Functional testing

Learning objectives

- Be able to explain the rationale for systematic (non-random) selection of test cases
  - Be able to explain the principles of partition testing and its underlying assumptions
- Be able to explain why functional test selection is a primary, base-line technique
  - Why we expect a specification-based partition to help select valuable test cases
- Distinguish functional testing from other systematic testing techniques

Functional testing

- Functional testing: Deriving test cases from program specifications
    - *Functional* refers to the source of information used in test case design, not to what is tested
- *Also known as*:
    - specification-based testing (from specifications)
    - black-box testing (no view of the code)
- Functional specification = description of intended program behavior
    - either formal or informal

Systematic vs Random Testing

- Random (uniform):
  - Pick possible inputs uniformly
  - Avoids designer bias
    - A real problem: The test designer can make the same logical mistakes and bad assumptions as the program designer (especially if they are the same person)
  - But treats all inputs as equally valuable
- Systematic (non-uniform):
  - Try to select inputs that are especially valuable
  - Usually by choosing representatives of classes that are apt to fail *often* or *not at all*
- Functional testing is systematic testing

Why Not Random?

- Non-uniform distribution of faults
- *Example:* Java class "roots" applies quadratic equation:

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

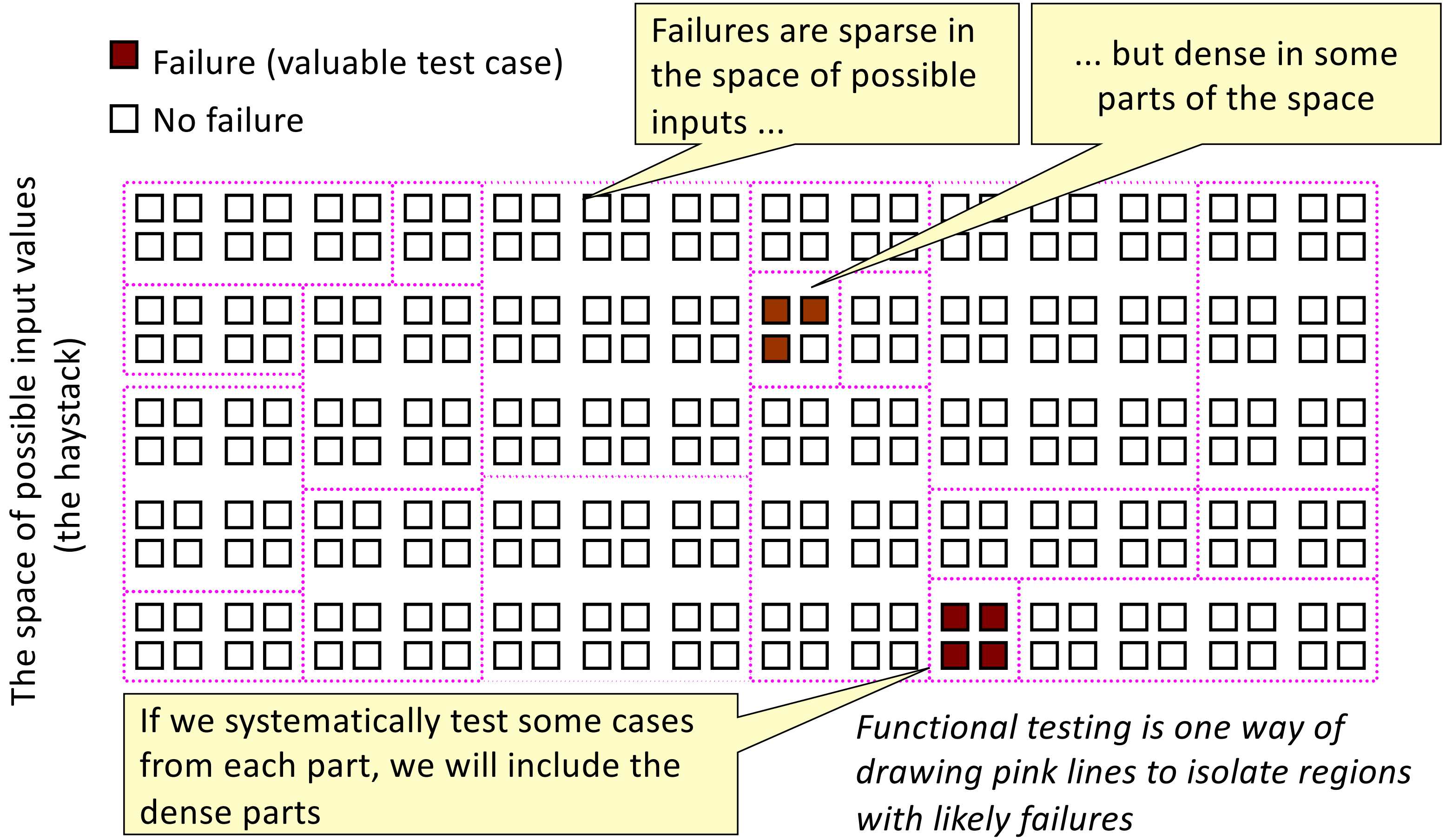
Incomplete implementation logic: Program does not properly handle the case in which $b^2 - 4ac = 0$ and $a=0$

Failing values are *sparse* in the input space — needles in a very big haystack. Random sampling is unlikely to choose a=0.0 and b=0.0

Consider the purpose of testing ...

- To estimate the proportion of needles to hay, sample randomly
  - Reliability estimation requires unbiased samples for valid statistics. *But that's not our goal!*
- To find needles and remove them from hay, look systematically (non-uniformly) for needles
  - Unless there are a *lot* of needles in the haystack, a random sample will not be effective at finding them
  - We need to use everything we know about needles, e.g., are they heavier than hay? Do they sift to the bottom?

Systematic Partition Testing



Functional testing is one way of drawing pink lines to isolate regions with likely failures

The partition principle

- Exploit some knowledge to choose samples that are more likely to include "special" or trouble-prone regions of the input space
  - Failures are sparse in the whole input space ...
  - ... but we may find regions in which they are dense
- (Quasi*-)Partition testing: separates the input space into classes whose union is the entire space
  - *Quasi because: The classes may overlap
- Desirable case: Each fault leads to failures that are dense (easy to find) in some class of inputs
  - sampling each class in the quasi-partition selects at least one input that leads to a failure, revealing the fault
  - seldom guaranteed; we depend on experience-based heuristics

Example of partitioning from ISO 29119-2

A.2 Fragment of test basis

"The insurance quote system shall generate an accept message, a reject message or an accept with excess warning message.

It will accept insurance applicants from the age of 18 and up to the age of 80 years on the day of application based on their input age in whole years; all other inputs shall be rejected.

Accepted applicants of 70 and over shall be accepted but with a warning that in the event of a claim they shall pay an excess."

A.3 Test completion criterion

"The test completion criterion is that 100 % equivalence partition coverage is achieved, and all test cases must result in a "pass" status on execution."

Partitioning from ISO 20119-2

A.4 Test model (TD1)

Based on the test completion criterion, the test model in Figure A.1 showing the equivalence partitions (with the black outlines) for the described system behaviour can be created.

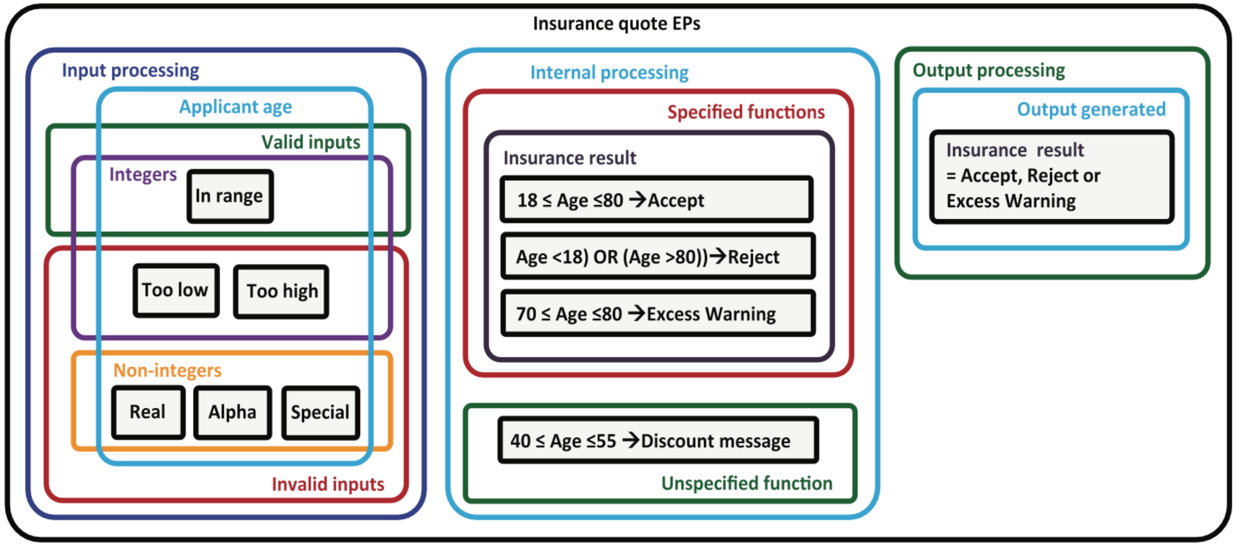


Figure A.1 — Equivalence partitions for the 'insurance quote system'

Functional testing: exploiting the specification

- Functional testing uses the specification (formal or informal) to partition the input space
  - E.g., specification of “roots” program suggests division between cases with zero, one, and two real roots
- Test each category, and boundaries between categories
  - No guarantees, but experience suggests failures often lie at the boundaries (as in the “roots” program)

Why functional testing?

- The base-line technique for designing test cases
  - Timely
    - Often useful in refining specifications and assessing testability *before* code is written
  - Effective
    - finds some classes of fault (e.g., missing logic) that can elude other approaches
  - Widely applicable
    - to any description of program behavior serving as spec
    - at any level of granularity from module to system testing.
  - Economical
    - typically less expensive to design and execute than structural (code-based) test cases

Early functional test design

- Program code is not necessary
  - Only a description of intended behavior is needed
  - Even incomplete and informal specifications can be used
    - Although precise, complete specifications lead to better test suites
- Early functional test design has side benefits
  - Often reveals ambiguities and inconsistency in spec
  - Useful for assessing testability
    - And improving test schedule and budget by improving spec
  - Useful explanation of specification
    - or in the extreme case (as in XP), test cases are the spec

Functional versus Structural: Classes of faults

- Different testing strategies (functional, structural, fault-based, model-based) are most effective for different classes of faults
- Functional testing is best for *missing logic* faults
  - A common problem: Some program logic was simply forgotten
  - Structural (code-based) testing will never focus on code that isn't there!

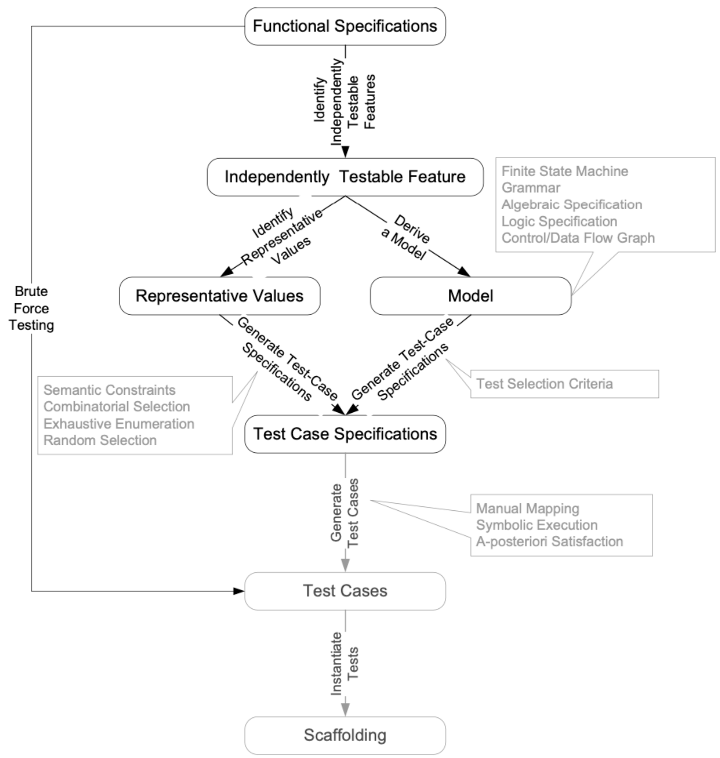
Functional vs structural test: granularity levels

- Functional test applies at all granularity levels:
  - Unit (from module interface spec)
  - Integration (from API or subsystem spec)
  - System (from system requirements spec)
  - Regression (from system requirements + bug history)
- Structural (code-based) test design applies to relatively small parts of a system:
  - Unit
  - Integration

Steps: From specification to test cases

- 1. Decompose the specification
    - If the specification is large, break it into *independently testable features* to be considered in testing
- 2. Select representatives
    - Representative values of each input, or
    - Representative behaviors of a *model*
        - Often simple input/output transformations don't describe a system. We use models in program specification, in program design, and in test design
- 3. Form test specifications
    - Typically: combinations of input values, or model behaviors
- 4. Produce and execute actual tests

From specification to test cases



Simple example: Postal code lookup

5-digit US

ities

- What are some representative values (or classes of value) to test?

Example: Representative values

Simple example with
one input, one output

- Correct zip code
  - With 0, 1, or many cities
- Malformed zip code
  - Empty; 1-4 characters; 6 characters; very long
  - Non-digit characters
  - Non-character data

Note prevalence of boundary values (0 cities, 6 characters) and error cases

Summary

- Functional testing, i.e., generation of test cases from specifications is a valuable and flexible approach to software testing
  - Applicable from very early system specs right through module specifications
- (quasi-)Partition testing suggests dividing the input space into (quasi-)equivalent classes
  - Systematic testing is intentionally non-uniform to address special cases, error conditions, and other small places
  - Dividing a big haystack into small, hopefully uniform piles where the needles might be concentrated