Testing Process and Methods

CS 490MT/5555, Fall 2015, Yongjie Zheng

Context of Software Testing

- Verification & Validation
  - Verification: checking that the software conforms to its specification.
  - Validation: checking that the software meets the customer's expectations. – more general
- Techniques of verification and validation
  - Inspections – static
    - Automated code analysis
    - Formal verification
  - Software testing - dynamic

Definition of Software Testing

- Software testing is a fundamental technique used to determine errors. It executes the software using representative data samples and comparing the actual results with the expected results.

Software Test: Pass/Fail

- Given a software system *S* and a test case *t*:
  - Test case *t passes* if the actual output for an execution of *S* with *t* is the same as the expected output for *t*; otherwise *t* fails.

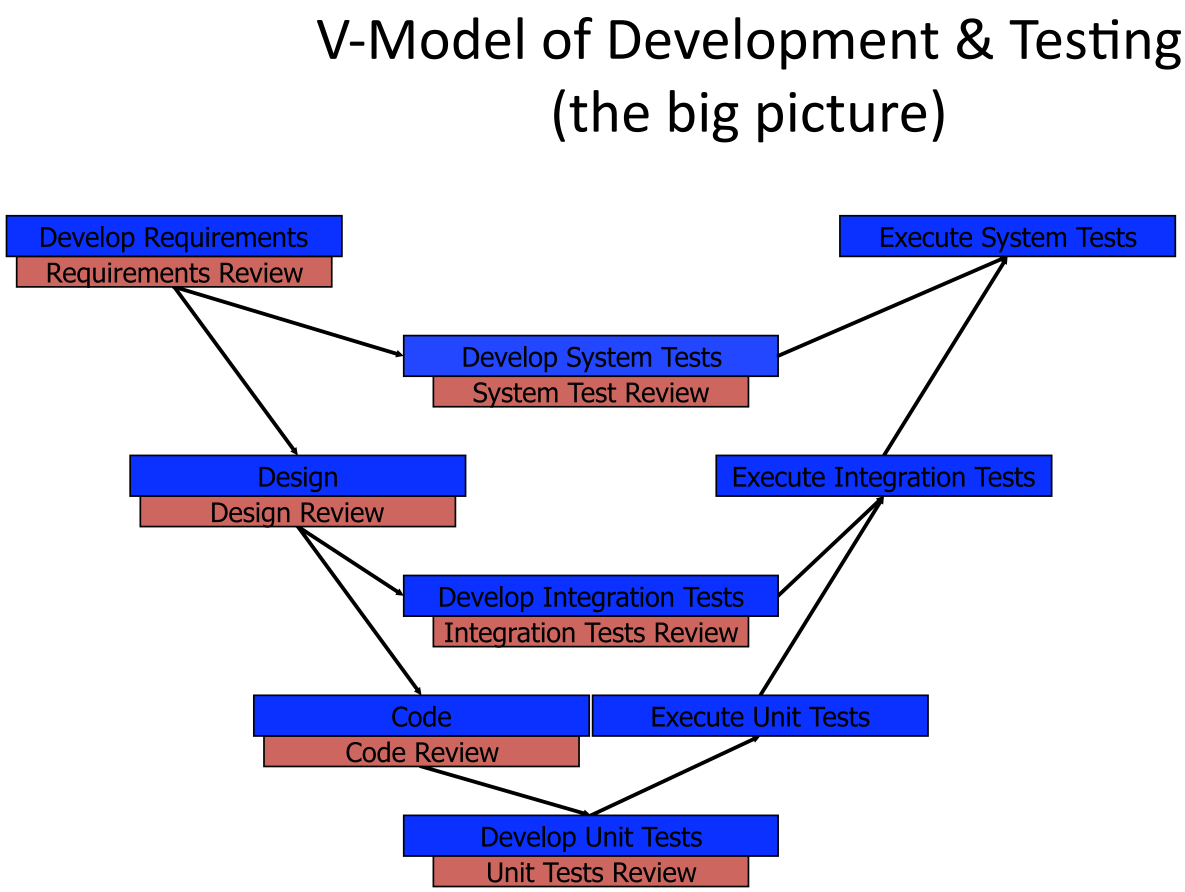
How to generate test cases

- White-box testing – structural, program-based testing
  - Test cases are designed, selected, and run based on structure of the source code (control-flow coverage, data-flow coverage).
  - Tests the nitty-gritty.
  - Drawbacks: need access to source.
- Black-box testing – functional, specification-based testing
  - Test cases are designed, selected, and run based on specifications.
  - Tests the overall system behavior.
  - Drawbacks: less systematic.

What to test

- Unit test
  - Testing individual modules.
- Integration test
  - Testing the composition of modules.
- System (acceptance) test
  - Testing the whole system against requirements specification.
- Regression test
  - Retesting a modified program.

V-Model


V-Model of Development & Testing
(the big picture)
Develop Requirements
Requirements Review
Execute System Tests
Develop System Tests
System Test Review
Design
Design Review
Execute Integration Tests
Develop Integration Tests
Integration Tests Review
Code
Code Review
Execute Unit Tests
Develop Unit Tests
Unit Tests Review

Let' s get them summarized a little bit …

	Unit Test	Integration Test	System Test	Regression Test
White-box test	★	★		★
Black-box test		★	★	★

Important Activities in Software Testing

- Test Data (Test Case) Generation
  - Input
    - White-box: structure coverage.
    - Black-box: specification based.
  - Expected Output
    - Test Oracle: the tester or an external mechanism that can accurately decide whether or not the output produced by a program is correct.
    - Non-testable.
      - No oracle: for example, to test a program that calculates the total volume of water on earth.
      - Have oracle, but hard to decide: for example, to test a program that sorts an integer array whose size is over 1,000.
- Localizing fault based on test results

Testing Techniques

- Test Data Generation
  - Ostrand, T. J. and Balcer, M. J. 1988. The category-partition method for specifying and generating fuctional tests. Commun. ACM 31, 6 (Jun. 1988), 676-686.
- Fault Localization
  - Jones, J. A., Harrold, M. J., and Stasko, J. 2002. Visualization of test information to assist fault localization. In Proceedings of the 24th international Conference on Software Engineering (Orlando, Florida, May 19 - 25, 2002). ICSE '02. ACM, New York, NY, 467-477.

Fault Localization Using Visualization Technique

- Intuition
  - Statements that are primarily executed by failed test cases are more suspicious than statements that are primarily executed by passed test cases.

$$suspiciousness(s) = \frac{\frac{failed(s)}{totalfailed}}{\frac{passed(s)}{totalpassed} + \frac{failed(s)}{totalfailed}}$$

Fault Localization Using Visualization Technique

- Input (S: a software system; t: test case; T: test suite)
  - The source code for S
  - The pass/fail results for executing S with each t in T
  - The code coverage of executing S with each t in T
    - The code coverage for t consists of the source code statements that are executed when S is run with t.
- Output
  - Suspicious score for each executed source code statement
  - Visualization of the source code in which the individual statements are colored according to their participation in the testing

Fault Localization Using Visualization Technique

- The following five slides are provided by [Prof. James A. Jones]().

$$suspiciousness(s) = \frac{\frac{failed(s)}{totalfailed}}{\frac{passed(s)}{totalpassed} + \frac{failed(s)}{totalfailed}}$$

```
mid() {
 int x,y,z,m;
```

	Code	3,3,5	1,2,3	3,2,1	5,5,5	5,3,4	2,1,3	suspiciousness
1:	`read("Enter 3 numbers:",x,y,z);`	•	•	•	•	•	•	0.5
2:	`m = z;`	•	•	•	•	•	•	0.5
3:	`if (y<z)`	•	•	•	•			0.5
4:	`if (x<y)`							.6
5:	`m = y;`							.0
6:	`else if (x<z)`							.7
7:	`m = y; // bug`							.8
8:	`else`			•	•			0.0
9:	`if (x>y)`			•	•			0.0
10:	`m = y;`							0.0
11:	`else if (x>z)`							0.0
12:	`m = x;`							0.0
13:	`print("Middle number is:", m);`							0.5
	`}` Pass Status	P	P	P	P	P	F	

$$susp(1) = \frac{\frac{1}{1}}{\frac{5}{5} + \frac{1}{1}} = 0.5$$

$$susp(7) = \frac{\frac{1}{1}}{\frac{1}{5} + \frac{1}{1}} = 0.8$$

Fault Localization Using Visualization Technique

For statement *s*:

Hue summarizes pass/fail results of test cases that executed *s*

Brightness presents the "confidence" of the hue assigned to *s*

Fault Localization Using Visualization Technique

		Test Cases					
		3,3,5	1,2,3	3,2,1	5,5,5	5,3,4	2,1,3
	`mid() {`						
	`int x,y,z,m;`						
1:	`read("Enter 3 numbers:",x,y,z);`	•	•	•	•	•	•
2:	`m = z;`	•	•	•	•	•	•
3:	`if (y<z)`	•	•	•	•	•	•
4:	`if (x<y)`	•	•			•	•
5:	`m = y;`		•				
6:	`else if (x<z)`	•				•	•
7:	`m = y;`	•					•
8:	`else`			•	•		
9:	`if (x>y)`			•	•		
10	`m = y;`			•			
11:	`else if (x>z)`				•		
12:	`m = x;`						
13:	`print("Middle number is:", m);`	•	•	•	•	•	•
	`}`						
	Pass Status	P	P	P	P	P	F

Fault Localization Using Visualization Technique

SeeSoft view

- each pixel represents a character in the source

```
mid() {
 int x,y,z,m;
 read("Enter 3 numbers:",x,y,z);
 m = z;
 if (y<z)
    if (x<y)
          m = y;
    else if (x<z)
          m = y;
 else
    if (x>y)
          m = y;
    else if (x>z)
          m = x;
 print("Middle number is:", m);
}
```

Fault Localization Using Visualization Technique

SeeSoft view

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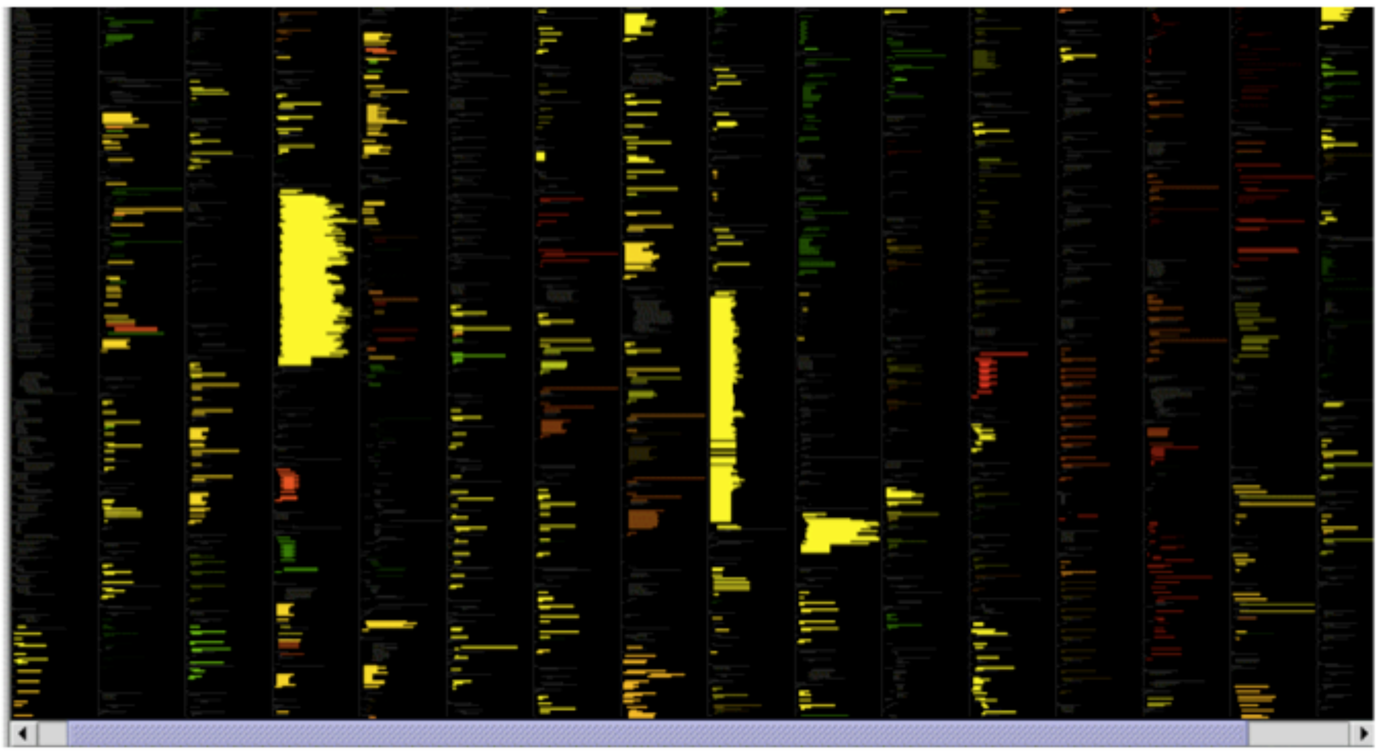

Category-Partition Method for Generating Functional Tests

- Goal
  - The tests are executed for all of the systems' functions
  - The tests are designed to maximize the chances of finding errors in the software.
    - Testing boundary conditions, special cases, error handlers, and cases where inputs and the system environment interact in potentially dangerous ways.
- Approach
  - Partition the input domain of a function being tested, and then select test data from each class of the partition.
  - The idea is: all elements within an equivalence class are essentially the same for the purpose of testing.

Category-Partition Method for Generating Functional Tests

- Specific Steps of Category-Partition Method
  - Decompose functional specification into **functional units** that can be tested independently.
  - Identifying **categories** based on parameters and environment conditions.
    - Parameters are the explicit inputs to a functional unit
    - Environment conditions are characteristics of the system's state at the time of executing a functional unit
    - A category is a major property or characteristic of a parameter or environment condition.
  - Partition each category into distinct **choices**.
  - Determine **constraints** among the choices.
  - Generate **testing specifications**.

Category-Partition Method for Generating Functional Tests

- Rule of Thumb
  - Choose test cases on the boundaries of the partitions plus cases close to the mid-point of the partition.
  - While the categories are derived entirely from information in the specification, the choices can be based on
    - The specification
    - The tester's past experience
    - Knowledge about the system

Category-Partition Method for Generating Functional Tests

- Example: Search

procedure Search (Key : ELEM ; T: ELEM_ARRAY;
Found : **out** BOOLEAN; L: **out** ELEM_INDEX) ;

Pre-condition
The array has at least one element
T'FIRST <= T'LAST

Post-condition
The element is found and is referenced by L
(Found and T (L) = Key)

or

The element is not in the array
(**not** Found **and**
not (**exists** i, T'FIRST >= i <= T'LAST, T (i) = Key))

Category-Partition Method for Generating Functional Tests

- Category Partitions for Search
  - Number of occurrences of key in the sequence
    - none, exactly one (assuming no duplicates in the sequence)
  - Position of key in the sequence
    - first element, middle element, last element
  - Sequence size
    - single value, many values

Category-Partition Method for Generating Functional Tests

Array	**Element**
Single value	In sequence
Single value	Not in sequence
More than 1 value	First element in sequence
More than 1 value	Last element in sequence
More than 1 value	Middle element in sequence
More than 1 value	Not in sequence

Input sequence (T)	**Key** (Key)	**Output** (Found, L)
17	17	true, 1
17	0	false, ??
17, 29, 21, 23	17	true, 1
41, 18, 9, 31, 30, 16, 45	45	true, 7
17, 18, 21, 23, 29, 41, 38	23	true, 4
21, 23, 29, 33, 38	25	false, ??

Facts About Testing

- Testing can only show the presence of errors, not their absence.
- Automatic test cases generation is impossible.
- A major problem that arises during integration testing is localizing errors.