Software Quality Engineering:

Testing, Quality Assurance, and Quantifiable Improvement

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Chapter 12. Testing Techniques: Adaptation, Specialization, and Integration

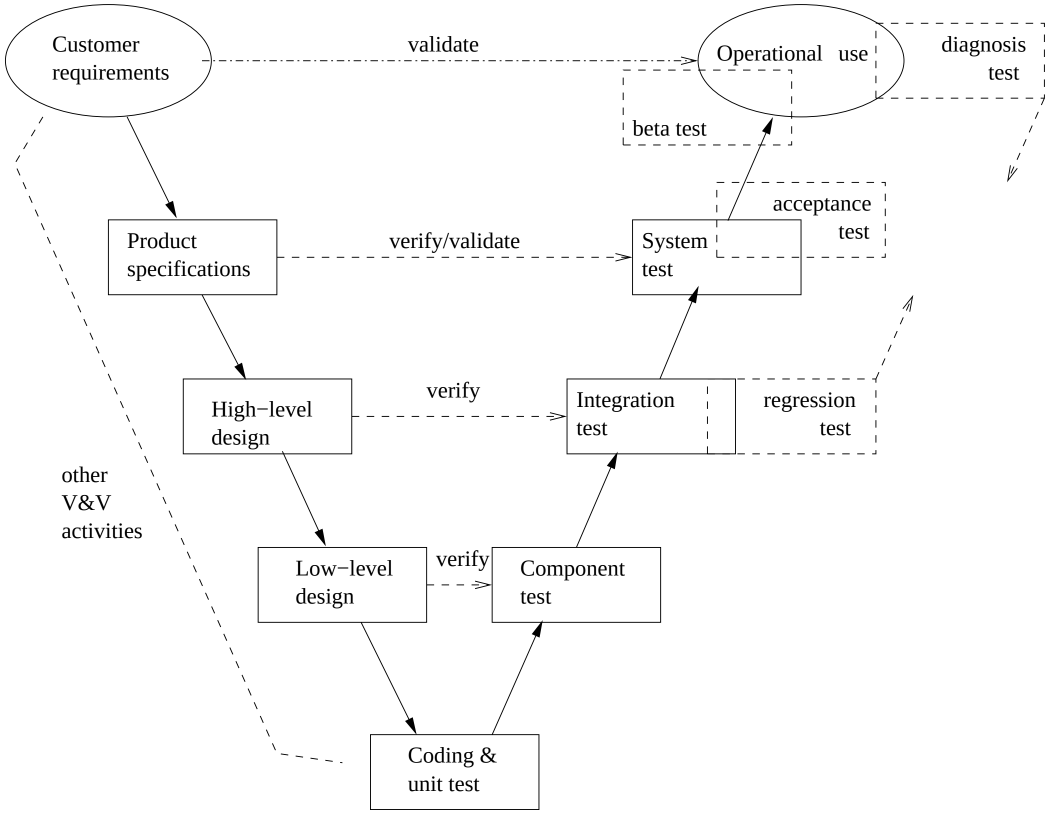
- Adaptation to Test Sub-phases
- Specialized Testing Techniques
- Integration and Web Testing Case Study

Applications of Testing Techniques

- Major testing techniques covered so far:
  - ▷ Ad hoc (non-systematic) testing.
  - ▷ Checklist-based testing.
  - ▷ Partition-based coverage testing.
  - ▷ Musa's OP for UBST.
  - ▷ Boundary testing (BT).
  - ▷ FSM-based coverage testing.
  - ▷ Markov chains and UMMs for UBST.
  - ▷ Control flow testing (CFT).
  - ▷ Data flow testing (DFT).

- Application and adaptation issues:
  - ▷ For different purposes/goals.
  - ▷ In different environments/sub-phases.
  - ▷ Existing techniques: select/adapt.
  - ▷ May need new or specialized techniques.

Testing Sub-Phases



- Annotated V-model for testing sub-phases: Fig 12.1 (p.204)
  - ▷ solid box: original sub-phase
  - ▷ dashed box: added sub-phase or specialized testing

Testing Sub-Phases

- Original sub-phases in V-model:
  - ▷ Operational use (not testing, strictly).
  - ▷ System test for product specification.
  - ▷ Integration test for high-level design.
  - ▷ Component test for low-level design.
  - ▷ Unit test for program code.

- Additional sub-phases/specialized testing:
  - ▷ Diagnosis test through all sub-phases.
  - ▷ Beta test for limited product release.
  - ▷ Acceptance test for product release.
  - ▷ Regression test for legacy products.

Unit Testing

- Key characteristics:
  - ▷ Object: unit (implemented code)
    - – function/procedure/subroutine in C, FORTRAN, etc.
    - – method in OO languages
  - ▷ Implementation detail ⇒ WBT.
    (BBT could be used, but less often.)
  - ▷ Exit: coverage (reliability undefined).

- Commonly used testing techniques:
  - ▷ Ad hoc testing.
  - ▷ Informal debugging.
  - ▷ Input domain partition testing and BT.
  - ▷ CFT and DFT.

Component Testing

- Key characteristics:
  - ▷ Object: component ($\supset$ unit), 2 types.
  - ▷ I. collection of units in C/FORTRAN/etc.
    – implementation detail ⇒ WBT.
  - ▷ II. class in OO languages
    – reusable component ⇒ BBT.
  - ▷ Exit: coverage (sometimes reliability).

- Commonly used testing techniques:
  - ▷ for traditional systems (component I)
    ≈ unit testing, but at larger scale
  - ▷ for OOS/COTS/CBSE (component II)
    ≈ system testing, but at smaller scale
    – see system testing techniques later

Integration Testing

- Key characteristics:
  - ▷ Object: interface and interaction among multiple components or subsystems.
  - ▷ Component as a black-box (assumed).
  - ▷ System as a white-box (focus).
  - ▷ Exit: coverage (sometimes reliability).
- Commonly used testing techniques:
  - ▷ FSM-based coverage testing.
  - ▷ Other techniques may also be used.
  - ▷ Sometimes treated as $\subset$ system testing $\Rightarrow$ see system testing techniques below.

System Testing

- Key characteristics:
  - ▷ Object: whole system and the overall operations, typically from a customer's perspective.
  - ▷ No implementation detail ⇒ BBT.
  - ▷ Customer perspective ⇒ UBST.
  - ▷ Exit: reliability (sometimes coverage).

- Commonly used testing techniques:
  - ▷ UBST with Musa or Markov OPs.
  - ▷ High-level functional checklists.
  - ▷ High-level FSM, possibly CFT & DFT.
  - ▷ Special case: as part of a "super"-system in embedded environment
    ⇒ test interaction with environment.

Acceptance Testing

- Key characteristics:
  - ▷ Object: whole system.
    – but defect fixing no longer allowed.
  - ▷ Customer acceptance in the market.
  - ▷ Exit: reliability.

- Commonly used testing techniques:
  - ▷ Repeated random sampling without defect fixing.
    (≈ assumption for IDRMs, Ch.22.)
  - ▷ UBST with Musa or Markov OPs.
  - ▷ External testing services/organizations may be used for system "certification".

Beta Testing

- Key characteristics:
  - ▷ Object: whole system
  - ▷ Normal usage by customers.
  - ▷ Exit: reliability.

- Commonly used testing techniques:
  - ▷ Normal usage.
  - ▷ Ad hoc testing by customers. (trying out different functions/features)
  - ▷ Diagnosis testing by testers/developers to fix problems observed by customers.

Testing Sub-Phases: Comparison

- Key characteristics for comparison:
  - ▷ Object and perspectives.
  - ▷ Exit criteria.
  - ▷ Who is performing the test.
  - ▷ Major types of specific techniques.

- "Who" question not covered earlier:
  - ▷ Dual role of programmers as testers in unit testing and component testing I.
  - ▷ Customers as testers in beta testing.
  - ▷ Professional testers in other sub-phases.
  - ▷ Possible 3rd party (IV&V) to test reusable components & system acceptance.

Testing Sub-Phases: Summary

- Summary: Table 12.1 (p.209)

Sub-phase	Persp.	Stopping	Who	Tech.
unit	WBT	coverage	programmer	db, s-list, BT, CFT, DFT
component				
type-I	WBT	coverage	programmer	s-list, BT, CFT, DFT
type-II	BBT	both	tester/3p	BT, CFT, DFT
integration	WBT	coverage	tester	FSM, CFT, DFT
system	BBT	both	tester	f-list, FSM, Musa, Markov
acceptance	BBT	usage	tester/3p	Musa, Markov
beta	BBT	usage	customer	normal usage

Specialized Testing

- Specialized testing tasks:
  - ▷ Some do not fit into specific sub-phases.
  - ▷ Different goals (other than reliability).
  - ▷ Non-standard application environment.

- Our coverage:
  - ▷ Defect diagnosis testing.
  - ▷ Defect-based testing.
  - ▷ Regression testing.
  - ▷ Testing beyond programs.
  - ▷ Testing for other goals/objectives.

Defect Diagnosis Testing

- Context of defect diagnosis testing:
  - ▷ In followup to discovered problems by customers or during testing.
  - ▷ Pre-test: understand/recreate problems.
  - ▷ Test result: faults located.
  - ▷ Followup with fault removal and re-run/re-test to confirm defect fixing.

- Defect diagnosis testing:
  - ▷ Typically involve multiple related runs.
  - ▷ Problem recreation as the starting point.
  - ▷ Perturbation and observation.
  - ▷ Domain knowledge important.
  - ▷ More recorded defect information $\Rightarrow$ less reliance on defect diagnosis.
  - ▷ Defect-based techniques (below) useful.

Defect-Based Testing

- General idea and generic techniques:
  - ▷ Focus: discovered or potential defects (and related areas).
  - ▷ Ad hoc testing based on defect guesses.
  - ▷ Risk identification ⇒ risk-based testing. (Part IV, esp. Ch.21)
  - ▷ Defect injection and mutation testing.

- Defect injection and testing:
  - ▷ Inject known defect (seed known fault).
  - ▷ Test for both seeded and ingenuous faults.
  - ▷ Missed faults ⇒ testing technique↑.
  - ▷ Also used in reliability modeling.

- Mutation testing ≈ defect injection testing, but systematic mutants used.

Regression Testing

- Context of regression testing:
  - ▷ In software maintenance and support:
    – ensure change $\not\Rightarrow$ negative impact.
  - ▷ In legacy software systems:
    – ensure quality of remaining functions,
    – during development/product update,
    – new part ≈ new development,
    – focus: integration sub-phase & after.
  - ▷ Re-test to verify defect fixing as well as no unintended consequences.

- Regression testing techniques:
  - ▷ Specialized analysis of change: Δ-analysis.
  - ▷ Focused testing on (new) Δ-part.
  - ▷ Integration of old and new.

Other Specialized Testing

- Testing beyond programs:
  - ▷ Embedded and heterogeneous systems:
    – test interactions with surroundings.
  - ▷ Web testing, in case study later.

- Testing to achieve other goals:
  - ▷ Performance testing;
  - ▷ Stress testing;
  - ▷ Usability testing, etc.

- Dynamic analysis and related techniques:
  - ▷ Simulation to reduce overall cost.
  - ▷ Prototyping, particularly in early phases.
  - ▷ Timing and sequencing analysis.
  - ▷ Event-tree analysis (ETA), Chapter 16.

Test Integration

- General idea:
  - ▷ Many activities and tasks.
  - ▷ Different techniques.
  - ▷ Individual advantages and limitations.
  - ▷ Much commonality exists.
  - ▷ Possibility of integration?
- Test integration: Advantages
  - ▷ combined strength ⇒ benefit↑.
  - ▷ common elements ⇒ cost↓.
  - ▷ flexibility↑.

Hierarchical Web Testing

- Case study from Chapter 10 continued:
  - ▷ Web navigation modeled by FSMs.
  - ▷ UBST using UMMs to overcome state explosion problem of FSMs.
  - ▷ Guiding existing web testing.
    (they typically focus on a small unit/facet)
  - ▷ Lack of structure for overall hits
    ⇒ use of simplified OPs (Musa OPs)

- Overall approach:
  - ▷ Top-tier: flat (Musa) OP.
  - ▷ Middle-tier: UMMs.
  - ▷ Bottom-tier: existing web testing.

Existing Web Testing

- Web functionality testing:
  - ▷ Focus on the web components identified in Ch.10.
  - ▷ HTML syntax checking via various tools.
  - ▷ Link checking.
  - ▷ Form testing.
  - ▷ Verification of end-to-end transactions.
  - ▷ Java and other program testing.

- Beyond web functionality testing:
  - ▷ Load testing.
  - ▷ Usability testing.
  - ▷ Browse rendering.

Web Testing (from Ch.10)

- Testing web navigations:
  - ▷ FSM-based testing in Chapter 10.
  - ▷ Web crawling via robots.

- UMMs for web testing (Chapter 10).
  - ▷ Availability/usage of web logs.
  - ▷ Some observations:
    - – skewed top hit pages and x-references
    - – the impact of structural hierarchy

Hierarchical Web Testing

- Overall approach:
  - ▷ Top-tier: flat (Musa) OP
    – for simplicity and skewed distribution.
  - ▷ Middle-tier: UMMs
    – importance of highly used navigations.
  - ▷ Bottom-tier: existing web testing
    – no need to re-invent wheels

- Implementation support:
  - ▷ TAR (top access report) ⇒ top-tier
  - ▷ CPR (call-pair report) to form clusters
    ⇒ middle tier UMMs
  - ▷ UMM refinement ⇒ bottom-tier
    – low-level Markov chains and
    – traditional (WBT-)testing models

Hierarchical Web Testing

- Implementation of the hierarchical web testing strategy: Fig 12.2 (p.218)

Top Level	Top Access Report (TAR) a flat list of frequently accessed services in ranking order (may be grouped by interconnection in customer usage scenarios)
Middle Level	Unified Markov Models (UMMs) for groups of TAR entries linked by CPR (call-pair report) (may be expanded into lower-level UMMs or other models)
Bottom Level	Detailed UMMs/other Models associated with frequently visited or critical nodes of UMMs (may correspond to testing models other than UMMs)