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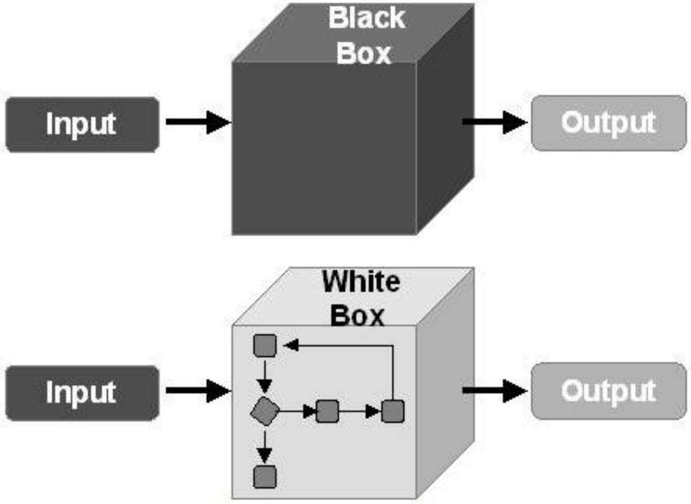
Software Testing & Debugging

Plan for today

- Blackbox vs Whitebox testing
- Blackbox testing techniques:
  - Partitioning of input/output space into equivalence classes
  - Boundary Analysis
  - Error Guessing

Blackbox and Whitebox Testing

- Blackbox testing views the software as a black box. The goal is to concentrate on the “software specifications”
  - also known as data-driven, io-driven, or specification-based testing
- Whitebox testing is concerned with the degree to which test cases cover the source code of the software
  - also know as Glassbox or logic-driven testing



Greybox Testing

- When there is only partial access/understanding of the internal structure of the software under test (SUT)
  - you know the algorithm, but not the exact implementation
  - you know the design or structure of the code, but not the exact implementation
  - Etc.
- *We do not examine this further in the class*

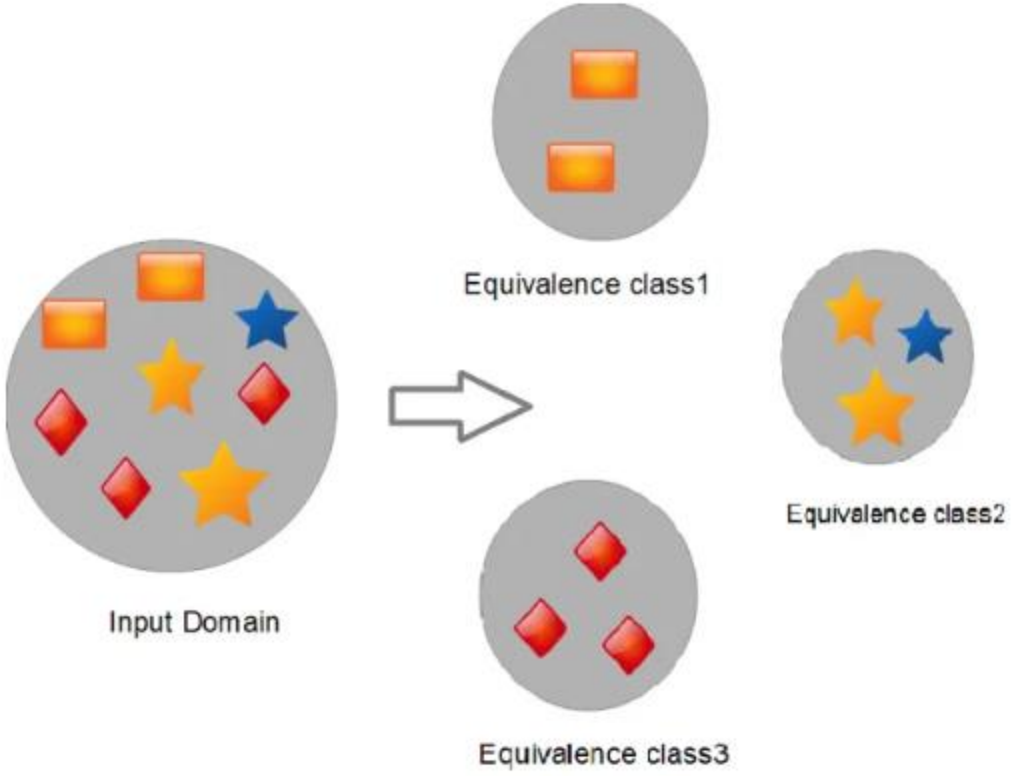
Blackbox and Whitebox Testing

- Blackbox testing:
  - test cases drawn solely from the specifications (e.g., formal specifications, API docs, user manual etc.)
  - ***exhaustive Blackbox testing*** is to try all possible inputs
- Whitebox testing:
  - test cases drawn by looking at (and manipulating) source code
  - ***exhaustive Whitebox testing*** is to try all execution paths

Equivalence Class

- A subset of the form {x ∈ X: x R a}, where **a** is an element of **X** and the notation "**x R y**" is used to mean that there is an equivalence relation between **x** and **y**
- In other words:
  - An **equivalence class (or equivalence block)** is the name that we give to the subset of **S** which includes **all elements that are equivalent to each other**. “Equivalent” is dependent on a specified relationship (i.e., characteristic), called an *equivalence relation or characteristic.* If there’s an equivalence relation between any two elements, they’re called equivalent.

Equivalence Class



Equivalence Class Examples

- **Example 1: X** is the set of all cars. **~** is the equivalence relation *"has the same color as"*, then equivalence classes consist of cars of different colors. e.g., set of all red cars, set of all blue cars, etc.
- **Example 2: I** is the set of all integer values. **~** is the equivalence relation *"has the same sign as"*, then equivalence classes consist of 1) set of all negative integers, 2) zero, and 3) set of all positive integers.
- **Example 3: A** is the set of all Matresses. ~ is the equivalence relation *"has the same size"*, then the equivalence classes consist of sets of all mattresses of the same size (i.e., Crib, Twin, Twin XL, Full, Queen, King, Cal King)

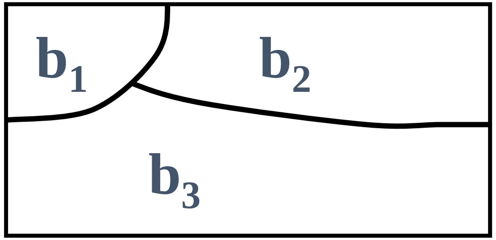
Partitioning domain into equivalence classes

- 1. Partition the input/output domain into a set of equivalence classes
- 2. Produce a representative concrete test case for each equivalence class
- The idea is:
  - if a test case from an equivalence class detects an error/failure, so does all the other test cases of the same equivalence class
  - conversely, if a test case from an equivalence class does not detect an error/failure, no other test cases of the same equivalence class does

Equivalence Partitioning

- Given characteristic (i.e., relation) **C:**
  the partition ***q*** defines a set of blocks(i.e., equivalence classes) over Domain **D:**

$$\boldsymbol{Bq = b_1, b_2, \ldots, b_Q}$$



- Two important properties for selecting equivalence classes correctly:
  - **disjointedness:** Blocks (i.e., classes) must be pairwise disjoint; that is no two blocks overlap

$$b_i \cap b_j = \Phi, \forall\ i \neq j, b_i, b_j \in B_q$$

  - **completeness:** Together the blocks cover entirety of the domain **D**

$$\bigcup_{b \in B_q} \boldsymbol{b} = \boldsymbol{D}$$

Relation (i.e., characteristic)

- Each partition is built based on a characteristic ***C***:
- Examples:
  - Object ‘a’ is null → two classes namely null and non-null
  - Input device type → multiple classes namely DVD, CD, VCR …
  - Shirt Size → multiple size classes namely xs, s, m, l, xl, xxl …
  - etc.

Example

- **Input:** Text file ***f***
- **Characteristic C:** Order of file ***f***
  - b_1= sorted in ascending order
  - b_2= sorted in descending order
  - b_3= not sorted in any specific order

Is this a valid partitioning based on "C"?

Steps to Input Space Partitioning

- Design the characteristics to create partition(s) over the input/output domain
  - ****It is POSSIBLE to design characteristics based on *output*****
- Decide on the blocks (i.e., equivalence classes) for each partitioning/characteristic
- Derive representative values for each block

Triangle Example

```
/**
* decides the type of the triangle given the lengths of the three sides
* @param a first length
* @param b second length
* @param c third length
* @return an int indicating the type of the triangle: 0 is invalid, 1 is scalene, 2 is isosceles, and 3 is equilateral
*/
public static int triangleType(int a, int b, int c)
```

Assume we do a partitioning over the **output** domain using characteristic “Geometric Classification”. From this, we derive four classes: 1) scalene, 2) isosceles, 3) equilateral, and 4) invalid.

Is the above a valid partitioning over the output domain?

Triangle Example

- Technically, an equilateral is (oftentimes) isosceles by definition!

1) Scalene
2) Isosceles but not equilateral,
3) equilateral,
4) invalid.

This is better!

Identifying Equivalence Classes

- Typically produced from specifications:
  - take sentences/phrases about the input/output, identify characteristic(s) based on the specified condition(s) and apply partitioning to produce the equivalence classes
    - Always produce both valid and invalid equivalence classes

Example: *"the count should range from 1 to 999 inclusive"*
one valid equivalence class: **1 ≤ count ≤ 999** ➔ test input value: 230
two invalid equivalence classes: **count > 999** ➔ test input value: 1002
count < 1 ➔ test input value: -1

- If an input specifies a "must-be" situation, produce one valid and one invalid equivalence class

Example: *"the first character of the string must be a digit"*
one valid equivalence class: **the string starts with a digit** ➔ **"1s2"**
one invalid equivalence class: **the string does not start with a digit** ➔ **"%h"**

Boundary Value Analysis

- Test conditions on bounds between equivalence classes
- Rationale:
  - likely source of programmer errors (< vs. <=, etc.)
  - Software specifications may be fuzzy/vague about behavior on boundaries
  - often uncovers internal hidden limits in code
    - Example:

Specs: array must be sized no less than 1 and no larger than 10

→ Three equivalence blocks: size < 1, 1<= size <= 10, size >10

→ try array sizes 0, 1, 10, and 11
(also, try MAX_INT and MIN_INT)

Boundary Value Analysis

- **Example 1:** input condition specifies the valid domain of an input value is between -1 and 1.0 → write test cases with values -1.0, 1.0, -1.001, and 1.001
- **Example 2:** input condition specifies an input file can contain 1 - 255 records → write test cases for files with 0, 1, 255, 256 records
- **Example 3:** output condition specifies payroll software computes the monthly FICA deduction of minimum $0.00 and the maximum of $1,165.25 → try to write/invent test cases that might cause a negative deduction or a deduction of more than $1,165.25

Error Guessing

- No systematic way
- Use your intuition/experience trying to cause errors/failures in the system
  - try different error-prone situations
  - **Examples:** zero for int values, null for objects, invalid inputs, out of bound inputs, empty sets/lists, sets/lists with one entry, inputs based on holes in the specifications, negative inputs where they are not relevant
- Complementary to other testing techniques

Relevant Reads

- Recommended Textbooks:
  - Intro to Software Testing (ch1, ch2)
  - The Art of Software Testing (ch1, ch2, ch4)

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