Software Testing

Lesson 6
Test Design Techniques
Dynamic Testing I
V1.2

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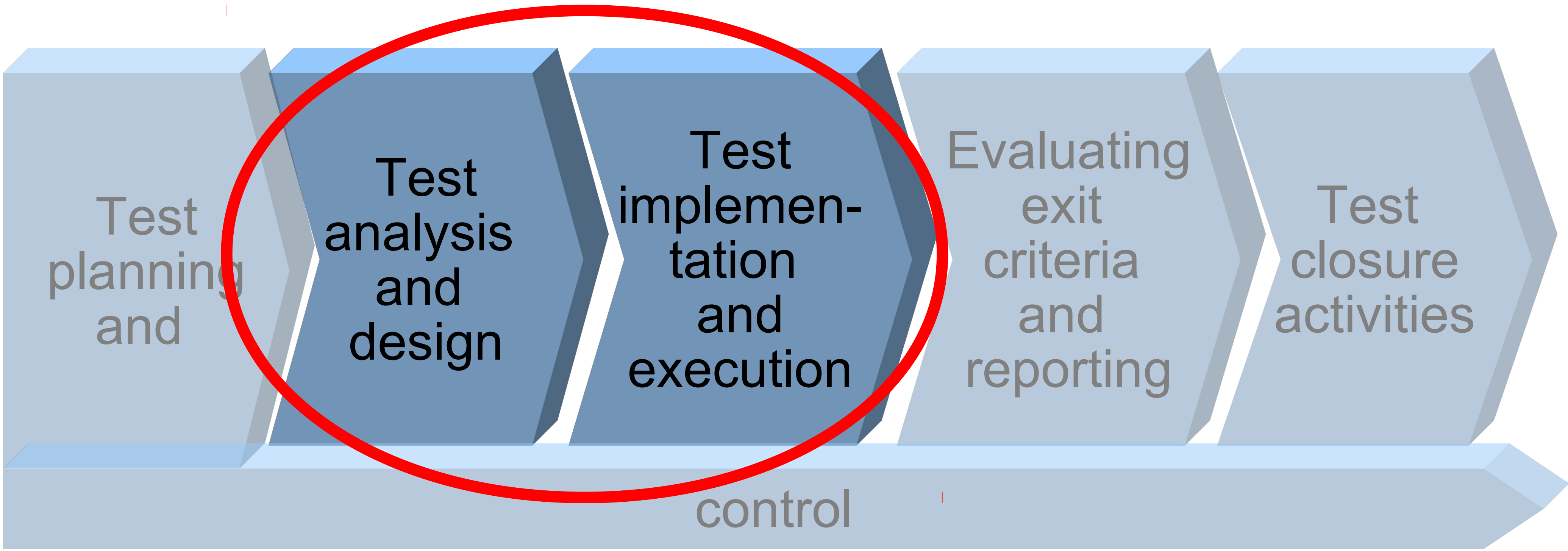
Contents

- Test Design Techniques – Dynamic Testing I
  - Test Development Process
  - Categories of Test Design Techniques
  - White-box Techniques (or Structure-based Techniques)
    - Structural Coverages
    - Statement Testing and Coverage
    - Decision Testing and Coverage
    - Statement Coverage / Decision Coverage
    - Other Structure-based Techniques
    - Structural Coverages – Challenges and Hints
    - Cyclomatic Complexity

Test Development Process



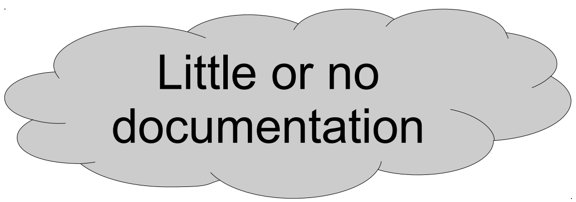
Test Development Process is the core of the Fundamental Test Process

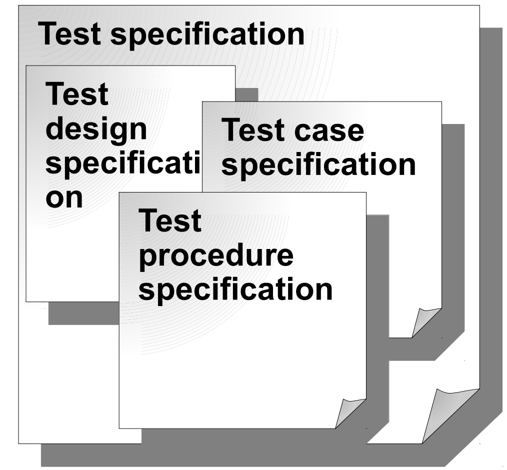
Test Development Process

Test Development Process covers

- Test Analysis
- Test Design
- Test Implementation
- Test Execution

Test Development Process





Informal ... to very formal

… depending on the context of the testing

- maturity of testing and development processes,
- time constraints,
- safety or regulatory requirements,
- people involved.

Test Development Process
Test Analysis

- Analysis of test basis documentation
  - ⇨ What to test?
  - ⇨ What are the test conditions*?
- Requested: Bidirectional traceability between

  Specifications and requirements ⇔ Test conditions

  - for impact analysis when requirements change,
  - to determine requirements coverage for a set of tests.

* Test condition = An item or event of a component or system that could be verified by one or more test cases, e. g. a function, transaction, feature, quality attribute, or structural element [ISTQB-GWP12].

Test Development Process
Test design

Creation / Specification of test cases and test data

- A test case consists of a set of
  - input values,
  - execution preconditions,
  - expected results, and
  - execution postconditions

  to cover a certain test objective(s) or test condition(s).

  - Description of expected results should include outputs, changes to data and states, any other consequences of the test.
  - If expected results are not defined, then a plausible, but erroneous, result may be interpreted as the correct one.
  - Expected results should ideally be defined before tests get executed.

Test Development Process
Test design

Out of ‘Standard for Software Test Documentation’
[IEEE STD 829-1998]

- Test design specification [ISTQB-GWP12]
  Document that specifies the test conditions (coverage items) for a test item, the detailed test approach and the associated high level test cases.
  A test plan could content several test design specifications.

- Test case specification [ISTQB-GWP12]
  Document that specifies a set of test cases (objective, inputs, test actions, expected results and execution pre conditions) for a test item. A test design specification could content several test case specifications.

Test Development Process
Test implementation

During test implementation test cases are

- developed,
- implemented,
- prioritized, and
- organized in the test procedure specification.

- Test procedure specification [ISTQB-GWP12]
  Document that specifies a sequence of actions for the execution of a test (test script or manual test scripts).

Test Development Process
Test execution

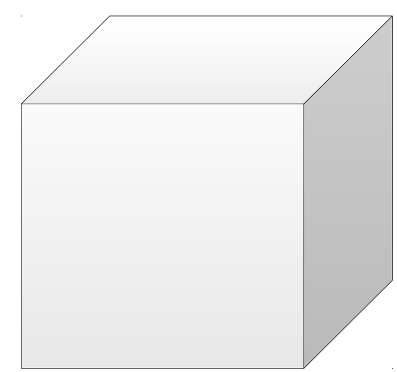
- Test execution schedule
  - contents and defines the execution order of
    - test procedures
      … specifies the sequence of actions for a test execution.
    - automated test procedures (automated test scripts)
      … if a test automation tool is used, contents sequence of actions.
  - takes into account factors like
    - regression tests,
    - prioritization,
    - technical dependencies,
    - logical dependencies.

Test Design Techniques

- Purpose of a test design technique is to identify
  - test conditions,
  - test cases, and
  - test data.

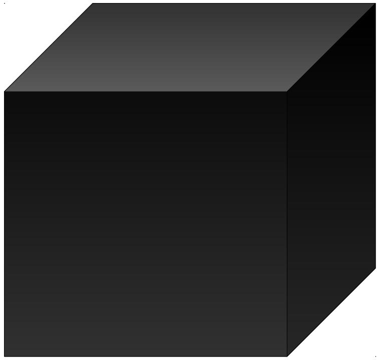
Test Design Techniques

- White-box test design techniques (also called structural or structure-based techniques)
  - based on an analysis of the structure of the component or system.
  - uses any information regarding the internal structure of the component or system to be tested



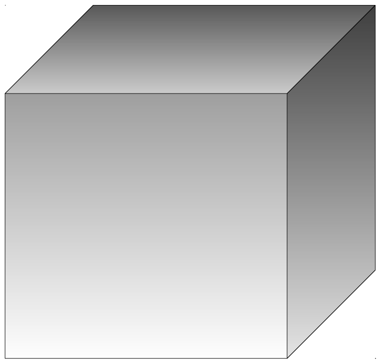
Test Design Techniques

- Black-box test design techniques (also called specification-based techniques)
  - based on an analysis of the test basis documentation,
  - include both functional and non-functional testing.
  - does not use any information regarding the internal structure of the component or system to be tested



Test Design Techniques

- Grey-box test design techniques [Wik14]
  - based partly on internals of a software, involves knowledge of internal data structures and algorithms for purposes of designing tests,
  - execute defined tests at the user, or black-box level.
  - uses some information about the inside, to better test from the outside.
  - is important with web applications



Test Design Techniques

Specification-based test design techniques

- Models, either formal or informal, are used for
  - the specification of the problem to be solved,
  - the software, or
  - the software components.
- Test cases can be derived systematically from these models

Test Design Techniques

Structure-based test design techniques

- Information about how the software is constructed is used to derive the test cases (e.g., code and detailed design information).
- The extent of coverage of the software can be measured for existing test cases, and further test cases can be derived systematically to increase coverage.

Test Design Techniques

Experience-based test design techniques

- Test cases are derived based on the knowledge and experience of testes, developers, users and other stakeholders about
  - the software,
  - its usage,
  - its environment,
  - likely defects and their distribution.

Test Design Techniques

Combination of Test Design Techniques

- Black-box and white-box testing may also be combined with experience-based techniques to effectively use the experience of developers, testers and users.

White-box Techniques

- White-box testing is based on an identified structure of the software or the system:
  - **Component level:** The structure of a software component, as for example
    - statements,
    - branches,
    - decisions,
    - distinct paths.
  - **Integration level:** The structure may be a call tree (a diagram in which modules call other modules).
  - **System level:** The structure may be a
    - menu structure,
    - web page structure,
    - business process.

White-box Techniques
Structural Coverages

Structural Coverage

- based on control flow analysis,
- gives no advice concerning test case creation,
- good starting point for thorough testing.

Other criteria for designing tests should be included in an effective testing strategy, based on

- data flow, and
- required functionality.

White-box Techniques Structural Coverages

Structural Coverage Metrics cover

- Statement testing
- Decision testing

Hint: Some sources mention that Decision testing is same like Branch testing, but ISTQB syllabus differs [ISTQB-GWP12]:

  - ***Branch coverage:*** *The percentage of branches that have been exercised by a test suite. 100% branch coverage implies both 100% decision coverage and 100% statement coverage.*
  - ***Decision coverage*** *(related to branch testing): The percentage of decision outcomes that have been exercised by a test suite. 100% decision coverage implies both 100% branch coverage and 100% statement coverage.*

White-box Techniques
Structural Coverages

More Structural Coverage Metrics are

- Condition testing
- Multiple condition testing
- Condition determination testing
- Linear Code Sequence and Jump (LCSAJ) or loop testing
- Path testing
- API* testing

See e.g. [ISTQB-CTALSTTA12] for details

* API (Application Programming Interface)

White-box Techniques
Statement Testing and Coverage

- Statement coverage
  - done in component testing.
  - assessment of the percentage of executable statements that have been covered by a test case suite.
  - Goals:
    - Execution of all statements of a program at least once.
    - Ensuring there is no unreachable code (“dead code”).

White-box Techniques
Statement Testing and Coverage

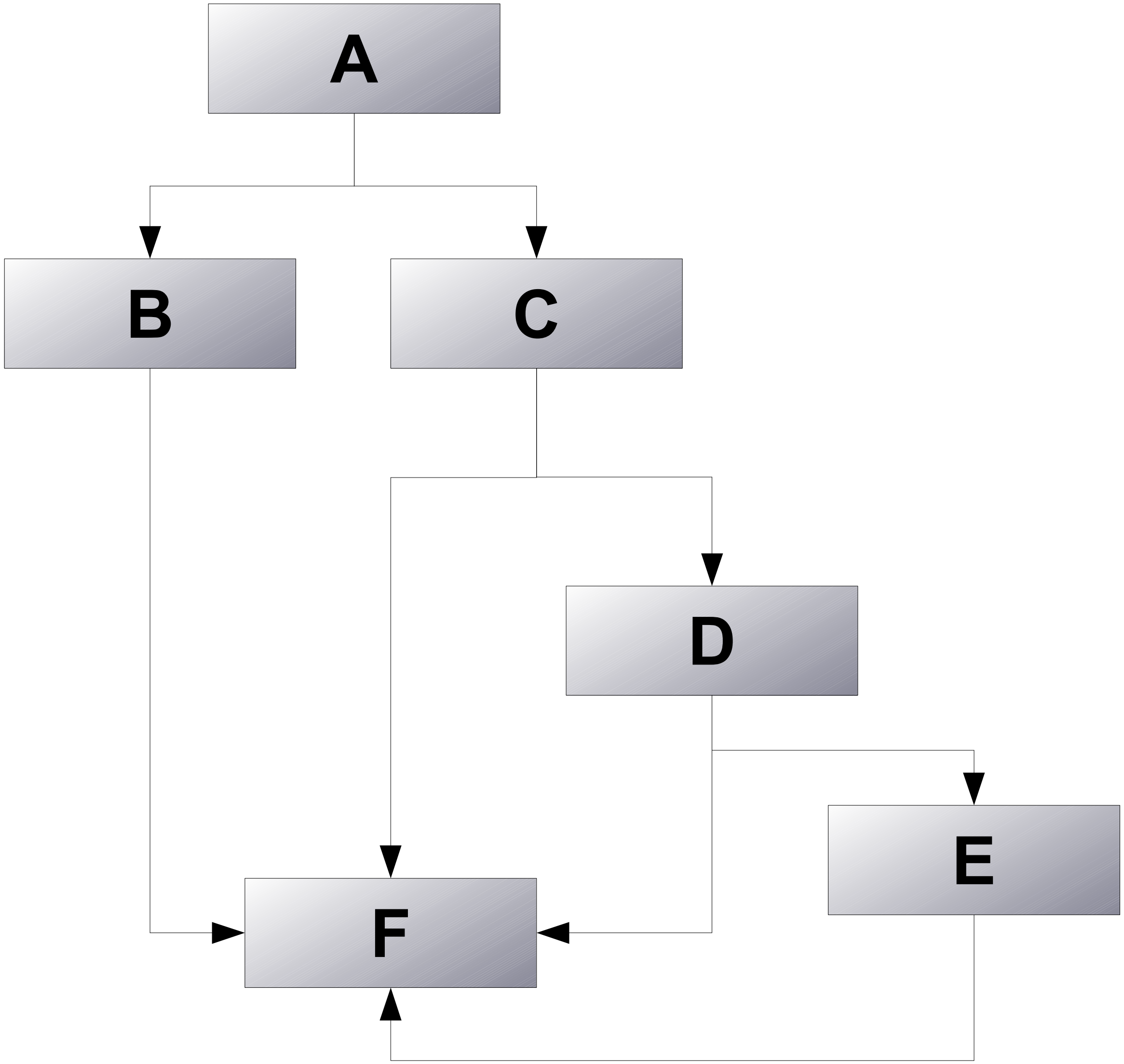
- Statement coverage is determined by

$$\frac{testedStatements}{allStatements}$$

  - testedStatements = number of executable statements covered by (designed or executed) test cases.
  - allStatements = number of all executable statements in the code under test.

White-box Techniques
Statement Testing and Coverage

- Example 1
  2 Test Cases for
  100 % Statement
  Coverage
  - A, B, F
  - A, C, D, E, F



White-box Techniques
Statement Testing and Coverage

- Example 2
  1 Test Case for
  100 % Statement
  Coverage

  TC1: x = 1, y =2
  Result: z = 3

```
/* z is greater value+1*/
int foo(int x, int y) {
    int z = x;
    if (y > x) {
        z = y;
    }
    z = z +1;
    return z;
}
```

White-box Techniques Decision Testing and Coverage

- Decision coverage, related to branch testing, is the assessment of the percentage of decision outcomes (e.g., the True and False options of an IF statement) that have been exercised by a test case suite.
- The decision testing technique derives test cases to execute specific decision outcomes.
- Branches originate from decision points in the code and show the transfer of control to different locations in the code.

White-box Techniques
Decision Testing and Coverage

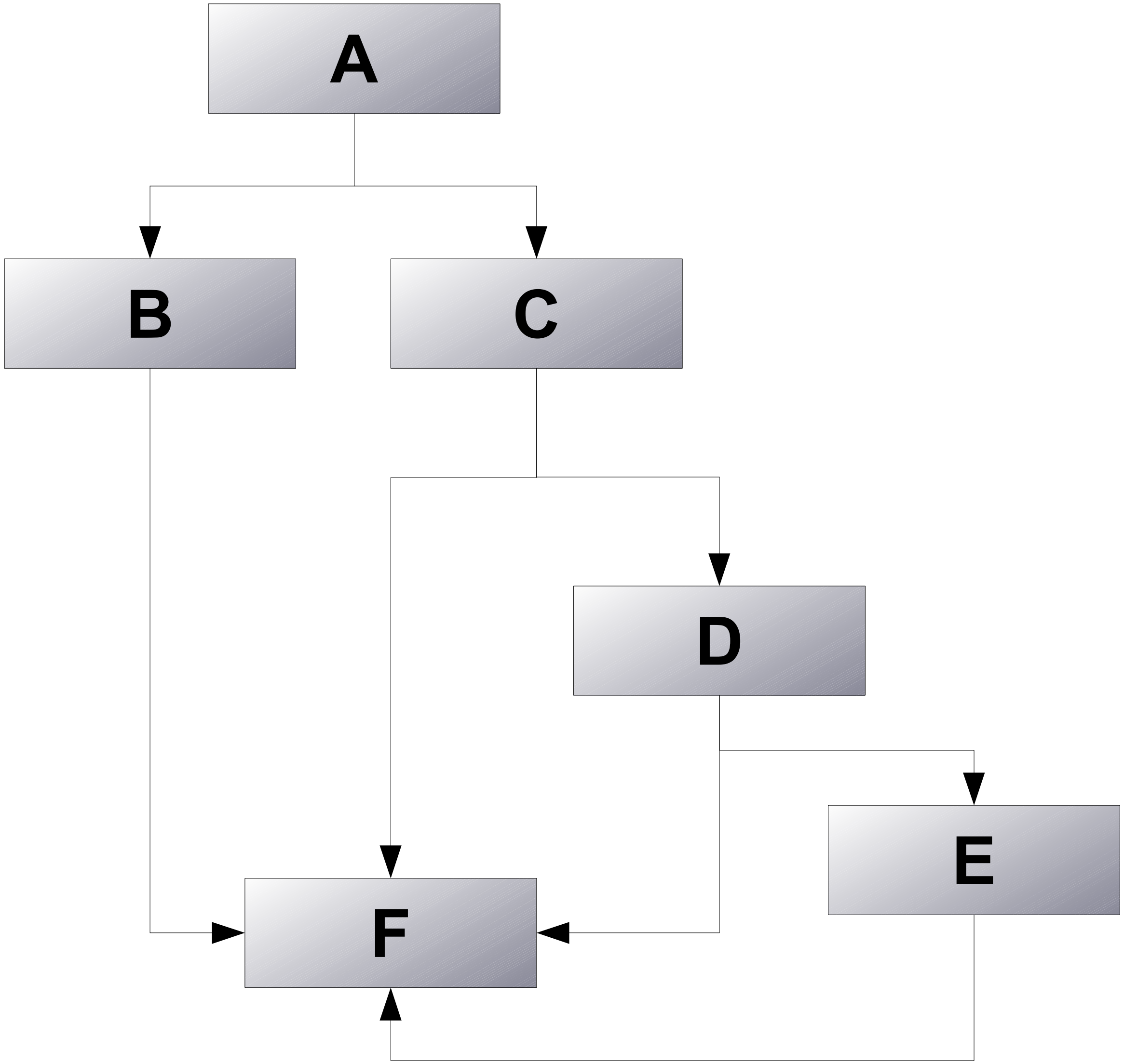
- Decision coverage is determined by

$$\frac{testedDecisions}{allDecisions}$$

  - testedDecisions = number of all decision outcomes covered by (designed or executed) test cases
  - allDecisions = number of all possible decision outcomes in the code under test.
- Decision testing is a form of control flow testing as it follows a specific flow of control through the decision points.

White-box Techniques
Decision Testing and Coverage

- Example 1
  4 Test Cases for
  100 % Decision
  Coverage
  - A, B, F
  - A, C, F
  - A, C, D, F
  - A, C, D, E, F



White-box Techniques
Decision Testing and Coverage

- Example 2
  2 Test Cases for
  100 % Decision
  Coverage

  TC1: x = 1, y =2
  Result: z = 3

  TC2: x = 3, y = 2
  Result: z = 4

```
/* z is greater value+1*/
int foo(int x, int y) {
    int z = x;
    if (y > x) {
        z = y;
    }
    z = z +1;
    return z;
}
```

White-box Techniques
Statement Coverage / Decision Coverage

- Decision coverage is stronger than statement coverage:
  - 100% decision coverage guarantees 100% statement coverage,
  - but not vice versa.

White-box Techniques
Statement Coverage / Decision Coverage

- Means
  50 % Decision coverage
  also
  50% Statement coverage?
  ==> No!

- TC1: x=3
  50 % Decision coverage
  75 % Statement coverage

- TC2: x=2
  50 % Decision coverage
  50 % Statement coverage

Code example

```
int foo(int x) {
    int a = 0;
    if (x>2) {
        a = a+1;
        a = a+1;
    } else
        a = a+1;
}
```

[Büc10]

White-box Techniques
Statement Coverage / Decision Coverage

Assessment

- Both statement and decision coverage are weak criteria.
- “Statement-coverage criterion is so weak that it is generally considered useless.” [p. 37 Mye04]
- Statement coverage and decision coverage should be considered as a minimal requirement.

White-box Techniques
Other Structure-based Techniques

- There are stronger levels of structural coverage beyond decision coverage, for example,
  - Condition coverage and
  - Multiple condition coverage.
- The concept of coverage can also be applied at other test levels.
- For example, at the integration level the percentage of modules, components or classes that have been exercised by a test case suite could be expressed as module, component or class coverage.

White-box Techniques Structural Coverages

Challenges [Büc10]

- Different metrics definitions around.
- Sometimes you can't achieve 100 % coverage.
- Coverage metrics have different names (e.g. Abbreviations have different meanings, like C0 or C1 for statement coverage).
- Not always clear, how coverages were measured (important when using tools).
- Kind of coding influences results of coverage analysis.

White-box Techniques
Structural Coverages

Hints [Büc10]

- Clarify, that you talk about the same structural coverage definitions.
- Clarify in using coverage measuring tools, how these work.
- Don't be relaxed because of 100% code coverage.

White-box Techniques Cyclomatic Complexity

- Complexity
  The degree to which a component or system has a design and / or internal structure that is difficult to understand, maintain and verify.
- The more complex a component or a system is, the higher the probability that
  - test coverage is not complete,
  - defects occur,
  - maintenance gets more difficult.

White-box Techniques Cyclomatic Complexity

- Cyclomatic complexity metric
  - could be used to measure the complexity of a module's decision structure.
  - is the number of linearly independent paths and therefore, the minimum number of paths that should be tested.

White-box Techniques Cyclomatic Complexity

- Cyclomatic complexity [McC76]:
  The number of independent paths through a program. Cyclomatic complexity M is defined as:

  $$M = L - N + 2P, \text{ where}$$

  - L = number of edges/links in a graph
  - N = number of nodes in a graph
  - P = number of disconnected parts of the graph (e.g. a called graph or subroutine)

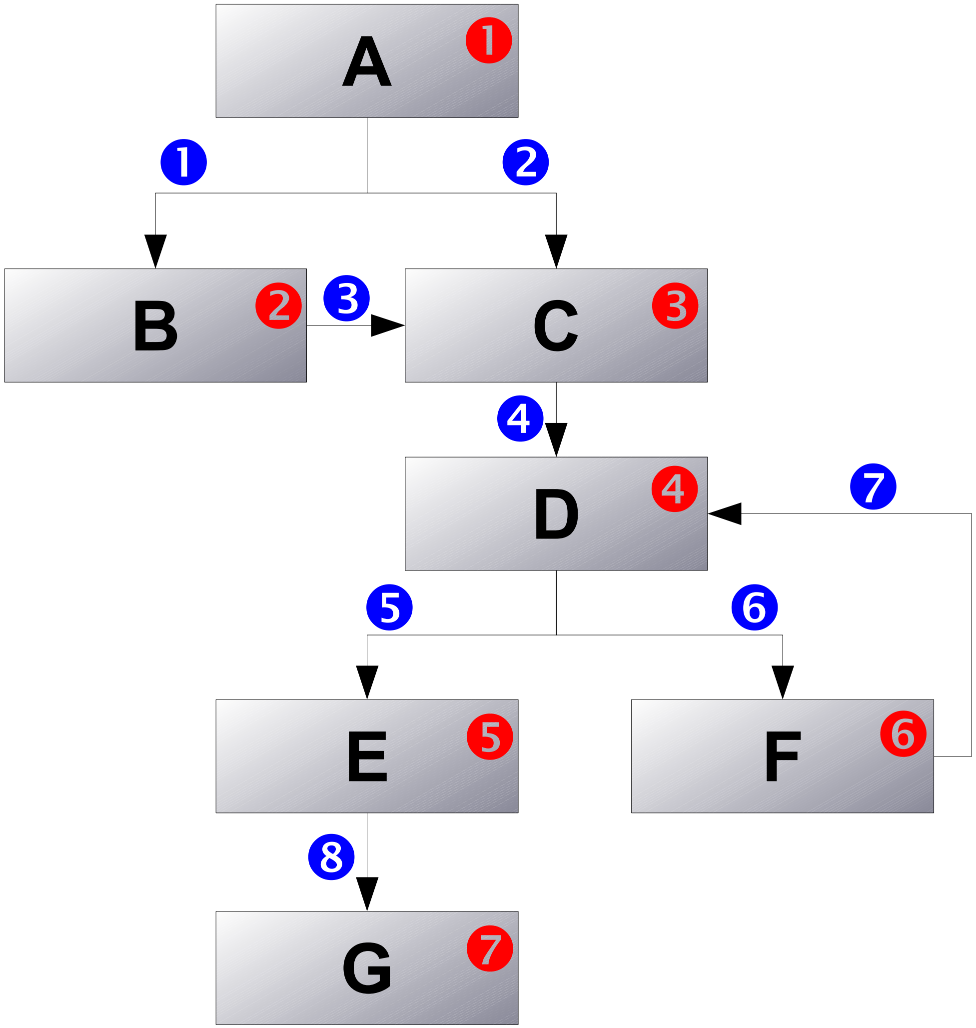
White-box Techniques Cyclomatic Complexity

Example:

$M = L - N + 2P$

$= 8 - 7 + 2$

$= 3$



White-box Techniques Cyclomatic Complexity

Example:

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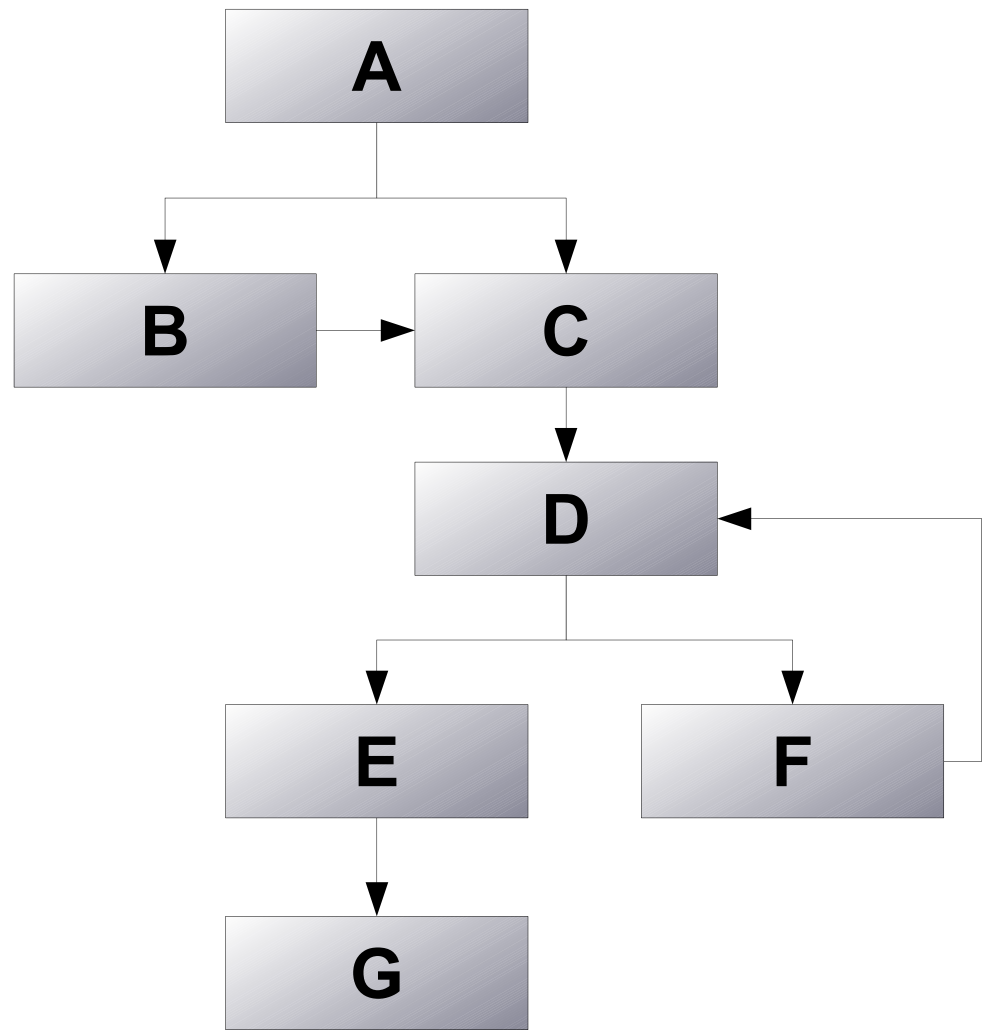


White-box Techniques Cyclomatic Complexity

- Cyclomatic complexity [McC76]:
  Alternative calculation, if you have a program with binary conditions **only**:
  $M = b + 1$, where
  b = number of binary conditions

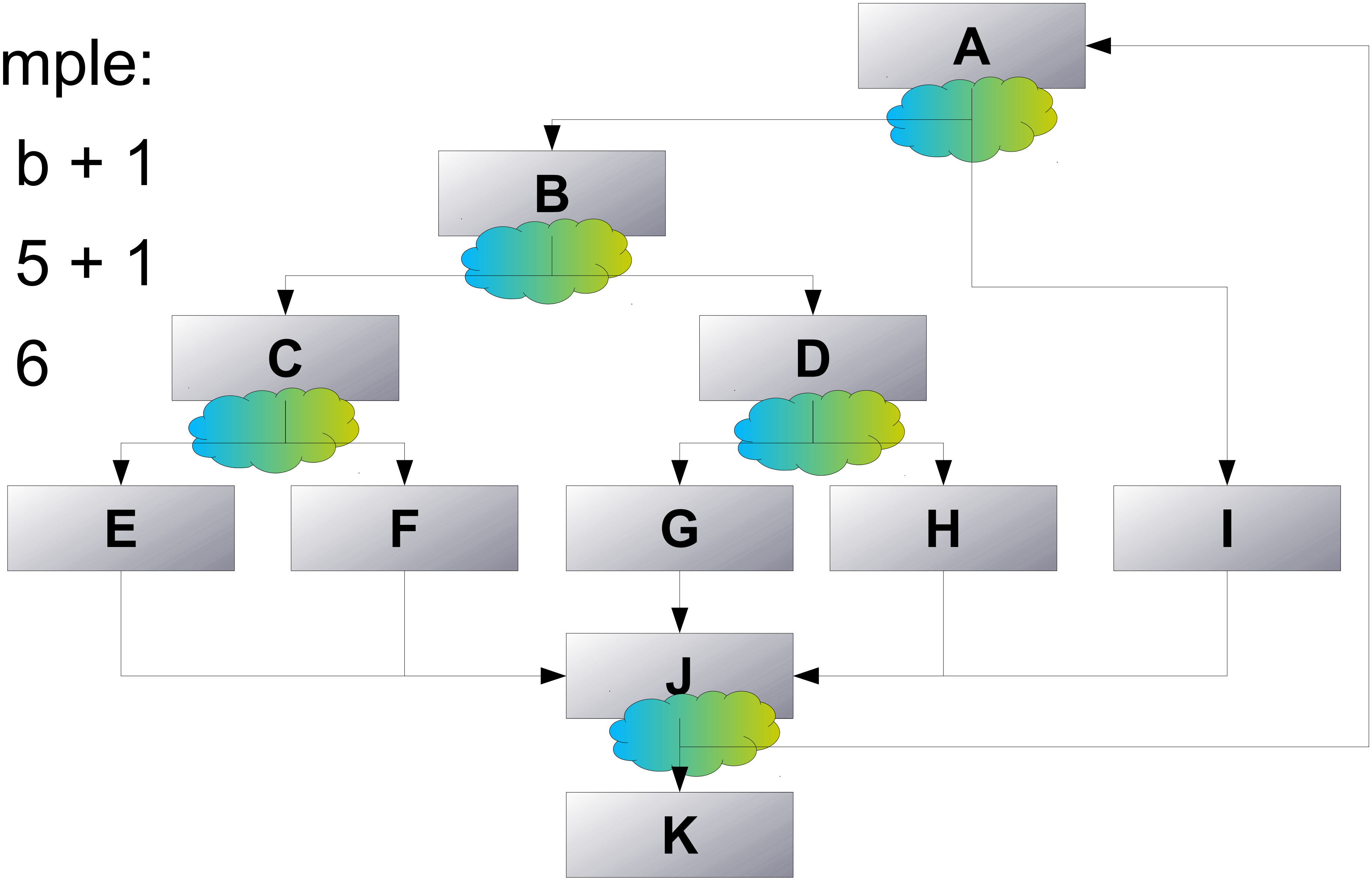
White-box Techniques
Cyclomatic Complexity

Example:

$M = b + 1$

$= 5 + 1$

$= 6$



White-box Techniques Cyclomatic Complexity

Cyclomatic Complexity M

- M is the upper bound for the number of test cases for decision coverage.
- M > 10 should be prevented (following McCabe).

White-box Techniques
Cyclomatic Complexity

- The higher M, the higher the probability of errors
  - Studies of Sharpe [Sha08] have shown
    - M = 11 had lowest probability of 28% of being fault-prone.
    - M = 38 had a probability of 50% of being fault-prone.
    - M ≥ 74 had 98 % plus probability of being fault-prone.
  - Walsh collected data of 276 modules [McC96, Wal79]:

    ≈ 50 % had M < 10 with 4,6/100 statements error rate.

    ≈ 50 % had M ≥ 10 with 5,6/100 statements error rate.

White-box Techniques Cyclomatic Complexity

- Weakness
  - Assumption that faults are proportional to decision complexity does not consider processing complexity and database structure.
  - It does not differ between different kinds of decisions, which is counter intuitive
    - An "IF-THEN-ELSE" statement is treated the same as a relatively complicated loop.
    - Also CASE statements are treated the same as nested IF statements.
  - It's possible that a program gets a high value for M, but is easy understandable (see example next page).

White-box Techniques Cyclomatic Complexity

Example:

```
const String monthsName (const int nummer) {
  switch(nummer)  {
   case 1: return "January";
   case 2: return "February";
   case 3: return "Mars";
   case 4: return "April";
   case 5: return "May";
   case 6: return "June";
   case 7: return "July";
   case 8: return "August";
   case 9: return "September";
   case 10: return "October";
   case 11: return "November";
   case 12: return "December";
  }
  return "unknown month number";
}
```

Program has a high cyclomatic complexity M = 13.

But it is easy to understand.

Sources (1/2)

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