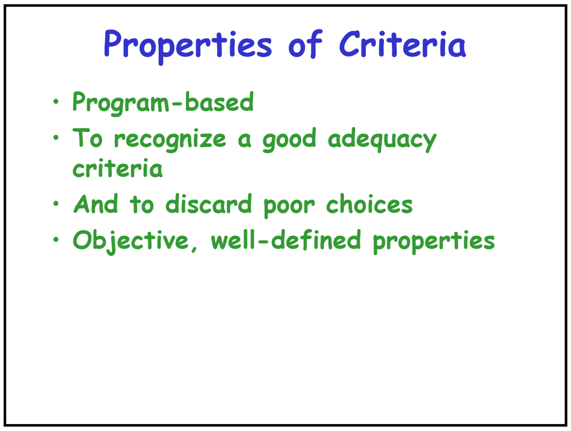
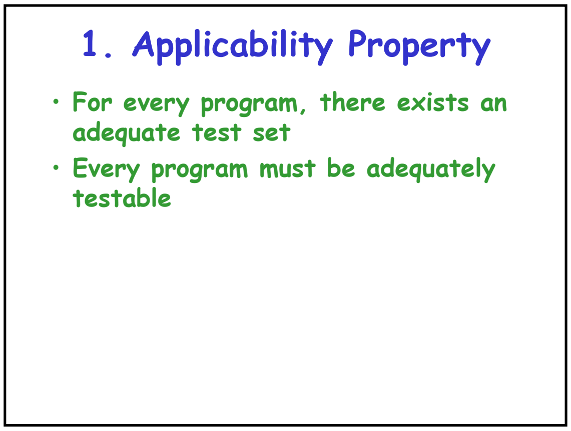


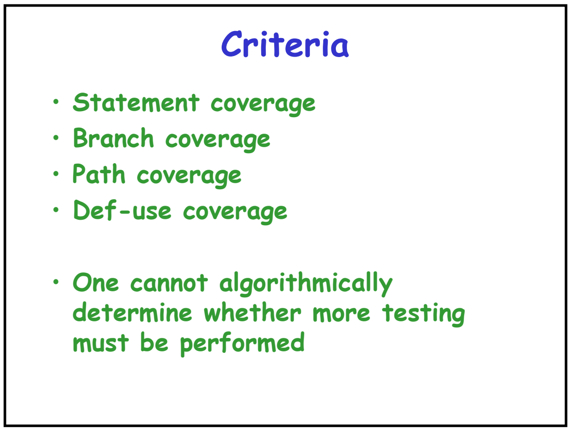
Properties of Criteria

- Program-based
- To recognize a good adequacy criteria
- And to discard poor choices
- Objective, well-defined properties



1. Applicability Property

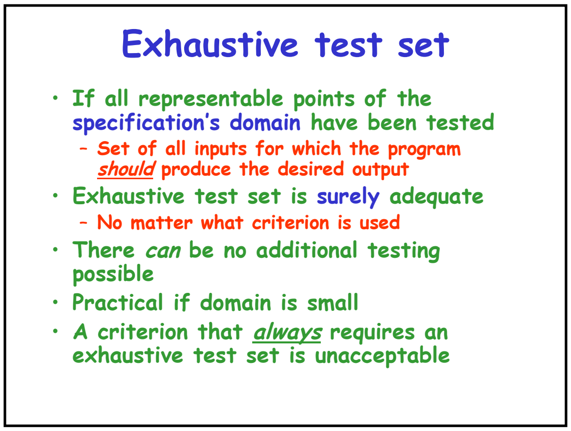
- For every program, there exists an adequate test set
- Every program must be adequately testable



Criteria

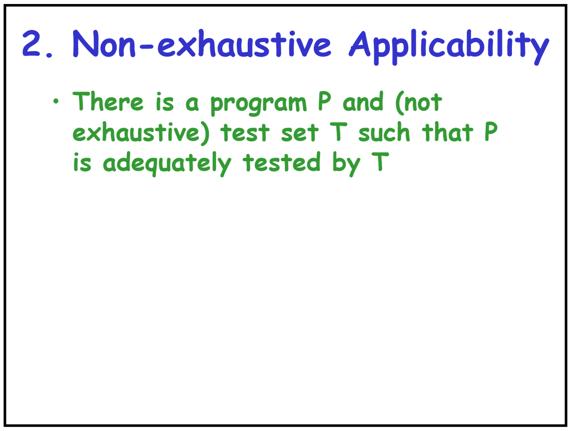
- Statement coverage
- Branch coverage
- Path coverage
- Def-use coverage

- One cannot algorithmically determine whether more testing must be performed



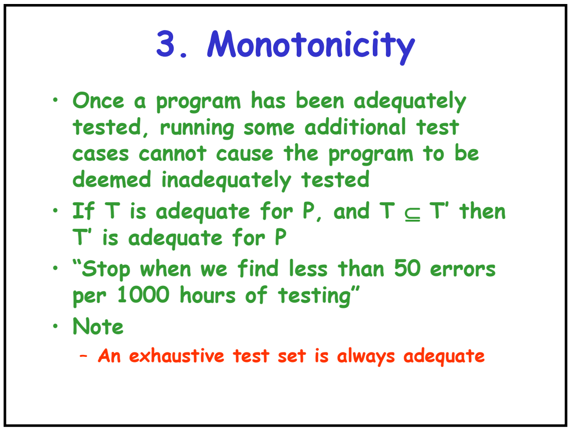
Exhaustive test set

- If all representable points of the specification's domain have been tested
  - Set of all inputs for which the program *should* produce the desired output
- Exhaustive test set is surely adequate
  - No matter what criterion is used
- There *can* be no additional testing possible
- Practical if domain is small
- A criterion that *always* requires an exhaustive test set is unacceptable



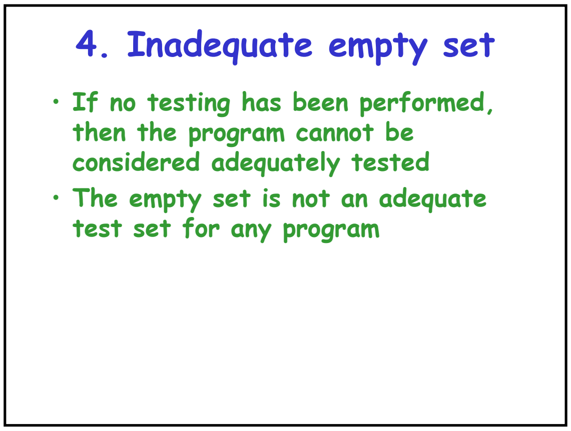
2. Non-exhaustive Applicability

- There is a program P and (not exhaustive) test set T such that P is adequately tested by T



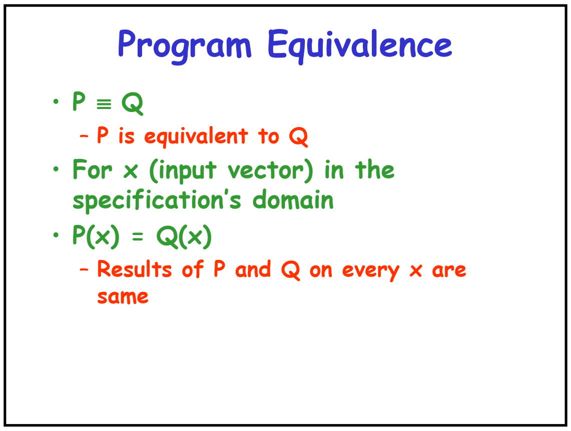
3. Monotonicity

- Once a program has been adequately tested, running some additional test cases cannot cause the program to be deemed inadequately tested
- If T is adequate for P, and $T \subseteq T'$ then T' is adequate for P
- "Stop when we find less than 50 errors per 1000 hours of testing"
- Note
  - An exhaustive test set is always adequate



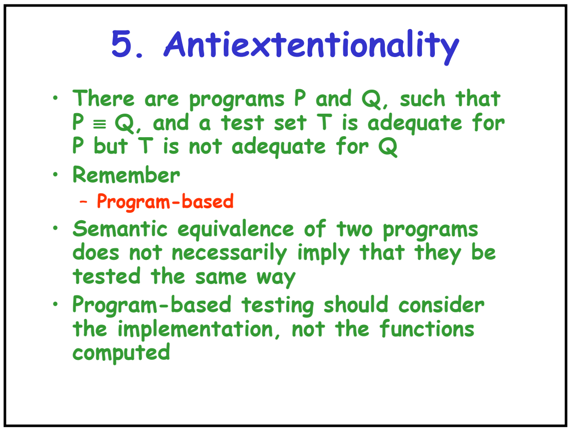
4. Inadequate empty set

- If no testing has been performed, then the program cannot be considered adequately tested
- The empty set is not an adequate test set for any program



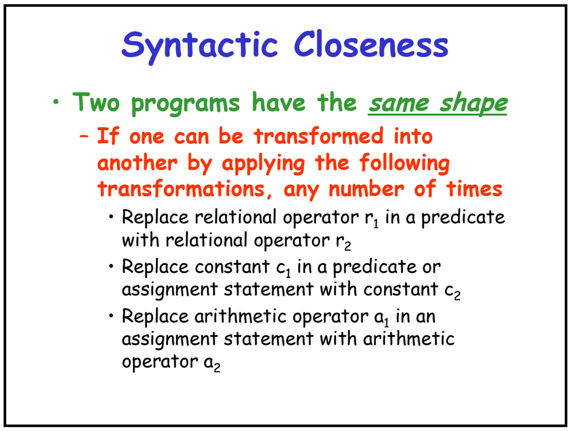
Program Equivalence

- P ≡ Q
  - P is equivalent to Q
- For x (input vector) in the specification's domain
- P(x) = Q(x)
  - Results of P and Q on every x are same



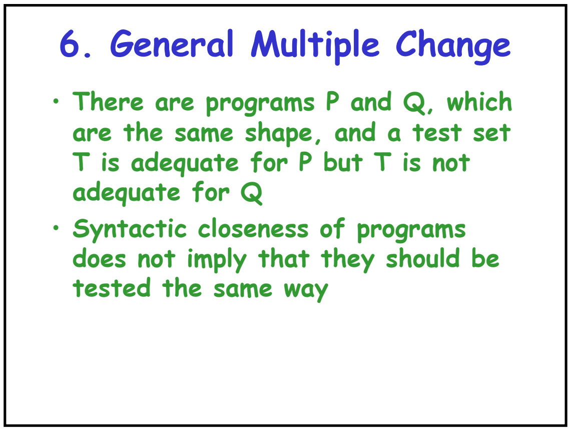
5. Antiextentionality

- There are programs P and Q, such that P ≡ Q, and a test set T is adequate for P but T is not adequate for Q
- Remember
  - Program-based
- Semantic equivalence of two programs does not necessarily imply that they be tested the same way
- Program-based testing should consider the implementation, not the functions computed



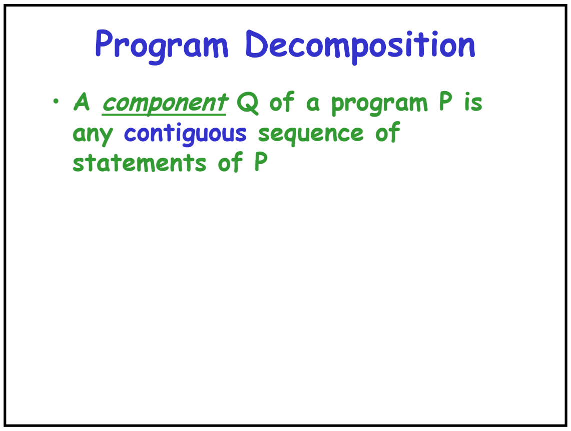
Syntactic Closeness

- Two programs have the ***same shape***
  - If one can be transformed into another by applying the following transformations, any number of times
    - Replace relational operator r_1 in a predicate with relational operator r_2
    - Replace constant c_1 in a predicate or assignment statement with constant c_2
    - Replace arithmetic operator a_1 in an assignment statement with arithmetic operator a_2



6. General Multiple Change

- There are programs P and Q, which are the same shape, and a test set T is adequate for P but T is not adequate for Q
- Syntactic closeness of programs does not imply that they should be tested the same way



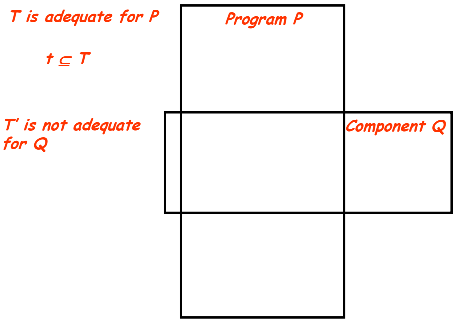
Program Decomposition

- A ***component*** Q of a program P is any contiguous sequence of statements of P

7. Antidecomposition

- There exists a program P, and
- component Q,
- such that test set T is adequate for P,
- T' is the set of vectors of values that variables can assume on entrance to Q for some t in T, and
- T' is not adequate for Q

Explanation



T is adequate for P

$t \subseteq T$

T' is not adequate for Q

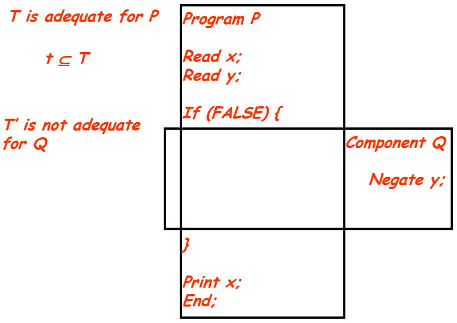
Program P

Component Q

Explanation

- Although a program has been adequately tested, it does not necessarily imply that each of its component pieces has been properly tested
- A routine that has been adequately tested in some environment or context has not necessarily been tested for other environments
- Even though P appears to be more complicated than Q, (P syntactically contains Q), semantically, Q may be more complex than P

Explanation



T is adequate for P

$t \subseteq T$

T' is not adequate for Q

```
Program P

Read x;
Read y;

If (FALSE) {
```

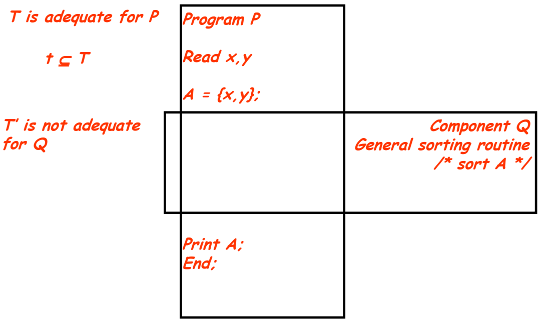
Component Q

Negate y;

```
}

Print x;
End;
```

Explanation



T is adequate for P

$t \subseteq T$

T' is not adequate for Q

```
Program P

Read x,y

A = {x,y};
```

Component Q

General sorting routine

/* sort A */

```
Print A;
End;
```

Criteria

- Statement coverage
- Branch coverage

- Antidecomposition property rules out criteria that do not recognize that the context of a piece of code is important

Program Composition

- Assume a structured programming language
  - Programs are single-entry/single-exit
  - All input statements appear at the start of the program
  - All output statements appear at the end of the program
- Programs P and Q
  - Using the same set of identifiers
  - Remove all output statements of P
  - Remove all input statements of Q
- P;Q is the composed program

8. Anticomposition

- There exist programs P and Q, and
- test set T,
- such that T is adequate for P, and
- the set of vectors of values that variables can assume on entrance to Q for inputs in T is adequate for Q, but
- T is not adequate for P;Q

Criteria

- Statement coverage
- Branch coverage
- Anticomposition property eliminates criteria that do not have provision for testing the interaction of program pieces

Gödel Numbering

- Definition
  - A unique numerical value for each program, such that the program can be algorithmically retrieved from this value
- For a program P with Gödel number p
  - A test set T is Gödel adequate for P if $p \in T$
- Any test set T that contains a program P's Gödel number is adequate for P

Examining Gödel Adequacy

- Gödel adequacy has nothing to do with a program's semantics, syntax or specifications
- Every program will always have an adequate test set of size one
- Does this criterion satisfy all the properties that we have discussed?
- Do you think that this criterion is useful?

Program Renaming

- P is a ***renaming*** of Q if
  - P is identical to Q, except
  - All instances of an identifier x_i of Q have been replaced by an identifier x_j where x_j does not appear in Q, or
  - If there exists a sequence Q = P_1, P_2, P_3, …, P_n = P, where
    - P_{i+1} is a renaming of P_i for i = 1, …, n-1

9. Renaming Property

- Let P be a renaming of Q
- Test set T is adequate for P iff T is adequate for Q

- Intuitively, an “inessential” change in a program, such as changing variable names, should not change the test data required to adequately test the program
- Gödel adequacy does not satisfy this property!!

Canonical Representation

- Given a Program P with k variables
  - Obtain its canonical representation by
  - Renaming variables using the set {x_1, x_2, …, x_k} where x_1 replaces the first variable used in the program and x_k replaces the kth variable used; x_i replaces the ith variable used

Gödel-class Numbering

- Definition
  - A unique numerical value for each program’s *canonical* form, such that the it can be algorithmically retrieved from this value
- For a program P with Gödel-class number p
  - A test set T is Gödel-class adequate for P if $p \in T$
- Any test set T that contains a program P’s Gödel-class number is adequate for P
- Does it satisfy Renaming Property?
- And all other 8 properties?

10. Statement Coverage

- If T is adequate for P, then T causes every *executable* statement of P to be executed