CSE 403: Software Engineering, Fall 2016

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Unit Testing

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Outline

- Software quality control
- Effective unit testing
- Coverage and regression testing

intro

basics of software quality control

Errors and faults

Ariane 5: 37 sec after launch. Cost: $1 billion.

Errors and faults

- **Error**: incorrect software behavior
    - Example: Software controller for the Ariane 5 rocket crashed (and so did the rocket).

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Errors and faults

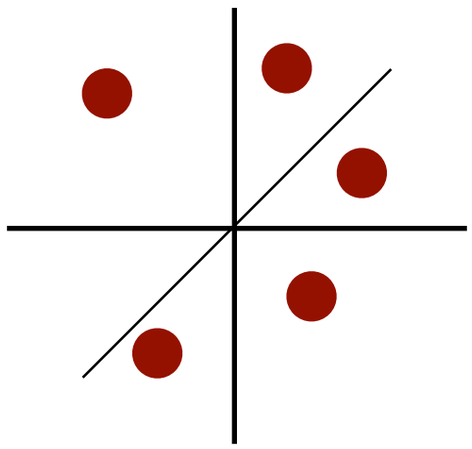
- **Error**: incorrect software behavior
    - Example: Software controller for the Ariane 5 rocket crashed (and so did the rocket).
- **Fault**: mechanical or algorithmic cause of error (bug)
    - Example: Conversion from 64-bit floating point to 16-bit signed integer value caused an exception.
    - Requirements specify desired behavior; if the system deviates from that, it has a fault.

Ariane 5: 37 sec after launch. Cost: $1 billion.

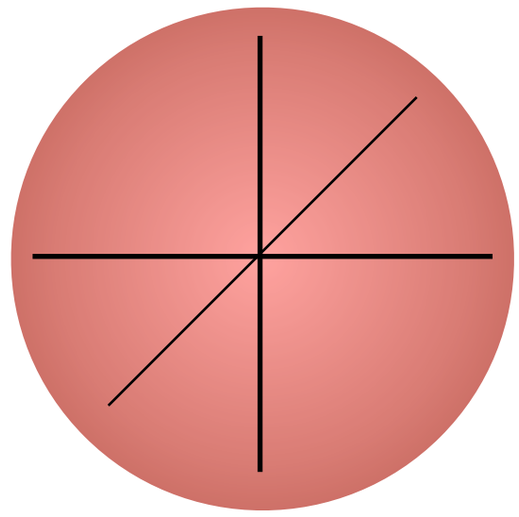
Software quality control techniques

- **Fault avoidance**: prevents errors before the system is released.
    - reviews, inspections, walkthroughs, development methodologies, **testing**, **verification**
- **Fault tolerance**: enables the system to recover from (some classes of) errors by itself.
    - rollbacks, redundancy, mirroring

Showing the presence and absence of bugs ...



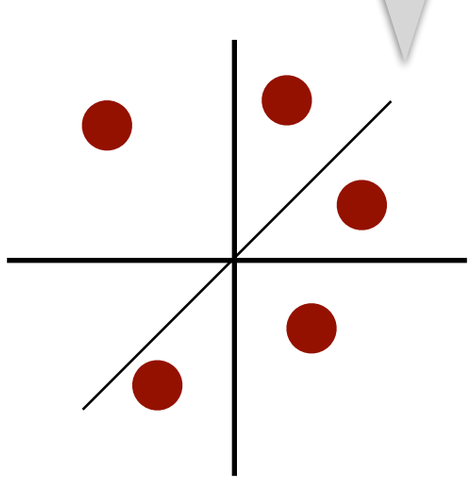
testing



verification

Showing the presence and absence of bugs ...

Detects the presence of bugs by running the code on a few carefully chosen inputs.



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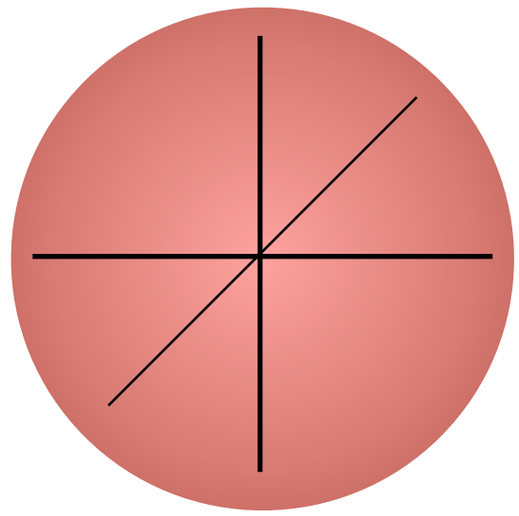

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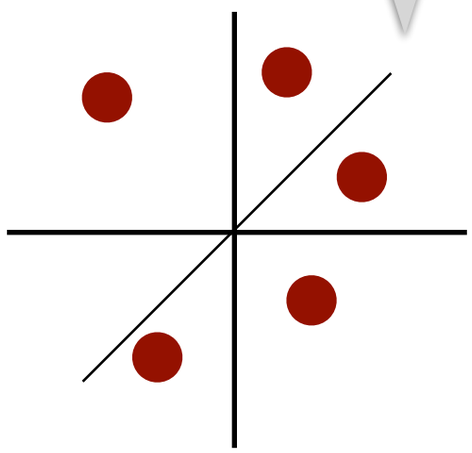
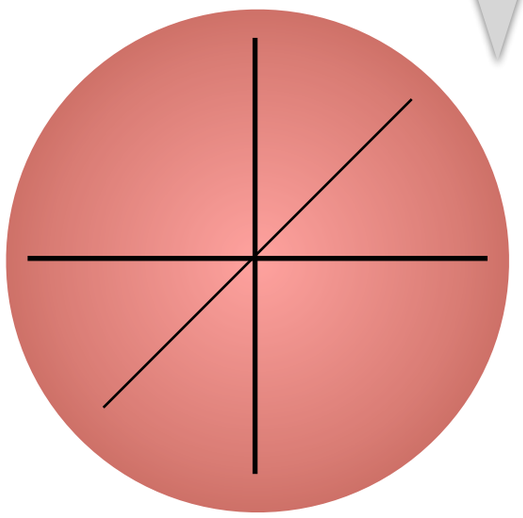


testing

Shows the absence of bugs on **all** possible inputs.



verification

Common kinds of testing

- **Unit testing**: tests the behavior of an individual module (method, class, interface)
    - Black-box testing
    - White-box testing
- **System testing**: tests the behavior of the system as a whole, with respect to scenarios and requirements
    - Functional testing, integration testing
    - Performance, load, stress testing
    - Acceptance, usability, installation, beta testing

effective unit testing

Two rules of unit testing

- Do it **early** and do it **often**
    - Catch bugs quickly, before they have a chance to hide
    - **Automate** the process if you can
- Be **systematic**
    - If you thrash about arbitrarily, the bugs will hide in the corner until you're gone

Four basic steps of a test

1. **Choose input** data
    - *without* looking at the implementation: black box
    - *with* knowledge of the implementation: white box
2. Define the **expected outcome**
3. Run on the input to get the **actual outcome**
4. **Compare** the actual and expected outcomes

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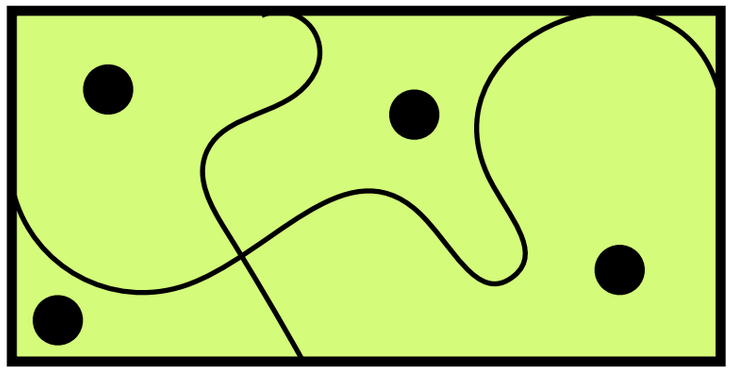
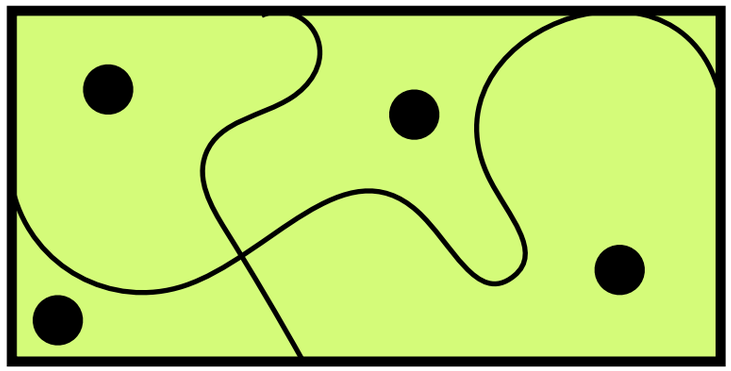
This is hard! Need a set of test cases that is small enough to run quickly, yet large enough to cover [all] interesting program behaviors.

Choosing inputs: two key ideas



Choosing inputs: two key ideas

- **Partition the input space**
    - Identify **subdomains** with the same behavior
    - Pick one input from each subdomain



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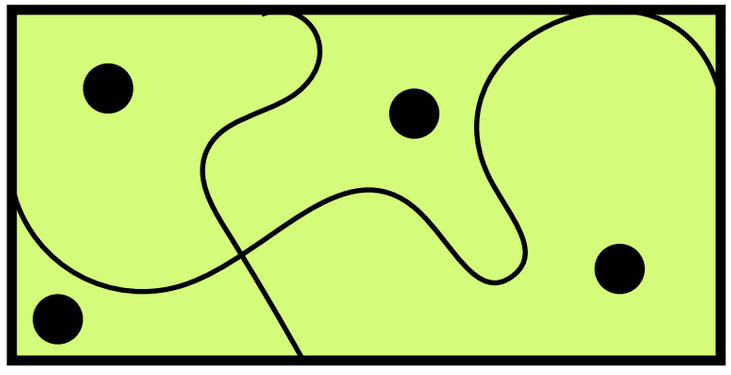
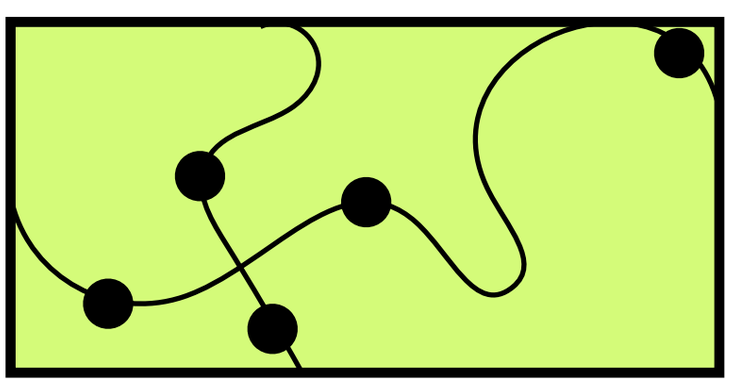


- **Boundary values**
  - Pick inputs at the **edges** of the subdomains.
  - Effective at finding corner case bugs:
    - off-by-one, overflow, aliasing, empty container



Partitioning the input space

```
// returns the maximum of a, b
public static int max(int a, int b) { … }
```

- Partition into
    - a < b, a = b, a > b
- Pick an input from each class
    - (1, 2), (0, 0), (2, 1)

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How would you partition the input space for

- BigInteger multiplication?
- Set intersection?

Choosing boundary values

```
// returns|x|
public static int abs(int a) { … }
```

- Partition into
  - a < 0, a > 0, **a = 0** (boundary)
- Other boundary values
  - Integer.MAX_VALUE
  - Integer.MIN_VALUE

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What are good boundary values for objects?

Black box testing

- Explores alternate paths through the **specification**.
    - Module under test is a black box: interface visible, internals hidden.

```
// If a >= b, returns a.  Otherwise returns b.
public static int max(int a, int b) { … }
```

- 3 paths, so 3 subdomains
    - (1, 2) => 2
    - (2, 1) => 2
    - (0, 0) => 0

Advantages of black box testing

- Process is not influenced by component being tested
    - Assumptions embodied in code not propagated to test data.
- Robust with respect to changes in implementation
    - Test data need not be changed when code is changed
- Allows for independent testers
    - Testers need not be familiar with code

Disadvantage of black box testing

- It will miss bugs in the implementation that are not covered by the specification
  - Control-flow details
  - Performance optimizations
  - Alternate algorithms for different cases

White box testing

- Explores alternate paths through the **implementation**
    - Module under test is a clear box: internals visible.

```
boolean[] primeTable = new boolean[CACHE_SIZE];

boolean isPrime(int x) {
  if (x>CACHE_SIZE) {
      for (int i=2; i<x/2; i++) {
        if (x%i==0) return false;
       }
      return true;
  } else {
      return primeTable[x];
  }
}
```

- Important transition at around x = CACHE_SIZE

(Dis)advantages of white box testing

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- Advantages
  - Finds an important class of boundaries.
  - Yields useful test cases.
  - In isPrime example, need to check numbers on each side of CACHE_SIZE
    - CACHE_SIZE-1, CACHE_SIZE, CACHE_SIZE+1

(Dis)advantages of white box testing

- Advantages
    - Finds an important class of boundaries.
    - Yields useful test cases.
    - In isPrime example, need to check numbers on each side of CACHE_SIZE
        - CACHE_SIZE-1, CACHE_SIZE, CACHE_SIZE+1
- Disadvantages
    - Tests may have the same bugs as implementation!

Properties of good and bad unit tests

- Tests should be self-contained and not depend on each other implicitly or explicitly.
- "Smells" (bad things to avoid) in tests:
    - Constrained test order
        - Test A must run before Test B.
    - Tests call each other
        - Test A calls Test B.
    - Mutable shared state
        - Tests A/B both use a shared object.

coverage and regression testing

Measuring test suite quality with coverage

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- Various kinds of coverage
    - **Statement**: is every statement run by some test case?
    - **Branch**: is every direction of an if or while statement (true or false) taken by some test case?
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  - Coverage is just a heuristic.
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  - High-cost to approach the limit.

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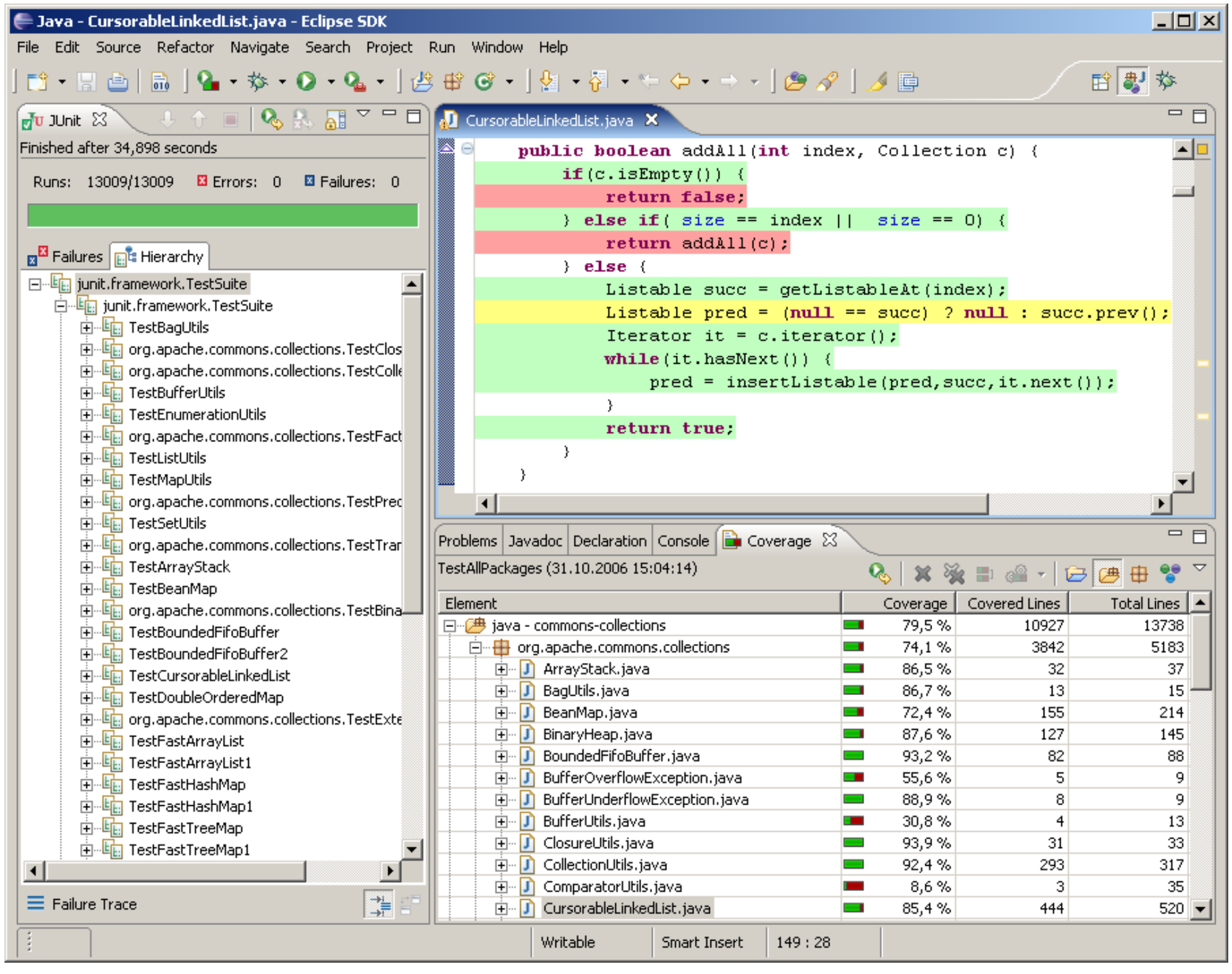
We will ask you to provide test-suite coverage metrics for your Feature-Complete Release.

Coverage measuring tools: EclEmma



Regression testing

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- Whenever you find a bug
    - Store the input that elicited that bug, plus the correct output
    - Add these to the test suite
    - Check that the test suite fails
    - Fix the bug and verify the fix

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- Whenever you find a bug
    - Store the input that elicited that bug, plus the correct output
    - Add these to the test suite
    - Check that the test suite fails
    - Fix the bug and verify the fix
- Why is this a good idea?
    - Ensures that your fix solves the problem.
    - Helps to populate test suite with good tests.
    - Protects against reversions that reintroduce bug:
        - It happened at least once, and it might happen again

Summary

- Unit testing helps
    - convince others that a module works;
    - catch problems earlier.
- Choose test data to cover
    - specification (black box testing)
    - code (white box testing)
- Testing can't generally prove the absence of bugs, but it can increase quality and confidence in the implementation.