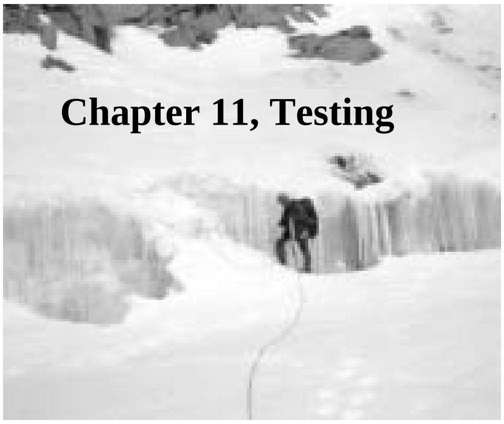
Object-Oriented Software Engineering
Using UML, Patterns, and Java

Chapter 11, Testing



Outline

- Terminology
- Types of errors
- Dealing with errors
- Quality assurance vs Testing
- Component Testing
  - **Unit testing**
  - **Integration testing**
- Testing Strategy
- Design Patterns & Testing
- System testing
  - **Function testing**
  - **Structure Testing**
  - **Performance testing**
  - **Acceptance testing**
  - **Installation testing**

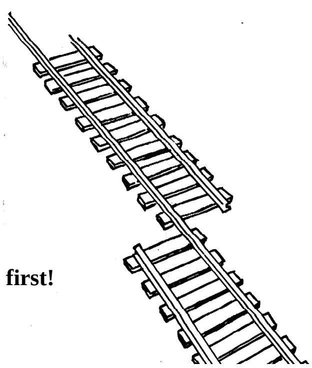
What is this?

A failure?

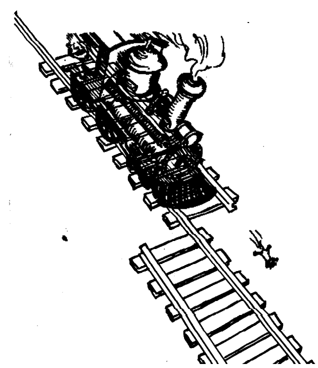
An error?

A fault?

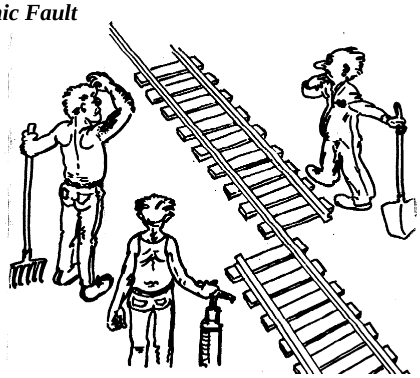
Need to specify the desired behavior first!



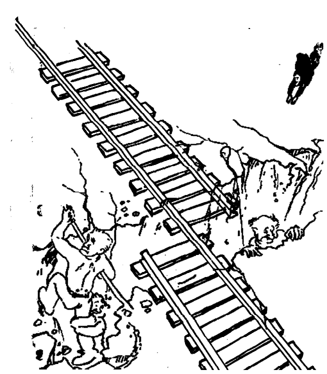
Erroneous State ("Error")



Algorithmic Fault



Mechanical Fault



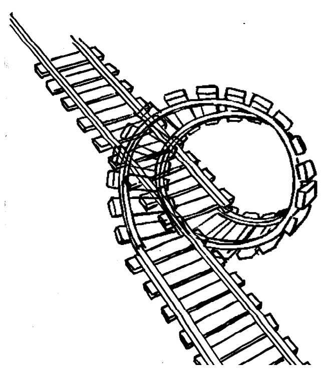
Terminology

- **Reliability:** The measure of success with which the observed behavior of a system confirms to some specification of its behavior.
- **Failure:** Any deviation of the observed behavior from the specified behavior.
- **Error:** The system is in a state such that further processing by the system will lead to a failure.
- **Fault (Bug):** The mechanical or algorithmic cause of an error.

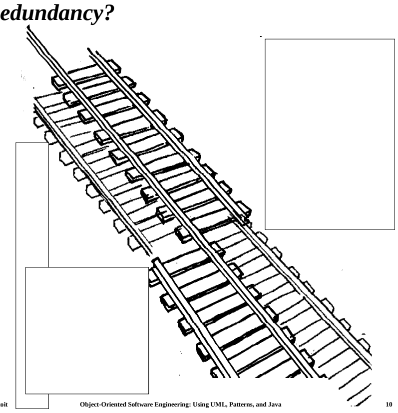
There are many different types of errors and different ways how we can deal with them.

How do we deal with Errors and Faults?

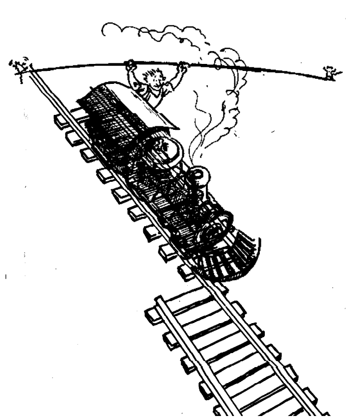
Verification?



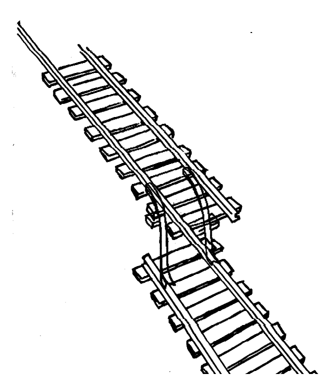
Modular Redundancy?



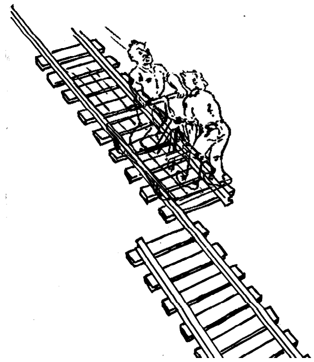
Declaring the Bug as a Feature?



Patching?



Testing?



Examples of Faults and Errors

- Faults in the Interface specification
  - **Mismatch between what the client needs and what the server offers**
  - **Mismatch between requirements and implementation**
- Algorithmic Faults
  - **Missing initialization**
  - **Branching errors (too soon, too late)**
  - **Missing test for null**
- Mechanical Faults (very hard to find)
  - **Documentation does not match actual conditions or operating procedures**
- Errors
  - **Stress or overload errors**
  - **Capacity or boundary errors**
  - **Timing errors**
  - **Throughput or performance errors**

Dealing with Errors

- Verification:
  - **Assumes hypothetical environment that does not match real environment**
  - **Proof might be buggy (omits important constraints; simply wrong)**
- Modular redundancy:
  - **Expensive**
- Declaring a bug to be a "feature"
  - **Bad practice**
- Patching
  - **Slows down performance**
- Testing (this lecture)
  - **Testing is never good enough**

Another View on How to Deal with Errors

- **Error prevention** (before the system is released):
  - **Use good programming methodology to reduce complexity**
  - **Use version control to prevent inconsistent system**
  - **Apply verification to prevent algorithmic bugs**
- **Error detection** (while system is running):
  - **Testing: Create failures in a planned way**
  - **Debugging: Start with an unplanned failures**
  - **Monitoring: Deliver information about state. Find performance bugs**
- **Error recovery** (recover from failure once the system is released):
  - **Data base systems (atomic transactions)**
  - **Modular redundancy**
  - **Recovery blocks**

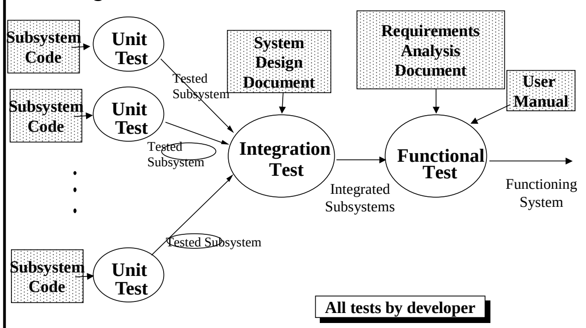
Some Observations

- It is impossible to completely test any nontrivial module or any system
  - **Theoretical limitations: Halting problem**
  - **Practial limitations: Prohibitive in time and cost**
- Testing can only show the presence of bugs, not their absence (Dijkstra)

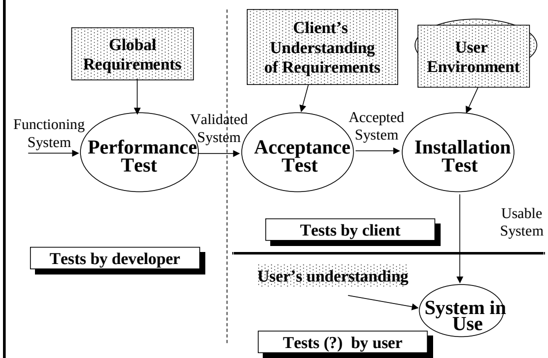
Testing takes creativity

- Testing often viewed as dirty work.
- To develop an effective test, one must have:
  - **Detailed understanding of the system**
  - **Knowledge of the testing techniques**
  - **Skill to apply these techniques in an effective and efficient manner**
- Testing is done best by independent testers
  - **We often develop a certain mental attitude that the program should in a certain way when in fact it does not.**
- Programmer often stick to the data set that makes the program work
  - **"Don't mess up my code!"**
- A program often does not work when tried by somebody else.
  - **Don't let this be the end-user.**

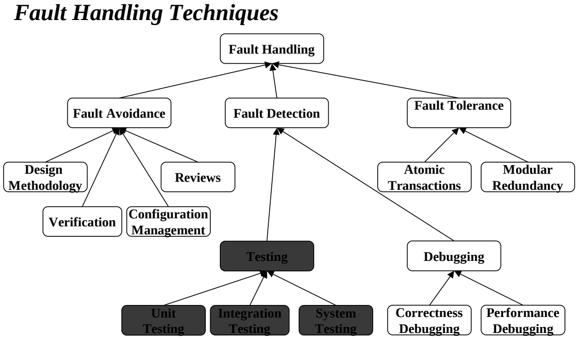
Testing Activities



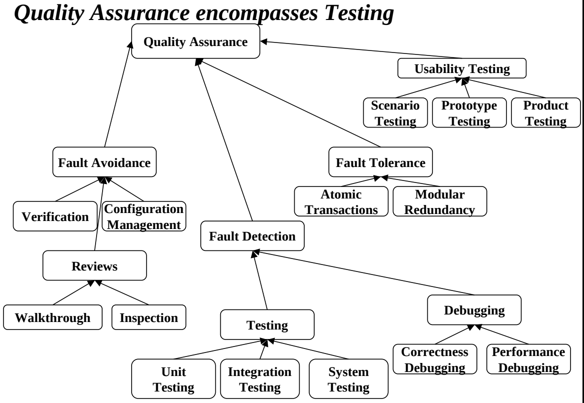
Testing Activities continued



Fault Handling Techniques



Quality Assurance encompasses Testing



Types of Testing

- Unit Testing:
  - **Individual subsystem**
  - **Carried out by developers**
  - **Goal: Confirm that subsystems is correctly coded and carries out the intended functionality**
- Integration Testing:
  - **Groups of subsystems (collection of classes) and eventually the entire system**
  - **Carried out by developers**
  - **Goal: Test the interface among the subsystem**

System Testing

- System Testing:
  - **The entire system**
  - **Carried out by developers**
  - **Goal: Determine if the system meets the requirements (functional and global)**
- Acceptance Testing:
  - **Evaluates the system delivered by developers**
  - **Carried out by the client. May involve executing typical transactions on site on a trial basis**
  - **Goal: Demonstrate that the system meets customer requirements and is ready to use**
- Implementation (Coding) and testing go hand in hand

Unit Testing

- Informal:
  - **Incremental coding**
- Static Analysis:
  - **Hand execution: Reading the source code**
  - **Walk-Through (informal presentation to others)**
  - **Code Inspection (formal presentation to others)**
  - **Automated Tools checking for**
    - **syntactic and semantic errors**
    - **departure from coding standards**
- Dynamic Analysis:
  - **Black-box testing (Test the input/output behavior)**
  - **White-box testing (Test the internal logic of the subsystem or object)**
  - **Data-structure based testing (Data types determine test cases)**

Black-box Testing

- Focus: I/O behavior. If for any given input, we can predict the output, then the module passes the test.
  - **Almost always impossible to generate all possible inputs ("test cases")**
- Goal: Reduce number of test cases by equivalence partitioning:
  - **Divide input conditions into equivalence classes**
  - **Choose test cases for each equivalence class. (Example: If an object is supposed to accept a negative number, testing one negative number is enough)**

Black-box Testing (Continued)

- Selection of equivalence classes (No rules, only guidelines):
  - **Input is valid across range of values. Select test cases from 3 equivalence classes:**
    - **Below the range**
    - **Within the range**
    - **Above the range**
  - **Input is valid if it is from a discrete set. Select test cases from 2 equivalence classes:**
    - **Valid discrete value**
    - **Invalid discrete value**
- Another solution to select only a limited amount of test cases:
  - **Get knowledge about the inner workings of the unit being tested => white-box testing**

White-box Testing

- Focus: Thoroughness (Coverage). Every statement in the component is executed at least once.
- Four types of white-box testing
  - **Statement Testing**
  - **Loop Testing**
  - **Path Testing**
  - **Branch Testing**

White-box Testing (Continued)

- Statement Testing (Algebraic Testing): Test single statements (Choice of operators in polynomials, etc)
- Loop Testing:
  - **Cause execution of the loop to be skipped completely. (Exception: Repeat loops)**
  - **Loop to be executed exactly once**
  - **Loop to be executed more than once**
- Path testing:
  - **Make sure all paths in the program are executed**
- Branch Testing (Conditional Testing): Make sure that each possible outcome from a condition is tested at least once

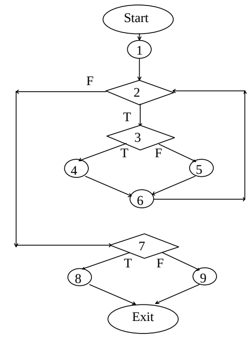
White-box Testing Example

```
FindMean(float Mean, FILE ScoreFile)
{ SumOfScores = 0.0; NumberOfScores = 0; Mean = 0;
 Read(ScoreFile, Score);  /*Read in and sum the scores*/
 while (! EOF(ScoreFile) {
         if ( Score > 0.0 ) {
                SumOfScores = SumOfScores + Score;
                NumberOfScores++;
          }
          Read(ScoreFile, Score);
 }
 /* Compute the mean and print the result */
 if (NumberOfScores > 0 ) {
              Mean = SumOfScores/NumberOfScores;
              printf("The mean score is %f \n",  Mean);
 } else
              printf("No scores found in file\n");
}
```

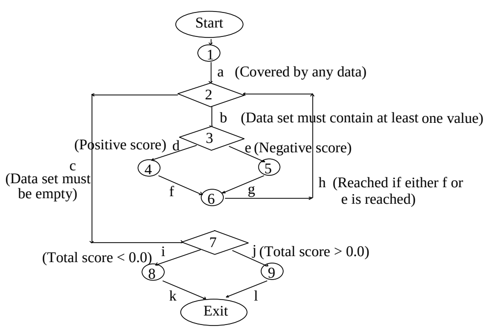
White-box Testing Example: Determining the Paths

```
FindMean (FILE ScoreFile)
{  float SumOfScores = 0.0;               <- 1
   int NumberOfScores = 0;
   float Mean=0.0; float Score;
   Read(ScoreFile, Score);
(2) while (! EOF(ScoreFile) {
 (3) if (Score  > 0.0 ) {
         SumOfScores = SumOfScores + Score;   <- 4
         NumberOfScores++;
    (5) }
      Read(ScoreFile, Score);              <- 6
   }
   /* Compute the mean and print the result */
(7) if (NumberOfScores > 0) {
        Mean = SumOfScores / NumberOfScores;    <- 8
        printf(" The mean score is %f\n", Mean);
   } else
        printf ("No scores found in file\n");   <- 9
}
```


Constructing the Logic Flow Diagram



Finding the Test Cases



Comparison of White & Black-box Testing

- White-box Testing:
  - **Potentially infinite number of paths have to be tested**
  - **White-box testing often tests what is done, instead of what should be done**
  - **Cannot detect missing use cases**
- Black-box Testing:
  - **Potential combinatorical explosion of test cases (valid & invalid data)**
  - **Often not clear whether the selected test cases uncover a particular error**
  - **Does not discover extraneous use cases ("features")**
- Both types of testing are needed
- White-box testing and black box testing are the extreme ends of a testing continuum.
- Any choice of test case lies in between and depends on the following:
  - **Number of possible logical paths**
  - **Nature of input data**
  - **Amount of computation**
  - **Complexity of algorithms and data structures**

The 4 Testing Steps

1. Select <u>what</u> has to be measured
   - **Analysis: Completeness of requirements**
   - **Design: tested for cohesion**
   - **Implementation: Code tests**
2. Decide <u>how</u> the testing is done
   - **Code inspection**
   - **Proofs (Design by Contract)**
   - **Black-box, white box,**
   - **Select integration testing strategy (big bang, bottom up, top down, sandwich)**
3. Develop <u>test cases</u>
   - **A test case is a set of test data or situations that will be used to exercise the unit (code, module, system) being tested or about the attribute being measured**
4. Create the <u>test oracle</u>
   - **An oracle contains of the predicted results for a set of test cases**
   - **The test oracle has to be written down before the actual testing takes place**

Guidance for Test Case Selection

- Use <u>*analysis knowledge*</u> about functional requirements (black-box testing):
  - **Use cases**
  - **Expected input data**
  - **Invalid input data**
- Use <u>*design knowledge*</u> about system structure, algorithms, data structures (white-box testing):
  - **Control structures**
    - **Test branches, loops, ...**
  - **Data structures**
    - **Test records fields, arrays, ...**
- Use <u>*implementation knowledge*</u> about algorithms:
  - **Examples:**
  - **Force division by zero**
  - **Use sequence of test cases for interrupt handler**

Unit-testing Heuristics

1. Create unit tests as soon as object design is completed:
   - **Black-box test: Test the use cases & functional model**
   - **White-box test: Test the dynamic model**
   - **Data-structure test: Test the object model**
2. Develop the test cases
   - **Goal: Find the minimal number of test cases to cover as many paths as possible**
3. Cross-check the test cases to eliminate duplicates
   - **Don't waste your time!**
4. Desk check your source code
   - **Reduces testing time**
5. Create a test harness
   - **Test drivers and test stubs are needed for integration testing**
6. Describe the test oracle
   - **Often the result of the first successfully executed test**
7. Execute the test cases
   - **Don't forget regression testing**
   - **Re-execute test cases every time a change is made.**
8. Compare the results of the test with the test oracle
   - **Automate as much as possible**