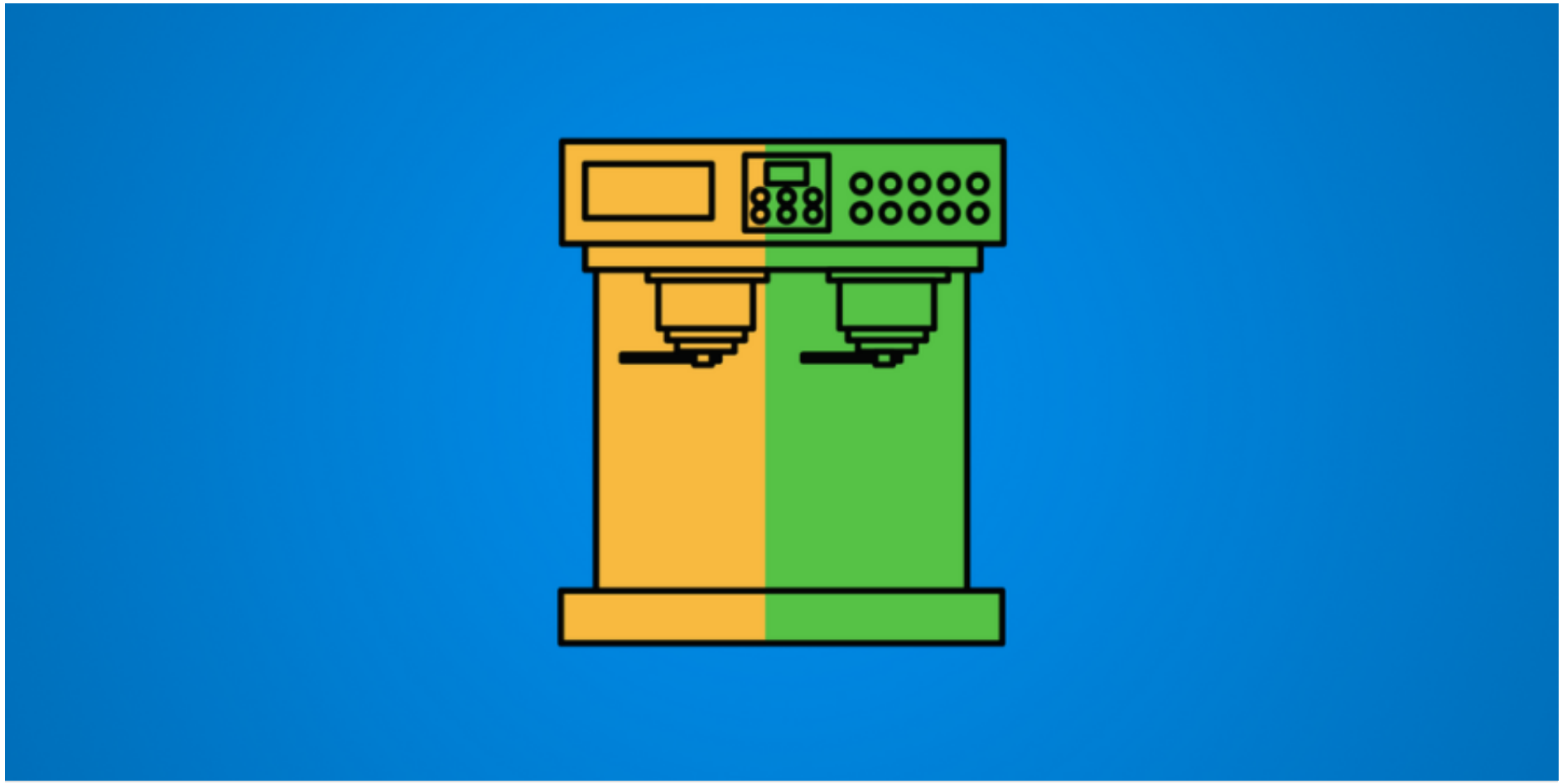

SOLID Design Principles Explained: Dependency Inversion Principle with Code Examples

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The SOLID design principles were promoted by Robert C. Martin (http://blog.cleancoder.com/) and are some of the best-known design principles in object-oriented software development. SOLID is a mnemonic acronym for the following five principles:

- **S** (https://stackify.com/solid-design-principles/)ingle Responsibility Principle (https://stackify.com/solid-design-principles/)
- **O** (https://stackify.com/solid-design-open-closed-principle/)pen/Closed Principle (https://stackify.com/solid-design-open-closed-principle/)
- **L** (https://stackify.com/solid-design-liskov-substitution-principle/%20target=)iskov Substitution Principle (https://stackify.com/solid-design-liskov-substitution-principle/)
- **I** (https://stackify.com/interface-segregation-principle/)nterface Segregation Principle (https://stackify.com/interface-segregation-principle/)
- **D**ependency Inversion Principle

Each of these principles can stand on its own and has the goal to improve the robustness and maintainability of object-oriented applications and software components. But they also add to each other so that applying all of them makes the implementation of each principle easier and more effective.

I explained the first four design principles in previous articles. In this one, I will focus on the Dependency Inversion Principle. It is based on the Open/Closed Principle (https://stackify.com/solid-design-open-closed-principle/) and the Liskov Substitution Principle (https://stackify.com/solid-design-liskov-substitution-principle/). You should, therefore, at least be familiar with these two principles, before you read this article.

Definition of the Dependency Inversion Principle

The general idea of this principle is as simple as it is important: High-level modules, which provide complex logic, should be easily reusable and unaffected by changes in low-level modules, which provide utility features. To achieve that, you need to introduce an abstraction that decouples the high-level and low-level modules from each other.

Based on this idea, Robert C. Martin's definition of the Dependency Inversion Principle consists of two parts:

1. High-level modules should not depend on low-level modules. Both should depend on abstractions.
2. Abstractions should not depend on details. Details should depend on abstractions.

An important detail of this definition is, that high-level **and** low-level modules depend on the abstraction. The design principle does not just change the direction of the dependency, as you might have expected when you read its name for the first time. It splits the dependency between the high-level and low-level modules by introducing an abstraction between them. So in the end, you get two dependencies:

1. the high-level module depends on the abstraction, and
2. the low-level depends on the same abstraction.

Based on other SOLID principles

This might sound more complex than it often is. If you consequently apply the Open/Closed Principle and the Liskov Substitution Principle to your code, it will also follow the Dependency Inversion Principle.

The Open/Closed Principle required a software component to be open for extension, but closed for modification. You can achieve that by introducing interfaces for which you can provide different implementations. The interface itself is closed for modification, and you can easily extend it by providing a new interface implementation.

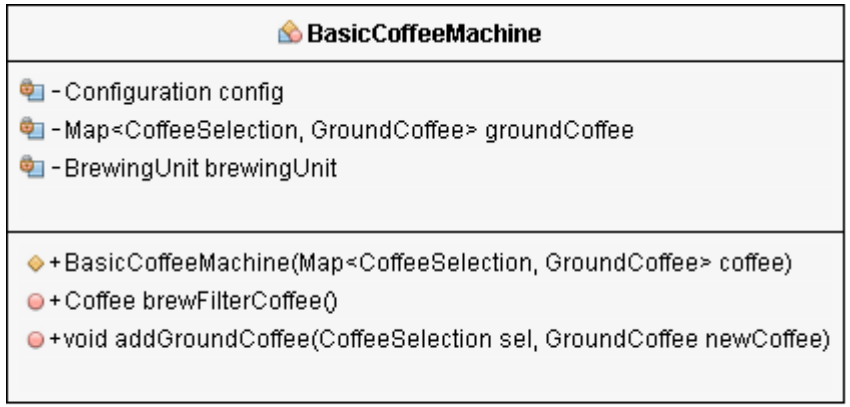
Your implementations should follow the Liskov Substitution Principle so that you can replace them with other implementations of the same interface without breaking your application.

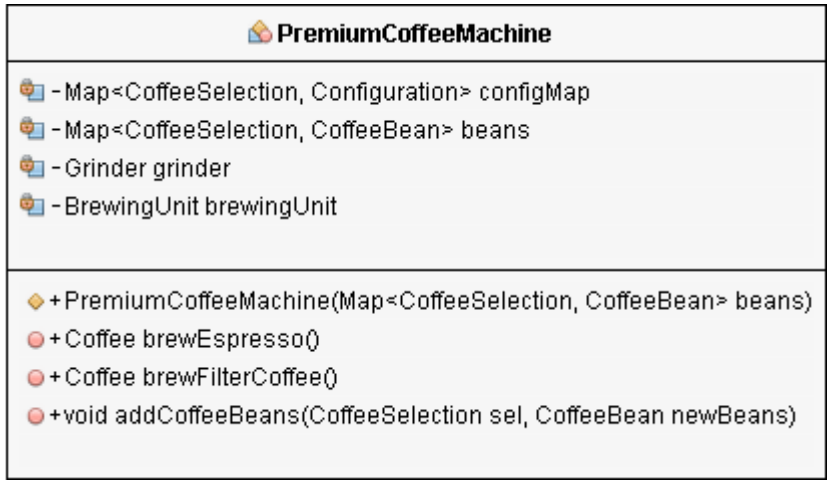
Let's take a look at the CoffeeMachine project in which I will apply all three of these design principles.

Brewing coffee with the Dependency Inversion Principle

You can buy lots of different coffee machines. Rather simple ones that use water and ground coffee to brew filter coffee, and premium ones that include a grinder to freshly grind the required amount of coffee beans and which you can use to brew different kinds of coffee.

If you build a coffee machine application that automatically brews you a fresh cup of coffee in the morning, you can model these machines as a *BasicCoffeeMachine* and a *PremiumCoffeeMachine* class.





Implementing the *BasicCoffeeMachine*

The implementation of the *BasicCoffeeMachine* is quite simple. It only implements a constructor and two public methods. You can call the *addGroundCoffee* method to refill ground coffee, and the *brewFilterCoffee* method to brew a cup of filter coffee.

```
import java.util.Map;
import(

public class BasicCoffeeMachine implements CoffeeMachine {

    private Configuration config;
    private Map<CoffeeSelection, GroundCoffee> groundCoffee;
    private BrewingUnit brewingUnit;

    public BasicCoffeeMachine(Map<CoffeeSelection, GroundCoffee> coffee).
        this.groundCoffee = coffee;
        this.brewingUnit = new BrewingUnit();
        this.config = new Configuration(30, 480);
    }

    @Override
    public Coffee brewFilterCoffee() {
        // get the coffee
        GroundCoffee groundCoffee = this.groundCoffee.get(CoffeeSelection.FILTER_COFFEE);
        // brew a filter coffee
       return this.brewingUnit.brew(CoffeeSelection.FILTER_COFFEE, groundCoffee, this.config.get
QuantityWater());
    }

    public void addGroundCoffee(CoffeeSelection sel, GroundCoffee newCoffee) throws CoffeeExcept
ion {
        GroundCoffee existingCoffee = this.groundCoffee.get(sel);
        if (existingCoffee != null) {
```

```
            if (existingCoffee.getName().equals(newCoffee.getName())) {
                existingCoffee.setQuantity(existingCoffee.getQuantity() + newCoffee.getQuantity
())
            } else {
                throw new CoffeeException("Only one kind of coffee supported for each CoffeeSele
ction.")
            }
        } else {
            this.groundCoffee.put(sel, newCoffee)
        }
    }
}
```

Implementing the *PremiumCoffeeMachine*

The implementation of the *PremiumCoffeeMachine* class looks very similar. The main differences are:

- It implements the *addCoffeeBeans* method instead of the *addGroundCoffee* method.
- It implements the additional *brewEspresso* method.

The *brewFilterCoffee* method is identical to the one provided by the *BasicCoffeeMachine*.

```
import java.util.HashMap;
import java.util.Map;

public class PremiumCoffeeMachine {
    private Map<CoffeeSelection, Configuration> configMap;
    private Map<CoffeeSelection, CoffeeBean> beans;
    private Grinder grinder
    private BrewingUnit brewingUnit;

    public PremiumCoffeeMachine(Map<CoffeeSelection, CoffeeBean> beans) {
        this.beans = beans;
        this.grinder = new Grinder();
        this.brewingUnit = new BrewingUnit();
        this.configMap = new HashMap<>();
        this.configMap.put(CoffeeSelection.FILTER_COFFEE, new Configuration(30, 480));
        this.configMap.put(CoffeeSelection.ESPRESSO, new Configuration(8, 28));
    }

    public Coffee brewEspresso() {
        Configuration config = configMap.get(CoffeeSelection.ESPRESSO);
        // grind the coffee beans
        GroundCoffee groundCoffee = this.grinder.grind(
            this.beans.get(CoffeeSelection.ESPRESSO),
            config.getQuantityCoffee())
        // brew an espresso
        return this.brewingUnit.brew(CoffeeSelection.ESPRESSO, groundCoffee,
            config.getQuantityWater());
```

```
        }
        throw(
    public Coffee brewFilterCoffee() {
        Configuration config = configMap.get(CoffeeSelection.FILTER_COFFEE);
        // grind the coffee beans
        GroundCoffee groundCoffee = this.grinder.grind(
            this.beans.get(CoffeeSelection.FILTER_COFFEE),
            config.getQuantityCoffee());
        // brew a filter coffee
        return this.brewingUnit.brew(CoffeeSelection.FILTER_COFFEE, groundCoffee,
            config.getQuantityWater());
    }

    public void addCoffeeBeans(CoffeeSelection sel, CoffeeBean newBeans) throws CoffeeException
{
        CoffeeBean existingBeans = this.beans.get(sel);
        if (existingBeans != null) {
            if (existingBeans.getName().equals(newBeans.getName())) {
                existingBeans.setQuantity(existingBeans.getQuantity() + newBeans.getQuantity());
            } else {
                throw new CoffeeException("Only one kind of coffee supported for each CoffeeSele
ction.");
            }
         } else {
             this.beans.put(sel, newBeans);
         }
    }
}
```

To implement a class that follows the Dependency Inversion Principle and can use the *BasicCoffeeMachine* or the *PremiumCoffeeMachine* class to brew a cup of coffee, you need to apply the Open/Closed and the Liskov Substitution Principle. That requires a small refactoring during which you introduce interface abstractions for both classes.

Introducing abstractions

The main task of both coffee machine classes is to brew coffee. But they enable you to brew different kinds of coffee. If you use a *BasicCoffeeMachine*, you can only brew filter coffee, but with a *PremiumCoffeeMachine*, you can brew filter coffee or espresso. So, which interface abstraction would be a good fit for both classes?

As all coffee lovers will agree, there are huge differences between filter coffee and espresso (https://www.perfectdailygrind.com/2017/07/espresso-vs-filter-whats-difference/). That's why we are using different machines to brew them, even so, some machines can do both. I, therefore, suggest to create two independent abstractions:

- The *FilterCoffeeMachine* interface defines the *Coffee brewFilterCoffee()* method and gets implemented by all coffee machine classes that can brew a filter coffee.
- All classes that you can use to brew an espresso, implement the *EspressoMachine* interface, which defines the *Coffee brewEspresso()* method.

As you can see in the following code snippets, the definition of both interface is pretty simple.

```
public interface CoffeeMachine {
    Coffee brewFilterCoffee();
}

public interface EspressoMachine {
    Coffee brewEspresso();
}
```

In the next step, you need to refactor both coffee machine classes so that they implement one or both of these interfaces.

Refactoring the *BasicCoffeeMachine* class

Let's start with the *BasicCoffeeMachine* class. You can use it to brew a filter coffee, so it should implement the *CoffeeMachine* interface. The class already implements the *brewFilterCoffee()* method. You only need to add *implements CoffeeMachine* to the class definition.

```
public class BasicCoffeeMachine implements CoffeeMachine {
    private Configuration config;
    private Map<CoffeeSelection, GroundCoffee> groundCoffee;
    private BrewingUnit brewingUnit;

    public BasicCoffeeMachine(Map<CoffeeSelection, GroundCoffee> coffee) {
        this.groundCoffee = coffee;
        this.brewingUnit = new BrewingUnit();
        this.config = new Configuration(30, 480);
    }

    @Override
    public Coffee brewFilterCoffee() {
        // get the coffee
        GroundCoffee groundCoffee = this.groundCoffee.get(CoffeeSelection.FILTER_COFFEE);
        // brew a filter coffee
        return this.brewingUnit.brew(CoffeeSelection.FILTER_COFFEE, groundCoffee, this.config.ge
tQuantityWater());
    }

    public void addGroundCoffee(CoffeeSelection sel, GroundCoffee newCoffee) throws CoffeeExcept
ion {
        GroundCoffee existingCoffee = this.groundCoffee.get(sel);
        if (existingCoffee != null) {
            if (existingCoffee.getName().equals(newCoffee.getName())) {
                existingCoffee.setQuantity(existingCoffee.getQuantity() + newCoffee.getQuantity
());
```

```
            } else {
                throw new CoffeeException("Only one kind of coffee supported for each CoffeeSelecti
on.");
            }
        } else {
            this.groundCoffee.put(sel, newCoffee);
        }
    }
}
```


Refactoring the *PremiumCoffeeMachine* class

The refactoring of the *PremiumCoffeeMachine* also doesn't require a lot of work. You can use the coffee machine to brew filter coffee and espresso, so the *PremiumCoffeeMachine* class should implement the *CoffeeMachine* and the *EspressoMachine* interfaces. The class already implements the methods defined by both interfaces. You just need to declare that it implements the interfaces.

```
import java.util.HashMap;
import java.util.Map;

public class PremiumCoffeeMachine implements CoffeeMachine, EspressoMachine {
    private Map<CoffeeSelection, Configuration> configMap;
    private Map<CoffeeSelection, CoffeeBean> beans;
    private Grinder grinder;
    private BrewingUnit brewingUnit;

    public PremiumCoffeeMachine(Map<CoffeeSelection, CoffeeBean> beans) {
        this.beans = beans;
        this.grinder = new Grinder();
        this.brewingUnit = new BrewingUnit();
        this.configMap = new HashMap<>();
        this.configMap.put(CoffeeSelection.FILTER_COFFEE, new Configuration(30, 480));
        this.configMap.put(CoffeeSelection.ESPRESSO, new Configuration(8, 28));
    }

    @Override
    public Coffee brewEspresso() {
        Configuration config = configMap.get(CoffeeSelection.ESPRESSO);
        // grind the coffee beans
        GroundCoffee groundCoffee = this.grinder.grind(
           this.beans.get(CoffeeSelection.ESPRESSO),
           config.getQuantityCoffee());
       // brew an espresso
       return this.brewingUnit.brew(CoffeeSelection.ESPRESSO, groundCoffee,
```

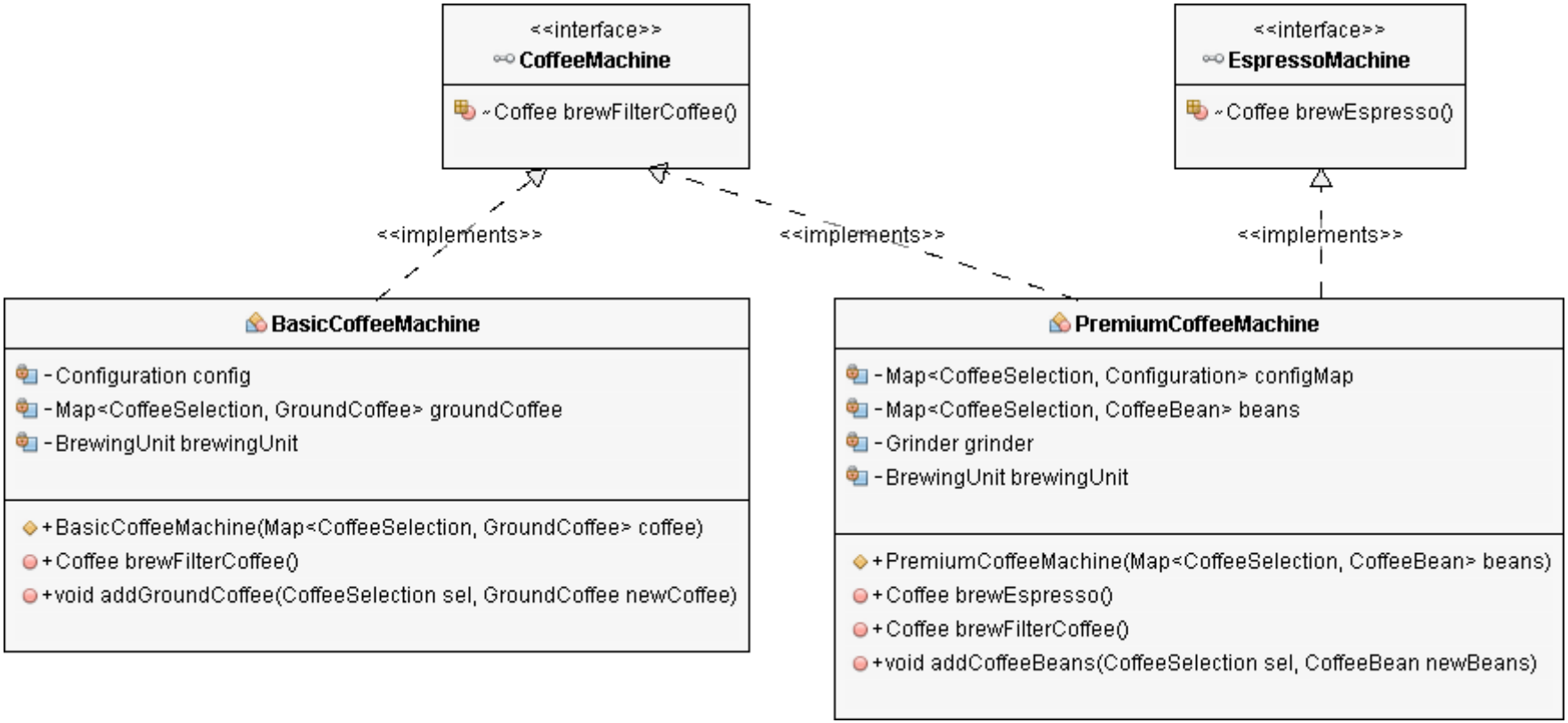
```
            config.getQuantityWater());
    }

    @Override
    public Coffee brewFilterCoffee() {
        Configuration config = configMap.get(CoffeeSelection.FILTER_COFFEE);
        // grind the coffee beans
        GroundCoffee groundCoffee = this.grinder.grind(
            this.beans.get(CoffeeSelection.FILTER_COFFEE),
            config.getQuantityCoffee());
        // brew a filter coffee
        return this.brewingUnit.brew(CoffeeSelection.FILTER_COFFEE,
            groundCoffee,config.getQuantityWater());
    }

    public void addCoffeeBeans(CoffeeSelection sel, CoffeeBean newBeans) throws CoffeeException
{
        CoffeeBean existingBeans = this.beans.get(sel);
        if (existingBeans != null) {
            if (existingBeans.getName().equals(newBeans.getName())) {
                existingBeans.setQuantity(existingBeans.getQuantity() + newBeans.getQuantity());
            } else {
                throw new CoffeeException("Only one kind of coffee supported for each CoffeeSele
ction.");
            }
        } else {
            this.beans.put(sel, newBeans);
        }
```

```
    }
}
```

The *BasicCoffeeMachine* and the *PremiumCoffeeMachine* classes now follow the Open/Closed and the Liskov Substitution principles. The interfaces enable you to add new functionality without changing any existing code by adding new interface implementations. And by splitting the interfaces into *CoffeeMachine* and *EspressoMachine*, you separate the two kinds of coffee machines and ensure that all *CoffeeMachine* and *EspressMachine* implementations are interchangeable.



Implementing the coffee machine application

You can now create additional, higher-level classes that use one or both of these interfaces to manage coffee machines without directly depending on any specific coffee machine implementation.

As you can see in the following code snippet, due to the abstraction of the *CoffeeMachine* interface and its provided functionality, the implementation of the *CoffeeApp* is very simple. It requires a *CoffeeMachine* object as a constructor parameter and uses it in the *prepareCoffee* method to brew a cup of filter coffee.

public class CoffeeApp {

```
public class CoffeeApp {
    private CoffeeMachine coffeeMachine;

    public CoffeeApp(CoffeeMachine coffeeMachine) {
     this.coffeeMachine = coffeeMachine
    }

    public Coffee prepareCoffee() throws CoffeeException {
        Coffee coffee = this.coffeeMachine.brewFilterCoffee();
        System.out.println("Coffee is ready!");
        return coffee;
    }
}
```

The only code that directly depends on one of the implementation classes is the *CoffeeAppStarter* class, which instantiates a *CoffeeApp* object and provides an implementation of the *CoffeeMachine* interface. You could avoid this compile-time dependency entirely by using a dependency injection framework, like Spring (https://spring.io/) or CDI (http://cdi-spec.org/), to resolve the dependency at runtime.

```
import java.util.HashMap;
import java.util.Map;

public class CoffeeAppStarter {
    public static void main(String[] args) {
        // create a Map of available coffee beans
        Map<CoffeeSelection, CoffeeBean> beans = new HashMap<CoffeeSelection, CoffeeBean>();
        beans.put(CoffeeSelection.ESPRESSO, new CoffeeBean(
            "My favorite espresso bean", 1000));
        beans.put(CoffeeSelection.FILTER_COFFEE, new CoffeeBean(
             "My favorite filter coffee bean", 1000))
        // get a new CoffeeMachine object
        PremiumCoffeeMachine machine = new PremiumCoffeeMachine(beans);
        // Instantiate CoffeeApp
        CoffeeApp app = new CoffeeApp(machine);
        // brew a fresh coffee
        try {
           app.prepareCoffee();
        } catch (CoffeeException e) {
            e.printStackTrace();
        }
    }
}
```

Summary

The Dependency Inversion Principle is the fifth and final design principle that we discussed in this series. It introduces an interface abstraction between higher-level and lower-level software components to remove the dependencies between them.

As you have seen in the example project, you only need to consequently apply the Open/Closed and the Liskov Substitution principles to your code base. After you have done that, your classes also comply with the Dependency Inversion Principle. This enables you to change higher-level and lower-level components without affecting any other classes, as long as you don't change any interface abstractions.

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