Aspect-Oriented Programming with Spring AOP and AspectJ

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Spring

Agenda

- Simplifying enterprise application development
  - AOP by example
- The goals of AOP
- Spring AOP and AspectJ
- Introducing AOP into your own projects
  - a roadmap
  - with plenty of examples

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The Spring approach

- Program simply using objects
  - aka "POJOs"
  - non-invasive
  - object-oriented
- Retain architectural choice
  - no environmental assumptions or dependencies in application objects
- Facilitate test-driven development

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The Spring approach

```
            t
   f        e
   l        s
object-oriented
   x        a
  simple    b
   b        l
   l        e
   e
```

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The Spring approach

Simple does not mean

simplistic

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The Spring approach

Simpler can be more

powerful

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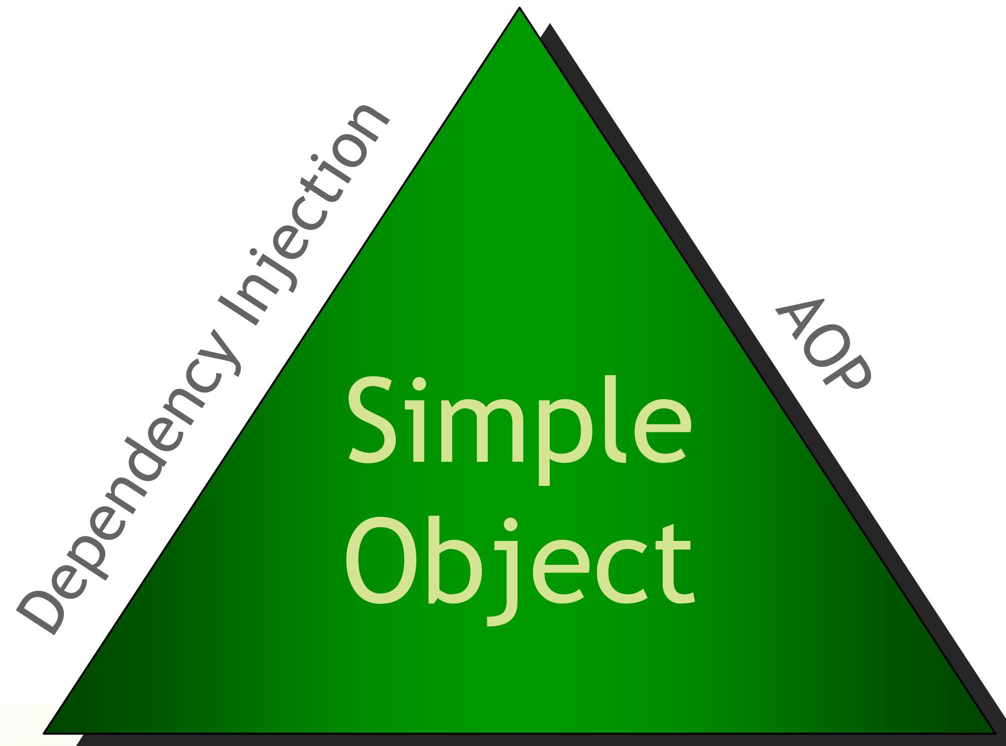
Enabling Technologies



Portable Service Abstractions

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AOP

- Aspect Oriented Programming (AOP)
  - Enables declarative specification of enterprise services
  - Enables modular implementation of requirements that impact multiple points in the application

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Enterprise application vocabulary

the **vocabulary** of enterprise applications

business service

service layer

repository

dao

controller

web layer

data access layer

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Requirements

- Many requirements are expressed in terms of this vocabulary
  - the service layer should be transactional
  - when a Hibernate dao operation fails the exception should be translated
  - service layer objects should not call the web layer
  - a business service that fails with a concurrency related failure can be retried

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Meaningful abstractions

It would be simpler…

and more *powerful*

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Meaningful abstractions

if we could use these

abstractions

directly in the

implementation

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System Architecture

```
@Aspect
public class SystemArchitecture {

  @Pointcut("within(a.b.c.service..*")
  public void inServiceLayer() {}

  @Pointcut("within(a.b.c.dao..*")
  public void inDataAccessLayer() {}

  @Pointcut("execution(* a.b.c.service.*.*(..))")
  public void businessService() {}

  …
}
```

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Spring

Requirements

- Many requirements are expressed in terms of this vocabulary
  - the service layer should be transactional
  - **when a Hibernate dao operation fails the exception should be translated**
  - service layer objects should not call the web layer
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Scenario…

- You have your own data access layer written using Hibernate 3
  - not using the Spring HibernateTemplate (yet?)
- In the service layer, you want to insulate yourself from Hibernate exceptions, and take advantage of Spring's fine-grained DataAccessException hierarchy
- After throwing a hibernate exception from a data access operation, convert it into a DataAccessException…

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Step 1: Define "dataAccessOperation"

- The requirements talk about "data access operations"
  - In AOP terminology, the execution of a data access operation is a join point

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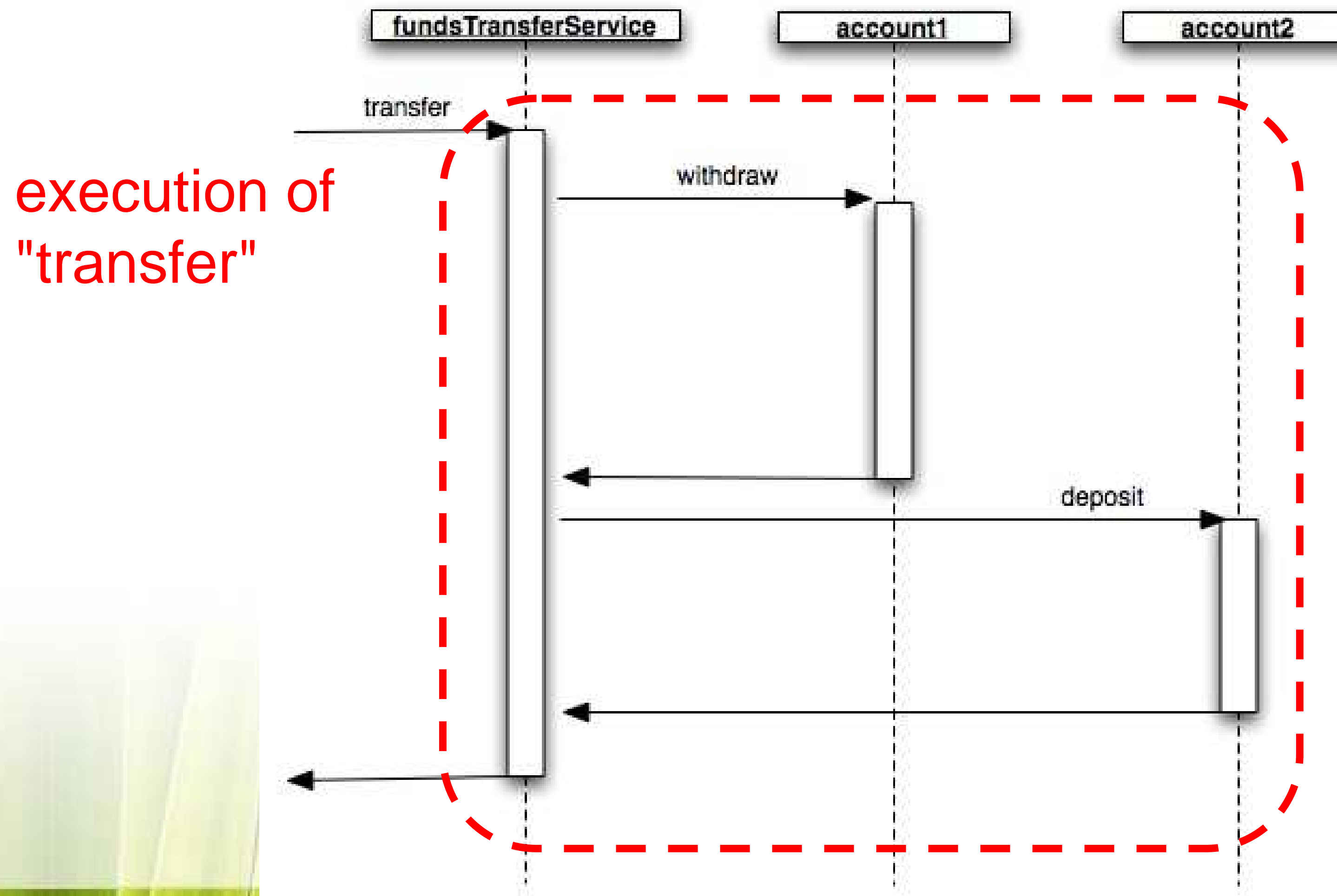
Understanding Join Points



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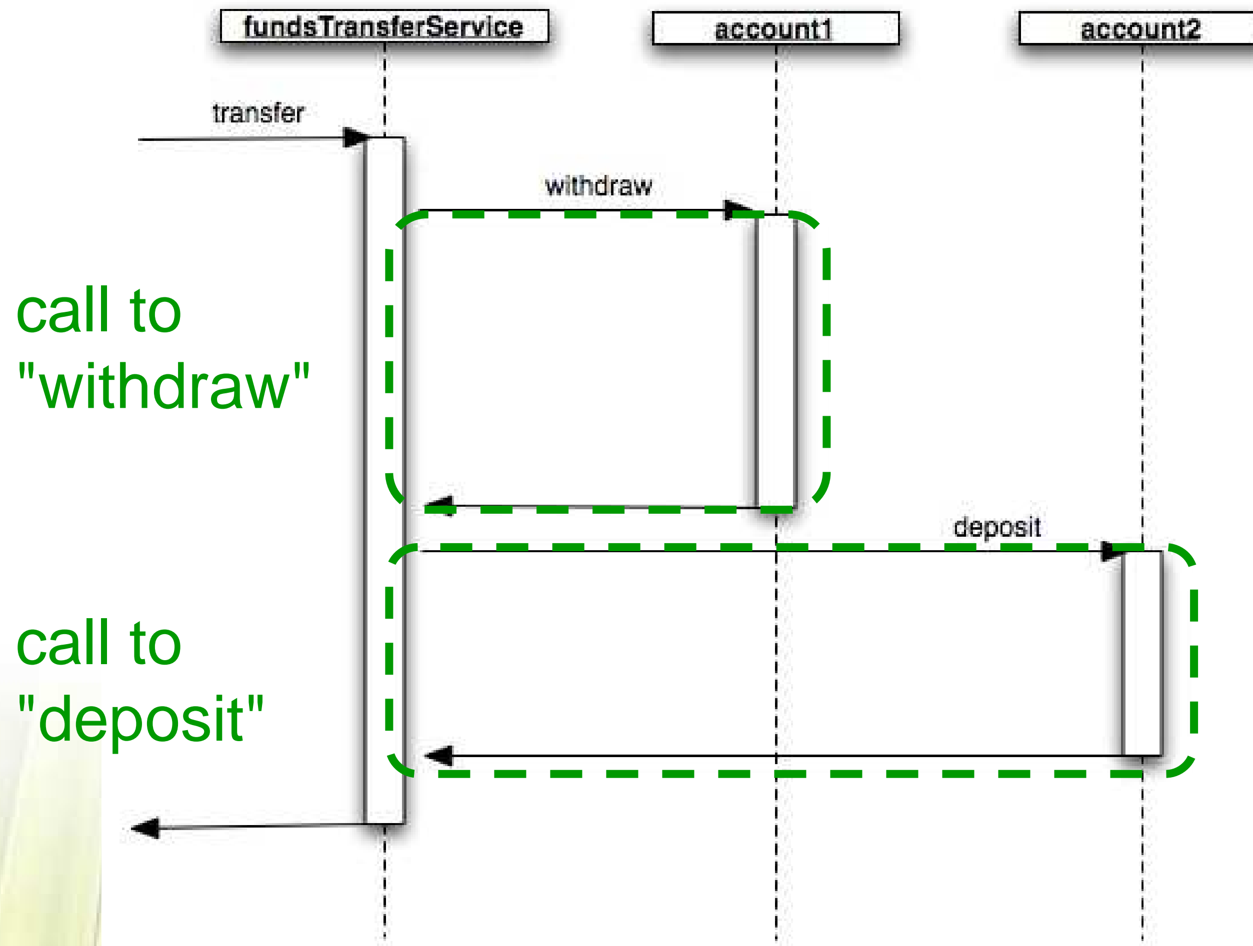
Understanding Join Points



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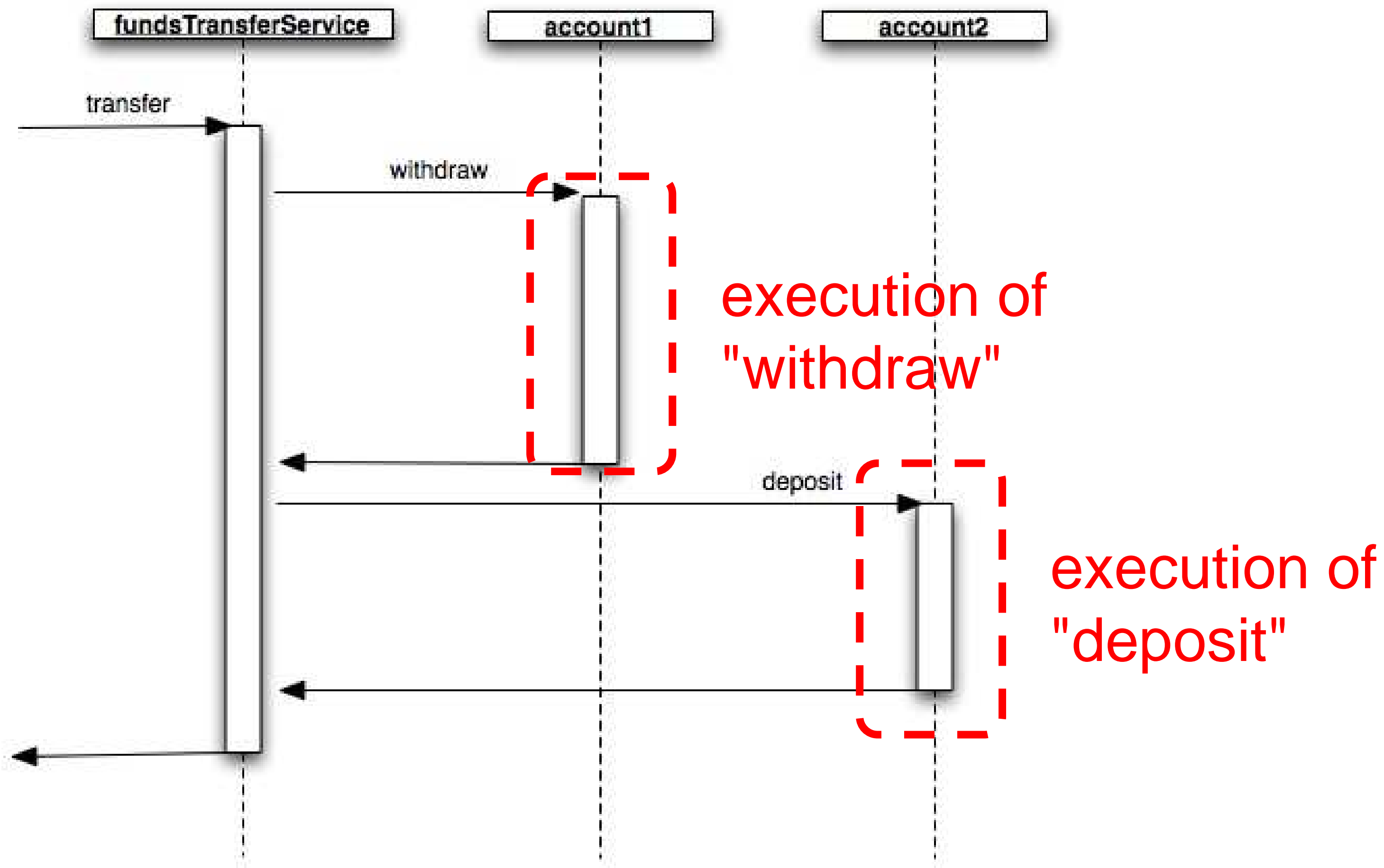
Understanding Join Points



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Pointcuts

- The join points that we are interested in are those that represent the execution of a data access operation
- We can write a predicate, known as a pointcut, to match them

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Pointcuts

```
@Pointcut("execution(* a.b.c.dao..*.*(..))")
public void dataAccessOperation() {}
```

```
public pointcut dataAccessOperation() :
  execution(* a.b.c.dao..*.*(..))
```

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Pointcuts

```
public pointcut dataAccessOperation() :
  execution(* (@Repository *).*(..));
```

- dataAccessOperation is an abstraction we can program against
  - the details of how it is defined are hidden

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Step 2: Use the abstraction

- How do we make use of this dataAccessOperation abstraction?
- Advice!
- Advice is associated with a pointcut expression
- Executes every time a join point matched by the expression occurs

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Advice

- Advice is like a method
  - except that it is never explicitly invoked
- Five kinds of advice:
  - before
  - after returning
  - after throwing
  - after
  - around

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Which advice kind?

- "After throwing a hibernate exception from a data access operation, convert it into a DataAccessException…"

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After throwing

```
@AfterThrowing(
  throwing="hibernateEx",
  pointcut="SystemArchitecture.dataAccessOperation()"
)
public void rethrowAsDataAccessException(
  HibernateException hibernateEx) {
  // convert exception and rethrow…
}
```

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Where does advice live?

- Advice is declared in an aspect
- Aspect are like classes
  - instances
  - state (fields)
  - behaviour (methods)
- Aspects can also have
  - pointcuts
  - advice
  - and a few other things…

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Aspect

```
@Aspect
public class HibernateExceptionTranslator {
    // …

    @AfterThrowing(
     throwing="hibernateEx",
     pointcut="SystemArchitecture.dataAccessOperation()"
    )
    public void rethrowAsDataAccessException(
     HibernateException hibernateEx) {
     // convert exception and rethrow…
    }
}
```

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Step 3: Configuration

```
<aop:aspectj-autoproxy/>

<bean id="hibernateExceptionTranslator"
   class="HibernateExceptionTranslator">
     <property name="hibernateTemplate"
                       ref="hibernateTemplate"/>
</bean>
```

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Schema alternative

- For JDK 1.4 and below
  - and annophobes ;)
- The exact same aspect can be declared in Spring XML, backed by a plain Java class

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Schema-based configuration

```
<aop:config>

  <aop:aspect ref="hibernateExceptionTranslator">
    <aop:after-throwing
       throwing="hibernateEx"
       pointcut="SystemArchitecture.dataAccessOperation()"
       method="rethrowAsDataAccessException"/>
  </aop:aspect>

</aop:config>
```

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Bean Implementation

```
public class HibernateExceptionTranslator {
  private HibernateTemplate hibernateTemplate;

  public void setHibernateTemplate(
    HibernateTemplate aTemplate){
    this.hibernateTemplate = aTemplate;
  }

  public void rethrowAsDataAccessException(
      HibernateException hibernateEx) {
    throw this.hibernateTemplate
        .convertHibernateAccessException(hibernateEx);
  }
}
```

parameter bound in pcut expression

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Demo

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Retry

- One subtype of DataAccessException is…
  - ConcurrencyFailureException
- Concurrency failures are potentially recoverable
  - If the operation is idempotent, we can retry it*
- We need a ConcurrentOperationExecutor…

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Concurrent Operation Recovery

```
public class ConcurrentOperationExecutor {
  private static final int DEFAULT_MAX_RETRIES = 2;
  private int maxRetries = DEFAULT_MAX_RETRIES;

  /** configurable via dependency injection */
  public void setMaxRetries(int numTimesToRetry) {
    this.maxRetries = numTimesToRetry;
  }

 …
```

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Concurrent Operation Recovery

```
public Object doConcurrentOperation(ProceedingJoinPoint pjp)
  throws Throwable {
   int numAttempts = 0;
   ConcurrencyFailureException failureException;
   do {
     numAttempts++;
     try { return pjp.proceed(); }
     catch(ConcurrencyFailureException ex) {
       failureException = ex;
     }
   }
   while(numAttempts <= this.maxRetries);
   throw failureException;
  }

}
```

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Concurrent Operation Recovery

```
<aop:config>

  <aop:aspect ref="concurrentOperationExecutor">
    <aop:pointcut id="idempotentOperation"
      expression= "SystemArchitecture.businessService()"/>

    <aop:around
        pointcut-ref="idempotentOperation"
        method="doConcurrentOperation"/>
  </aop:aspect>

</aop:config>
```

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Concurrent Operation Recovery

```
<bean id="concurrentOperationExecutor"
    class="ConcurrentOperationExecutor">
    <property name="maxRetries" value="3"/>
</bean>
```

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Demo

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Recap:

- Created an abstraction: idempotentOperation
- Used around advice to retry failing idempotentOperations
- Packaged in a ConcurrentOperationExecutor aspect
- Configured using Spring

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Idempotent operations

- It would be nice if all of our service layer operations were idempotent
- But what if some of them aren't?
- We'd need a way to identify and retry only the idempotent subset…

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Idempotent operations

```
@Retention(RetentionPolicy.RUNTIME)
public @interface Idempotent {}
```

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Idempotent operations

- Just update the abstraction (pointcut expression)…

```
<aop:pointcut id="idempotentOperation"
    expression=
        "SystemArchitecture.businessService()
         and @annotation(Idempotent)"/>
```

- easier than APT??? ;)

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The goals of AOP

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The DRY Principle

"Every piece of system knowledge should have a single, authoritative, unambiguous representation"

- Dave Thomas

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Separation of Concerns

- “But nothing is gained --on the contrary!-- by tackling these various aspects simultaneously. It is what I sometimes have called "the separation of concerns", which, even if not perfectly possible, is yet the only available technique for effective ordering of one's thoughts, that I know of.”

  - Edsger W. Dijkstra, 1974

  On the role of scientific thought

- A software engineering principle, each module
  - does one thing
  - knows one thing
  - keeps the secret of how it does it hidden

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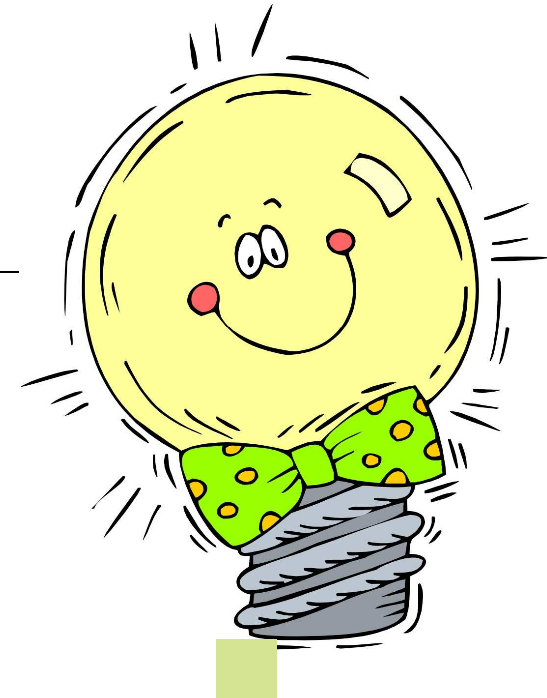
Tip

- Always strive for

DRY SoC(k)s.



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The 1:1 principle

- If you…
  - Don't Repeat Yourself
- and you..
  - maintain a clear Separation of Concerns
- then you end up with…
  - The 1:1 principle

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The 1:1 principle

"There should be a clear, simple, 1:1 correspondence between design-level requirements and the implementation"

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It's hard to stay dry sometimes

- If the state of a domain object changes, mark it as dirty
- All service layer operations should take place inside a transaction
- Expose usage statistics for all data-access objects
- Initialize resources lazily on first use

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When dry breaks down…

- The examples all have the following in common:
  - a *single requirement* cannot be represented in a single, authoritative, unambiguous place in the system
  - the *system knowledge* is diffused and scattered throughout the implementation

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Common violations of 1:1

- 1:n
  - a single design requirement is *scattered* across multiple parts of the implementation
- n:1
  - implementation details for multiple requirements are *tangled* up inside the same module
- 1:0
  - it was too hard to implement so we didn't bother
- n:n
  - it's all mixed up… (the normal case!)

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The aspects value-proposition

- AOP is fundamentally a modularity technology
  - from 1:n -> 1:1
- A new kind of module, called an *aspect* encapsulates the implementation of requirements that cut-across many parts of the system
  - these are sometimes called "cross-cutting concerns"
- Improved… agility, testability, maintainability, option value, reuse, flexibility, quality, 100m sprint times, …

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AOP is about modularity

- Well defined modules (aspects)
- With well-defined semantics
- Fully type checked
- Not "just another framework"

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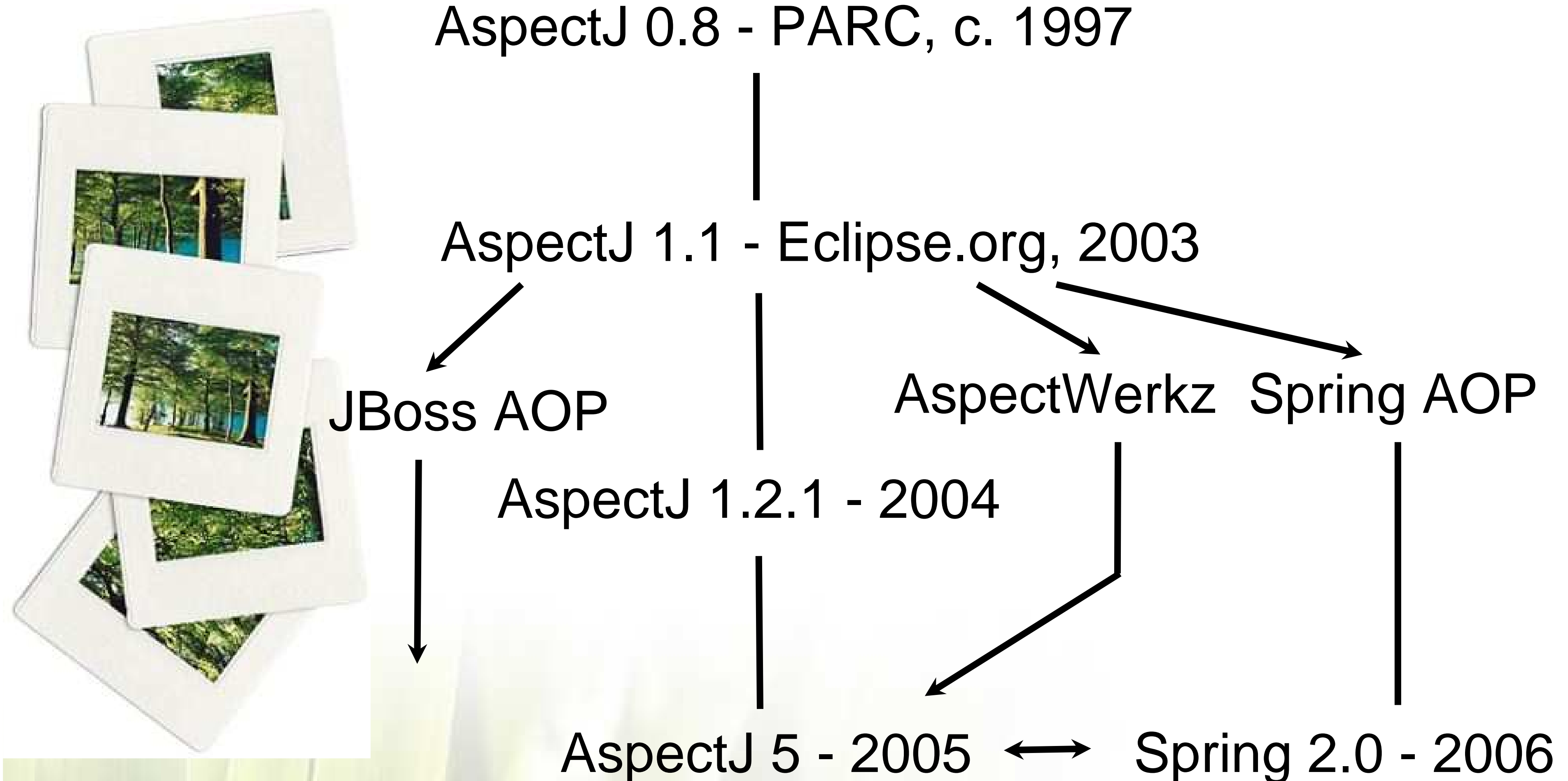
The AOP family tree (industry)



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Spring AOP and AspectJ

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AspectJ: A Programming Language

- Every legal Java program is a legal AspectJ program
- Compilation produces standard class files that can be run on any JVM
- Strongly typed
- The best performing AOP implementation
- Rich pointcut language
- Sophisticated IDE support in Eclipse (AJDT)

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AspectJ language

- Compilation with ajc

```
public aspect HelloFromAspectJ {

  public pointcut main() :
     execution(* main(..))")

  after() returning : main() {
    System.out.println("Hello from AspectJ!");
  }
}
```

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@AspectJ development style

- Supports regular compilation with javac
  - (followed by binary weaving)

```
@Aspect
public class HelloFromAspectJ {

  @Pointcut("execution(* main(..))")
  public void main() {}

  @AfterReturning("main()")
  public void sayHello { … }
}
```

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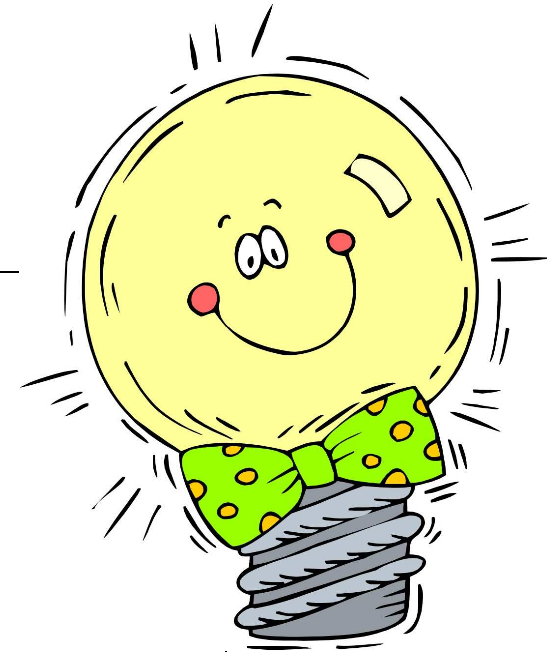
Tip



- If you are developing @AspectJ style aspects you can use AJDT and get *compile-time support* for pointcut expressions and cross-reference information in the IDE.

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AspectJ weaving

- AspectJ supports:
  - compile-time weaving (source -> .class),
  - binary weaving (.class -> .class),
  - and load-time weaving

- ajc command-line compiler
- ajdoc javadoc tool
- ant task
- maven support also available

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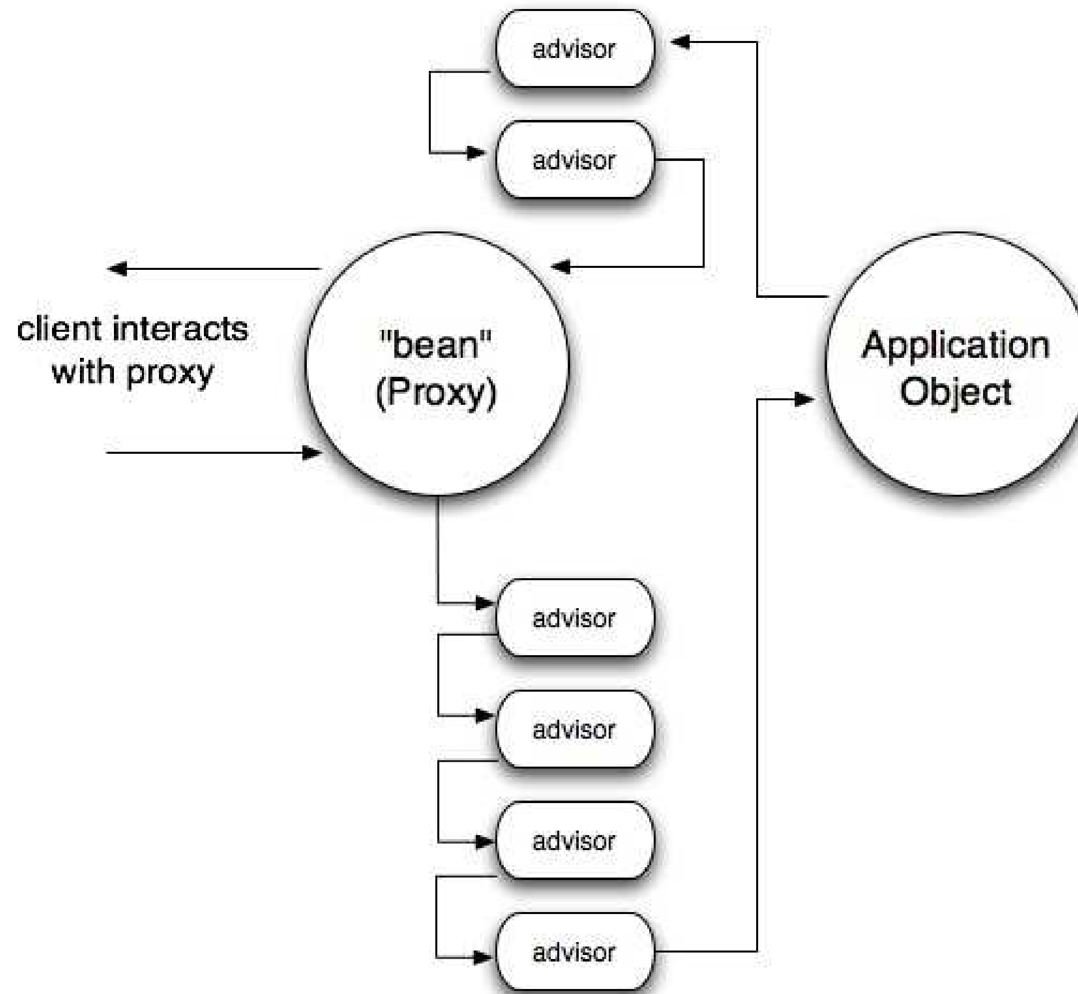
Spring AOP: Proxy-based system



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Spring 2.0 AOP

- Aspects are defined in Spring configuration file
  - supports both XML based definition
  - and @AspectJ aspects!
- XML defined aspects are backed by regular classes

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Spring 2.0 and AspectJ

- Spring and AspectJ are still distinct projects
- Spring just uses the AspectJ pointcut parsing and matching APIs
  - using AspectJ as a library, not as a weaving engine
- Gives the same syntax and semantics across Spring AOP and AspectJ
  - perfect if you are going to use both
  - or start out with Spring AOP, and then want to introduce AspectJ at some point

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XML based aspect definition

```
<aop:config>
  <aop:aspect ref="helloAspect">
    <aop:pointcut id="main"
      expression="execution(* main(..))"/>
    <aop:after-returning
      pointcut-ref="main"
      method="sayHello"/>
  </aop:aspect>
</aop:config>

<bean id="helloAspect" class="…"/>
```

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"Aspect" class

```
public class HelloWorldService {

   public void sayHello() {
     System.out.println("hello");
   }

}
```

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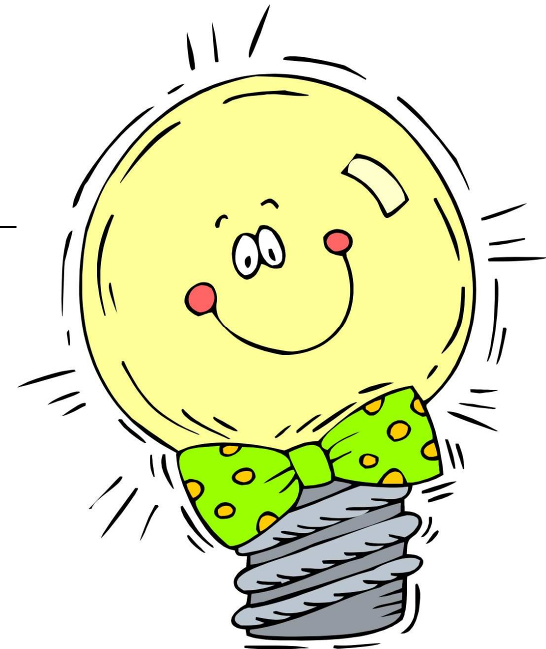
Tip



- The pointcut expression used by Spring AOP doesn't just *look like* AspectJ, it *is* AspectJ.

So everything you learn about AspectJ pointcuts applies to Spring AOP too

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Execution Join Points only

- But Spring AOP can only support one join point kind: method-execution join points.

So if you use call, get, set etc. you'll get an 'IllegalArgumentException'

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Using @AspectJ aspects

```
<aop:aspectj-autoproxy/>

<bean id="myAspect"
   class="org.sfw…MyAspect/>
```


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A typical enterprise app…

View

Text Area

Cancel OK

Web Tier Actions

Action A

Action B

Business Services

Service 1

Service 2

Service 3

Data Access

DAOs/ Repositories

ent

Domain model

Class Name
Attributes
Attributes

Class Name
Attributes
Attributes

Class Name
Attributes
Attributes

Class Name
Attributes
Attributes

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Spring

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Spring managed

View

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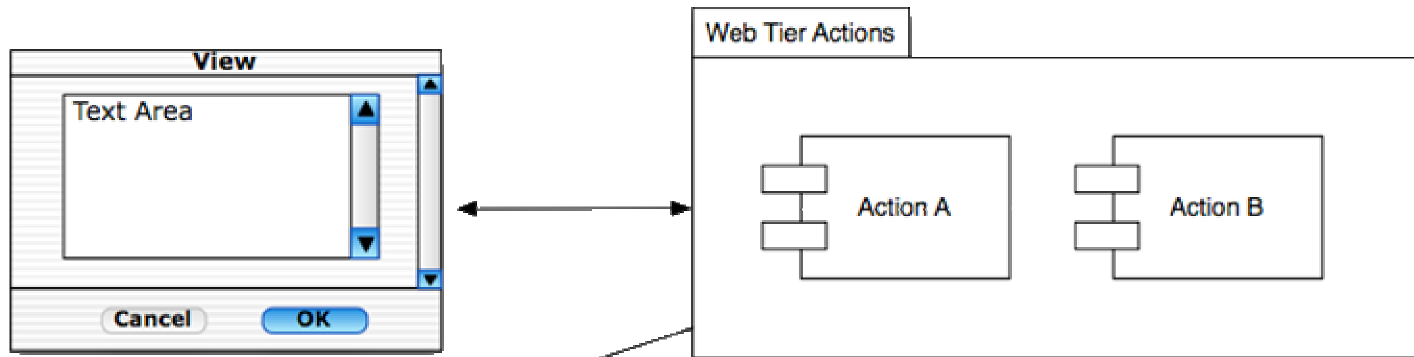
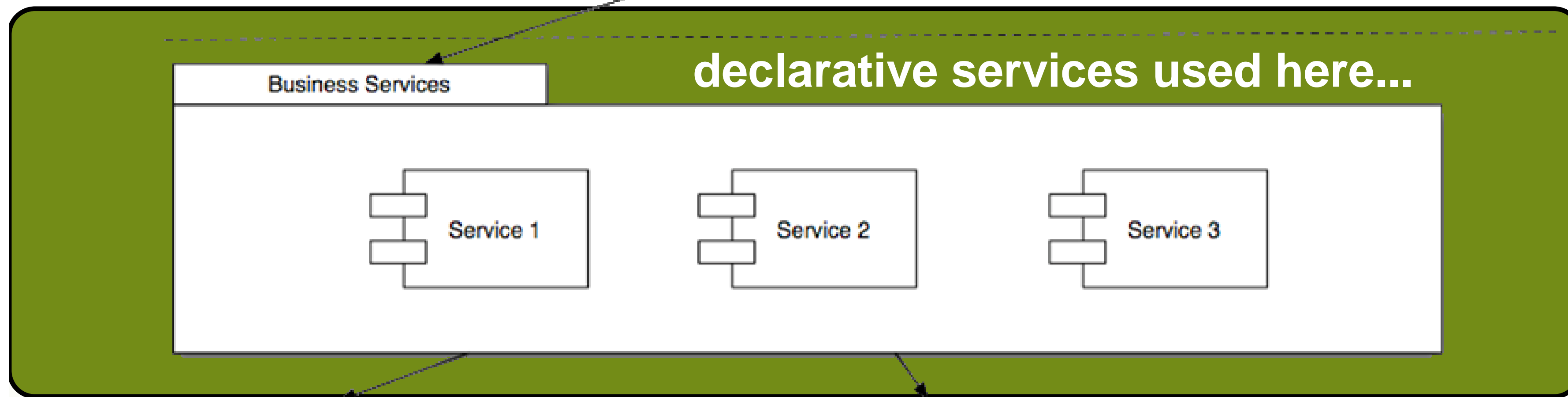
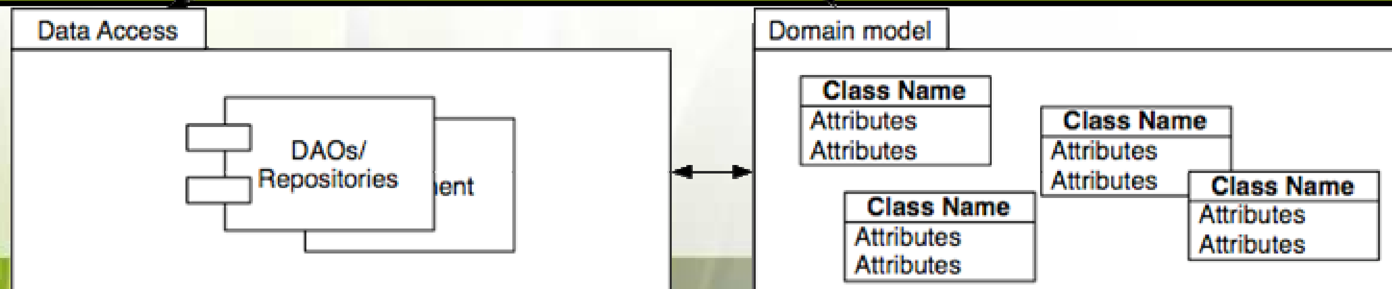
A typical enterprise app...







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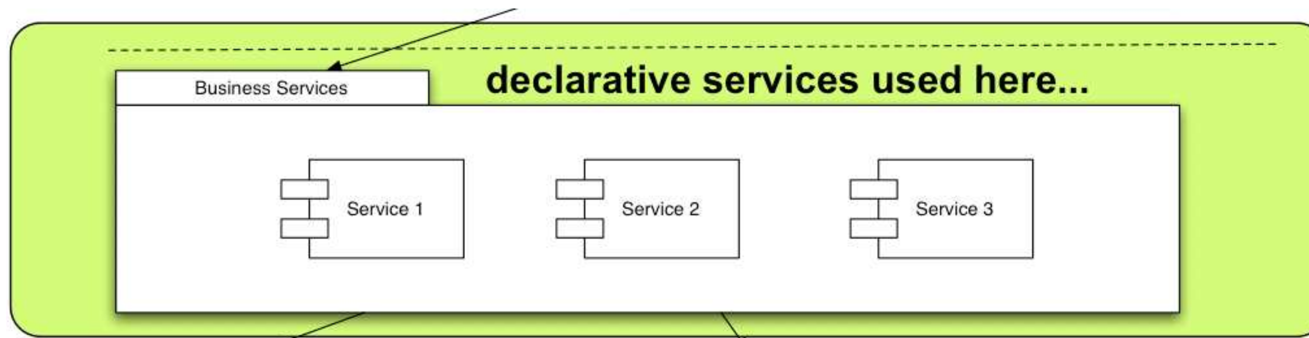

- The business services layer is where declarative services are often used
  - transactions
  - security
- Natural fit for Spring AOP
  - Spring already managing instantiation and configuration
- This support is mature and widely deployed
  - use immediately

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Business Services

- Other Spring AOP based facilities you may consider using here
  - JMX support
  - Remoting
  - Lazy instantiation
- Spring AOP good fit for:
  - Spring managed beans
  - execution based join points
  - coarser-grained service application

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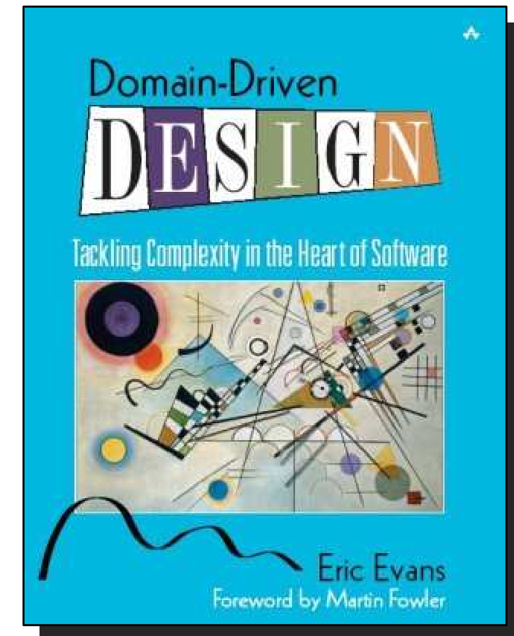
Separation of concerns again

- Here's a way to think about it...
- We want to separate the
  - business concerns
  - from the technical concerns
- Business services, domain objects, and DAO interfaces
  - written in terms of the UBIQUITOUS LANGUAGE



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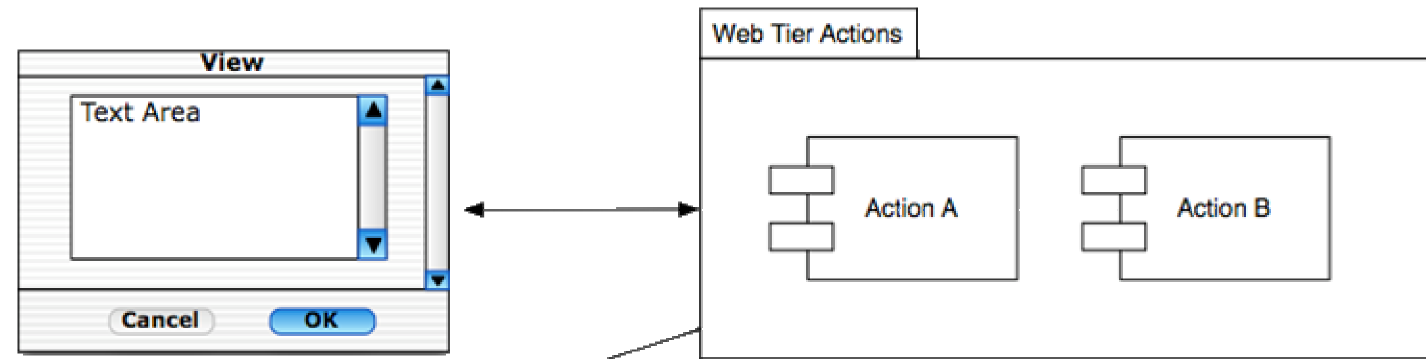
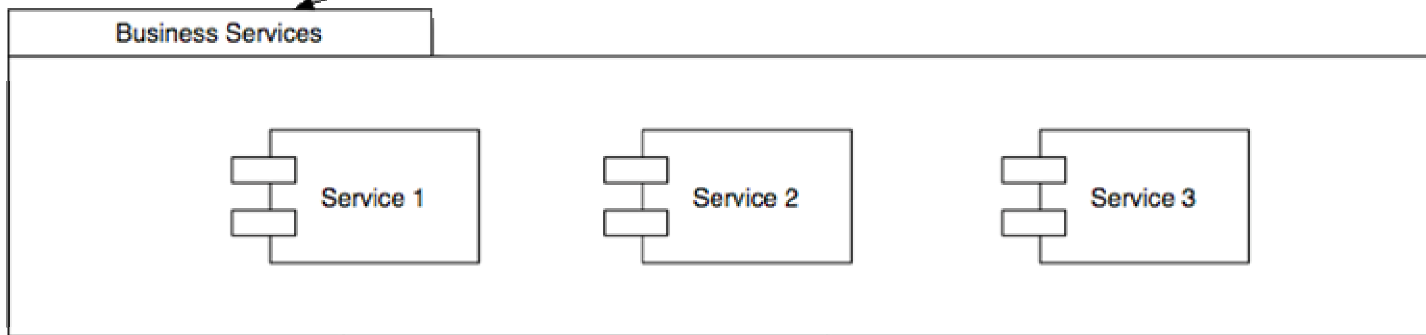
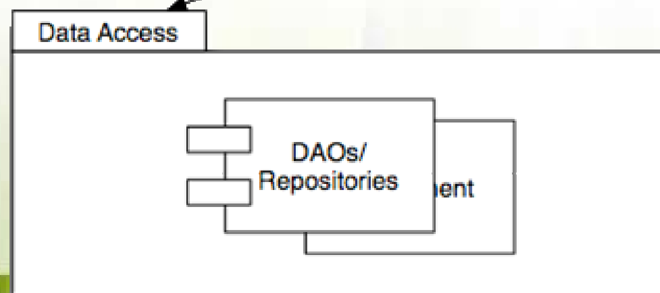
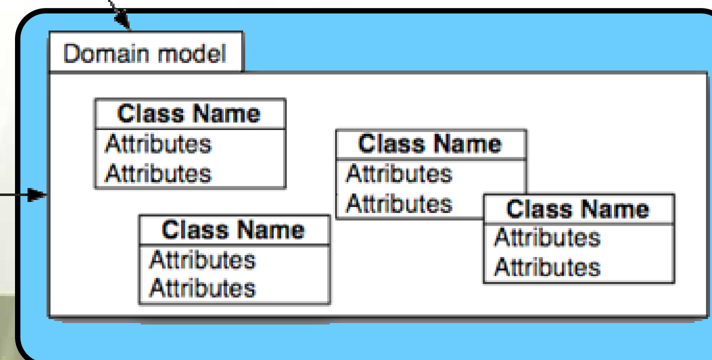
A typical enterprise app...









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Spring

Domain model

- The domain model is classic territory for AspectJ
  - fine-grained objects
  - created and managed outside of Spring container control
- Also use AspectJ for
  - pervasive aspects across the rest of the system
  - needing richer join point model
    - e.g. *calls* to third-party libraries...
  - or performance sensitive

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Spring

Part 1 : Summary

- We want to implement enterprise requirements in as simple and straightforward a manner as possible
  - use the appropriate implementation "vocabulary"
- AOP is about modularity
  - getting closer to the ideal of the "1:1 principle"
- AspectJ and Spring AOP are the leading AOP implementations
  - tightly integrated
- Can use together or independently

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In Part 2…

- How to start simplifying your own projects using AOP
  - an adoption roadmap
- With more concrete examples…
- Plus:
  - What about EJB3?, and…
  - I hear you teach a course on this stuff?

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Part 2: Adopting AOP

Adrian Colyer
Interface21

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Adoption Roadmap

1. Use the out-of-the-box Spring aspects
   - transactions etc.
2. Introduce your own Spring-AOP based aspects as needed
3. Add enforcement and exploration aspects using AspectJ
4. Add infrastructure aspects using AspectJ
5. Add domain aspects using AspectJ

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Adopting Spring-AOP

- No tools issues
  - use standard java compiler and language
- No extra compilation/weaving steps
- Runtime proxy framework already well tested in many large production applications
- If Spring-AOP can handle your requirements, it's the natural choice

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Requirements

- Many requirements are expressed in terms of this vocabulary
  - **the service layer should be transactional**
  - when a Hibernate dao operation fails the exception should be translated
  - service layer objects should not call the web layer
  - a business service that fails with a concurrency related failure can be retried

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Transactions

```
<aop:config>
  <aop:advisor
    pointcut="SystemArchitecture.businessService()"
    advice-ref="tx-demarcation"
  />
</aop:config>
```

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Transactions

```
<tx:advice id="tx-demarcation">
  <method name="*"
    propagation="REQUIRED"
    isolation="DEFAULT"/>
</tx:advice>
```

- Gives us TX-REQUIRED semantics for the service layer

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Spring

Read-only operations

- Important to distinguish read-only operations for performance reasons
- We could…
  - list them all in a pointcut expression
  - use a naming pattern

    <method name="get*" … />
  - use annotations
    - either @ReadOnly on operations, or…
    - annotation-driven transactions

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Transactional annotation

```
/**
 * default to required, read-write for all
 *  operations
 */
@Transactional
public class AccountService {
  /** this one is read-only… */
  @Transactional(readOnly=true)
  public Account getAccount(AccountNum accNo) {
   …
  }
  …
}
```

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Transactional annotation

- Now the configuration just becomes…

<!– tell Spring to perform transaction demarcation on bean operations based on @Transactional annotations -->

<tx:annotation-driven/>

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Adoption Roadmap

1. Use the out-of-the-box Spring aspects
   - transactions etc.
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Spring AOP aspects

- Already seen two examples:
  - Exception translation
  - Concurrent operation retry

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Schema or @AspectJ?

- If you can, use @AspectJ
  - richer support for pointcut composition than schema
  - supports aspect instantiation models
- @AspectJ aspects have the advantage that they can be understood by AspectJ too
  - can also make use of AJDT tools in development

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Example: Security

- Security impacts all architectural layers
- Conceptually…
  – before a securedOperation() we need to authenticate and authorize
  – after returning we may need to filter results or deny access based on credentials of the requesting Principal

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Security Protocol (acegi)

```
@Aspect
public abstract class AbstractAccessControlManager
extends AbstractSecurityInterceptor{
  …

  @Pointcut("")
  protected abstract void securedOperation();

  @Around("securedOperation()")
  public void doSecuredOperation(ProceedingJoinPoint pjp){
    Object result = null;
    InterceptorStatusToken token = super.beforeInvocation(pjp);
    try { result = pjp.proceed(); }
    finally { result = super.afterInvocation(token,result); }
    return result;
  }

}
```


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Service layer

```
@Aspect
public class ServiceLayerAccessControl extends
   AbstractAccessControlManager {

  @Pointcut("SystemArchitecture.businessService()")
  protected void securedOperation() {}

}
```


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Configuration

```
<aop:aspectj-autoproxy/>

<bean id="serviceLayerAccessControl"
  class="abc.ServiceLayerAccessControl">
  <property name="authenticationManger"  ref="authenticationManager"/>
  <property name="accessDecisionManager"
            ref="serviceLayerAccessDecisionManager"/>
  <property name="afterInvocationManager"
            ref="resultAccessControlDecisionManager"/>
  <property name="securityAttributes"
            ref="serviceLayerSecurityAttributes"/>
</bean>
```

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Demo

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Adoption Roadmap

1. Use the out-of-the-box Spring aspects
   - transactions etc.
2. Introduce your own Spring-AOP based aspects as needed
3. **Add enforcement and exploration aspects using AspectJ**
4. Add infrastructure aspects using AspectJ
5. Add domain aspects using AspectJ

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Adopting AspectJ

- skill & experience
- value derived from AOP

exploration & enforcement

infrastructure aspects

domain aspects

time and confidence

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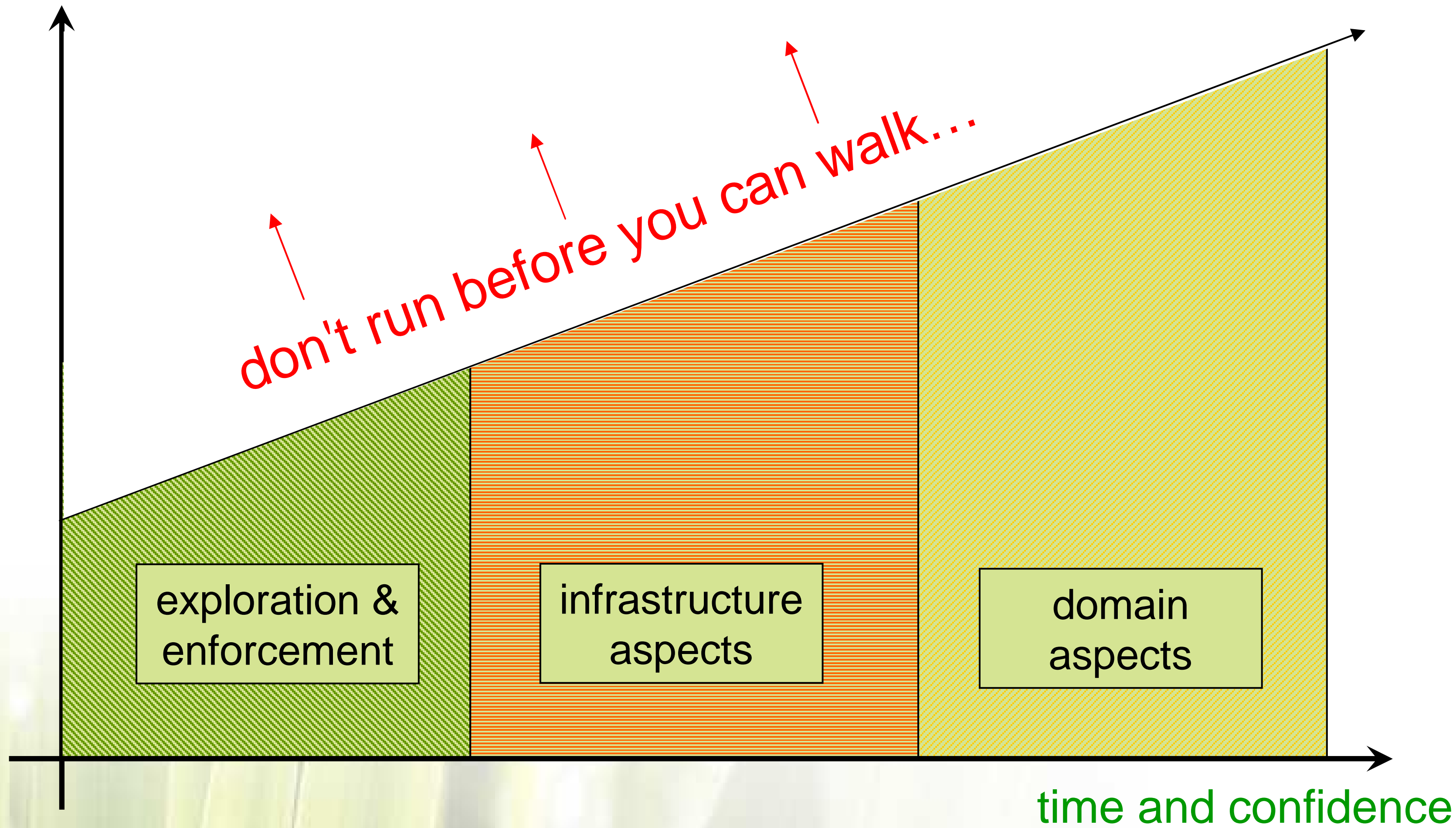
Spring

Adopting AspectJ



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Exploration and Enforcement

- Exploration aspects
  - used to analyze / debug / troubleshoot application
  - developer aids used during the development process
    - not part of the production system
- Enforcement aspects
  - design-level assertions

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Exploration and Enforcement

- What these aspects have in common is…
  - no runtime dependency on AspectJ
  - no need for all developers to switch to using AJDT
- Very low risk way to get started with AspectJ
  - and very beneficial too!

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Permitted component interactions

```
/** … */
public aspect SystemArchitecture {
 …
 /*
  * no other module should depend on the
  * web tier
  */
 declare warning
   : callToWebTier() && !inWebTier()
   : "no external dependencies on web tier";

  …
}
```

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Permitted component interactions

```
/** … */
public aspect SystemArchitecture {
 …
 declare warning
   : callToDaoImpl() && !inDaoImpl()
   : "please use Dao interfaces instead";

 pointcut inPermittedDaoClient() :
   inServiceLayer() || inDaoImpl();

 declare warning
   : callToDao() && !inPermittedDaoClient()
   : "only service layer and Dao implementations
      themselves should be calling Daos";
  …
}
```

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Demo

- Hibernate usage guidelines…

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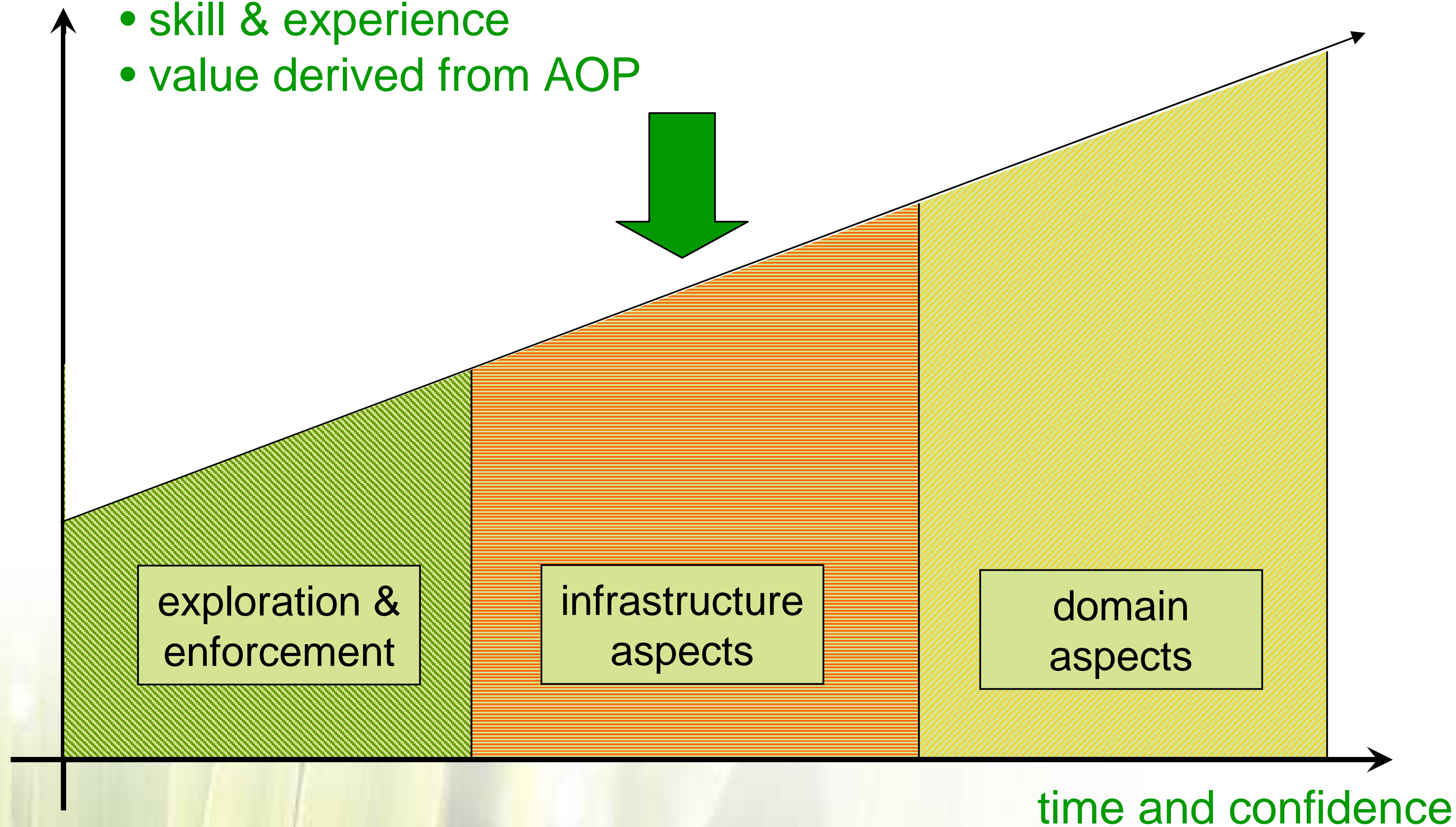
Infrastructure aspects



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Infrastructure aspects

- At the next stage of adoption, introduce 'infrastructure' aspects
  - not a black-and-white definition
  - in general, an infrastructure aspect is not critical to the basic operation of your application
    - e.g. profiling, tracing, auditing, …
- Not all team members need to be familiar with writing aspects
  - using an aspect is a whole different thing to writing one

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Example: Profiling

- Profile all operations in an application
- Or just one use-case that is not performing as expected
- Spans multiple layers, fine-grained
  - -> AspectJ based solution
  - … with Spring configuration

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Spring

Profiling aspect

```
public aspect Profiler {
  private ProfilingStrategy profiler;

  public void
   setProfilingStrategy(ProfilingStrategy p) {
    this.profiler = p;
  }

  …
```

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Profiling aspect

```
  pointcut profiledOperation() :
    Pointcuts.anyPublicMethod() &&
    SystemArchitecture.inMyApplication();

  Object around() : profiledOperation() {
      Object token =
        this.profiler.start(thisJoinPointStaticPart);
      Object ret = proceed();
      this.profiler.stop(token,thisJoinPointStaticPart);
      return ret;
  }

}
```

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Profiling configuration

```
<bean id="profiler" class="Profiler"
  factory-method="aspectOf">
 <property name="profilingStrategy">
  <ref local="jamonProfilingStrategy"/>
 </property>
</bean>
```

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Spring

Demo

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Use-case based profiling

- Simple to profile only for a given use-case of interest

```
pointcut profiledUseCase() :
  execution(* transfer(..)) &&
  SystemArchitecture.inServiceLayer();

pointcut profiledOperation() :
   Pointcuts.anyPublicMethod() &&
   SystemArchitecture.inMyApplication() &&
   cflow(profiledUseCase());
```

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INTERFACE21

Example: Domain object security

- Security by ACL on individual domain objects
  - Can secure repository (Dao) operations using Spring AOP
  - to secure operations on domain objects themselves, you need to use AspectJ

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Spring

Service layer security (recap)

```
@Aspect
public class ServiceLayerAccessControl extends
   AbstractAccessControlManager {

  @Pointcut("SystemArchitecture.businessService()")
  protected void securedOperation() {}

}
```

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Domain model security

```
@Aspect
public class DomainModelAccessControl extends
   AbstractAccessControlManager {

  @Pointcut("Pointcuts.anyPublicMethod() &&
             SystemArchitecture.inDomainModel()")
  public void securedOperation() {}

}
```

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Spring

INTERFACE21

Configuration

```
<!-- <aop:aspectj-autoproxy/> -->
<bean id="domainModelAccessControl"
  class="abc.DomainModelAccessControl" factory-method="aspectOf">
  <property name="authenticationManger"  ref="authenticationManager"/>
  <property name="accessDecisionManager"
            ref="domainModelAccessDecisionManager"/>
  <property name="afterInvocationDecisionManager"
            ref="resultAccessDecisionManager"/>
  <property name="securityAttributes"
            ref="domainModelSecurityAttributes"/>
</bean>
```

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Spring

Demo

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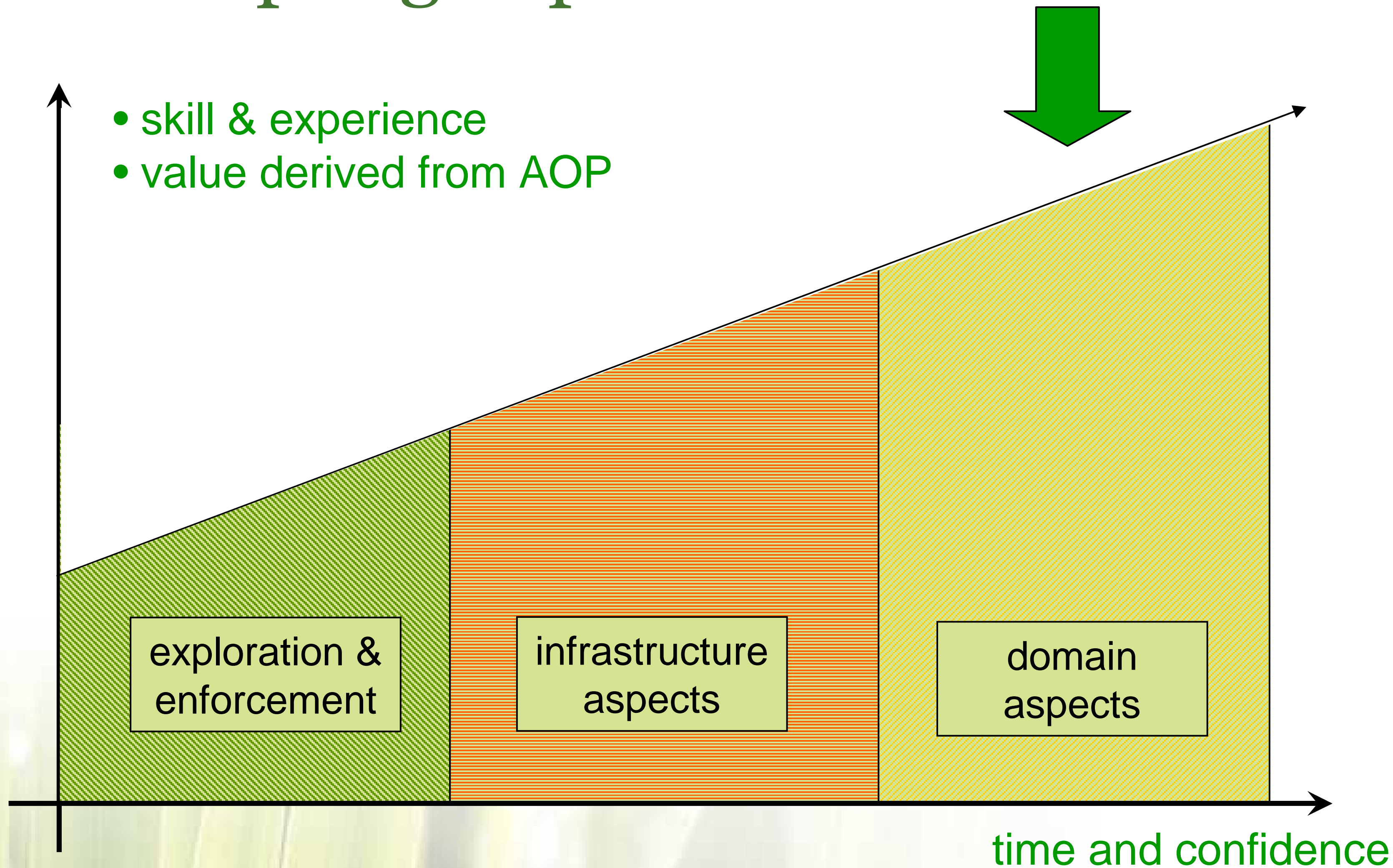
Adopting AspectJ



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Domain aspects

- Domain aspects implement function critical to the basic functioning of your application
  - not really easy to build and run any part of the system without them
- Cross a threshold here…
  - whole team needs to be comfortable with seeing aspects in the code
  - with debugging and maintaining them
  - whole team really needs to be using aspect-friendly development environment
    - i.e. AJDT

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Examples from AspectJ

- The AspectJ compiler itself is built using AspectJ…
- We extend the JDT compiler
  - want to make our changes as modular as possible
  - separate from main body of JDT code so that it is easy to integrate new drops of the JDT code

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Detecting empty catch blocks

```
/**
 * We get asked for this capability so often,
 * I thought I would simply extend the compiler
 * to support it.
 *
 * @author Adrian
 * @since 1.5.1
 */
public aspect WarnOnSwallowedException {

  pointcut resolvingATryStatement(
   TryStatement tryStatement, BlockScope inScope)
      : execution(* TryStatement.resolve(..)) &&
        this(tryStatement) &&
        args(inScope,..);
```

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Detecting empty catch blocks

```
    after(TryStatement tryStatement, BlockScope inScope) returning
          : resolvingATryStatement(tryStatement,inScope) {
      if (tryStatement.catchBlocks != null) {
          for (int i = 0; i < tryStatement.catchBlocks.length; i++) {
            Block catchBlock = tryStatement.catchBlocks[i];
            if (catchBlock.isEmptyBlock() ||
              catchBlock.statements.length == 0) {
                   warnOnEmptyCatchBlock(catchBlock,inScope);
            }
          }
      }
    }

    private void warnOnEmptyCatchBlock(
      Block catchBlock, BlockScope inScope) {
        inScope.problemReporter()
             .swallowedException(catchBlock.sourceStart(),
                                 catchBlock.sourceEnd());
    }
}
```

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Domain aspect examples

- Observing
- Publishing events
- Domain object DI
- Business and application rules
- …

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What about EJB3 ?

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Example from EJB spec

```
@Stateless
@Interceptors({
com.acme.AccountAudit.class,
com.acme.Metrics.class,
com.acme.CustomSecurity.class
})
public class AccountManagementBean implements AccountManagement {
    public void createAccount(int accountNumber, AccountDetails
    details) { ... }
    public void deleteAccount(int accountNumber) { ... }
    public void activateAccount(int accountNumber) { ... }
    public void deactivateAccount(int accountNumber) { ... }
...
}
```

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Aspect: Metrics gathering

```
public class Metrics {
    @AroundInvoke
    public Object profile(InvocationContext inv) throws Exception {
        long time = System.currentTimeMillis();
        try {
            return inv.proceed();
        } finally {
            long endTime = time - System.currentTimeMillis();
            System.out.println(inv.getMethod() +
            " took " + endTime + "milliseconds.");
        }
    }
}
```

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Aspect: Auditing

- `public void deleteAccount(AccountDetails details)`

```
public class AccountAudit {
   @AroundInvoke
   public Object auditAccountOperation(InvocationContext inv) throws
         Exception {
         try {
                Object result = inv.proceed();
                Auditor.audit(inv.getMethod().getName(),
                              inv.getParameters[0]);
                return result;
         } catch (Exception ex) {
                Auditor.auditFailure(ex);
                throw ex;
         }
   }
}
```

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Spring

True AOP approach

- No unneccessary annotations in service layer

```
@Stateless
@Interceptors({
com.acme.AccountAudit.class,
com.acme.Metrics.class,
com.acme.CustomSecurity.class
})
public class AccountManagementBean implements AccountManagement {
    public void createAccount(int accountNumber, AccountDetails
    details) { ... }
    public void deleteAccount(int accountNumber) { ... }
    public void activateAccount(int accountNumber) { ... }
    public void deactivateAccount(int accountNumber) { ... }
...
}
```

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Use an AOP solution that offers true pointcuts

Ability to reference and *reuse* named pointcuts, as well as define them inline

```
@Aspect
public class MetricsAspect {

    @Around("SystemArchitecture.serviceLayerOperation()")
    public void profileServiceLayerOperation(ProceedingJoinPoint jp) throws
    Throwable {
          long time = System.currentTimeMillis();
          try {
                    return jp.proceed();
          }  finally {
                    long endTime = time - System.currentTimeMillis();
                    System.out.println(jp.getSignature().getName() +
                              " took " + endTime + "milliseconds.");
          }
    }
}
```

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Audit aspect

```
@Aspect
public class AuditAspect {
   @Around("SystemArchitecture.serviceLayerOperation() &&
   args(details, ..)")
   public void auditAccountOperation(ProceedingJoinPoint jp,
   AccountDetails details) throws Throwable {
         try {
                 Object result = jp.proceed();
                 Auditor.audit(inv.getMethod().getName(), details);
                 return result;
         }  catch (Exception ex) {
                 Auditor.auditFailure(ex);
                 throw ex;
         }

}
```

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Simple?

Annotations crosscut multiple classes and methods, or verbose XML in DD

```
@Interceptors(com.acme.AccountAudit.class)
public void createAccount(AccountDetails details)  {

@Interceptors(com.acme.AccountAudit.class)
public void deleteAccount(AccountDetails details)  {


public class AccountAudit {
      @AroundInvoke
      public Object auditAccountOperation(InvocationContext
      inv)
                                                  throws
      Exception {
          try {
      `       Object result = inv.proceed();
              if (inv.getParameters().length > 0 &&
               (inv.getParameters()[0] instanceof
      AccountDetails)){
                          Auditor.audit(
                            inv.getMethod().getName(),
                           (AccountDetails)
      inv.getParameters[0]);
              }
              return result;
          }  catch (Exception ex) {
                  Auditor.auditFailure(ex);
                  throw ex;
            }
      }
}
```

Necessary fix to prevent `ArrayIndexOutOfBoundsException`

- **One single, *simple* module**

```
@Aspect
public class AuditAspect {
      @Around("SystemArchitecture.serviceLayerOperation() &&
      args(details, ..)")
      public void auditAccountOperation(ProceedingJoinPoint jp,
                                    AccountDetails details)
                                          throws Throwable {
              try {
                   Object result = inv.proceed();
                   Auditor.audit(
                              inv.getMethod().getName(), details);
                   return result;
              }  catch (Exception ex) {
                   Auditor.auditFailure(ex);
                   throw ex;
              }
}
```

Type safe
No risk of invocation with incorrect arguments

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Verdict

- Missing the key abstraction that pointcuts give you
- Untyped – easy to make mistakes
- Unproven model

- Tried to make something that was simpler…
  - actually made something that was more complex to use, *and* less powerful

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Summary

- We want to implement enterprise requirements in as simple and straightforward a manner as possible
  - use the appropriate implementation "vocabulary"
- AOP is about modularity
  - getting closer to the ideal of the "1:1 principle"
- AspectJ and Spring AOP are the leading AOP implementations
  - tightly integrated
  - Can use together or independently
- Adoption can proceed in phases
- Simpler and more powerful than EJB3

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About the course

- 4 days
- Mix of hands-on experience and classroom lectures
- Covers Spring AOP and AspectJ

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Spring

Day 1

- What is AOP?
  - goals and motivation, how AOP works
  - key terms and concepts introduced
- Spring AOP and AspectJ
  - how to write and build aspects in Spring AOP and AspectJ
- Basic Pointcuts
  - the pointcut language, writing robust pointcuts, style tips
- Design level assertions
  - enforcing layering and other design constraints
  - using the tools – working with AJDT, and integrating into your builds

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Day 2

- Advice types
  - understanding the different kinds of advice
  - exception management with aspects
- Pointcuts with parameters
  - example: clustered caching
- Using an aspect library
  - how to use an existing library, load-time weaving
- Infrastructure aspects
  - transactions, security, tracing, profiling, failure handling, jmx,…

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Day 3

- Matching on Java 5 features
  - generics, annotations etc.
- Using annotations (wisely…)
  - asynchronous task execution, auditing
- Mixins and inter-type declarations
  - read-write locking, annotation bridging, dirty tracking, bean-name aware
- Aspects and design patterns

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Day 4

- Aspects
  - abstract aspect and instantiation models
  - generating application events
- Testing
  - tips and techniques for testing aspects
- Aspect libraries
  - writing and packaging reusable aspects
  - creating an aspect library for use by your project / organisation
- Adoption roadmap
  - how to introduce AOP to your project or organisation

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INTERFACE21

The End!

- questions…

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Spring