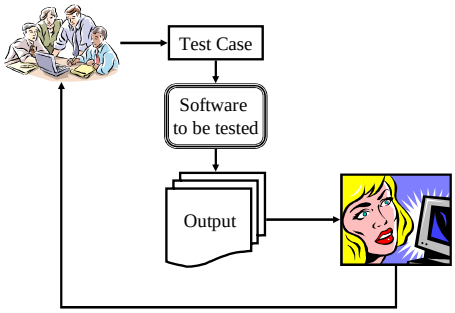
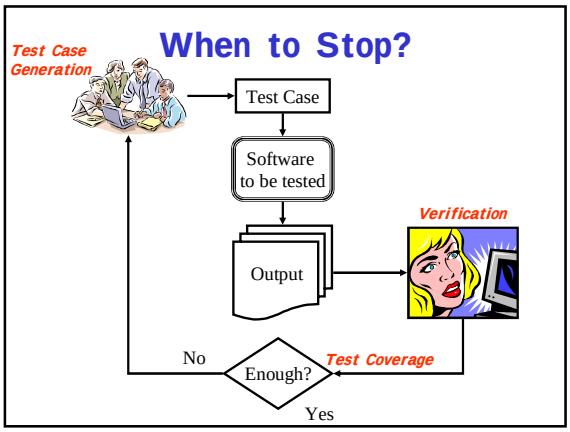
Software Testing

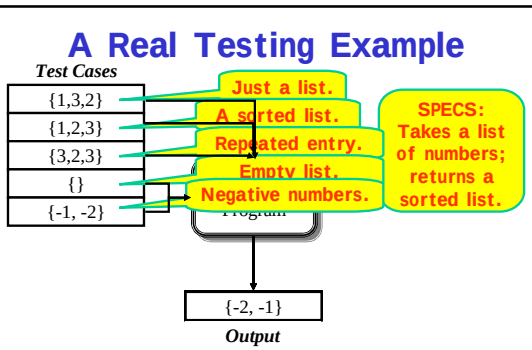
Testing: Our Experiences



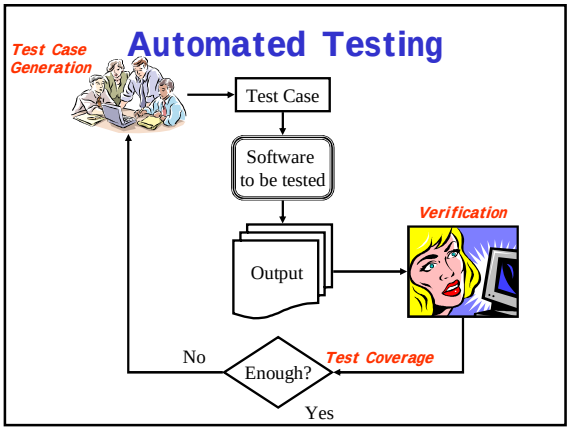
When to Stop?



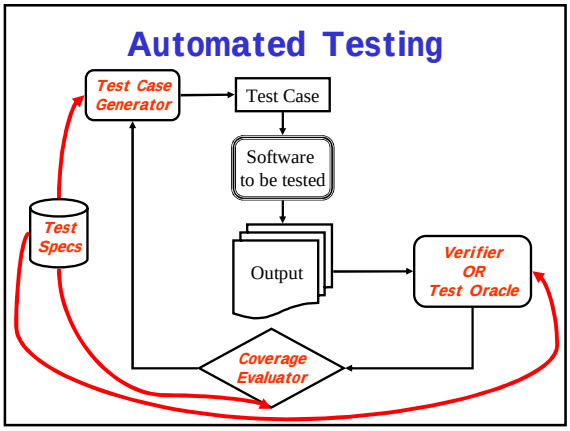
A Real Testing Example



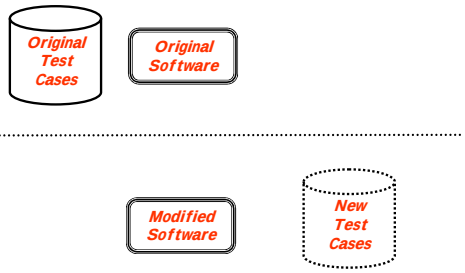
Automated Testing



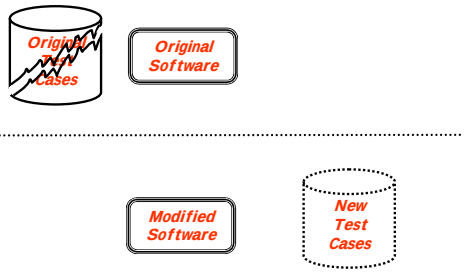
Automated Testing



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

  } Conflicting Goals?

Types of Testing

- Execution-based Testing
- Non-execution based Testing

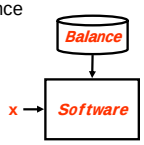
- Discussion

Execution-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



White-box Testing

- **Example**

x: 1..1000;

Generate test cases to cover each statement

```
1    INPUT-FROM-USER(x);
     If (x <= 300) {
2          INPUT-FROM-FILE(BALANCE);
           If (x <= BALANCE)
3               GiveMoney x;
4          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**

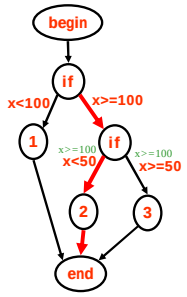
Determining Adequacy

- **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**

```
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