Software Testing

Testing: Our Experiences

When to Stop?

A Real Testing Example

SPECS: Takes a list of numbers; returns a sorted list.
Automated Testing

Testing the New Version

Regression Testing
What is Testing?

- Process of determining whether a task has been correctly carried out [Schach '96]
- Goals of testing
  - Reveal Faults
    - Correctness
    - Reliability
    - Usability
    - Robustness
    - Performance

Types of Testing

- Execution-based Testing
- Non-execution based Testing

Executions-based Testing

- Generating and Executing Test Cases on the Software
- Types of Execution-based Testing
  - Testing to Specifications
    - Black-box Testing
  - Testing to Code
    - Glass-box (White-box) Testing

Black-box Testing

- Discussion: MAC/ATM Machine Example
  - Specs
    - Cannot withdraw more than $300
    - Cannot withdraw more than your account balance

Conflicting Goals?
White-box Testing

• Example
  
  x: 1..1000;

  1 INPUT-FROM-USER(x);
    If (x <= 300) {
      2 INPUT-FROM-FILE(BALANCE);
      3     If (x <= BALANCE)
      4       GiveMoney x;
      5     else Print “You don’t have $x in your account!!”
    } else
    5     Print “You cannot withdraw more than $300”;
     6 Eject Card;

Discussion

• Which is superior?
• Each technique has its strengths – Use both

Determining Adequacy

• Statement coverage
• Branch coverage
• Path coverage
• All-def-use-path coverage

Surprise Quiz

• Determine test cases so that each print statement is executed at least once

```plaintext
input(x);
if (x < 100)
  print "Line 1";
else {
  if (x < 50) print "Line 2"
  else print "Line 3";
}
```
Non-execution Based

- Walkthroughs
  - Manual simulation by team leader
- Inspections
  - Developer narrates the reading
- Key Idea
  - Review by a team of experts: Syntax checker?
- Code Readings
- Formal Verification of Correctness
  - Very Expensive
  - Justified in Critical Applications
- Semi-formal: Some Assertions

Simulation

- Integration with system hardware is central to the design
- Model the external hardware
- Model the interface

- Examples
- Discussion

Boundary-value Analysis

- Partition the program domain into input classes
- Choose test data that lies both inside each input class and at the boundary of each class
- Select input that causes output at each class boundary and within each class
- Also known as stress testing

Testing Approaches

- Top-down
- Bottom-up
- Big Bang
- Unit testing
- Integration testing
- Stubs
- System testing
Mutation Testing

- Errors are introduced in the program to produce “mutants”
- Run test suite on all mutants and the original program

Test Case Generation

- Test Input to the Software
- Some researchers/authors also define the test case to contain the expected output for the test input

Category-partition Method

- Key idea
  - Method for creating functional test suites
  - Role of test engineer
    - Analyze the system specification
    - Write a series of formal test specifications
  - Automatic generator
    - Produces test descriptions

Steps

- Decompose the functional specification into functional units
  - Characteristics of functional units
    - They can be tested independently
    - Examples
      - A top-level user command
      - Or a function
- Decomposition may require several stages
- Similar to high-level decomposition done by software designers
  - May be reused, although independent decomposition is recommended
Steps

• Examine each functional unit
  - Identify parameters
    • Explicit input to the functional unit
  - Environmental conditions
    • Characteristics of the system's state
• Test Cases
  - Specific values of parameters
  - And environmental conditions

Steps

• “Test cases are chosen to maximize chances of finding errors”
• For each parameter & environmental condition
  - Find categories
    • Major property or characteristic
    • Examples
      - Browsers, Operating Systems, array size
    • For each category
      - Find choices
        • Examples: (IE 5.0, IE 4.5, Netscape 7.0), (Windows NT, Linux), (100, 0, -1)

Steps

• Develop “Formal Test Specification” for each functional unit
  - List of categories
  - Lists of choices within each category
• Constraints
• Automatically produces a set of “test frames”
  - Consists of a set of choices

AI Planning Method

• Key Idea
  - Input to Command-driven software is a sequence of commands
  - The sequence is like a plan
• Scenario to test
  - Initial state
  - Goal state
Example

- VCR command-line software
- Commands
  - Rewind
    - If at the end of tape
  - Play
    - If fully rewound
  - Eject
    - If at the end of tape
  - Load
    - If VCR has no tape

Preconditions & Effects

- Rewind
  - Precondition: If at end of tape
  - Effects: At beginning of tape
- Play
  - Precondition: If at beginning of tape
  - Effects: At end of tape
- Eject
  - Precondition: If at end of tape
  - Effects: VCR has no tape
- Load
  - Precondition: If VCR has no tape
  - Effects: VCR has tape

Preconditions & Effects

- Rewind
  - Precondition: end_of_tape
  - Effects: ¬end_of_tape
- Play
  - Precondition: ¬end_of_tape
  - Effects: end_of_tape
- Eject
  - Precondition: end_of_tape
  - Effects: ¬has_tape
- Load
  - Precondition: ¬has_tape
  - Effects: has_tape

Initial and Goal States

- Initial State
  - end_of_tape
- Goal State
  - ¬end_of_tape
- Plan?
  - Rewind
**Initial and Goal States**

- **Initial State**
  - ¬end_of_tape & has_tape

- **Goal State**
  - ¬has_tape

- **Plan?**
  - Play
  - Eject

**Test Coverage & Adequacy**

- How much testing is enough?
- When to stop testing
- Test data selection criteria
- Test data adequacy criteria
  - Stopping rule
  - Degree of adequacy
- Test coverage criteria
- Objective measurement of test quality

**Preliminaries**

- Test data selection
  - What test cases

- Test data adequacy criteria
  - When to stop testing

- Examples
  - Statement Coverage
  - Branch coverage
  - Def-use coverage
  - Path coverage

**Goodenough & Gerhart ['75]**

- What is a software test adequacy criterion
  - Predicate that defines “what properties of a program must be exercised to constitute a thorough test”, i.e., one whose successful execution implies no errors in a tested program
Uses of test adequacy

• Objectives of testing
  • In terms that can be measured
    - For example branch coverage
• Two levels of testing
  • First as a stopping rule
  • Then as a guideline for additional test cases

Categories of Criteria

• Specification based
  • All-combination criterion
    • choices
  • Each-choice-used criterion
• Program based
  • Statement
  • Branch
• Note that in both the above types, the correctness of the output must be checked against the specifications

Others

• Random testing
• Statistical testing
• Interface based