Testing

15-413: Introduction to Software Engineering

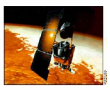
Jonathan Aldrich

Some slides from Tom Ball
and others in MSR's FSE group

Why Test?

Mars Climate Orbiter

- Purpose: to relay signals from the Mars Polar Lander once it reached the surface of the planet
- Disaster: smashed into the planet instead of reaching a safe orbit
- Why: Software bug - failure to convert English measures to metric values
- $165M

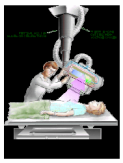


Shooting Down of Airbus 320

- 1988
- US Vicennes shot down Airbus 320
- Mistook airbus 320 for a F-14
- 290 people dead
- Why: Software bug - cryptic and misleading output displayed by the tracking software

THERAC-25 Radiation Therapy

- THERAC-25, a computer-controlled radiation-therapy machine
- 1986: two cancer patients at the East Texas Cancer Center in Tyler received fatal radiation overdoses
- Why: Software bug - mishandled race condition (i.e., miscoordination between concurrent tasks)



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Testing: Current Challenges

- Test is huge cost of product development
- Test effectiveness and software quality hard to measure

- Incomplete, informal and changing specifications
- Downstream cost of bugs is enormous
- Lack of spec and implementation testing tools

- Integration testing across product groups
- Patching nightmare
- Versions exploding
- …

Testing Word

- Student-suggested issues
  - It's huge – can't test all combine all features
  - Simulate user interaction
  - Prepare audience different from testers
  - Platforms/hardware
  - Embedded external applications
  - What is the specified behavior / AI
  - Compatibility with old file formats

Testing Word

- inputs
  - keyboard
  - mouse/pen
  - .doc, .htm, .xml, …
- outputs (WYSIWYG)
  - printers
  - displays
  - .doc, .htm, .xml, …
- variables
  - fonts
  - templates
  - languages
  - dictionaries
  - styles
- Interoperability
  - Access
  - Excel
  - COM
  - VB
  - emacs
  - sharepoint
  - internet
- Other features
  - 34 toolbars
  - 100s of commands
  - ? dialogs
- Constraints
  - huge user base

Microsoft Powerpoint EULA Point 11

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What are the goals of testing?

- Student answers
  - Make sure it doesn't crash
  - Regression testing – no new bugs
  - Make sure you meet the spec
  - Make sure you don't have harmful side effects

What are the goals of testing?

- Reveal faults
- Establish confidence
- Clarify the specification
- Represent the customer/verify contract

Limitations of Testing

- Testing can only show the presence of errors, not their absence
  - Dijkstra, 1972
- Why?

Black-box Testing

- Verify each piece of functionality of the system
  - Black-box: don't look at the code
- Systematic testing
  - Test each use case
  - Test combinations of functionality (bold + italic + font + size)
    - Generally have to sample
  - Test incorrect user input
  - Test each "equivalence class" (similar input/output)
  - Test uncommon cases
    - Generating all error messages
    - Using uncommon functionality
  - Test borderline cases
    - Edges of ranges, overflow inputs, array of size 0 or 1

Exercise: test binary search

- in/not in the array
- array with duplicate elements
- empty array, 1-element array
- even vs. odd array sizes
- unsorted/sorted array
  - Spec says array must be sorted
- < or > every element in array

White-box Testing

- Look at the code (white-box) and try to systematically cause it to fail
- Coverage criteria: a way to be systematic
  - Function coverage
    - Execute each function
  - Statement coverage
    - Most common
  - Edge coverage
    - Take both sides of each branch
  - Path coverage
    - Note: infinite number of paths!
    - Typical compromise: 0-1-many loop iterations
  - Condition coverage
    - Choose a set of predicates
    - Cover each statement with each combination of predicates
  - Exercise data structures
    - Each conceptual state or sequence of states
- Typically cannot reach 100% coverage
  - Especially true of paths, conditions

Unit Tests

- Usually automated
- Focus on one function at a time
  - May need to call other functions for setup
- Often specified by developer
  - Always in XP

Functional Tests

- Test entire end-to-end system functionality
- Often organized by use cases
- Often driven by separate testing team
  - Customer / customer representative in XP

Design for Testing

- Ensure components can be tested in isolation
  - Minimize dependences on other components
  - Provide constructors to set up objects for testing

Acceptance tests

- Functional tests that the customer uses to evaluate the quality of the system

Design by contract

- General meaning
  - Specify a contract between client and implementation of a module
    - Using pre- and post-conditions
    - System works if both parties fulfill their contract
- Specific setting of testing
  - Verify pre- and post-conditions while running
  - Assign blame based on which one fails
  - Turns a system execution into a set of unit tests

Regression Testing

- A suite of tests is run every time the system changes
- Goal: to catch any new bugs introduced by change
  - Need to add tests for new functionality
  - But still test the old functionality also!
  - Note: in some cases, old test cases *should* return a different result, depending on the change that was made

Nightly Builds

- Building a release of a large project every night
  - Catches integration problems where a change “breaks the build”
    - Breaking the build is a BIG deal—may result in midnight calls to the responsible engineer
- Typically, run regression test after building
  - Plot progress on tests over time

When are you done testing?

- Most common
  - Run out of time or money
- Can try to use statistical models
  - Only as good as your characterization of the input
  - Which is often quite bad
    - Exception: stable systems for which you have empirical data (telephones)
    - Exception: good mathematical model (avionics)
- Can seed faults
  - Halt when an “adequate” percentage is found
  - Implication: same percentage of unknown errors found
    - But is this really true?
- Rule of thumb: when error detection rate drops

Testing Quality Attributes

- Throughput
  - Increase load steadily through a series of tests until performance is unacceptable
    - Load profile should match actual operation profile of system
    - “Stress testing” tests the system beyond intended design limits
      - Look at failure behavior
      - Identify defects related to heavy load
- Reliability
  - Run for a period of time against operational profile, estimate reliability metric
  - Challenges:
    - Hard to know correct profile
    - Expensive to generate profile
    - Need large test cases to generate statistical confidence
      - Which is irrelevant anyway if the profile is off
  - Basically no good way to do this

Testing Quality Attributes

- Fault tolerance
  - Programmatically cause a fault and test that the system can recover
- Security
  - Attack team
- Usability
  - Measure user performance on some task
- Portability
  - Test against multiple platforms
- Evolvability
  - Design extension

Defect Tracking

- Organized handling of defects
  - Defect description
  - Problem analysis
  - Product and version affected
  - Originator, Owner
  - Status: open, confirmed, closed
  - Severity
  - Date reported, fixed
- Widely used in open source, industry
  - Tools like Bugzilla

Test Plan

- Strategy
  - Unit? Functional? White/Black box? Design by contract?
  - During requirements? Before coding? During test phase?
  - Quality attribute testing?
  - Nightly builds?
  - Completeness criterion?
- Document acceptance tests
  - Trace each requirement to one or more acceptance tests
- Tools
  - Generation? Regression? Selection? Coverage? Defect tracking?
- People
  - Developer or dedicated testers?