Software Engineering I: Software Technology

WS 2008/09

Unit Testing

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Outline

This lecture

- Terminology
- Testing Activities
- Unit testing

Next lecture

- Integration testing
  - Testing strategies
- System testing
  - Function testing
  - Structure testing
  - Acceptance testing.

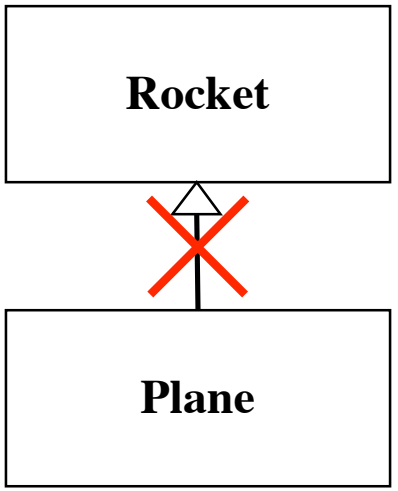
Terminology

- Failure: Any deviation of the observed behavior from the specified behavior
- Erroneous state (error): The system is in a state such that further processing by the system can lead to a failure
- Fault: The mechanical or algorithmic cause of an error ("bug")
- Validation: Activity of checking for deviations between the observed behavior of a system and its specification.

F-16 Bug



- What´s the failure?
- What´s the error?
- What´s the fault?
  - Bad use of implementation inheritance
  - A Plane is **not** a rocket.



Examples of Faults and Errors

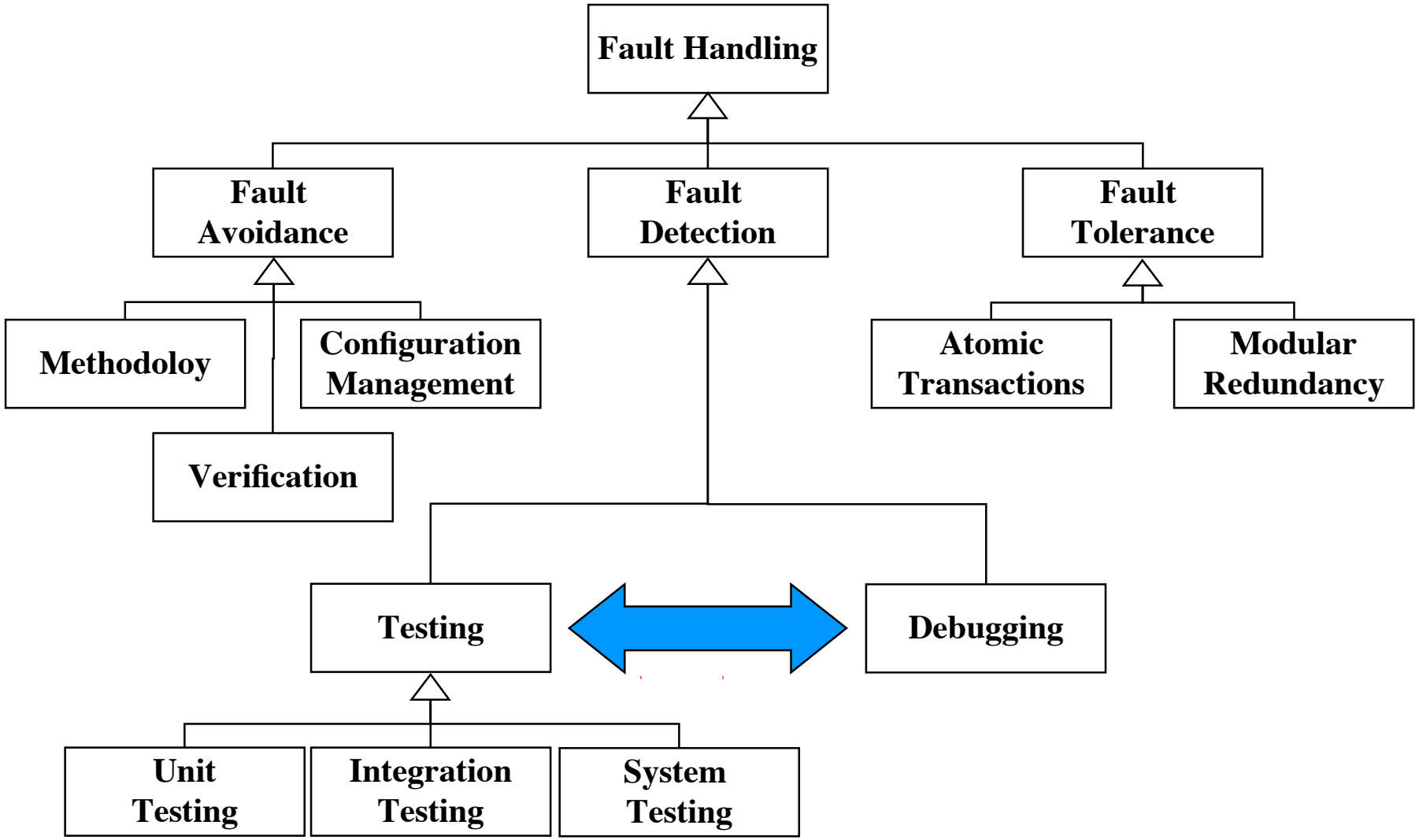
- Faults in the Interface specification
  - Mismatch between what the client needs and what the server offers
  - Mismatch between requirements and implementation
- Algorithmic Faults
  - Missing initialization
  - Incorrect branching condition
  - Missing test for null

- Mechanical Faults (very hard to find)
  - Operating temperature outside of equipment specification
- Errors
  - Null reference errors
  - Concurrency errors
  - Exceptions.

Another View on How to Deal with Faults

- Fault avoidance
  - Use methodology to reduce complexity
  - Use configuration management to prevent inconsistency
  - Apply verification to prevent algorithmic faults
  - Use Reviews
- Fault detection
  - Testing: Activity to provoke failures in a planned way
  - Debugging: Find and remove the cause (Faults) of an observed failure
  - Monitoring: Deliver information about state => Used during debugging
- Fault tolerance
  - Exception handling
  - Modular redundancy.

Taxonomy for Fault Handling Techniques



Observations

- It is impossible to completely test any nontrivial module or system
  - Practical limitations: Complete testing is prohibitive in time and cost
  - Theoretical limitations: e.g. Halting problem
- "Testing can only show the presence of bugs, not their absence" (Dijkstra).
- Testing is not for free

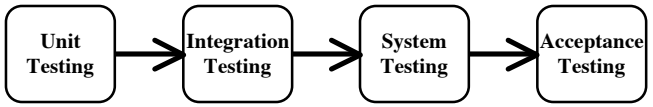
=> Define your goals and priorities

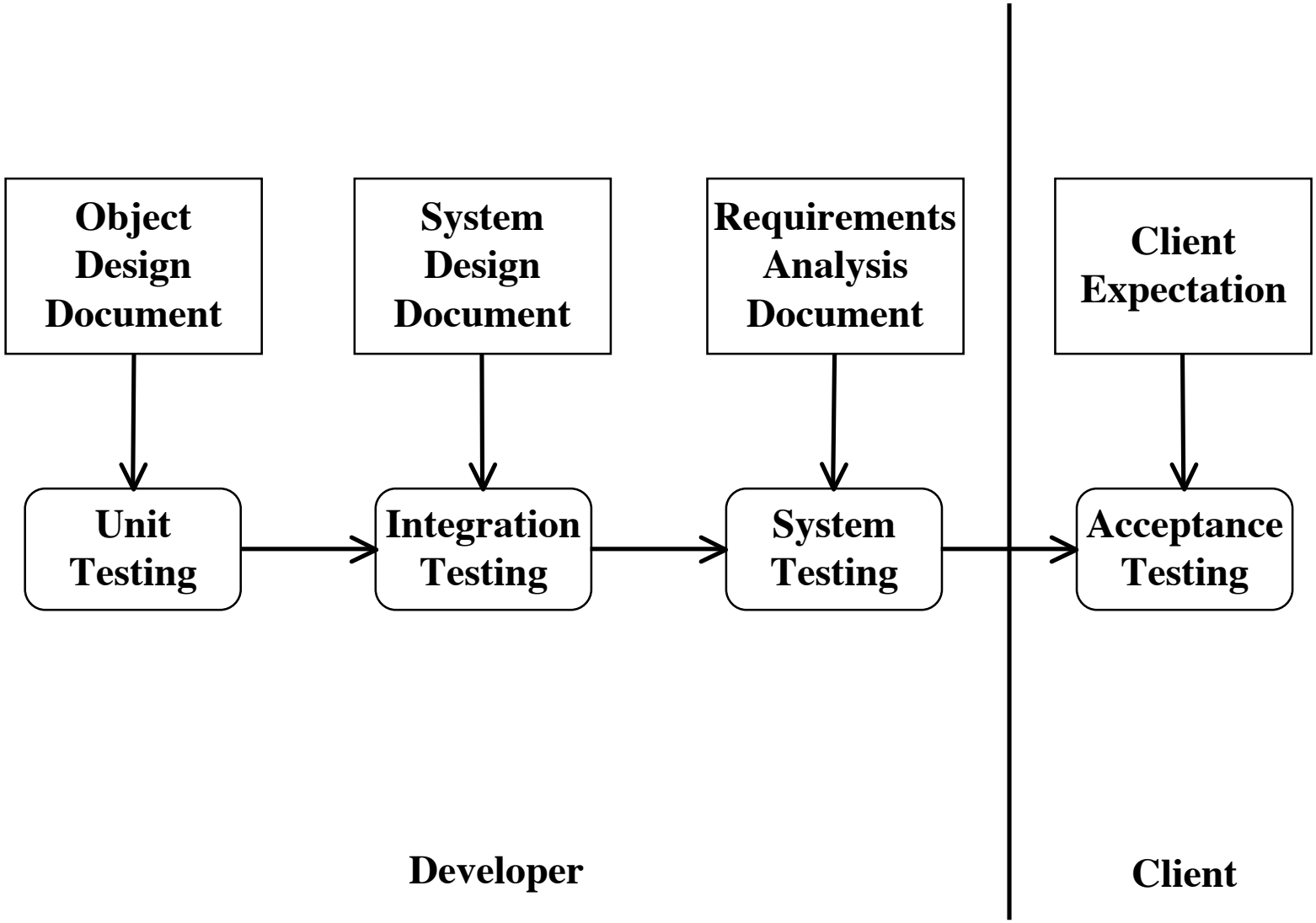
Testing takes creativity

- To develop an effective test, one must have:
  - Detailed understanding of the system
  - Application and solution domain knowledge
  - Knowledge of the testing techniques
  - Skill to apply these techniques
- Testing is done best by independent testers
  - We often develop a certain mental attitude that the program should in a certain way when in fact it does not
  - Programmers often stick to the data set that makes the program work
  - A program often does not work when tried by somebody else.

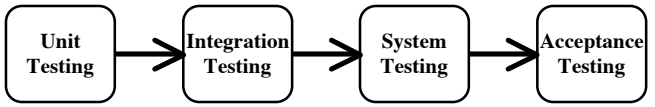
behave

Testing Activities



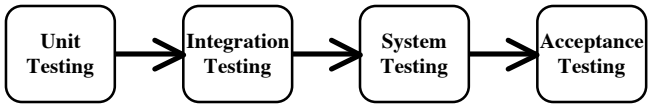


Types of Testing



- Unit Testing
  - Individual component (class or subsystem)
  - Carried out by developers
  - Goal: Confirm that the component or subsystem is correctly coded and carries out the intended functionality
- Integration Testing
  - Groups of subsystems (collection of subsystems) and eventually the entire system
  - Carried out by developers
  - Goal: Test the interfaces among the subsystems.

Types of Testing continued...



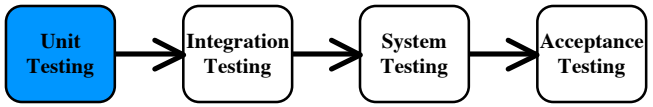
- System Testing
  - The entire system
  - Carried out by developers
  - Goal: Determine if the system meets the requirements (functional and nonfunctional)
- Acceptance Testing
  - Evaluates the system delivered by developers
  - Carried out by the client. May involve executing typical transactions on site on a trial basis
  - Goal: Demonstrate that the system meets the requirements and is ready to use.

When should you write a test?

- Traditionally after the source code to be tested

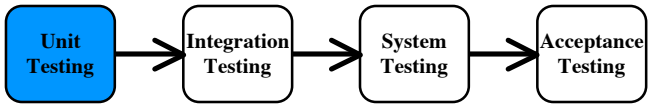
- In XP before the source code to be tested
  - Test-Driven Development Cycle
    - Add a test
    - Run the automated tests
      => see the new one fail
    - Write some code
    - Run the automated tests
      => see them succeed
    - Refactor code.

Unit Testing

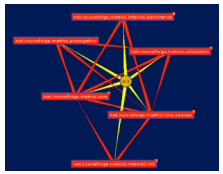


- Static Testing (at compile time)
  - Static Analysis
  - Review
    - Walk-through (informal)
    - Code inspection (formal)
- Dynamic Testing (at run time)
  - Black-box testing
  - White-box testing.

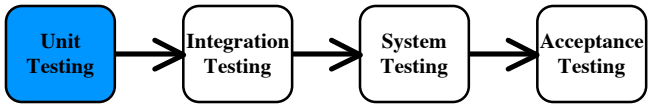
Static Analysis with Eclipse



- Compiler Warnings and Errors
  - *Possibly uninitialized Variable*
  - *Undocumented empty block*
  - *Assignment has no effect*
- Checkstyle
  - Check for code guideline violations
  - http://checkstyle.sourceforge.net
- FindBugs
  - Check for code anomalies
  - http://findbugs.sourceforge.net
- Metrics
  - Check for structural anomalies
  - http://metrics.sourceforge.net



Black-box testing



- Focus: I/O behavior
  - If for any given input, we can predict the output, then the component passes the test
  - Requires test oracle
- Goal: Reduce number of test cases by equivalence partitioning:
  - Divide input conditions into equivalence classes
  - Choose test cases for each equivalence class.

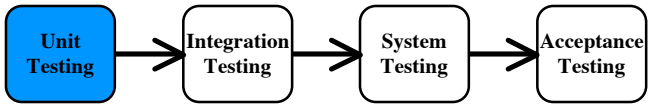
Black-box testing: Test case selection

a) Input is valid across range of values
- Developer selects test cases from 3 equivalence classes:
  - Below the range
  - Within the range
  - Above the range

b) Input is only valid, if it is a member of a discrete set
- Developer selects test cases from 2 equivalence classes:
  - Valid discrete values
  - Invalid discrete values

- No rules, only guidelines.

Status: Where are we now?



- Terminology
- Testing Activities
- Unit testing
  - Static Testing
  - Dynamic Testing
    - Blackbox Testing
      - Example...

Black box testing: An example

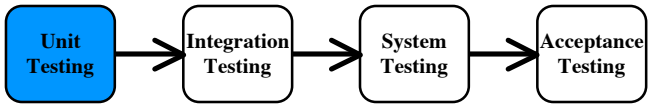
```
public class MyCalendar {

  public int getNumDaysInMonth(int month, int year)
      throws InvalidMonthException
  { … }
}
```

Representation for `month`:
1: January, 2: February, …., 12: December

Representation for `year`:
1904, … 1999, 2000,…, 2006, …

How many test cases do we need for the black box testing of `getNumDaysInMonth()`?

White-box testing overview



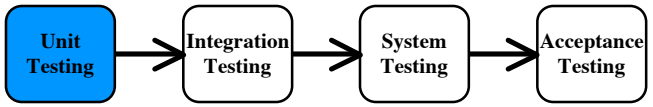
- Code coverage
- Branch coverage
- Condition coverage
- Path coverage

=> Details in the exercise session about testing

Unit Testing Heuristics

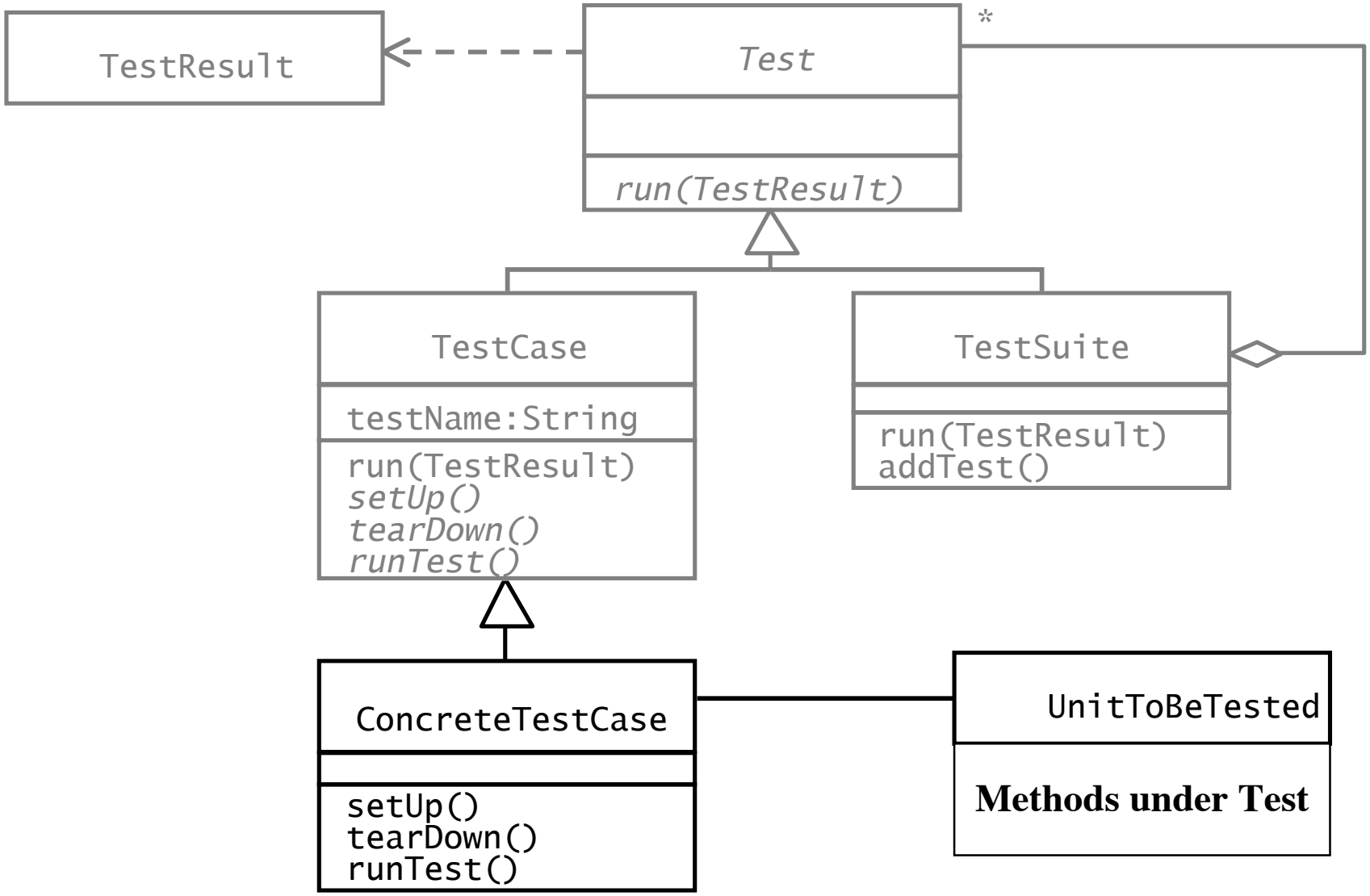
1. Create unit tests when object design is completed
   - Black-box test: Test the functional model
   - White-box test: Test the dynamic model
2. Develop the test cases
   - Goal: Find effective number of test cases
3. Cross-check the test cases to eliminate duplicates
   - Don't waste your time!
4. Desk check your source code
   - Sometimes reduces testing time
5. Create a test harness
   - Test drivers and test stubs are needed for integration testing
6. Describe the test oracle
   - Often the result of the first successfully executed test
7. Execute the test cases
   - Re-execute test whenever a change is made ("regression testing")
8. Compare the results of the test with the test oracle
   - Automate this if possible.

JUnit: Overview



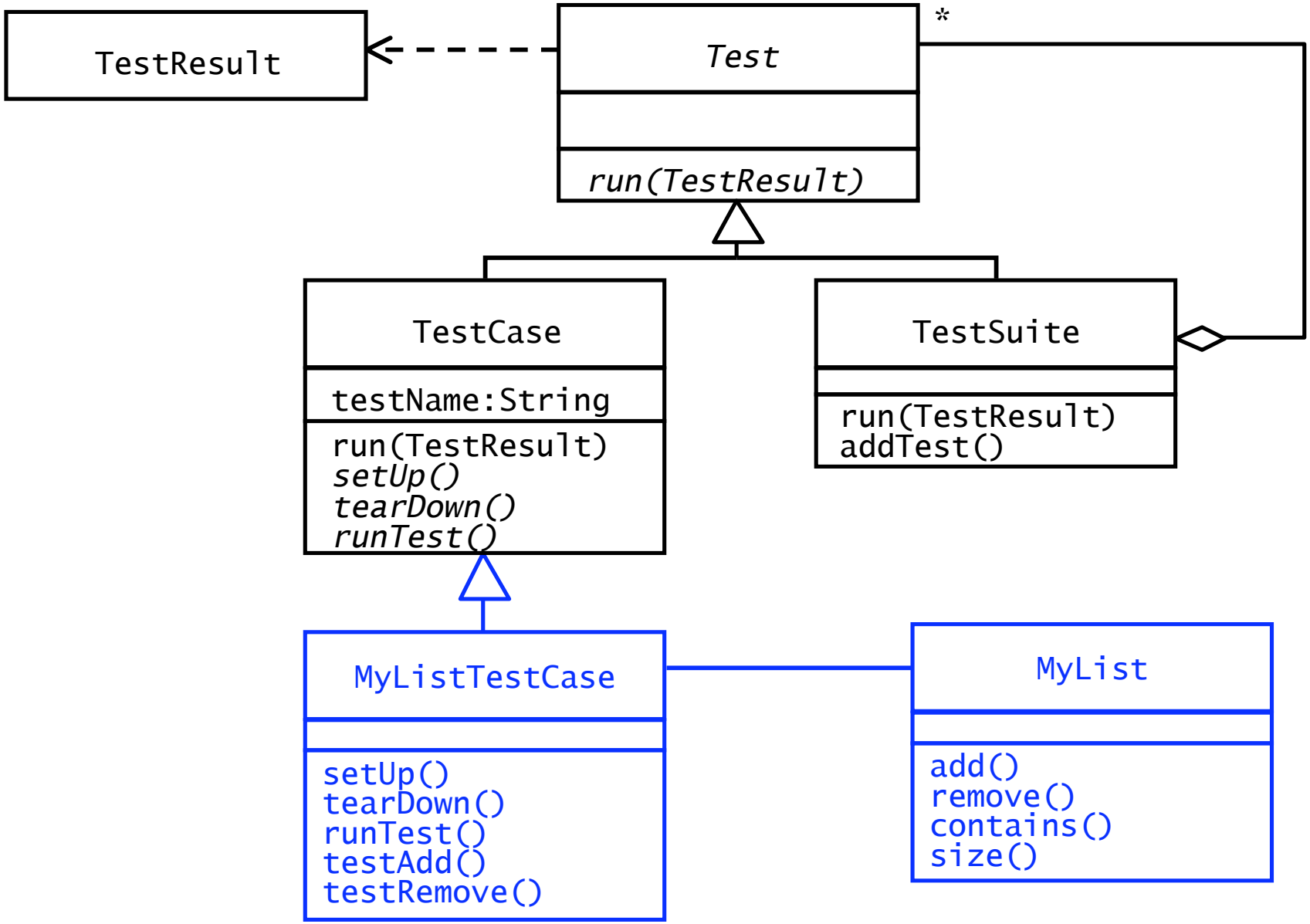
- A Java framework for writing and running unit tests
  - Test cases and fixtures
  - Test suites
  - Test runner
- Written by Kent Beck and Erich Gamma
- Written with "test first" and pattern-based development in mind
  - Tests written before code
  - Allows for regression testing
  - Facilitates refactoring
- JUnit is Open Source
  - www.junit.org
  - JUnit Version 4, released Mar 2006

JUnit Classes



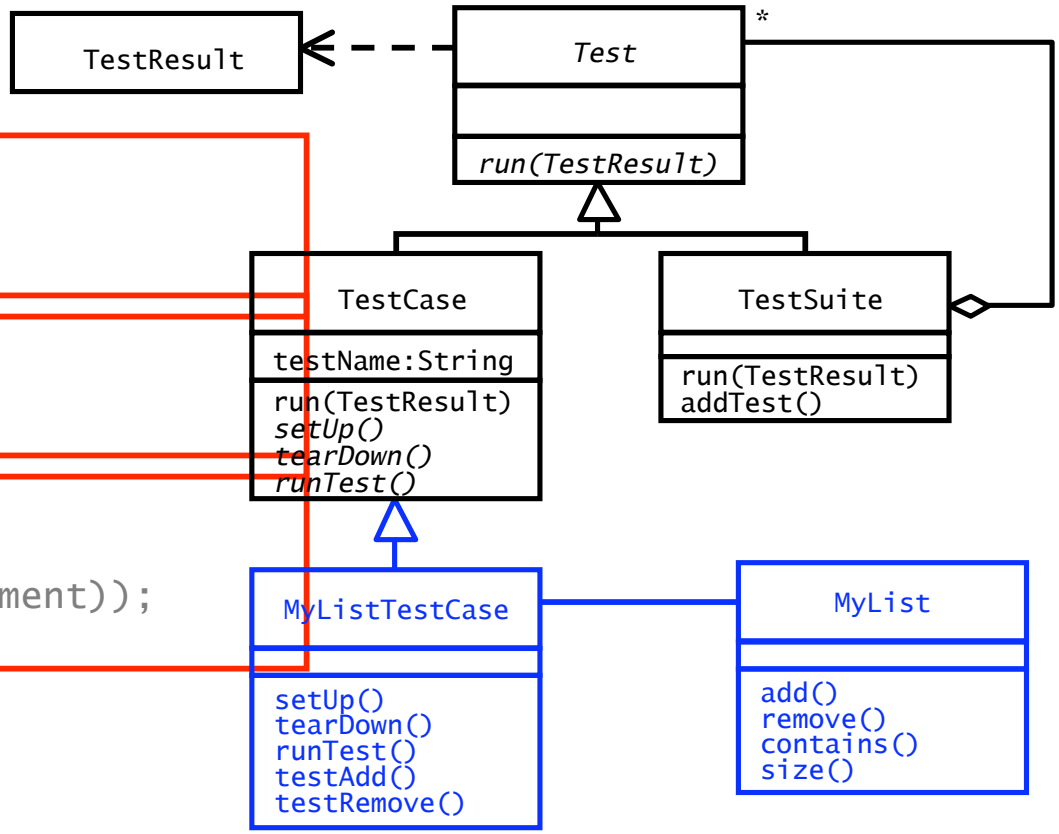
An example: Testing MyList

- Unit to be tested
  - MyList
- Methods under test
  - add()
  - remove()
  - contains()
  - size()
- Concrete Test case
  - MyListTestCase


TestResult
Test
*
run(TestResult)
TestCase
testName:String
run(TestResult)
setUp()
tearDown()
runTest()
TestSuite
run(TestResult)
addTest()
MyListTestCase
setUp()
tearDown()
runTest()
testAdd()
testRemove()
MyList
add()
remove()
contains()
size()

Writing TestCases in JUnit

```
public class MyListTestCase extends TestCase {

public MyListTestCase(String name) {
   super(name);
}
public void testAdd() {
   // Set up the test
   List aList = new MyList();
   String anElement = "a string";

   // Perform the test
   aList.add(anElement);

   // Check if test succeeded
   assertTrue(aList.size() == 1);
   assertTrue(aList.contains(anElement));
}
protected void runTest() {
   testAdd();
}
}
```



Writing Fixtures and Test Cases

```
public class MyListTestCase extends TestCase {
// …
private MyList aList;
private String anElement;
public void setUp() {
   aList = new MyList();
   anElement = “a string”;
}
```

Test Fixture

```
public void testAdd() {
   aList.add(anElement);
   assertTrue(aList.size() == 1);
   assertTrue(aList.contains(anElement));
}
```

Test Case

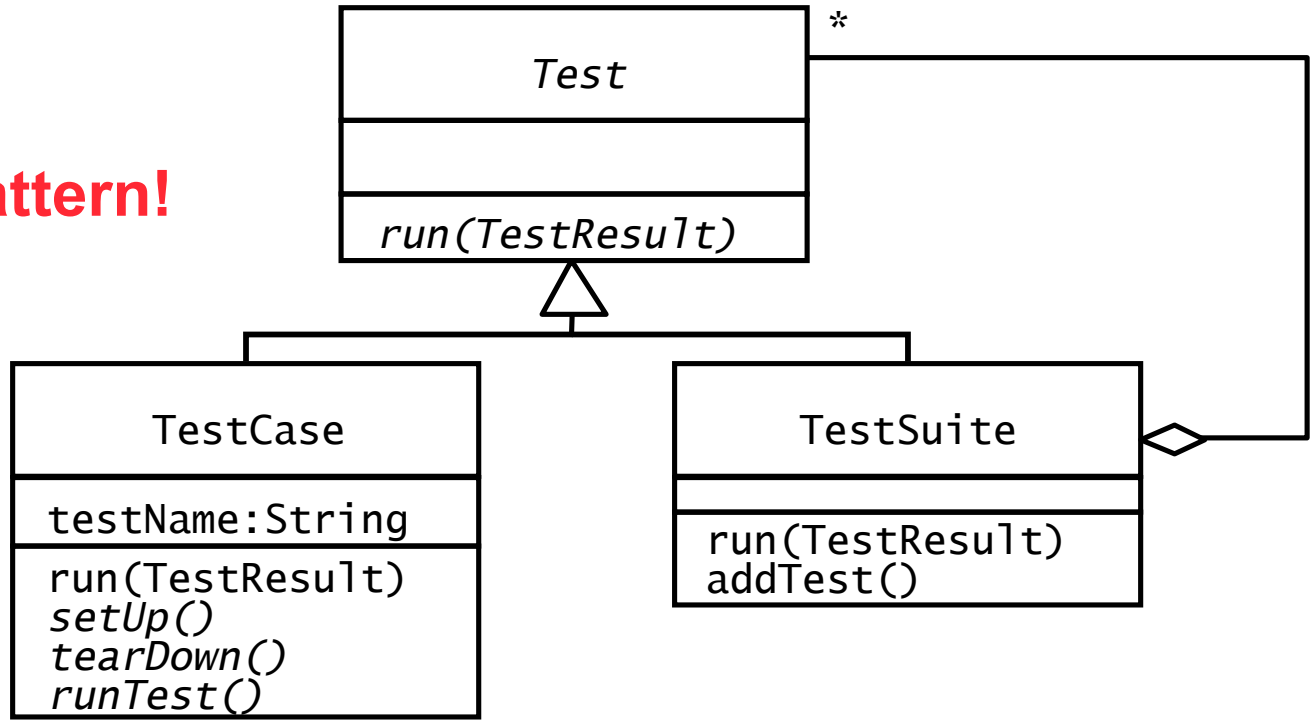
```
public void testRemove() {
   aList.add(anElement);
   aList.remove(anElement);
   assertTrue(aList.size() == 0);
   assertFalse(aList.contains(anElement));
}
```

Test Case

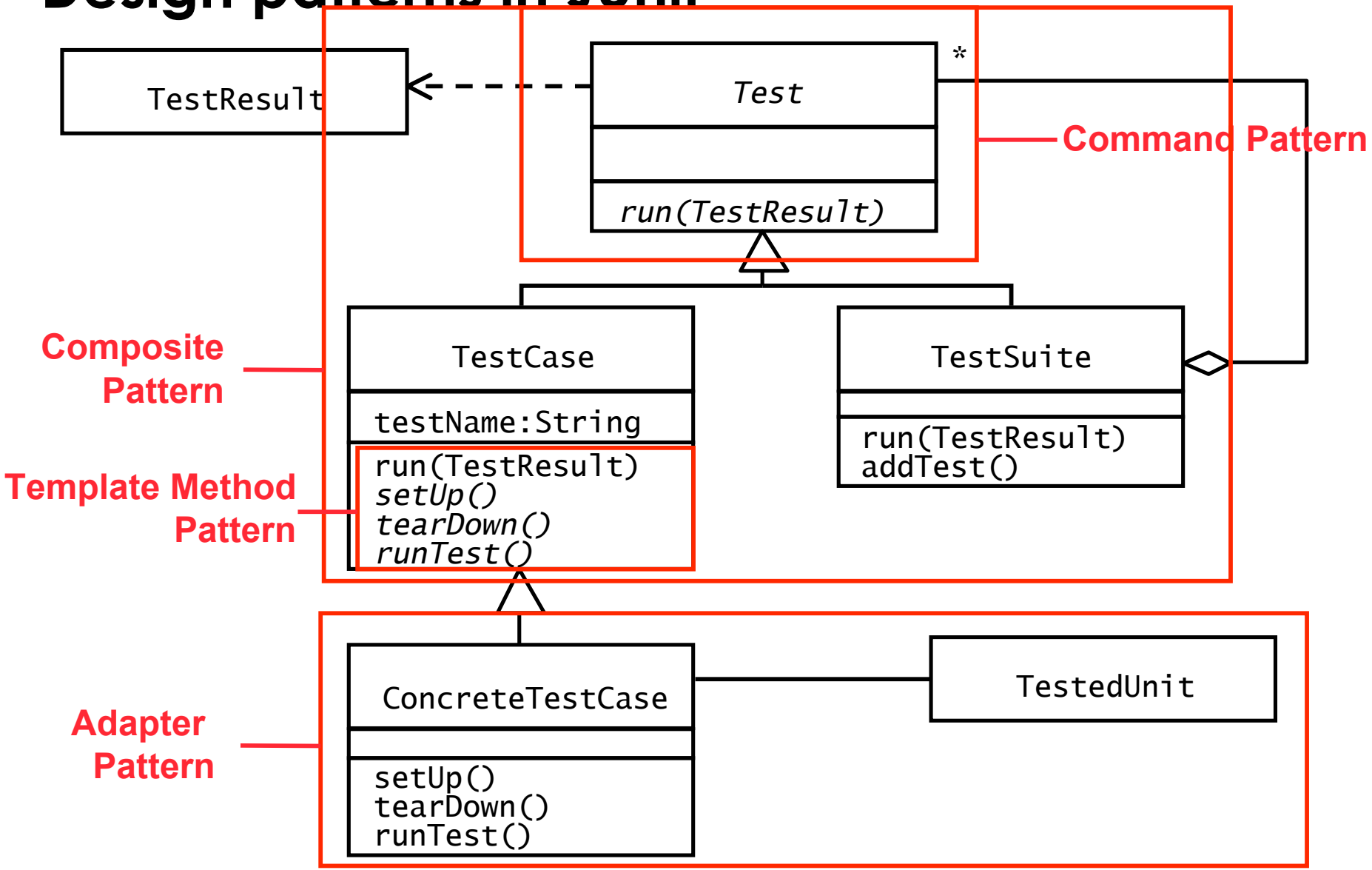
Collecting TestCases into TestSuites

```
public static Test suite() {
  TestSuite suite = new TestSuite();
  suite.addTest(new MyListTest("testAdd"));
  suite.addTest(new MyListTest("testRemove"));
  return suite;
}
```

Composite Pattern!



Design patterns in JUnit



Other JUnit features

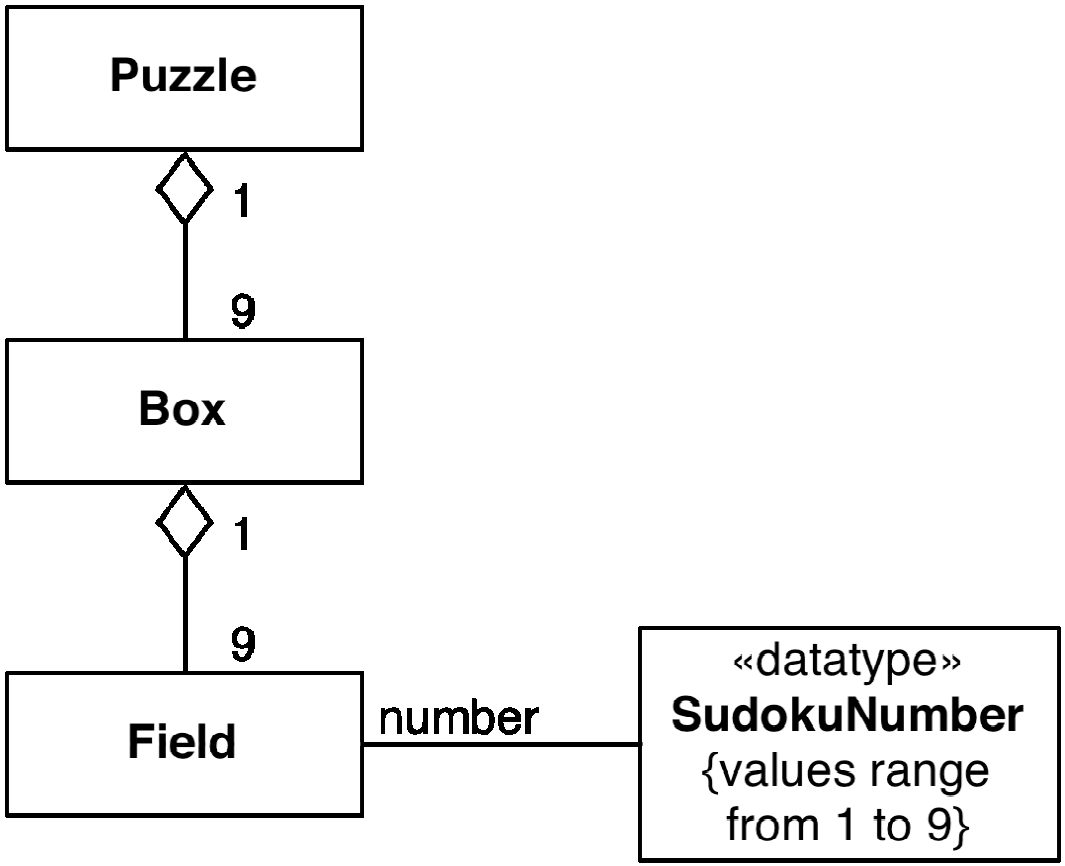
- Textual and GUI interface
  - Displays status of tests
  - Displays stack trace when tests fail
- Integrated with Maven and Continuous Integration
  - http://maven.apache.org
    - Build and Release Management Tool
  - http://Maven.apache.org/continuum
    - Continous integration server for Java programs
  - All tests are run before release (regression tests)
  - Test results are advertised as a project report
- Many specialized variants
  - Unit testing of web applications
  - J2EE applications

Exam Questions

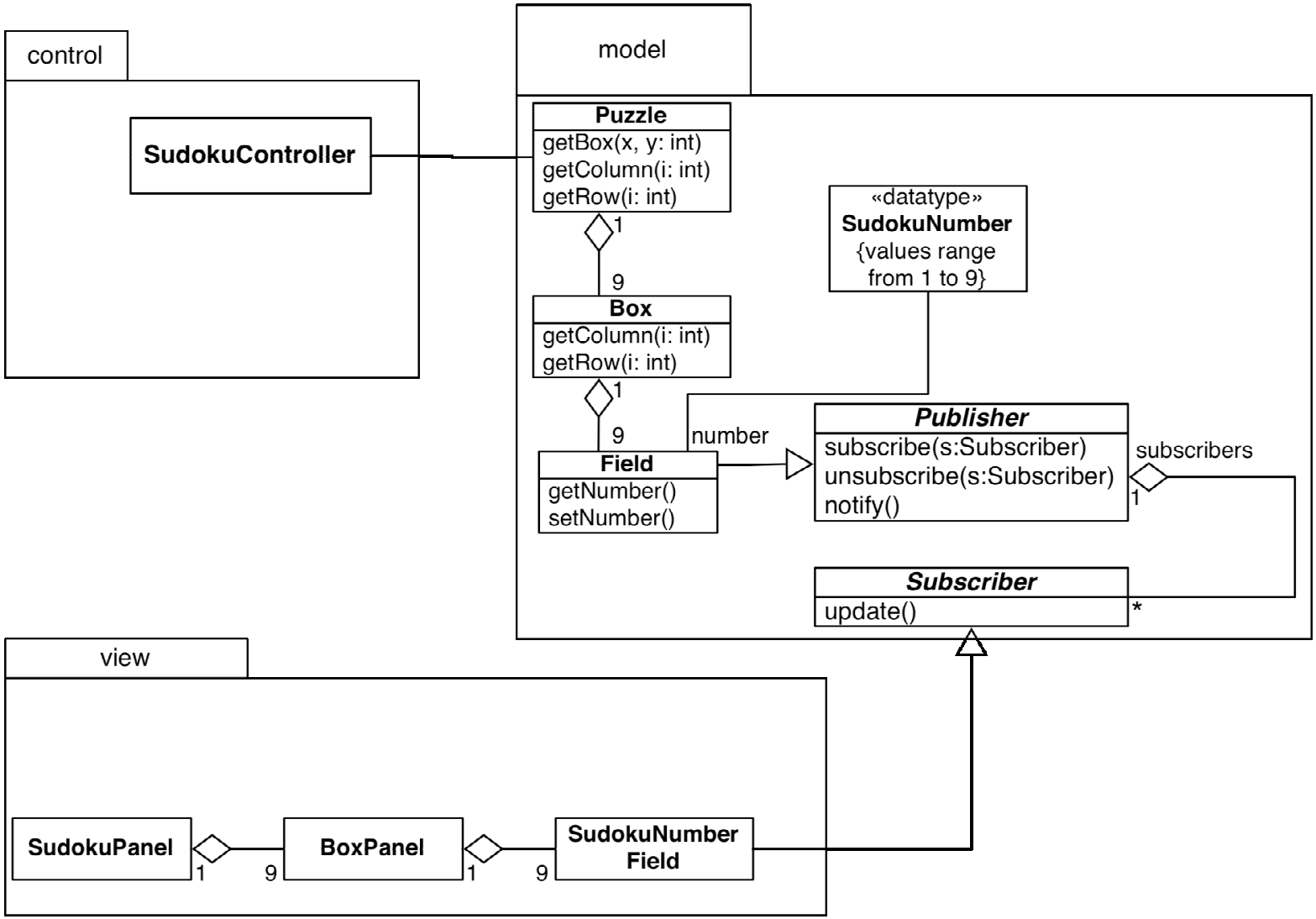
Sudoku Example

- Consider a Sudoku puzzle application.
- A standard Sudoku puzzle consists of 9 Boxes, which in turn contain 9 fields. A Field has a number whose value may range from 1 to 9.
- Describe the system model with the following three class diagrams:
  - Analysis object model
  - System design object model (use MVC)
  - Object design model
- Assume that you have changed the constraints of the standard puzzle: The Sudoku now consists of a 16x16 board and the set of possible values for a field now contains 1-digit hexadecimal values.
- How does the model change?

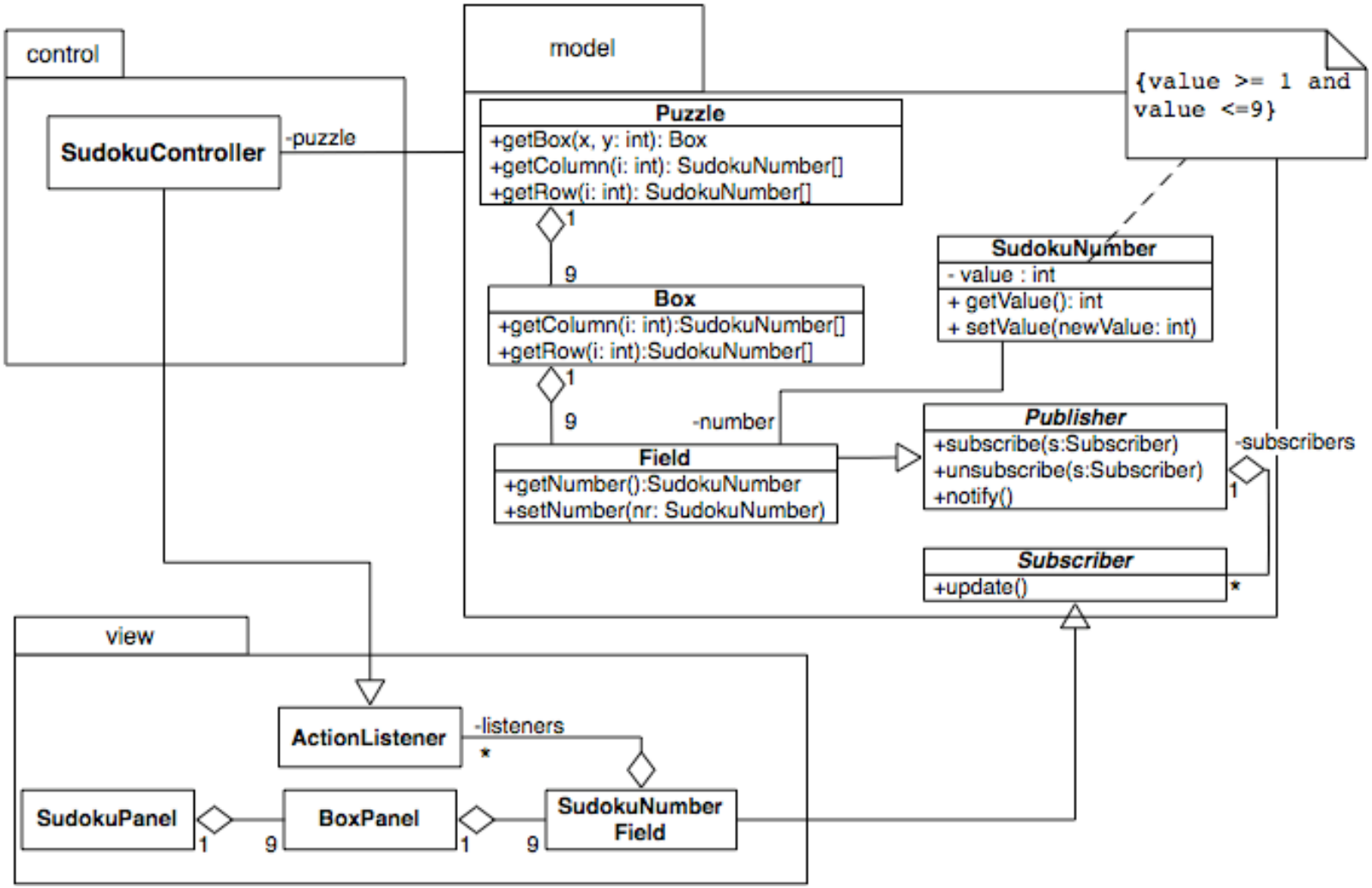
Sudoku Analysis Object Model



Sudoku System Object Model



Sudoku Object Design Model



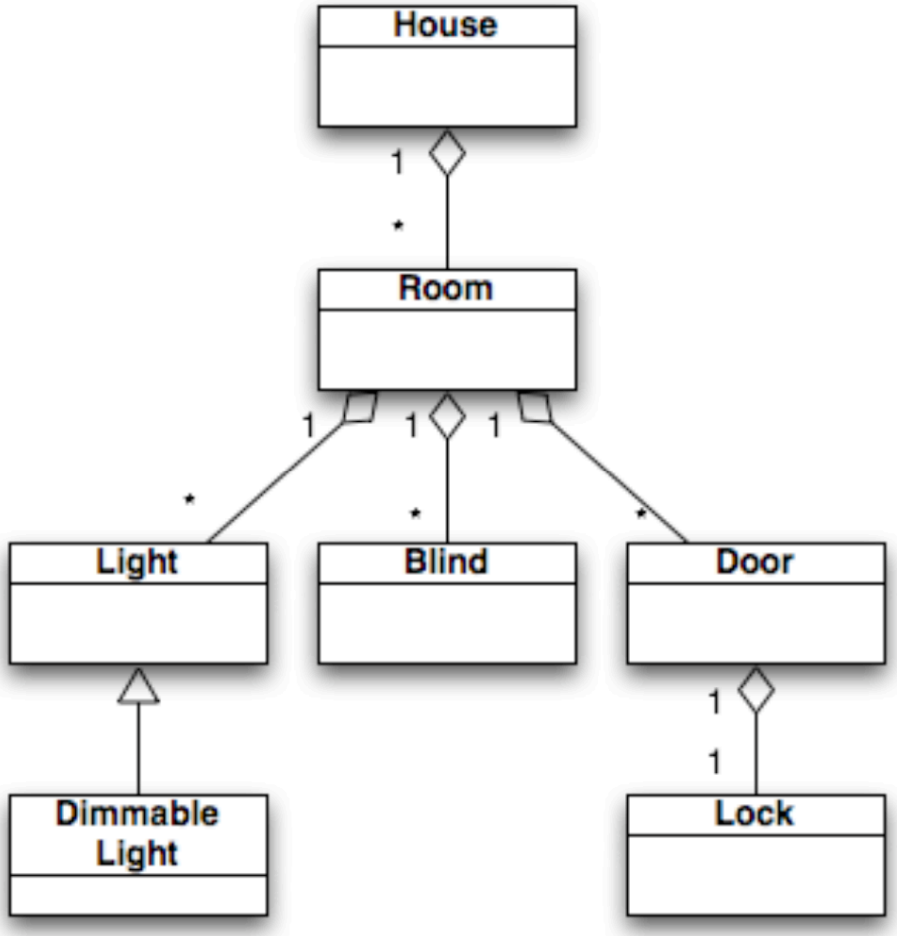
16 x 16 Sudoku

- The multiplicities change as well as the definition of the SudokuNumber enumeration. If OCL constraints have been specified they will change as well.

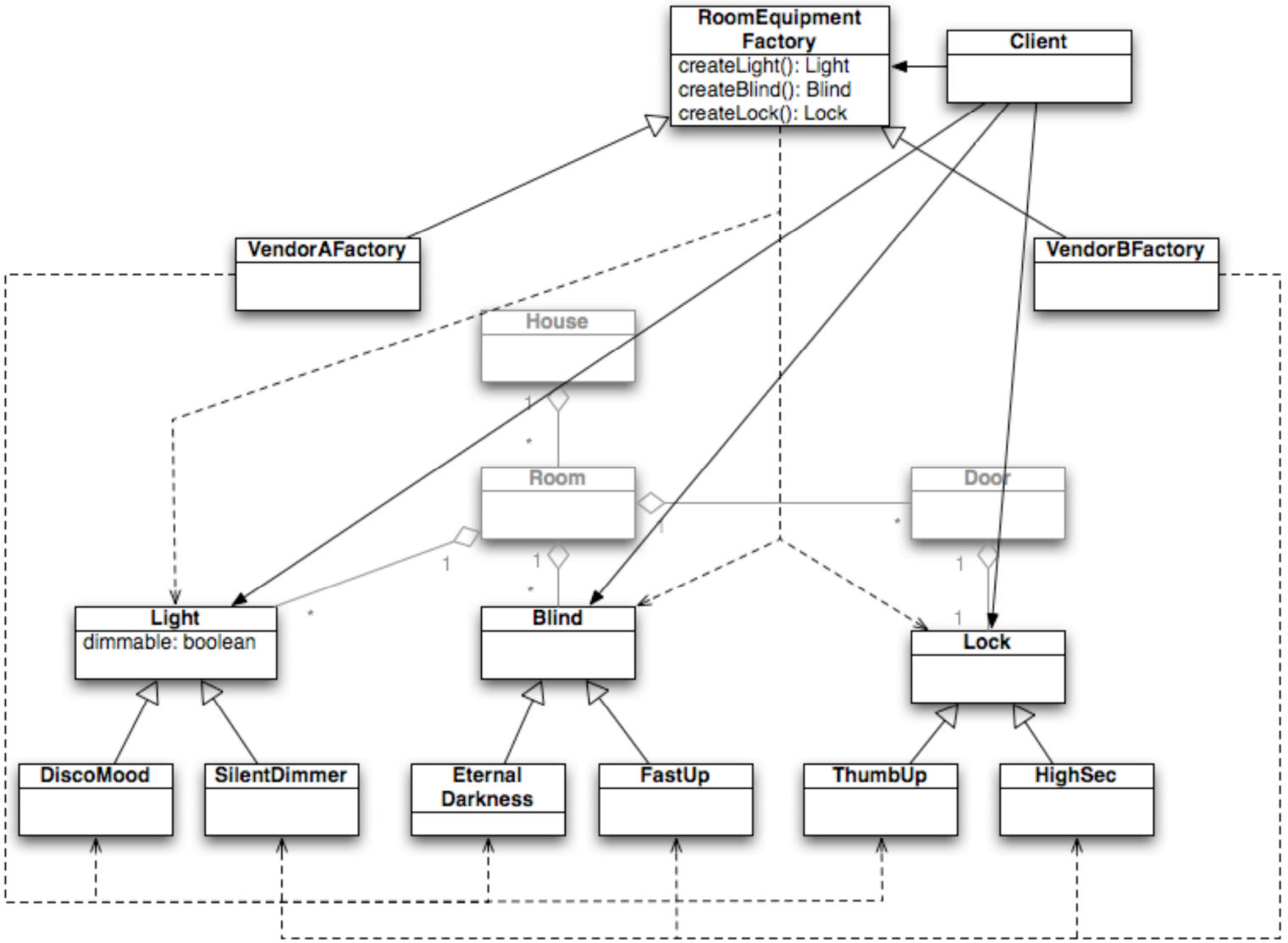
Intelligent House

- *A house consists of several rooms. A room can have lights, blinds and doors. A door is equipped with a lock. Some lights are dimmable.*
  - *Create an analysis object model of the house using Abbot's technique.*
  - *The house can be equipped with device families (blinds, door locks and lights) from different vendors. Vendor A provides the A product family that consists of the EternalDarkness blinds, the DiscoMood lights and ThumbUp door locks. Vendor B provides the B product family of FastUp blinds, SilentDimmer lights and HighSec door locks. Draw an object design model that has the property to allow the use of different product families. How do you ensure your design is reusable?*

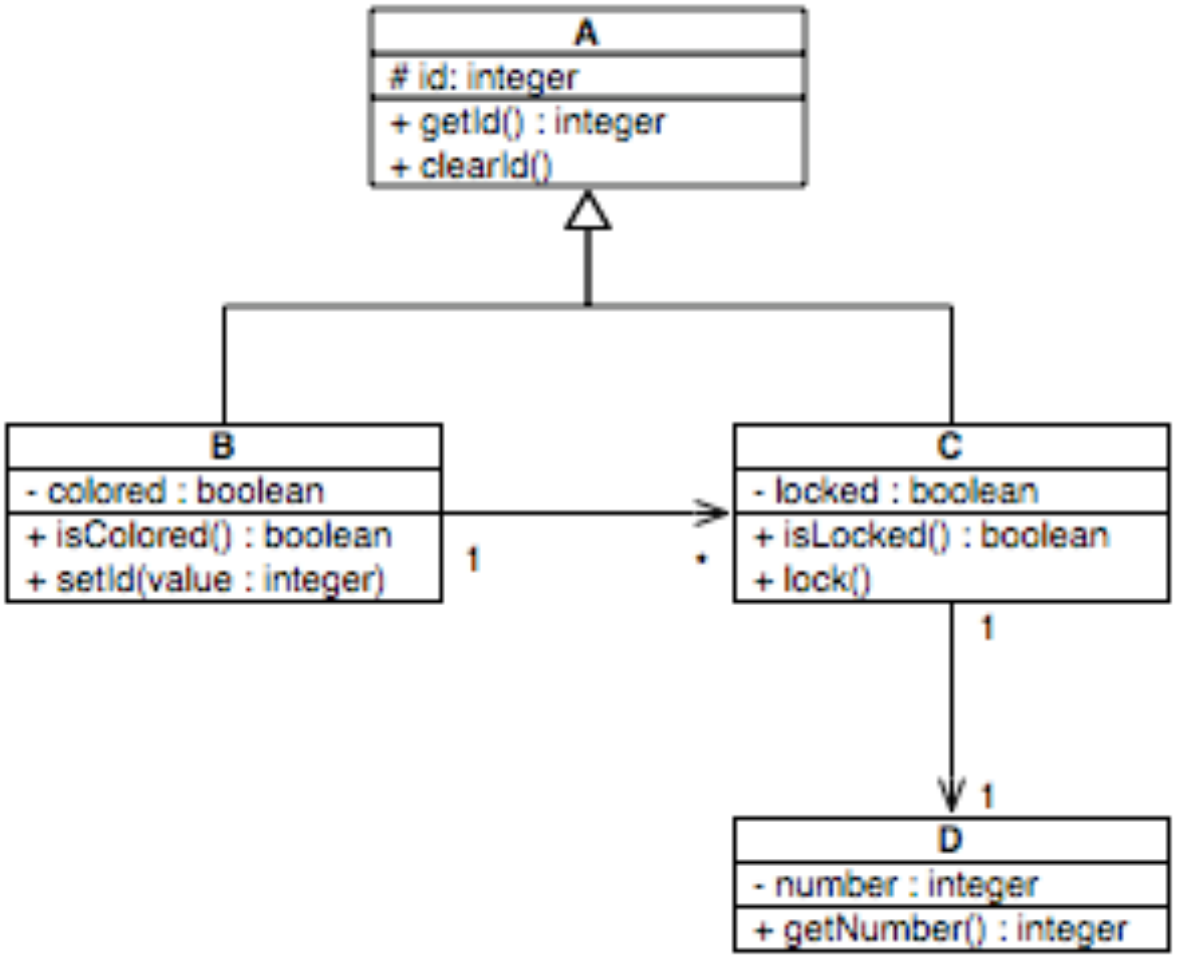
Intelligent House Analysis Object Model



Intelligent House AbstractFactory



Mapping Models into Code



Class A

```
public class A {
  protected int id;

  public int getId() {
      return id;
}

public void clearId() {
  id = null;
}
}
```

Class B

```
public class B extends A {
  private boolean colored;
  Collection<C> refC;

  public boolean isColored() {
      return colored;
  }

  public void setId(int id) {
      this.id=id;
  }
}
```

Class C

```
public class C extends A {
  private boolean locked;
  private int number;

  public boolean isLocked() {
      return locked;
  }

  public void lock() {
      locked = true;
  }

  public int getNumber() {
      return number;
  }
}
```

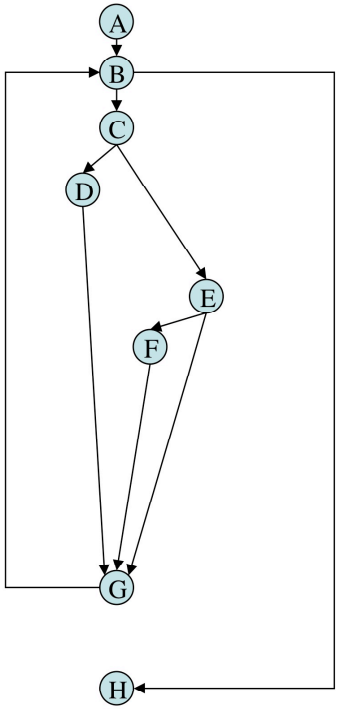
Methodologies

- What is the difference between Techniques, Methodologies and Tools:
- Techniques: Formal procedures for producing results using some well-defined notation.
- Methodologies: Collection of techniques applied across software development and unified by a philosophical approach.
- Tools: Instruments or automated systems to accomplish a technique.

Unit Testing Whitebox Test

```
m1();                              A
for (i=0; i<j; i++) {              B
   if (b>a) {                      C
       b=a;                        D
   }
   else if (c==3) {                E
       c++;                        F
   }
   m2();                           G
}
m2();                              H
```

Whitebox Testing Solution



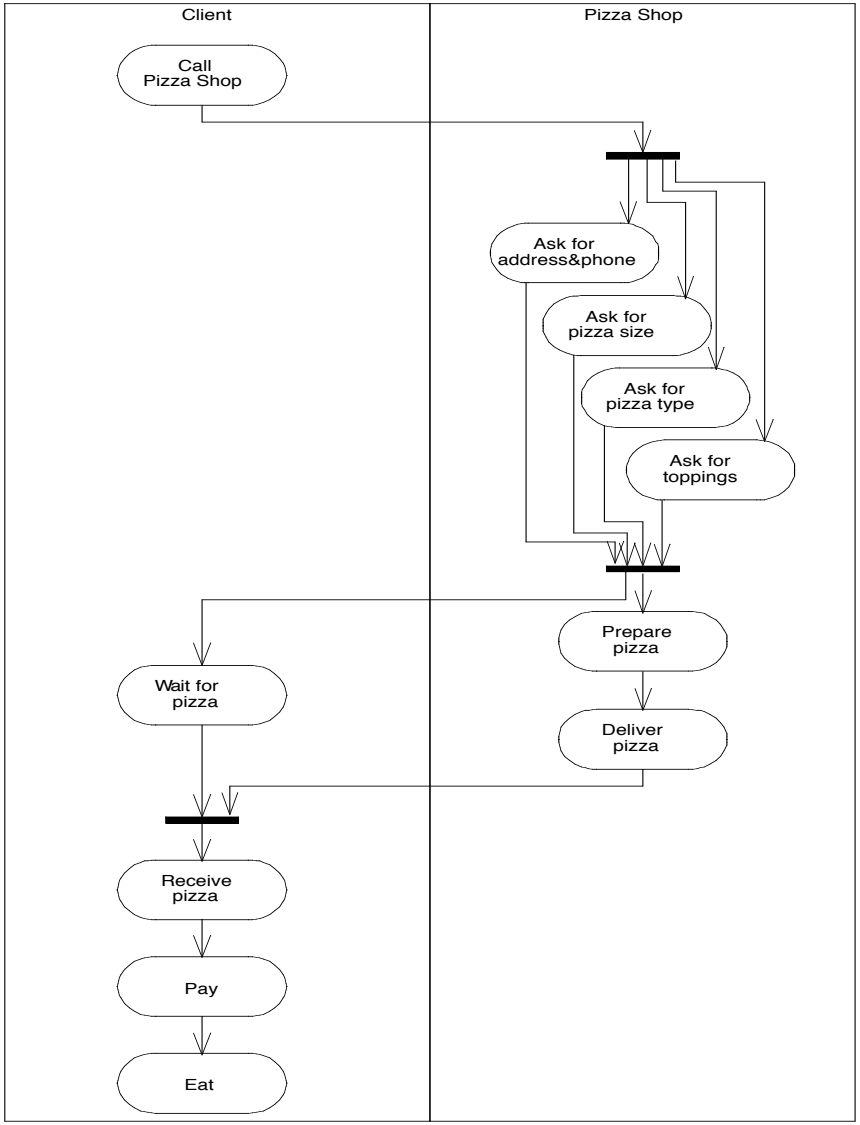

```
m1();                          } A
for (i=0; i<j; i++) {          } B
   if (b>a) {                  } C
    b=a;                       } D
   }
   else if (c==3) {            } E
    c++;                       } F
   }
   m2();                       } G
}
m2();                          } H
```

A, B, C, D, G, B, C, E, F, G B, H

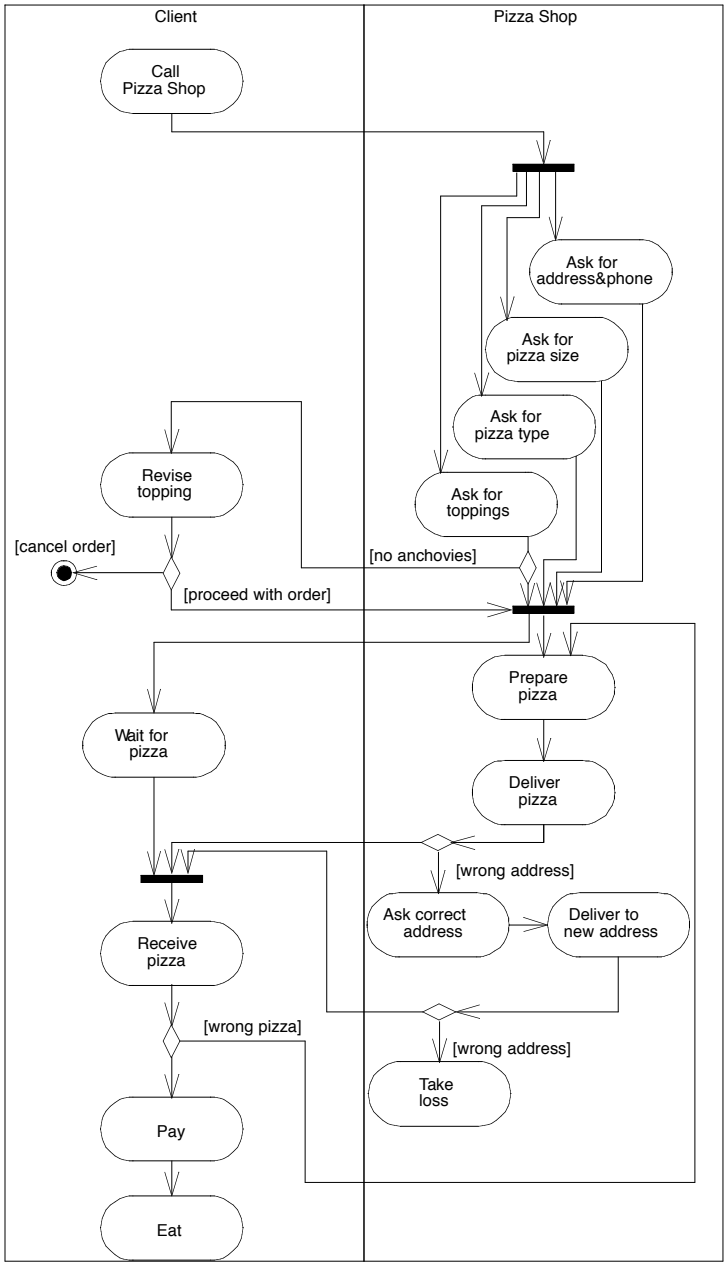
Pizza Service

- ***Ordering a pizza***
  - Consider the process of ordering a pizza by phone. Draw an activity diagram representing each step of the process, from the moment you pick up the phone to the point when you start eating the pizza. Do not represent any exceptions. Include activities that others need to perform.
- ***Exceptions***
  - Add exception handling to the activity diagram you developed. Consider at least three exceptions (e.g., operator wrote down wrong address, delivery man delivers wrong pizza, store is out of anchovies).

Ordering a Pizza



Exceptions


Client
Pizza Shop
Call Pizza Shop
Ask for address&phone
Ask for pizza size
Ask for pizza type
Ask for toppings
Revise topping
[cancel order]
[no anchovies]
[proceed with order]
Prepare pizza
Wait for pizza
Deliver pizza
[wrong address]
Ask correct address
Deliver to new address
Receive pizza
[wrong pizza]
[wrong address]
Take loss
Pay
Eat