Square, Rectangle and the Liskov Substitution Principle

Alexandre Dutertre · Follow

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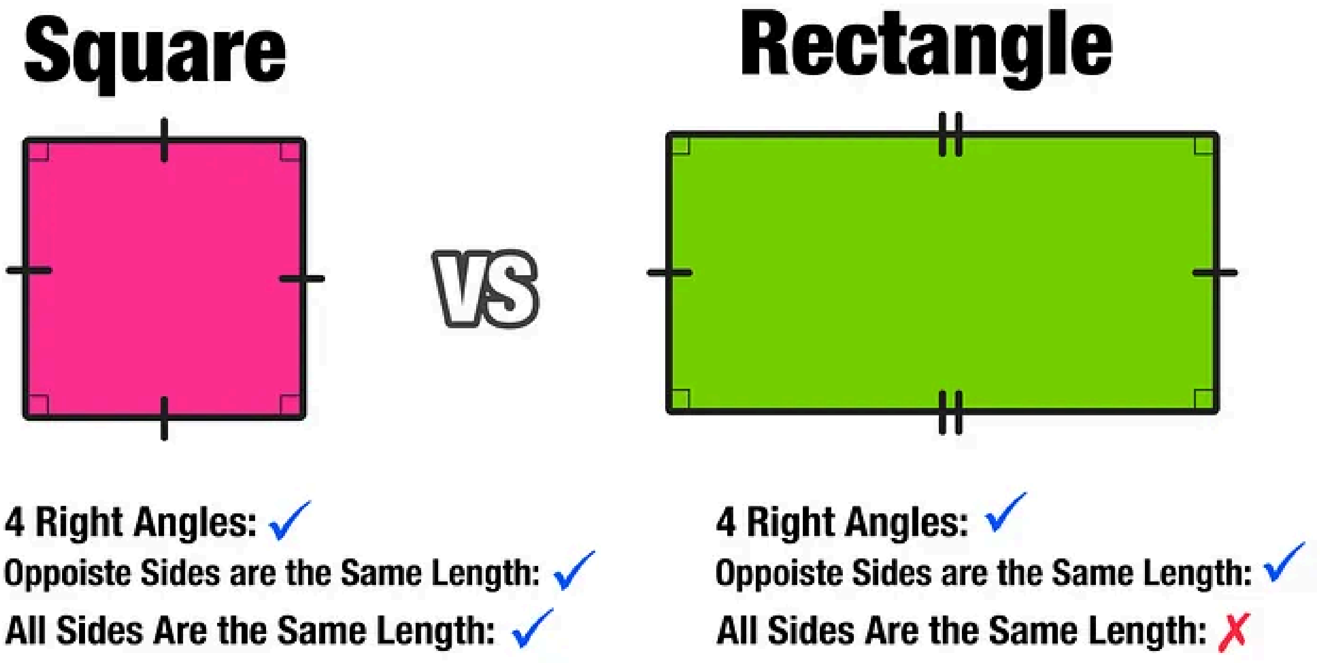
Square
VS
Rectangle
4 Right Angles: ✓
Oppoiste Sides are the Same Length: ✓
All Sides Are the Same Length: ✓
4 Right Angles: ✓
Oppoiste Sides are the Same Length: ✓
All Sides Are the Same Length: ✗

When creating classes for shapes, it's easy to imagine a square as just being a rectangle with all sides having the same length, like in geometry. Thus, making the `Square` class inherits from the `Rectangle` class. However, this could bring unexpected behavior from our program, as it violates the **Liskov substitution principle** (LSP). We will see how we can fix that problem.

What is the Liskov substitution principle

The Liskov substitution principle is the third principle of the mnemonic acronym **SOLID**:

- **S**ingle-responsability principle
- **O**pen-closed principle
- **L**iskov substitution principle
- **I**nterface segregation principle
- **D**ependency inversion principle

It was introduced by Barbara Liskov, during a conference called ***Data abstraction and hierarchy***, in 1987. This principle defines the subtype notion as such:

> *if f(x) is a property provable about objects x of type T, then f(y) should be true for objects y of type S where S is a subtype of T.*

An objet can be replaced by a sub-object without breaking the program, as what holds for T-objects holds for S-objects is what must be understood.

A square breaks that principle since it doesn't have a different `height` and `width`. So not everything true for `Rectangle` is true for `Square`. Let's see it using code and the `Shape`, `Rectangle` and `Square` classes.

Shape class

```
class Shape
{
    public virtual int Area()
    {
        throw new NotImplementedException("Area() is not implemented");
    }
}
```

Rectangle class

```
class Rectangle : Shape
{
    private int width;
    private int height;

    public int Width
    {
        get => width;
        set
        {
            if (value < 0)
                throw new ArgumentException("Width must be greater than or equal
            width = value;
        }
    }

    public int Height
    {
        get => height;
        set
        {
            if (value < 0)
                throw new ArgumentException("Height must be greater than or equa
            height = value;
        }
    }

    public new int Area() => width * height;
    public override string ToString() => $"[Rectangle] {width} / {height}";
}
```

Square class

```
class Square : Rectangle
{
    private int size;

    public int Size
    {
        get => size;
        set
        {
            if (value < 0)
                throw new ArgumentException("Size must be greater than or equal
            size = value;
            Height = value;
            Width = value;
        }
    }

    public override string ToString() => $"[Square] {size} / {size}";
}
```

If we were to use the setter `Size` , the program would still work as intended. However if we use directly the setters `Width` and `Height` with our square, it would break the program.

```
class Program
{
    static void Main(string[] args)
    {
        Square aSquare = new Square();
        try
        {
            aSquare.Width = 12;
            aSquare.Height = 8;

            Console.WriteLine("aSquare width: {0}", aSquare.Width);
            Console.WriteLine("aSquare height: {0}", aSquare.Height);
            Console.WriteLine("aSquare size: {0}", aSquare.Size);
            Console.WriteLine("aSquare area: {0}", aSquare.Area());
            Console.WriteLine(aSquare.ToString());
        }
        catch (Exception e)
        {
            Console.WriteLine(e);
        }
    }
}
```

Here is the output obtained when running the `dotnet run` command:

```
aSquare width: 12
aSquare height: 8
aSquare size: 0
aSquare area: 96
[Square] 0 / 0
```

We can see that there is a problem when getting the `Size`, using the `Area()` and `ToString()` methods since the field `size` was never assigned. We're using the methods as if we were expecting a rectangle, aside from `aSquare.Size`, but it behaves differently since it's a square.

Overriding the getters and setters isn't an option since it modifies the behavior of the methods from the `Rectangle` class which violates the LSP.

Possible correction

One possible correction to this problem, would be to make the `Shape` class **`abstract`** and make both `Rectangle` and `Square` inherits from the `Shape` class. Here is a possible implementation:

Shape class

```
abstract class Shape
{
    protected int width;
    protected int height;

    public abstract int Area();
}
```

Rectangle class

```
class Rectangle : Shape
{
    public int Width
    {
        get => width;
        set
        {
            if (value < 0)
                throw new ArgumentException("Width must be greater than or equal
            width = value;
        }
    }

    public int Height
    {
        get => height;
        set
        {
            if (value < 0)
                throw new ArgumentException("Height must be greater than or equa
            height = value;
        }
    }

    public override int Area() => width * height;

    public override string ToString() => $"[Rectangle] {width} / {height}";
}
```

Square class

```
class Square : Shape
{
    public int Size
    {
        get => width;
        set
        {
            if (value < 0)
                throw new ArgumentException("Size must be greater than or equal
            width = value;
            height = value;
        }
    }

    public int Width
    {
        get => width;
        set
        {
            if (value < 0)
                throw new ArgumentException("Width must be greater than or equal
            width = value;
            height = value;
        }
    }

    public int Height
    {
        get => height;
        set
        {
            if (value < 0)
                throw new ArgumentException("Height must be greater than or equa
            width = value;
            height = value;
        }
    }

    public override int Area() => width * width;

    public override string ToString() => $"[Square] {width} / {width}";
}
```

If we modify `main.cs` to add output for a rectangle:

```
class Program
{
    static void Main(string[] args)
    {
        Square aSquare = new Square();
        Rectangle aRectangle = new Rectangle();

        try
        {
            aSquare.Width = 12;
            aSquare.Height = 8;
            aRectangle.Width = 12;
            aRectangle.Height = 8;

            Console.WriteLine("aSquare width: {0}", aSquare.Width);
            Console.WriteLine("aSquare height: {0}", aSquare.Height);
            Console.WriteLine("aSquare size: {0}", aSquare.Size);
            Console.WriteLine("aSquare area: {0}", aSquare.Area());
            Console.WriteLine(aSquare.ToString());
            Console.WriteLine("------------------------");
            Console.WriteLine("aRectangle width: {0}", aRectangle.Width);
            Console.WriteLine("aRectangle height: {0}", aRectangle.Height);
            Console.WriteLine("aRectangle area: {0}", aRectangle.Area());
            Console.WriteLine(aRectangle.ToString());
        }
        catch (Exception e)
        {
            Console.WriteLine(e);
        }
        }
    }
```

We obtain the following output.

```
aSquare width: 8
aSquare height: 8
```

```
aRectangle width: 12
aRectangle height: 8
aRectangle area: 96
[Rectangle] 12 / 8
```

The `Shape` class is made `abstract` as by itself it doesn't refer to anything concrete, and `abstract` classes are an important part in this principle. The `Rectangle` and `Square` classes inherits from this class as they are shapes.

By separating the `Rectangle` and `Square` classes, we ensure that there are no problems during the code execution as the classes holds their own implementation of the `Area()` method and their own definition for `Width` and `Height`.

Overriding isn't a problem here, because it doesn't modify the expected behavior for `Area()`, which is to return the area. That's why it was made `abstract` in the `Shape` class, to indicate it must be overridden.

Conclusion

- Contrary to geometry, squares aren’t rectangles in Object-Oriented Programming
- Subclasses must respect the Liskov substitution principle
- The LSP dictates that everything true for the class, must be true for the subclass
- The problem can be fixed by making `Square` and `Rectangle` inherits from `Shape` and have their own definitions of the getters and setters and `Area()` without modifying the expected behavior

Sources

Liskov substitution principle - Wikipedia

The Liskov substitution principle (LSP) is a particular definition of a subtyping relation, called strong behavioral…

en.wikipedia.org

Takeaway

External resource: The Liskov Substitution Principle: www.objectmentor.com/resources/articles/lsp.pdf We identified…

stg-tud.github.io

Why would Square inheriting from Rectangle be problematic if we override the SetWidth and SetHeight…

If a Square is a type of Rectangle than why cant a Square inherit from a Rectangle? Or why is it a bad design? First…

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LSP - Is Square A Rectangle? - Code Coach

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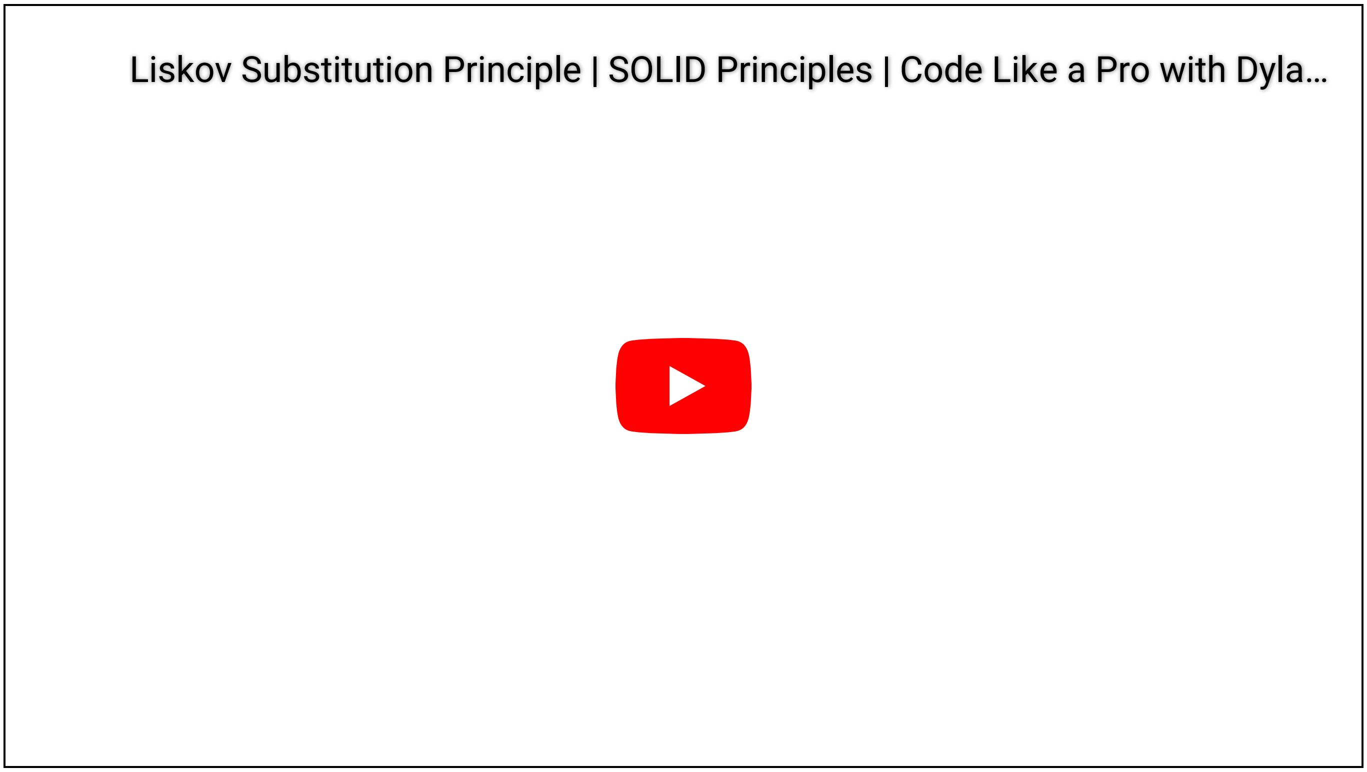
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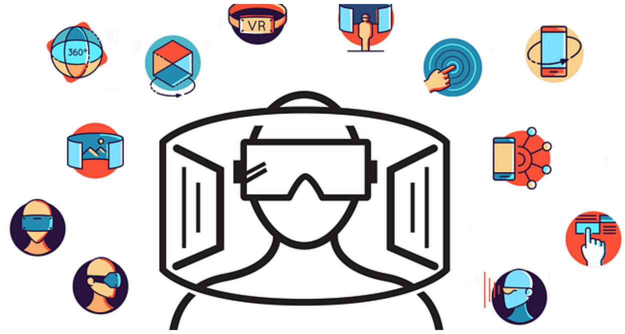

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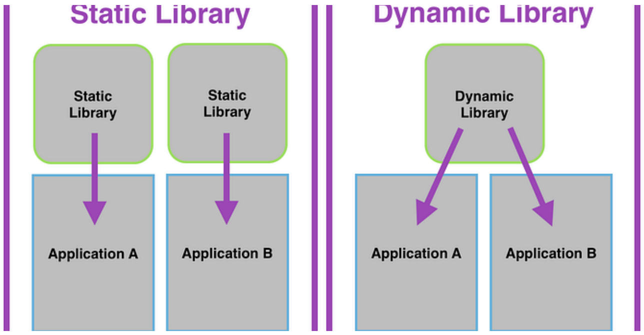

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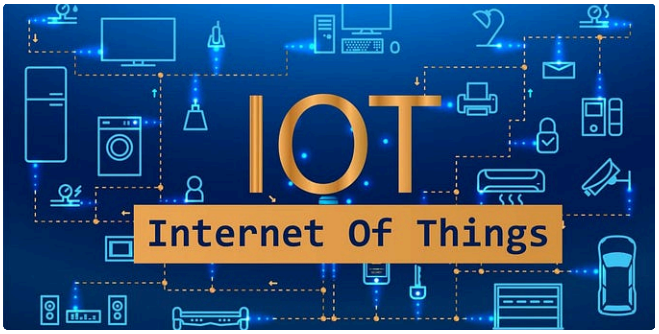

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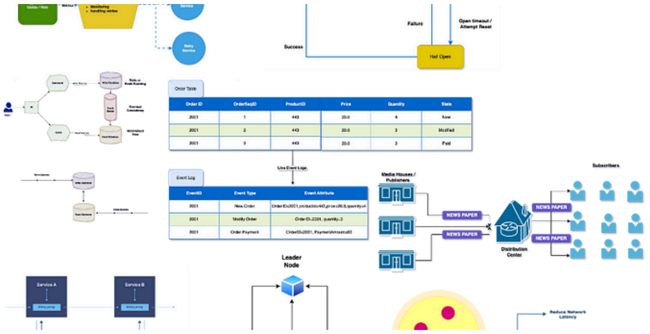

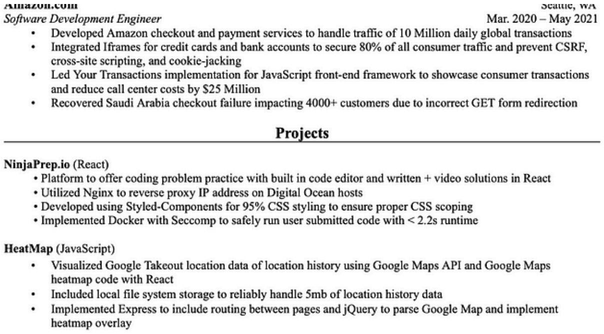

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- Led Your Transactions implementation for JavaScript front-end framework to showcase consumer transactions and reduce call center costs by $25 Million
- Recovered Saudi Arabia checkout failure impacting 4000+ customers due to incorrect GET form redirection

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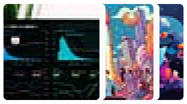

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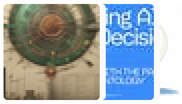

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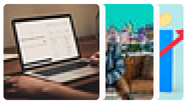

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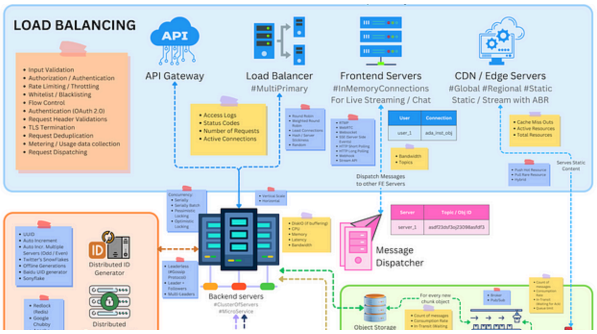

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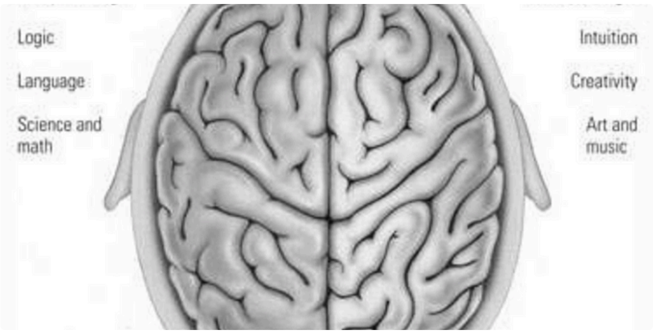

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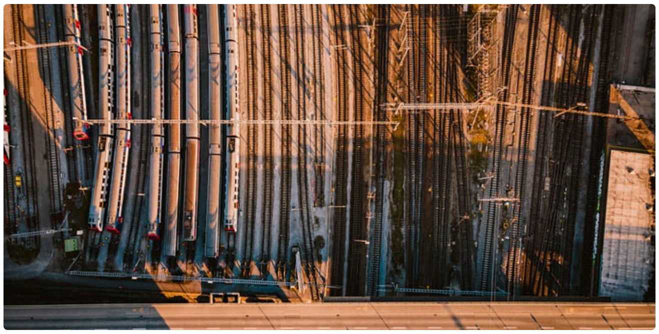

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