Revision Notes for CO220 Software Engineering Design

Autumn 2017

1 Test-Driven Development

TDD Cycle

1. Write a failing test (API design): should be **simple**, have **descriptive name** and test a **single** behaviour.
2. Code to pass test (internals design): should be as **simple** as possible.
3. Refactor (structural design): **don't forget to refactor!**

Refactoring Process of improving the design of a piece of code, without changing its functionality.

- Should be applied **little and often** to continuously improve design.
- Only refactor in a **green state**. Tests ensure that behaviour is preserved.
- Should be **automated** to be done quickly and reliably.
- Small transformations are **combined** to achieve larger refactorings.

Example Transformations

1. **Compose (extract) method**: Break down method into chunks to make it shorter. Allows us to give a name for a concept and increase level of abstraction. Try to keep a constant level of abstraction.
2. **Inline variable**: Instead of using a temporary variable, inline its usages. Reduces number of elements in method.
3. **Extract to common class**: First work to make duplication exactly the same. Then refactor it, e.g. to another object. Reduces duplication.

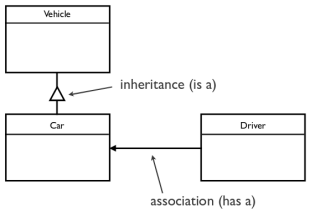
Technical Debt When features are added quickly, in an inelegant way. If not fixed quickly, **technical debt** builds up.

JUnit and JMock

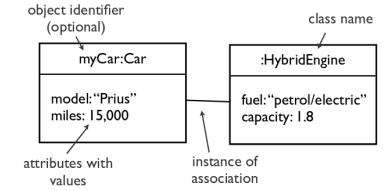
```
public class TestObjectTest {
  // Set up mockery, constants, mock objects and tested object
  @Rule public JUnitRuleMockery context = new JUnitRuleMockery();

  final Order EXAMPLE_PARAM = new ...;

  CalledObject calledObject = context.mock(CalledObject.class);

  TestObject testObject = new TestObject(calledObject, ...)

  @Test
  public void doesSomethingSpecific() {
    // Set up local variables for exceptions / return values
    SomeException exception = new SomeException();

    // Set up expectations
    context.checking(new Expectations() {{
      // Ignore: ignoring / allowing
      ignoring(unimportantMockObject);
      allowing(someMockObject).someMethod(with(any(ParamType.class)));
                              will(throwException(exception));

      // Expect: exactly(n) / atLeast(n) / atMost(n)
      exactly(1).of(anotherMockObject).someOtherMethod(exception);
      exactly(1).of(anotherMockObject).anotherMethod(EXAMPLE_PARAM);
                                      will(returnValue(x));

      // Don't expect: never
      never(aDifferentMockObject).aDifferentMethod();
    }});

    // Set up triggers
    testObject.testedMethod(EXAMPLE_PARAM, ...);
    testObject.anotherTestedMethod();

    // Make assertions
    assertThat(testObject.getSomeValue(), is(x));
  }
}
```

2 UML Diagrams

UML Class Diagrams

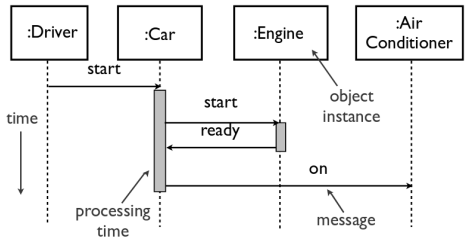


UML Object Diagrams



We may well have multiple instances of the same type in the same diagram

UML Sequence Diagrams



3 Object Oriented Design

Four Elements of Simple Design In order of importance:

1. Behaves correctly.
2. Minimises duplication.
3. Maximises clarity.
4. Has fewer elements.

Bad Design

- **Rigidity**: software is hard to change.
- **Fragility**: when we change one part, other parts break unexpectedly.
- **Immobility**: it is hard to reuse elements of the code in other applications.

Commands vs. Queries

- **Commands**: **Ask another object to do something for us**. Don't care how it's done, don't expect return value. Changes state of invoked object.
- **Queries**: **Ask another object to tell us a value** (so we can do something with it). Should return value, but not have side effects on state of invoked object.

Tell Don't Ask Objects send messages, requesting actions, but do not expect return values. Only queries return values.

Law of Demeter **Only talk to your immediate friends**. Implementations that depend on pieces of the system further away result in tight coupling.
Avoid **train wrecks**: `getX().getY().getZ().doSomething()`.

Visibility

- **Encapsulation**: ensure object's behaviour is only affected through its API. Implementation and state of objects should be encapsulated. Reduces fragility.
- **Information hiding**: conceal how an object implements functionality. Increases abstraction, chunking up program into concepts.

Key idea: Make things `private` unless they should exposed as an API for other objects (and generally avoid `protected`).

Coupling and Cohesion

- **Coupling**: How dependent two classes are towards each other. Reducing coupling reduces fragility and allows reuse.
- **Cohesion**: An object should have one basic responsibility. Increasing cohesion makes objects easier to reason about and reuse.

We can reduce coupling by using interfaces as roles.

4 Design Patterns

4.1 Behavioural Patterns

4.1.1 Null Object Pattern

Problem Checking for null is ugly.

Solution Use an interface and add a Null Object class that does nothing.

Example

```
interface Track {
    public void play();
}

class NullTrack implements Track {
    public void play() {
        // do nothing
    }
}
```

4.1.2 Template Method Pattern

Problem Requirements change over time, sometimes we need to adapt a small part of an algorithm.

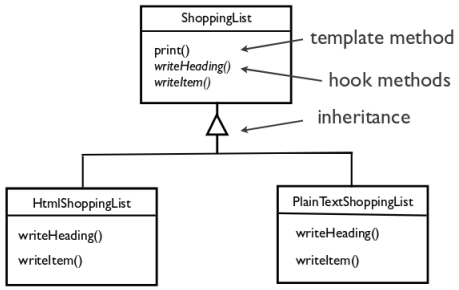
Solution Extend via inheritance.

Refactorings

1. **Extract method** for smallest differing block of code.
2. **Extract superclass** and make differing method abstract.

Don't forget to remove duplication in tests (e.g. using lambda to create simple instance of superclass).

Example



Benefits

- Follows **Hollywood Principle** (don't call us, we'll call you): Concrete classes only define methods that are called when the superclass needs them (they don't call up).
- Follows **Open-Closed Principle**: You should be able to extend a class's behaviour without modifying it.
  - Change behaviour by adding new code, rather than changing existing code.
  - **Separate things that change from things that stay the same**.

Drawbacks Immobility caused by coupling.

4.1.3 Strategy Pattern

Problem Requirements change over time, sometimes we need to adapt a small part of an algorithm.

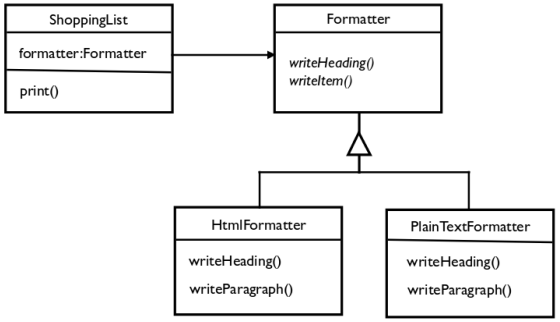
Solution Extend via delegation.

Refactorings

1. **Extract method** for smallest differing block of code.
2. **Extract delegate** for the method.
3. **Extract interface** from the delegate class.
4. **Define constructor**, pass in the delegate class **as argument**.

Don't forget to remove duplication in tests (use a mock object).

Example



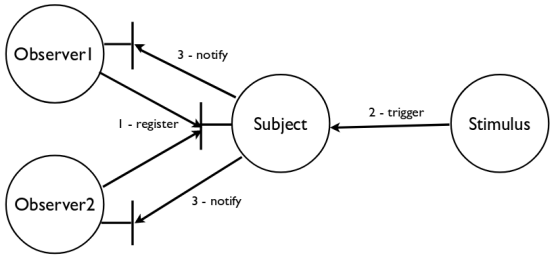
Benefits Does the same as the template method but with looser coupling.

4.1.4 Observer Pattern

Problem E.g. do X when someone presses button Y. (**Interactive applications**).

Solution Subscribe to changes of state.

Example

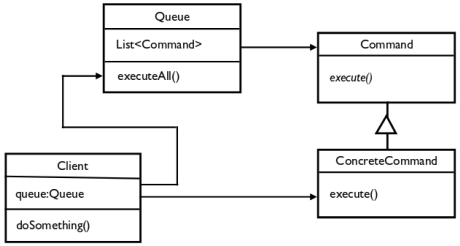


4.1.5 Command Pattern

Problem Want to queue / log executed commands.

Solution Wrap up a piece of behaviour to do now or later, in an object.

Example



4.2 Creational Patterns

4.2.1 Factory Pattern

Problems

- Constructors are not clear.
- Required type may not be known until runtime.

Solution Name constructors.

Refactorings

1. **Replace constructor with factory**.

Examples

Factory methods can have names, unlike constructors

```
class TimeZone {
  static TimeZone forId(String id) {...}
  static TimeZone forOffsetHours(int offset)
   { return new TimeZone(3); }
}

TimeZone.forId("Europe/London");
TimeZone.forOffsetHours(3);
```

instead of:

```
new TimeZone(3);
```

this version has a lot less **clarity of intention**

We can decide which type to return at run-time

can return any sub-type of Logo, polymorphically

```
class LogoFactory {
  static Logo createLogo() {
    if (config.country().equals(Country.UK) {
      return new FlagLogo("Union Jack");
    }
    if (config.country().equals(Country.USA) {
      return new FlagLogo("Stars and Stripes");
    }
    return new DefaultLogo();
  }

  class FlagLogo implements Logo {...}
  class DefaultLogo implements Logo {...}
}
```

4.2.2 Builder Pattern

Problem May be many constructor parameters.

Solution Collect object's configuration parameters.

Refactorings

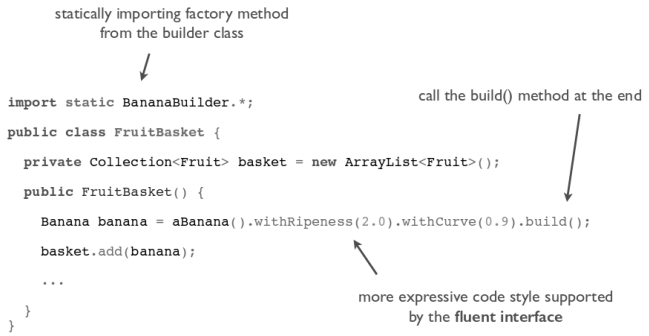
1. **Replace constructor with builder**.
2. **Rename** `create()` to `build()`.
3. **Replace** (builder) **constructor with factory**.
4. **Statically import** factory.

Example

```
public class BananaBuilder {

    private double ripeness = 0.0;
    private double curve = 0.5;

    private BananaBuilder() {}

    public static BananaBuilder aBanana() {
        return new BananaBuilder();
    }

    public Banana build() {
        Banana banana = new Banana(curve);
        banana.ripen(ripeness);
        return banana;
    }

    public BananaBuilder withRipeness(double ripeness){
        this.ripeness = ripeness;
        return this;
    }

    public BananaBuilder withCurve(double curve) {
        this.curve = curve;
        return this;
    }
}
```

private constructor enforces that builder itself is created using factory method

configuration methods return 'this', giving a **fluent interface** which allows method chaining



4.2.3 Singleton Pattern

Problem **Require** that you only have one of a type of object.

Solution Keep a single instance and make the constructor private.

Example

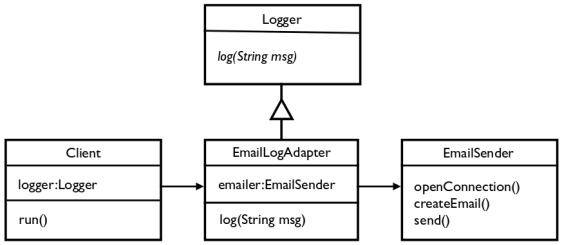
Drawbacks Accessing object requires tight coupling.

4.3 Structural Patterns

4.3.1 Adapter Pattern

Problem Have an X but need a Y. E.g. translate a message from a common format used in a message bus.

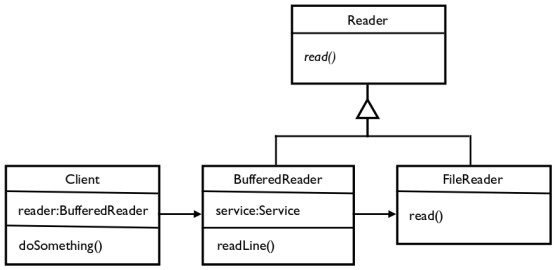
Example



4.3.2 Decorator Pattern

Problem Have an X but want a better X.

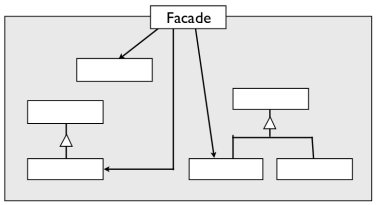
Example



4.3.3 Facade Pattern

Problem Have an X but want a simpler X.

Example



4.3.4 Proxy Pattern

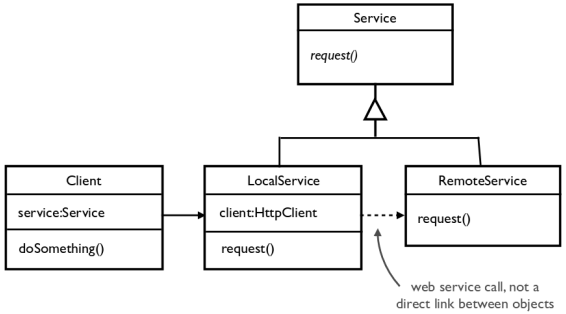
Problem I have an X but it's too slow.

Solution Control access to a surrogate object.

Points to Note

- You may need an **adaptor** to get an external service to implement the same interface as your proxy.
- The adapator should have a few **basic** tests.

Example



Extensions **Caching** can reduce latency of subsequent calls.

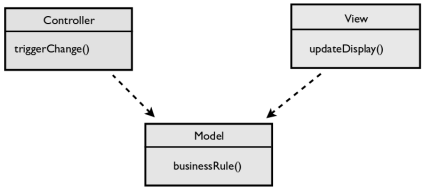
4.4 Architectural Styles

4.4.1 Model-View-Controller

Problem Same data but different views.

Solution Separation of concerns in interactive apps.

Example

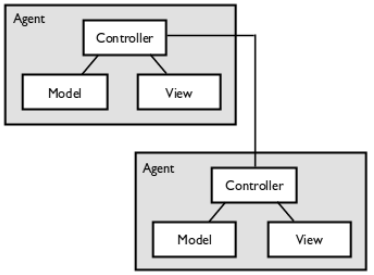


4.4.2 Presentation-Abstraction-Control

Problem GUIs with hierarchical structure.

Solution Define a tree of MVC agents that communicate up and down.

Example



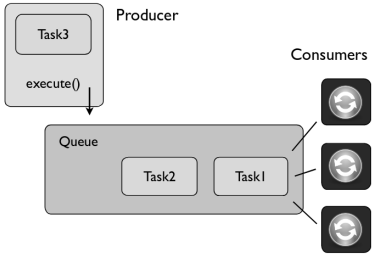
Alternative Use an event bus to allow communication between all agents.

4.4.3 Publish-Subscribe Pattern

Problem Producers and consumers / balancing load.

Solution Keep a queue of commands.

Example

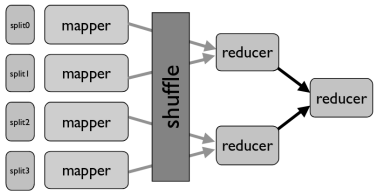


4.4.4 Map-Reduce Pattern

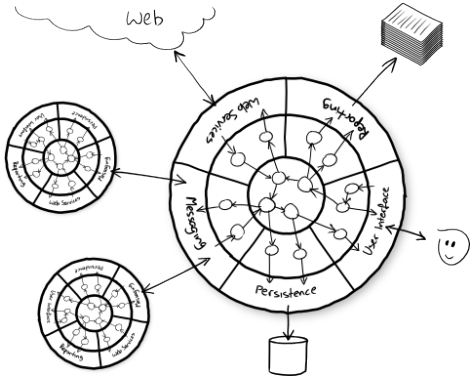
Problem Large scale data processing.

Solution Divide computation into map and reduce phases to allow easy parallelisation.

Example



4.4.5 Ports and Adapters / Hexagonal Architecture



- Separate core application logic from services which the application depends on.
- Access other services only through adapters.
- **Unit test** individual objects, mocking external services at the adapter level.
- **Integration test** the adapters.
- **System tests** run a small set of end-to-end test scenarios.

5 Metrics

Coupling

- **Afferent coupling**: How many other classes use (arrive at) this class (measures **responsibility**).
- **Efferent coupling**: How many classes are used by (exit) this class (measures **independence**).
- **Instability**: $Ce/(Ce + Ca)$. Core parts should be stable. Parts at the edges, e.g. UI, don't need to be.

Cyclomatic Complexity

- Counts nodes and edges in the control flow of a program (number of possible different executions).
- Gives lower bound on number of tests required.

WILT Whitespace Integrated over Lines of Text is strongly correlated with cyclomatic complexity.

ABC Metrics Counts occurrences of:

- Assignments
- Branches
- Conditions

Flog is an ABC metric tailored to Ruby. **Flay** identifies duplication.

Lifeline Graph complexity over time.

Turbulence Number of commits made to each file, compared against complexity of code.

6 Legacy Systems

Legacy system: software you have inherited and that is of value to you.

Key Ideas

- **Understand system structure**: dependency graphs / dependency structure matrices.
- **Preserve existing behaviour**: keep stuff that works and don't change too much.
- **Test harness**: introduce automated tests around any changes you make.
  - **Seams**: place where you can alter behaviour without editing it in that place.
  - Every seam has an **enabling point**: place where you can make the decision to use one behaviour or another.
  - **Sensing**: verify correct calls are made when we can't access values our code computes.

7 Concurrency

Key Ideas Try to separate code that manages threads and concurrent execution.

- Implementing `Runnable` instead of extending `Thread` reduces coupling.
- `Runnables` can be run synchronously or asynchronously.
- `Callables` can also return values and throw exceptions.
- `Executors` can maintain a queue of commands. Queues can act as load balancers.
- `ExecutorServices` allow us wait for all tasks to complete (or use a latch).
  - `ExecutorService executor = executors.newFixedThreadPool(n)`.
  - `Future future = executor.submit(callable)` (use a lambda to keep concise).
- `Futures` allow us to wait for a result (`future.get()`).
  - Need to `catch InterruptedException | ExecutionException`. In most cases, just `throw` a new `RuntimeException`.
- If no return value is expected, we can use `executor.shutdown()` and `executor.awaitTermination(n, timeUnit)`.

8 Interactive Applications

Graphical User Interfaces (Views)

- **Use** a `JFrame` (rather than **extending** it).
- Define a `JPanel`, to which we add `JButtons`, `JTextFields`, ...
- Add the panel to the frame using `frame.getContentPane().add(panel)`.
- Make the window appear using:
  - `frame.setSize(x, y)`.
  - `frame.setVisible(true)`.
  - `frame.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE)`.

Controller Use lambdas to implement `ActionListeners` that pass input to a model. E.g.

```
// Controller
private void addNumberButton(JPanel panel, int num) {
  JButton button = new JButton(Integer.toString(num));
  button.addActionListener(actionEvent -> model.input(num));
  panel.add(button);
}
```

Observers Your **view** should add itself as an (`Updatable`) **observer** of the **model**. E.g.

```
// View
private void display() {
  calculatorEngine.addObserver(this);
  ... setup display and make visible ...
}

@Override
public void updateWith(int value) {
  outputTextField.setText(Integer.toString(value));
}

// Model
public void addObserver(Updatable view) {
  observers.add(view);
}

private void notifyObservers(int value) {
  observers.forEach(observer -> observer.updateWith(value));
}
```

9 Web Applications

Key Ideas

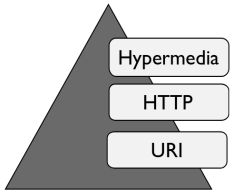
- **Serve data rather than pages**: providing an API. We can then:
  - Process and render (e.g. using AJAX) the data (to many clients).
  - Use it in another server side application.
- **Model** often involves business logic, data from DBs, etc.
- **Controller** has to handle **Routing** / **parameters** / GET and POST **requests**.

- Provide **views** (templates) for different clients.
- **Cloud** hosting often preferred to minimise responsibility/downtime and adapt quickly to demand.

10 Distribution and Remoting

Key Ideas

- Use **HTTP** (methods, status codes) to make requests.
- **REST** (Representational State Transfer): resources identified by URIs and have a representation (e.g. using XML or JSON).
- Hide away mechanics of how services are accessed.
- **Richardson maturity model**:



  - Level 0: Don't use URIs or different methods. Usually use a single URI.
  - Level 1: Use URIs to represent resources, but don't HTTP use methods.
  - Level 2: Use URIs and different methods, and return appropriate status codes.
  - Level 3: Fully RESTful. Representations contain hyperlinks to other resources. E.g. do a search for records rather than looking up a given record.

11 Continuous Delivery

Agile Methods E.g. Extreme Programming, Scrum, Kanban. Favour an iterative approach with **small development cycles**.

Continuous Integration Developers should merge in work often to avoid integration problems. Run automated tests to keep `master` healthy.