TS Spring

Day 3: Aspect-oriented programming

Introduction

- https://github.com/banckaert/ts-spring-aop
- Why this course?
  - AOP is a powerful tool
  - AOP is a fundamental part of the Spring Framework (and Java EE)

  ⇔
  - Seldom used to its full potential
  - Trainings and books on the subject are often academic and unpractical

Overview

- Why Aspect-oriented Programming (AOP)?
  - How AOP helps to solve problems in enterprise applications
- My First Aspect
  - First example of an aspect
- Advices
  - What code can be used in aspects?
- Pointcuts
  - How to define where aspects are added to your application

Overview

- Aspects and Architecture
  - Expressing architecture using Pointcuts
  - Make architecture a part of your application
- Spring AOP: under the hood
  - How Aspects are added to Objects
  - Deeper understanding about Spring’s AOP internals
- Spring AOP: Spring Aspect Library
  - Out-of-the-box aspects for your application
- Aspects, the real world
  - Some ideas for your own aspects

Why Aspect-oriented Programming (AOP)?

- Why AOP?
- Reducing Boiler Plate Code using AOP
- How AOP Works
- Cross-Cutting Concerns
- Summary

Why AOP?

- What is AOP?
  - Aspect Oriented Programming (AOP)
  - Complements Object Oriented Programming (OOP)
  - Unit of modularisation: OOP Class vs. AOP Aspect
  - Modularisation across types and objects (Cross Cutting Concerns)
- What does AOP bring to the table?
  - AOP reduces Boiler Plate Code
  - AOP is used to add enterprise features to your application

Reducing Boiler Plate Code using AOP (1/5)

```
19    public void someMethod() {
20        final String METHODNAME = "someMethod";
21        logger.trace("entering " + CLASSNAME + "." + METHODNAME);
22        TransactionStatus tx = transactionManager
23                .getTransaction(new DefaultTransactionDefinition());
24        try {
25            // Business Logic
26        } catch (RuntimeException ex) {
27            logger.error("exception in " + CLASSNAME + "." + METHODNAME, ex);
28            tx.setRollbackOnly();
29            throw ex;
30        } finally {
31            transactionManager.commit(tx);
32            logger.trace("exiting " + CLASSNAME + "." + METHODNAME);
33        }
34    }
```

Reducing Boiler Plate Code using AOP (2/5)

- Logging
- Transactions
- Exception Handling

```
19    public void someMethod() {
          final String METHODNAME = "someMethod";
          logger.trace("entering " + CLASSNAME + "." + METHODNAME);
          TransactionStatus tx = transactionManager
                  .getTransaction(new DefaultTransactionDefinition());
24        try {
25            // Business Logic
26        } catch (RuntimeException ex) {
              logger.error("exception in " + CLASSNAME + "." + METHODNAME, ex);
              tx.setRollbackOnly();
29            throw ex;
30        } finally {
              transactionManager.commit(tx);
              logger.trace("exiting " + CLASSNAME + "." + METHODNAME);
33        }
34    }
```

Reducing Boiler Plate Code using AOP (3/5)

~~Logging~~

Transactions

Exception Handling

```
19    public void someMethod() {


          TransactionStatus tx = transactionManager
                  .getTransaction(new DefaultTransactionDefinition());
24        try {
25            // Business Logic
26        } catch (RuntimeException ex) {
              logger.error("exception in " + CLASSNAME + "." + METHODNAME, ex);
              tx.setRollbackOnly();
29            throw ex;
30        } finally {
              transactionManager.commit(tx);

33        }
34    }
```

Reducing Boiler Plate Code using AOP (4/5)

~~Logging~~

~~Transactions~~

Exception Handling

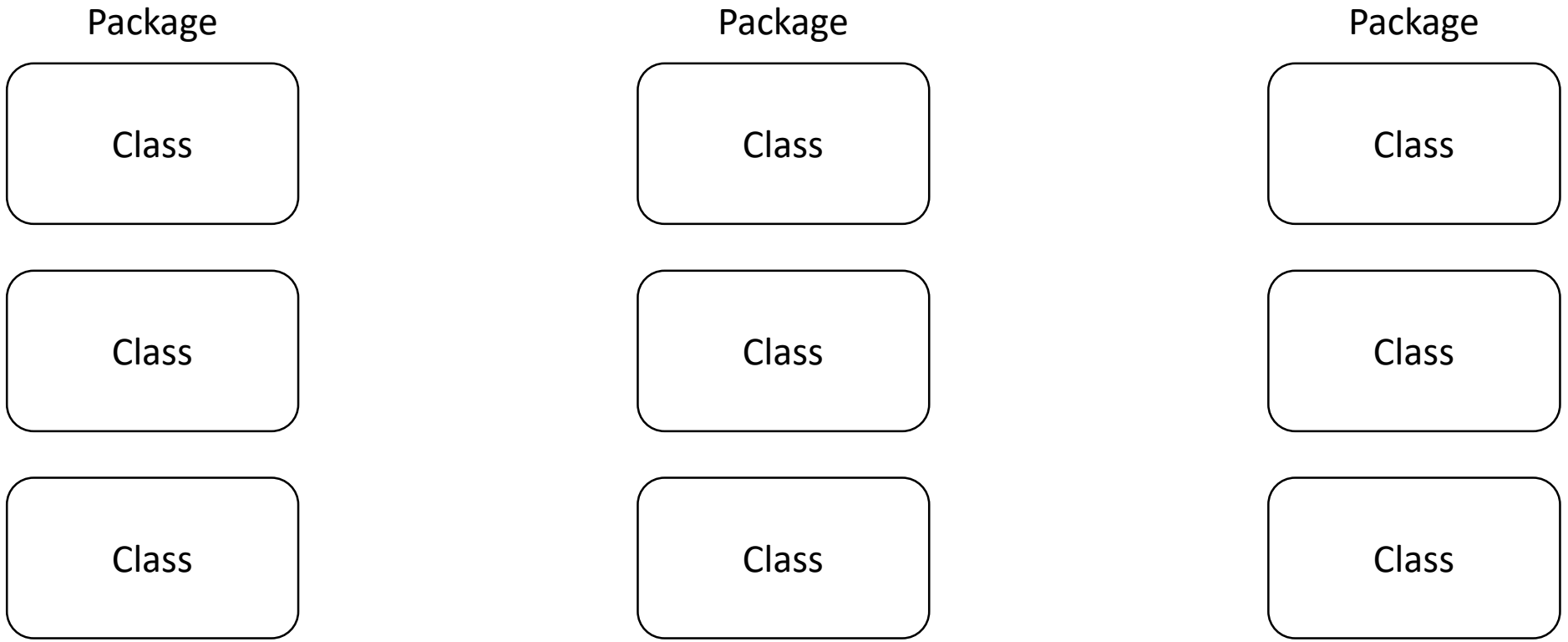
```
19    public void someMethod() {
24        try {
25            // Business Logic
26        } catch (RuntimeException ex) {
              logger.error("exception in " + CLASSNAME + "." + METHODNAME, ex);
29            throw ex;
30        } finally {
33        }
34    }
```

Reducing Boiler Plate Code using AOP (5/5)

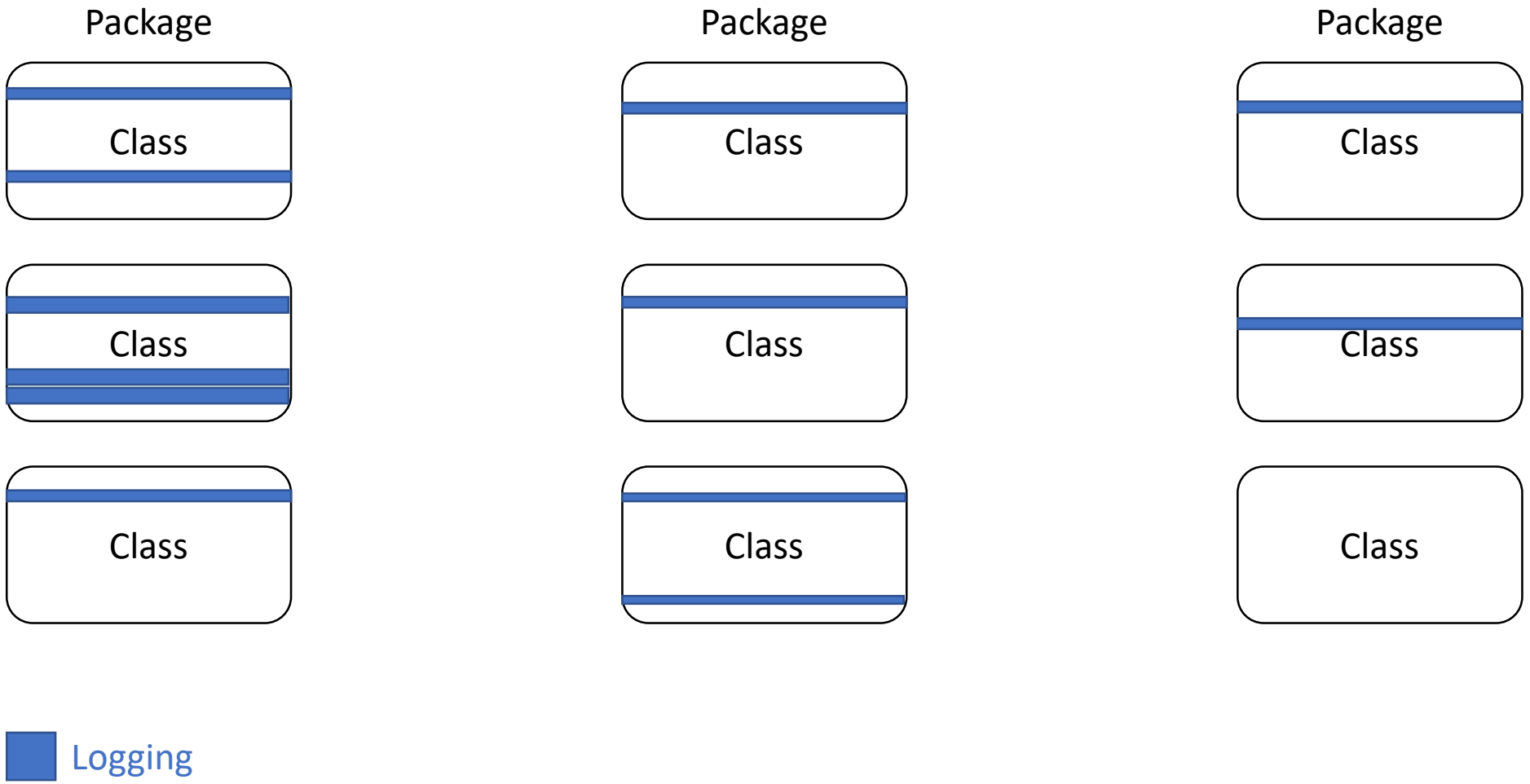
- ~~Logging~~
- ~~Transactions~~
- ~~Exception Handling~~

```
19    public void someMethod() {
25        // Business Logic
34    }
```

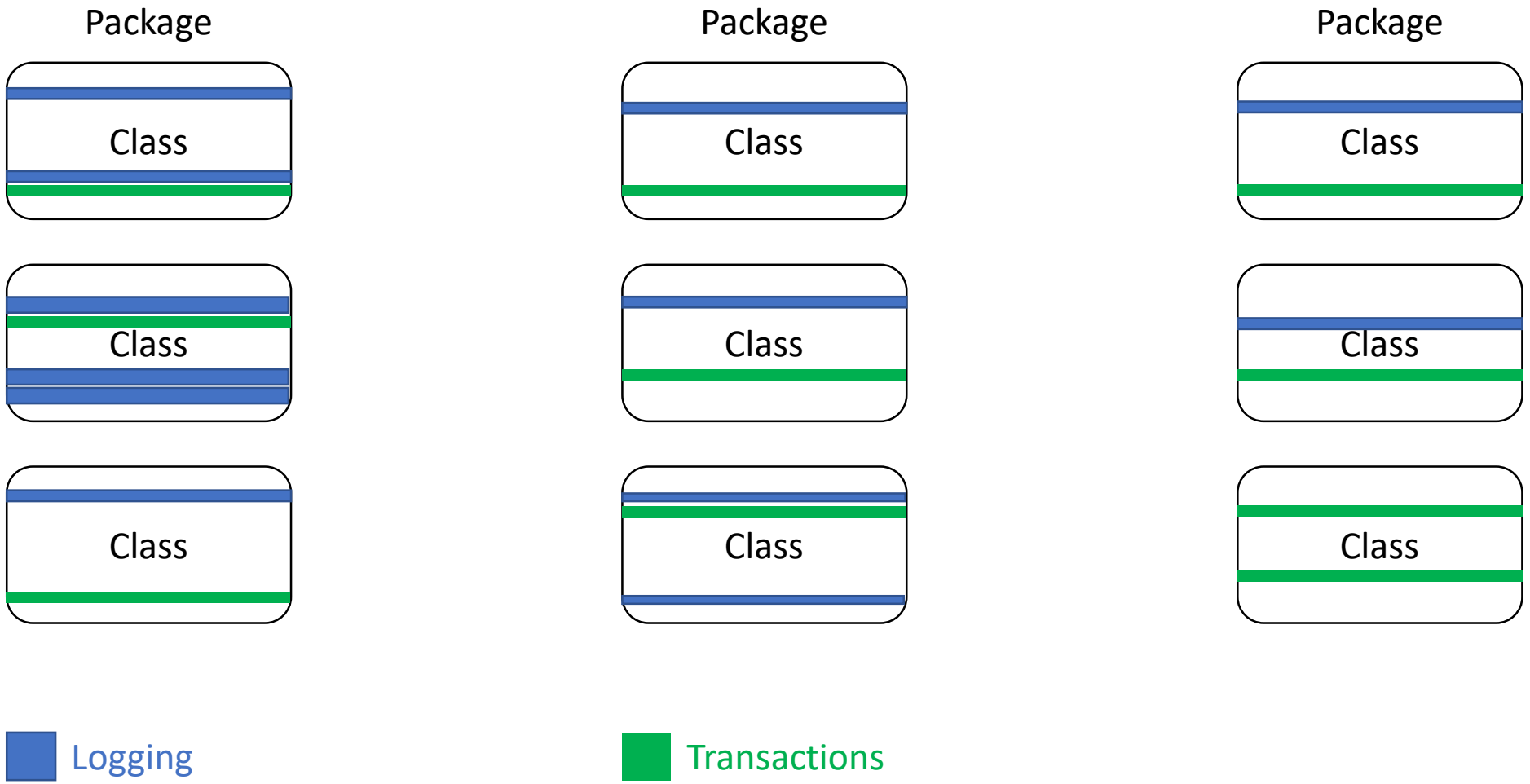
How AOP Works



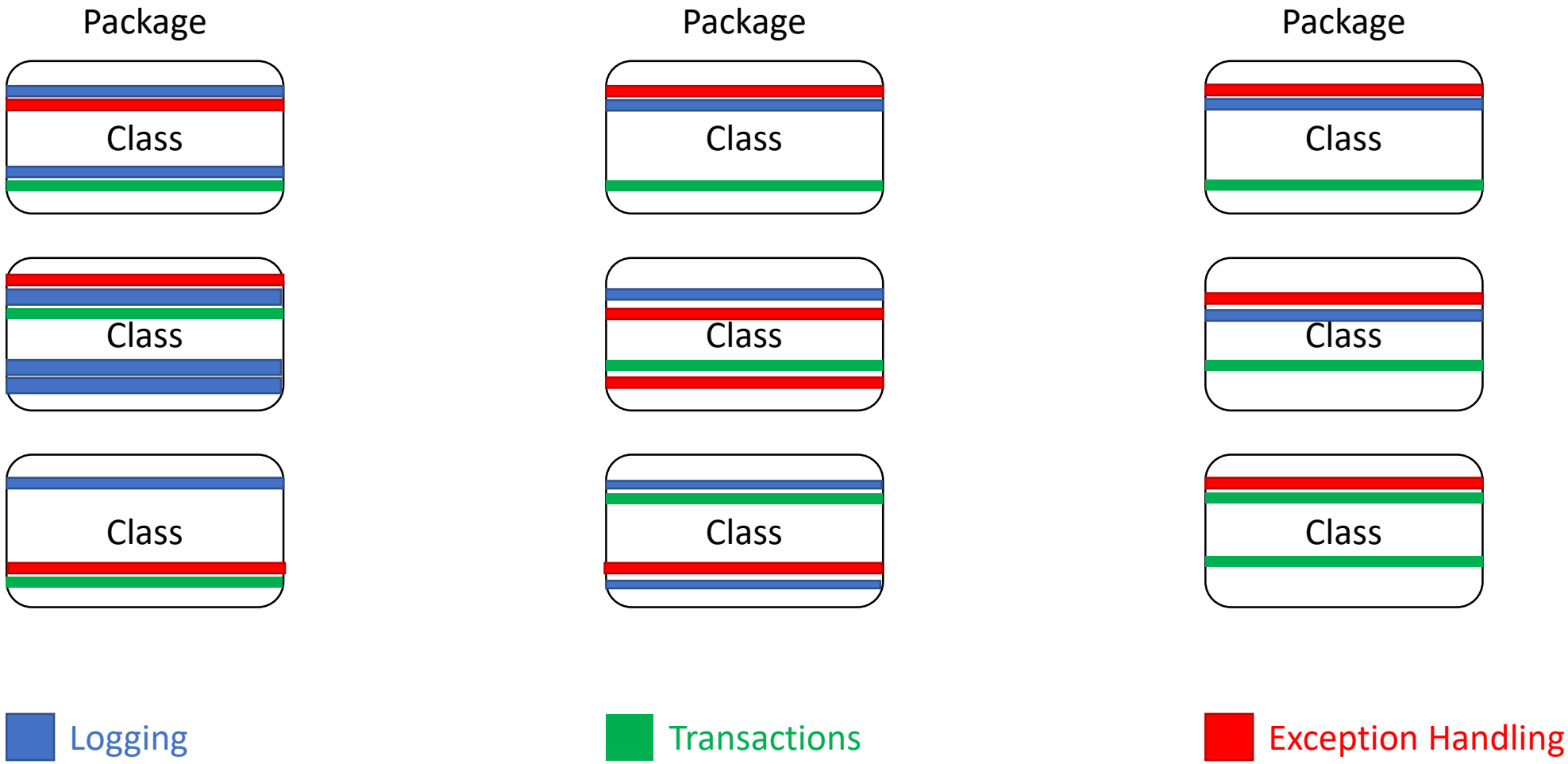
How AOP Works



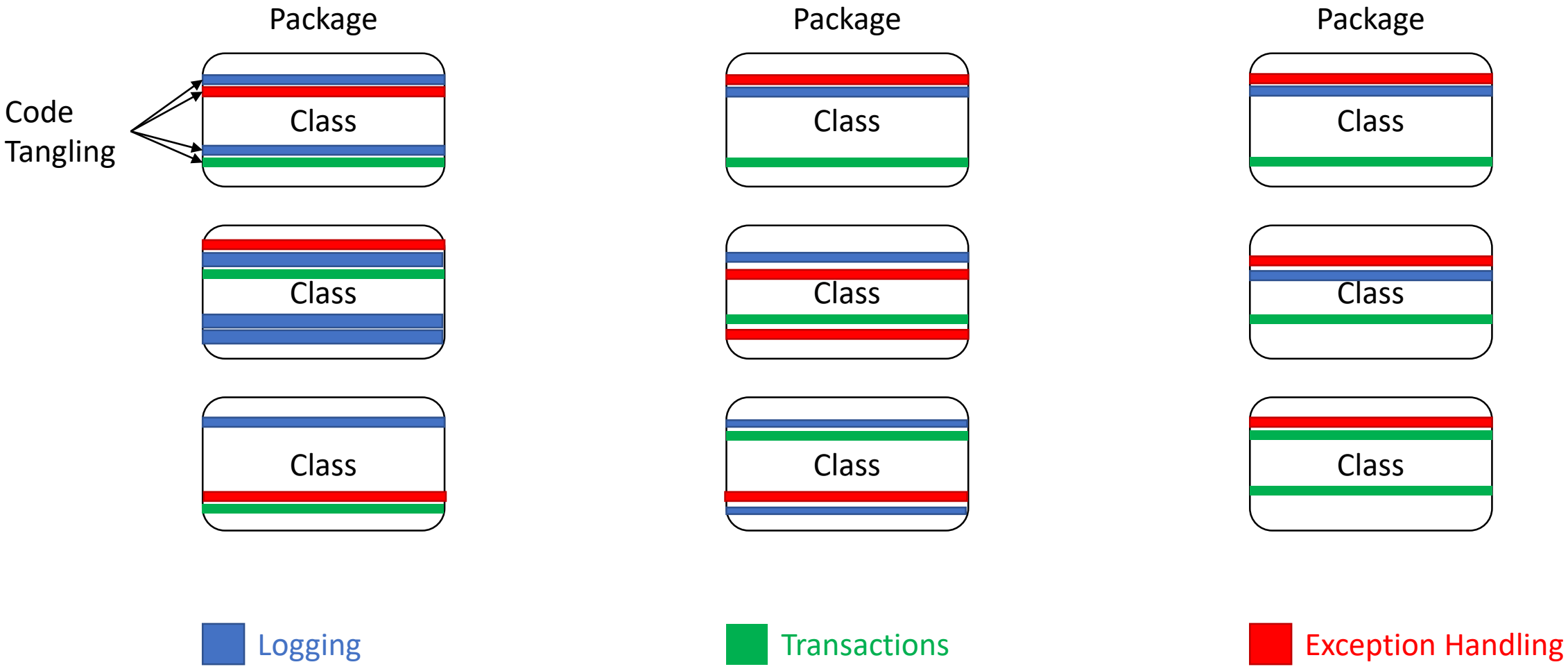
How AOP Works



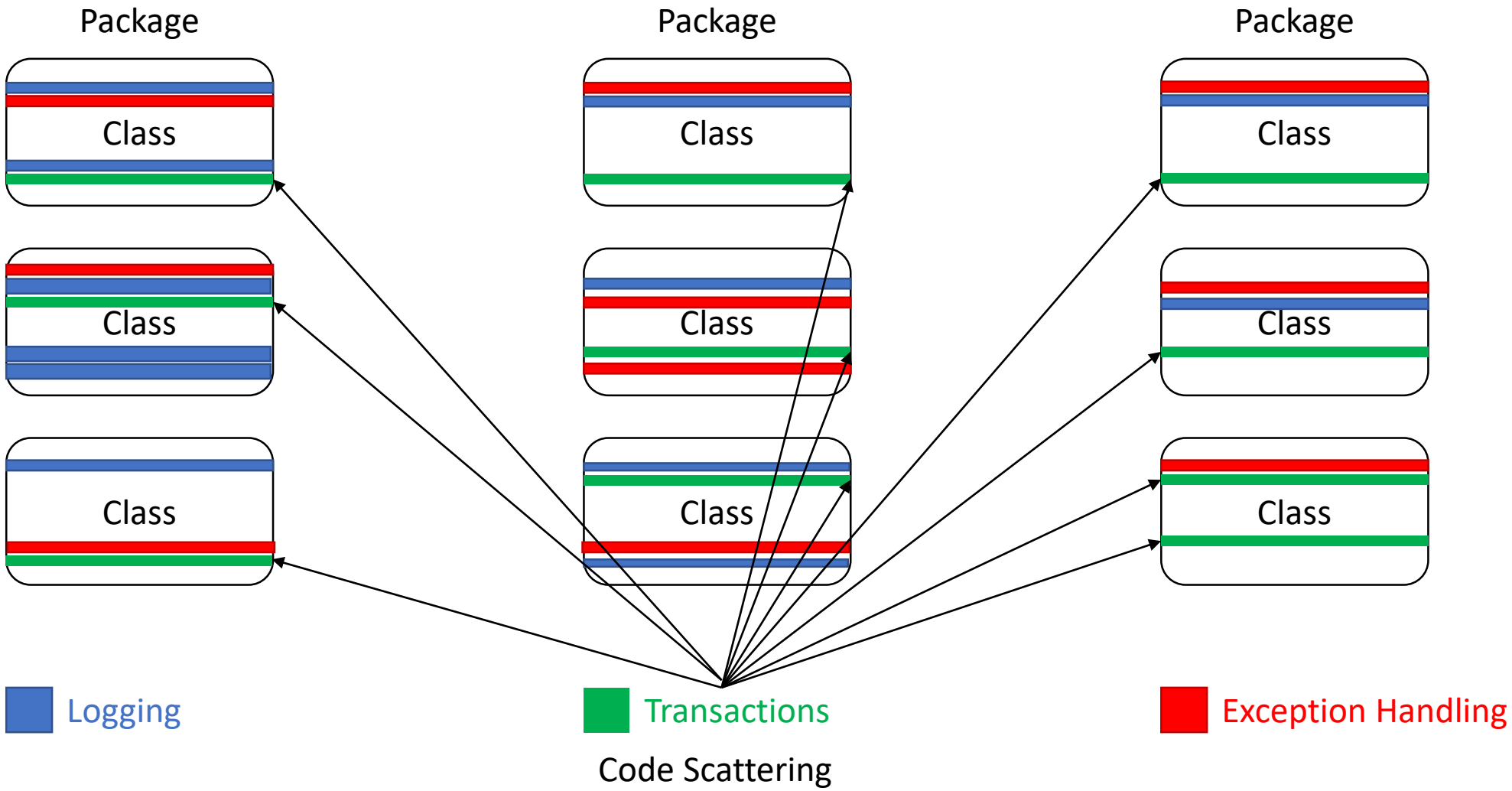
How AOP Works



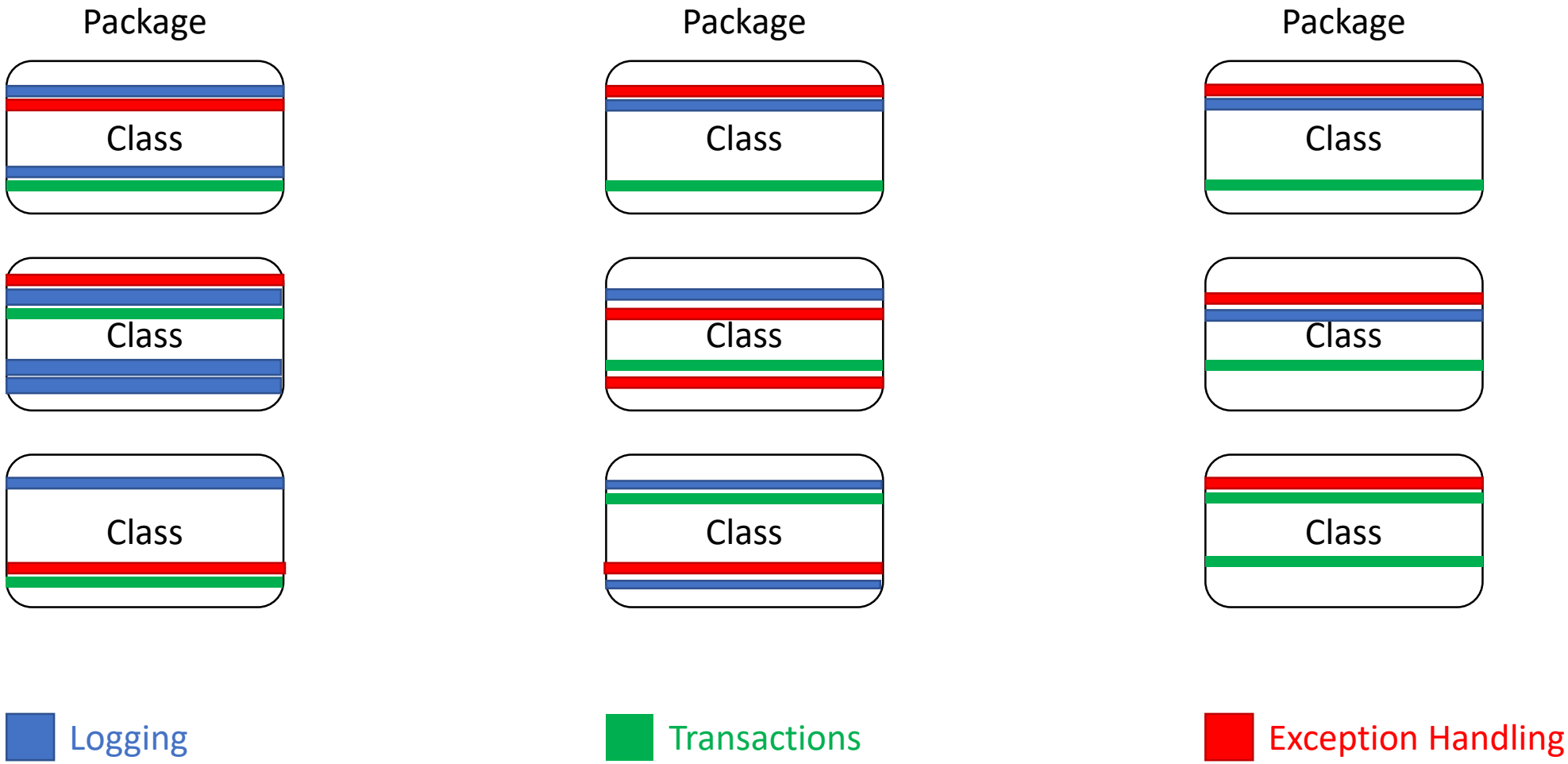
How AOP Works



How AOP Works



How AOP Works



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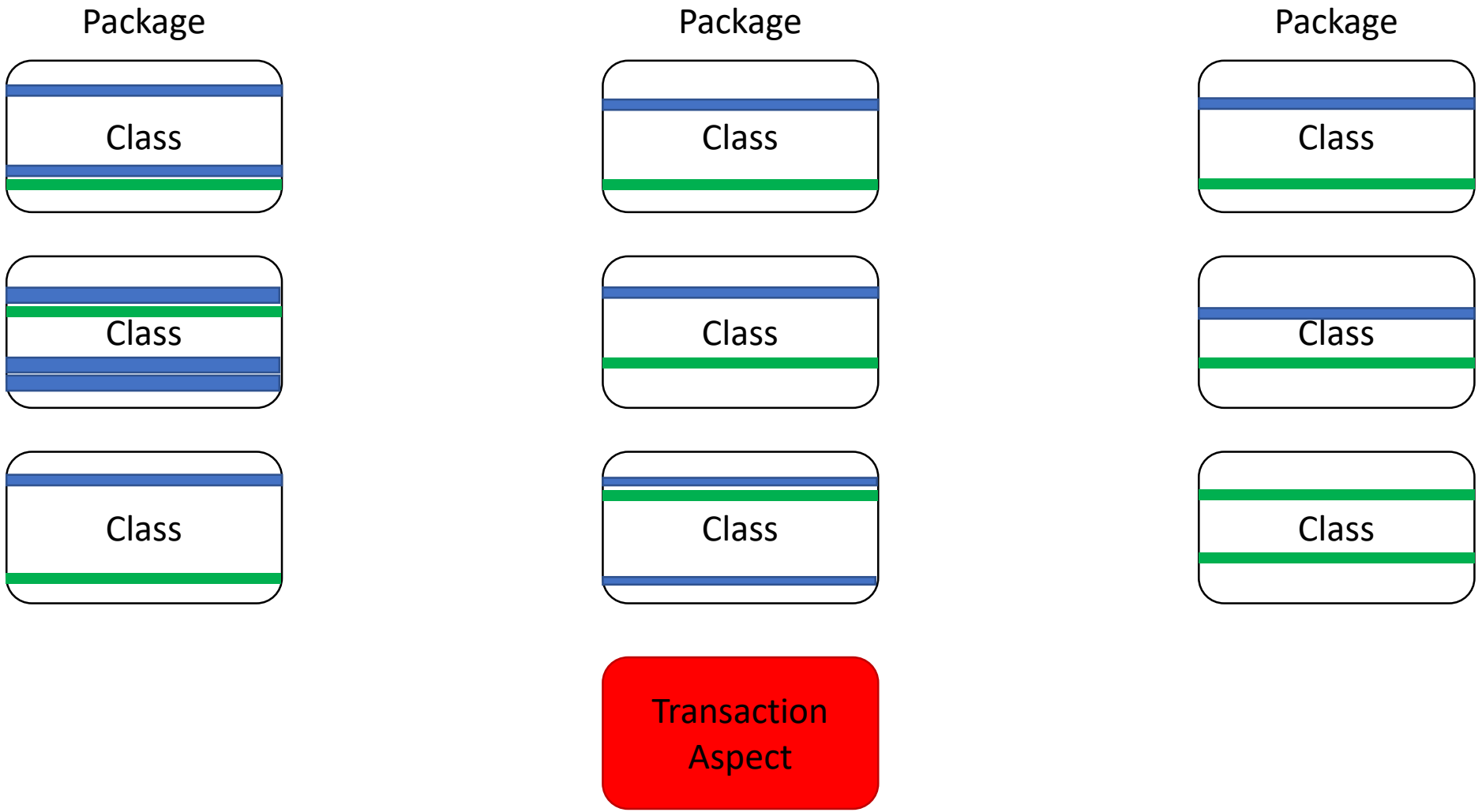

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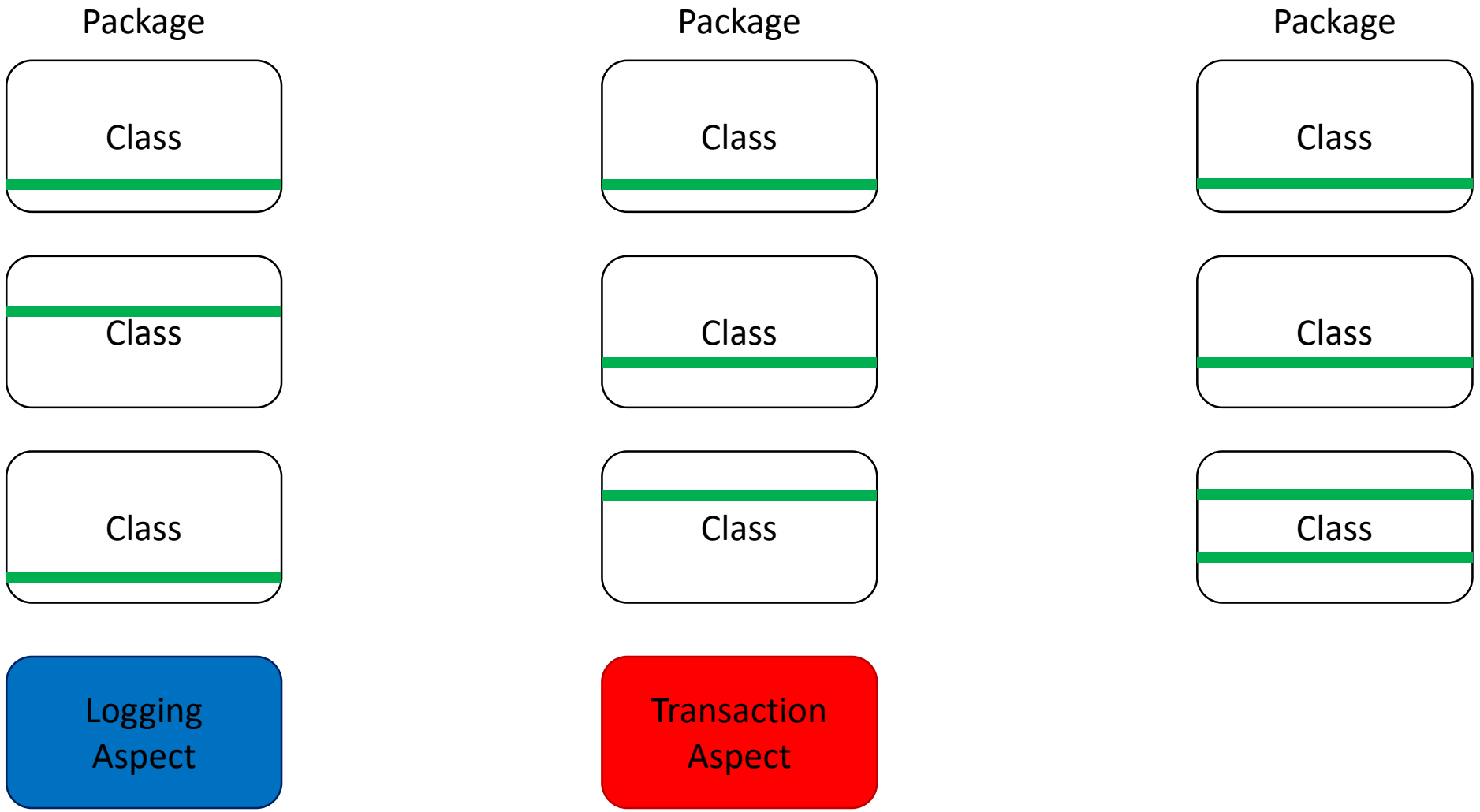
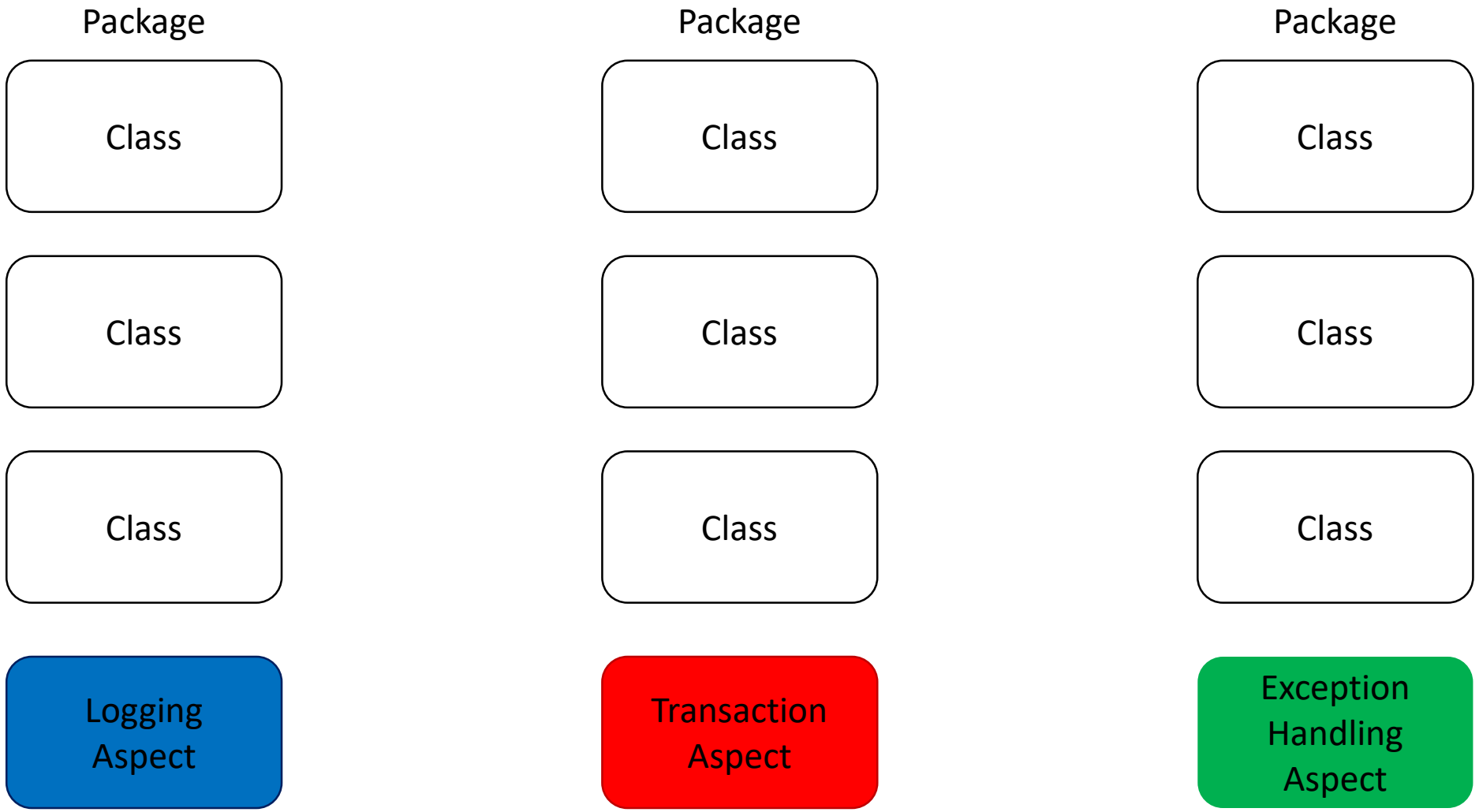


How AOP Works



Cross-Cutting Concerns

- Logging, Transactions and Exception Handling
- OOP: Different classes contain same/similar code

⇔

- AOP: centralized implementation

Summary

- Without AOP cross-cutting concerns are introduced across the code
- Mostly of a technical nature
  - Logging
  - Exception handling
  - Transactions
  - Security
  - …
- Result
  - Code tangling: Multiple concerns in each piece of code
  - Code scattering: Aspects are not implemented in one place
- Aspect-oriented programming resolves these issues

- Exercise - aop01

My First Aspect

- What is an Aspect?
- JoinPoint
- My First Aspect
- Weaving
- Spring configuration
- Summary

What is an Aspect?

- Aspect implements cross cutting concern
  - ⇔‘that scattered code’
  - ⇔Boiler Plate Code

Aspect	=	**Pointcut**	+	**Advice**
		Where the Aspect is applied (Set van Joinpoints)		What Aspect code is executed

JoinPoint

- Point in the control flow of a program
- Advices are provided with information about the join point
  - Class name
  - Method name

My First Aspect

- Logging

```
19    public void someMethod() {
          final String METHODNAME = "someMethod";
          logger.trace("entering " + CLASSNAME + "." + METHODNAME);
22        TransactionStatus tx = transactionManager
23                .getTransaction(new DefaultTransactionDefinition());
24        try {
25            // Business Logic
26        } catch (RuntimeException ex) {
27            logger.error("exception in " + CLASSNAME + "." + METHODNAME, ex);
28            tx.setRollbackOnly();
29            throw ex;
30        } finally {
31            transactionManager.commit(tx);
              logger.trace("exiting " + CLASSNAME + "." + METHODNAME);
33        }
34    }
```

My First Aspect

```java
@Component
@Aspect
public class TracingAspect {

    public boolean isEnteringCalled() {
        return enteringCalled;
    }

    Logger logger = LoggerFactory.getLogger(TracingAspect.class);

    boolean enteringCalled = false;

    @Before("execution(* *(..))")
    public void entering(JoinPoint joinPoint) {
        enteringCalled = true;
        logger.trace("entering "
                + joinPoint.getStaticPart().getSignature().toString());
    }

}
```

Weaving

- The process of adding Advices to the main program code at the configured JoinPoints

Spring configuration - XML

```xml
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns:aop="http://www.springframework.org/schema/aop"
    xmlns:context="http://www.springframework.org/schema/context"
    xsi:schemaLocation="http://www.springframework.org/schema/aop http://www.springframework.org/schema/aop/spring-aop-3.2.xsd
        http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context http://www.springframework.org/schema/context/spring-context-3.2.xsd">

    <aop:aspectj-autoproxy />

    <context:component-scan base-package="simpleaspect" />

</beans>
```

Spring configuration - Java

```java
package configuration;

import org.springframework.context.annotation.ComponentScan;
import org.springframework.context.annotation.Configuration;
import org.springframework.context.annotation.EnableAspectJAutoProxy;

@Configuration
@EnableAspectJAutoProxy
@ComponentScan(basePackages="simpleaspect")
public class SimpleAspectConfiguration {

}
```

Summary

- Aspect =
  - Advice – what code is executed +
  - Pointcut – where the code is executed
- Aspects are Spring Beans
  - @Aspect
- Advices are methods
- @Before annotation
  - With pointcut expression
- Activate AOP
  - XML or
  - Java Config

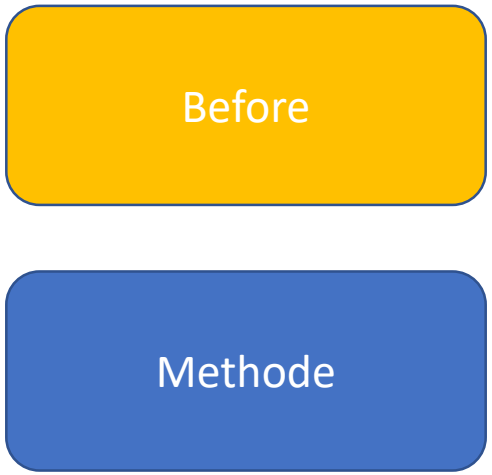
- Exercise - aop02

Advices

- So far: “Before” Advices
- There’s more

Advices – Types of Advices

Advices – Types Advices



Advices – Types Advices

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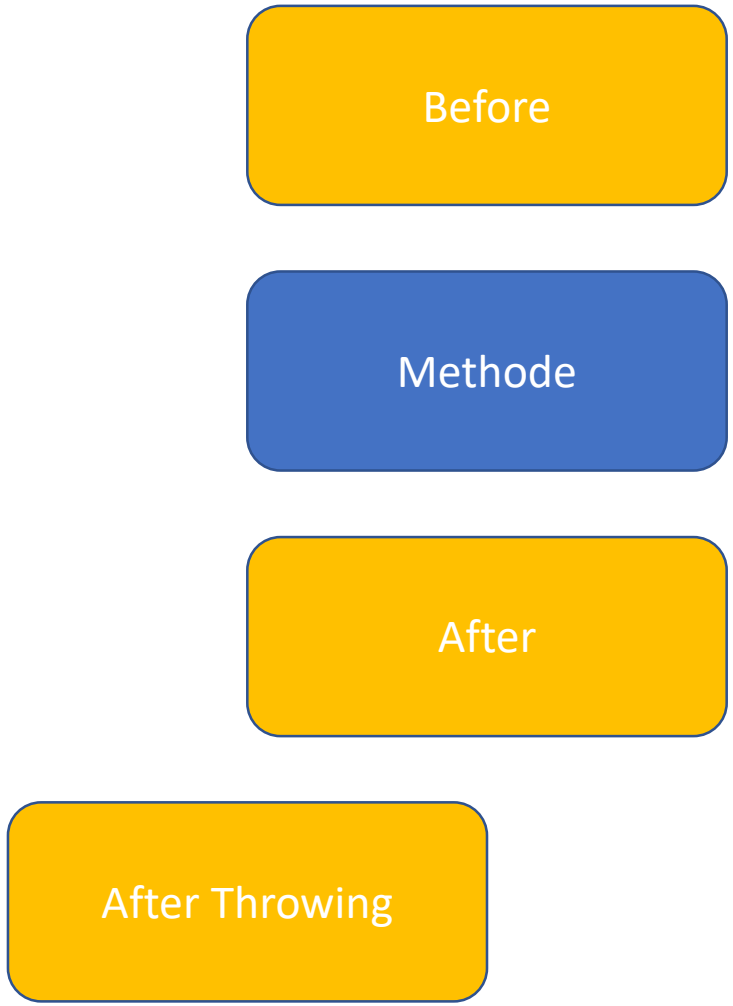
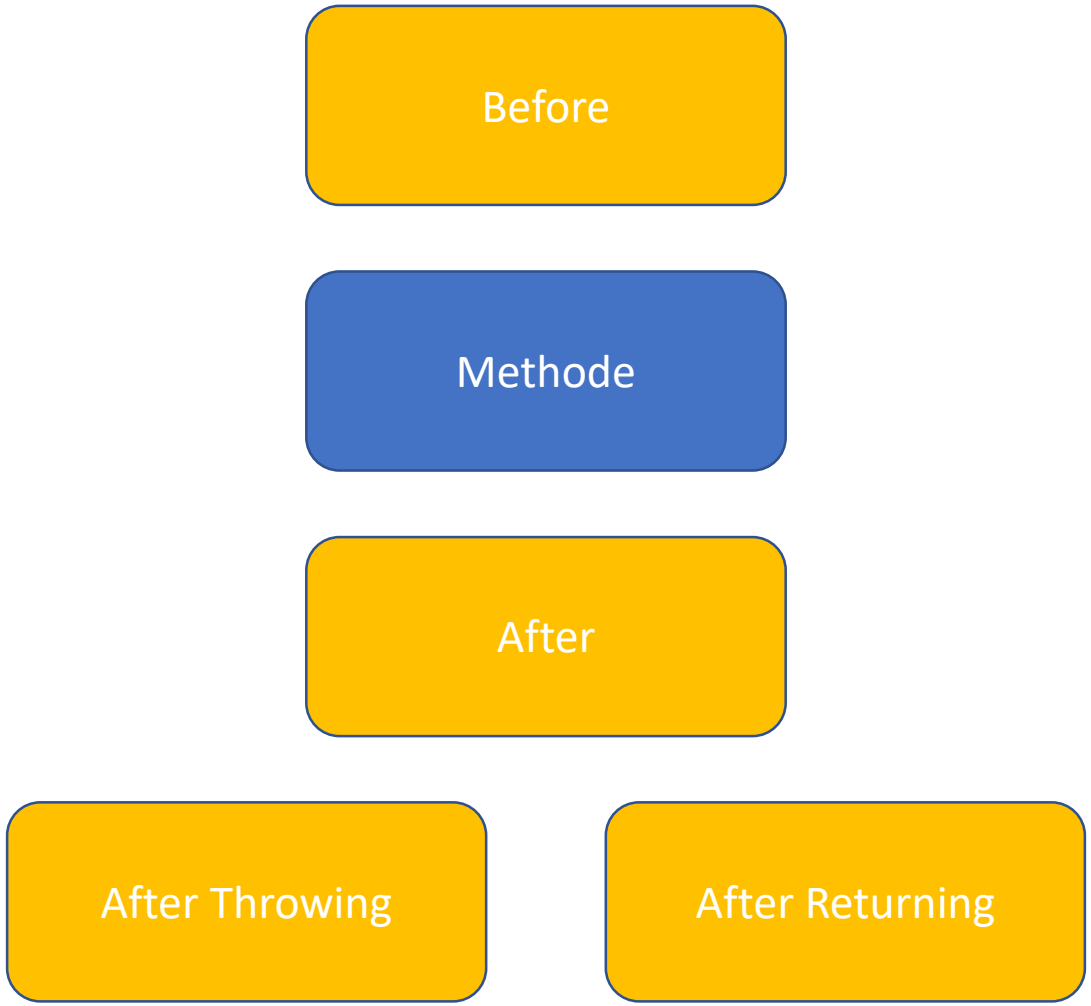
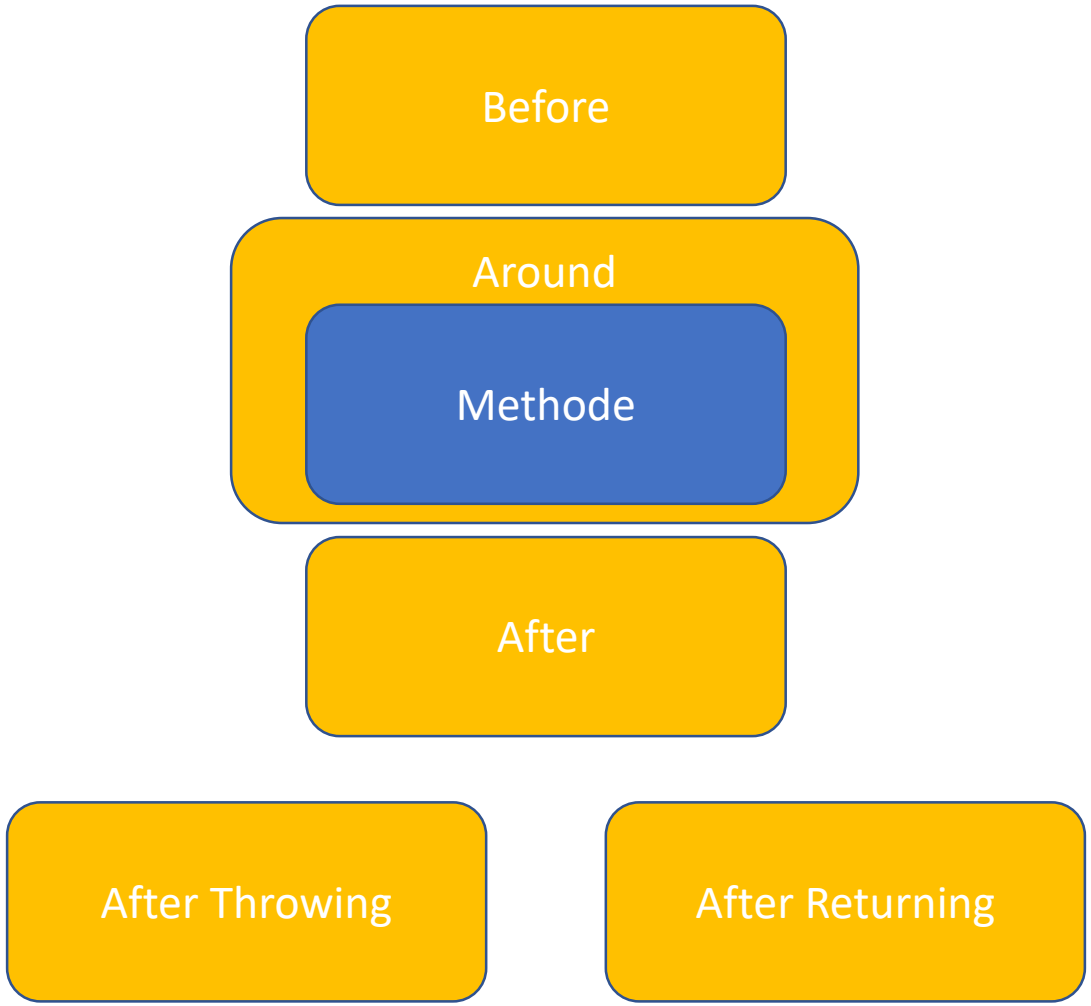


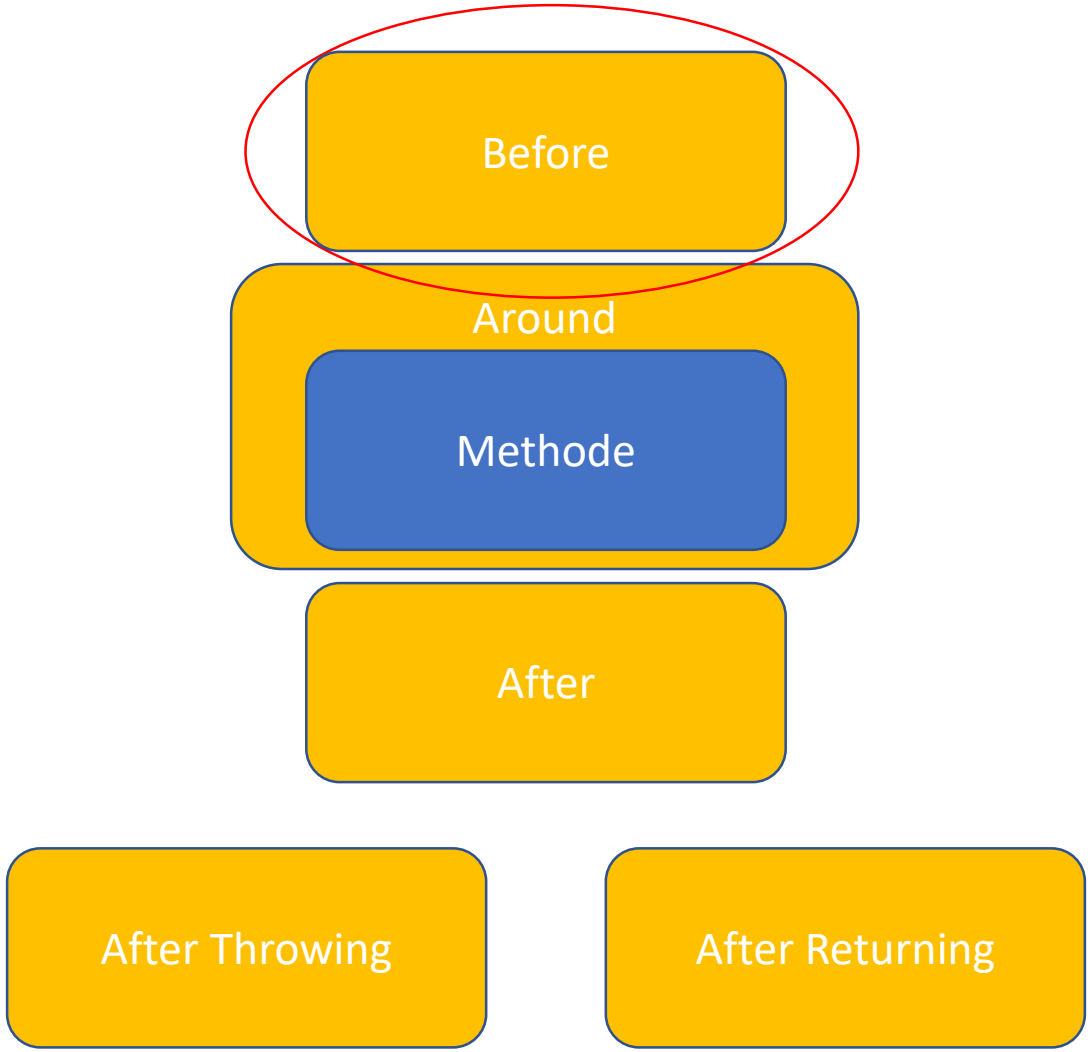
Advices – Types Advices



Advices – Types Advices



Advices – Before



Advices - Before

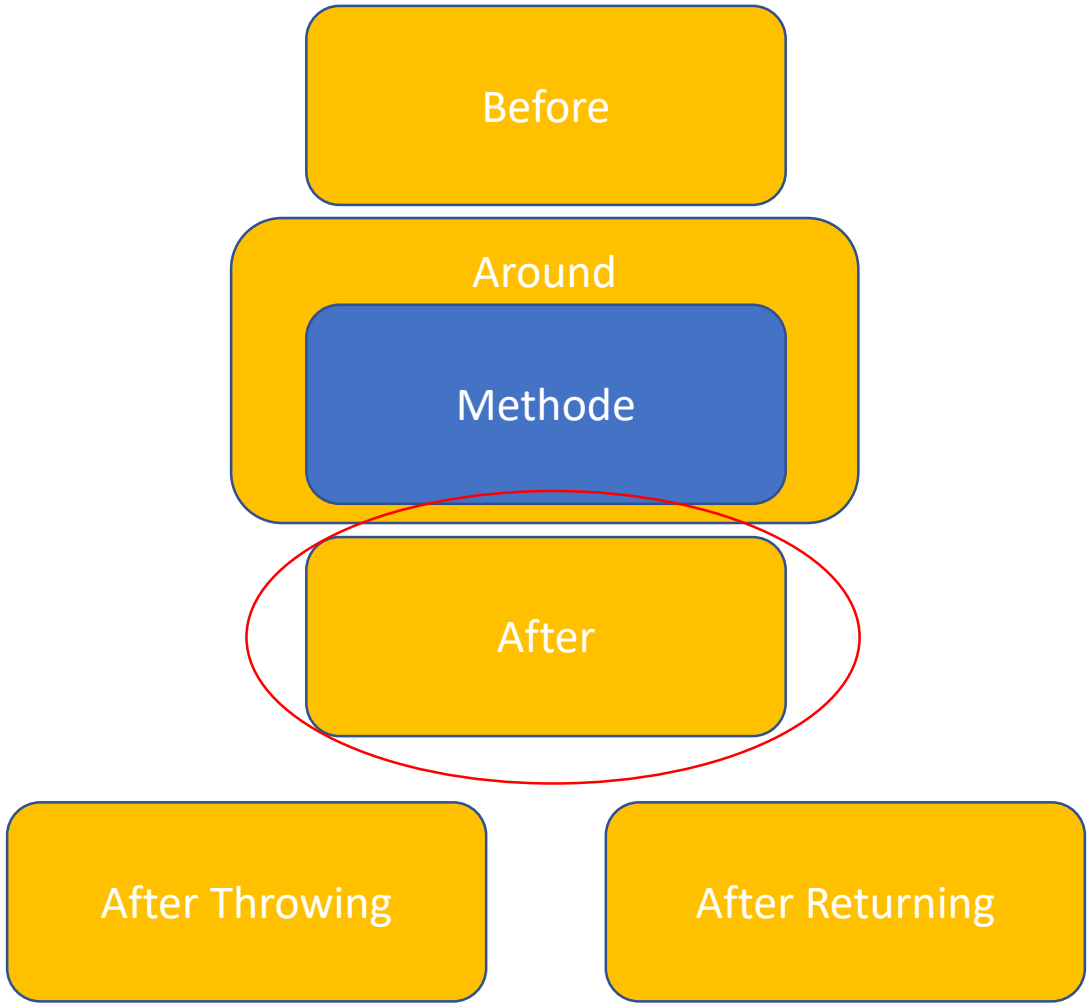
- Execution BEFORE the method
- Exception

  => prevents method execution

  => propagated to caller

```
26    @Before("execution(void someMethod())")
27    public void entering(JoinPoint joinPoint) {
28      beforeCalled = true;
29      logger.trace("entering "
30          + joinPoint.getStaticPart().getSignature().toString());
31    }
```

Advices – After



Advices – After

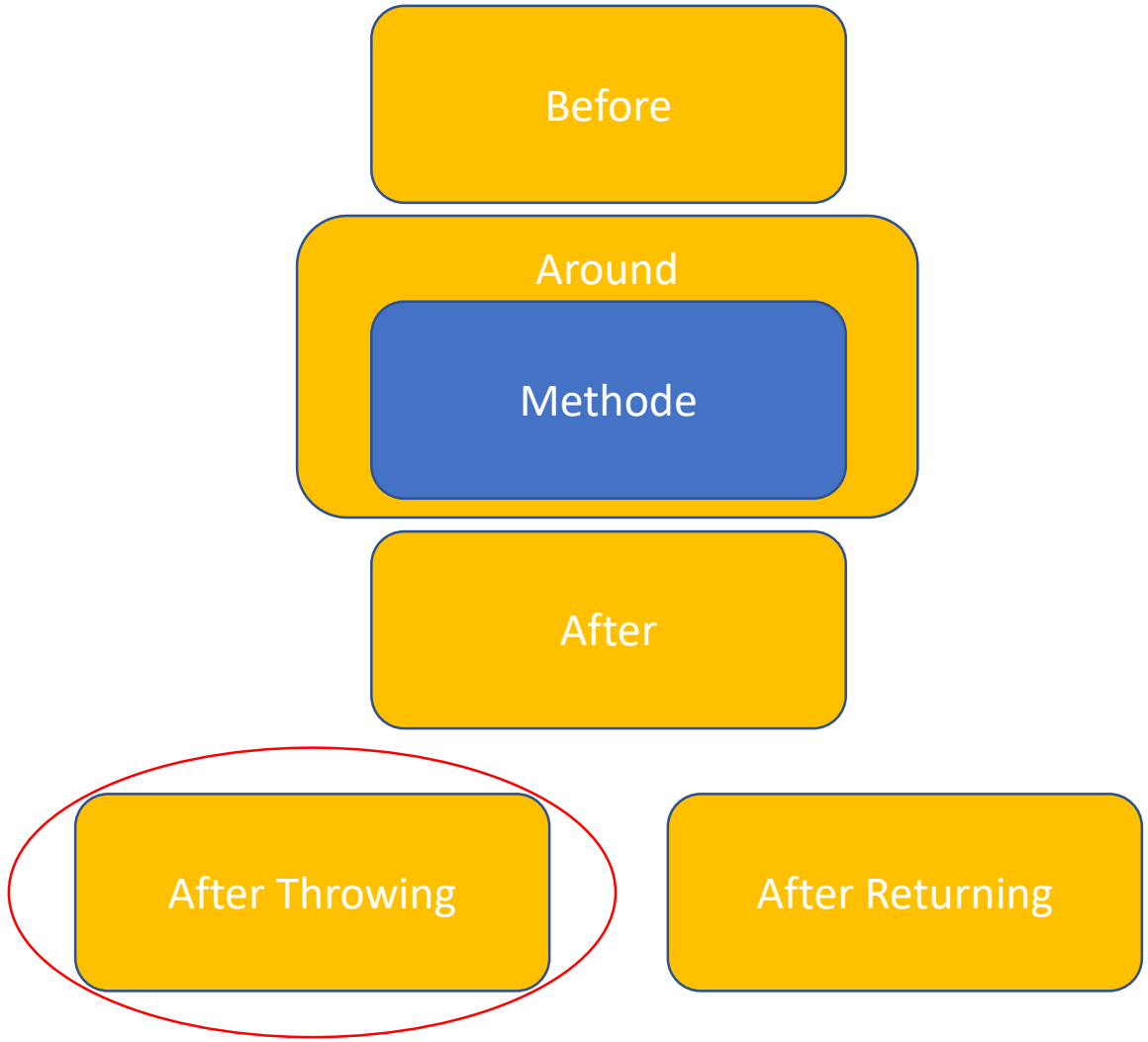
- Execution AFTER the method
- Exception

  => could have been thrown

  => or method could have been executed successfully

```
26  @After("execution(* *(..))")
27   public void exiting(JoinPoint joinPoint) {
28      afterCalled = true;
29      logger.trace("exiting "
30              + joinPoint.getSignature());
31      for (Object arg : joinPoint.getArgs()) {
32         logger.trace("Arg : " + arg);
33      }
34   }
```

Advices – After Throwing



Advices – After Throwing

- Execution AFTER the method THREW an exception
- Exception

  => propagated to caller

  => can be accessed from code

  => Type Safe: e.g. only executed if a RuntimeExceptionis thrown

```
25  @AfterThrowing(pointcut = "execution(void throwsRuntimeException())", throwing = "ex")
26  public void logException(RuntimeException ex) {
27    afterThrowingCalled = true;
28    logger.error("Exception ", ex);
29  }
```

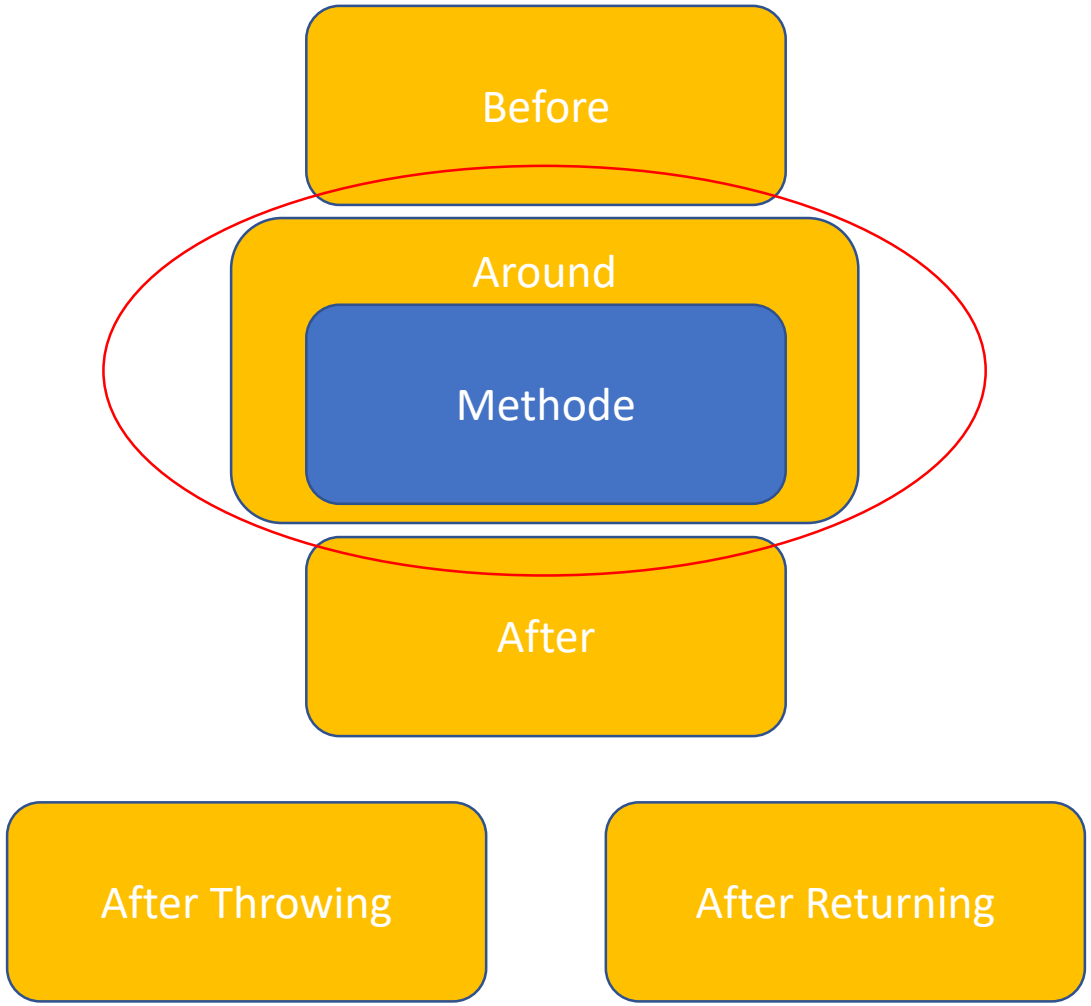
Advices – After Returning

Advices – After Returning

- Execution AFTER the method RETURNED successfully
- Result can be accessed from code
- Type Safe: e.g. only called if a String is returned

```
25    @AfterReturning(pointcut = "execution(* *(..))", returning = "string")
26     public void logResult(String string) {
27         afterReturningCalled = true;
28         logger.trace("result " + string);
29     }
```

Advices – Around



Advices – Around

- Wraps AROUND the method

- Prevent method execution
- … even without throwing an exception (<> Before Advice)

=> only advice that can catch exceptions

=> only advice that can modify return value

- Current method call is passed to the Advice
- ProceedingJoinPoint
- Can be executed or skipped

Advices – Around

```
21      @Around("execution(* *(..))")
22      public Object trace(ProceedingJoinPoint proceedingJP ) throws Throwable {
23          String methodInformation =
24                  proceedingJP.getStaticPart().getSignature().toString();
25          logger.trace("Entering "+methodInformation);
26          called=true;
27          try {
28              return proceedingJP.proceed();
29          } catch (Throwable ex) {
30              logger.error("Exception in "+methodInformation, ex);
31              throw ex;
32          } finally {
33              logger.trace("Exiting "+methodInformation);
34          }
35      }
```

Advices – Around

- Most powerful advice

=> can be used instead of Before and After

=> powerful but complex

- With great power comes great responsibility

Advices

- Exercise - aop3

Pointcuts

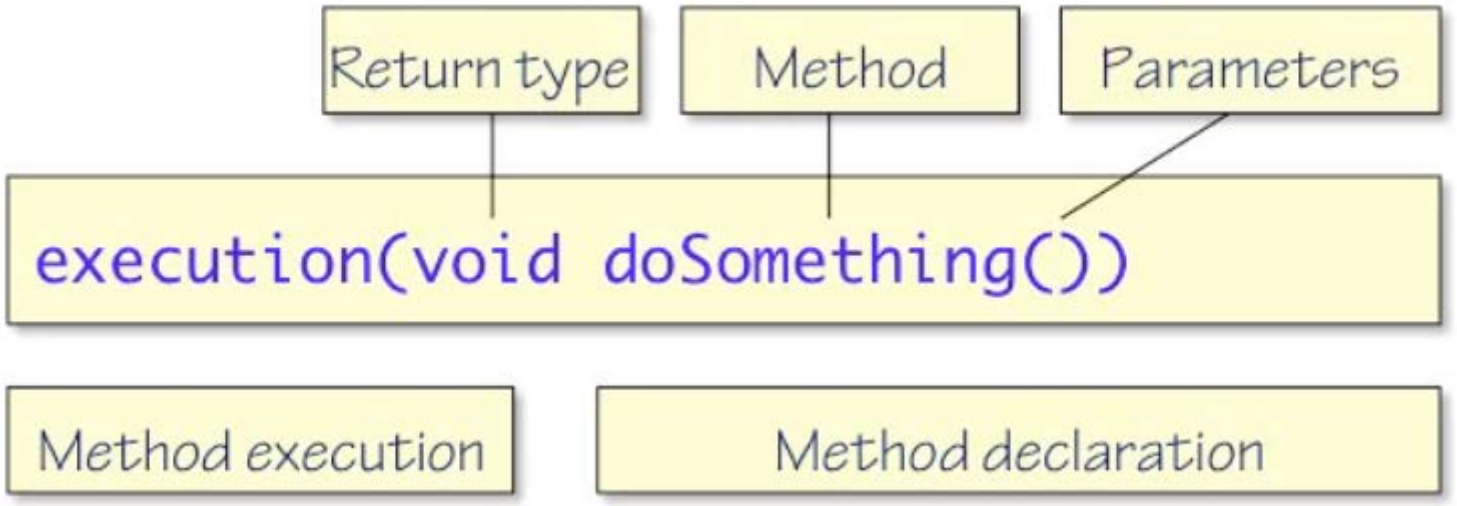
- So far: aspects on specific methods or all methods
- There’s more

Pointcuts

- Pointcut Expressions
- On Packages and Classes
- On Annotations
- On Spring Beans
- Combining Pointcuts
- Pointcut Reuse
- Summary

Pointcut Expressions

- @PointCut
- Defines where an aspect is added to the program flow
- Pointcut



- Wildcards, wildcards, wildcards…

Pointcut Expressions

execution(hello())*

- Method: hello
- Parameters: none
- Return type: any

execution(hello(int, int))*

- Method: hello
- Parameters: 2 x int
- Return type: any

Pointcut Expressions

execution(hello(*))*

- Method: hello
- Parameters: 1 parameter of any type
- Return type: any

execution(hello(..))*

- Method: hello
- Parameters: any number of parameters of any type
- Return type: any

On Packages and Classes

execution(int com.axxes.services.Service.hello(int))

- Method: hello
  - Class: Service
  - Package: com.axxes.services
- Parameters: 1 parameter of type int
- Return type: int

execution(com.axxes..*Service.*(..))*

- Method: any
  - Class: with class name ending with Service
  - Package: com.axxes or sub package
- Parameters: any number of parameters of any type
- Return type: any

On Packages and Classes

execution(*.*(..))*

- Method: any
  - Class: any
  - Package: default
- Parameters: any number of parameters of any type
- Return type: any

execution(*..*.*(..))*

- Method: any
  - Class: any
  - Package: any package or sub package
- Parameters: any number of parameters of any type
- Return type: any

On Annotations

*execution(@com.axxes.annotations.Annotation * *(..))*

- Annotated method

execution((@ com.axxes.annotations.Annotation *).*(..))*

- Annotated class

On Spring Beans

*bean(*Service)*

- Bean name default: class name
- Beans definition
  - Java Config: @Bean method name
  - Annotation: parameter to @Component, @Service, @Repository
  - XML: name / id attribute of bean element

Combining Pointcuts

- Boolean operators: &&, ||, !, …

execution(service.*.*(..)) || execution(* repository.*.*(..))*

Pointcut Reuse

- Problem: Pointcut expression repeated every time a pointcut is used
  => Solution: Around Advice on annotated stub

```
public class MyPointcuts {

        @Pointcut("execution(@annotation.Trace * *(..))")
        public void traceAnnotated() {
        }
        Use @Pointcut annotation
}       Note: Method's purpose is just to be annotated
```

```
@Around("MyPointcuts.traceAnnotated()")
public void trace(ProceedingJoinPoint proceedingJP )
 throws Throwable {
}
```

Summary

- Pointcuts: Where should an advice be added?
- Pointcut Expressions, use of wildcards
- Pointcuts through:
  - Methods (within class on classpath)
  - Annotations
  - Bean names
- Combine and reuse Pointcuts

- Exercise – aop04

AOP and Architecture

- Problems with Architecture
- Criticism on AOP
- Architecture in terms of Aspects, a plan
- Summary

Problems with Architecture

- Architecture in documents
  - Not read
  - Not followed
  - Lots of boilerplate code

< = >

- Architecture in code => AOP to the rescue!

Problems with Architecture

- For each call to a service
  - Call must be traced
  - Exceptions must be logged
- For each call to a repository
  - Call must be traced
  - Performance must be traced
  - Exceptions must be logged

=>

- Specific behavior should be added
  - Tracing, exception handling, …
- … to specific parts of the the architecture
  - Repositories, services etc

Criticism on AOP

- Control flow is obscured
- Pointcut may depend on runtime condition

=>

- AOP adds random code to random parts of the system
- It is hard to reason about the system
- What happens when?

<=>

Not true when AOP is used properly

Architecture in terms of Aspects, a plan

- Aim: Add behavior to parts of the architecture using AOP

- Methodology:
  - Step 1 : Define architecture as Pointcuts
  - Step 2 : Define behavior using Advices
  - Step 3 : Add Advices to correct Pointcuts

- Result: No more technical boiler plate

Summary

- AOP adds behavior to specific parts of the system

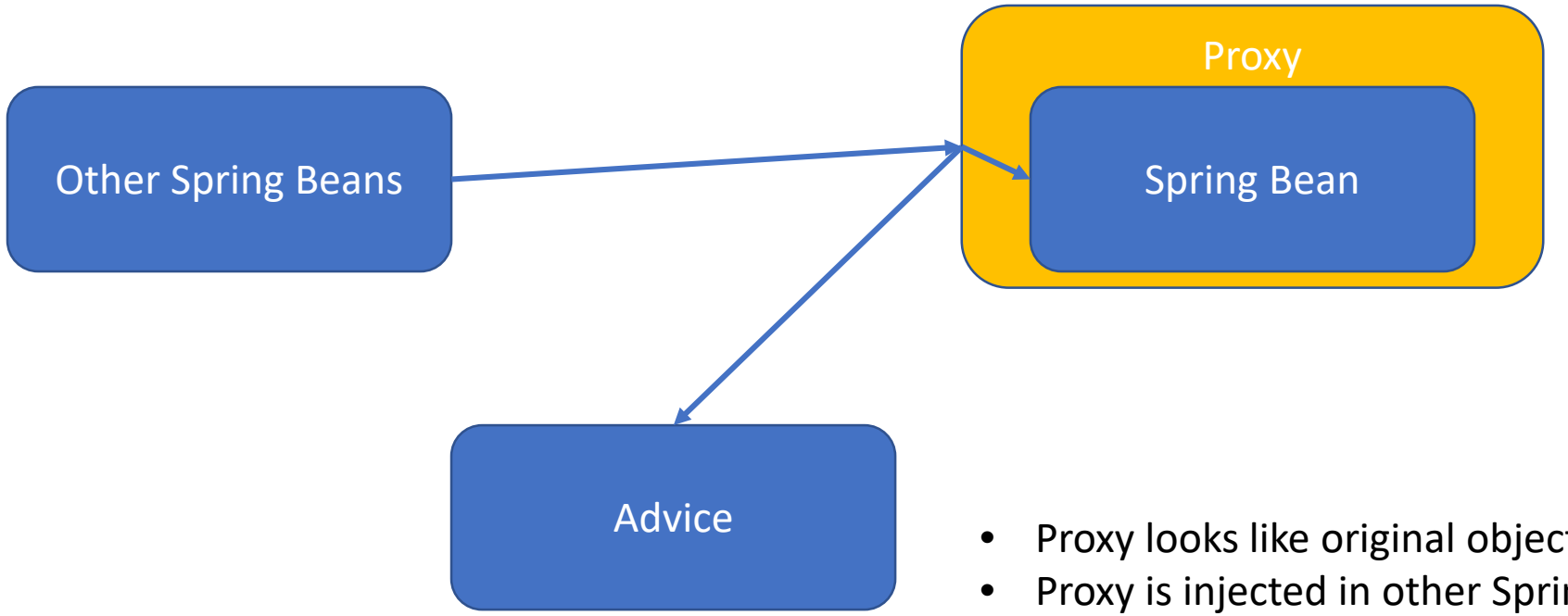
- Pointcuts can express architecture
- Should be added to the project early

- No Exercise -> LAB at the end of the session!

AOP in Spring (How It Works)

- Proxies
- Local Method Calls
- Pitfalls of proxies
- How proxies are implemented
- Limits of proxies
- Summary

Proxies



- Proxy looks like original object
- Proxy is injected in other Spring Beans
- Interfaces -> Dynamic Proxies
- Otherwise -> CGLIB generated sub classes

Local Method Calls

- Call never reaches proxy
- => No call to Advice

Pitfalls of proxies

```java
package com.axxes.demo;

import org.springframework.transaction.annotation.Transactional;

public class TxExample {

    @Transactional
    public void transactionalMethod() {
    }

    public void callsTransactionalMethod() { transactionalMethod(); }

}

```

- @Transactional is implemented using Spring AOP
- @Transactional will not be evaluated when called via callsTransactionalMethod()

How proxies are implemented

- Dynamic Proxies
  - Feature of the JDK
  - Allow dynamic method dispatch
  - For interfaces only
- CGLIB is used
  - Byte code instrumentation library
  - Subclass dynamically create subclass
  - Subclass implements the proxy
  - When no interface is implemented
  - Or if proxy-target-class is set to true

Limits of proxies

- Work only on public methods

-> No protected, private

- Works only on methods calls from outside
- Spring Dependency Injection makes it transparent

Summary

- Spring AOP uses proxy based AOP
  - CGLIB (subclasses)
  - or Dynamic Proxies (interfaces)
- DI makes proxies transparent
- Beware: Call on the local object will not go through the proxy
- Can write code to create proxies

- Exercise – aop05

AOP in Spring (Spring Aspect Library)

- Spring offers some Aspects OTB
- Apply to most common usage of Aspects
  - Caching
  - Exception handling
  - Logging
  - Transactions
  - …
- High Quality Code (Open Source)
- Save time & effort

AOP in Spring (Spring Aspect Library)

- Logging

```
19    public void someMethod() {
          final String METHODNAME = "someMethod";
          logger.trace("entering " + CLASSNAME + "." + METHODNAME);
22        TransactionStatus tx = transactionManager
23                .getTransaction(new DefaultTransactionDefinition());
24        try {
25            // Business Logic
26        } catch (RuntimeException ex) {
27            logger.error("exception in " + CLASSNAME + "." + METHODNAME, ex);
28            tx.setRollbackOnly();
29            throw ex;
30        } finally {
31            transactionManager.commit(tx);
              logger.trace("exiting " + CLASSNAME + "." + METHODNAME);
33        }
34    }
```

The Spring Context

```
10    <context:component-scan base-package="com.axxes" />
11
12    <bean id="debugInterceptor" class="org.springframework.aop.interceptor.DebugInterceptor" />
13
14    <aop:config>
15        <aop:advisor advice-ref="debugInterceptor"
16            pointcut="SystemArchitecture.Service() || SystemArchitecture.Repository()" />
17    </aop:config>
18
```

Other Tracing Aspects

- Package org.springframework.aop.interceptor
  - CustomizableTraceInterceptor: Can customize the trace output
  - SimpleTraceInterceptor: Basic information
  - DebugInterceptor: Full information
  - …
  - PerformanceMonitorInterceptor: Performance measurement in ms

=>

There’s plenty available OTB

Other Aspects

- Caching, Exception handling, Logging, Transactions,… and Security

- AsyncExecutionInterceptor to process method calls asynchronously
- ConcurrencyThrottleInterceptor to limit the number of threads in an object

- …

AOP in Spring (Spring Aspect Library)

- Transactions

```
19    public void someMethod() {
20        final String METHODNAME = "someMethod";
21        logger.trace("entering " + CLASSNAME + "." + METHODNAME);
          TransactionStatus tx = transactionManager
                  .getTransaction(new DefaultTransactionDefinition());
24        try {
25            // Business Logic
26        } catch (RuntimeException ex) {
27            logger.error("exception in " + CLASSNAME + "." + METHODNAME, ex);
              tx.setRollbackOnly();
29            throw ex;
30        } finally {
              transactionManager.commit(tx);
32            logger.trace("exiting " + CLASSNAME + "." + METHODNAME);
33        }
34    }
```

The Spring Context

```
<context:component-scan base-package="com.axxes" />

<bean id="transactionManager" class="com.axxes.transaction.StubPlatformTransactionManager" />

<tx:advice id="txAdvice" transaction-manager="transactionManager">
    <tx:attributes>
        <tx:method name="find*" read-only="true" />
        <tx:method name="*" />
    </tx:attributes>
</tx:advice>

<aop:config>
    <aop:advisor advice-ref="txAdvice"
        pointcut="SystemArchitecture.Service()||SystemArchitecture.Repository()" />
</aop:config>
```

Summary

- Spring provides a library of aspects
- Include tracing, transactions…
- Using pointcuts enterprise services can be transparently added to the business logic

- Exercise – aop06a (tracing) and aop06b (transactions)

Aspects, the real world

- Spring’s aspect library contains some interesting aspect
- But can we do more?
- Which challenges you suppose can be solved with AOP?

Example 1:Retry

- Retry a method call if it fails
- Can help to resolve transient failures

- Exercise – aop07a

Retry

- Don’t use
  - If a service is not accessible:
    - Calls are buffered
    - Calls pile up
  - The service comes up again
    - immediately swamped with requests
    - go down again
  - Not very smart
  - Especially when calling external systems

Example 2: Circuit Breaker

- If an error occurs the circuit breaker breaks the circuit
  - service is not called anymore
  - exception is immediately forwarded to the caller
- After a while the service is called again
  - retry after some time
  - or retry after number of calls
- If the call succeeds the circuit breaker is closed again

- Exercise – aop07b

Circuit Breaker

- Usable, but room for improvement
  - After a failure slowly ramp up
  - Incorporate a STRATEGY
    - isAvailable() : boolean
    - reportSuccess()
    - reportFailure()
    - …
  - Use a fallback
    - Default value
    - Simplified service
    - Cache

Example 3: JPA / JDBC

- Problem: JPA contains a cache
- Changes are not immediately propagated to the database
- JDBC calls might see incorrect data

=>

Solution: Flush EntityManager every time a JDBC call happens

Exercise – aop07c

Example 4: Context Security

- Customer may only see his Account
- Account is a domain object – no Spring Bean

- Exercise – aop07d

Summary

- Manipulate how a method is called
  - Exception Handling
  - Record calls
  - Filter
  - Adjust return values
  - …

Aspects - LAB

- Free exercise based on the project from the first 2 days