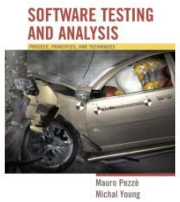
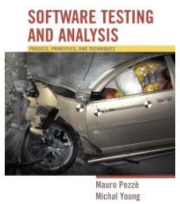
Data flow testing



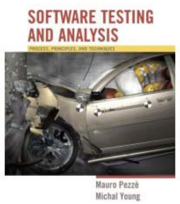
Learning objectives

- Understand why data flow criteria have been designed and used
- Recognize and distinguish basic DF criteria
  - All DU pairs, all DU paths, all definitions
- Understand how the infeasibility problem impacts data flow testing
- Appreciate limits and potential practical uses of data flow testing

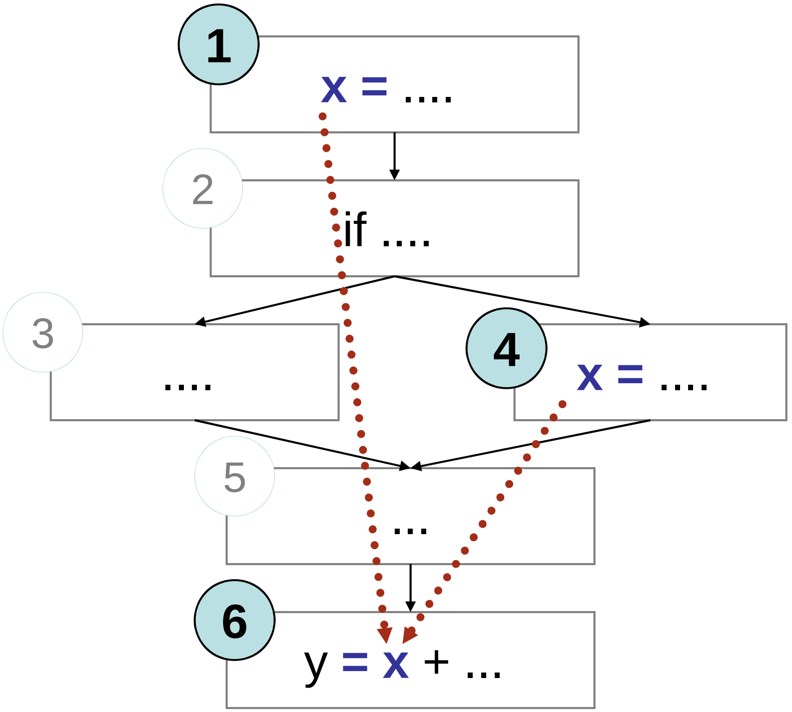


Motivation

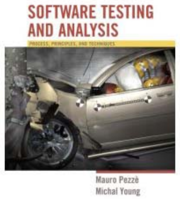
- Middle ground in structural testing
  - Node and edge coverage don't test interactions
  - Path-based criteria require impractical number of test cases
    - And only a few paths uncover additional faults, anyway
  - Need to distinguish "important" paths
- Intuition: Statements interact through *data flow*
  - Value computed in one statement, used in another
  - Bad value computation revealed only when it is used



Data flow concept



- Value of x at 6 could be computed at 1 or at 4
- Bad computation at 1 or 4 could be revealed only if they are used at 6
- (1,6) and (4,6) are *def-use (DU) pairs*
  - defs at 1,4
  - use at 6



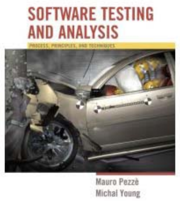
Terms

- DU pair: a pair of *definition* and *use* for some variable, such that at least one DU path exists from the definition to the use

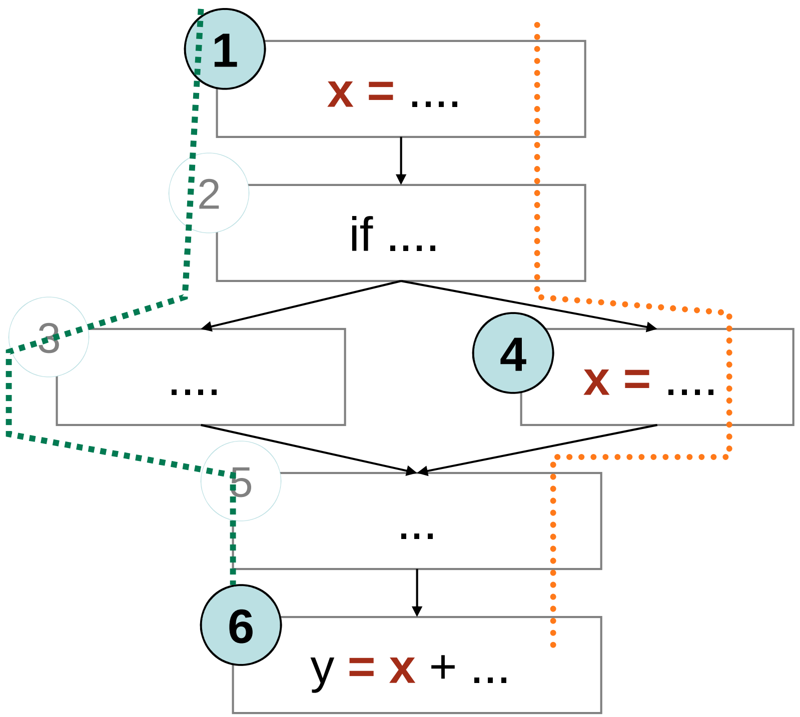
  x = … is a *definition* of x

  = … x … is a *use* of x

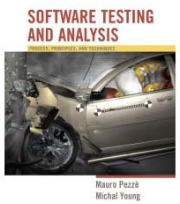
- DU path: a definition-clear path on the CFG starting from a definition to a use of a same variable
  - Definition clear: Value is not replaced on path
  - Note – loops could create infinite DU paths between a def and a use



Definition-clear path



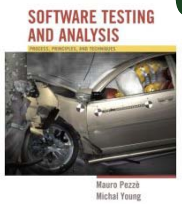
- 1,2,3,5,6 is a definition-clear path from 1 to 6
  - x is not re-assigned between 1 and 6
- 1,2,4,5,6 is not a definition-clear path from 1 to 6
  - the value of x is “killed” (reassigned) at node 4
- (1,6) is a DU pair because 1,2,3,5,6 is a definition-clear path



Adequacy criteria

- All DU pairs: Each DU pair is exercised by at least one test case
- All DU paths: Each *simple* (non looping) DU path is exercised by at least one test case
- All definitions: For each definition, there is at least one test case which exercises a DU pair containing it
  - (Every computed value is used somewhere)

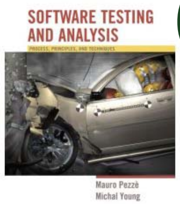
Corresponding coverage fractions can also be defined



Difficult cases

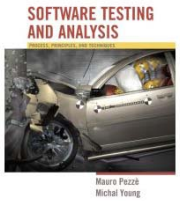
- x[i] = ... ; ... ; y = x[j]
  - DU pair (only) if i==j
- p = &x ; ... ; *p = 99 ; ... ; q = x
  - *p is an alias of x
- m.putFoo(...); ... ; y=n.getFoo(...);
  - Are m and n the same object?
  - Do m and n share a “foo” field?

- Problem of *aliases*: Which references are (always or sometimes) the same?

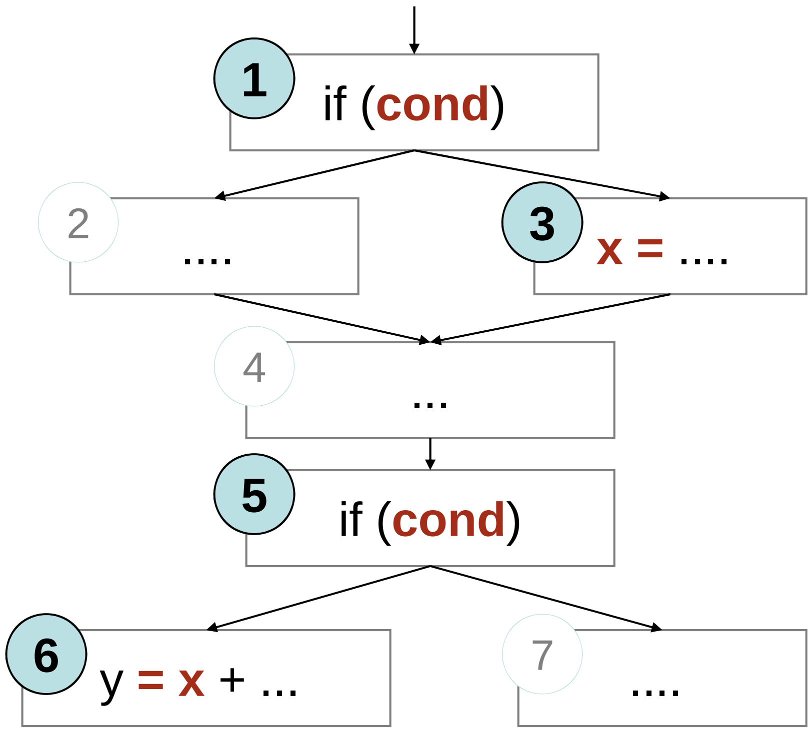


Data flow coverage with complex structures

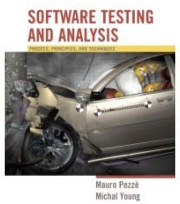
- Arrays and pointers are critical for data flow analysis
  - Under-estimation of aliases may fail to include some DU pairs
  - Over-estimation, on the other hand, may introduce unfeasible test obligations
- For testing, it may be preferrable to accept under-estimation of alias set rather than over-estimation or expensive analysis
  - Controversial: In other applications (e.g., compilers), a *conservative* over-estimation of aliases is usually required
  - Alias analysis may rely on external guidance or other global analysis to calculate good estimates
  - Undisciplined use of dynamic storage, pointer arithmetic, etc. may make the whole analysis infeasible



Infeasibility

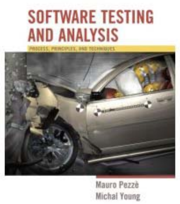


- Suppose *cond* has not changed between 1 and 5
  - Or the conditions could be different, but the first implies the second
- Then (3,5) is not a (feasible) DU pair
  - But it is difficult or impossible to determine which pairs are infeasible
- Infeasible test obligations are a problem
  - No test case can cover them



Infeasibility

- The path-oriented nature of data flow analysis makes the infeasibility problem especially relevant
  - Combinations of elements matter!
  - Impossible to (infallibly) distinguish feasible from infeasible paths. More paths = more work to check manually.
- In practice, reasonable coverage is (often, not always) achievable
  - Number of paths is exponential in worst case, but often linear
  - All DU *paths* is more often impractical



Summary

- Data flow testing attempts to distinguish "important" paths: Interactions between statements
  - Intermediate between simple statement and branch coverage and more expensive path-based structural testing
- Cover Def-Use (DU) pairs: From computation of value to its use
  - Intuition: Bad computed value is revealed only when it is used
  - Levels: All DU pairs, all DU paths, all defs (some use)
- Limits: Aliases, infeasible paths
  - Worst case is bad (undecidable properties, exponential blowup of paths), so pragmatic compromises are required