Software Engineering

Software Testing
Objectives

• To explain the different types of testing techniques used to discover program faults

• To introduce guidelines for interface testing

• To understand the principles of CASE tool support for testing
What is Defect testing?

Testing is:

• the process of **exercising a program**

• with the specific intent of **finding errors**

• **prior to delivery** to the end user.
Types of testing

- Defect testing
  - Exhaustive Testing
  - Black-box testing
  - Equivalence partitioning
  - White-box ‘Structural’ testing
  - Path testing
- Integration testing
- Interface testing
- Stress testing
- Object-oriented (OO) testing
- XP Automated testing
- Regression testing
- Acceptance testing
- Monkey testing

- Testing workbenches
What Testing Shows

- errors
- requirements conformance
- performance
- an indication of quality

Software Engineering

SW Testing

Slide 5
Statistics:
Defect Distribution in SW Life Cycle

![Pie chart showing defect distribution in software processes.]

- Requirements: 56%
- Design: 27%
- Code: 7%
- Others: 10%
Testing & Verification & Validation

- Testing = Verification + Validation

- Verification: Static Testing (no run)

- Validation: Dynamic Testing (Run code)
Use Cases & Functional Test Cases

- Write functional test case early
Who Tests the Software

**Developer**
- understands the system
- has the source code
- white-box ‘Unit’ testing
- will test "gently"
- driven by delivery ‘schedule’ constraint

**Independent tester**
- must learn about the system
- has no source code
- black-box ‘Acceptance’ testing
- will attempt to break the sys (ME!!)
- driven by quality constraint
Testing phases

Component (Unit) testing → Integration testing

Software developer → Independent testing team
The testing process

• **Component (Unit) testing: needs source code (White-box)**
  - Testing of individual program components
  - Usually the responsibility of the **component developer**
  - Tests are derived from the **developer’s experience**

• **Integration testing (Acceptance testing, Black-box testing)**
  - Testing of groups of components integrated to create a system or sub-system
  - The responsibility of an **independent testing team**
  - Tests are based on a **system specification (Acceptance testing)**
Exhaustive Testing

If there are $10^{14}$ possible paths and we execute one test per millisecond, it would take 3,170 years to test this program!!
Test Case Design

"Bugs lurk in corners and congregate at boundaries ..."

*Boris Beizer*

**OBJECTIVE** to uncover errors

**CRITERIA** in a complete manner

**CONSTRAINT** with a *minimum* of effort and time
Test data and test cases

- **Test data**
  - Inputs to test the system

- **Test case ‘Test scenario’ includes:**
  - Inputs to test the system
  - and the predicted outputs
The defect testing process

1. Design test cases
2. Prepare test data
3. Run program with test data
4. Compare results to test cases
5. Test cases
6. Test data
7. Test results
8. Deliverable
9. Test reports

Specs of test input & predicted sys output
Black-box testing

- Program is considered as a ‘black-box’
- No need to know or access source code
- Functionality testing
- No implementation testing (implementation testing needs source code)
- Test cases are based on the system specification
- Test planning can begin early in the software process
Black-box Testing

“Functionality testing”

Input: Test Case

Program

“No need for source code”

Sys Input

Predicted sys output

Compare

Sys Output

Output: Test Report
Black-box Testing

- **Input test data** (I)
  - Inputs causing anomalous behaviour
- **System / component**
  - Compare output with predicted values
- **Output test results** (O_e)
  - Outputs which reveal the presence of defects
Equivalence partitioning

- Objective: Reduce the number of test cases
Equivalence partitioning - cont.

- A way to derive test cases
- Is a black-box testing method
- Input data with common characteristics (positive numbers, negative numbers, strings without blanks, etc)
- Each of these classes is an equivalence partition
- Program behaves in an equivalent way for each member of an Equivalence partition
- Divides the input domain into classes of data form which test cases can be derived
Equivalence partitioning – cont.
Equivalence partitioning - cont.

- Guide lines for test case selection for partitions
  - At the **boundaries** of the partition
  - Close to **mid-point** of the partition
Equivalence partitioning - Example 1

- Program specs states:
  - Accepts 4 to 10 inputs
  - Each input is 5-digit integer greater >= than 10,000

- Partition system inputs and outputs into ‘equivalence sets’
Equivalence partitioning - cont.

Example

- **Input values**
  - Between 10000 and 99999
    - Less than 10000
    - More than 99999
  - 9999
  - 10000
  - 50000
  - 100000
  - 99999

- **Number of input values**
  - Invalid
  - Valid

- **Mid-point**
  - BV

- **Input values**
  - Less than 10000
  - Between 10000 and 99999
  - More than 99999
  - 10000
  - 50000
  - 99999
  - Valid
  - BV
Equivalence partitioning - cont.

Example 1

- If input is a 5-digit integer between 10,000 and 99,999, equivalence partitions are (fig 20.5 Sommerville)
  - <10,000,
  - 10,000 - 99,999
  - and > 99,999

- **Test cases: 6 cases**
  - 00000, (invalid special value that may be checked)
  - 09999, (invalid left boundary value)
  - 10000, (valid left boundary value)
  - 50000, (valid mid value)
  - 99999, (valid right boundary value)
  - 100000, (invalid right boundary value)

*Remember: Bugs lurk in corners & congregate at boundaries*
Structural testing ‘White-box testing’

- **Synonyms:**
  - Glass-box, Clear-box, Transparent-box
- For small program units
- Needs **source code**

- Objective: is to exercise **all program statements**
- (not all path combinations)
White-box testing

Tests \rightarrow Test data

Component code \rightarrow Derives

Test outputs

Starting point: known code
Path testing

• Each path through the program is executed at least once

• For loops & conditions

• Used at unit testing and module testing levels
Program flow graphs

• **Flow Graph:**
  - nodes representing program decisions
  - arcs representing the flow of control
  - Ignore sequential statements (assignments, procedures calls, I/O)

• Statements with conditions are therefore nodes in the flow graph

• **Cyclomatic complexity =**
  \[
  \text{Number of edges} - \text{Number of nodes} + 2
  \]
Cyclomatic complexity

- Cyclomatic complexity = number of tests to test all control statements

- Cyclomatic complexity = number of conditions in a program

- Although all paths are executed, all combinations of paths are not executed
Example: Path testing
Binary search flow graph

```
while bottom <= top
    if (elemArray [mid] == key
    (if (elemArray [mid]< key
```

```
bottom > top
```
Independent paths

• Cyclomatic complexity $= 11 - 9 + 2 = 4$

• Thus 4 independent paths:
  • 1, 2, 3, 8, 9
  • 1, 2, 3, 4, 6, 7, 2
  • 1, 2, 3, 4, 5, 7, 2
  • 1, 2, 3, 4, 6, 7, 2, 8, 9

• Test cases should be derived so that all of these paths are executed
Integration testing *(black-box)*

- Tests complete systems or subsystems composed of integrated components

- Integration testing should be **black-box** testing with tests derived from the **specification**

- Main difficulty is localising errors

- *Incremental integration* testing reduces this problem
Incremental integration testing

Recall: XP Continuous Integration of: Stories + (Acceptance & Unit Tests)

Minimal system

T1, T2, T3 are repeated to insure right interaction of C with A & B
Approaches to integration testing

• **Top-down integration testing**
  - Start with high-level system and integrate from the top-down replacing individual components by **stubs**
  - **Stubs** have the **same interface** as the components but **very limited functionality**

• **Bottom-up integration testing (XP)**
  - Integrate and test low-level components (or stories in XP), with **full functionality**, before developing higher level components, until the complete system is created

• In practice, combination of both
Top-down integration testing

Level 1

Level 2

Level 2

Level 2

Level 2

Level 3

Level 2 stubs

Level 2 stubs

Level 2 stubs

Level 2 stubs
Bottom-up integration testing
Testing approaches

• Architectural validation
  
  Top-down integration testing is better at discovering errors in the system architecture

• System demonstration
  
  Top-down integration testing allows a limited demonstration at an early stage in the development

• Test implementation
  
  Often easier with bottom-up integration testing
Interface testing

- Takes place when modules or sub-systems are integrated to create larger systems

- Objectives are to detect faults due to interface errors or invalid assumptions about interfaces

- Particularly important for object-oriented development as objects are defined by their interfaces
Interface testing
Interfaces types

- Parameter interfaces
  - Data passed from one procedure to another

- Shared memory interfaces
  - Block of memory is shared between procedures

- Message passing interfaces
  - Sub-systems request services from other sub-systems
Interface testing guidelines

• Design tests so that parameters to a called procedure are at the extreme ends of their ranges

• Use stress testing in message passing systems
Stress testing

- Exercises the system **beyond its maximum design load**.
- Stressing the system often causes defects to come to light.
- Stress testing failure behaviour.
  - Systems **should not fail catastrophically**.
  - Stress testing checks for unacceptable loss of service or data.

- Particularly relevant to **distributed systems** which can exhibit severe degradation as a network becomes overloaded.
Object-oriented (OO) testing

- The components to be tested are object classes that are instantiated as objects
Object-oriented testing: Testing levels

- Testing operations (methods) associated with objects

Remember: XP Unit Testing by developers on operations

Testing levels:
- Testing object classes
- Testing clusters of cooperating objects
- Testing the complete OO system
Object class testing

• Complete test coverage of a class involves:
  - Testing all operations (methods) associated with an object
  - Setting and interrogating all object attributes
  - (Recall: XP Unit testing for all methods and attributes of a class)

• Inheritance makes it more difficult to design object class tests
  - the information to be tested is not localised
Key Testing Issues

- Give high testing priority for parts of a system which are commonly used
  - give less priority for parts which are rarely executed
- Equivalence partitions
  - are sets of test cases where the program should behave in an equivalent way
  - aims at reducing the number of test cases
- Black-box testing is based on the system specification
- Structural testing identifies test cases which cause all paths through the program to be executed
Key Testing Issues

• Test coverage:
  measures ensure that all statements have been executed at least once.

• For OO testing:
  test object classes, test all operations, attributes and states