Testing of chosen Design Patterns with JUnit and Mockito

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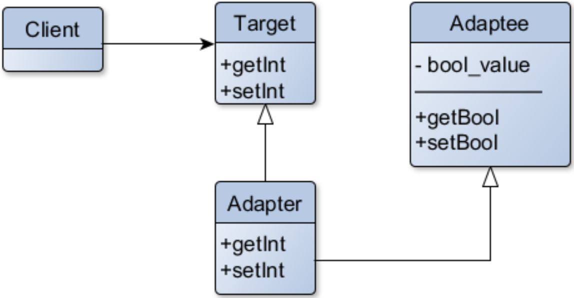
Introduction

- We have identified a collection of **structural** and **behavioral design patterns**: Class Adapter, Object Adapter, Proxy, Decorator, Composite, Observer, State, Visitor.
- For each pattern we realize an implementation in Java and we develop a **reasoned test suite** based on a realistic **fault model** and on chosen **coverage criteria**.
- We realize the tests through the *JUnit* plug-in for Eclipse and the *Mockito* framework. *EclEmma* is used to provide a code coverage measure.

Class Adapter

Adapts a pre-existent class to a new interface through inheritance. Through the new interface the old methods can be directly presented, modified or produce aggregated results.



Class Adapter - Fault Model

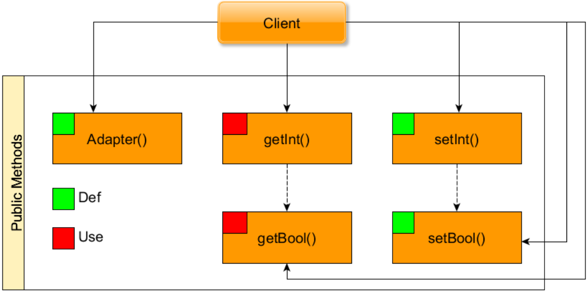
Given that the pattern focuses on allowing access to legacy methods through a new interface, failures are found in the following situations:

- the adapter did not inherit from the legacy class or the new interface
- the adapter cannot interact with the legacy methods

Solutions

- test the ways in which the variable *bool_value* interacts and is modified by the methods

Class Adapter - Data Flow Graph

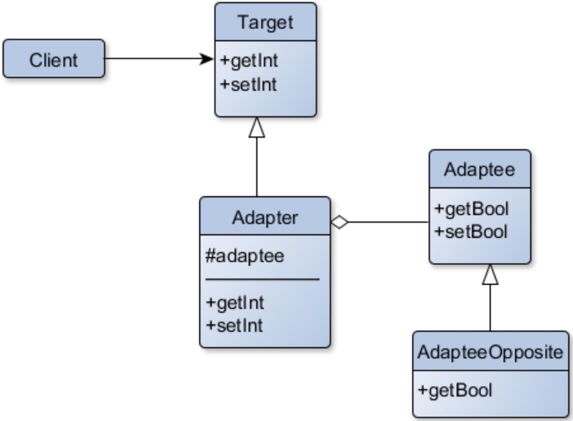


We generated a test suite capable of testing all the *all-uses* paths:

- Adapter() getInt()
- Adapter() getBool()
- Adapter() setInt() getInt()
- Adapter() setInt() getBool()
- Adapter() setBool() getInt()

Object Adapter

Adapts a pre-existent class to a new interface through class composition. Through the new interface the old methods can be directly presented, modified or produce aggregated results.



Object Adapter - Fault Model

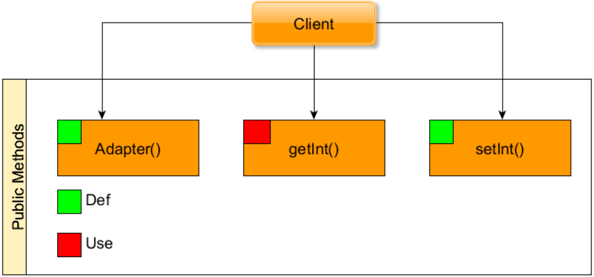
Given that the pattern focuses on allowing access to legacy methods through a new interface, failures are found in the following situations:

- the adapter did not inherit from the legacy class or the new interface
- the adapter cannot interact with the legacy methods
- the instance contained in the adapter, which inherited the adaptee class, has overrode its methods in an unforeseen way

Solutions

- test the ways in which the variable *bool_value* interacts with the methods, considering all the possible alternative implementations

Object Adapter - Data Flow Graph



We generated a test suite capable of testing all the *all-uses* paths:

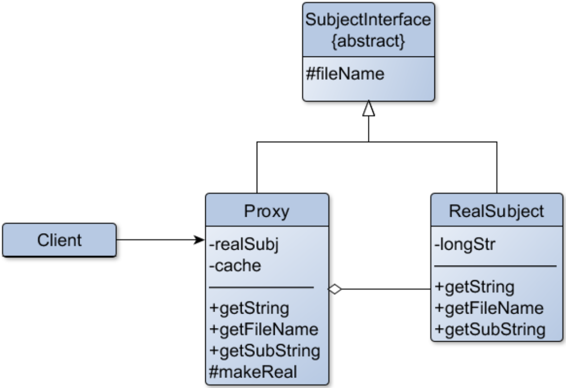
- Adapter() getInt()
- Adapter() setInt() getInt()

To these are also added the topology tests:

- Adapter(Adaptee) getInt()
- Adapter(AdapteeOpposite) getInt()

Proxy

The Proxy pattern is constituted by a class functioning as an interface to something else, usually a complex or heavy object. It is used to access the real serving object behind the scenes, it either provides a cached result or transmits the request to the actual object.



Proxy - Fault Model

The pattern focuses on optimizing or controlling the access to the heavy subject. We have failures in the following situations:

- the access to the RealSubject is impeded
- the cached copies provided by the Proxy differ from the actual source

Solutions

- test the ways in which the variable *realSubj* interacts and is modified by the methods
  - $\rightarrow$ by slight modification of the tests we can automatically verify the cached versions validity

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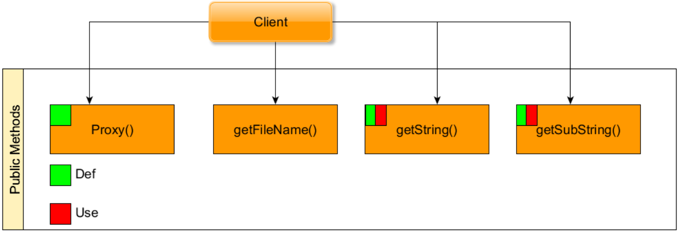
Proxy - Data Flow Graph

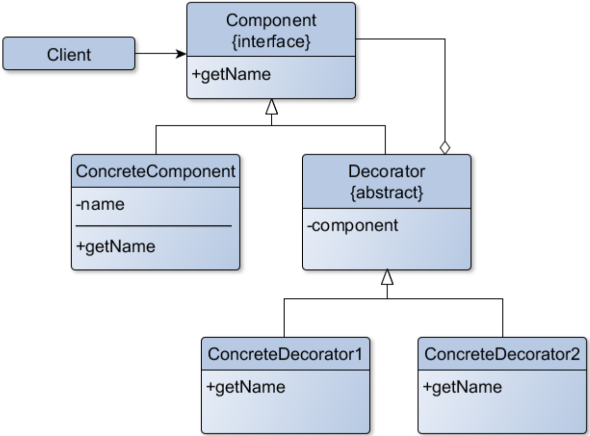


We generated a test suite capable of testing all the *all-uses* paths:

- Proxy() getString()
- Proxy() getString() getString()
- Proxy() getSubString()
- Proxy() getString() getSubString()
- Proxy() getSubString() getSubString()
- Proxy() getSubString() getString()

Decorator

The Decorator pattern allows behavior to be added to an individual object, either statically or dynamically, without affecting the behavior of other objects from the same class.



Decorator - Fault Model

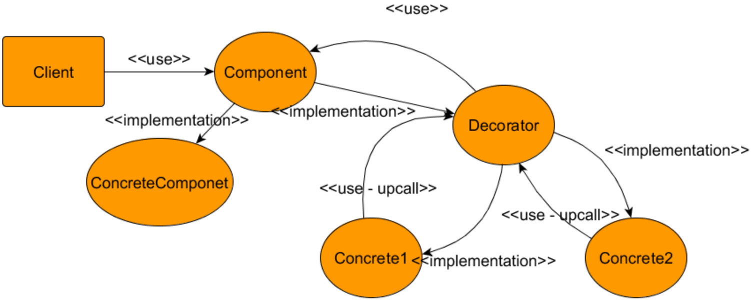
The pattern focuses on allowing an extension of functionality in objects. Grave errors are found in the following situations:

- the call to the *operation (getName)* does not reach the Component or results in unexpected behavior

Solutions

- test the correctness of the sequence of method calls in different hierarchies of classes

Decorator - Class Dependency Graph

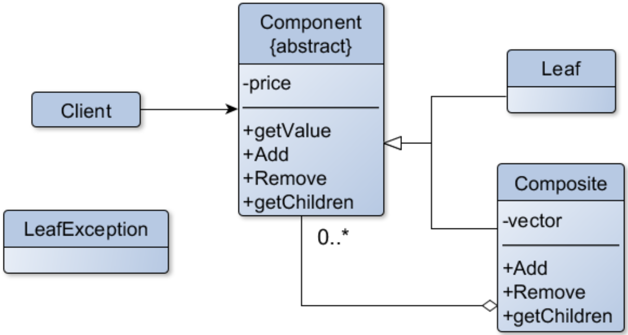


We decided to generate a test suite dependent on the *all-edges* criterion. We identified the 3 cases of:

- ConcreteComponent
- Decorator ConcreteComponent
- Decorator Decorator ConcreteComponent

Composite

The Composite pattern "composes" objects into tree structures to represent part-whole hierarchies. Implementing the composite pattern lets clients treat individual objects and compositions uniformly.



Composite - Fault Model

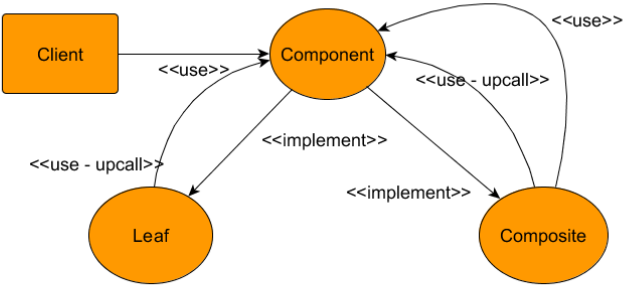
The pattern focuses on treating uniformly individual and compound objects. Grave errors are found in the following situations:

- the common *operation* works differently than expected
- the composite-specific methods produce unexpected effects when called on a Leaf object

Solutions

- test the way *operation* works under the possible hierarchies at runtime
- test the way the different objects behave under calls from composite-specific methods

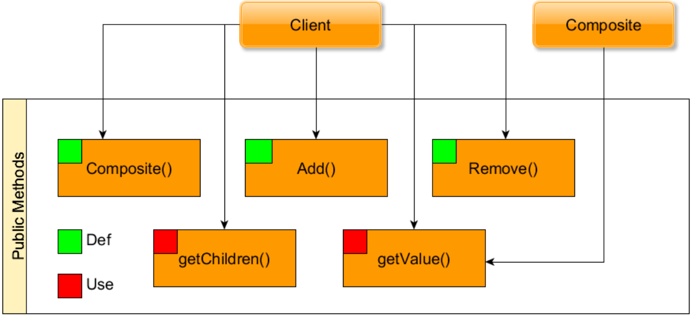
Composite - Data Flow Graph



We generated a test suite capable of testing all the *all-uses* paths:

- Component() getChild()
- Component() getValue()
- Component() add() getChild()
- Component() add() getValue()
- Component() add() add() remove() getChild()
- Component() add() add() remove() getValue()

Composite - Class Dependency Graph

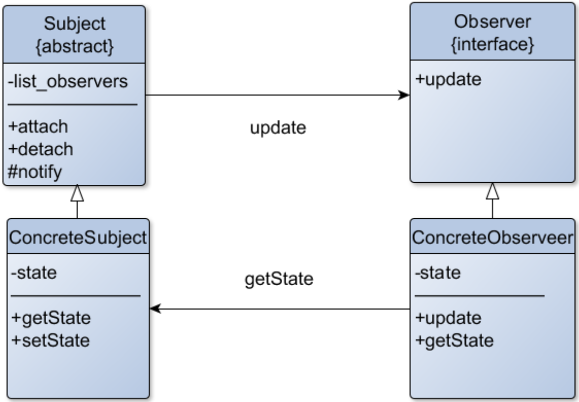


We identified the 3 cases of:

- single Leaf
- Composite containing Leaf
- Composite containing Composite

Observer

In the Observer pattern an object, called the subject, maintains a list of its dependents, called observers, and notifies them automatically of any state changes, usually by calling one of their methods.



Observer - Fault Model

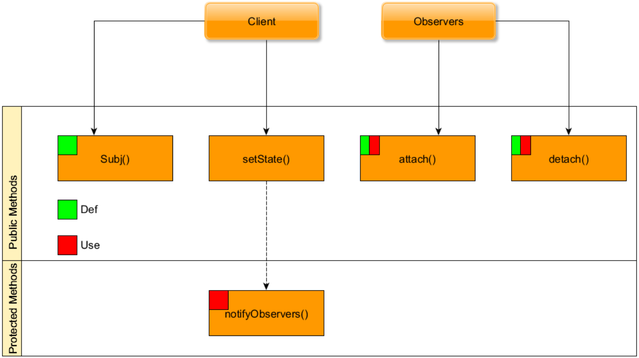
The pattern focuses on maintaining updated objects that expressed the interest in a specific subject. Failures are found in the following situations:

- *attach* and *detach* do not produce the expected results
- after a change of the subject state the following observers are not *notified*
- the observer after being notified does not execute correctly the *update* method

Solutions

- test the way *list_observers* is modified after an inter-class method invocation
- test the way the *state* of the observer is modified after a notification

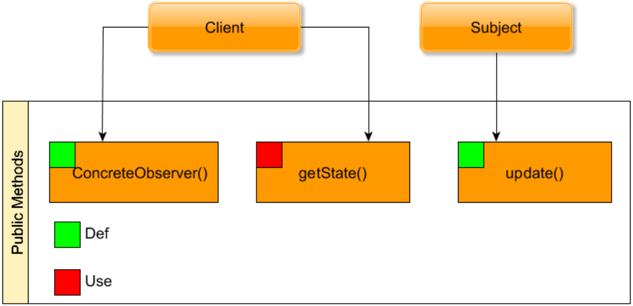
Observer - Data Flow Graph: field *list_ observer*



We generated a test suite capable of testing all the *all-uses* paths:

- Subject() setState()[notify()]
- Subject() detach()
- Subject() attach()x3 detach()x2
- Subject() attach()x2 detach()x2 attach() detach() attach()

Observer - Data Flow Graph: field *state*

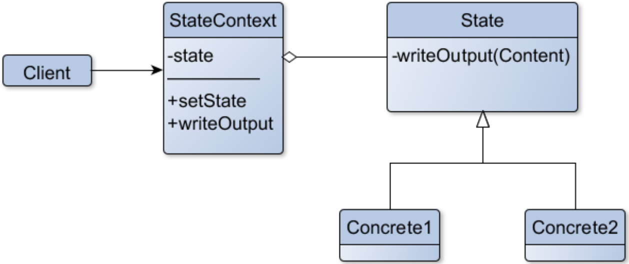


We generated a test suite capable of testing all the *all-uses* paths:

- ConcreteObserver() getState()
- ConcreteObserver() update() getState()

State

The State pattern implements a state machine by implementing each individual state as a derived class of the state pattern interface, and implementing state transitions by invoking methods defined by the pattern's superclass.



State - Fault Model

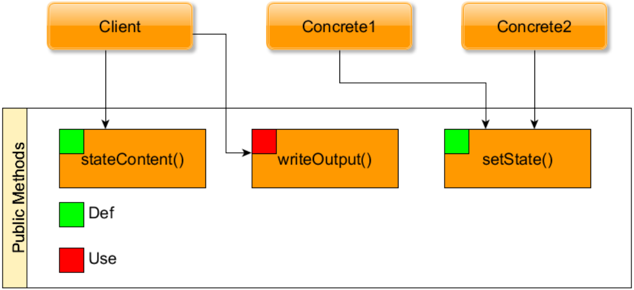
The pattern focuses on delegating the actual methods implementation to internal state classes. Grave errors are found in the following situations:

- internal state changes in an erroneous manner
- the internal state methods produce unexpected side effects or results
- the internal classes' inner state changes in an erroneous manner

Solutions

- test the way the *state* field interacts with the StateContext methods

State - Data Flow Graph

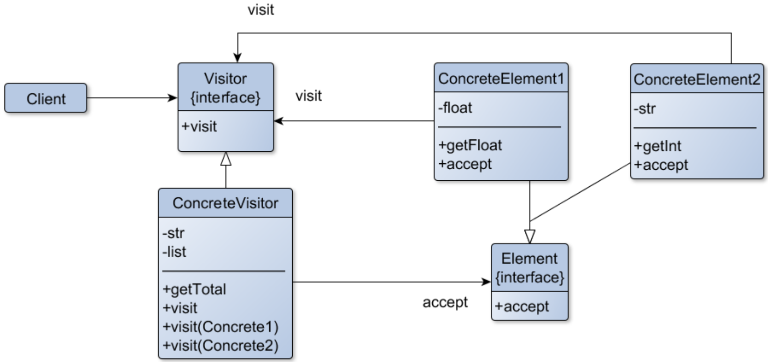


We generated a test suite capable of testing all the *all-uses* paths:

- StateContext() writeOutput()
- StateContext() setState() writeOutput()
- StateContext() writeOutput() writeOutput()

Visitor

The Visitor pattern is a way of separating an algorithm from an object structure on which it operates. The pattern allows one to add new virtual functions to a family of classes without modifying the classes themselves.



Visitor - Fault Model

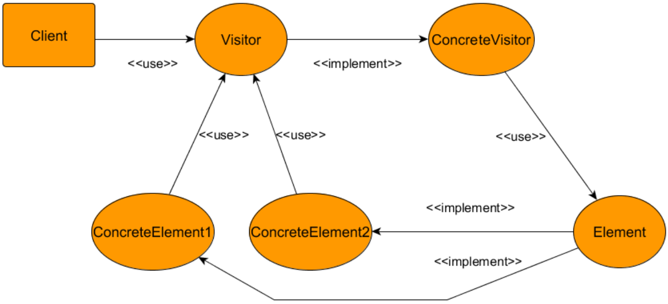
The pattern focuses on treating uniformly objects of different types while operating on them with different specializations of the same function. A failure is produced by the following situation:

- the wrong *visit()* is applied to an Element

Solutions

- test the way *visit* works when applied to all possible hierarchies of Element types

Visitor - Class Dependency Graph



We identified the 2 cases of:

- Visitor ConcreteVisitor Element ConcreteElement2 Visitor
- Visitor ConcreteVisitor Element ConcreteElement1 Visitor

JUnit

JUnit is an open source unit testing framework for the Java programming language. The framework allows the programmer to easily create *drivers* for the tests and the ability to verify the produced outputs.

- *Annotation*s identify the test methods
- *Assertion*s tests for expected results

Main benefits of the framework are:

- JUnit tests can be run automatically and check their own results and provide immediate feedback without a need to manually comb through a report of test results.
- JUnit tests can be organized into test suites containing test cases and even other test suites.
- Junit shows test progress through an user-friendly bar that is green while the tests have not encountered errors and turns red when a test fails.

Mockito

- Mockito is an open source testing framework for Java. The framework allows the creation of test double objects also called mock objects.
  - → mock testing frameworks allow the faking of external dependencies so that the object being tested is isolated from external behaviors
  - → ensuring that objects perform the way they are expected to would require the creation of tests that actually exercise each behavior and verify that it performs as expected. *Costs comparable to implementing the other classes*

Mockito

While utilizing the framework we identified some noteworthy details:

- in the Proxy class we utilized *spy* on the very class we were testing to allow injection of other mocked classes.
- when using *spy* the *doReturn().when()* construct is to be preferred to the *when().myMethod()* construct due to the fact that the latter actually executes the function and produces side-effects before returning the designed output.
- returning an Answer() allows for side-effects to be produced when a mocked object's method is called.
- Answer is not necessary if the side-effects are produced only on the very class under test due to the fact that one can independently produce them by simply calling the respective tested methods.

Conclusions

- We identified a collection of structural and behavioral design patterns. For each pattern, we:
  - produced an implementation
  - identified its main faults
  - created a reasoned test suite based on the fault model and on a coverage criteria chosen pattern by pattern
- We realized both Unit and Integration tests through the JUnit plug - in for Eclipse and the Mockito framework.
  - → applied EclEmma to provide a code coverage measure
- We identified both the untested branches and the reason for which they were not covered.
- In the end most patterns presented a full code coverage.