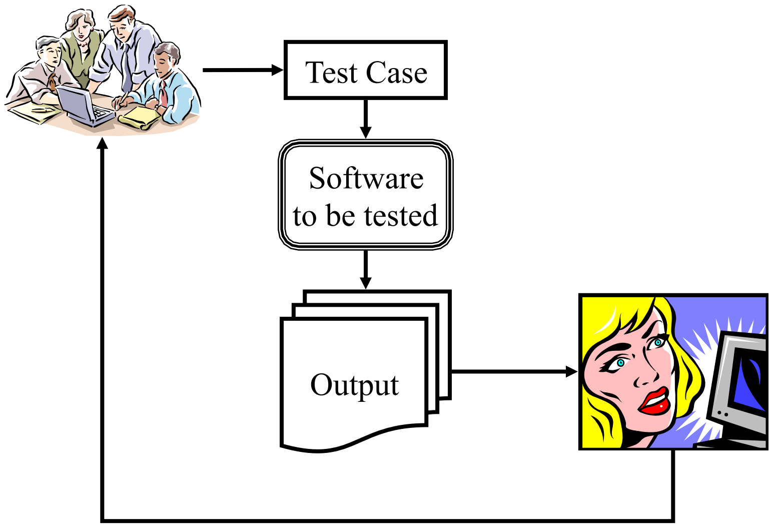
Software Testing

Testing: Our Experiences

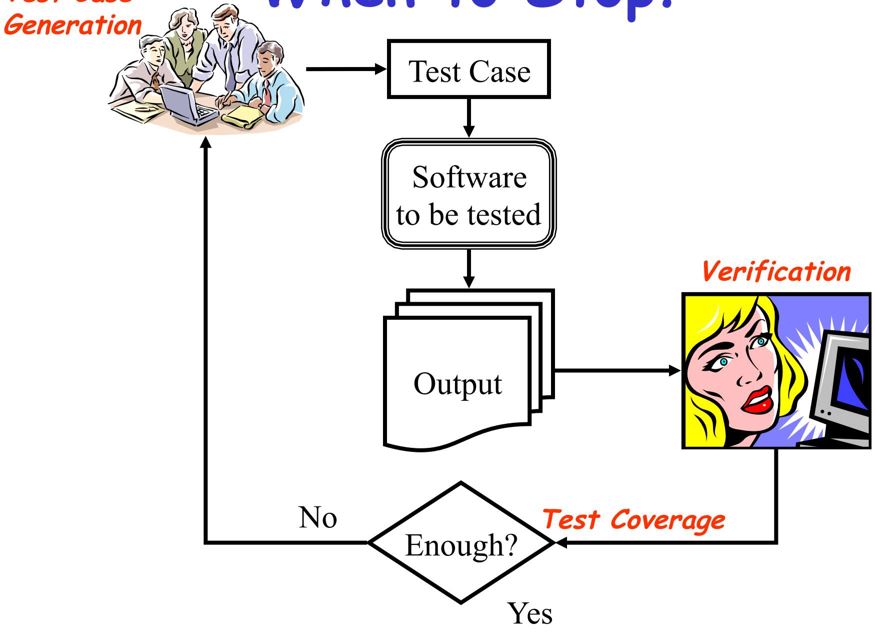


Test Case

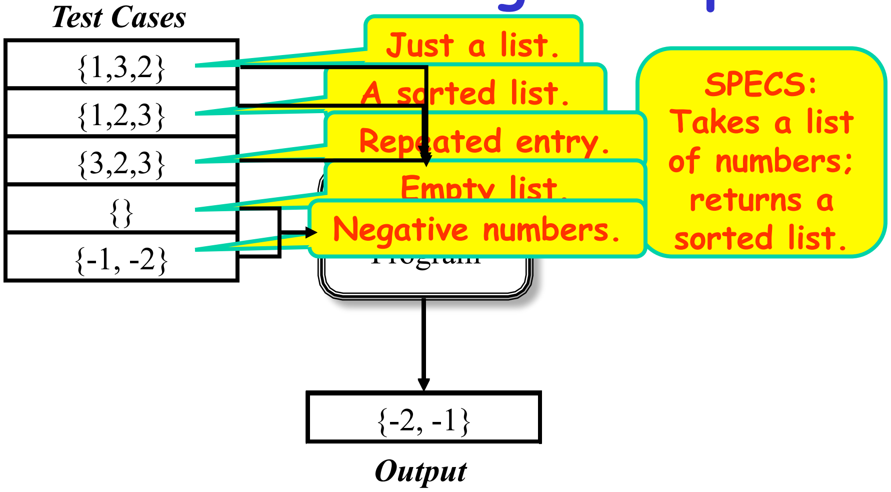
Software
to be tested

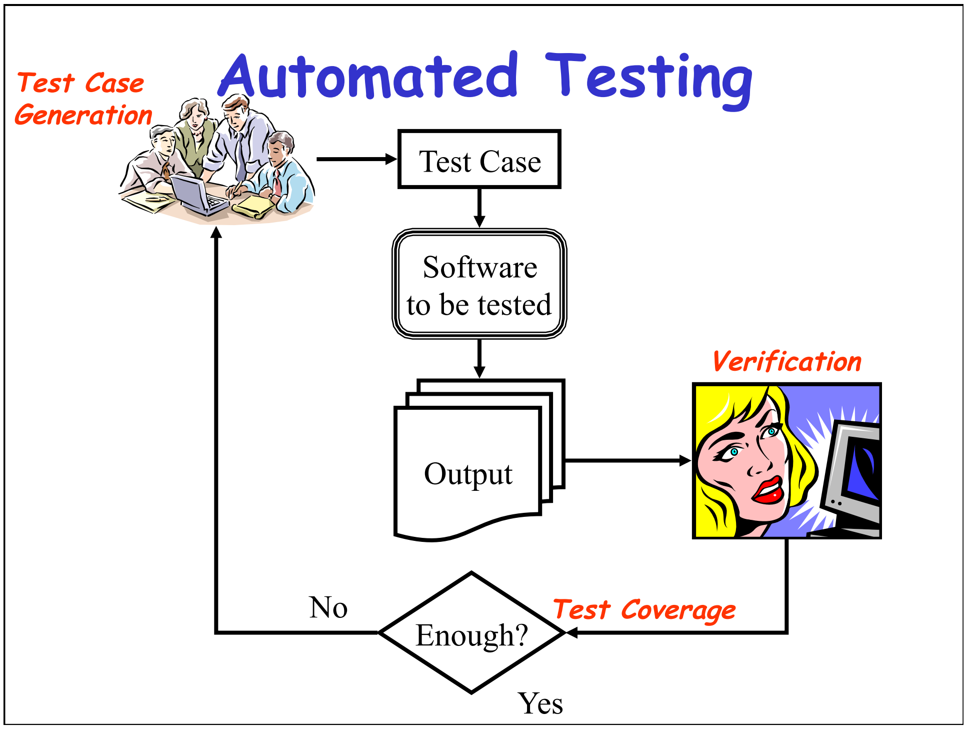
Output

When to Stop?



A Real Testing Example





Automated Testing

Test Case Generation

Test Case

Software to be tested

Output

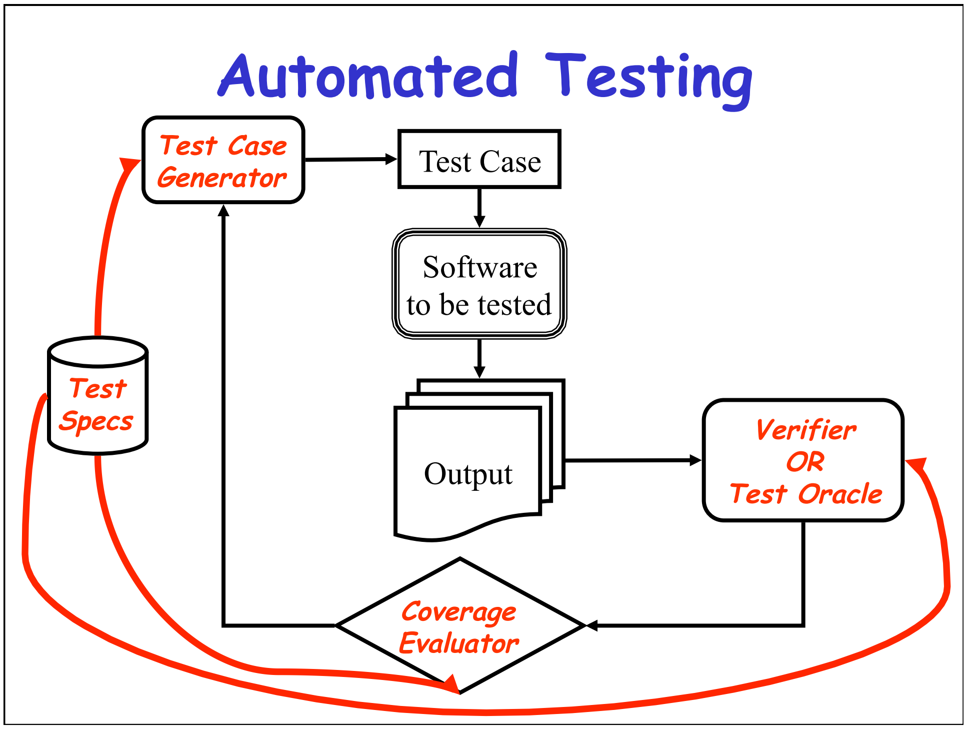
Verification

No

Enough?

Test Coverage

Yes



Automated Testing

Test Case Generator

Test Case

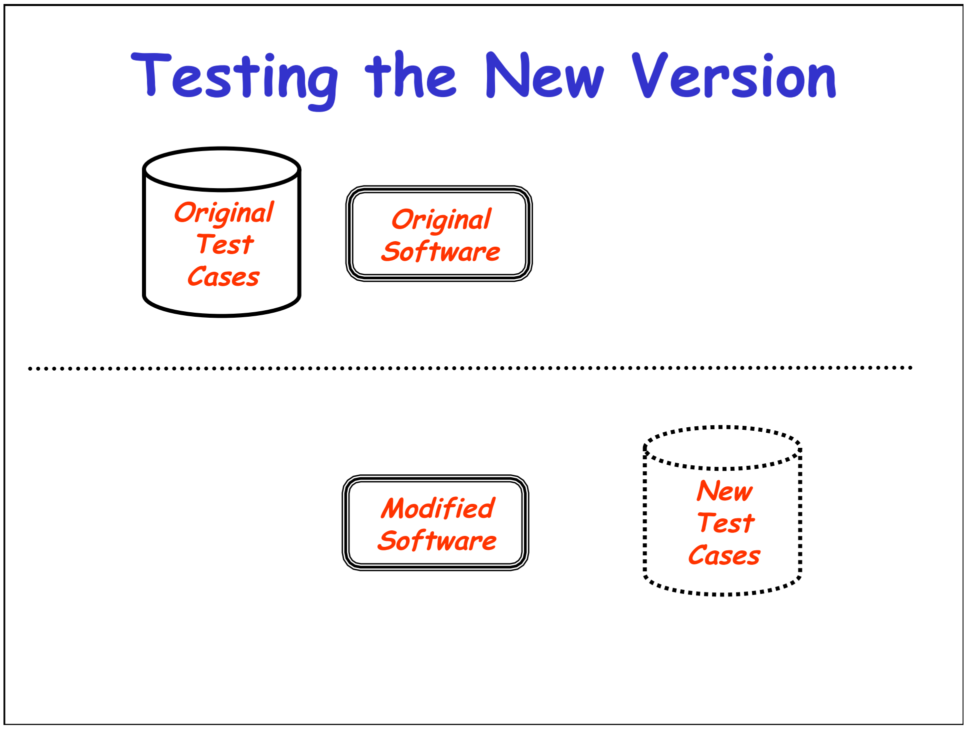
Software to be tested

Test Specs

Output

Verifier OR Test Oracle

Coverage Evaluator



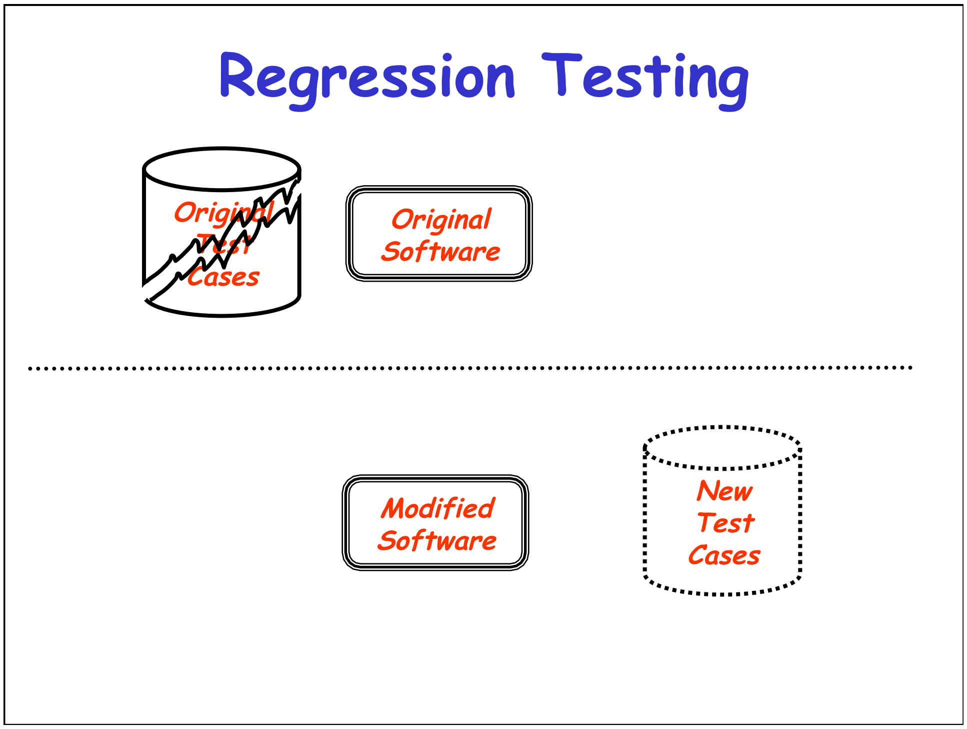
Testing the New Version

Original Test Cases

Original Software

Modified Software

New Test Cases



Regression Testing

Original Test Cases

Original Software

Modified Software

New Test Cases

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

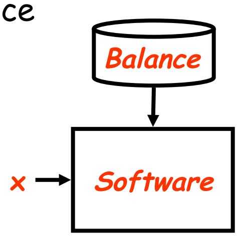
- Discussion

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

Generate test cases to cover each statement

x: 1..1000;

```
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

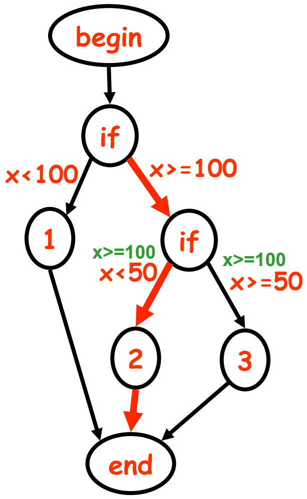
Determining Adequacy

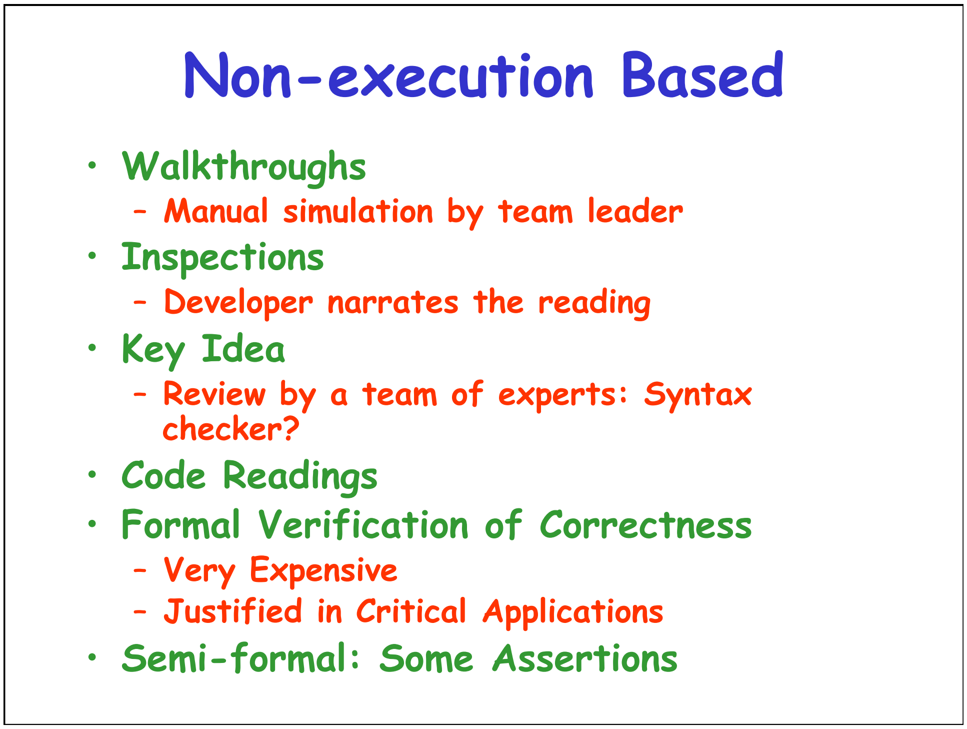
- Statement coverage
- Branch coverage
- Path coverage
- All-def-use-path coverage

Surprise Quiz

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

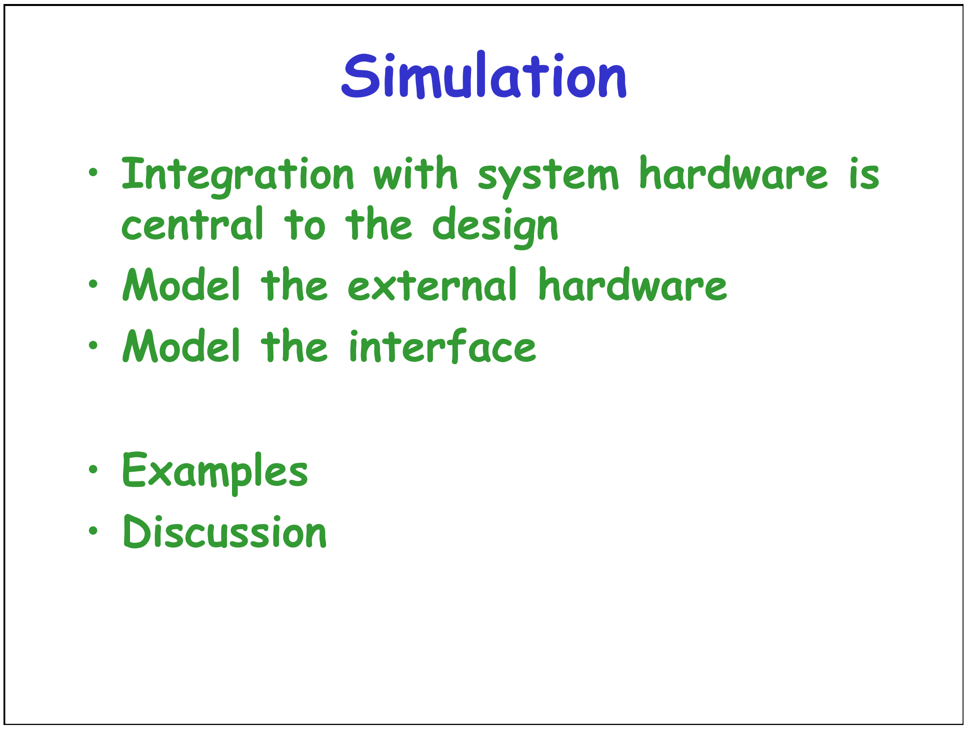
```
input(x);
if (x < 100)
        print "Line 1";
else {
        if (x < 50) print "Line 2"
        else print "Line 3";
}
```





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

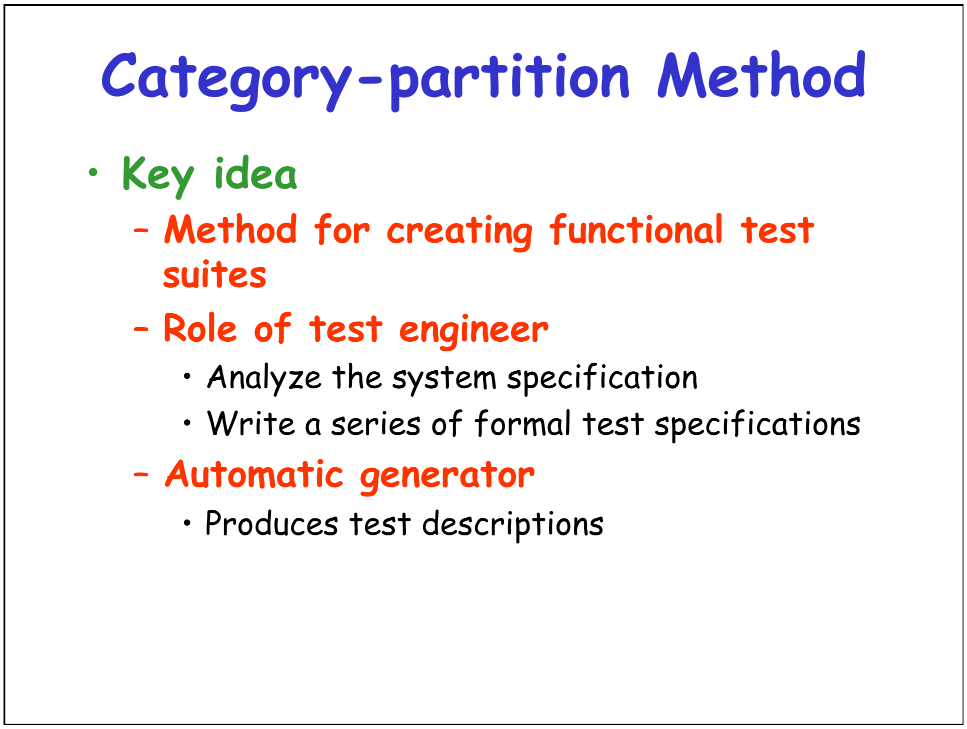
- Unit testing
- Integration testing
- Stubs
- System testing

Mutation Testing

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

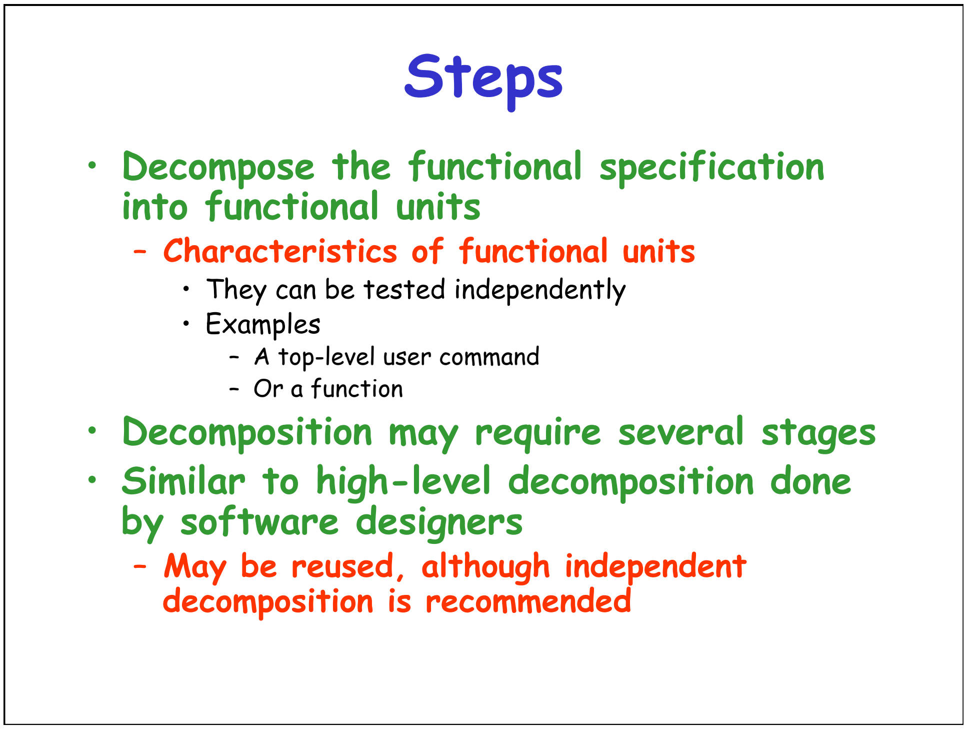
Test Case Generation

- 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]

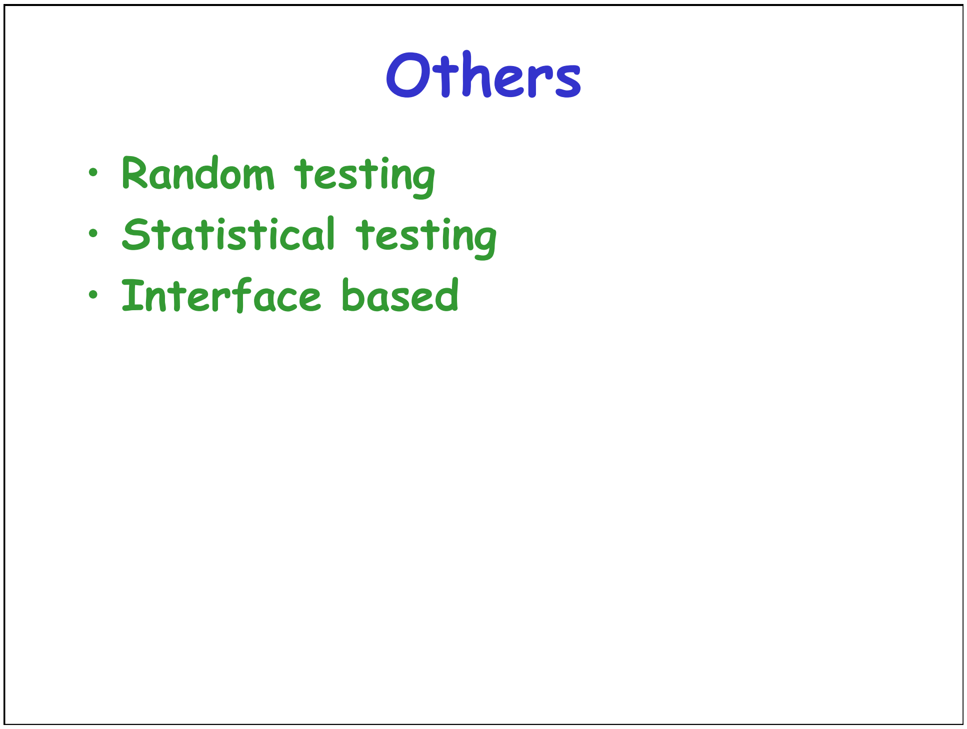
- What is a software test adequacy criterion
  - Predicate that defines “what properties of a program must be exercised to constitute a thorough test”, i.e., one whose successful execution implies no errors in a tested program

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