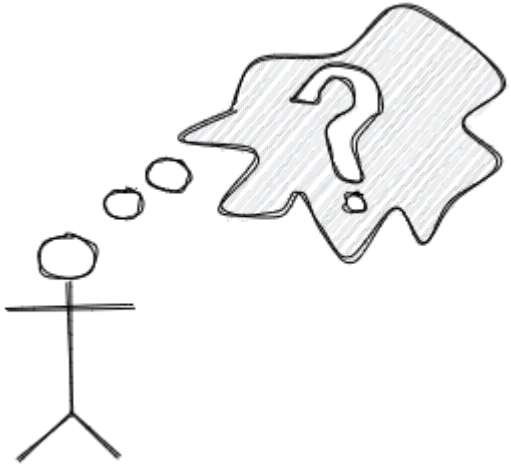
Object Oriented Programming - Day 1

Looking Back



- Who remembers …
    - Structural vs Behavioral Modelling?
    - State Machines?

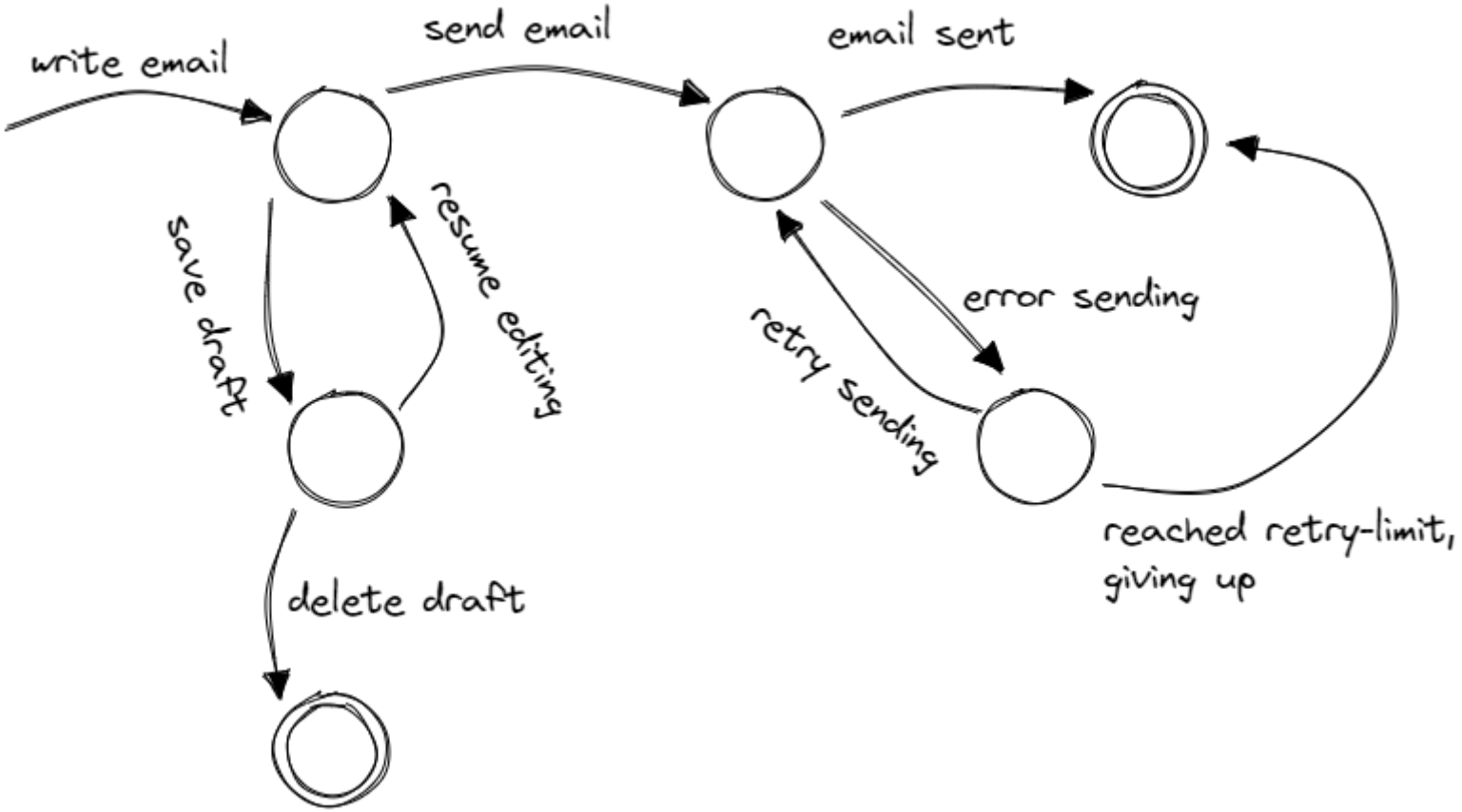
Structural vs Behavioral Modelling

- Structural
    - Class Diagrams
    - What talks to what?

    - Easier to get started on
- Behavioral
    - State Machines / Flow Charts
    - Actual decisions to make to get to output
    - Harder

State Machines

- Two basic elements
    - States and Transitions
    - Labels on transition denote *available* inputs
    - End states have double circle



Movng State Machines to Code

- Label the states with their properties
- Check inputs for valid state transitions

Module: Best practices

Software Engineering

Engineering:

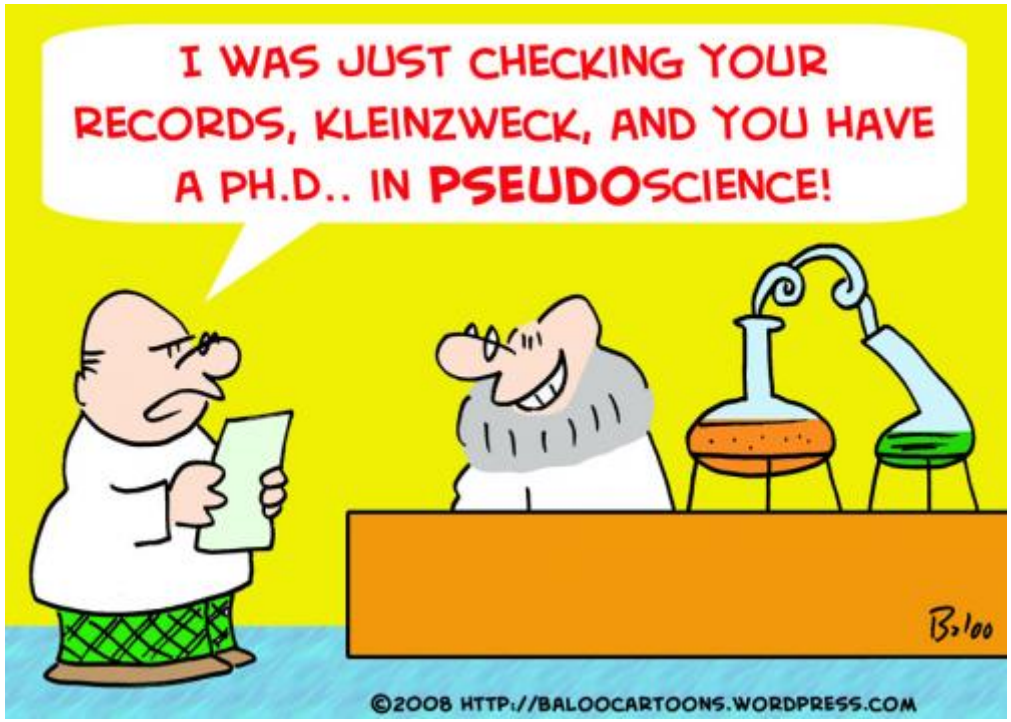
> Engineering is the use of **scientific principles** to design and build machines, structures, and other items, including bridges, tunnels, roads, vehicles, and buildings.

Engineer:

> professionals who invent, design, analyze, build and test machines, complex systems, structures, gadgets and materials to fulfill functional objectives and requirements while considering the limitations imposed by practicality, regulation, safety and cost.

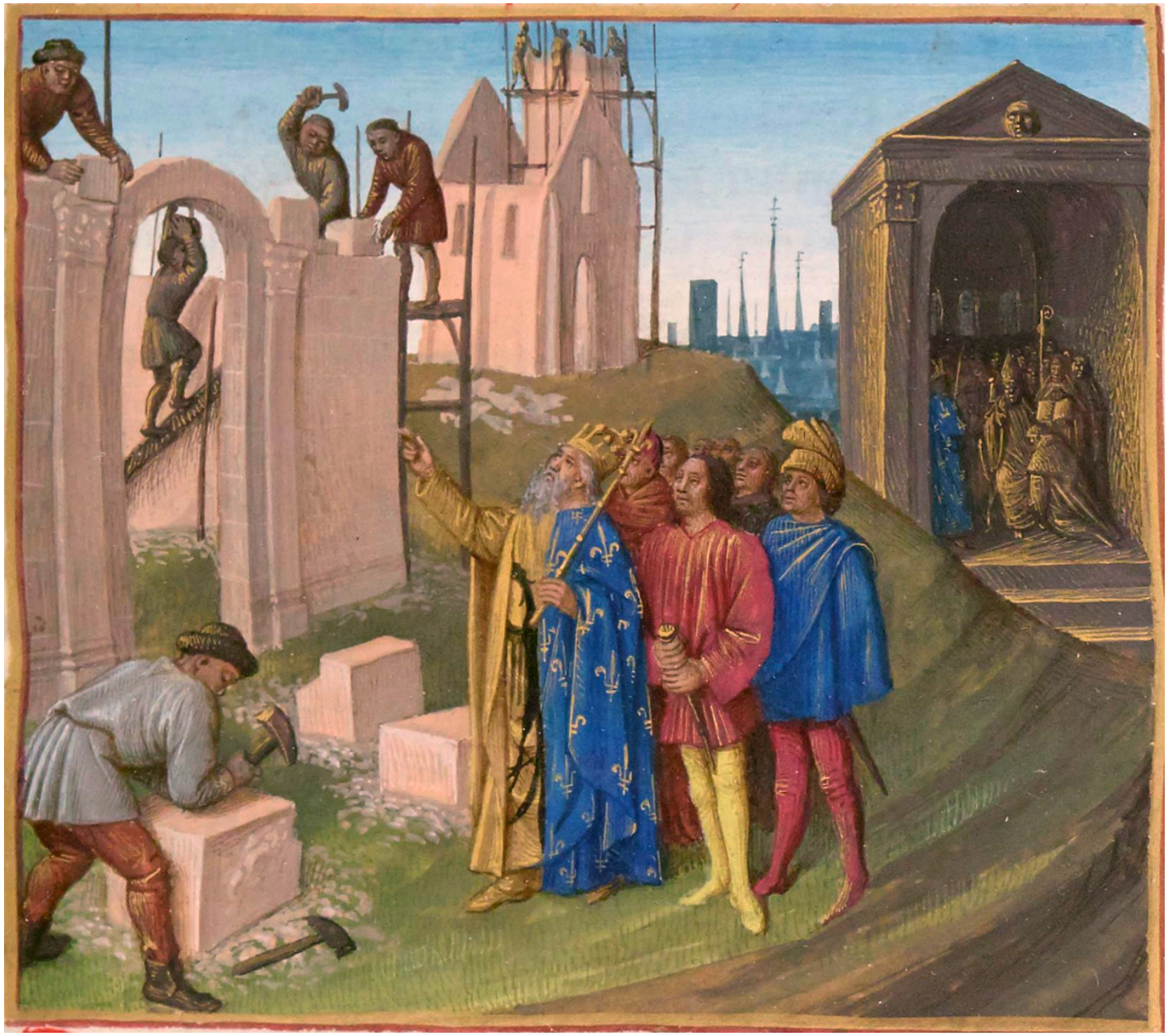
Software Engineering

Is it really "engineering"?



Software Engineering

Like building cathedrals in the 16th century



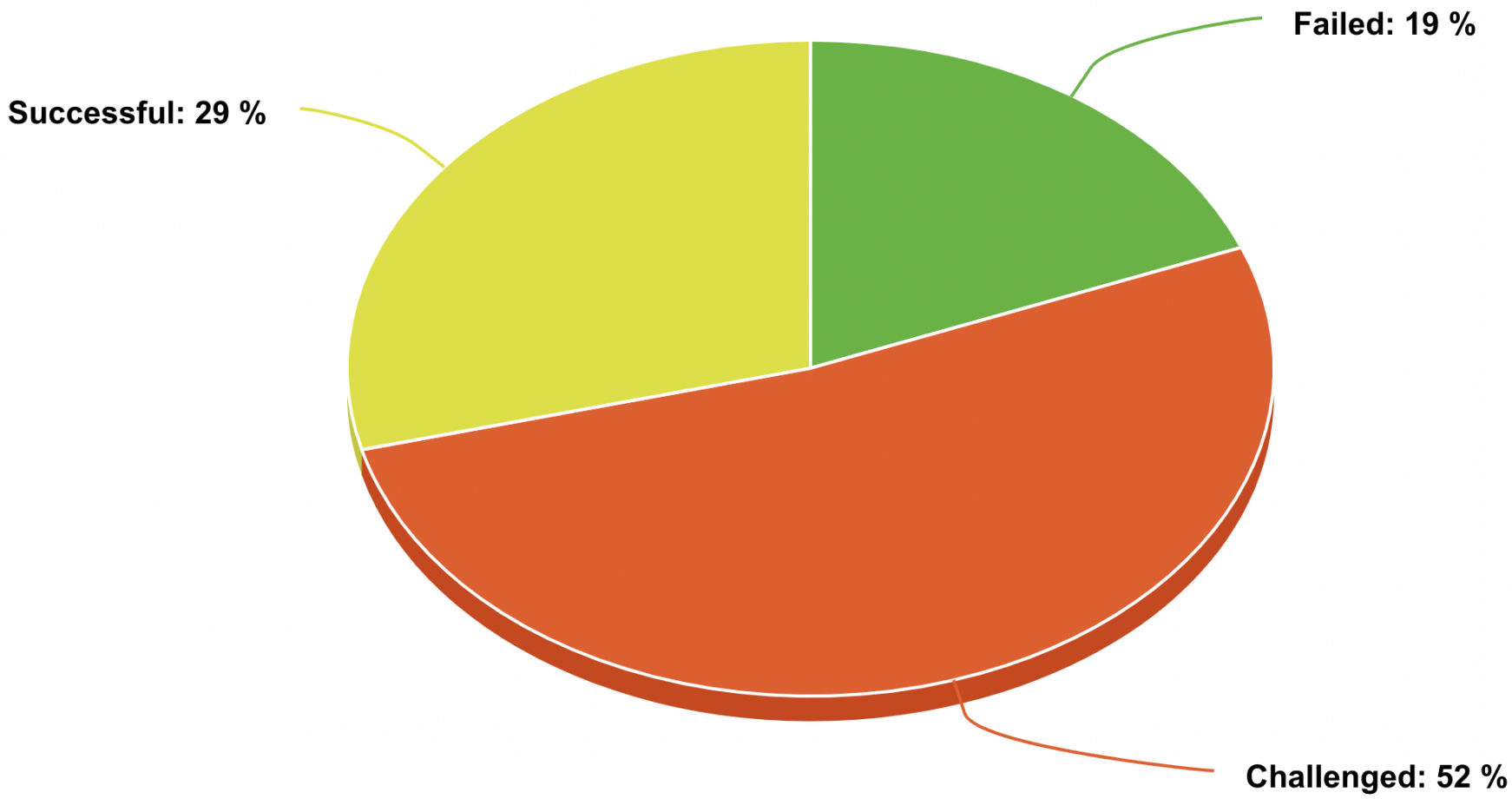
(Picture of a 16th century stakeholder, checking up on the project team)

Software Engineer

Sometimes ad-hoc measures to prevent the structure from collapsing are required

Success rate

Both 16th century cathedrals and 21th century software projects tend to fail often



Best practices

Clever acronyms:

- DRY (Don’t Repeat Yourself)
- KISS (Keep It Simple, Stupid/Silly/Simon)
- YAGNI (You Aren’t Gonna Need It)

Best practices

Principles:

- The single responsibility principle
- The open/closed principle
- The Liskov substitution principle
- The interface segregation principle
- The dependency inversion principle
- The principle of least astonishment
- The principle of least knowledge (the "Law Of Demeter")

Design patterns

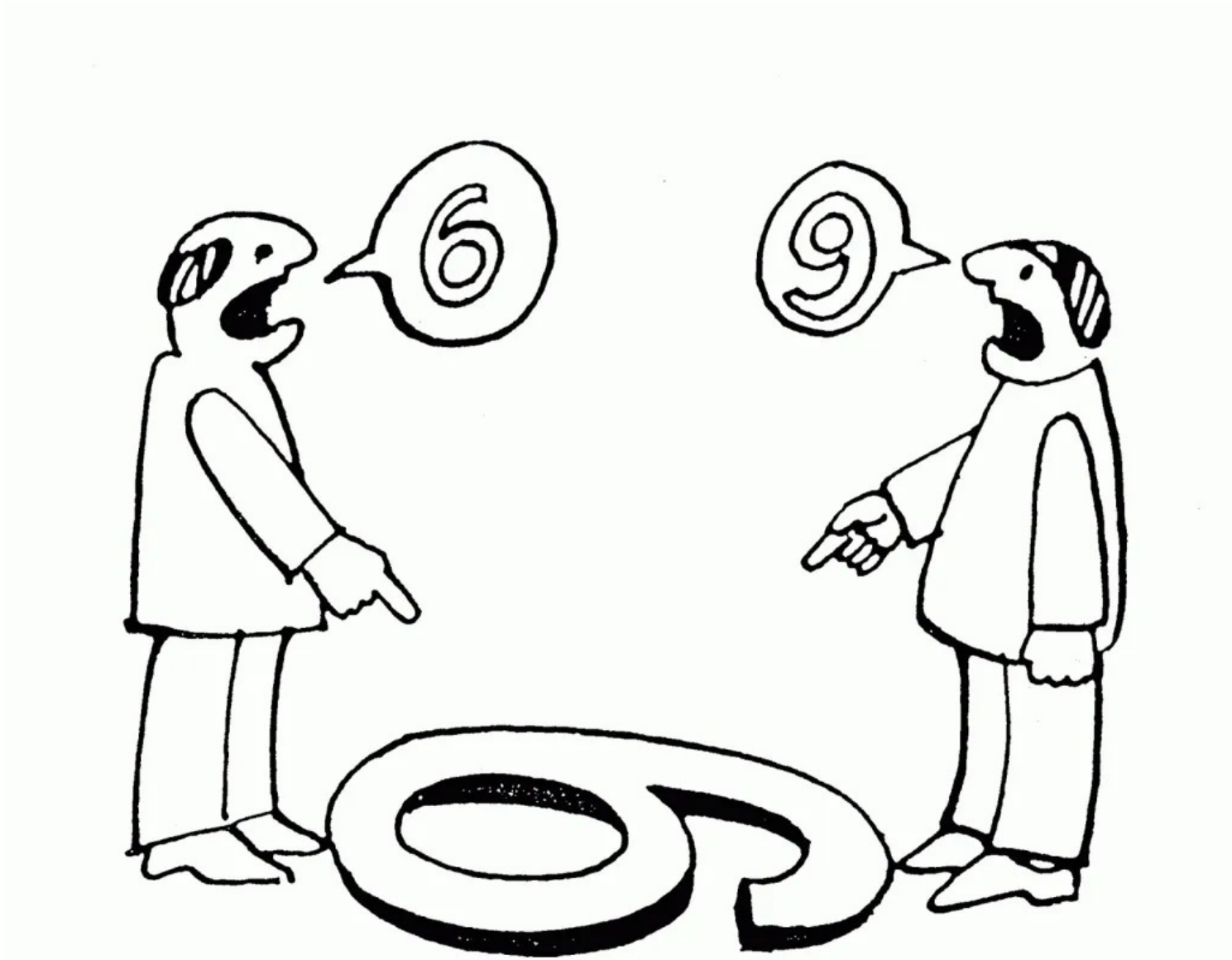
Reusable solutions to common problems in software design

- Factory
- Decorator
- Visitor
- Bridge
- Composite
- …

Best practices

Sometimes people just don’t agree what is "best"

- TDD
- Functional Programming
- Singleton Pattern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Disclaimer

Every "best practice" can be a "bad practice" in certain situations. Don’t follow too blindly!

DRY

"Don’t Repeat Yourself"

```
class App {
    public static void main(String[] args) {
        System.out.println("I will not repeat myself!");
        System.out.println("I will not repeat myself!");
        System.out.println("I will not repeat myself!");
        System.out.println("I will not repeat myself!");
        System.out.println("I will not repeat myself!");
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        System.out.println("I will not repeat myself!");
        System.out.println("I will not repeat myself!");
        System.out.println("I will not repeat myself!");
        System.out.println("I will not repeat myself!");
    }
}
```

DRY

DRY is about removing repeated expressions/statements:

```
double input = 36;

// The square root of any number is always bigger than zero:
double guessTooLow = 0;

// The quare root of any number is always smaller than that number itself:
```

```
double guessTooHigh = input;

// Our best guess is right in the middle of those two:
double bestGuess = (guessTooLow + guessTooHigh) / 2;

// Check if we are done:
boolean foundSquareRoot = bestGuess * bestGuess == input;

while (!foundSquareRoot) {

    // Print our best guess:
    System.out.println("Best guess: " + bestGuess);

    if (bestGuess * bestGuess < input) {
        guessTooLow = bestGuess;
    }

    if (bestGuess * bestGuess > input) {
        guessTooHigh = bestGuess;
    }

    // Improve our guess:
    bestGuess = (guessTooLow + guessTooHigh) / 2;

    // Check if we are done now:
    foundSquareRoot = bestGuess * bestGuess == input;
}
System.out.println("Found: " + bestGuess);
```

DRY

We decided to introduce a function and use that everywhere the expression `(guessTooLow + guessTooHigh) / 2` appears:

```
double midPoint(double x, double y) {
    return (x + y) / 2;
}
```

DRY

```
double input = 36;

// The square root of any number is always bigger than zero:
double guessTooLow = 0;

// The quare root of any number is always smaller than that number itself:
double guessTooHigh = input;

// Our best guess is right in the middle of those two:
double bestGuess = midPoint(guessTooLow, guessTooHigh);

// Check if we are done:
boolean foundSquareRoot = bestGuess * bestGuess == input;

while (!foundSquareRoot) {

    // Print our best guess:
    System.out.println("Best guess: " + bestGuess);

    if (bestGuess * bestGuess < input) {
        guessTooLow = bestGuess;
    }

    if (bestGuess * bestGuess > input) {
        guessTooHigh = bestGuess;
    }
```

```
    // Improve our guess:
    bestGuess = midPoint(guessTooLow, guessTooHigh);

    // Check if we are done now:
    foundSquareRoot = bestGuess * bestGuess == input;
}
System.out.println("Found: " + bestGuess);
```

DRY

First 10,000 decimals of $\sqrt{2}$

1.
4142135623 7309504880 1688724209 6980785696 7187537694 8073176679 7379907324 7846210703 8850387534 3276415727 3501384623 0912297024 9248360558
5073721264 4121497099 9358314132 2666592750 5592755799 9505011527 8206057147 0109559971 6059702745 3459686201 4728517418 6408891986 0955232923
0484308714 3214508397 6260362799 5251407989 6872533965 4633180882 9640620615 2583523950 5474575028 7759961729 8355752203 3753185701 1354374603
4084988471 6038689997 0699004815 0305440277 9031645424 7823068492 9369186215 8057846311 1596668713 0130156185 6898723723 5288509264 8612494977
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3462573306 0012349737 4435581809 6567846464 1533905146 5691932456 2353140577 9193698988 4236471835 2537580525 7713311200 7971040683 1549266540
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1798098596 8111540446 4437285689 5928683197 7797786934 6415984697 4513391774 1537904877 8808300220 5833504674 6555323028 5873258351...

DRY

Instead of

```
bestGuess * bestGuess == input
```

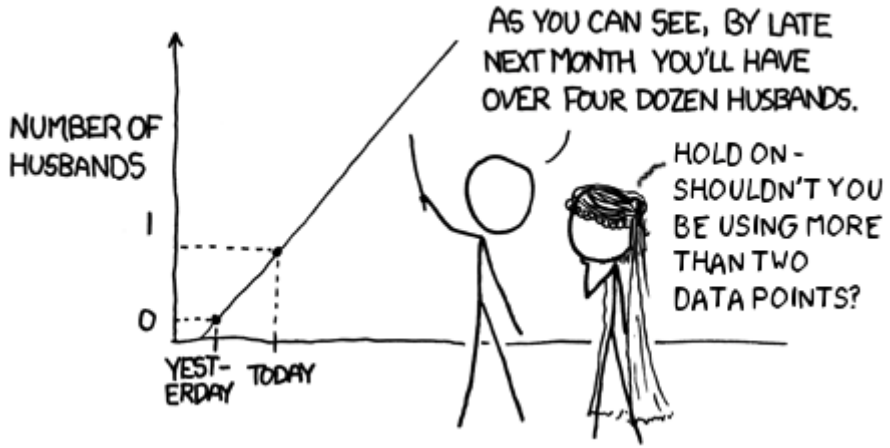
we'd like to use

```
Math.abs(bestGuess * bestGuess - input) < 0.00001
```

We need to make sure to update *both* copies!

Rule Of Three

Don't apply DRY too soon!

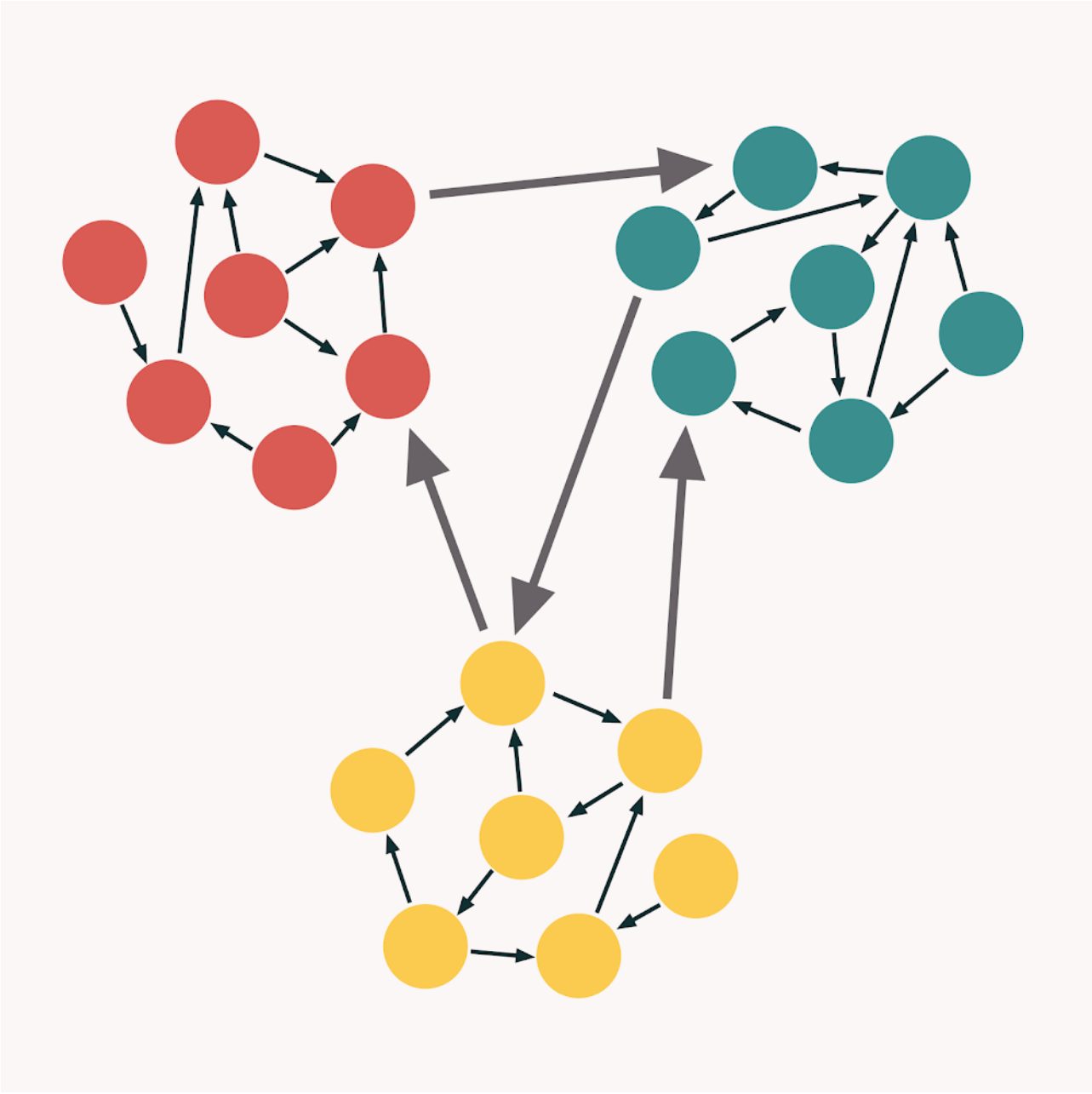


Single Responsibility Principle

Don’t bundle all methods in one class. Example: `Receipt`

- Methods for the store’s customer loyalty program
- Methods to update the inventory
- Methods for accounting
- Methods for marketing
- Methods used by a store designer

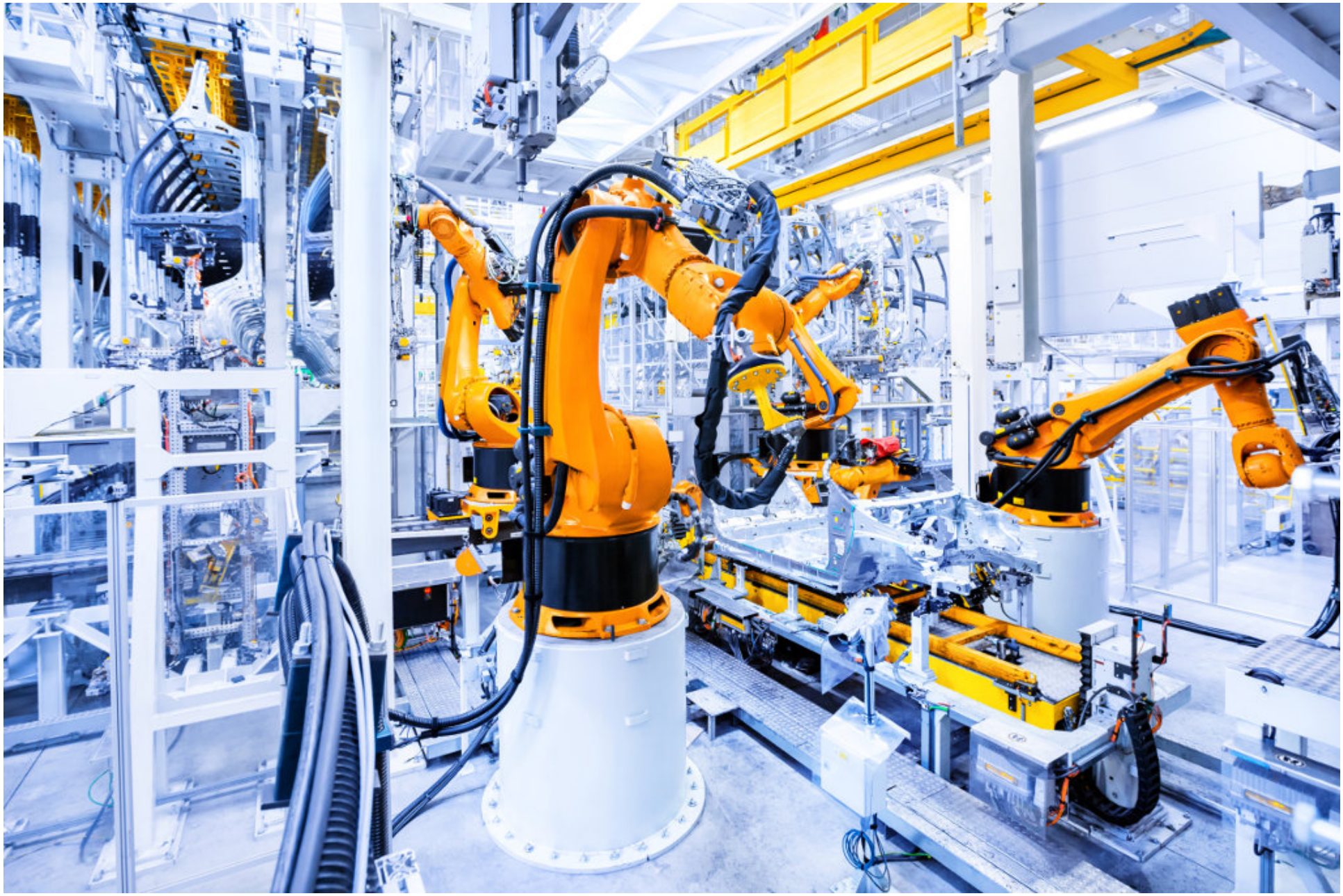
Single Responsibility Principle



Single Responsibilitiy Principle

Don’t take it too far

Factory Pattern



Factory Pattern

Helps stick to the single responsibility principle

- A `PlaneFactory` should produce a `Plane`
- A `BoatFactory` should produce a `Boat`
- A `CarFactory` should produce a `Car` (but may produce a `Mercedes` or a `Tesla`)

Code reviews

Many benefits:

- Check if requirements are satifisfied
- Look for bugs
- Identify code that is hard to understand/maintain
- Show you more elegant/efficient way to implement feature
- Let you know about some handy helper functions

Automated tests

Many benefits:

- Check if code behaves as it should
- See how it "feels" to create an instance of a class you just wrote, and to call its methods


QUALITY
MAX
MAX

Module: Designing classes

- Recap encapsulation
- Decide what to expose
- Immutability
- Visibility and access modifiers
- Reference escapism
- Defensive programming
- Exercises

Recap encapsulation

```
// We want this
double price = purchase.getPrice();

// We don't want this
purchase.price = 0.00; // Now it's free!
```

Recap encapsulation

```
// Instead of this
class Purchase {
    public double price;
}

// We do this
```

```
class Purchase {
    private double price;

    public double getPrice() {
        return price;
    }
}
```

Why?

Your class can look like this

```
class Purchase {
    private double price;

    public double getPrice() {
        return price;
    }
}
```

```
double price = purchase.getPrice();
```

Why?

Or like this

```
class Purchase {
    private int priceInCents;
```

```
    public double getPrice() {
        return priceInCents / 100;
    }
}
```

```
double price = purchase.getPrice();
```

Why?

Or even this:

```
class Purchase {
    // No field at all!

    public double getPrice() {
        return callDatabase().getPrice();
    }
}
```

```
double price = purchase.getPrice();
```

Recap encapsulation

- Freedom to change code
- No freedom for clients to mess with things

Decide what to expose

- It’s an art, not a science
- There are rules of thumb:
- Expose methods, not fields
- Expose only what you need, no more
- Favour immutability

Expose methods, not fields

```
class Purchase {
    public int priceInCents;
}
```

vs

```
class Purchase {
    private int priceInCents;

    public int getPriceInCents() {
        return priceInCents;
    }
}
```

Expose methods, not fields

- Move to a different interface
- Remain compatibility

```
class Purchase {
    private double price;

    public double getPrice() {
        return price;
    }

    public int getPriceInCents() {
        return Math.round(price * 100);
    }
}
```

Expose only what you need

- It’s easy to add things
- Its **hard** to remove things

Expose only what you need

Let’s say we have this

```
class Purchase {
    private int priceInEuros;
```

```
    private int priceRemainderInCents;

    public double getPrice() {
        return priceInEuros + (priceRemainderInCents / 100);
    }

    // Let's add these methods! It's easy!
    public int getPriceInEuros() {
        return priceInEuros;
    }

    public int getPriceRemainderInCents() {
        return priceRemainderInCents;
    }
}
```

Expose only what you need

We want to: * change the implementation * remove `getPriceInEuros()` and `getPriceRemainderInCents()`

But wait!

- The Accountancy team uses `getPriceInEuros()` for tax reasons!
- We can’t remove it
- Tax rules change, now they want us to change the implementation
- ¬
- Nooooo

- We have to support it forever

Immutability

Programmer speak for

classes whose internal values you can’t change

Immutability

So, instead of this:

```
class Purchase {
    private double price;

    public double getPrice() {
        return price;
    }

    public double setPrice(double newValue) {
        this.price = newValue;
    }
}
```

Immutability

Do this:

```
class Purchase {
```

```
    private final double price;

    public double getPrice() {
        return price;
    }
}
```

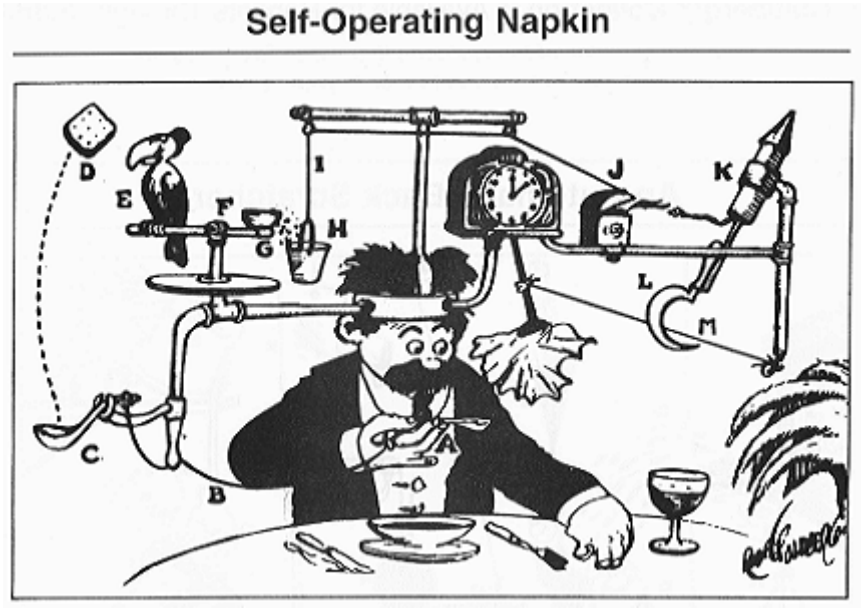
- No setter method
- Field is `final`

Why?

- Only expose what you need
- Easier to understand
    - Takes a while to appreciate
- Also: good for concurrency
    - You can forget about that

Why?

Less moving parts



Visibility and access modifiers

```
// private access
private int getPrice() { return 0; }

// default access
int getPrice() { return 0; }

// protected access
protected int getPrice() { return 0; }

// public access
public int getPrice() { return 0; }
```

Public & private access

- Public access
    - Visible to all classes
- Private access
    - Visible to current class only

Default access

```
// default access
int getPrice() { return 0; }
```

- Visible to all classes in same package
- "package private"
- "package protected"

Default access

```
package nl.yoink.training.domain;

public class Product {
    String getName() { return name; }
}

// ...
```

```
package nl.yoink.training.domain;

class Purchase {
    private final Product product;

    public getProductName() {
        return product.getName(); // yes
    }
}
```

```
package nl.yoink.training.domain;

public class Product {
    String getName() { return name; }
}

// ...

package nl.yoink.training.express;

class ExpressPurchace {
    private final Product product;

    public getProductName() {
        return product.getName(); // no
    }
}
```

Protected access

- Visible to all classes in same package

- Visible to all subclasses

Protected access

```
package nl.yoink.training.domain;

public class Product {
    String getName() { return name; }
}

// ...

package nl.yoink.training.express;

class ExpressPurchace {
    private final Product product;

    public getProductName() {
        return product.getName(); // no
    }
}
```

Protected access

```
package nl.yoink.training.domain;

public class Product {
    String getName() { return name; }
}

// ...
```

```
package nl.yoink.training.express;

class ExpressPurchace extends Purchase {
    private final Product product;

    public getProductName() {
        return product.getName(); // yes
    }
}
```

Default & protected access

- Rarely used in practice

Reference escapism

```
class Receipt {
    private final double[] amounts;

    public Receipt(double[] amounts) {
        this.amounts = amounts;
    }

    public double[] getAmounts() {
        return amounts;
    }
}
```

Reference escapism

```
double[] initial = { 1.0, 2.0, 3.0 };
Receipt receipt = new Receipt(initial);
```

Call `getAmounts()`:

```
receipt.getAmounts();
// double[3] { 1.0, 2.0, 3.0 }
```

Reference escapism

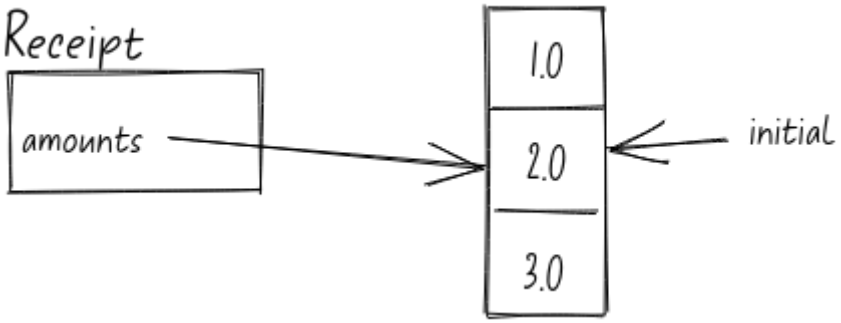
```
double[] initial = { 1.0, 2.0, 3.0 };
Receipt receipt = new Receipt(initial);
initial[1] = 42.0;
```

Call `getAmounts()`:

```
receipt.getAmounts();
// double[3] { 1.0, 42.0, 3.0 }
```

Reference escapism

What happened?



"The reference has escaped the boundaries of the class"

Reference escapism

```
double[] initial = { 1.0, 2.0, 3.0 };
Receipt receipt = new Receipt(initial);
double[] observed = receipt.getAmounts();
observed[1] = 42.0;
```

Call `getAmounts()`:

```
receipt.getAmounts();
// double[3] { 1.0, 42.0, 3.0 }
```

Reference escapism

How to prevent this?

- Use primitive values
- Use immutable objects
- Program defensively

Defensive programming

Assume your clients want to attack you

Try to prevent these attacks

Arrays

```
import java.util.Arrays;

class Receipt {
    private final double[] amounts;

    public Receipt(double[] amounts) {
        this.amounts = Arrays.copyOf(amounts, amounts.length);
    }

    public double[] getAmounts() {
        return Arrays.copyOf(amounts, amounts.length);
    }
}
```

Arrays

It works for the constructor:

```
double[] initial = { 1.0, 2.0, 3.0 };
Receipt receipt = new Receipt(initial);
initial[1] = 42.0;

receipt.getAmounts();
// double[3] { 1.0, 2.0, 3.0 }
```

Arrays

It works for the getter:

```
double[] initial = { 1.0, 2.0, 3.0 };
Receipt receipt = new Receipt(initial);
double[] observed = receipt.getAmounts();
observed[1] = 42.0;

receipt.getAmounts();
// double[3] { 1.0, 2.0, 3.0 }
```

Cloneable

Some (mutable) types implement `Cloneable`:

```
GregorianCalendar time = new GregorianCalendar();
```

```
GregorianCalendar copy = time.clone();
```

Cost

Copying large objects is expensive

- memory
- time

Wrapped types

Some (mutable) types can be wrapped:

```
List<String> strings = new ArrayList<>();
List<String> copy = Collections.umodifiableList(copy);
```

What does wrapping mean?

```
// Real implementation is different
public class UnmodifiableList<T> implements List<T> {
    private final List<T> underlying;

    public UnmodifiableList(List<T> underlying) {
        this.underlying = underlying;
    }

    public T get(int index) {
        return underlying.get(index);
```

```
    }

    public void add(T element) {
        throws new UnsupportedOperationException();
    }
}
```

Cost

Wrapping objects is cheap

- memory
- time

Exercises

Fill in access modifiers in the following classes, and explain your choices.

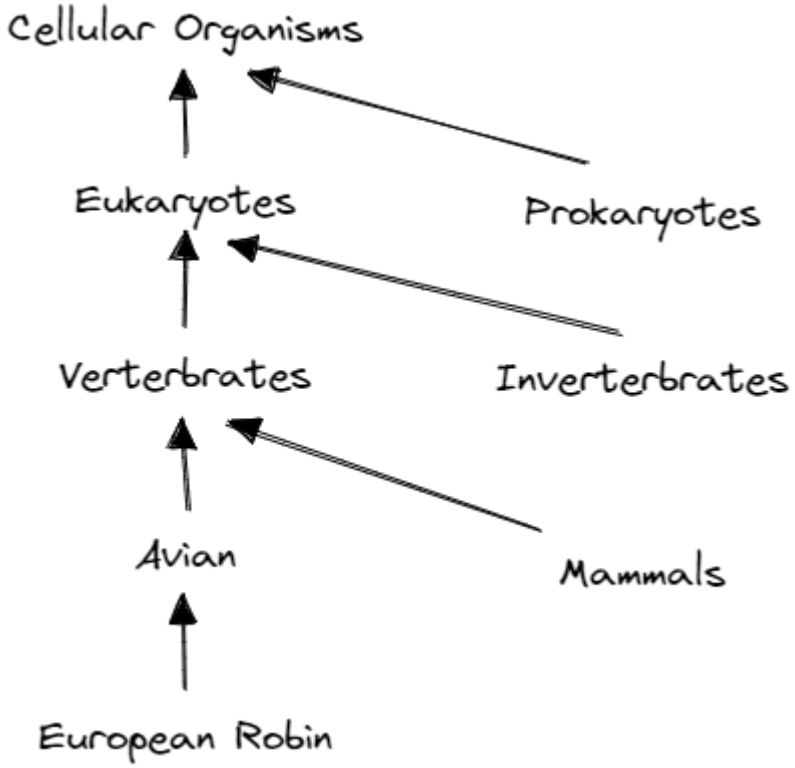
```
class Person {
    final String name;
    final int age;

    Person(String name, int age) {
        this.name = name;
        this.age = age;
    }

    String getName() {
        return name;
    }
```

```
    int getAge() {
        return age;
    }
}
```

Exercises

- Prove by writing a Java program that reference escapism really happens.
- Prove by writing a Java program that with primitive values, reference escapism doesn't happen.
- Can we have reference escapism with `java.util.GregorianCalendar`? And with `java.time.LocalDateTime`? Write programs to prove it.
- Fix the vulnerable programs above using defensive programming techniques.

Module: inheritance (part 1)



Animals or shapes?

Shapes!

They have

- position
- area

- ability to be drawn on a canvas

Rectangle

```
public class Rectangle {
    private double x;
    private double y;
    private double width;
    private double height;

    public Rectangle(double x, double y, double width, double height) {
        this.x = x;
        this.y = y
        this.width = width;
        this.height = height;
    }

    public double getX() { return x; }
    public void setX(double x) { this.x = x; }
    public double getY() { return y; }
    public void setY(double y) { this.y = y; }
    public double getWidth() { return width; }
    public void setWidth(double width) { this.width = width; }
    public double getHeight() { return height; }
    public void setHeight(double height) { this.height = height; }

    public double area() {
        return edge * edge;
    }

    public void drawOn(Canvas canvas) {
        // cool rectangle drawing logic comes here
    }
```

```
}
```

Circle

```
public class Circle {
    private double x;
    private double y;
    private double radius;

    public Circle(double x, double y, double radius) {
        this.x = x;
        this.y = y
        this.radius = radius;
    }

    public double getX() { return x; }
    public void setX(double x) { this.x = x; }
    public double getY() { return y; }
    public void setY(double y) { this.y = y; }
    public double getRadius() { return radius; }
    public void setRadius(double radius) { this.radius = radius; }

    public double area() {
        return Math.PI * radius * radius;
    }

    public void drawOn(Canvas canvas) {
        // cool circle drawing logic comes here
    }
}
```

Triangle

```
public class Triangle {
    private double x;
    private double y;
    private double base;
    private double height;

    public Triangle(double x, double y, double base, double height) {
        this.x = x;
        this.y = y
        this.base = base;
        this.height = height;
    }

    public double getX() { return x; }
    public void setX(double x) { this.x = x; }
    public double getY() { return y; }
    public void setY(double y) { this.y = y; }
    public double getBase() { return base; }
    public void setBase(double base) { this.base = base; }
    public double getHeight() { return height; }
    public void setHeight(double height) { this.height = height; }

    public double area() {
        return base * height / 2;
    }

    public void drawOn(Canvas canvas) {
        // cool triangle drawing logic comes here
    }
}
```

Similarities

What similarities did you see?

Sharing behaviour

```
public abstract class Shape {
    private double x;
    private double y;

    public Shape(double x, double y) {
        this.x = x;
        this.y = y
    }

    public double getX() { return x; }
    public void setX(double x) { this.x = x; }
    public double getY() { return y; }
    public void setY(double y) { this.y = y; }

    public abstract double area();

    public abstract void drawOn(Canvas canvas);
}
```

What did we see?

- `abstract` class
    - We can’t call the constructor anymore

- `abstract` methods
    - `;` instead of code

Extending Shape

```
public class Rectangle extends Shape {
    private double edge;

    public Rectangle(double x, double y, double width, double height) {
        super(x, y);
        this.width = width;
        this.height = height;
    }

    public double getWidth() { return width; }
    public void setWidth(double width) { this.width = width; }
    public double getHeight() { return height; }
    public void setHeight(double height) { this.height = height; }

    @Override
    public double area() {
        return edge * edge;
    }

    @Override
    public void drawOn(Canvas canvas) {
        // cool rectangle drawing logic comes here
    }
}
```

Super and sub

- Shape is the *superclass* of Rectangle
    - A class can have only 1 superclass
- Rectangle is a *subclass* of Shape
    - A class can have many subclasses

What did we see?

- class `extends Shape`
- Constructor calls super constructor with `super(x, y);`
    - Required
    - Must be first in method
- Abstract methods now get body
    - @Override

What's more

`x` and `y` are private in Shape

Rectangle must use `getX()` and `getY()`

Circle

```
public class Circle extends Shape {
    private double radius;

    public Circle(double x, double y, double radius) {
        super(x, y);
        this.radius = radius;
    }

    public double getRadius() { return radius; }
    public void setRadius(double radius) { this.radius = radius; }

    @Override
    public double area() {
        return Math.PI * radius * radius;
    }

    @Override
    public void drawOn(Canvas canvas) {
        // cool circle drawing logic comes here
    }
}
```

Extending classes

Let’s define Square

Is it a Rectangle?

Square

```
public class Square extends Rectangle {
    private double edge;

    public Square(double x, double y, double edge) {
        super(x, y, edge, edge);
    }

    public double getEdge() { return edge; }
    public void setEdge(double edge) { this.edge = edge; }
}
```

What did we see?

- You can extend a class that is not abstract
- You can extend a class that already extends something else
    - All Java classes extend Object
- Constructor params don't need to be identical
    - You still have to call `super()`
- Square has everything that Rectangle has
    - `getWidth()`, `getHeight()`, `drawOn()`

But wait!

`setEdge()` doesn't update width or height!

```
public void setEdge(double edge) {
    this.edge = edge;
    setWidth(edge);
    setHeight(edge);
}
```

Now it does

But wait!

We need to do the same with `setWidth()` and `setHeight()`:

```
@Override
public void setWidth(double width) {
    setWidth(width);
    setHeight(width);
    setEdge(width);
}

@Override
public void setHeight(double width) {
    setHeight(width);
    setWidth(width);
    setEdge(width);
}
```

But wait!

`setWidth()` and `setHeight()` call each other:

infinite loop!

Other options

Can you think of some?

Other options

We can’t remove the methods from the class in Java

Is Square still a Rectangle if we could?

Other options

Make `width` and `height` fields protected

Breaks encapsulation?

Other options

Make `setWidth()` and `setHeight()` throw exceptions

Ugly

Other options

Make all Shapes immutable

Requires re-architecting the code

Other options

Make Square extend Shape directly

Square is no longer a rectangle

Other options

Which is the best?

It depends

Polymorphism

Is a way to allow for change and extensibility

Canvas

What is it?

- HTML canvas
- GUI canvas
- Headless canvas

Canvas

```
public abstract class Canvas {
    public abstract void drawPixel(double x, double y);

    public void drawLine(double x1, double y1, double x2, double y2) {
        // calculate all pixels in the line, and draw each of those pixels
    }

    public void drawEllipse(double centerX, double centerY, double width, double height) {
        // calculate all pixels on the ellipse, and draw each of those pixels
    }
}

public class HtmlCanvas extends Canvas {
    @Override
    public void drawPixel(double x, double y) {
        // HTML-specific pixel drawing
    }
}

public class GuiCanvas extends Canvas {
    @Override
    public void drawPixel(double x, double y) {
        // native pixel drawing
    }
}
```

Canvas

Shape doesn’t care what kind of canvas it is

As long as `drawPixel()`, `drawLine()` and `drawEllipse()` are there

Drawing

```
@Override
public void drawOn(Canvas canvas) {
    canvas.drawLine(x, y, x, y + height);
    canvas.drawLine(x, y + height, x + width, y + height);
    canvas.drawLine(x + width, y + height, x + width, y);
    canvas.drawLine(x + width, y, x, y);
}
```

Polymorphism

- We ask for a Canvas
- We get HtmlCanvas, or GuiCanvas, or some other Canvas
- We don’t care which one we get

Composition over inheritance

- X is-a Y
    - extending
    - inheritance
- X has-a Y
    - fields/properties

- composition

is-a vs has-a

- Rectangle is-a Shape
- Circle is-a Shape
- Shape has-a x coordinate and a y coordinate
- Rectangle has-a width and a height

We get it wrong sometimes

Sometimes we use is-a

when has-a would be better

Example

Payroll system entities:

- Person
- Employee
- Manager

Example

Employee is-a Person

Manager is-a Person

Example

But a Manager is also an Employee!

Example

Composition to the rescue!

Example

```
class Person {
    private String name;
    private int age;
}

class Employee {
    private Person person;
    private double salary;
}

class Manager {
    private Person person;
    private Employee[] minions;
```

```
}
```

Best practice

Prefer composition ('has-a') over inheritance ('is-a')

Exercise

Write down the implementation of Triangle when it extends Shape.

Exercise

Try to add a function that calculates the circumference of all Shapes. What problems do you run into?

Exercise

Can you think of a way to take advantage of the polymorphism of Shapes? I.e., what could you do with Shapes where it doesn’t matter whether they are Rectangles, Circles, or Triangles?

Exercise

Does it make sense to have Manager extend Employee?

Exercise

In the introduction I mentioned one of two common inheritance examples: shapes. The other one, of course, is animals! Come up with an inheritance hierarchy of animals. Each animal has a sound it can make, a number of legs, and a type of food it likes. Try to implement this in Java. For inspiration:

think cats, dogs, tigers, giraffes, butterflies, crickets, salmon, and cephalopods, and add whatever else you can think of! Do fish make sounds? What other properties can you come up with?