Introduction to Software Testing
Chapter 6
Practical Considerations

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The Toolbox

- Chapters 1-5 fill up a "toolbox" with useful criteria for testing software
- To move to level 3 (reducing risk) or level 4 (mental discipline of quality), testing must be integrated into the development process
- Most importantly :
  - In any activity, knowing the tools is only the first step
  - The key is utilizing the tools in effective ways
- Topics :
  - Regression testing (6.1)
  - Integrating software components and testing (6.2)
  - Integrating testing with development (6.3)
  - Test plans (6.4)
  - Checking the output (6.5)

Chapter 6 Outline

1. Regression Testing
2. Integration and Testing
3. Test Process
4. Test Plans
5. Identifying Correct Outputs

Regression Testing (6.1)

Definition

The process of re-testing software that has been modified

- **Most software today has very little new development**
  - **Correcting, perfecting, adapting, or preventing problems with existing software**
  - **Composing new programs from existing components**
  - **Applying existing software to new situations**
- **Because of the deep interconnections among software components, changes in one method can cause problems in methods that seem to be unrelated**
- **Not surprisingly, most of our testing effort is regression testing**
- **Large regression test suites accumulate as programs (and software components) age**

Automation and Tool Support

Regression tests must be automated

- **Too many tests to be run by hand**
- **Tests must be run and evaluated quickly**
  - **Often overnight, or more frequently for web applications**
- **Testers do not have time to view the results by inspection**
- **Types of tools :**
  - **Capture / Replay – *Capture* values entered into a GUI and *replay* those values on new versions**
  - **Version control – Keeps track of collections of *tests*, expected *results*, where the tests *came from*, the *criterion* used, and their past *effectiveness***
  - **Scripting software – Manages the process of obtaining test *inputs*, *executing* the software, obtaining the *outputs*, *comparing* the results, and generating *test reports***
- **Tools are plentiful and inexpensive (often free)**

Managing Tests in a Regression Suite

- Test suites **accumulate** new tests over time
- Test suites are usually run in a **fixed**, **short**, period of **time**
  - Often **overnight**, sometimes more frequently, sometimes less
- At some point, the number of tests can become **unmanageable**
  - We cannot finish running the tests in the time allotted
- We can always add **more computer** hardware
- But is it **worth** it?
- How many of these tests really need to be run ?

Policies for Updating Test Suites

- Which **tests to keep** can be based on several policies
  - Add a new test for every **problem report**
  - Ensure that a **coverage criterion** is always satisfied

- Sometimes harder to choose tests **to remove**
  - Remove tests that **do not contribute** to satisfying coverage
  - Remove tests that have **never found a fault** (risky !)
  - Remove tests that have found the **same fault** as other tests (also risky !)

- **Reordering** strategies
  - If a suite of *N* tests satisfies a coverage criterion, the tests can often be reordered so that the first *N-x* tests satisfies the criterion – so the remaining tests can be removed

When a Regression Test Fails

- **Regression tests are evaluated based on whether the test result on the new program *P* is equivalent to the test result on the previous version *P-1***
  - **If they differ, the test is considered to have failed**
- **Regression test failures represent three possibilities :**
  - **The software has a fault – *Must fix the fix***
  - **The test values are no longer valid on the new version – *Must delete or modify the test***
  - **The expected output is no longer valid – *Must update the test***
- **Sometimes hard to decide which !!**

Evolving Tests Over Time

- Changes to external interfaces can sometimes cause all tests to fail
  - Modern capture / replay tools will not be fooled by trivial changes like color, format, and placement
  - Automated scripts can be changed automatically via global changes in an editor or by another script

- Adding one test does not cost much – but over time the cost of these small additions start to pile up

Choosing Which Regression Tests to Run

Change Impact Analysis (CIA)

How does a change impact the rest of the software ?

- **When a small change is made in the software, what portions of the software can be impacted by that change ?**
- **More directly, which tests need to be re-run ?**
  - ***Conservative* approach : Run all tests**
  - ***Cheap* approach : Run only tests whose test requirements relate to the statements that were changed**
  - ***Realistic* approach : Consider how the changes propagate through the software**
- **Clearly, tests that never reach the modified statements do not need to be run**
- **Lots of clever algorithms to perform CIA have been invented**
  - **Few if any available in commercial tools**

Rationales for Selecting Tests to Re-Run

- **Inclusive** : A selection technique is *inclusive* if it includes tests that are "*modification revealing*"
  - Unsafe techniques have less than 100% inclusiveness
- **Precise** : A selection technique is *precise* if it omits regression tests that are not modification revealing
- **Efficient** : A selection technique is *efficient* if deciding what tests to omit is cheaper than running the omitted tests
  - This can depend on how much automation is available
- **General** : A selection technique is *general* if it applies to most practical situations

Summary of Regression Testing

- We spend far more time on regression testing than on testing new software
- If tests are based on covering criteria, all problems are much simpler
  - We know why each test was created
  - We can make rationale decisions about whether to run each test
  - We know when to delete the test
  - We know when to modify the test
- Automating regression testing will save much more than it will cost

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Integration and Testing (6.2)

Big Bang Integration

Throw all the classes together, compile the whole program, and system test it

- **The polite word for this is risky**
  - **Less polite words also exist …**
- **The usual method is to start small, with a few classes that have been tested thoroughly**
  - **Add a small number of new classes**
  - **Test the connections between the new classes and pre-integrated classes**
- ***Integration testing* : testing interfaces between classes**
  - **Should have already been tested in isolation (unit testing)**

Methods, Classes, Packages

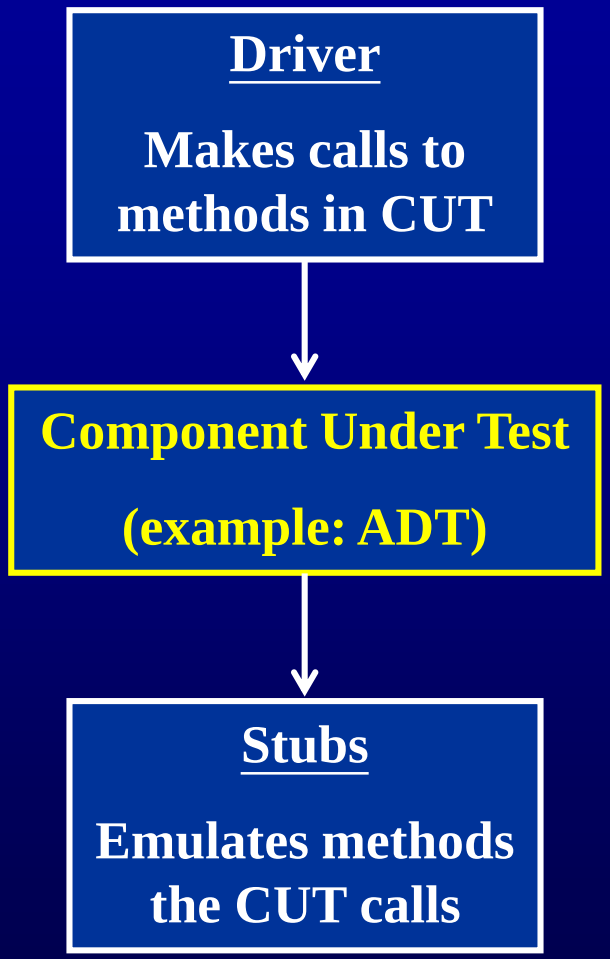
- **Integration can be done at the method level, the class level, package level, or at higher levels of abstraction**
- **Rather than trying to use all those words in every slide …**
- **Or not using any specific word …**
- **We use the word component in a generic sense**

- ***A component is a piece of a program that can be tested independently***

- **Integration testing is done in several ways**
  - **Evaluating two specific components**
  - **Testing integration aspects of the full system**
  - **Putting the system together "piece by piece"**

Software Scaffolding

- ***Scaffolding*** **is extra software components that are created to support integration and testing**
- **A *stub* emulates the results of a call to a method that has not been implemented or integrated yet**
- **A *driver* emulates a method that makes calls to a component that is being tested**



Stubs

- The **first responsibility** of a stub is to allow the CUT to be compiled and linked without error
  - The **signature** must match
- What if the called method needs to **return values** ?
- These values will **not be the same** the full method would return
- It may be important for testing that they satisfy certain limited **constraints**
- **Approaches**:
  1. Return **constant values** from the stub
  2. Return **random** values
  3. Return values from a **table lookup**
  4. Return values **entered by the tester** during execution
  5. Processing **formal specifications** of the stubbed method

More costly / more effective

Drivers

- Many good programmers add drivers to every class as a matter of habit
  - Instantiate objects and carry out simple testing
  - Criteria from previous chapters can be implemented in drivers
- Test drivers can easily be created automatically
- Values can be hard-coded or read from files

Class Integration and Test Order (CITO)

- **Old programs** tended to be very hierarchical
- Which **order to integrate** was pretty easy:
  - Test the "**leaves**" of the call tree
  - Integrate up to the **root**
  - Goal is to minimize the number of **stubs** needed
- **OO programs** make this more complicated
  - Lots of kinds of **dependencies** (call, inheritance, use, aggregation)
  - **Circular** dependencies : A inherits from B, B uses C, C aggregates A
- **CITO** : *Which order should we integrate and test* ?
  - Must "**break cycles**"
  - Common goal : **least stubbing**
- **Designs** often have few cycles, but cycles creep in during **implementation**

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Test Process (6.3)

We know <u>what</u> to do … but now … <u>how</u> can we do it?

Testing by Programmers

- The **important issue** is about quality
- Quality cannot be "**tested in**"!

Changes in Software Production

- **Teamwork has changed**
  - *1970*: we built **log cabins**
  - *1980*: we built **small buildings**
  - *1990*: we built **skyscrapers**
  - *200X*: we are building **integrated communities** of buildings
- **We do more maintenance than construction**
  - Our **knowledge base** is mostly about testing new software
- **We are reusing code in many ways**
- **Quality vs efficiency is a constant source of stress**
- **Level 4 thinking requires the recognition that quality is usually more crucial than efficiency**
  - Requires **management** buy-in !
  - Requires that programmers **respect** testers

Test Activities

Software requirements →	Define test objectives (criteria) Project test plan
System design →	Design system tests Design acceptance tests Design usability test, if appropriate
Intermediate design →	Specify system tests Integration and unit test plans Acquire test support tools Determine class integration order
Detailed design →	Create tests or test specifications

Test Activities (2)

Implementation →	Create tests Run tests when units are ready
Integration →	Run integration tests
System deployment →	Apply system test Apply acceptance tests Apply usability tests
Operation and maintenance →	Capture user problems Perform regression testing

Managing Test Artifacts

- Don't fail because of lack of organization
- Keep track of :
  - Test design documents
  - Tests
  - Test results
  - Automated support
- Use configuration control
- Keep track of source of tests – when the source changes, the tests must also change

Professional Ethics

- If you can't test it, don't build it
- Put quality first : Even if you lose the argument, you will gain respect
- Begin test activities early
- Decouple
  - Designs should be independent of language
  - Programs should be independent of environment
  - Couplings are weaknesses in the software!
- Don't take shortcuts
  - If you lose the argument you will gain respect
  - Document your objections
  - Vote with your feet
  - Don't be afraid to be right!

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Test Plans (6.4)

- **The most common question I hear about testing is**

“ *How do I write a test plan*? ”

- **This question usually comes up when the focus is on the document, not the contents**
- **It’s the contents that are important, not the structure**
  - **Good testing is more important than proper documentation**
  - **However – documentation of testing can be very helpful**
- **Most organizations have a list of topics, outlines, or templates**

Standard Test Plan

- ANSI / IEEE Standard 829-1983 is ancient but still used

Test Plan

A document describing the scope, approach, resources, and schedule of intended testing activities. It identifies test items, the features to be tested, the testing tasks, who will do each task, and any risks requiring contingency planning.

- Many organizations are required to adhere to this standard
- Unfortunately, this standard emphasizes documentation, not actual testing – often resulting in a **well documented vacuum**

Types of Test Plans

- **Mission plan** – tells "**why**"
  - Usually one mission plan per organization or group
  - Least detailed type of test plan
- **Strategic plan** – tells "**what**" and "**when**"
  - Usually one per organization, or perhaps for each type of project
  - General requirements for coverage criteria to use
- **Tactical plan** – tells "**how**" and "**who**"
  - One per product
  - More detailed
  - Living document, containing test requirements, tools, results and issues such as integration order

Test Plan Contents – System Testing

- Purpose
- Target audience and application
- Deliverables
- Information included
  - Introduction
  - Test items
  - Features tested
  - Features not tested
  - Test criteria
  - Pass / fail standards
  - Criteria for starting testing
  - Criteria for suspending testing
  - Requirements for testing restart
  - Hardware and software requirements
  - Responsibilities for severity ratings
  - Staffing & training needs
  - Test schedules
  - Risks and contingencies
  - Approvals

Test Plan Contents – Tactical Testing

- Purpose
- Outline
- Test-plan ID
- Introduction
- Test reference items
- Features that will be tested
- Features that will not be tested
- Approach to testing (criteria)
- Criteria for pass / fail
- Criteria for suspending testing
- Criteria for restarting testing
- Test deliverables
- Testing tasks
- Environmental needs
- Responsibilities
- Staffing & training needs
- Schedule
- Risks and contingencies
- Approvals

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Identifying Correct Outputs (6.5)

Oracle Problem

Does a program execute correctly on a specific input ?

- **With simple software methods, we have a very clear idea whether outputs are correct or not**
- **But for most programs it's not so easy**
- **This section presents four general methods for checking outputs:**
  1. **Direct verification**
  2. **Redundant computation**
  3. **Consistency checks**
  4. **Data redundancy**

(1) Direct Verification

Using a program to check the answer

- Appealing because it eliminates some human error
- Fairly expensive – requiring more programming
- Verifying outputs is deceptively hard
  - One difficulty is getting the post-conditions right
- Not always possible – we do not always know the correct answer
  - Flow calculations in a stream – the solution is an approximation based on models and guesses; we don't know the correct answers !
  - Probability of being in a particular state in a Petri net – again, we don't know the correct answer

Direct Verification Example

- Consider a simple **sort** method
- **Post-condition** : Array is in sorted order

Input	8	92	7	14
Output	1	2	3	4
Output	92	14	8	7

Oops !

Oops !

- **Post-condition** : Array sorted from lowest to highest and contains all the elements from the input array

Input	87	14	14	87
Output	14	14	14	87

Oops !

- **Post-condition** : Array sorted from lowest to highest and is a *permutation* of the input array

Direct Verification Example – *Cont.*

```
Input : Array A
   Make copy B of A
   Sort A
   // Verify A is a permutation of B
   Check A and B are of the same size
   For each object in A
      Check if object appears in A and B the same number of times
   // Verify A is ordered
   for each index i except the last in A
      Check if A [i] <= A [i+1]
```

- **This is almost as complicated as the sort method under test !**
- **We can easily make mistakes in the verification methods**

(2) Redundant Computation

Computing the answer in a different way

- Write **two programs** – check that they produce the same answer
- Very **expensive** !
- Problem of **coincident failures**
  - That is, both programs fail on the same input
  - Sadly, the "**independent failure assumption**" is **not** valid in general
- This works best if completely **different algorithms** can be used
  - Not clear exactly what "completely different" means
- Consider **regression testing**
  - Current software checked against prior version
  - Special form of redundant computation
  - Clearly, independence assumption does not hold
    - But still extremely powerful

(3) Consistency Checks

Check part of the answer to see if it makes sense

- Check if a **probability** is negative or larger than one
- Check **assertions** or **invariants**
  - No duplicates
  - Cost is greater than zero
  - Internal consistency constraints in databases or objects
- These are only **partial solutions**
- Consistency Checks do **not** always apply, but are very useful within those limits

(4) Data Redundancy

Compare results of different *inputs*

- **Check for "identities"**
  - **Testing *sin (x) : sin(a+b) = sin(a)cos(b) + cos(a)sin(b)***
    - **Choose *a* at random**
    - **Set *b=x-a***
    - **Note failure independence of *sin(x), sin(a)***
    - **Repeat process as often as desired; choose different values for *a***
    - **Possible to have arbitrarily high confidence in correctness assessment**
  - **Inserting an element into a structure and removing it**
- **These are only partial solutions**
- **Data Redundancy does not always apply, but is very useful within those limits**

Summary – Chapter 6

- A major obstacle to the adoption of advanced test criteria is that they affect the process
  - It is very hard to change a process
  - Changing process is required to move to level 3 or level 4 thinking
- Most testing is actually regression testing
- Test criteria make regression testing much easier to automate
- OOP has changed the way in which we integrate and test software components
- To be successful, testing has to be integrated throughout the process
- Identifying correct outputs is almost as hard as writing the program