SOLID principles - Liskov, Interface Segregation, and Dependency Inversion

Key Terms

Liskov Substitution Principle

> Objects in a program should be replaceable with instances of their subtypes without altering the correctness of that program.

Interface Segregation Principle

> Many client-specific interfaces are better than one general-purpose interface.

Dependency Inversion Principle

> Depend upon abstractions. Do not depend upon concrete classes.

Liskov Substitution Principle

Let us take a look at our final version of the `Bird` class from the last session. We started with a `Bird` class which had SRP and OCP violations. We now have a `Bird` abstract class which can be extended by the `Eagle` , `Penguin` and `Parrot` subclasses.

```
classDiagram
    Bird <|-- Eagle
    Bird <|-- Penguin
    Bird <|-- Parrot
    class Bird{
        +weight: int
        +colour: string
        +type: string
        +size: string
        +beakType: string
        +fly()
    }
    class Eagle{
        +fly()
    }
    class Penguin{
        +fly()
    }
    class Parrot{
        +fly()
    }
```

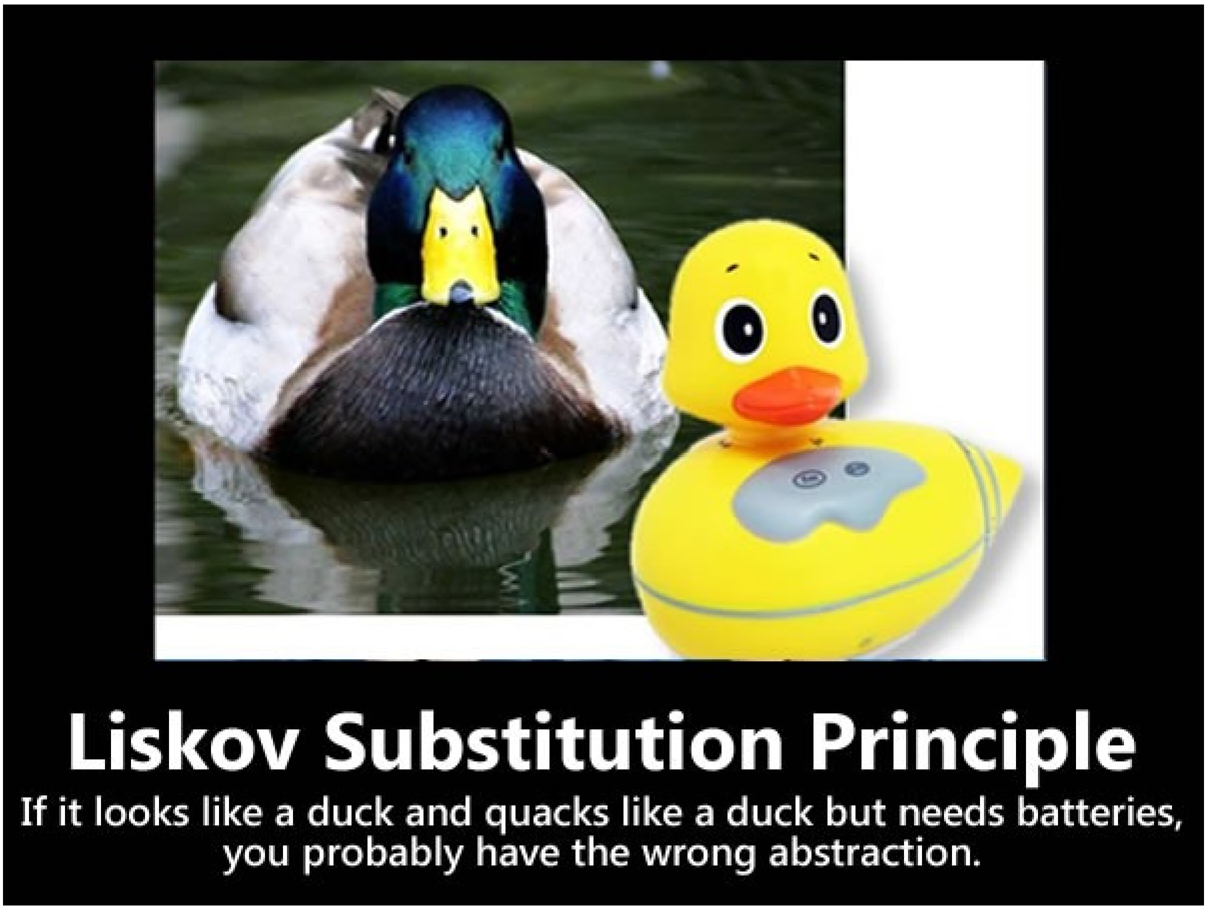
We have also added a `fly()` method to the `Bird` class. All the subclasses of `Bird` have to implement this method. A penguin cannot fly, yet we have added a `fly()` method to the `Penguin` class. How can we handle this?

- `Dummy method` - We can add a dummy method to the `Penguin` class which does nothing.
- `Return null`
- `Throw an exception`

In the above methods, we are trying to force a contract on a class which does not follow it. If we try to use a `Penguin` object in a place where we expect a `Bird` object, we could have unexpected outcomes. For example, if we call the `fly()` method on a `Penguin` object, we would get an exception. This is not what we want. We want to be able to use a `Penguin` object in a place where we expect a `Bird` object. We want to be able to call the `fly()` method on a `Penguin` object and get the same result as if we had called it on a `Sparrow` object. This is where the Liskov Substitution Principle comes into play.

```
birds: List[Bird] = [Eagle(), Penguin(), Parrot()]
for bird in birds:
    bird.fly()
```

This is a violation of the Liskov Substitution Principle. The Liskov Substitution Principle states that objects in a program should be replaceable with instances of their subtypes without altering the correctness of that program. In other words, if we have a `Bird` object, we should be able to replace it with an instance of its subclasses without altering the correctness of the program. In our case, we cannot replace a `Bird` object with a `Penguin` object because the `Penguin` object requires special handling.



Creating new abstract classes

A way to solve the issue with the `Penguin` class is to create a new set of abstract classes, `FlyableBird` and `NonFlyableBird`. The `FlyableBird` class will have the `fly()` method and the `NonFlyableBird` class will not have the `fly()` method. The `Penguin` class will extend the `NonFlyableBird` class and the `Eagle` and `Parrot` classes will extend the `FlyableBird` class. This way, we can ensure that the `Penguin` class does not have to implement the `fly()` method.

```
classDiagram
    class Bird{
        +weight: int
        +colour: string
        +type: string
        +size: string
        +beakType: string
    }
    class FlyableBird{
        +fly()
    }
    Bird <|-- FlyableBird
    FlyableBird <|-- Eagle
    FlyableBird <|-- Parrot

    class NonFlyableBird{
        +eat()
    }
    Bird <|-- NonFlyableBird
    NonFlyableBird <|-- Penguin

    class Eagle{
        +fly()
    }
    class Penguin{
        +eat()
    }
    class Parrot{
        +fly()
    }
```

This is an example of multi-level inheritance. The issue with the above approach is that we are tying behaviour to the class hierarchy. If we want to add a new type of behaviour, we will have to add a new abstract class. For instance if we can have birds that can swim and birds that cannot swim, we will have to create a new abstract class `SwimableBird` and `NonSwimableBird` and add them to the class hierarchy. But now how do you extends from two abstract classes? You can't. Then we would have to create classes with composite behaviours such as `SwimableFlyableBird` and `SwimableNonFlyableBird`.

```
classDiagram
    class Bird{
        +weight: int
        +colour: string
        +type: string
        +size: string
        +beakType: string
    }
    class SwimableFlyableBird{
        +fly()
        +swim()
    }
    Bird <|-- SwimableFlyableBird
    SwimableFlyableBird <|-- Swan

    class NonSwimableFlyableBird{
        +fly()
    }
    Bird <|-- NonSwimableFlyableBird
    NonSwimableFlyableBird <|-- Eagle

    class SwimableNonFlyableBird{
        +swim()
    }

    Bird <|-- SwimableNonFlyableBird
    SwimableNonFlyableBird <|-- Penguin

    class NonSwimableNonFlyableBird{
        +eat()
    }

    Bird <|-- NonSwimableNonFlyableBird
    NonSwimableNonFlyableBird <|-- Toy Bird

    class Swan{
        +fly()
        +swim()
    }

    class Eagle{
        +fly()
    }

    class Penguin{
        +eat()
    }

    class Toy Bird{
        +makeSound()
    }
```

If we want to add a new type of behaviour, we will have to add a new abstract class. This is why we should not tie behaviour to the class hierarchy.

Creating new base classes

We can solve the issue with the `Penguin` class by creating new base class. We can create a `Flyable` class and a `Swimmable` class. The `Penguin` class will implement the `Swimmable` base class and the `Eagle` and `Parrot` classes will implement the `Flyable` base class. This way, we can ensure that the `Penguin` class does not have to implement the `fly()` method.

```
classDiagram
    class Bird{
        <<abstract>>
        +weight: int
        +colour: string
        +type: string
        +size: string
        +beakType: string

        +makeSound()
    }

    Bird <|-- Eagle
    Bird <|-- Parrot
    Bird <|-- Penguin
    class Flyable{
        <<abstract>>
        +fly()*
    }
    Flyable <|-- Eagle
    Flyable <|-- Parrot

    class Swimmable{
        <<abstract>>
        +swim()*
    }
    Swimmable <|-- Penguin

    class Eagle{
        +fly()
    }
    class Penguin{
        +swim()
    }
    class Parrot{
        +fly()
    }
```

Since we are not tying behaviour to the class hierarchy, we can add new types of behaviour without having to add new abstract classes. For instance, if we want to add a new type of behaviour, we can create a new abstract class `CanSing` and add it to the class hierarchy.

```
class Flyable(ABC):
    @abstractmethod
    def fly(self) -> None:
        pass

class Swimmable(ABC):
    @abstractmethod
    def swim(self) -> None:
        pass

@dataclass
class Bird(ABC):
    weight: int
    colour: str
    type: str
    size: str
    beak_type: str

    @abstractmethod
    def make_sound(self) -> None:
        pass

class Eagle(Bird, Flyable):
    def fly(self) -> None:
        print("Eagle is gliding")

    def make_sound(self) -> None:
        print("Eagle is making sound")

class Penguin(Bird, Swimmable):
    def swim(self) -> None:
        print("Penguin is swimming")

    def make_sound(self) -> None:
        print("Penguin is making sound")
```

Summary

- The Liskov Substitution Principle states that objects in a program should be replaceable with instances of their subtypes without altering the correctness of that program.
- To identify violations, we can check if we can replace a class with its subclasses having to handle special cases and expect the same behaviour.

- Do not tie behaviour to the class hierarchy. Instead, create new base classes so that we can add new types of behaviour without having to add new intermediate levels in the class hierarchy.

Interface Segregation Principle

Segregation means keeping things separated, and the Interface Segregation Principle is about separating the interfaces.

The principle states that many client-specific interfaces are better than one general-purpose interface. Clients should not be forced to implement a function they do no need. Declaring methods in an interface that the client doesn't need pollutes the interface and leads to a "bulky" or "fat" interface
Here, interface refers to the interface of a class and can be interchangeably used with the abstract classes.

A client should never be forced to implement an interface that it doesn't use, or clients shouldn't be forced to depend on methods they do not use. In other words, we should not create fat interfaces. A fat interface is an interface that has too many methods. If we have a fat interface, we will have to implement all the methods in the interface even if we don't use them. This is known as the interface segregation principle.

Let us take the example of our `Bird` class. To not tie the behaviour to the class hierarchy, we created a new base class `Flyable` and implemented it in the `Eagle` and `Parrot` classes.

```
class Flyable(ABC):
    @abstractmethod
    def fly(self) -> None:
        pass

    @abstractmethod
    def make_sound(self) -> None:
        pass
```

Along with the `fly()` method, we also have the `make_sound()` method in the `Flyable` class. This is because the `Eagle` and `Parrot` classes both make sounds when they fly. But what if we have a class that implements the `Flyable` abstract class? The class does not make a sound when it flies. This is a violation of the abstract class segregation principle. We should not have the `make_sound()` method in the `Flyable` abstract class.

Larger interfaces should be split into smaller ones. By doing so, we can ensure that implementing classes only need to be concerned about the methods that are of interest to them. If a class exposes so many members that those members can be broken down into groups that serve different clients that don't use members from the other groups, you should think about exposing those member groups as separate interfaces.

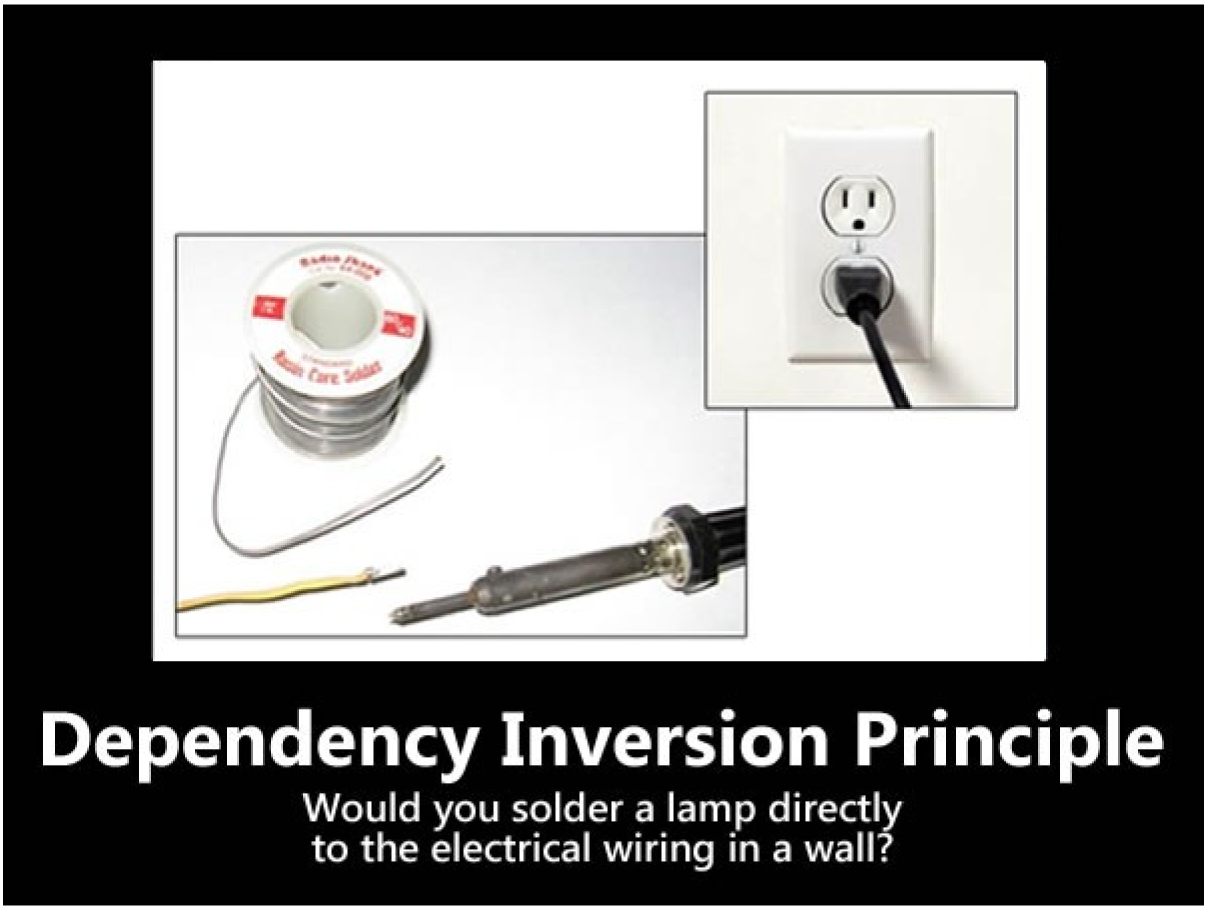
Precise application design and correct abstraction is the key behind the Interface Segregation Principle. Though it'll take more time and effort in the design phase of an application and might increase the code complexity, in the end, we get a flexible code.

Dependency Inversion Principle

The principle of dependency inversion refers to the decoupling of software modules. This way, instead of high-level modules depending on low-level modules, both will depend on abstractions. If the OCP states the goal of OO architecture, the DIP states the primary mechanism for achieving that goal.

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. Dependency inversion principle consists of two parts:

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



Our bird class looks pretty neat now. We have separated the behaviour into different lean interfaces which are implemented by the classes that need them. When we add new sub-classes we identify an issue. For birds that have the same behaviour, we have to implement the same behaviour multiple times.

```
class Eagle(Flyable):
    def fly(self) -> None:
        print("Eagle is gliding")

class Sparrow(Flyable):
    def fly(self) -> None:
        print("Sparrow is gliding")
```

The above can be solved by adding a default method to the `Flyable` abstract class. This way, we can avoid code duplication.
But which method should be the default implementation? What if in future we add more birds that have the same behaviour? We will have to change the default implementation or either duplicate the code.

Instead of default implementations, let us abstract the common behaviours to a separate helper classes. We will create a `GlidingBehaviour` class and a `FlappingBehaviour` class.

```java
public class Eagle implements Flyable {
    private GlidingBehaviour glidingBehaviour;

    public Eagle() {
        this.glidingBehaviour = new GlidingBehaviour();
    }

    @Override
    public void fly() {
        glidingBehaviour.fly();
    }
}
```

```python
class GlidingBehaviour:
    def glide(self) -> None:
        print("Gliding")

class FlappingBehaviour:
    def flap(self) -> None:
        print("Flapping")
```

The `Eagle` and `Sparrow` classes will implement the `Flyable` abstract class and use the `GlidingBehaviour` class. The `Parrot` class will implement the `Flyable` abstract class and use the `FlappingBehaviour` class. This way, we can avoid code duplication.

```python
class Eagle(Bird, Flyable):
    def __init__(self) -> None:
        self.flyable = GlidingBehaviour()

    def fly(self) -> None:
        self.flyable.glide()

class Sparrow(Bird, Flyable):
    def __init__(self) -> None:
        self.flyable = FlappingBehaviour()

    def fly(self) -> None:
        self.flyable.flap()
```

Now we have a problem. The `Eagle` class is tightly coupled to the `GlidingBehaviour` class. If we want to change the behaviour of the `Eagle` class, we will have to open the Eagle class to change the behaviour.
For instance, if we want to change the `Eagle` class to use the `FlappingBehaviour` class, we will have to modify the `Eagle` class to call the `flap()` method instead of the `glide()` method. This violates the open-closed principle since it is not closed for modification.

This is where the dependency inversion principle comes into play. We should not depend on concrete classes. We should depend on abstractions.

Naturally, we rely on a base class as the abstraction. We create a new abstract class `FlyingBehaviour` and implement it in the `GlidingBehaviour` and `FlappingBehaviour` classes.

```
class FlyingBehaviour(ABC):
    @abstractmethod
    def fly(self) -> None:
        pass

class GlidingBehaviour(FlyingBehaviour):
    def fly(self) -> None:
        print("Gliding")

class FlappingBehaviour(FlyingBehaviour):
    def fly(self) -> None:
        print("Flapping")
```

The `Eagle` class will now depend on the `FlyingBehaviour` abstract class.

```
class Eagle(Bird, Flyable):
    def __init__(self, flyingBehaviour: FlyingBehaviour) -> None:
        self.flyable = flyingBehaviour

    def fly(self) -> None:
        self.flyable.fly()
```

Now, you can pass any class that implements the `FlyingBehaviour` abstract class to the `Eagle` class. This way, we can change the behaviour of the `Eagle` class without having to modify the `Eagle` class. This is known as the dependency inversion principle.

```
eagle = Eagle(GlidingBehaviour())
eagle.fly()
```

```
eagle = Eagle(FlappingBehaviour())
eagle.fly()
```

Summary

- The dependency inversion principle states that depend upon abstractions. Do not depend upon concrete classes to avoid tight coupling and make the code more extensible.

- Create base classes for the behaviour and implement them in the classes that need them.
- Pass the base class to the classes that need them. This way, we can change the behaviour of the classes without having to modify the classes.

Reading list

- LSP (http://web.archive.org/web/20151128004108/http://www.objectmentor.com/resources/articles/lsp.pdf)
- SOLID - Recap (https://www.cs.odu.edu/~zeil/cs330/latest/Public/solid/)