SYSC 4101 / SYSC 5105

Input Space Partitioning—Criteria
Part I

Test Criteria Based on Structure [Offutt]

- Graphs

- Logical Expressions

(not X or not Y) and A and B

- Input Domain Characterization

A: {0,1,>1}
B: {600,700,800}
C: {swe,cs,isa,infs}

Describes the input domain of the software under test (method, component, system)

- Syntactic Structures

```
if (x>y)
        z = x - y;
else
        z = 2 * x
```

Basic Principles

- Choosing elements from the input space, from the specification
- The specification provides information on
  - The input parameters, but not only (see later)
  - The allowed ranges of each parameter: Equivalence class partitioning + Boundary value analysis
    - What are the boundaries of the range? (where faults often are)
    - What is a within-range value?
    - What is an out-of-range value? (robustness)
- Equivalence classes
  - The behavior of the software is assumed to be the same for all the values of the class.
  - Sense of completeness (each class is exercised)
  - No redundancy (one input per class)
- Account for the test engineer expertise

Basic Principles—Illustrated

- Consider a function that takes an integer as input with the following specification:
  - If input is strictly negative, behavior A is triggered
  - If input is in range [0, 10], behavior B is triggered
  - If input is in range]10, 20], behavior C is triggered
  - If input is strictly greater than 20, behavior D is triggered
- Equivalence classes—4 inputs

Any value in this range triggers behavior D. It should be enough to use one (and only one) of those values

- Boundary value analysis added—7 inputs (faults happen at boundaries)

- Further boundary value analysis—13 inputs (faults at/around boundaries)

Which option to select? It depends on context, on user expertise

Step-by-Step Procedure

1. Identify functions/functionalities to be tested
2. For each function, identify
   A. The parameters of the function
      - These are part of the function interface/specification
   B. The environment variables
      - What, in the (execution) environment of the function, could impact the function's behavior?
      - These often come from the expertise of the test engineer
3. For each parameter or environment variable, identify the characteristics of interest from a testing point of view
   - They are stated in plain language (no actual value)
   - Characteristics are "*major properties*" of the parameter (or environment variable)
   - "Major property" means that the characteristic is relevant from the point of view of the function's behavior
   - They represent orthogonal perspectives (≠ perspectives per category)

Step-by-Step Procedure (cont.)

4. For each characteristic, identify blocks
   - A characteristics implicitly specifies a domain of values
     (not necessarily values of a parameter of the function)
   - Blocks are a partition of the characteristic's domain into sets of values
   - Blocks are often equivalence classes / boundaries
   - Advice: try to state them in plain language (instead of individual values)
5. For each block, identify representative values
   - Values are not used until the very, very end of the process (see test frames and test cases)

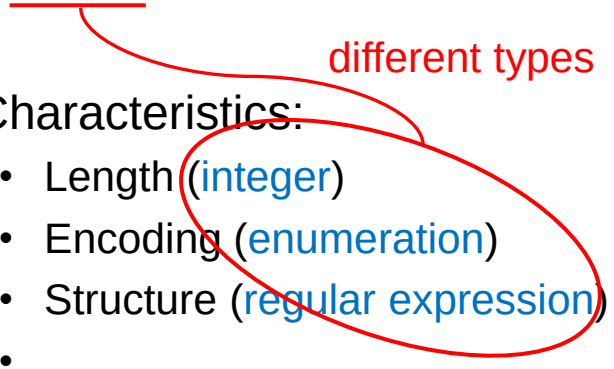
```
Tested function
        └──Function's parameters and environment variables
                └──Parameter/variable characteristics
                        └──Characteristic's blocks
                                └──Values of block
```

This is the input model, the test model.

On Characteristics …

- Characteristics can specify various types of values
- These types are different from input parameter or environment variable type

- Example:
  - A string input to the program under test
  - Characteristics:
    - Length (integer)
    - Encoding (enumeration)
    - Structure (regular expression)
    - …



Orthogonal perspectives on type String

Template, Type-Specific Equivalence Classes (and Boundaries)

- Range
  - One class with values inside the range
  - Two classes with values outside the range
  - Possibility to add classes for the boundaries and values immediately around boundaries
- String
  - At least one class with legal strings (depending on what is considered “legal”)
  - At least one class with illegal strings
  - It is sometimes possible to identify what a boundary is (e.g., all digits)
  - Possibility to also consider the contents of a legal string and further identify classes (can different contents impact behaviour?)

Template, Type-Specific Equivalence Classes (and Boundaries)

- Array
  - One class containing all legal arrays
  - One class for the empty array
  - One class for arrays larger than expected
  - Possibility to add classes for the boundary of the array size and values immediately around such boundary
  - Possibility to add classes depending on the structural contents of the array (if specified, if leads to alternative behaviours)
- Enumeration
  - Each value is a separate class
  - May be able to group enumeration elements (depending on triggered behaviours)

Quality of the Input Model?

It is paramount to check the Input Model !

- Any missing information about how the function behaves ?
  - Can be very subjective
- Are the blocks of a characteristic disjoint ?
  - Selecting one block excludes the others
  - An input value for a parameter that fits the specification of a characteristics can only belong to one block of that characteristic
- Are the blocks of a characteristic complete ?
  - The blocks cover the entire input space (implicitly defined by the characteristic)
    - The blocks of a characteristic, together, represent all the possible values the parameter can have along the perspective (characteristics)
- Tool support for this verification (i.e., disjointness, completeness) is possible.

Example

Example: Input Characteristics for a Payment Processing System

- In a payment processing system, a user inputs details like a **credit card number**, **expiration date**, and **CVV**. The system validates the input before processing the payment.

The input characteristics for each of these parameters could be defined as follows:

Example

- **Credit Card Number:**
  - **Valid Length**: The card number must be exactly 16 digits.
  - **Format**: It should consist of only numeric digits.
- **Expiration Date:**
  - **Valid Format**: The expiration date should be in the format
  - **Boundary Test for Expiration**
- **CVV (Card Verification Value):**
  - **Valid Length**: CVV must be exactly 3 digits (for most cards) or 4 digits (for certain cards like American Express).
  - **Format**: Numeric values only.

Example: Define Blocks

- **1. Credit Card Number:**
- **Valid Length**: The card number must be exactly 16 digits.
    - Valid: 16 digits.
    - Invalid: Less than 16 digits.
    - Invalid: More than 16 digits.
- **Format**: It should consist of only numeric digits.
    - Valid: Numeric digits only.
    - Invalid: Contains alphabets or special characters.

Example: Define Blocks

- **Expiration Date:**
- **Valid Format**: The expiration date should be in the format MM/YY.
    - Valid: Two digits for the month and two digits for the year (e.g., 05/25).
    - Invalid: Wrong format (e.g., 5/2025, 05-2025, 2025/05).
- **Boundary Test for Expiration**:
    - Valid: A future date.
    - Invalid: A past date (already expired).

Example: Define Blocks

- **CVV (Card Verification Value):**
  - **Valid Length**: CVV must be exactly 3 digits (for most cards)
    - Valid: 3 digits
    - Invalid: Less than or more than the required number of digits.
- **Format**: Numeric values only.
    - Valid: Numeric values only.
    - Invalid: Contains letters or special characters.

Criteria → Test Frames (combination of blocks)

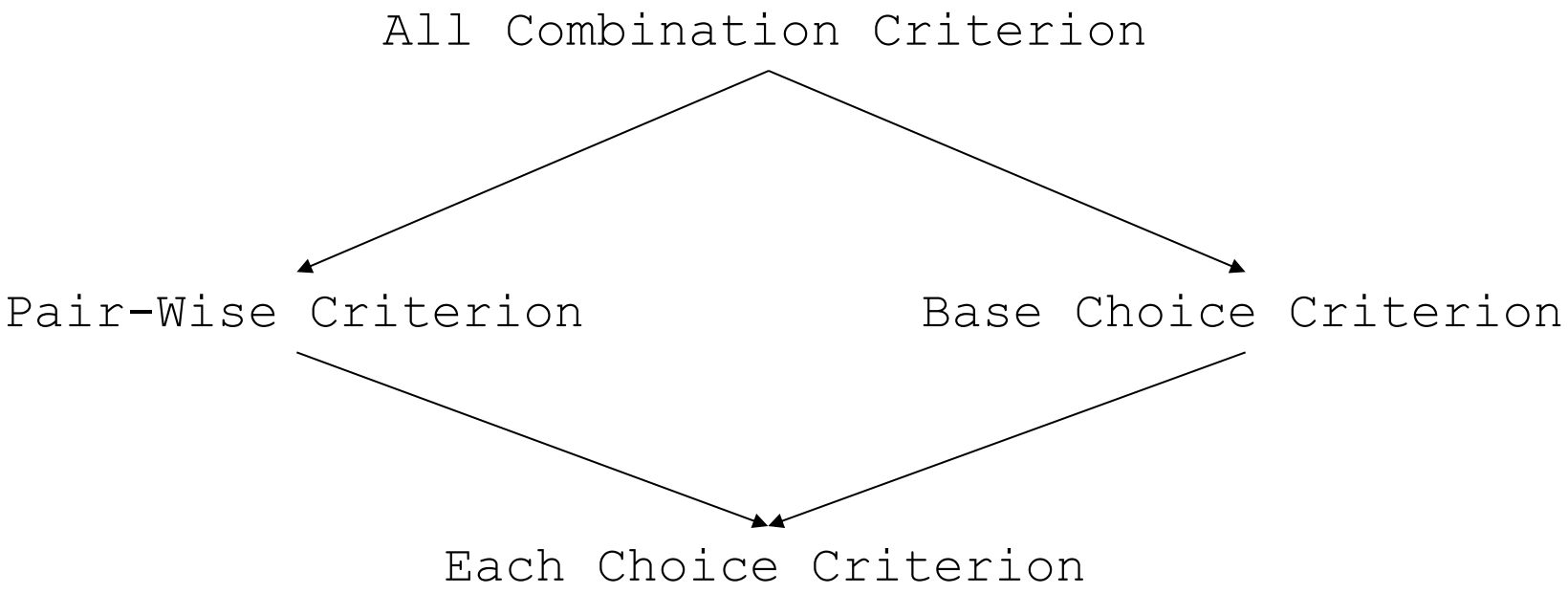
- All Combinations Criterion
  - All combinations of blocks from all characteristics must be used at least once.
- Each Choice/Block Criterion
  - Each block of each characteristic must be used at least once.
- Pair-Wise Criterion
  - Each block of each characteristic must be combined with a block for each other characteristic.

    (Identify pairs of blocks first, and then identify a minimum set of combinations of blocks to "exercise" the pairs.)
- Base Choice Criterion
  - A base choice block is chosen for each characteristic, and a base test frame is formed by using the base choice for each characteristic.
  - Subsequent test frames are chosen by holding all but one base choice constant and using each non-base choice in each other characteristic.

Criteria → Test Frames →Test Cases

- A test frame is a combination of blocks from characteristics
  - Cannot combine two blocks from the same characteristic
  - Refer to conditions equivalence classes (blocks) must satisfy.
- A set of test frames satisfy a criterion (notion of adequacy)
- A test frame is not a test case
- A test frame is a test case specification
  - It tells what a test case should look like
  - It provides conditions that test inputs (the test case) should satisfy
- From a test frame to a test case
  - Need to select input values such that the conditions imposed by the test frame, i.e., its combination of blocks, are satisfied
  - Create one test case for each test frame

Criteria Comparison (subsumption)



Constraints Among Partitions

- Some combinations of blocks may be infeasible
- Constraints
  - Relations between blocks of different characteristics
    - Recall blocks for a given characteristic are disjoint (cannot be combined)
    - So we only define constraints between blocks of different characteristics
  - Can constrain different blocks of different characteristics
- *Properties, Selectors* associated with blocks
  - Specifying (with a name) a property.
    - Notation: [PropertyName]
  - Selection of (in)compatible property(ies).
    - Notation: [if PropertyName], [if propNameA and propNameB], [if not propName] …
- Special cases: [Error], and [Single]

Constraints

- [Error]
  - It is assumed that if the parameter or environment variable has this particular value (values from the block), any call of the function using that block will result in the same error.
  - A block marked with [Error] is not combined with blocks in the other categories to create *test frames*.
    - Meaning that blocks from other categories do not matter
  - During the test, the tester can set the test's other parameters and environment conditions at will, e.g., base blocks.
- [Single]
  - This notation is intended to describe special, unusual, or redundant conditions that do not have to be combined with all possible blocks.
  - A block marked with [Single] is not combined with blocks in the other categories to create *test frames*.
  - A judgment by the tester that the marked block can be adequately tested with only one test case.

Conclusions

- Identifying parameters and environments conditions, characteristics, and blocks, heavily relies on the experience/expertise of the tester
- Makes testing decisions explicit (e.g., constraints), open for review
- Once the first step is completed, i.e., identifying characteristics, blocks and constraints, the technique is straightforward and can be automated
  - Using a criterion to generate test frames and then test cases (i.e., identifying test inputs)
- The technique for test case reduction (thanks to constraints) makes it useful for practical testing

Functionality-Based Input Domain Modeling vs. Category Partition

Mapping of terminology…

Between the terminology of the textbook (left) and the terminology of the original publication defining the technique.

Functionality-Based Input Domain Modeling	Category Partition
• Tested function	➢ Tested function
	➢ Parameters + Environment variables
• Characteristics	➢ Categories
• Blocks	➢ Choices
• Values	➢ Values