Chapter 6

Equivalence Class Testing

Outline

- Motivation. Why bother?
- Equivalence Relations and their consequences
- “Traditional” Equivalence Class Testing
- Four Variations of Equivalence Class Testing
- Examples

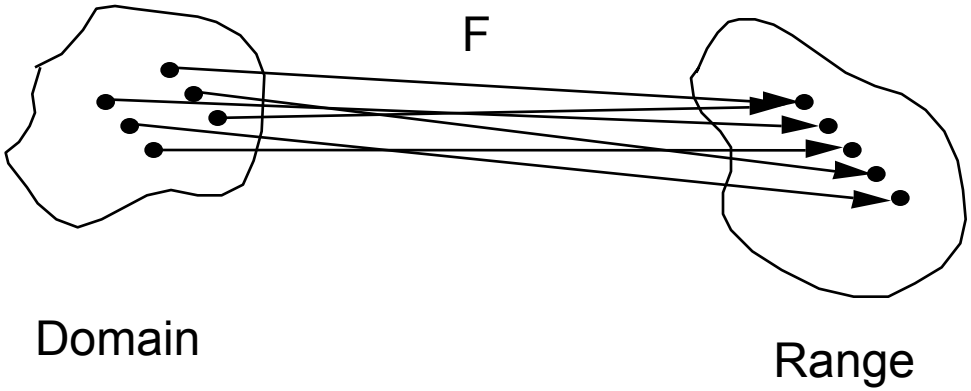
Motivation

- In chapter 5, we saw that all four variations of boundary value testing are vulnerable to
  - gaps of untested functionality, and
  - significant redundancy, that results in extra effort
- The mathematical notion of an equivalence class can potentially help this because
  - members of a class should be “treated the same” by a program
  - equivalence classes form a partition of the input space
- Recall (from chapter 3) that a partition deals explicitly with
  - redundancy (elements of a partition are disjoint)
  - gaps (the union of all partition elements is the full input space)

Motivation (continued)

- If you were testing the Triangle Program, would you use these test cases?
  - (3, 3, 3), (10, 10, 10), (187, 187, 187)
- In Chapter 5, the normal boundary value test cases covered June 15 in five different years. Does this make any sense?
- Equivalence class testing provides an elegant strategy to resolve such awkward situations.

Equivalence Class Testing

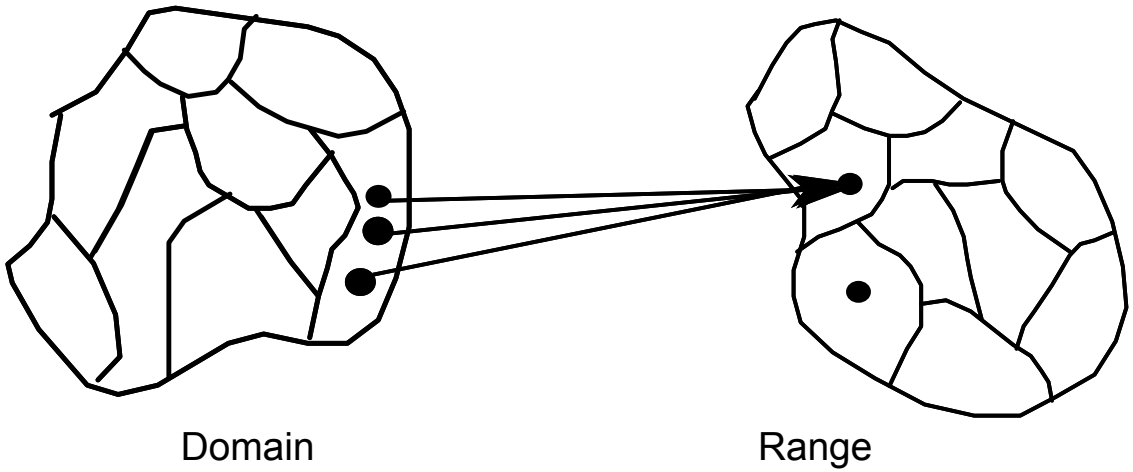


Equivalence class testing uses information about the functional mapping itself to identify test cases

Equivalence Relations

- Given a relation R defined on some set S, R is an equivalence relation if (and only if), for all, x, y, and z elements of S:
  - R is reflexive, i.e., xRx
  - R is symmetric, i.e., if xRy, then yRx
  - R is transitive, i.e., if xRy and yRz, then xRz
- An equivalence relation, R, induces a partition on the set S, where a partition is a set of subsets of S such that:
  - The intersection of any two subsets is empty, and
  - The union of all the subsets is the original set S
- Note that the intersection property assures no redundancy, and the union property assures no gaps.

Equivalence Partitioning



- Define a relation R on the input domain D as: ∀ x, y ϵ D, xRy iff F(x) = F(y), where F is the program function.
- R is the "treated the same" relation
- Exercise: show that R is an equivalence relation

Equivalence Partitioning (continued)

- Works best when F is a many-to-one function
- Test cases are formed by selecting one value from each equivalence class.
- Identifying the classes may be hard

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Forms of Equivalence Class Testing

- "Traditional"—focus on invalid inputs
- Normal: classes of valid values of inputs
- Robust: classes of valid and invalid values of inputs
- Weak: (single fault assumption) one from each class
- Strong: (multiple fault assumption) one from each class in Cartesian Product
- We compare these for a function of two variables, $F(x_1, x_2)$
- Extension to problems with 3 or more variables is "obvious".

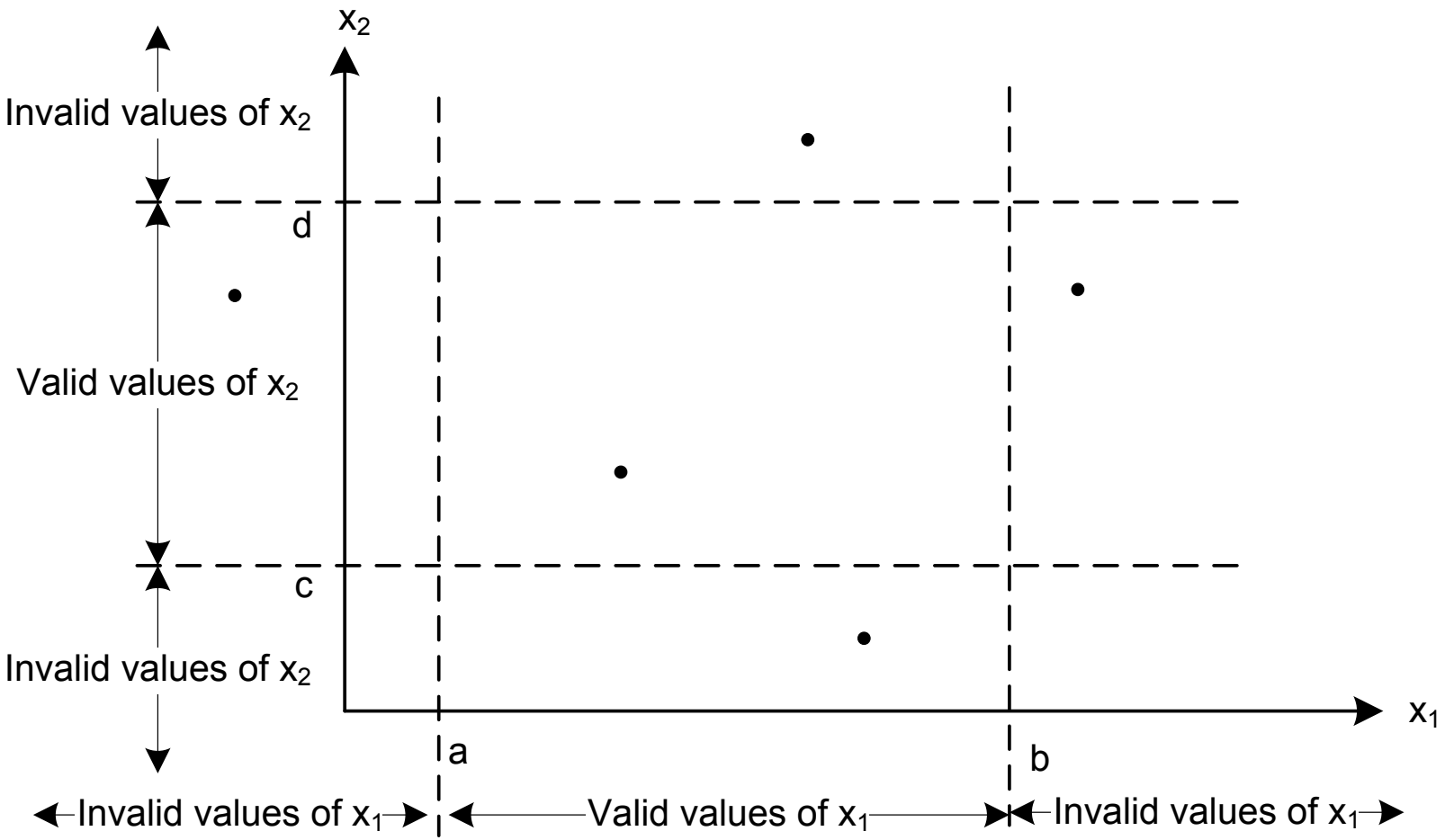
"Traditional" Equivalence Class Testing

- Programmer arrogance:
  - in the 1960s and 1970s, programmers often had very detailed input data requirements.
  - if input data didn't comply, it was the user's fault
  - the popular phrase—Garbage In, Garbage Out (GIGO)
- Programs from this era soon developed defenses
  - (many of these programs are STILL legacy software)
  - as much as 75% of code verified input formats and values
- "Traditional" equivalence class testing focuses on detecting invalid input.
  - (almost the same as our "weak robust equivalence class testing")

Continuing Example

- (only 2-dimensions for drawing purposes)
- easy to extend to more variables
- $F(x_1, x_2)$ has these classes...
  - valid values of x_1: $a \leq x_1 \leq b$
  - invalid values of x_1: $x_1 < a$, $b < x_1$
  - valid values of x_2: $c \leq x_2 \leq d$
  - invalid values of x_2: $x_2 < c$, $d < x_2$
- Process
  - test F for valid values of all variables,
  - then test one invalid variable at a time
  - (note this makes the single fault assumption)

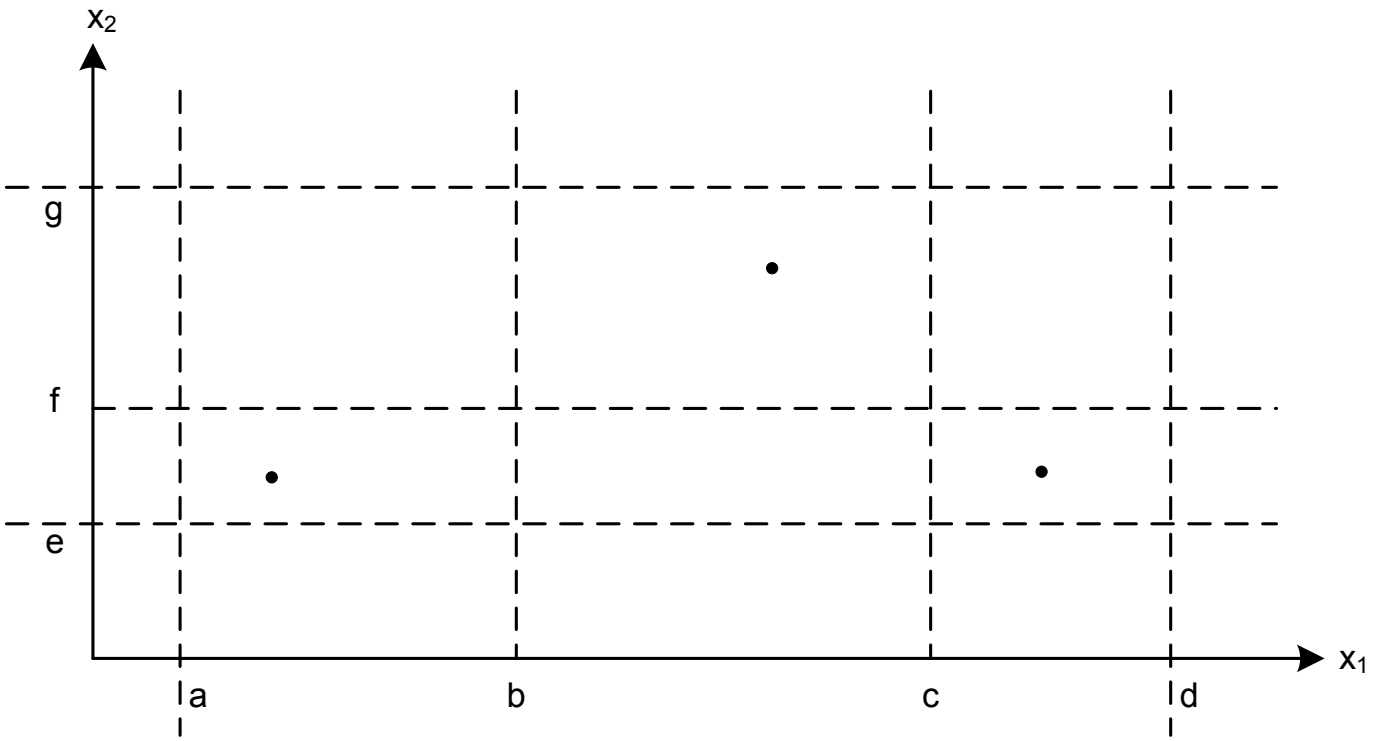
Example


x2
Invalid values of x2
d
Valid values of x2
c
Invalid values of x2
x1
a
b
Invalid values of x1
Valid values of x1
Invalid values of x1

Weak Normal Equivalence Class Testing

- Identify equivalence classes of valid values.
- Test cases have all valid values.
- Detects faults due to calculations with valid values of a single variable.
- OK for regression testing.
- Need an expanded set of valid classes
  - valid classes: {a <= x1 < b}, {b <= x1 < c}, {c <= x1 <= d}, {e <= x2 < f}, {f <= x2 <= g}
  - invalid classes: {x1 < a}, {x1 > d}, {x2 < e}, {x2 > g}

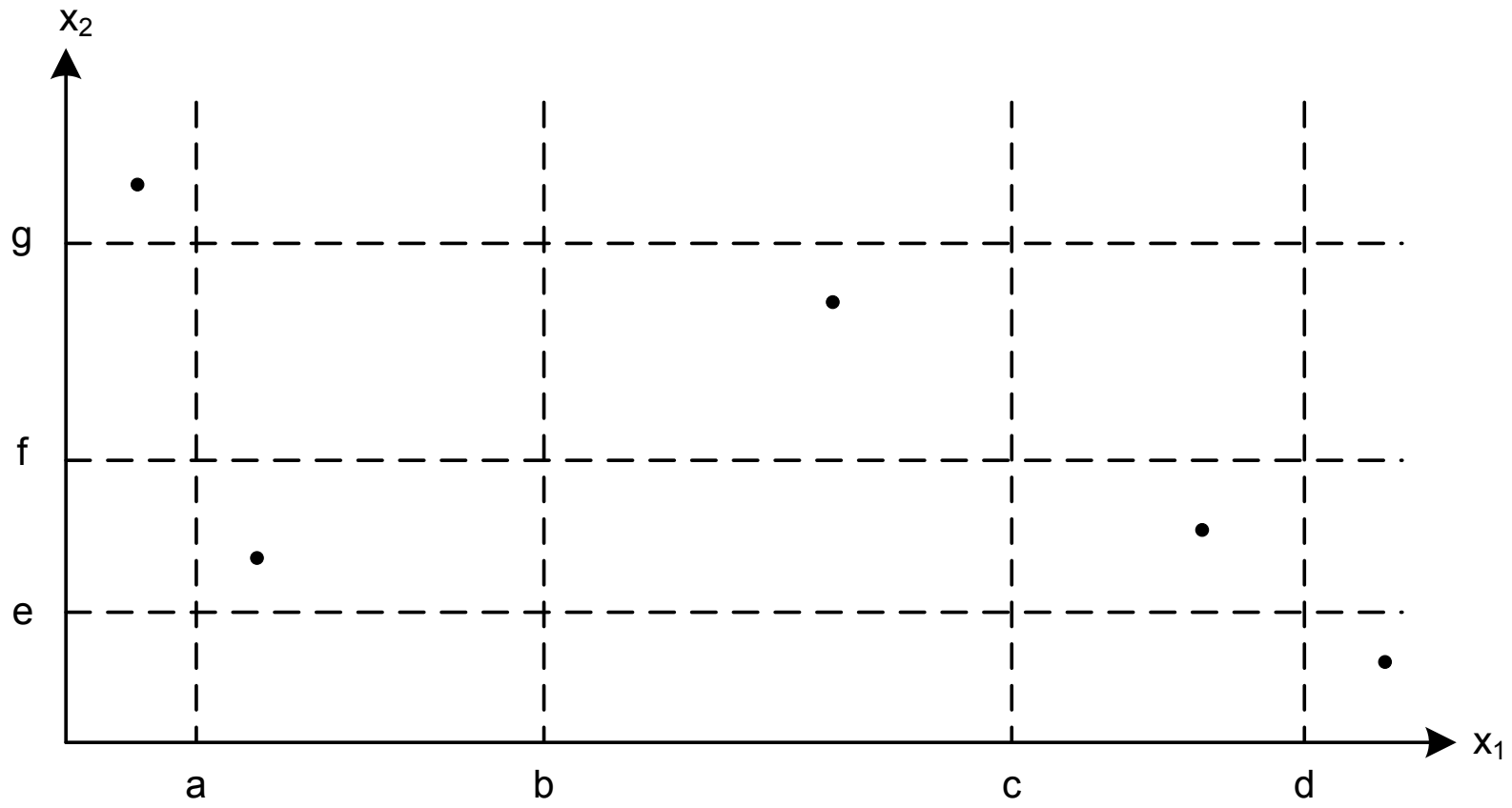
Weak Normal Equivalence Class Test Cases



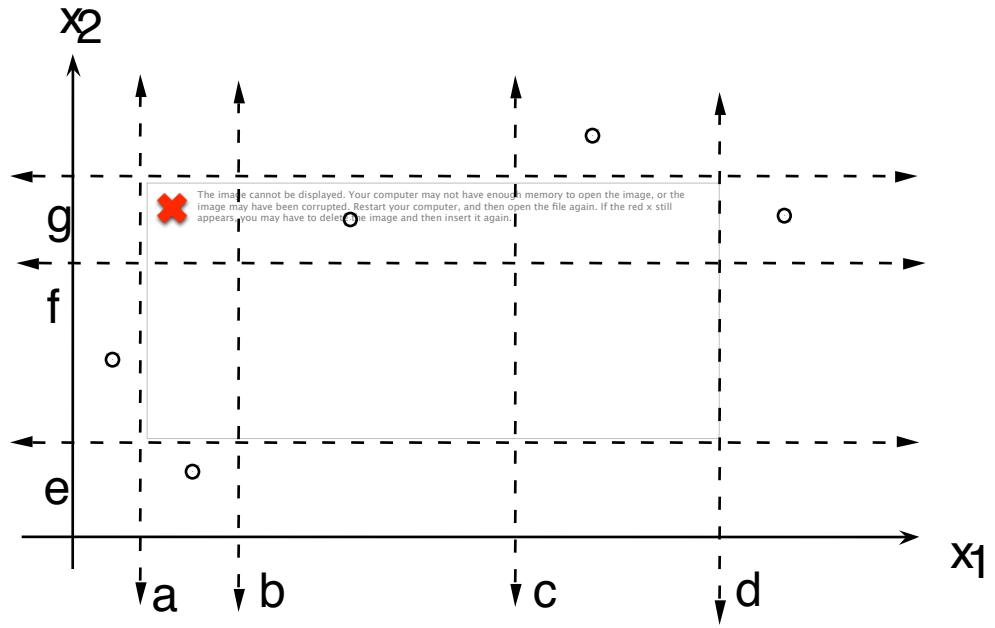
Weak Robust Equivalence Class Testing

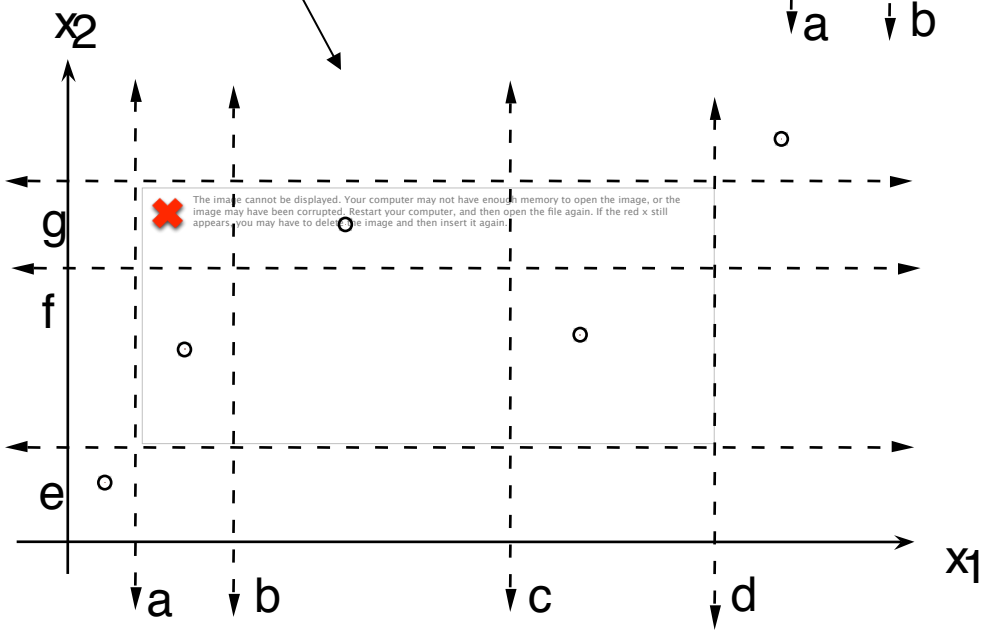
- Identify equivalence classes of valid and invalid values.
- Test cases have all valid values except one invalid value.
- Detects faults due to calculations with valid values of a single variable.
- Detects faults due to invalid values of a single variable.
- OK for regression testing.

Weak Robust Equivalence Class Test Cases



Is this preferable to this? Why?

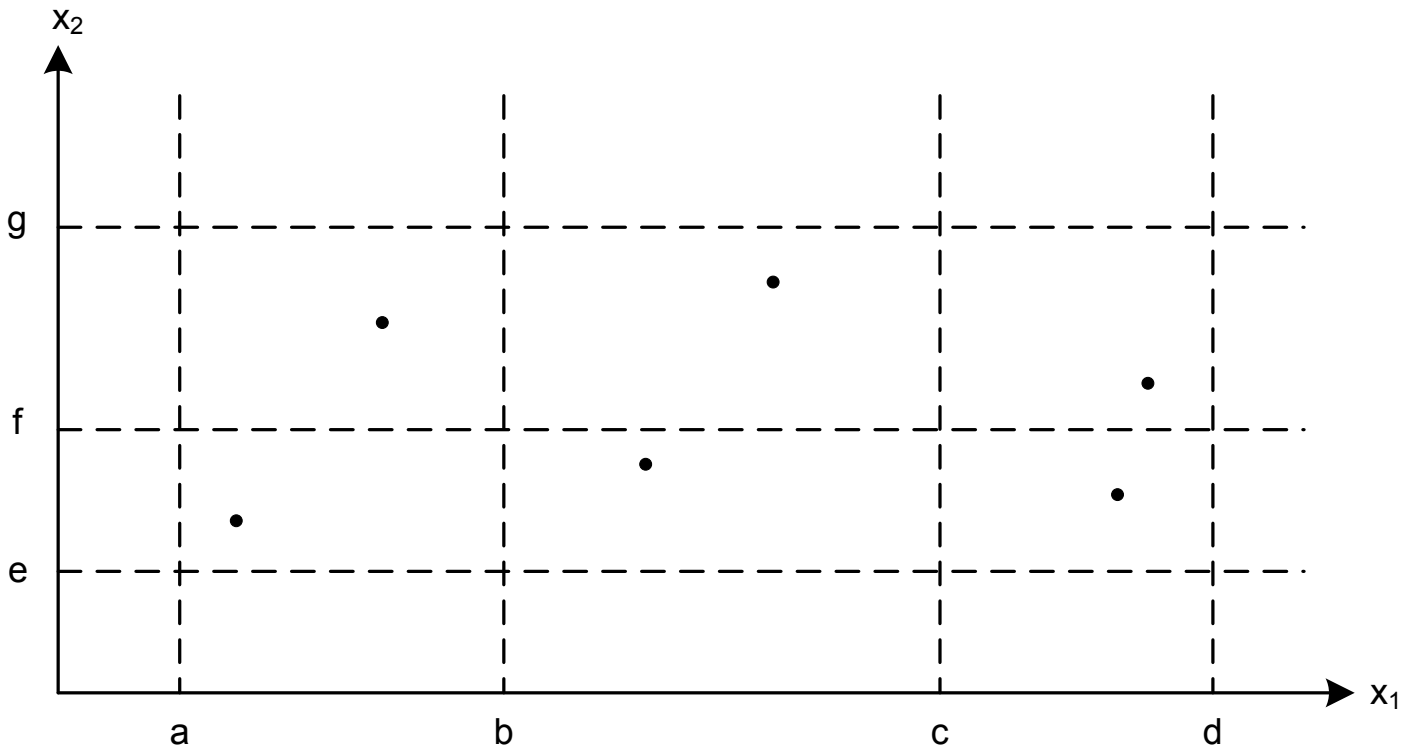




Strong Normal Equivalence Class Testing

- Identify equivalence classes of valid values.
- Test cases from Cartesian Product of valid values.
- Detects faults due to interactions with valid values of any number of variables.
- OK for regression testing, better for progression testing.

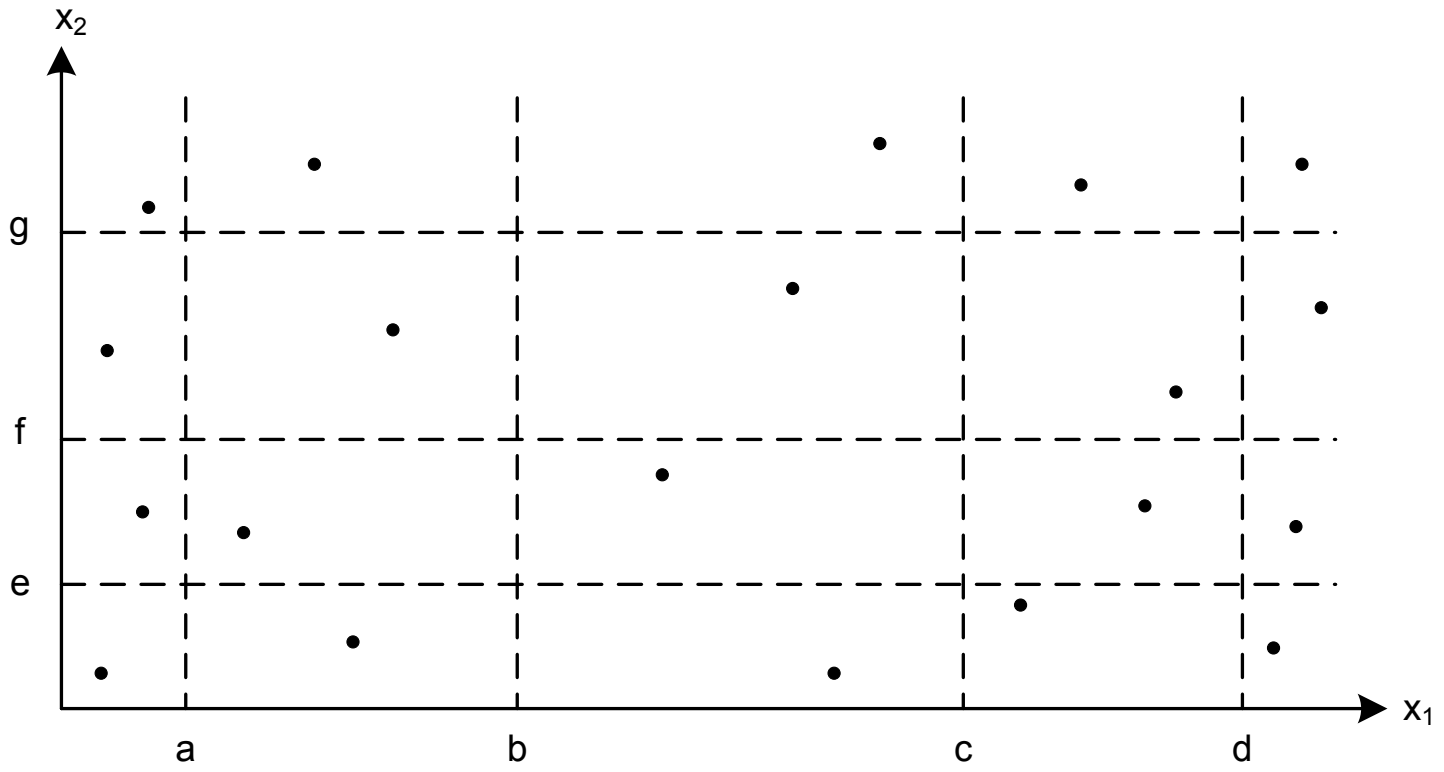
Strong Normal Equivalence Class Test Cases



Strong Robust Equivalence Class Testing

- Identify equivalence classes of valid and invalid values.
- Test cases from Cartesian Product of all classes.
- Detects faults due to interactions with any values of any number of variables.
- OK for regression testing, better for progression testing.
  - (Most rigorous form of Equivalence Class testing, BUT,
  - Jorgensen's First Law of Software Engineering applies.)
- Jorgensen's First Law of Software Engineering:
  - The product of two big numbers is a really big number.
  - (More elegant: scaling up can be problematic)

Strong Robust Equivalence Class Test Cases



Selecting an Equivalence Relation

- There is no such thing as THE equivalence relation.
- If x and y are days, some possibilities for Nextdate are:
  - x R y iff x and y are mapped onto the same year
  - x R y iff x and y are mapped onto the same month
  - x R y iff x and y are mapped onto the same date
  - x R y iff x(day) and y(day) are “treated the same”
  - x R y iff x(month) and y(month) are “treated the same”
  - x R y iff x(year) and y(year) are “treated the same”
- Best practice is to select an equivalence relation that reflects the behavior being tested.

NextDate Equivalence Classes

- Month:
  - M1 = { month : month has 30 days}
  - M2 = { month : month has 31 days}
  - M3 = { month : month is February}

- Day
  - D1 = {day : 1 <= day <= 28}
  - D2 = {day : day = 29 }
  - D3 = {day : day = 30 }
  - D4 = {day : day = 31 }

- Year (are these disjoint?)
  - Y1 = {year : year = 2000}
  - Y2 = {year : 1812 <= year <= 2012 AND (year ≠ 0 Mod 100) and (year = 0 Mod 4)
  - Y3 = {year : (1812 <= year <= 2012 AND (year ≠ 0 Mod 4)

Not Quite Right

- A better set of equivalence classes for year is
  - Y1 = {century years divisible by 400} i.e., century leap years
  - Y2 = {century years not divisible by 400} i.e., century common years
  - Y3 = {non-century years divisible by 4} i.e., ordinary leap years
  - Y4 = {non-century years not divisible by 4} i.e., ordinary common years
- All years must be in range: 1812 <= year <= 2012
- Note that these equivalence classes are disjoint.

Weak Normal Equivalence Class Test Cases

Select test cases so that one element from each input domain equivalence class is used as a test input value. The number of test cases is the same as the highest number of equivalence classes for a variable.

Test Case	Input Domain Equiv. Classes	Input Values	Expected Outputs
WN-1	M1, D1, Y1	April 1 2000	April 2 2000
WN-2	M2, D2, Y2	Jan. 29 1900	Jan. 30 1900
WN-3	M3, D3, Y3	Feb. 30 1812	impossible
WN-4	M1, D4, Y4	April 31 1901	impossible

Notice that all forms of equivalence class testing presume that the variables in the input domain are independent; logical dependencies are not recognized.

Strong Normal Equivalence Class Test Cases

- With 4 day classes, 3 month classes, and 4 year classes, the Cartesian Product will have 48 equivalence class test cases. (Jorgensen's First Law of Software Engineering strikes again!)
- Note some judgment is required. Would it be better to have 5 day classes, 4 month classes and only 2 year classes? (40 test cases)
- Questions such as this can be resolved by considering Risk.

Revised NextDate Domain Equivalence Classes

- Month:
  - –M1 = { month : month has 30 days}
  - –M2 = { month : month has 31 days except December}
  - –M3 = { month : month is February}
  - –M4 = {month : month is December}
- Day
  - –D1 = {day : 1 <= day <= 27}
  - –D2 = {day : day = 28 }
  - –D3 = {day : day = 29 }
  - –D4 = {day : day = 30 }
  - –D5 = {day : day = 31 }
- Year (are these disjoint?)
  - –Y1 = {year : year is a leap year}
  - –Y2 = {year : year is a common year}

The Cartesian Product of these contains 40 elements.

When to Use Equivalence Class Testing

- Variables represent logical (rather than physical) quantities.
- Variables "support" useful equivalence classes.
- Try to define equivalence classes for
  - The Triangle Problem
    - 0 < sideA < 200
    - 0 < sideB < 200
    - 0 < sideC < 200
  - The Commission Problem (exercise)

Another Equivalence Class Strategy

- "Work backwards" from output classes.
- For the Triangle Problem, could have
  - {x, y, z such that they form an Equilateral triangle}
  - {x, y, z such that they form an Isosceles triangle with x = y}
  - {x, y, z such that they form an Isosceles triangle with x = z}
  - {x, y, z such that they form an Isosceles triangle with y = z}
  - {x, y, z such that they form a Scalene triangle}
- How many equivalence classes will be needed for x,y,z such that they are not a triangle?

In-Class Exercise

- Apply the “working backwards” approach to develop equivalence classes for the Commission Problem.
- Hint: use boundaries in the output space.

Assumption Matrix

	Valid Values	Valid and Invalid Values
Single fault	Boundary Value Weak Normal Equiv. Class	Robust Boundary Value Weak Robust Equiv. Class
Multiple fault	Worst Case Boundary Value Strong Normal Equiv. Class	Robust Worst Case Boundary Value Strong Robust Equiv. Class