Software Systems Verification and Validation

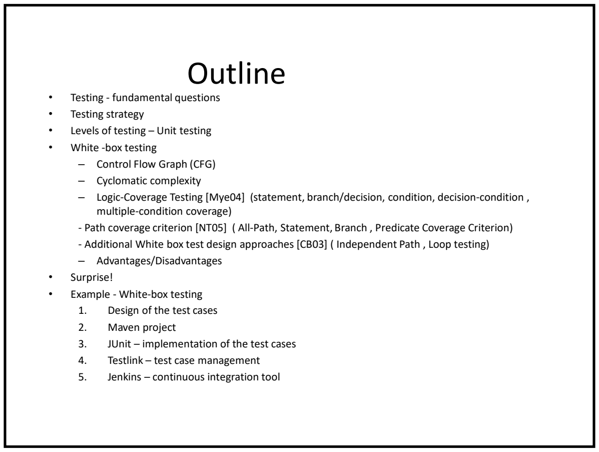
Lecture 3: WBT

Assoc. Prof. Andreea Vescan

Babeş-Bolyai University

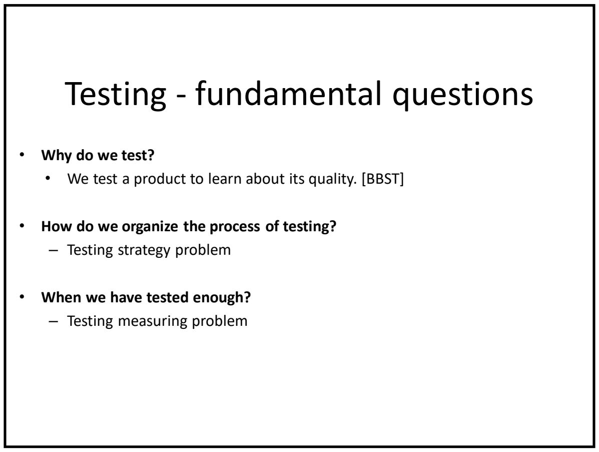
Cluj-Napoca

2018-2019



Outline

- Testing - fundamental questions
- Testing strategy
- Levels of testing – Unit testing
- White -box testing
  - Control Flow Graph (CFG)
  - Cyclomatic complexity
  - Logic-Coverage Testing [Mye04] (statement, branch/decision, condition, decision-condition , multiple-condition coverage)
  - Path coverage criterion [NT05] (All-Path, Statement, Branch , Predicate Coverage Criterion)
  - Additional White box test design approaches [CB03] (Independent Path , Loop testing)
  - Advantages/Disadvantages
- Surprise!
- Example - White-box testing
  1. Design of the test cases
  2. Maven project
  3. JUnit – implementation of the test cases
  4. Testlink – test case management
  5. Jenkins – continuous integration tool

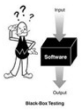


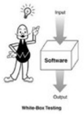
Testing - fundamental questions

- **Why do we test?**
  - We test a product to learn about its quality. [BBST]
- **How do we organize the process of testing?**
  - Testing strategy problem
- **When we have tested enough?**
  - Testing measuring problem

Testing strategies [BBST]

- **Testing strategy is:**
  - The guiding framework for deciding what tests (what test techniques) are best suited to your product.
  - **Context** and **information objectives** are (or should be) the drivers of any **testing strategy.**





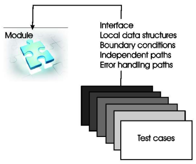
- **Selecting the Testing techniques ?**
  - Techniques differ in core.

Levels of testing

Unit testing (cont)

Test case design

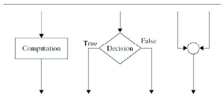
- Information needed when designing test cases for a module:
  - specification of the module
  - the module's source code
- Test case design procedure for a module test is:
  - Analyze the logic of the module using white-box methods.
  - Applying black-box methods to the module's specification.



White-box testing

A Control Flow Graph

- A Control Flow Graph (CFG) is a graphical representation of a program unit.
- A CFG has exactly one entry node and exactly one exit node.
- Three symbols are used to construct a CFG
  - nodes - sequential statements, decision and looping predicates
  - edges - represent transfer of control
- Path in the CFG [NT05] - is represented as a sequence of computation and decision nodes from the entry node to the exit node.
- An independent path [CB03] is any path through the program that introduces at least one new set of processing statements or a new condition.



White-box testing

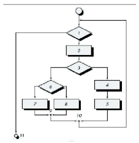
Cyclomatic complexity

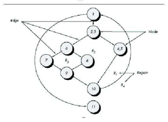
- Cyclomatic complexity
  - The number of independent paths in the basis set of a program and provides us with an upper bound for the number of tests that must be conducted to ensure that all statements have been executed at least once.
  - CC = The number of regions of the flow graph.
  - CC = E - N + 2, where E - #edges, N - #nodes.
  - CC = P+1, where P - #predicate nodes

White-box testing

Cyclomatic complexity - example

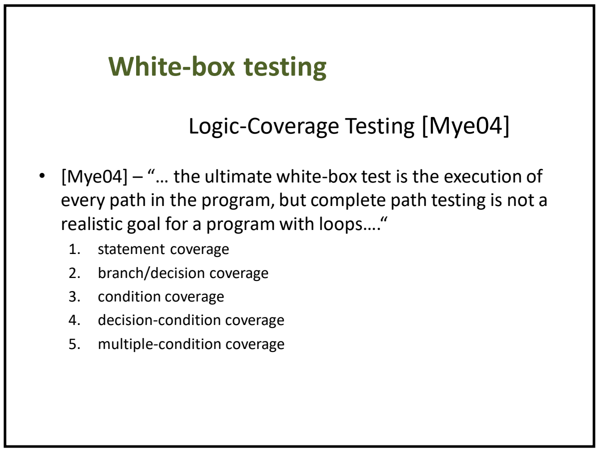
- CC
  - CC = four regions = 4.
  - CC = 11 edges - 9 nodes + 2 = 4.
  - CC = 3 predicate nodes + 1 = 4.
- A set of independent paths:
  - path 1: 1-11.
  - path 2: 1-2-3-4-5-10-1-11.
  - path 3: 1-2-3-6-8-9-10-1-11.
  - path 4: 1-2-3-6-7-9-10-1-11.





Outline

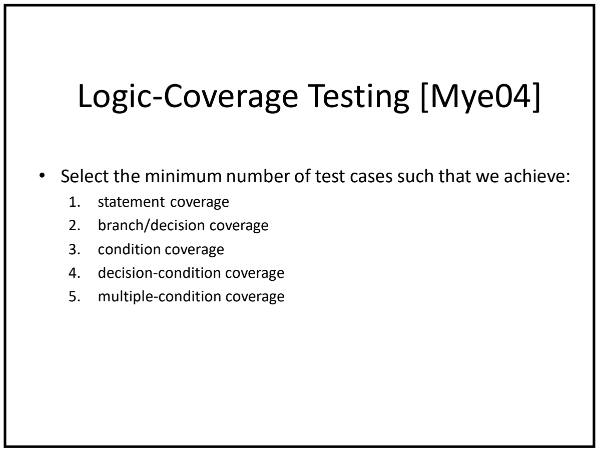
- Testing - fundamental questions
- Testing strategy
- White -box testing
  - Control Flow Graph (CFG)
  - Cyclomatic complexity
  - Logic-Coverage Testing [Mye04] (statement, branch/decision, condition, decision-condition , multiple-condition coverage)
  - Path coverage criterion [NT05] (All-Path, Statement, Branch , Predicate Coverage Criterion)
  - Additional White box test design approaches [CB03] (Independent Path , Loop testing)
  - Advantages/Disadvantages
- Surprise!
- Example - White-box testing
  1. Design of the test cases
  2. Maven project
  3. JUnit – implementation of the test cases
  4. Testlink – test case management
  5. Jenkins – continuous integration tool



White-box testing

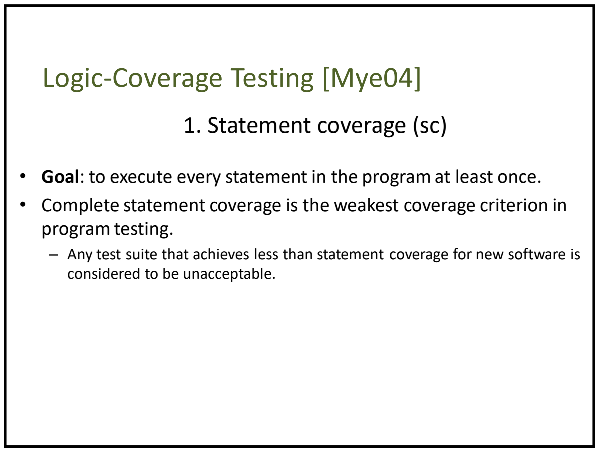
Logic-Coverage Testing [Mye04]

- [Mye04] – "… the ultimate white-box test is the execution of every path in the program, but complete path testing is not a realistic goal for a program with loops…."
  1. statement coverage
  2. branch/decision coverage
  3. condition coverage
  4. decision-condition coverage
  5. multiple-condition coverage



Logic-Coverage Testing [Mye04]

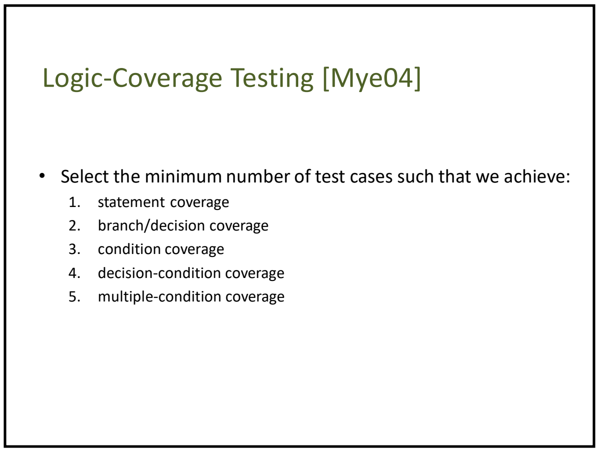
- Select the minimum number of test cases such that we achieve:
  1. statement coverage
  2. branch/decision coverage
  3. condition coverage
  4. decision-condition coverage
  5. multiple-condition coverage



Logic-Coverage Testing [Mye04]

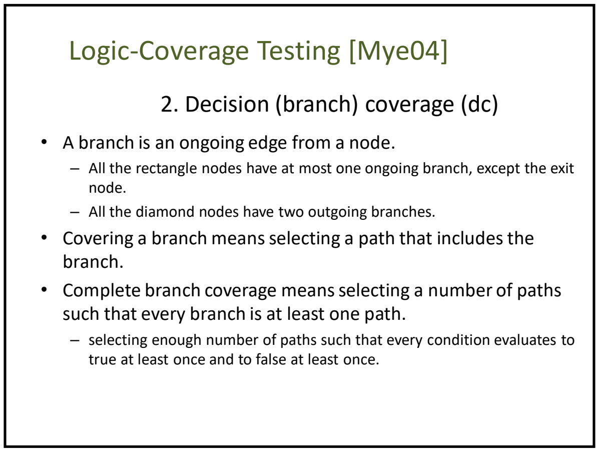
1. Statement coverage (sc)

- **Goal**: to execute every statement in the program at least once.
- Complete statement coverage is the weakest coverage criterion in program testing.
  - Any test suite that achieves less than statement coverage for new software is considered to be unacceptable.



Logic-Coverage Testing [Mye04]

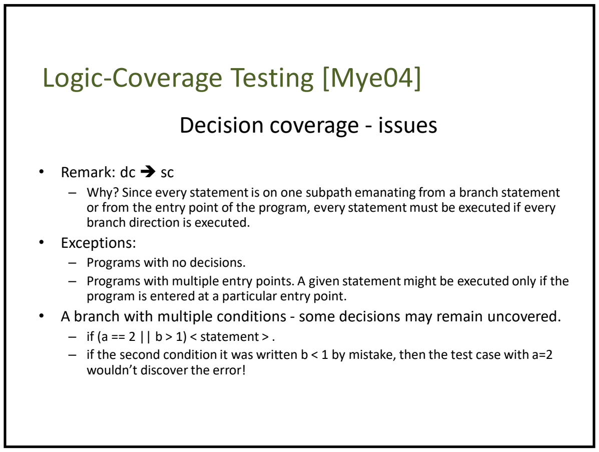
- Select the minimum number of test cases such that we achieve:
  1. statement coverage
  2. branch/decision coverage
  3. condition coverage
  4. decision-condition coverage
  5. multiple-condition coverage



Logic-Coverage Testing [Mye04]

2. Decision (branch) coverage (dc)

- A branch is an ongoing edge from a node.
  - All the rectangle nodes have at most one ongoing branch, except the exit node.
  - All the diamond nodes have two outgoing branches.
- Covering a branch means selecting a path that includes the branch.
- Complete branch coverage means selecting a number of paths such that every branch is at least one path.
  - selecting enough number of paths such that every condition evaluates to true at least once and to false at least once.



Logic-Coverage Testing [Mye04]

Decision coverage - issues

- Remark: dc ➔ sc
  - Why? Since every statement is on one subpath emanating from a branch statement or from the entry point of the program, every statement must be executed if every branch direction is executed.
- Exceptions:
  - Programs with no decisions.
  - Programs with multiple entry points. A given statement might be executed only if the program is entered at a particular entry point.
- A branch with multiple conditions - some decisions may remain uncovered.
  - if (a == 2 || b > 1) < statement > .
  - if the second condition it was written b < 1 by mistake, then the test case with a=2 wouldn't discover the error!

Logic-Coverage Testing [Mye04]

- Select the minimum number of test cases such that we achieve:
  1. statement coverage
  2. branch/decision coverage
  3. condition coverage
  4. decision-condition coverage
  5. multiple-condition coverage

Logic-Coverage Testing [Mye04]

3. Condition coverage (cc)

- **Goal**: to write enough test cases to ensure that each condition in a decision takes on all possible outcomes at least once.
- cc ➔ dc (in general).
  – cc may cause (but does not always) every individual condition in a decision to be executed with both outcomes.
- Exceptions:
  – if (A&&B) < statement >
  – cc ➔ TC1 for A true, B false, and TC2 for A false and B true
  – But the statement is not executed (dc for True is not covered!
  – ➔there is a need for decision/condition coverage

Logic-Coverage Testing [Mye04]

- Select the minimum number of test cases such that we achieve:
  1. statement coverage
  2. branch/decision coverage
  3. condition coverage
  4. decision-condition coverage
  5. multiple-condition coverage

Logic-Coverage Testing [Mye04]

4. Decision/condition coverage (dcc)

- **Goal**: requires sufficient test cases that:
  - each condition in a decision takes on all possible outcomes at least once;
  - each decision takes on all possible outcomes at least once;
  - each point of entry is invoked at least once.
- dc ➔ cc (in general)
- Exceptions:
  - When certain condition mask other conditions
  - Results of conditions in && and || expressions can mask or block the evaluation of other conditions (i.e. if an && condition is false then none of subsequent conditions in the expression need to be evaluated)
  - Thus, errors in logical expressions are not necessarily revealed by the condition-coverage and decision/condition coverage criteria

Logic-Coverage Testing [Mye04]

Hierarchy of strengths for sc, dc, cdc

- From weakest to strongest: sc, dc, cdc.
- The implication for this approach to test design is that the stronger the criterion, the more defects will be revealed by the tests.
- In most cases the stronger the coverage criterion, the larger the number of test cases that must be developed to ensure complete coverage.
- ➔the tester must decide (based on the type of code, reliability requirements, resources available) which criterion to select!

Logic-Coverage Testing [Mye04]

- Select the minimum number of test cases such that we achieve:
  1. statement coverage
  2. branch/decision coverage
  3. condition coverage
  4. decision-condition coverage
  5. multiple-condition coverage

Logic-Coverage Testing [Mye04]

5. Multiple condition coverage (mcc)

- Goal: write sufficient test cases that:
  - all possible combinations of condition outcomes in each decision, and
  - all points of entry are invoked at lest once.
- mcc ➔ dcc (in general)
- Remark: A set of test cases satisfying the multiple-condition criterion also satisfies the decision coverage, condition coverage, and decision/condition coverage criteria.

Logic-Coverage Testing [Mye04]

Minimum test criterion

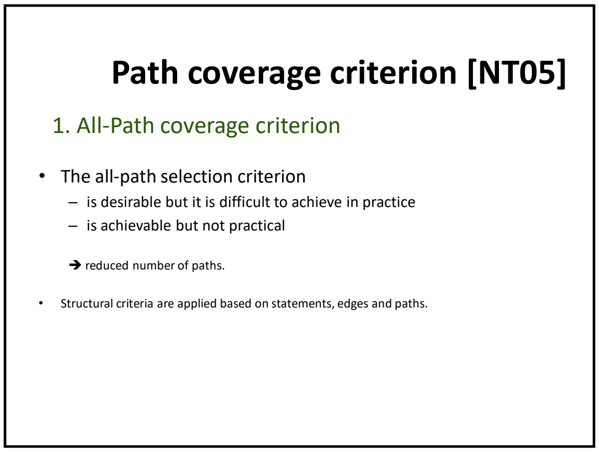
- For programs containing only one condition per decision:
  - Test cases to evoke all outcomes of each decision at least once, and
  - Test cases to invoke each point of entry at least once, to ensure that all statements are executed at least once.
- For programs containing decisions having multiple conditions:
  - Test cases to evoke all possible combinations of condition outcomes in each decision, and
  - all points of entry to the program, at least once.

White-box testing

Path coverage criterion [NT05]

- [NT05] – "A path is represented as a sequence of computation and decision nodes from the entry node to the exit node."

1. All-Path coverage criterion
2. Statement coverage criterion
3. Branch coverage criterion
4. Predicate Coverage Criterion



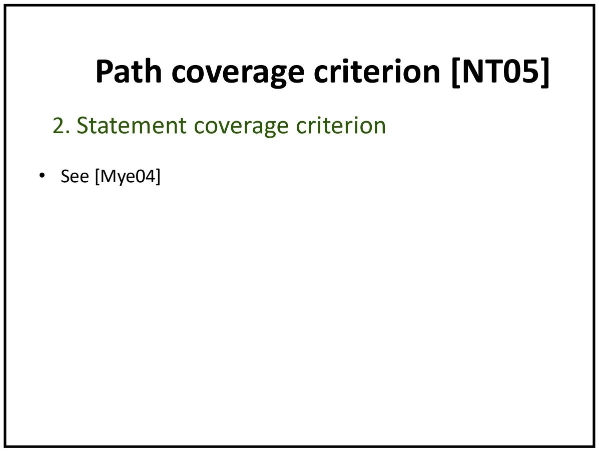
Path coverage criterion [NT05]

1. All-Path coverage criterion

- The all-path selection criterion
  - is desirable but it is difficult to achieve in practice
  - is achievable but not practical

  ➔ reduced number of paths.

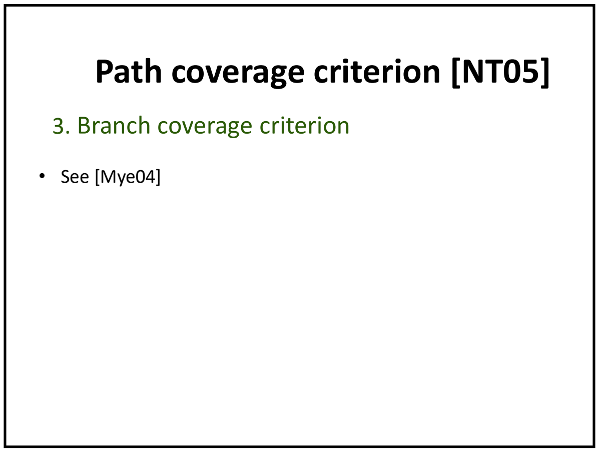
- Structural criteria are applied based on statements, edges and paths.



Path coverage criterion [NT05]

2. Statement coverage criterion

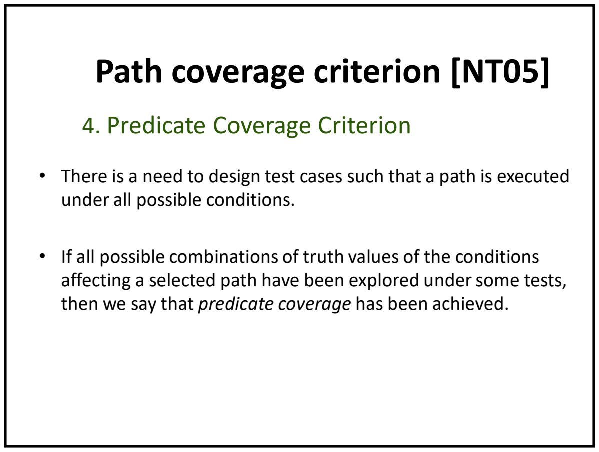
- See [Mye04]



Path coverage criterion [NT05]

3. Branch coverage criterion

- See [Mye04]

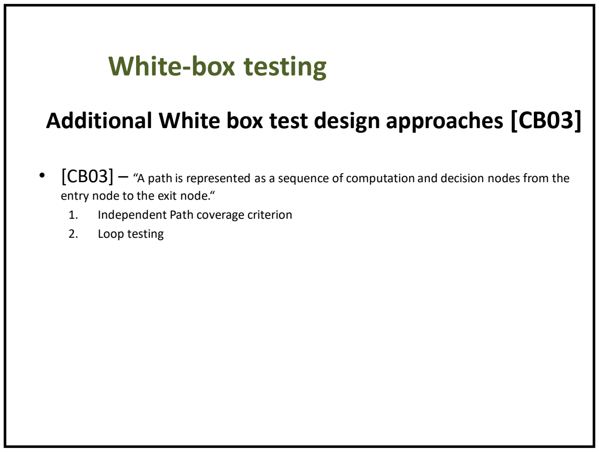


Path coverage criterion [NT05]

4. Predicate Coverage Criterion

- There is a need to design test cases such that a path is executed under all possible conditions.

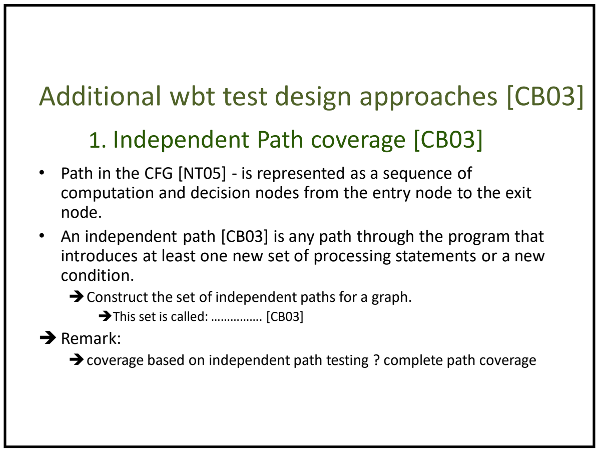
- If all possible combinations of truth values of the conditions affecting a selected path have been explored under some tests, then we say that *predicate coverage* has been achieved.



White-box testing

Additional White box test design approaches [CB03]

- [CB03] – "A path is represented as a sequence of computation and decision nodes from the entry node to the exit node."
  1. Independent Path coverage criterion
  2. Loop testing



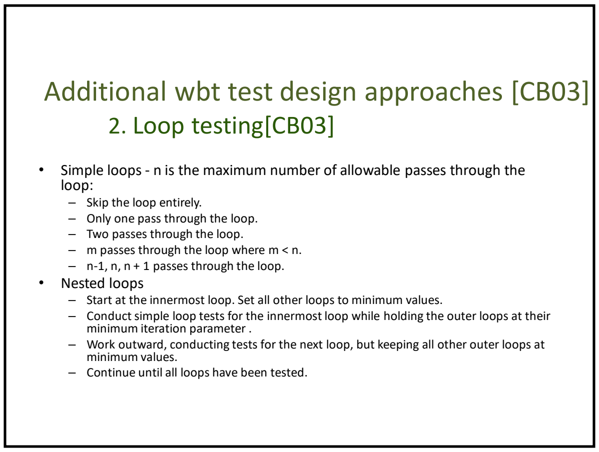
Additional wbt test design approaches [CB03]

1. Independent Path coverage [CB03]

- Path in the CFG [NT05] - is represented as a sequence of computation and decision nodes from the entry node to the exit node.
- An independent path [CB03] is any path through the program that introduces at least one new set of processing statements or a new condition.
  - ➔Construct the set of independent paths for a graph.
    - ➔This set is called: ……………. [CB03]

➔ Remark:

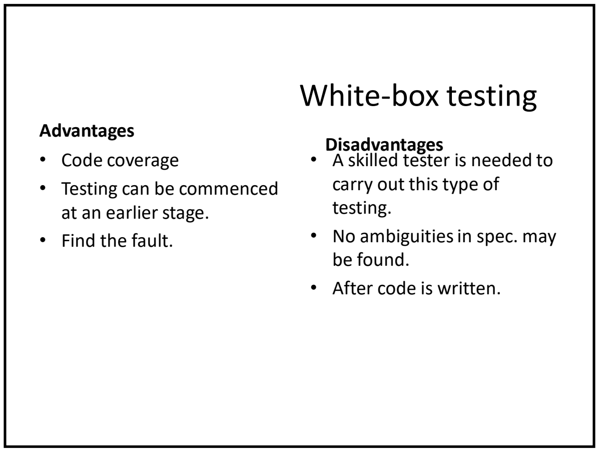
- ➔coverage based on independent path testing ? complete path coverage



Additional wbt test design approaches [CB03]

2. Loop testing[CB03]

- Simple loops - n is the maximum number of allowable passes through the loop:
  - 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.
- 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 .
  - Work outward, conducting tests for the next loop, but keeping all other outer loops at minimum values.
  - Continue until all loops have been tested.



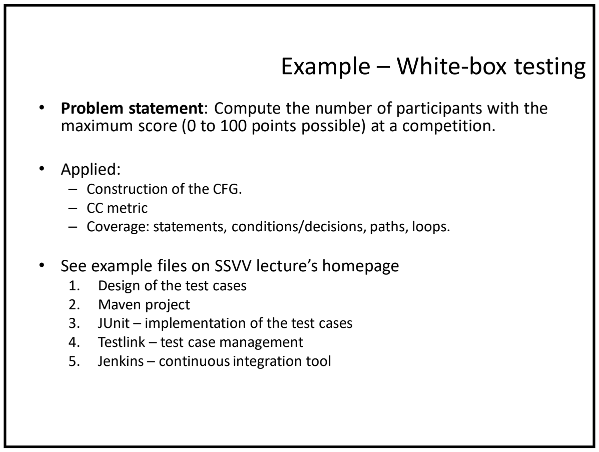
White-box testing

Advantages

- Code coverage
- Testing can be commenced at an earlier stage.
- Find the fault.

Disadvantages

- A skilled tester is needed to carry out this type of testing.
- No ambiguities in spec. may be found.
- After code is written.



Example – White-box testing

- **Problem statement**: Compute the number of participants with the maximum score (0 to 100 points possible) at a competition.

- Applied:
  - Construction of the CFG.
  - CC metric
  - Coverage: statements, conditions/decisions, paths, loops.

- See example files on SSVV lecture’s homepage
  1. Design of the test cases
  2. Maven project
  3. JUnit – implementation of the test cases
  4. Testlink – test case management
  5. Jenkins – continuous integration tool

Example – White-box testing

1. Design of the test cases

- Applied:
  - Construction of the CFG.
  - CC metric
  - Coverage: statements, conditions/decisions, paths, loops.
- Test case design - SSVV lecture's homepage.

Example – White-box testing

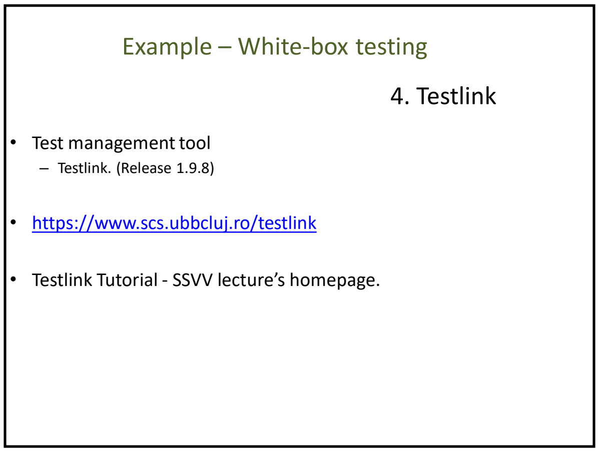
2. Maven

- goal - to allow a developer to comprehend the complete state of a development effort in the shortest period of time
- https://maven.apache.org/what-is-maven.html
- Maven
- Maven Tutorial - SSVV lecture's homepage.

Example – White-box testing

3. JUnit

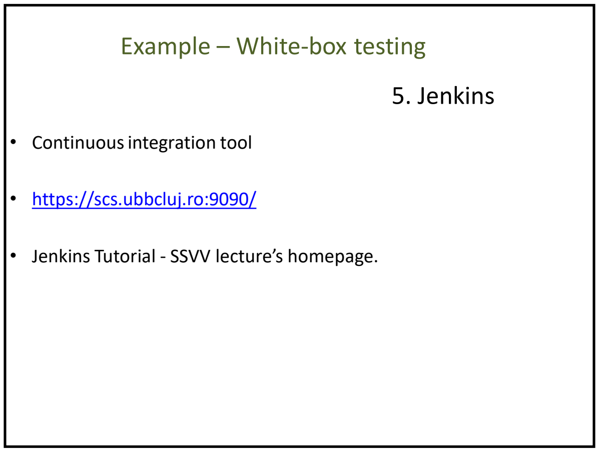
- JUnit
  - Implementing test case
  - Executing test case
- JUnit Tutorial - SSVV lecture's homepage



Example – White-box testing

4. Testlink

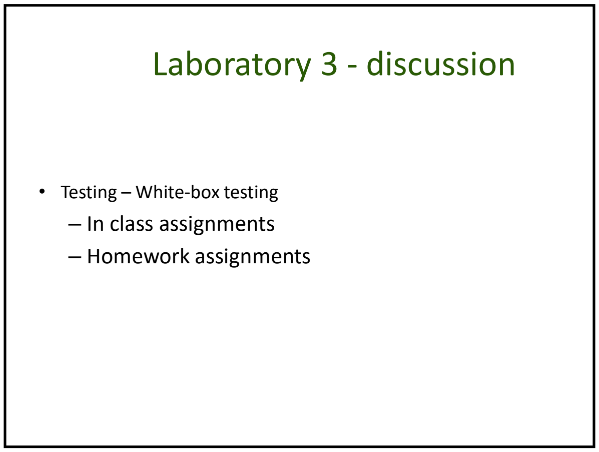
- Test management tool
  - Testlink. (Release 1.9.8)
- https://www.scs.ubbcluj.ro/testlink
- Testlink Tutorial - SSVV lecture's homepage.



Example – White-box testing

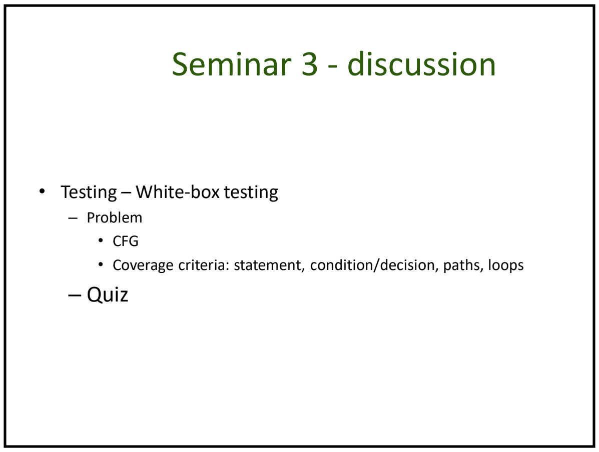
5. Jenkins

- Continuous integration tool
- https://scs.ubbcluj.ro:9090/
- Jenkins Tutorial - SSVV lecture's homepage.



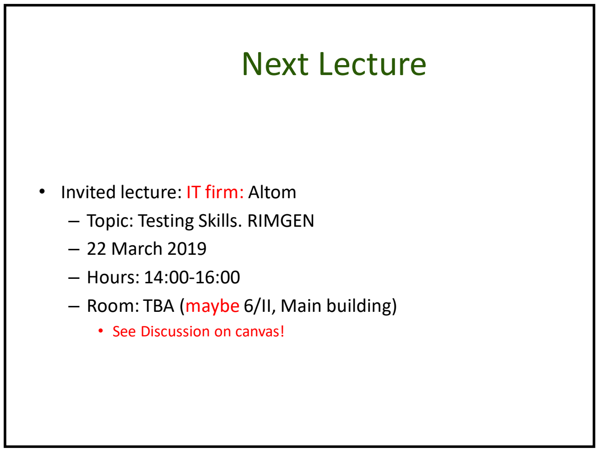
Laboratory 3 - discussion

- Testing – White-box testing
  - In class assignments
  - Homework assignments



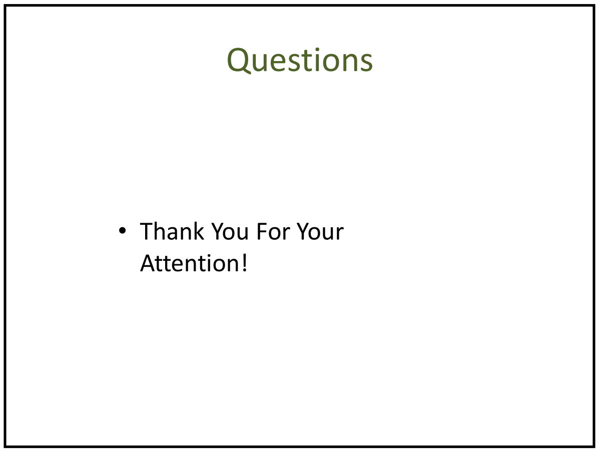
Seminar 3 - discussion

- Testing – White-box testing
  - Problem
    - CFG
    - Coverage criteria: statement, condition/decision, paths, loops
  - Quiz



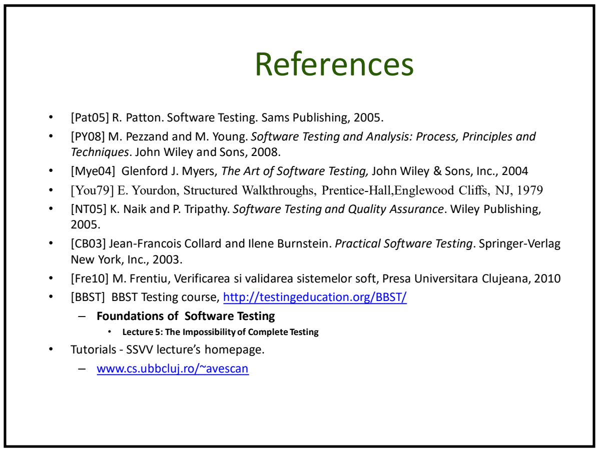
Next Lecture

- Invited lecture: IT firm: Altom
  - Topic: Testing Skills. RIMGEN
  - 22 March 2019
  - Hours: 14:00-16:00
  - Room: TBA (maybe 6/II, Main building)
    - See Discussion on canvas!



Questions

- Thank You For Your Attention!



References

- [Pat05] R. Patton. Software Testing. Sams Publishing, 2005.
- [PY08] M. Pezzand and M. Young. *Software Testing and Analysis: Process, Principles and Techniques*. John Wiley and Sons, 2008.
- [Mye04] Glenford J. Myers, *The Art of Software Testing,* John Wiley & Sons, Inc., 2004
- [You79] E. Yourdon, Structured Walkthroughs, Prentice-Hall,Englewood Cliffs, NJ, 1979
- [NT05] K. Naik and P. Tripathy. *Software Testing and Quality Assurance*. Wiley Publishing, 2005.
- [CB03] Jean-Francois Collard and Ilene Burnstein. *Practical Software Testing*. Springer-Verlag New York, Inc., 2003.
- [Fre10] M. Frentiu, Verificarea si validarea sistemelor soft, Presa Universitara Clujeana, 2010
- [BBST] BBST Testing course, http://testingeducation.org/BBST/
  - **Foundations of Software Testing**
    - **Lecture 5: The Impossibility of Complete Testing**
- Tutorials - SSVV lecture’s homepage.
  - www.cs.ubbcluj.ro/~avescan