Introduction to Testing

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Defect Reduction Techniques

- Review
- Testing
- Formal verification
- Development process
- Systematic methodologies

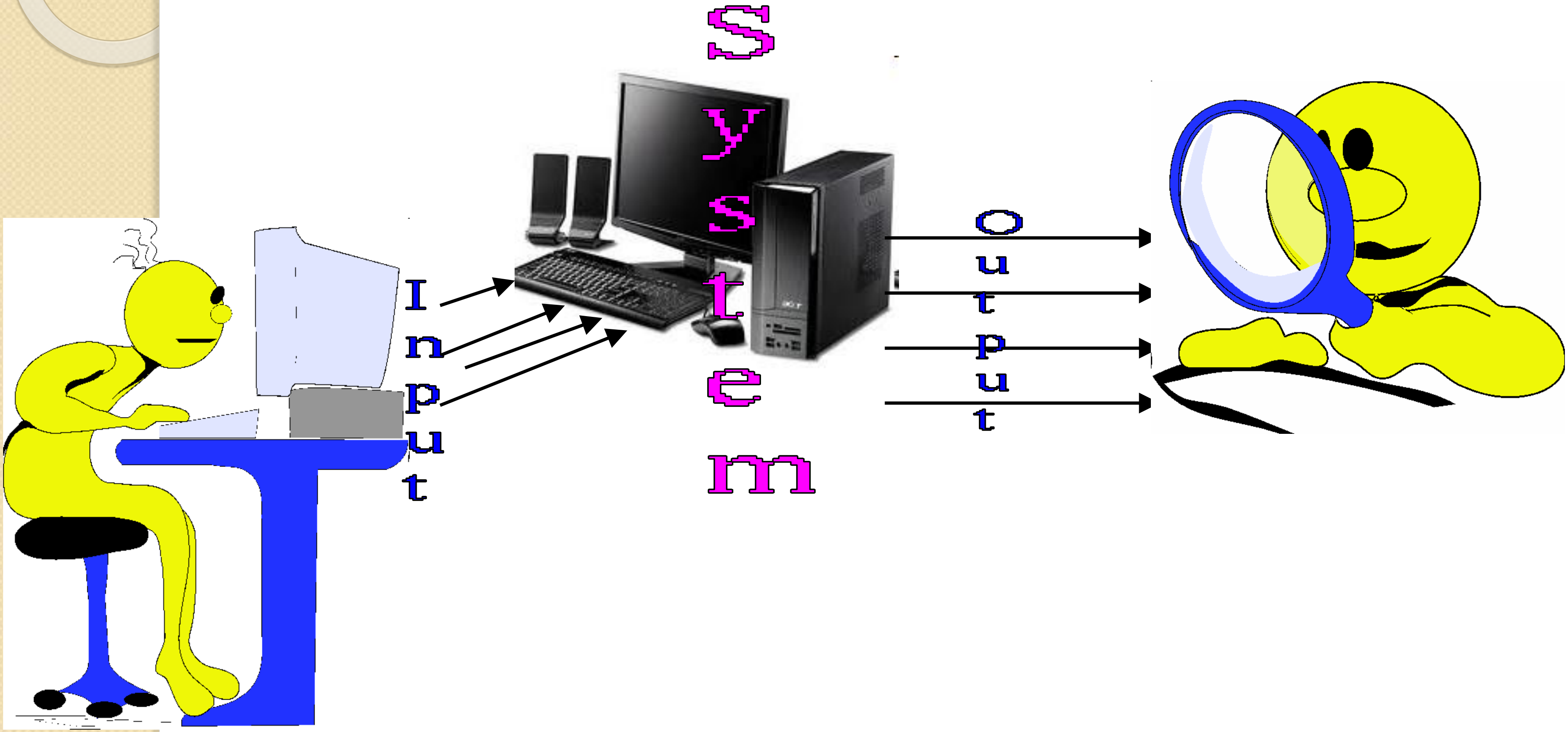
Why Test?

- Ariane 5 rocket self-destructed 37 seconds after launch
- Reason: A control software bug that went undetected
  - Conversion from 64-bit floating point to 16-bit signed integer value had caused an exception
    - The floating point number was larger than 32767
    - Efficiency considerations had led to the disabling of the exception handler.
- Total Cost: over $1 billion

How Do You Test a Program?

- Input test data to the program.
- Observe the output:
  - Check if the program behaved as expected.

How Do You Test a Program?



How Do You Test a Program?

- If the program does not behave as expected:
  - Note the conditions under which it failed.
  - Later debug and correct.

What's So Hard About Testing ?

- Consider `int proc1(int x, int y)`
- Assuming a 64 bit computer
  - Input space = 2^{128}
- Assuming it takes 10secs to key-in an integer pair
  - It would take about a billion years to enter all possible values!
  - Automatic testing has its own problems!

Testing Facts

- Consumes largest effort among all phases
  - Largest manpower among all other development roles
  - Implies more job opportunities
- About 50% development effort
  - But 10% of development time?
  - How?

Testing Facts

- Testing is getting more complex and sophisticated every year.
    - Larger and more complex programs
    - Newer programming paradigms

Overview of Testing Activities

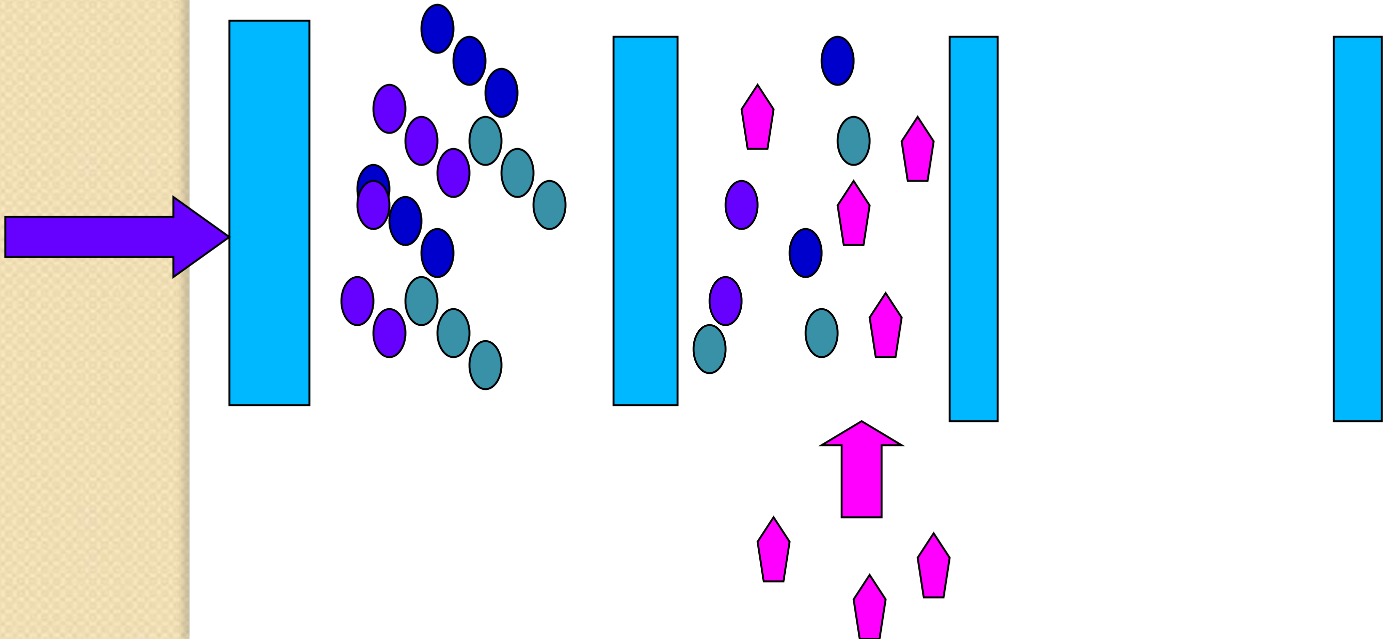
- Test Suite Design
- Run test cases and observe results to detect failures.
- Debug to locate errors
- Correct errors.

Error, Faults, and Failures

- A failure is a manifestation of an error (also defect or bug).
  - Mere presence of an error may not lead to a failure.

Pesticide Effect

- Errors that escape a fault detection technique:
  - Can not be detected by further applications of that technique.



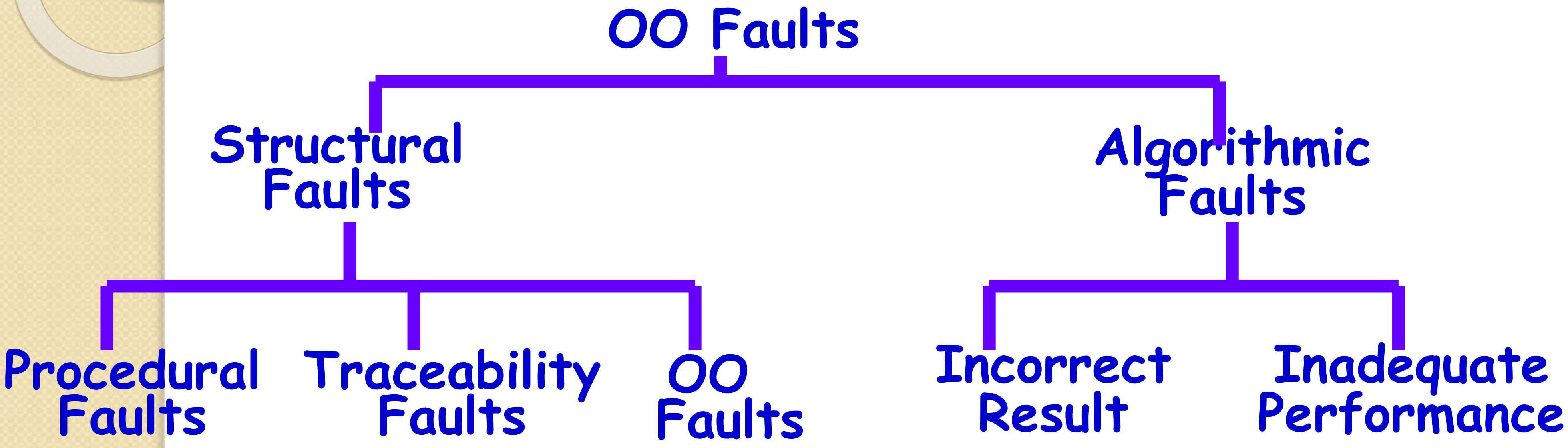
Pesticide Effect

- Assume we use 4 fault detection techniques and 1000 bugs:
  - Each detects only 70% bugs
  - How many bugs would remain
  - $1000*(0.3)^4=81$ bugs

Fault Model

- Types of faults possible in a program.
- Some types can be ruled out
    - Concurrency related-problems in a sequential program

Fault Model of an OO Program



OO Faults

Structural Faults

Algorithmic Faults

Procedural Faults

Traceability Faults

OO Faults

Incorrect Result

Inadequate Performance

Hardware Fault-Model

- Simple:
  - Stuck-at 0
  - Stuck-at 1
  - Open circuit
  - Short circuit
- Simple ways to test the presence of each
- Hardware testing is fault-based testing

Software Testing

- Each test case typically tries to establish correct working of some functionality
  - Executes (covers) some program elements
  - For restricted types of faults, fault-based testing exists.

Test Cases and Test Suites

- Test a software using a set of carefully designed test cases:
  - The set of all test cases is called the test suite

Test Cases and Test Suites

- A test case is a triplet [I,S,O]
  - I is the data to be input to the system,
  - S is the state of the system at which the data will be input,
  - O is the expected output of the system.

Verification versus Validation

- Verification is the process of determining:
  - Whether output of one phase of development conforms to its previous phase.
- Validation is the process of determining:
  - Whether a fully developed system conforms to its SRS document.

Verification versus Validation

- Verification is concerned with phase containment of errors,
  - Whereas the aim of validation is that the final product be error free.

Design of Test Cases

- Exhaustive testing of any non-trivial system is impractical:
  - Input data domain is extremely large.
- Design an optimal test suite:
  - Of reasonable size and
  - Uncovers as many errors as possible.

Design of Test Cases

- If test cases are selected randomly:
  - Many test cases would not contribute to the significance of the test suite,
  - Would not detect errors not already being detected by other test cases in the suite.
- Number of test cases in a randomly selected test suite:
  - Not an indication of effectiveness of testing.

Design of Test Cases

- Testing a system using a large number of randomly selected test cases:
  - Does not mean that many errors in the system will be uncovered.
- Consider following example:
  - Find the maximum of two integers x and y.

Design of Test Cases

- The code has a simple programming error:

-
  ```
  If (x>y) max = x;
              else max = x;
  ```
- Test suite {(x=3,y=2);(x=2,y=3)} can detect the error,
- A larger test suite {(x=3,y=2);(x=4,y=3);(x=5,y=1)} does not detect the error.

Design of Test Cases

- Systematic approaches are required to design an optimal test suite:
  - Each test case in the suite should detect different errors.

Design of Test Cases

- There are essentially three main approaches to design test cases:
  - Black-box approach
  - White-box (or glass-box) approach
  - Grey-box testing

Black-Box Testing

- Test cases are designed using only functional specification of the software:
  - Without any knowledge of the internal structure of the software.
- For this reason, black-box testing is also known as functional testing.

White-box Testing

- Designing white-box test cases:
  - Requires knowledge about the internal structure of software.
  - White-box testing is also called structural testing.
  - In this unit we will not study white-box testing.

White-Box Testing

- There exist several popular white-box testing methodologies:
  - Statement coverage
  - Branch coverage
  - Path coverage
  - Condition coverage
  - MC/DC coverage
  - Mutation testing
  - Data flow-based testing

Why Both BB and WB Testing?

Black-box

- Impossible to write a test case for every possible set of inputs and outputs
- Some code parts may not be reachable
- Does not tell if extra functionality has been implemented.

White-box

- Does not address the question of whether or not a program matches the specification
- Does not tell you if all of the functionality has been implemented
- Does not discover missing program logic

Coverage-Based Testing Versus Fault-Based Testing

- Idea behind coverage-based testing:
  - Design test cases so that certain program elements are executed (or covered).
  - Example: statement coverage, path coverage, etc.
- Idea behind fault-based testing:
  - Design test cases that focus on discovering certain types of faults.
  - Example: Mutation testing.

Thank You