COMP 354: Introduction to Software Engineering

Software Component Testing

Based on Chapter 19 of the textbook

Strategic Approach to Testing

- You should conduct effective technical reviews as this can eliminate many errors before testing begins.
- Testing begins at the component level and works "outward" toward the integration of the entire system.
- Different testing techniques are appropriate for different software engineering approaches and at different points in time.
- Testing is conducted by the developer of the software and (for large projects) an independent test group.
- Testing and debugging are different activities, but debugging must be accommodated in any testing strategy.

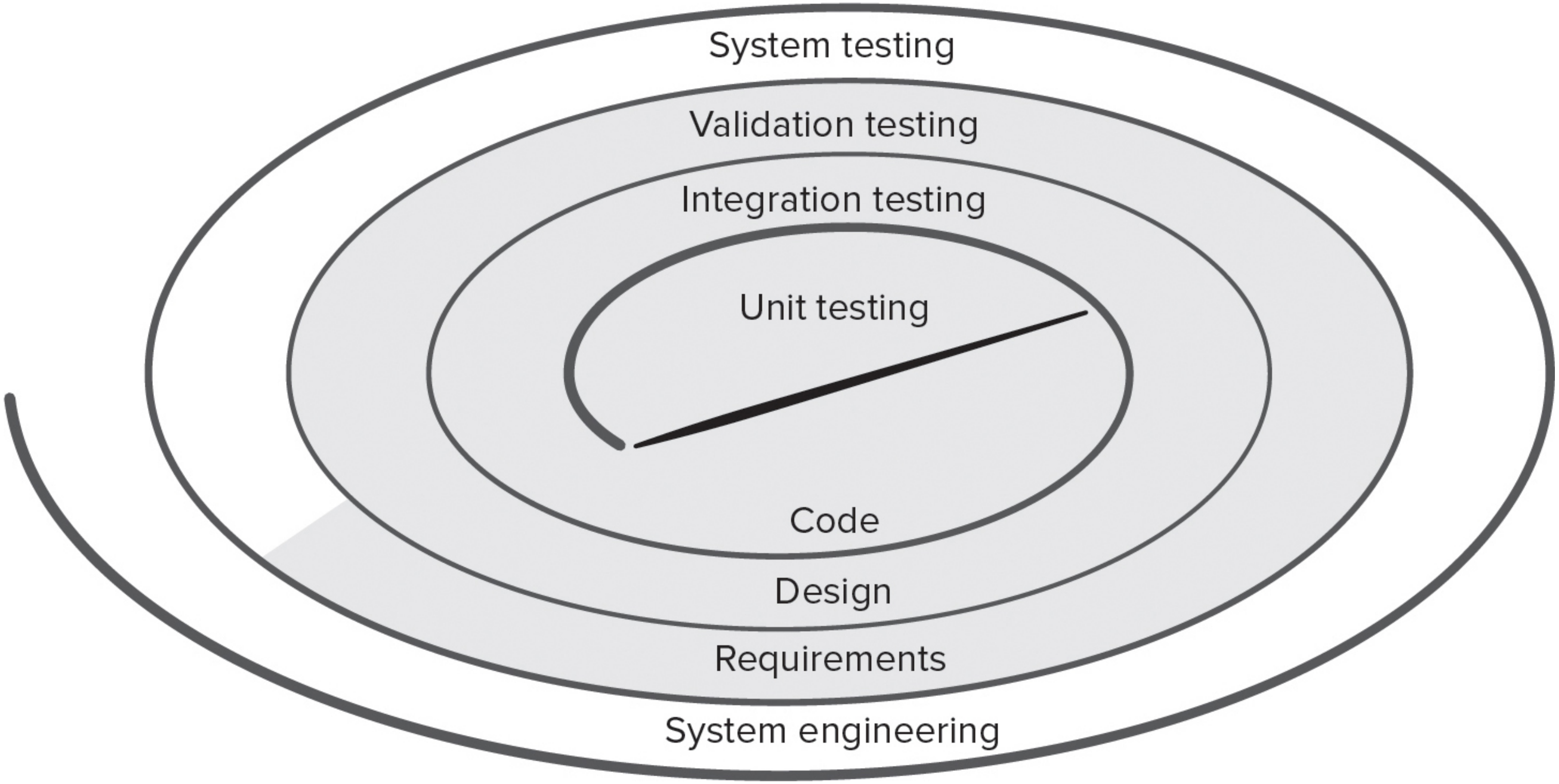
Verification and Validation

- Verification refers to the set of tasks that ensure that software correctly implements a specific function.
  - Verification: Are we building the product right?
- Validation refers to a different set of tasks that ensure that the software that has been built is traceable to customer requirements.
  - Validation: "Are we building the right product?"

Organizing for Testing

- Software developers are always responsible for testing individual program components and ensuring that each performs its designed function or behavior.
- Only after the software architecture is complete does an independent test group become involved.
- The role of an independent test group (ITG) is to remove the inherent problems associated with letting the builder test the thing that has been built.
- ITG personnel are paid to find errors.
- Developers and ITG work closely throughout a software project to ensure that thorough tests will be conducted.

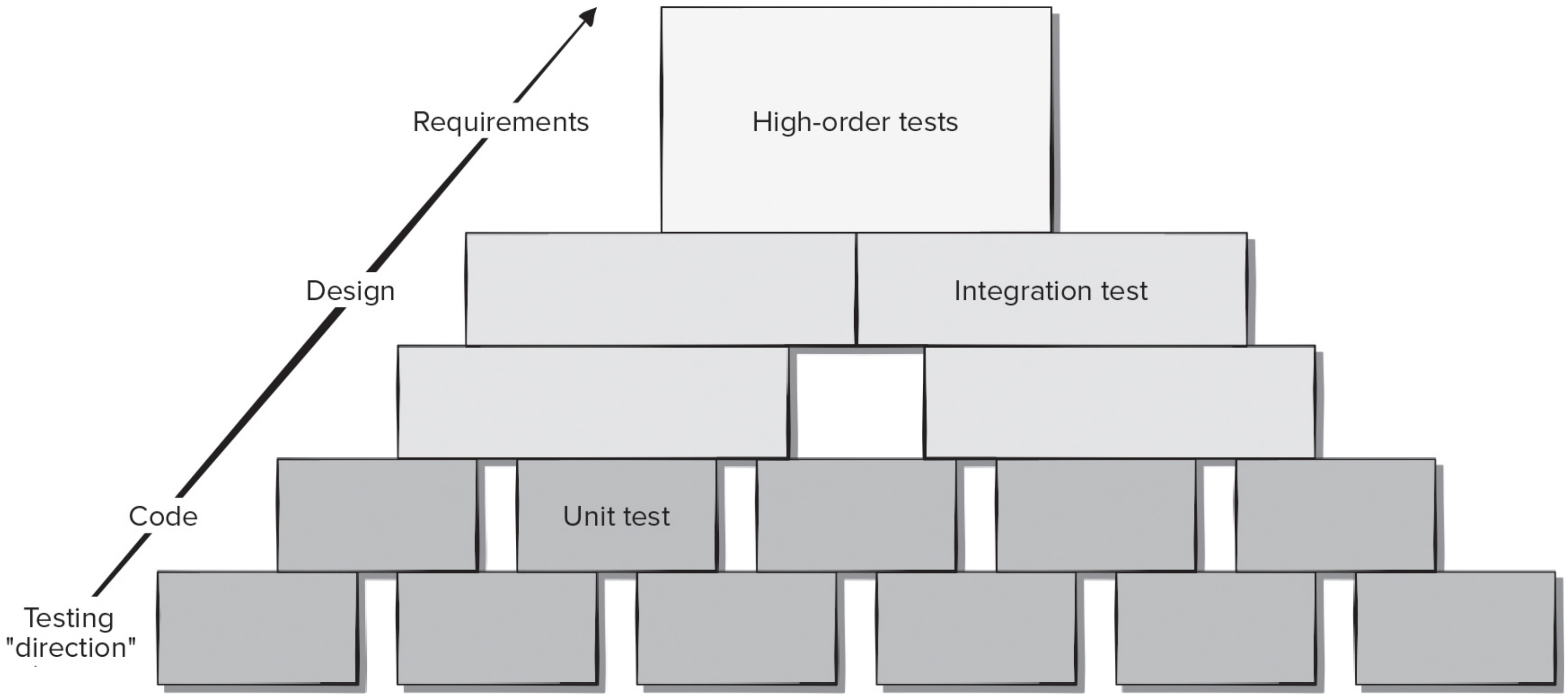
Testing Strategy



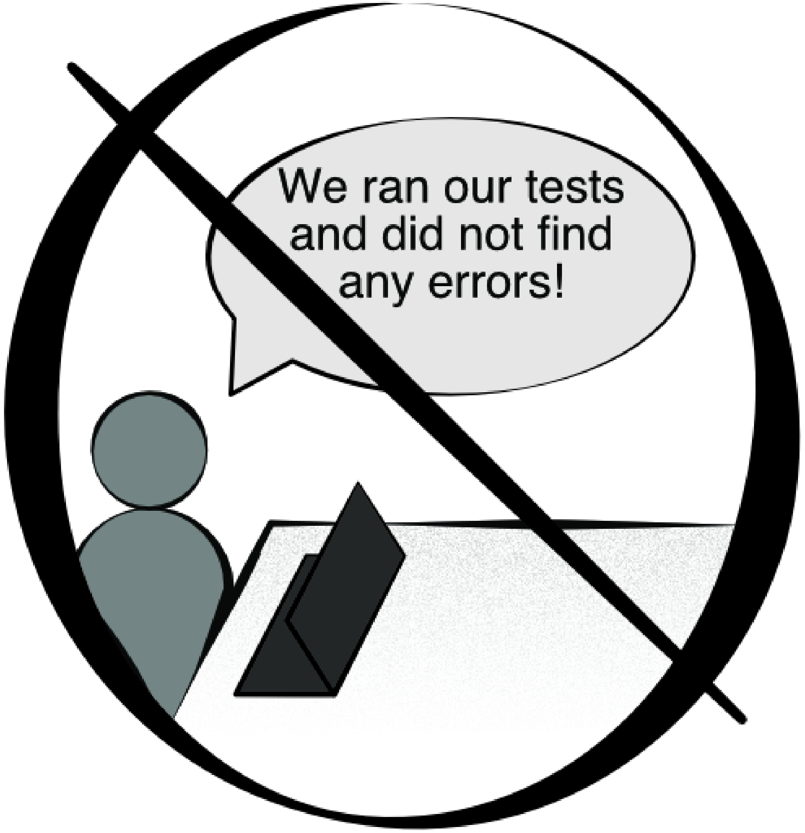
Testing the Big Picture

- Unit testing begins at the center of the spiral and concentrates on each unit (for example, component, class, or content object) as they are implemented in source code.
- Testing progresses to integration testing, where the focus is on design and the construction of the software architecture. Taking another turn outward on the spiral.
- Validation testing, is where requirements established as part of requirements modeling are validated against the software that has been constructed.
- In system testing, the software and other system elements are tested as a whole.

Software Testing Steps



When is Testing Done?



Criteria for Done

- You’re never done testing; the burden simply shifts from the software engineer to the end user. (Wrong).
- You’re done testing when you run out of time or you run out of money. (Wrong).
- The statistical quality assurance approach suggests executing tests derived from a statistical sample of all possible program executions by all targeted users.
- By collecting metrics during software testing and making use of existing statistical models, it is possible to develop meaningful guidelines for answering the question: “When are we done testing?”

Test Planning

1. Specify product requirements in a quantifiable manner long before testing commences.
2. State testing objectives explicitly.
3. Understand the users of the software and develop a profile for each user category.
4. Develop a testing plan that emphasizes “rapid cycle testing.”
5. Build “robust” software that is designed to test itself.
6. Use effective technical reviews as a filter prior to testing.
7. Conduct technical reviews to assess the test strategy and test cases themselves.
8. Develop a continuous improvement approach for the testing process.

Test Recordkeeping

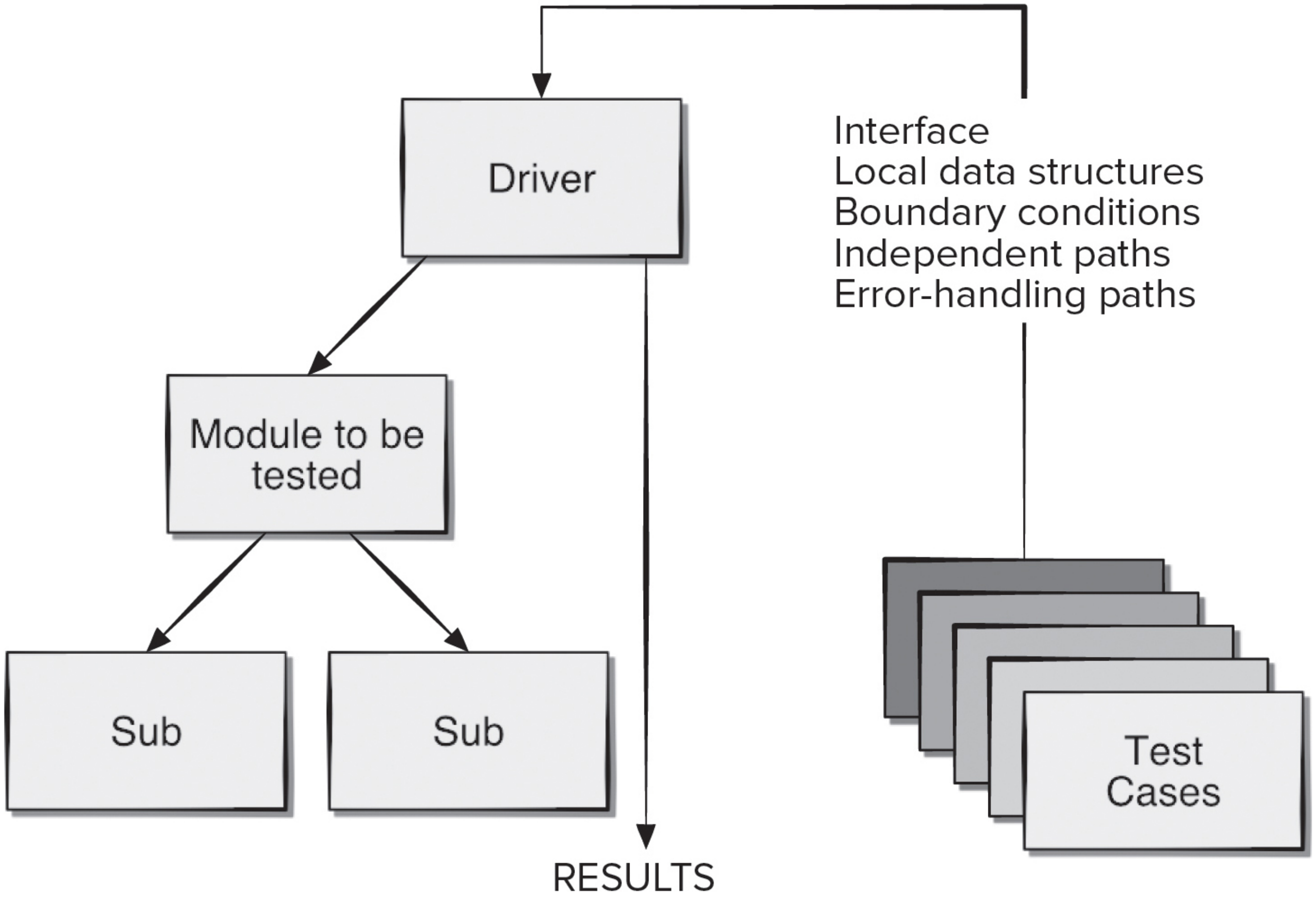
Test cases can be recorded in Google Docs spreadsheet:

- Briefly describes the test case.
- Contains a pointer to the requirement being tested.
- Contains expected output from the test case data or the criteria for success.
- Indicate whether the test was passed or failed.
- Dates the test case was run.
- Should have room for comments about why a test may have failed (aids in debugging).

Role of Scaffolding

- Components are not stand-alone program some type of scaffolding is required to create a testing framework.
- As part of this framework, driver and/or stub software must often be developed for each unit test.
- A driver is nothing more than a “main program” that accepts test-case data, passes such data to the component (to be tested), and prints relevant results.
- Stubs (dummy subprogram) serve to replace modules invoked by the component to be tested.
- A stub uses the module’s interface, may do minimal data manipulation, prints verification of entry, and returns control to the module undergoing testing.

Unit Test Environment



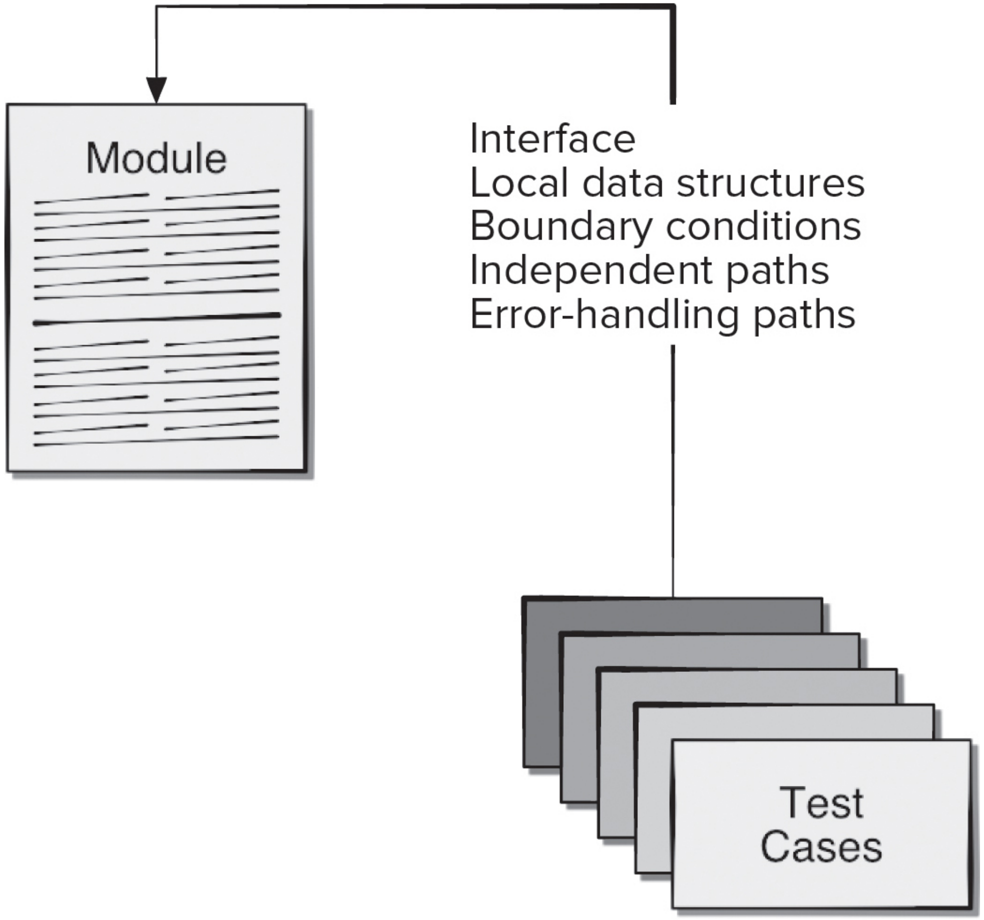
Cost Effective Testing

- Exhaustive testing requires every possible combination and ordering of input values be processed by the test component.
- The return on exhaustive testing is often not worth the effort, since testing alone cannot be used to prove a component is correctly implemented.
- Testers should work smarter and allocate their testing resources on modules crucial to the success of the project or those that are suspected to be error-prone as the focus of their unit testing.

Test Case Design

- Design unit test cases before you develop code for a component to ensure that code that will pass the tests.
- Test cases are designed to cover the following areas:
  - The module interface is tested to ensure that information properly flows into and out of the program unit.
  - Local data structures are examined to ensure that stored data maintains its integrity during execution.
  - Independent paths through control structures are exercised to ensure all statements are executed at least once.
  - Boundary conditions are tested to ensure module operates properly at boundaries established to limit or restrict processing.
  - All error-handling paths are tested.

Module Tests



Interface
Local data structures
Boundary conditions
Independent paths
Error-handling paths

Error Handling

- A good design anticipates error conditions and establishes error-handling paths which must be tested.
- Among the potential errors that should be tested when error handling is evaluated are:
  - Error description is unintelligible.
  - Error noted does not correspond to error encountered.
  - Error condition causes system intervention prior to error handling,
  - Exception-condition processing is incorrect.
  - Error description does not provide enough information to assist in the location of the cause of the error.

Traceability

- To ensure that the testing process is auditable, each test case needs to be traceable back to specific functional or nonfunctional requirements or anti-requirements.
- Often nonfunctional requirements need to be traceable to specific business or architectural requirements.
- Many test process failures can be traced to missing traceability paths, inconsistent test data, or incomplete test coverage.
- Regression testing requires retesting selected components that may be affected by changes made to other collaborating software components.

White Box Testing

Using white-box testing methods, you can derive test cases that:

- Guarantee that all independent paths within a module have been exercised at least once.
- Exercise all logical decisions on their true and false sides.
- Execute all loops at their boundaries and within their operational bounds.
- Exercise internal data structures to ensure their validity.

Basis Path Testing

Determine the number of independent paths in the program by computing Cyclomatic Complexity:

- The number of regions of the flow graph corresponds to the cyclomatic complexity.
- Cyclomatic complexity $V(G)$ for a flow graph G is defined as

  $$V(G) = E - N + 2$$

  E is the number of flow graph edges

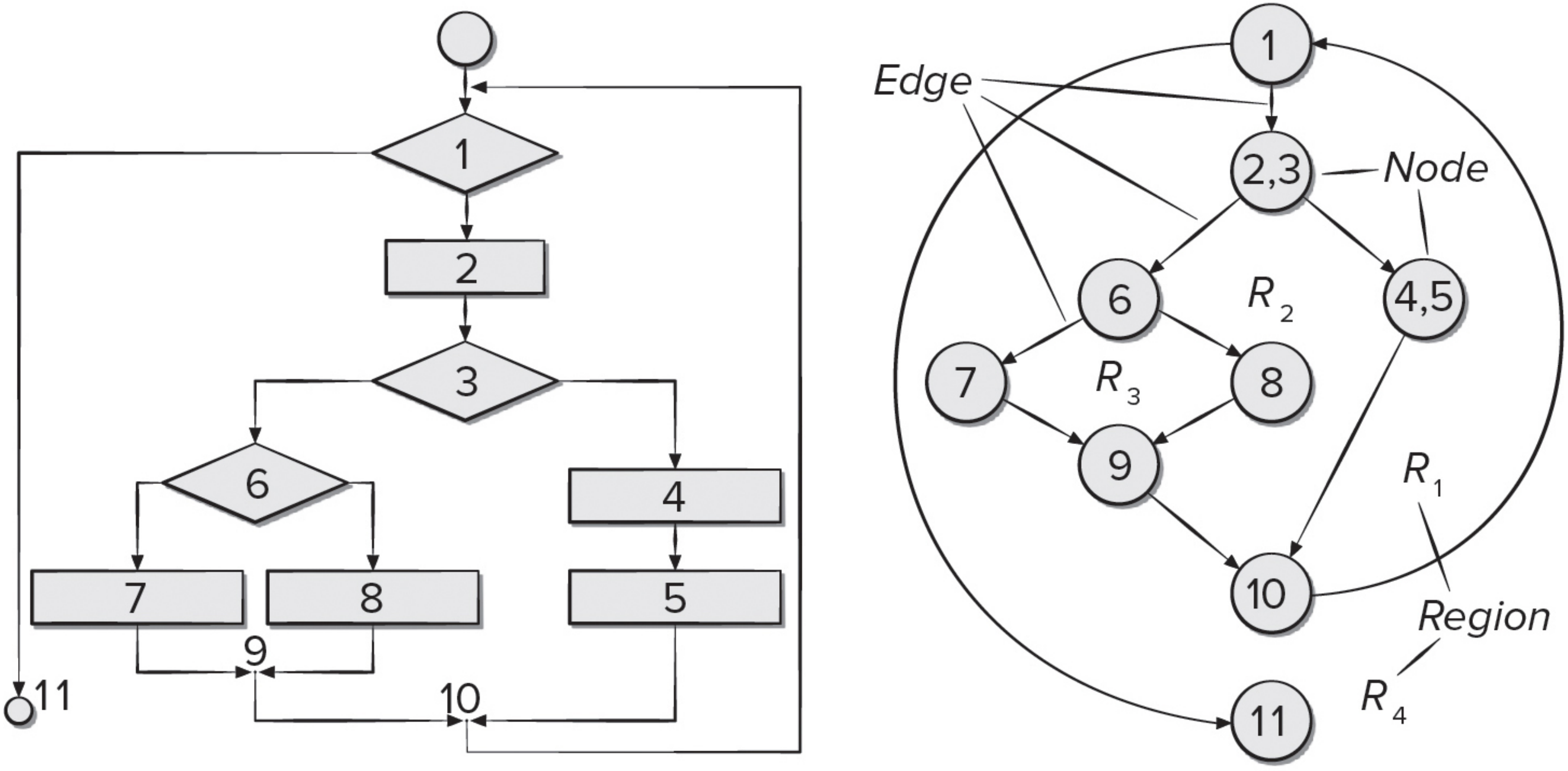
  N is the number of nodes.
- Cyclomatic complexity $V(G)$ for a flow graph G is also defined as

  $$V(G) = P + 1$$

  P is number of predicate nodes contained in the

  flow graph G.

Flowchart (a) and Flow Graph (b)



(a)

(b)

Basis Path Testing

- Cyclomatic Complexity of the flow graph is 4

  The flow graph has four regions.

  $V(G)$ = 11 edges – 9 nodes + 2 = 4.

  $V(G)$ = 3 predicate nodes + 1 = 4.

- An independent path is any path through the program that introduces at least one new set of processing statements or a new condition (we need 4 independent paths to test)

  Path 1: 1-11

  Path 2: 1-2-3-4-5-10-1-11

  Path 3: 1-2-3-6-8-9-10-1-11

  Path 4: 1-2-3-6-7-9-10-1-11

Basis Path Testing

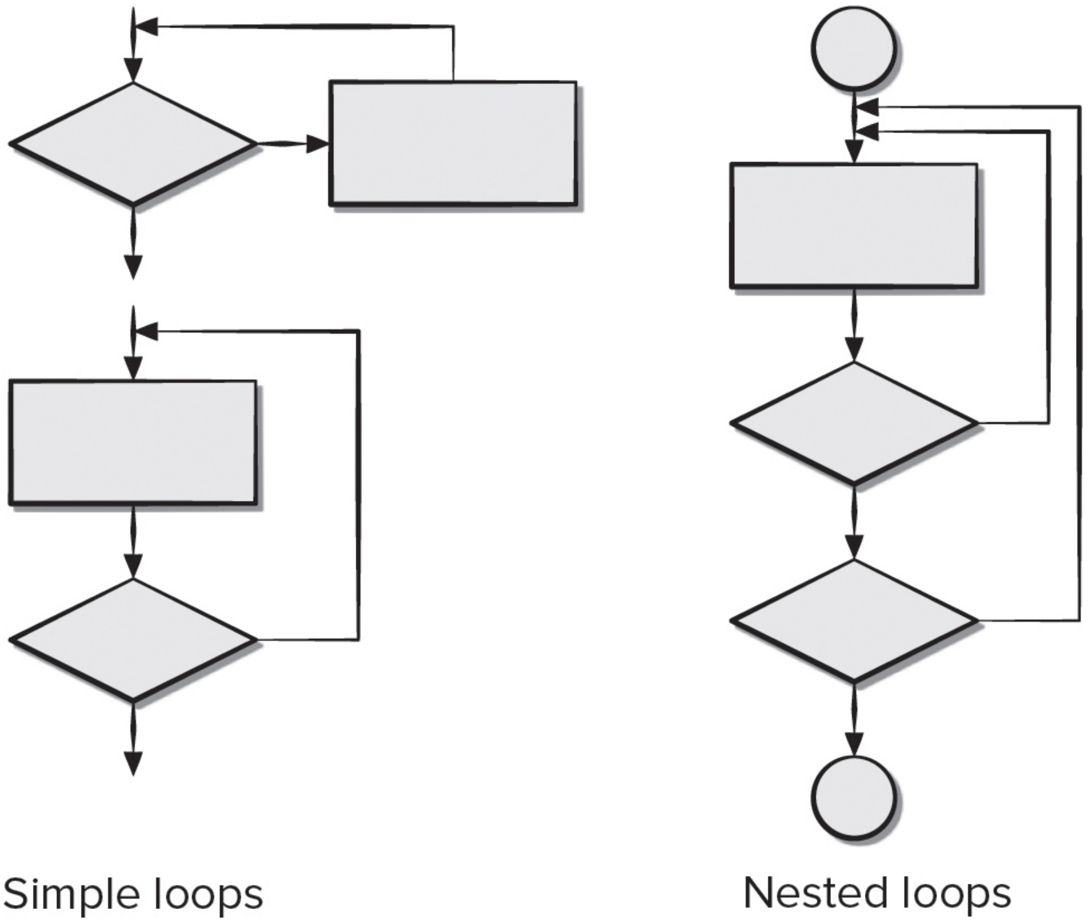
Designing Test Cases

- Using the design or code as a foundation, draw a corresponding flow graph.
- Determine the cyclomatic complexity of the resultant flow graph.
- Determine a basis set of linearly independent paths.
- Prepare test cases that will force execution of each path in the basis set.

Control Structure Testing

- Condition testing is a test-case design method that exercises the logical conditions contained in a program module.
- Data flow testing selects test paths of a program according to the locations of definitions and uses of variables in the program.
- Loop testing is a white-box testing technique that focuses exclusively on the validity of loop constructs.

Classes of Loops



Loop Testing

Test cases for simple loops:

- Skip the loop entirely.
- Only one pass through the loop.
- Two passes through the loop.
- m passes through the loop where m < n.
- n – 1, n, n + 1 passes through the loop.

Test cases for nested loops:

- Start at the innermost loop. Set all other loops to minimum values.
- Conduct simple loop tests for the innermost loop while holding the outer loops at their minimum iteration parameter (for example, loop counter) values.
- Add other tests for out-of-range or excluded values.
- Work outward, conducting tests for the next loop, but keeping all other outer loops at minimum values and other nested loops to "typical" values.
- Continue until all loops have been tested.

Black Box Testing

- Black-box (functional) testing attempts to find errors in the following categories:
  - Incorrect or missing functions.
  - Interface errors.
  - Errors in data structures or external database access.
  - Behavior or performance errors.
  - Initialization and termination errors.
- Unlike white-box testing, which is performed early in the testing process, black-box testing tends to be applied during later stages of testing.

Black Box Testing

Black-box test cases are created to answer questions like:

- How is functional validity tested?
- How are system behavior and performance tested?
- What classes of input will make good test cases?
- Is the system particularly sensitive to certain input values?
- How are the boundaries of a data class isolated?
- What data rates and data volume can the system tolerate?
- What effect will specific combinations of data have on system operation?

Black Box – Interface Testing

- Interface testing is used to check that a program component accepts information passed to it in the proper order and data types and returns information in proper order and data format.
- Components are not stand-alone programs testing interfaces requires the use stubs and drivers.
- Stubs and drivers sometimes incorporate test cases to be passed to the component or accessed by the component.
- Debugging code may need to be inserted inside the component to check that data passed was received correctly.

Black Box – Boundary Value Analysis (BVA)

- Boundary value analysis leads to a selection of test cases that exercise bounding values.
- Guidelines for BVA:
  - If an input condition specifies a range bounded by values a and b, test cases should be designed with values a and b and just above and just below a and b.
  - If an input condition specifies a number of values, test cases should be developed that exercise the min and max numbers as well as values just above and below min and max.
  - Apply guidelines 1 and 2 to output conditions.
  - If internal program data structures have prescribed boundaries (for example, array with max index of 100) be certain to design a test case to exercise the data structure at its boundary.

Object-Oriented Testing (OOT)

To adequately test OO systems, three things must be done:

- The definition of testing must be broadened to include error discovery techniques applied to object-oriented analysis and design models.
- The strategy for unit and integration testing must change significantly.
- The design of test cases must account for the unique characteristics of OO software.

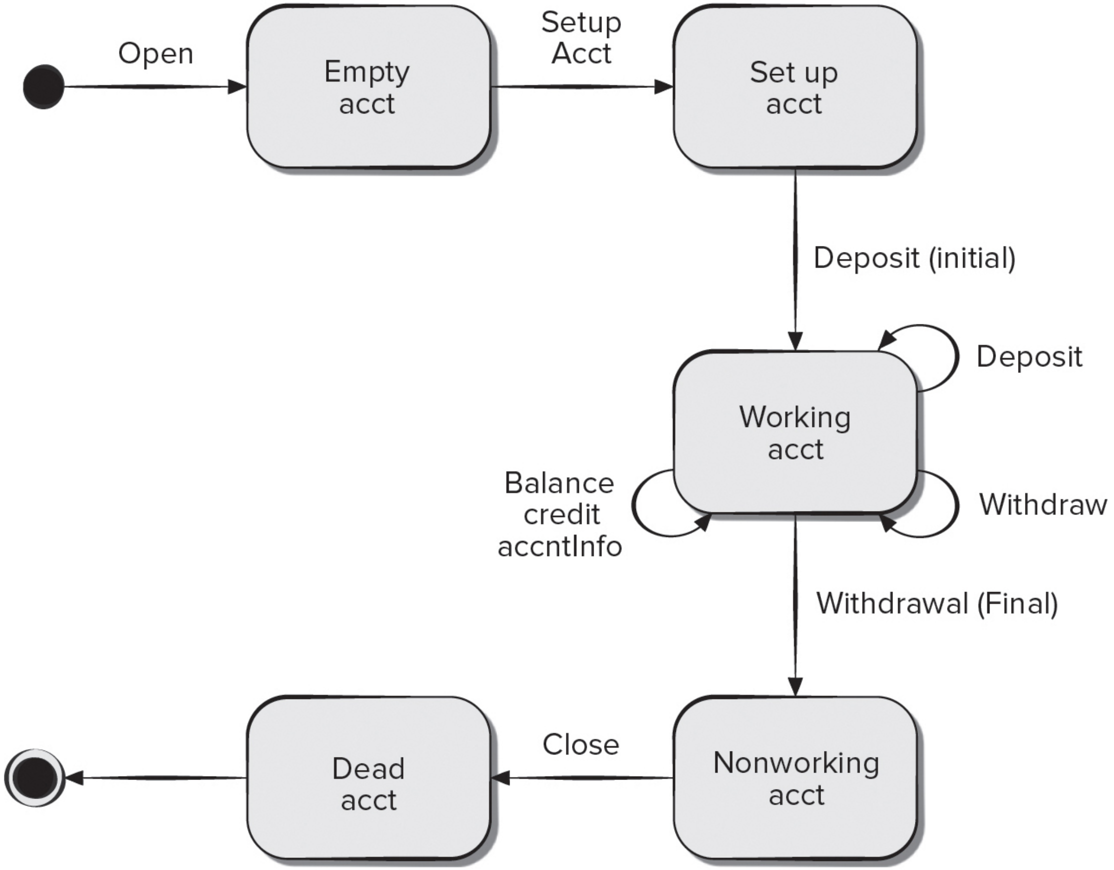
OOT – Class Testing

- Class testing for object-oriented (OO) software is the equivalent of unit testing for conventional software.
- Unlike unit testing of conventional software, which tends to focus on the algorithmic detail of a module and the data that flow across the module interface.
- Class testing for OO software is driven by the operations encapsulated by the class and the state behavior of the class.
- Valid sequences of operations and their permutations are used to test that class behaviors - equivalence partitioning can reduce number sequences needed.

OOT– Behavior Testing

- A state diagram can be used to help derive a sequence of tests that will exercise dynamic behavior of the class.
- Tests to be designed should achieve full coverage by using operation sequences cause transitions through all allowable states.
- When class behavior results in a collaboration with several classes, multiple state diagrams can be used to track system behavioral flow.
- A state model can be traversed in a breadth-first manner by having test case exercise a single transition and when a new transition is to be tested only previously tested transitions are used.

State Diagram for Account Class



Source: Kirani, Shekhar and Tsai, W. T., "Specification and Verification of Object-Oriented Programs," Technical Report TR 94-64, University of Minnesota, December 1994, 79.