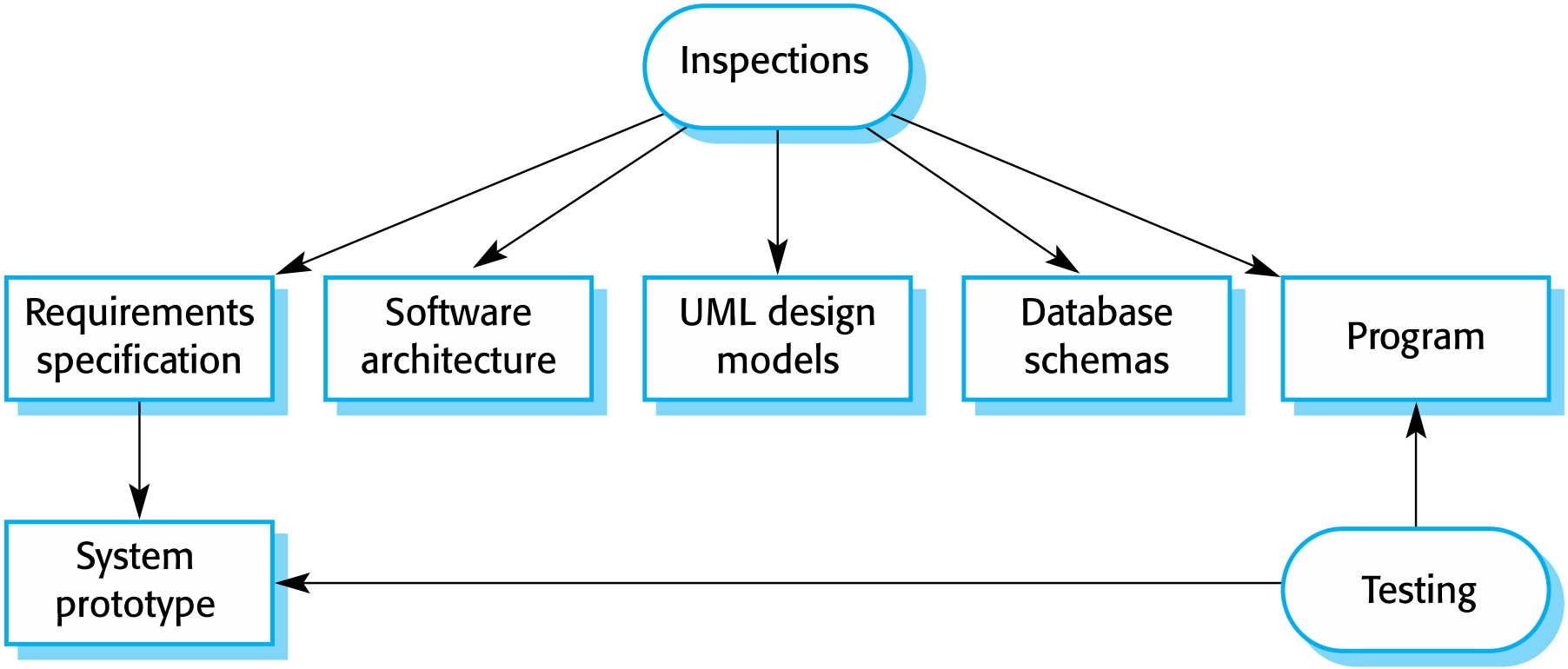
Testing process goals

- Validation testing
  - To demonstrate to the developer and the system customer that the software meets its requirements
  - A successful test shows that the system operates as intended.
- Defect testing
  - To discover faults or defects in the software where its behavior is incorrect or not in conformance with its specification
  - A successful test is a test that makes the system perform incorrectly and so exposes a defect in the system.

Inspections and testing

- Software inspections and reviews
  - Concerned with analysis of the static system representation to discover problems (static verification)
  - May be supplement by tool-based document and code analysis.
- Software testing
  - Concerned with exercising and observing product behaviour (dynamic verification)
  - The system is executed with test data and its operational behaviour is observed.

Inspections and testing



Software inspections

- These involve people examining the source representation with the aim of discovering anomalies and defects.
- Inspections not require execution of a system so may be used before implementation.
- They may be applied to any representation of the system (requirements, design,configuration data, test data, etc.).
- They have been shown to be an effective technique for discovering program errors.

Advantages of inspections

- During testing, errors can mask (hide) other errors. Because inspection is a static process, you don't have to be concerned with interactions between errors.
- Incomplete versions of a system can be inspected without additional costs. If a program is incomplete, then you need to develop specialized test harnesses to test the parts that are available.
- As well as searching for program defects, an inspection can also consider broader quality attributes of a program, such as compliance with standards, portability and maintainability.

Inspections and testing

- Inspections and testing are complementary and not opposing verification techniques.
- Both should be used during the V & V process.
- Inspections can check conformance with a specification but not conformance with the customer's real requirements.
- Inspections cannot check non-functional characteristics such as performance, usability, etc.

Stages of testing

- Development testing
- Release testing
- User testing

What is development testing?

Development testing

- Development testing includes all testing activities that are carried out by the team developing the system.
  - Unit testing, where individual program units or object classes are tested. Unit testing should focus on testing the functionality of objects or methods.
  - Component testing, where several individual units are integrated to create composite components. Component testing should focus on testing component interfaces.
  - System testing, where some or all of the components in a system are integrated and the system is tested as a whole. System testing should focus on testing component interactions.

Unit testing

- Unit testing is the process of testing individual components in isolation.
- It is a defect testing process.
- Units may be:
  - Individual functions or methods within an object
  - Object classes with several attributes and methods
  - Composite components with defined interfaces used to access their functionality.

Automated testing

- Whenever possible, unit testing should be automated so that tests are run and checked without manual intervention.
- In automated unit testing, you make use of a test automation framework (such as JUnit) to write and run your program tests.
- Unit testing frameworks provide generic test classes that you extend to create specific test cases. They can then run all of the tests that you have implemented and report, often through some GUI, on the success of otherwise of the tests.

Choosing unit test cases

- The test cases should show that, when used as expected, the component that you are testing does what it is supposed to do.
- If there are defects in the component, these should be revealed by test cases.
- This leads to 2 types of unit test case:
  - The first of these should reflect normal operation of a program and should show that the component works as expected.
  - The other kind of test case should be based on testing experience of where common problems arise. It should use abnormal inputs to check that these are properly processed and do not crash the component.

General testing guidelines

- Choose inputs that force the system to generate all error messages
- Design inputs that cause input buffers to overflow
- Repeat the same input or series of inputs numerous times
- Force invalid outputs to be generated
- Force computation results to be too large or too small.

Component testing

- Software components are often composite components that are made up of several interacting objects.
  - For example, in the weather station system, the reconfiguration component includes objects that deal with each aspect of the reconfiguration.
- You access the functionality of these objects through the defined component interface.
- Testing composite components should therefore focus on showing that the component interface behaves according to its specification.
  - You can assume that unit tests on the individual objects within the component have been completed.

Interface testing

- Objectives are to detect faults due to interface errors or invalid assumptions about interfaces.
- Interface types
  - Parameter interfaces Data passed from one method or procedure to another.
  - Shared memory interfaces Block of memory is shared between procedures or functions.
  - Procedural interfaces Sub-system encapsulates a set of procedures to be called by other sub-systems.
  - Message passing interfaces Sub-systems request services from other sub-systems

Interface errors

- Interface misuse
  - A calling component calls another component and makes an error in its use of its interface e.g. parameters in the wrong order.
- Interface misunderstanding
  - A calling component embeds assumptions about the behaviour of the called component which are incorrect.
- Timing errors
  - The called and the calling component operate at different speeds and out-of-date information is accessed.

System testing

- System testing during development involves integrating components to create a version of the system and then testing the integrated system.
- The focus in system testing is testing the interactions between components.
- System testing checks that components are compatible, interact correctly and transfer the right data at the right time across their interfaces.
- System testing tests the emergent behavior of a system.

Use-case testing

- The use-cases developed to identify system interactions can be used as a basis for system testing.
- Each use case usually involves several system components so testing the use case forces these interactions to occur.
- The sequence diagrams associated with the use case documents the components and interactions that are being tested.

Testing policies

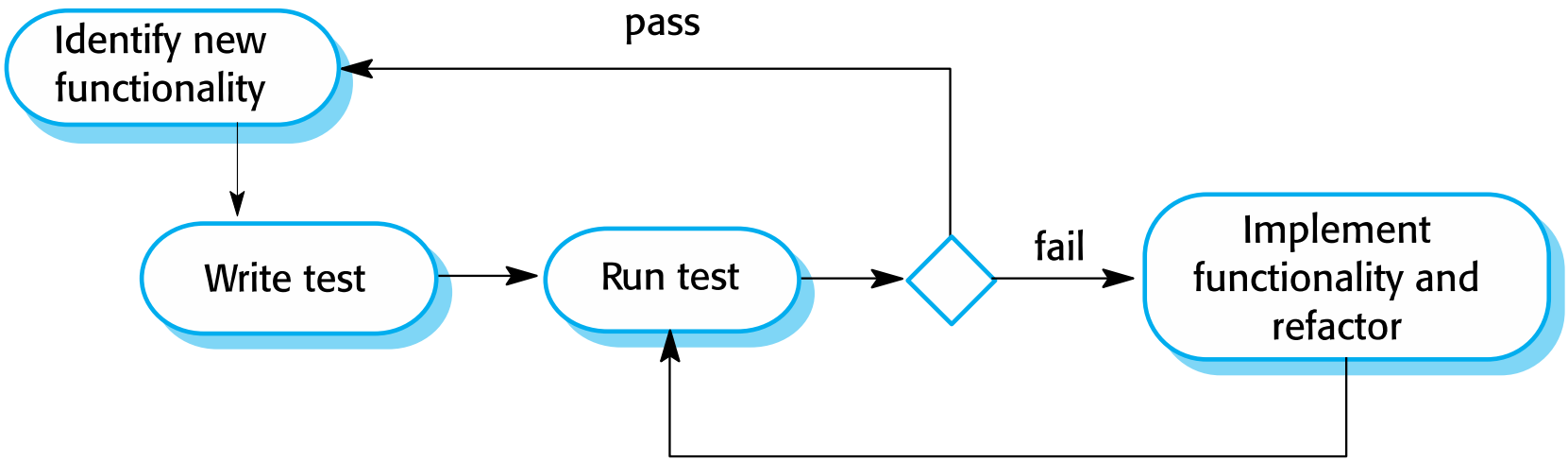
- Exhaustive system testing is impossible so testing policies which define the required system test coverage may be developed.
- Examples of testing policies:
  - All system functions that are accessed through menus should be tested.
  - Combinations of functions (e.g. text formatting) that are accessed through the same menu must be tested.
  - Where user input is provided, all functions must be tested with both correct and incorrect input.

What is test-driven development?

Test-driven development

- Test-driven development (TDD) is an approach to program development in which you inter-leave testing and code development.
- Tests are written before code and 'passing' the tests is the critical driver of development.
- You develop code incrementally, along with a test for that increment. You don't move on to the next increment until the code that you have developed passes its test.
- TDD was introduced as part of agile methods such as Extreme Programming. However, it can also be used in plan-driven development processes.

Test-driven development



Benefits of test-driven development

- Code coverage
  - Every code segment that you write has at least one associated test so all code written has at least one test.
- Regression testing
  - A regression test suite is developed incrementally as a program is developed.
- Simplified debugging
  - When a test fails, it should be obvious where the problem lies. The newly written code needs to be checked and modified.
- System documentation
  - The tests themselves are a form of documentation that describe what the code should be doing.

Regression testing

- Regression testing is testing the system to check that changes have not ‘broken’ previously working code.
- In a manual testing process, regression testing is expensive but, with automated testing, it is simple and straightforward. All tests are rerun every time a change is made to the program.
- Tests must run ‘successfully’ before the change is committed.

What is release testing?

Release testing

- Release testing is the process of testing a particular release of a system that is intended for use outside of the development team.
- The primary goal of the release testing process is to convince the supplier of the system that it is good enough for use.
  - Release testing, therefore, has to show that the system delivers its specified functionality, performance and dependability, and that it does not fail during normal use.
- Release testing is usually a black-box testing process where tests are only derived from the system specification.

What is the difference between release testing and system testing?

Release testing and system testing

- Release testing is a form of system testing.
- Important differences:
  - A separate team that has not been involved in the system development, should be responsible for release testing.
  - System testing by the development team should focus on discovering bugs in the system (defect testing). The objective of release testing is to check that the system meets its requirements and is good enough for external use (validation testing).

Performance testing

- Part of release testing may involve testing the emergent properties of a system, such as performance and reliability.
- Tests should reflect the profile of use of the system.
- Performance tests usually involve planning a series of tests where the load is steadily increased until the system performance becomes unacceptable.
- Stress testing is a form of performance testing where the system is deliberately overloaded to test its failure behavior.

What is user testing?

User testing

- User or customer testing is a stage in the testing process in which users or customers provide input and advice on system testing.
- User testing is essential, even when comprehensive system and release testing have been carried out.
  - The reason for this is that influences from the user's working environment have a major effect on the reliability, performance, usability and robustness of a system. These cannot be replicated in a testing environment.

Types of user testing

- Alpha testing
  - Users of the software work with the development team to test the software at the developer's site.
- Beta testing
  - A release of the software is made available to users to allow them to experiment and to raise problems that they discover with the system developers.
- Acceptance testing
  - Customers test a system to decide whether or not it is ready to be accepted from the system developers and deployed in the customer environment. Primarily for custom systems.

Agile methods and acceptance testing

- In agile methods, the user/customer is part of the development team and is responsible for making decisions on the acceptability of the system.
- Tests are defined by the user/customer and are integrated with other tests in that they are run automatically when changes are made.
- There is no separate acceptance testing process.
- Main problem here is whether or not the embedded user is ‘typical’ and can represent the interests of all system stakeholders.

Reading material for the exam

- These lecture slides (for all three lectures)
- Ian Sommerville's slides for chapters 1-4 & 8
  http://iansommerville.com/software-engineering-book/slides/
- Articles:
  https://medium.com/@samerbuna/software-engineering-is-different-from-programming-b108c135af26
  http://faculty.salisbury.edu/~xswang/Research/Papers/SERelated/no-silver-bullet.pdf
  http://www.effectiveengineer.com/blog/hidden-costs-that-engineers-ignore