Testing

- Objectives of software testing
- Types of testing
- Testing strategy
- Reflections

Testing Fundamentals

- Coding produces errors
  - Data show 30-85 errors are made per 1000 SLOC
- Testing: processes of executing the code to detect errors
- In practice, it is impossible to check for all possible errors by testing
- Even checking a useful subset is expensive
  - 40%-80% of development cost
  - Must be re-done when software changes
  - Potentially unbounded effort

Testing Fundamentals (2)

- Reality: must settle for testing a subset of possible inputs
  - Even extensively tested software contains 0.5-3 errors per 1000 SLOC
    - Pesticide Paradox: every method used to prevent or find bugs leaves a residue of subtler bugs against which those methods are ineffectual [Beizer]
  - Always a tradeoff of cost vs. errors found
- Fundamental cost/benefit questions
  - Which subsets of possible test cases will find the most errors?
  - Which will find the most important errors?
  - How much testing is enough?
Ideal Testing Goal

- Goal: choose a sufficiently small but adequate set of test cases (input domain)
  - Small enough to economically run the complete set and re-run when software changes
  - "Adequate" much harder to define, generally means some combination of:
    - Acceptably close to required functional behavior
    - Contains no catastrophic faults
    - Reliable to an acceptable level (mean time to failure)
    - Within tolerance levels for qualities like performance, security, etc.

Testing Objectives

- Disagreement over how best criteria for choosing the test set leads to two general approaches
- Fault Detection: testing intended to find as many faults as possible
- Confidence Building: testing intended to increase confidence that the software works as intended

Why continuing disagreement?

- Both approaches have notable weaknesses
- Fault Detection (bug hunt)
  - Tests according to coverage criteria
  - Equal chance, cost for finding arbitrary error
  - Implicitly assumes all bugs are equal, clearly not true in many cases
- Confidence Building (usage emulation)
  - Tests according to expected use
  - Higher chance of finding bugs that users will routinely encounter, misses others
  - Implicitly assumes that infrequent bugs are unimportant, also untrue in many cases
### Methods by Adequacy Criteria

- Methods often classified by the criteria used to choose the test set.
- Classification based on the source of information to derive test cases:
  - black-box testing (functional, specification-based)
  - white-box testing (structural, program-based)
- Classification based on the criterion to measure the adequacy of a set of test cases:
  - coverage-based testing
  - fault-based testing
  - error-based testing

### White-Box Testing

- Also “clear box”
- Testing strategies based on knowledge of the code within a module.
- Generally applies one or more forms of coverage criteria:
  - Every non-commentary line of code is executed (statement coverage)
  - Every branch is taken (branch coverage)
  - Every block of code is executed (block coverage)
  - Every path is executed (path coverage)
  - Every defined variable is (correctly) used (define-use coverage)

### Black-Box Testing

- Testing strategies based on knowledge of interface specification, but not of code that implements it.
- For module tests:
  - Returned values conform to syntactic and semantic specifications for the interface
  - Inputs beyond parameter bounds, or that violate syntax or semantics, throw exceptions
  - Performance requirements are met (where defined)
- For integration and system tests:
  - Sunny day, rainy day scenarios produce expected results
  - Can be based on use cases
Coverage Testing

- Looks at internal code structure (white-box)
- Test set adequacy defined by some form of coverage criteria
  - E.g., % of statements executed
- Three techniques:
  - control-flow coverage
  - data-flow coverage
  - coverage-based testing of requirements

Example: Control Flow Coverage

- Model program as flow graph
  - E.g., branches are nodes with multiple edges
  - An execution is one path through the graph
  - Generally very large number of possible paths
- Adequacy based on coverage of some aspect of the graph, in increasing order:
  - Node coverage: execute each statement
  - Branch coverage: execute each branch
  - Path coverage: execute every path
- % Coverage provides a test-set metric
- Many supporting tools

Example: Fault-based Testing

- Does not look at code structure (black-box)
- Looks for a test set with a high ability to detect faults
- Two techniques:
  - Fault seeding
  - Mutation testing
Fault Seeding

• Adequacy of test set judged by ability to find seeded errors
  – Seeds errors randomly into the code
  – Look at percentage of seeded errors found
  – Better test sets find more of the seed errors
• Infer that those sets will also find more latent errors
  – Look for high percentage of seeded to latent errors

Example: Operational Scenarios

• Focus on confidence building (rather than error-detection), also black-box
• Based on knowledge about how users (will) use the system
  – Inputs based on statistical sampling of actual inputs
  – Inputs based on estimates, use cases, user observation, focus groups, etc.
• Supports statistical inference about the likelihood of a failure in actual use (i.e., Cleanroom)
  – Usability requirements
  – Performance requirements
• Misses unlikely events
  – Low-frequency events tend not to be tested (edge cases, exceptions, unpredictable behavior)
  – Some low frequency events are critical

Experimental Results

• There is no uniformly best technique
• Different techniques tend to reveal different types of faults
• Multiple techniques reveal more faults (at a cost)
• Cost-effectiveness of run-time testing is low, particularly compared to inspections (most tests find no errors)
  – Design review: 8.44
  – Code review: 1.38
  – Testing: 0.17
Interpretation

• A combination of manual and automated techniques is most cost effective
• People are better at detecting many kinds of errors than machines
  – Logic errors
  – Misinterpretations, etc.
• Machines are better at repetitive checks and minute details (comparing values)
• Testing works best in a supporting role (checking assumptions)
  – Activity of producing test cases and results double checks other artifacts
  – Is it well enough defined to write a good test case?
  – Are edge cases defined? Etc.
  – Gives feedback on assumptions and expectations: does the system do what we expect?

Best Approach

• Start early, test often
  – For every work product, we ask: How can I find defects as early as possible?
    – Create test plans and test cases as a way of checking the qualities of requirements, design, etc.
• Use a combination of methods
  – Inspections and reviews of every artifact
  – Testing at every stage possible
    • Manual
    • Module
    • System

Software Testing in Practice

• Most companies' new hires are testers
  – Regarded as less prestigious, lower skilled activity
• Most testing work is manual; help from tools is still limited
• In many cases, testing is not performed using systematic testing methods or techniques
• Often delayed, cut short by schedule pressure
• Sometimes there are "conflicts of interest" between testers and developers
  – Testing should be "destructive" as possible
  – Difficult attitude for developer
• Result is poor return for time/money spent
QA Planning

- Effective testing must be part of the overall plan
  - Fully supported by management (time, budget, skills)
  - Fully integrated into the development plan from the beginning
- Include use and evaluation of results
  - Process for addressing defects found
  - Measures of code quality
  - Measures of test quality and completeness
- Test results must provide feedback for improvement
  - Better QA process
  - Better coding practices, etc.
- Look at example plan

Quality is Cumulative

- Are the requirements valid?
- Complete? Consistent? Implementable?
- Testable?
- Does the design satisfy requirements?
- Are all functional capabilities included?
- Are qualities addressed (performance, maintainability, usability, etc.)?
- Do the modules work together to implement all the functionality?
- Are likely changes encapsulated?
- Is every module well defined
- Implement the required functionality?
- Race conditions? Memory leaks? Buffer overflows?

Questions