Modul - Fortgeschrittene Programmierkonzepte

Bachelor Informatik

08 - Design Patterns, pt. 2

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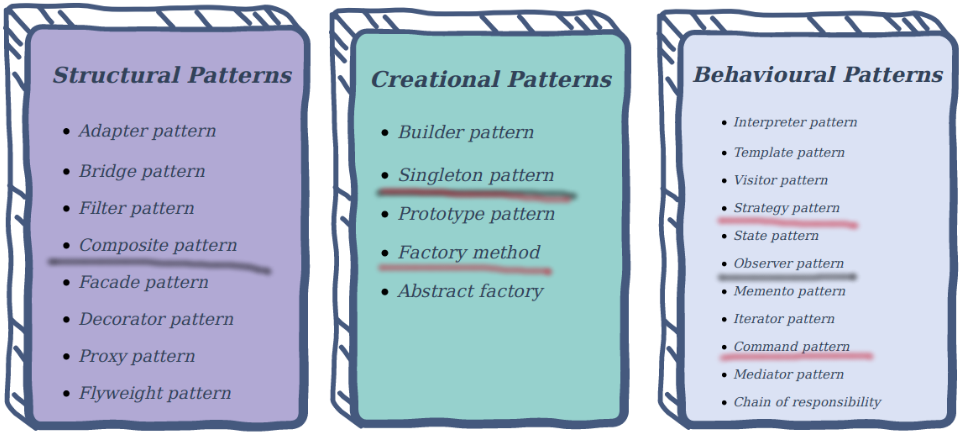
Agenda for today

What is on the menu for today?

- Singleton Pattern
- Strategy Pattern
- Factory Pattern
- Command Pattern



Singleton - Pattern

The task is pretty simple:

How can you ensure that a certain object is unique among your application?

Singleton in Java

In Java, there are a number of ways to realize that.

1. Restrict access to the constructor! Avoid that someone can create instances.
2. The safest thing to do is to make the constructor *private*.
3. If we can only create instances *from within the class*, we can allocate a static attribute at startup.

```java
class Singleton {
    public static final Singleton instance = new Singleton();

    private Singleton() {

    }
}
```

```java
Singleton.instance.doSomething();
```

Singleton in Java

This works ...

- ... if the constructor is trivial and no further setup of `instance` is required.

But what if you need to do some extra work for `instance` to be ready-to-use?

-> The answer is: use a *static initializer block*.

> And one more thing: the public visibility does not allow to guard the instance, e.g. from simultaneous access from multiple threads. To fix this, use a getter method.

Singleton in Java

```java
class Singleton {
    private final static Singleton instance;

    static {
        instance = new Singleton();

        // do more work...
    }

    private Singleton() {

    }

    public static Singleton getInstance() {
        // guard if necessary...
        return instance;
    }
}
```

> The drawback of this solution is that the singleton is now instantiated at startup, and regardless if it is actually used.

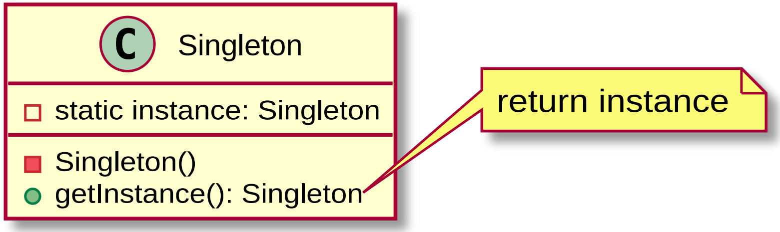
Singleton in Java

To fix this, use a lazy initializer:

```
class Singleton {
    private static Singleton instance;  // note: no final!

    public static Singleton getInstance() {
        if (instance == null) {
            instance = new Singleton();

            // do more stuff...
        }

        return instance;
    }

    private Singleton() {...}
}
```

Singleton

Structure and Participants



- `Singleton`
  - typically responsible for managing its unique instance
  - provides operation to obtain unique instance (in Java: `static` method)

Singleton

Discussion

- Singletons are standard practice to avoid resource conflicts or overallocation.
- However, they are at the same time (strongly) disencouraged if working in a multi-threaded (parallel) environment:
  - while the actual resource conflict can be (usually) solved with locking,
  - the process itself may dramatically reduce the benefit of parallel processing.

For advanced developers: Favor *dependency injection* over singletons.

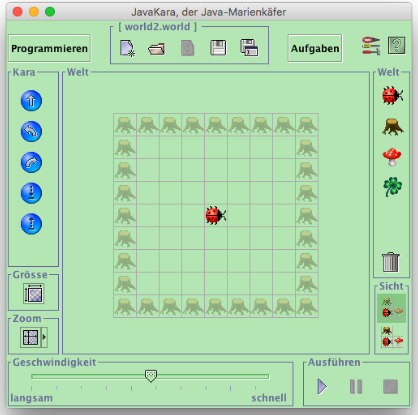
Singleton

Examples

- Logging facilities
- Event busses and dispatch queues
- Device handles (there is only 1 physical device, e.g. `System.out`)
- Service objects (eg. API wrappers, …)
- Helper classes

Strategy-Pattern

Strategy - Pattern



The *strategy* pattern helps to abstract a certain method from its actual implementation. It is so fundamental to Java that it has the syntax keyword `interface` to separate *declarations* from *implementations*.

Do you have an example where you have used a *strategy* pattern already?

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Simple Example (Sorting)

Sort a list in ascending or descending order, using different `Comparator<T>`s.

```
List<Integer> list = new LinkedList<>();
list.add(4); list.add(7); list.add(1); list.add(1);

Collections.sort(list, new Comparator<Integer>() {
    @Override
    public compare(Integer a, Integer b) {
        return a.compareTo(b);
    }
});

Collections.sort(list, new Comparator<Integer>() {
    @Override
    public compare(Integer a, Integer b) {
        return b.compareTo(a);  // note the flipped order!
    }
});
```

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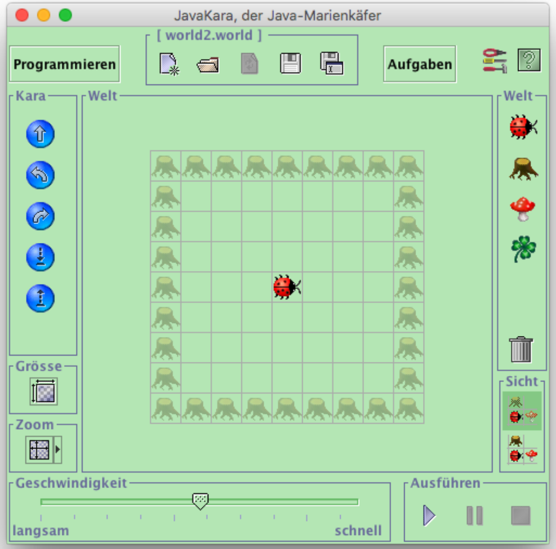
Other Example (Game)

Check out JavaKara, a little robot bug that can be moved through a tiny world.



Strategy with Kara

Here is a small code snippet to get Kara working:

```java
public class Kara extends JavaKaraProgram {
    public static void main(String[] args) throws Exception {
        Kara k = new Kara();
        k.run("src/main/resources/world2.world");
    }

    @Override
    public void myMainProgram() {
        kara.move();         // one step forward
        kara.turnLeft();     // you guessed it...
        kara.turnRight();
        kara.treeFront();    // tree ahead?
        kara.putLeaf();      // take a clover leaf
        kara.removeLeav();   // remove a clover leaf
    }
}
```

What is the strategy to place leafs on every field?

Strategy

My Strategy thinking:

To have *kara* explore the whole room (starting from the center), I could think of two *strategies*:

- walk concentric growing circles until the room is fully explored
- walk to the top-right corner; then sweep left-to-right, top-to-bottom.

The sample code can be found in https://github.com/hsro-inf-fpk/hsro-inf-fpk.github.io/tree/master/examples/src/main/java/designpattern/strategy.

Check out the `StrategyExampleBad`, which has two explicit plans,

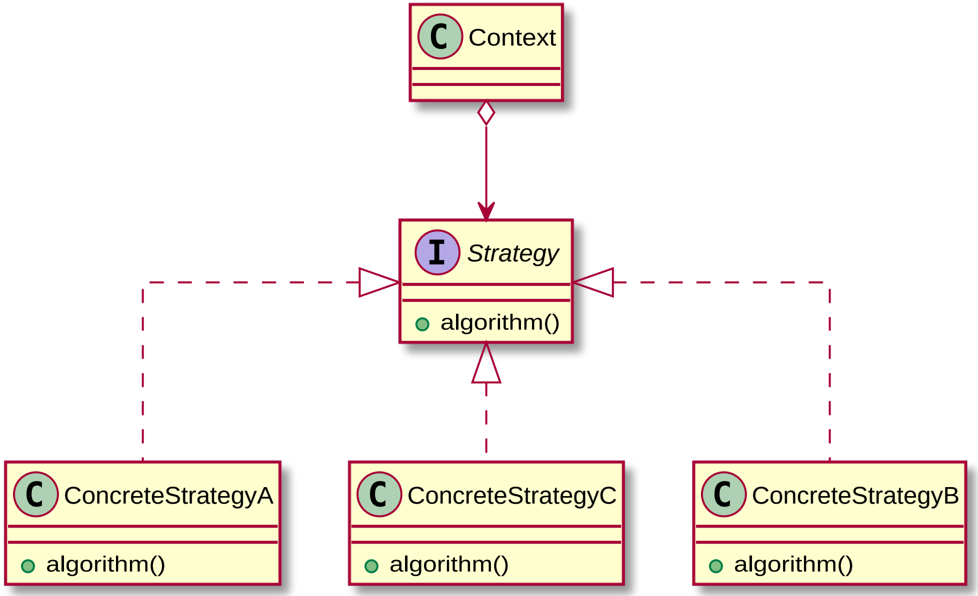
1. `planA()` and
2. `planB()`.

Contrast it with the implementation in `StrategyExample`: here, the logic of the strategy is moved to a separate class which is instantiated as needed.

Strategy

Structure and Participants

Mechanism to provide different implementations to achieve the same outcome.



Strategy

Discussion

The strategy pattern is used to represent a similar functionality with different implementations: For example, the `Stream.filter(Predicate<T> p)`, `Iterable.iterator()` or `Collection.sort(Comparator<T> c)`.

You can easily spot potential refactoring areas if you have code such as

```
if (isWav())
    return decodeWav(data);
else if (isMP3())
    return decodeMP3(data);
else
    return data.raw;
```

with the `decode{Wav,MP3}()` methods being members of the class. Refactor to the strategy pattern by extracting them from the class and use them via a common interface.

Strategy

Examples

- `Comparator` interface, to customize sorting
- Encryption and authentication protocols
- Media encoders (mp3, mp4, aac, etc.)
- Serializers ("save as..." feature)

Do you have other examples?

Factory

A factory provides instances that fulfill a certain interface.

Factory

Simple Example

A package with public interfaces but package-private classes.

```java
package mypackage;

public interface Klass {
    void method();
}
```

```java
package mypackage;

class KlassImpl implements Klass {
    public void method() {
        System.out.println("Hello World!");
    }
}
```

Factory

Simple Example

So from outside the package, you can't instanciate `KlassImpl`:

```
package someApp;
class MyApp {
    public static void main(String... args) {
        mypackage.Klass k = new mypackage.KlassImpl();  // not visible!
    }
}
```

> **This is where you need a factory method, often attached to an abstract class or as a default method to an interface.**

Factory

Simple Example

```
package mypackage;

public interface Klass {
    void method();
    default Klass create() {
        return new KlassImpl();  // inside package: visible!
    }
}
```

```
mypackage.Klass k = mypackage.Klass.create();
```

As you can see, the *user* of the package relies on the interface, and has no idea on which class was actually instantiated.

Factory

Another Example

Recall the `Composite` pattern and the strcuture of JSON document and XML:

```
{
    "key": "value",
    "nested": {
        "key": "value"
    }
}
```

```
<element>
    <key>value</key>
    <element>
        <key>value</key>
    </element>
</element>
```

Factory

Another Example

With Java interfaces this could look like:

```
interface Component {
    String toString();
}

interface Composite extends Component {
    void add(Component c);
}

interface Leaf extends Component {
}
```

Factory

Another Example

Without a factory, you would have to manually construct the composite:

```
JsonComposite root = new JsonComposite("root");
root.add(new JsonLeaf("key", "value"));

Composite nested = new JsonComposite("nested");
nested.add(new JsonLeaf("key", "value"));
root.add(nested);

System.out.println(root);
// "root": {"key": "value", "nested": {"key": "value"}}
```

And similarly for `XmlComposite`.

Factory

Another Example

If you abstract the instance creation into a factory, you could generalize the code significantly (for JSON and XML):

```
interface CompositeFactory {
    Composite createComposite(String name);
    Leaf createLeaf(String name, String value);
}
class JsonFactory implements CompositeFactory {
    @Override
    public Composite createComposite(String name) {
        return new JsonComposite(name);
    }
    @Override
    public Leaf createLeaf(String name, String value) {
        return new JsonLeaf(name, value);
    }
}
```

Factory

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Another Example

And now, you can use it:

```
CompositeFactory f = new JsonFactory();
// CompositeFactory f = new XmlFactory();

Composite root = f.createComposite("root");
root.add(f.createLeaf("key", "value"));

Composite nested = f.createComposite("nested");
nested.add(f.createLeaf("key", "value"));

root.add(nested);

System.out.println(root);
```

In case, you want to get the XML representation, you only need to replace the factory that produces the concrete clases; the construction logic remains the same.

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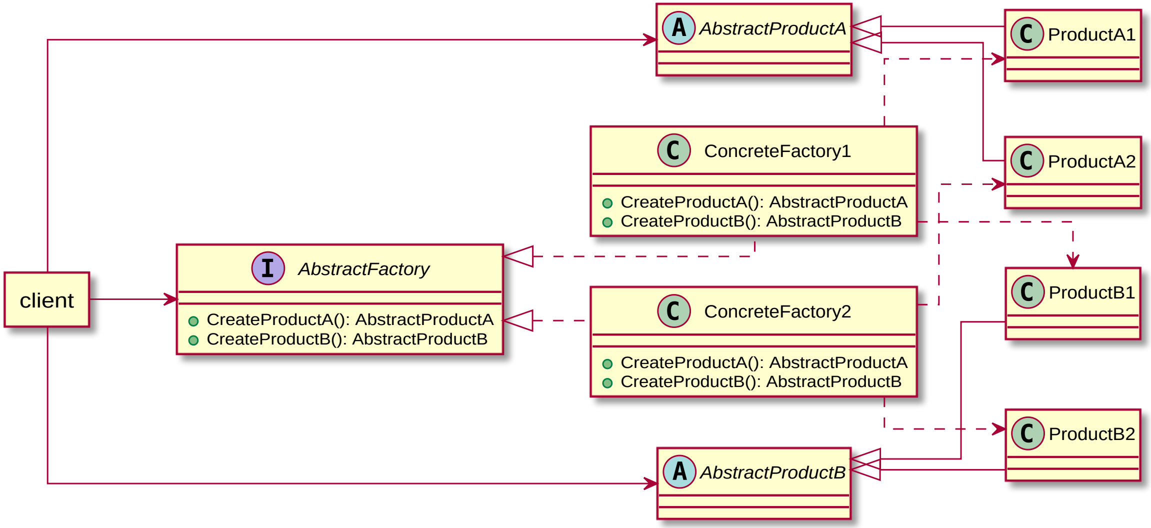
Structure and Participants

Structure to enforce the use of abstract factories and products, by hiding the actual instantiation of the concrete factory and products.



Structure and Participants

- `AbstractFactory`
  - declares interface for operations that create the abstract products
- `ConcreteFactory`
  - *implements* the operations and procudes concrete products
- `AbstractProduct`
  - declares interface for operations
- `ConcreteProduct`
  - *implements* the operations
- `Client`
  - uses only interfaces declared by `AbstractFactory` and `AbstractProduct`

Factory

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Discussion

- The factory pattern is omnipresent:
    - sometimes it is realized as a single *factory method*
    - sometimes as a larger factory serving different objects.

The most common use is when developing against interfaces where the implementing classes are package-private.

The package would then expose a *factory* that allows to generate instances that implement the public interfaces -- with internals hidden from the client.

Factory

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Examples

Typically objects that are either complicated to instantiate or which should not be exposed outside of a package.

- Iterators
- Objects that have complex intantiation protocols
- Logging instances
- API wrappers

Command

Mechanism to organize, execute and undo operations on certain objects.

Command

Example - Kara

We could write a program that takes input from the command line and uses that to direct *kara* around.

```
public class InteractiveKara extends JavaKaraProgram {
    public static void main(String[] args) throws IOException {
        ...
            try {
                switch ((char) c) {
                    case 'm': program.kara.move(); break;
                    case 'l': program.kara.turnLeft(); break;
                    case 'r': program.kara.turnRight(); break;
                        case 't': program.kara.removeLeaf(); break;
                    case 'd': program.kara.putLeaf(); break;
                }
            } catch (RuntimeException e) {
                System.out.println(e);
                System.exit(0);
            }...
```

Command

Example

> Note the `try ... catch` for `RuntimeException`: this happens if you have *kara* walk into a tree, or try to pick up a leaf where there is none.

So here is the problem: The above program works nicely until we hit a tree or otherwise raise an exception, at which point the while application is **terminated**.

Can you think of a mechanism that instead allows us to back-track where we came from?

(if we screw up, can we undo the previous moves?)

Command

Example

> Note the `try ... catch` for `RuntimeException`: this happens if you have *kara* walk into a tree, or try to pick up a leaf where there is none.

So here is the problem: The above program works nicely until we hit a tree or otherwise raise an exception, at which point the while application is **terminated**.

Can you think of a mechanism that instead allows us to back-track where we came from?

(if we screw up, can we undo the previous moves?)

We can, if we take care of the following aspects:

- for every action, we need to know the reverse
- we need to keep track of every successful action
- (optionally) we can manually "forget" our history, if we're at a good place.

Command

Example

Keeping track of past commands is covered by the command pattern. Instead of directly calling the actions on kara, we make *objects* that will do the actual work:

```
interface Command {
    void execute();
    default void undo() {
        throw new UnsupportedOperationException();
    }
}
```

Now, if we keep a journal (stack) of commands, it is easy to go back: just remove them one-by-one and call `.undo()`.

Command

Example

```
class MoveCommand implements Command {
    private JavaKaraProgram.JavaKara kara;
    public MoveCommand(JavaKaraProgram.JavaKara kara) {
        this.kara = kara;
    }
    @Override
    public void execute() {
        kara.move();
    }
    @Override
    public void undo() {
        // turn back, move
        new TurnCommand(kara, 2).execute();
        kara.move();
        // turn to original direction
        new TurnCommand(kara, 2).execute();
    }
}
```

Command

```java
public class CommandExample extends JavaKaraProgram {
    public static void main(String[] args) throws IOException {
        ...
        // this will keep track of the successful commands
        Stack<Command> history = new Stack<>();
        while ((c = System.in.read()) != -1) {
            // ...
            Command cmd = new IdleCommand();
            switch ((char) c) {
                case 'm': cmd = new MoveCommand(program.kara); break;
                case 'l': cmd = new TurnCommand(program.kara, -1); break;
                // ...
            }
            try {
                cmd.execute();
                history.push(cmd);
            } catch (RuntimeException e) {
                // go back to beginning, restart
                while (history.size() > 0) history.pop().undo();
            }
 ...}
```

Command

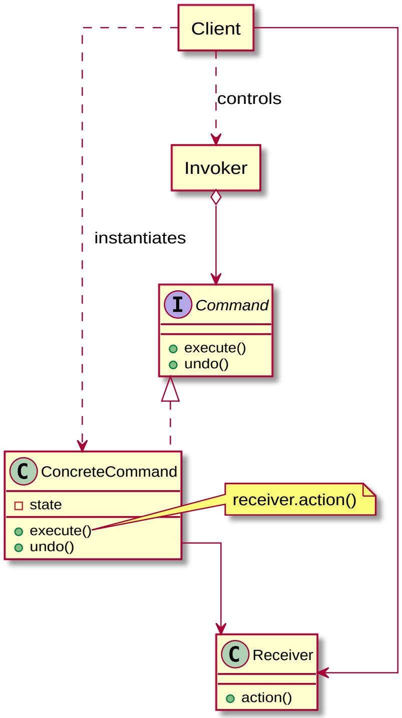
Example

The complete example code can be found at

https://inf-git.fh-rosenheim.de/inf-fpk/hsro-inf-fpk-github-io/-/tree/master/examples/src/main/java/designpattern/command.

Command: UML

Structure and Participants



Command

Structure and Participants

- `Command`
  - declares an interface for executing an operation
- `ConcreteCommand`
  - *implements* the operation
  - uses the receiver as needed
- `Client` (application)
  - creates `ConcreteCommand` and hands receiver
- `Invoker`
  - actually calls `.execute()`
- `Receiver`
  - the object used by the strategy

Command

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Discussion

The command pattern is more frequent than you might initially think.

Think of it this way:

- whenever you allow the user to sequentially apply certain commands to your data/state, you may want to be able to undo those at some point.
- Building up a stack of actions automatically leads to adopting the command pattern.

Command

Examples

- Editors that support undo or macros
- Databases with transaction/rollback support
- Filesystems with journalling
- Version control (eg. git)

Summary

Lessons learned for today ...

- ... the Singleton pattern
- ... the Factory pattern
- ... Strategy pattern
- ... Command pattern

Final Thought!