# Aspect Oriented Programming

2013-2014

Course 5

# Course 5 Contents

- AspectJ Language:
  - Annotations
  - Static crosscutting
  - Examples

# Annotations

- From version 1.5
- Annotations provide data about a program code (class, method, package, etc) that is not part of the program itself.
- They have no direct effect on the operation of the code they annotate.
- Usages:
  - *Information for the compiler* — Annotations can be used by the compiler to detect errors or suppress warnings.
  - *Compiler-time and deployment-time processing* — Software tools can process annotation information to generate code, XML files,etc.
  - *Runtime processing* — Some annotations are available to be examined at runtime.

# Defining Annotations

```
[meta-annotations declaration]
public @interface AnnotationName {
  [annotation's elements]
}
```

4 meta-annotations (`java.lang.annotation` package) :

- **`@Target(ElementType)`:** Where this annotation can be applied.
  - **`CONSTRUCTOR`:** Constructor declaration
  - **`FIELD`:** Field declaration (including enum constants)
  - **`LOCAL_VARIABLE`:** Local variable declaration
  - **`METHOD`:** Method declaration
  - **`PACKAGE`:** Package declaration
  - **`PARAMETER`:** Parameter declaration
  - **`TYPE`:** Class, interface(including annotation) or enum declaration.

# Defining Annotations

Meta-annotations (cont.):

- `@Retention(RetentionPolicy)`: How long the annotation information is kept:
  - `SOURCE`: Annotations are discarded by the compiler..
  - `CLASS`: Annotations are available in the class file generated by the compiler but can be discarded by the VM.
  - `RUNTIME`: Annotations are retained by the VM at run time, so they may be read reflectively.
- `@Documented`: Include this annotation in the Javadocs.
- `@Inherited`: Allow subclasses to inherit parent annotations.

Remark:

If `@Target` is omitted, it can be applied to any of the mentioned elements.

# Annotation Elements

- Syntax:

```
Type elementName() [default default_value];
```

where `Type` may be:

  - All primitives(`int`, `float`, `double`, `byte`, etc.)
  - `String`
  - `Class`
  - Enums (`enum`)
  - Annotations (`annotation`)
  - Arrays of any of the above.

Remarks:

1. The compiler will report an error if you try to use any other types.
2. An annotation without any elements, is called a *marker annotation*.

# Default values constraints

- There are two constraints:

1. No element can have an unspecified value. (Elements must either have default values or values provided by the class that uses the annotation.).
2. None of the non-primitive type elements are allowed to take `null` as a value, either when declared in the source code or when defined as a default value in the annotation interface.

# Using annotations

The annotation appears first, often (by convention) on its own line, and may include elements with named or unnamed values:

Remarks:

1. If there is just one element named "`value`" then the name may be omitted.
2. If an annotation has no elements, the parentheses may be omitted.

# Annotation - example

Declaration:

```
import java.lang.annotation.*;
@Target(ElementType.METHOD)
@Retention(RetentionPolicy.RUNTIME)
public @interface UseCase {
    public int id();
    public String description() default "no description";
}
```

Usage:

```
public class A{
  @UseCase(id=3, description="abcd")
  public void f(){ }
}
```

# Built-in annotations

- JSE defines 3 built-in annotations:
  - **`@Override`** to indicate that a method definition is intended to override a method in the base class. This generates a compiler error if you accidentally misspell the method name or give an improper signature.

```
class A{
  @Override
  public String toString(){...}
}
```

  - **`@Deprecated`** to produce a compiler warning if this element is used.
  - **`@SuppressWarnings`** to turn off inappropriate compiler warnings: **`unchecked`**, **`deprecated`**

```
@SuppressWarnings("unchecked", "deprecated")
void metodaA() { }
```

# Annotations and AspectJ

- AspectJ allows the use of annotations in pointcuts.
- Annotations used as a part of a statically determinable pointcut must have at least class-retention policy so the compiler retains them in the class file. Others need runtime retention so the compiler retains them in the class files and the VM makes them available at runtime.
- Annotation-based type signature pattern
- Annotation-based method signature pattern
- Annotation-based field signature pattern
- Annotation-based pointcuts

# Annotation-based type signature pattern

- AspectJ allows the use of annotations in type signature patterns.

```
@Retention(RetentionPolicy.RUNTIME)
public @interface Sensitive {
    int level();
}

@Sensitive(level=5)
public class MedicalRecord {
   ...
}
```

# Annotation-based type signature pattern

- Examples

**`@Secured Account`**

The **`Account`** type with the **`Secured`** annotation

**`@Sensitive *`**

Any type marked with the **`Sensitive`** annotation.

```
@Sensitive(level=5)
class MedicalRecord {...}
```

```
@Sensitive(level=10)
class NuclearDesign { ...}
```

**`@Business* Customer+`**

The **`Customer`** type or its subtypes that carry an annotation of a type whose name starts with **`Business`**

```
@BusinessEntity
class Customer {...}
```

```
@BusinessCritical
class PlatinumCustomer extends Customer
{...}
```

# Annotation-based method signature pattern

- AspectJ supports selecting methods based on the annotations they carry.

```
public class Account {
    ...
    @Transactional
    public void credit(double amount) {
      ...
    }
    ...
}
```

# Annotation-based method signature pattern

- Examples

```
@Secured * *(..)
```

Any method marked with the `@Secured` annotation.

```
@Secured @Transactional * *(..)
```

Any method marked with both `@Secured` and `@Transactional` annotations.

```
@(Secured || Transactional) * *(..)
```

Any method marked with either a `@Secured` or `@Transactional` annotation.

```
(@Sensitive *) *(..)
```

Any method that returns a type marked with a `@Sensitive` annotation.

```
MedicalRecord getRecord()
```

# Annotation-based method signature pattern

- Examples

`* (@BusinessEntity *).*(..)`

Any method defined in a type annotated with the `@BusinessEntity` annotation.

`* *(@RequestParam (*))`

Any method with one parameter marked with the `@RequestParam` annotation. The parentheses around that last * are used to group the parameter type.

`eg. void show(@RequestParam Long id)`

`* *(@Sensitive *)` or `* *((@Sensitive *))`

Any method with one parameter whose type carries the `@Sensitive` annotation.

eg. `void create(MedicalRecord mr)`

# Annotation-based method signature pattern

- Examples

`* *(@RequestParam (@Sensitive *))`

Any method with one parameter marked with the `@RequestParam` annotation, where the parameter's type is marked with the `@Sensitive` annotation.

eg. `void create(@RequestParam MedicalRecord mr)`

# Annotation-based field signature pattern

- AspectJ can use field-level annotations.

```
public class Account {
   @Id private Long id;
   ...
}
```

# Annotation-based field signature pattern

- Examples

```
@Sensitive * *.*
```

Any field that is marked with the `@Sensitive` annotation, regardless of the field's type, declaring type, or name

eg. `private @Sensitive SSN socialSecurityNumber;`

```
(@Sensitive *) *.*
```

Any field whose type is marked with the `@Sensitive` annotation.

```
* (@Sensitive *).*
```

Any field defined in a type annotated with the `@Sensitive` annotation.

# Annotation-based pointcuts

- AspectJ allows selection based on annotations carried by types, methods, and fields.
- Annotation-based pointcuts come in two forms:
  - selection based on matching annotation types
  - collection of the matching annotations.

Eg.

1. If `MedicalRecord` is annotated with `@Sensitive`, `@this(Sensitive)` selects all join points where `this` is of `MedicalRecord` type.

2. If the `@Sensitive` annotation is marked as `@Inherited` it also matches join points where `this instanceof MedicalRecord` is true.

# Annotation-based pointcuts

- `@this(TypePattern or ObjectIdentifier)`

  Any join point where the this object's type carries the annotation of the `TypePattern` type.
- `@target(TypePattern or ObjectIdentifier)`

  Any join point where the target object's type carries the annotation of the `TypePattern` type.
- `@args(TypePattern or ObjectIdentifier, ..)`

  Any join point where the arguments' type carries annotations of the `TypePattern`.
- `@within(TypePattern or ObjectIdentifier)`

  Any join point in the lexical scope of a type that carries an annotation matching the specified `TypePattern`.

# Annotation-based pointcuts

- `@withincode(TypePattern or ObjectIdentifier)`

  Any join point where the matching program element (method or constructor) carries an annotation matching the `TypePattern`.
- `@annotation(TypePattern or ObjectIdentifier)`

  Any join point where the subject carries the specified annotation:
  - For method, constructor, and advice-execution join points, the subject is the same as the program element.
  - For field-access and exception handler join points, the subject is the field or exception being accessed
  - For initialization and pre-initialization join points, the subject is the first called constructor matching the specified signature.
  - For static initialization join points, the subject is the type being initialized.

# Static Crosscutting

- Sometimes there is a need to modify the static structure of the system in order to implement a crosscutting functionality.
- Static crosscutting modifies the static structure of the types (classes, interfaces, and other aspects) and their weave-time behavior.
- There are three types of static crosscutting:
  - Inter-type declaration (ITD)
  - Weave-time error and warning declarations
  - Exception softening

# Static Crosscutting

- *Inter-type declaration* (ITD): One type (an aspect) makes declarations for another type (an interface, a class, or an aspect). It consists of support for member introduction, type-hierarchy modification, and annotation supplementation.
- *Weave-time error and warning declarations*: It detects the presence of a join point and issues errors and warnings during the weaving process.
- *Exception softening.* It lets the programmer deal with checked exceptions in a crosscutting manner.

# Inter-type declarations

- Member introduction rules:

1. *An aspect may only introduce members with* `public` *or* `private` *access specification:*
   - public access - the introduced member is visible to other parts of the system (plain Java classes or aspects).
   - private access - the introduced member is visible only to the introducing aspect. When using a private introduction, the name of the member woven into the types is a mangled version.
2. *Multiple aspects may introduce the same named members as long as they have private access.*
   - It is an error to introduce the same public member through multiple aspects.

# Inter-type declarations

3. *An aspect may introduce fields (final as well as non-final), methods, and constructors to classes and interfaces.*
   - The aspect may introduce methods along with their implementations to an interface.
   - Contrary to standard Java rules, interfaces may also contain method implementations ( not only declarations) and may also contain non final instance fields.
4. *If a class contains a method, and an aspect introduces the same method to its base interface, the implementation in the class takes precedence.*
   - Similar to overriding a method, but the super() method cannot be called.
5. *A member-introduction declaration can use only one type.*
   - The use of wildcards is prohibited.
   - You can combine a member declaration with a type modification to get the effect of introducing a member into multiple types.

# Inter-type declarations - Examples

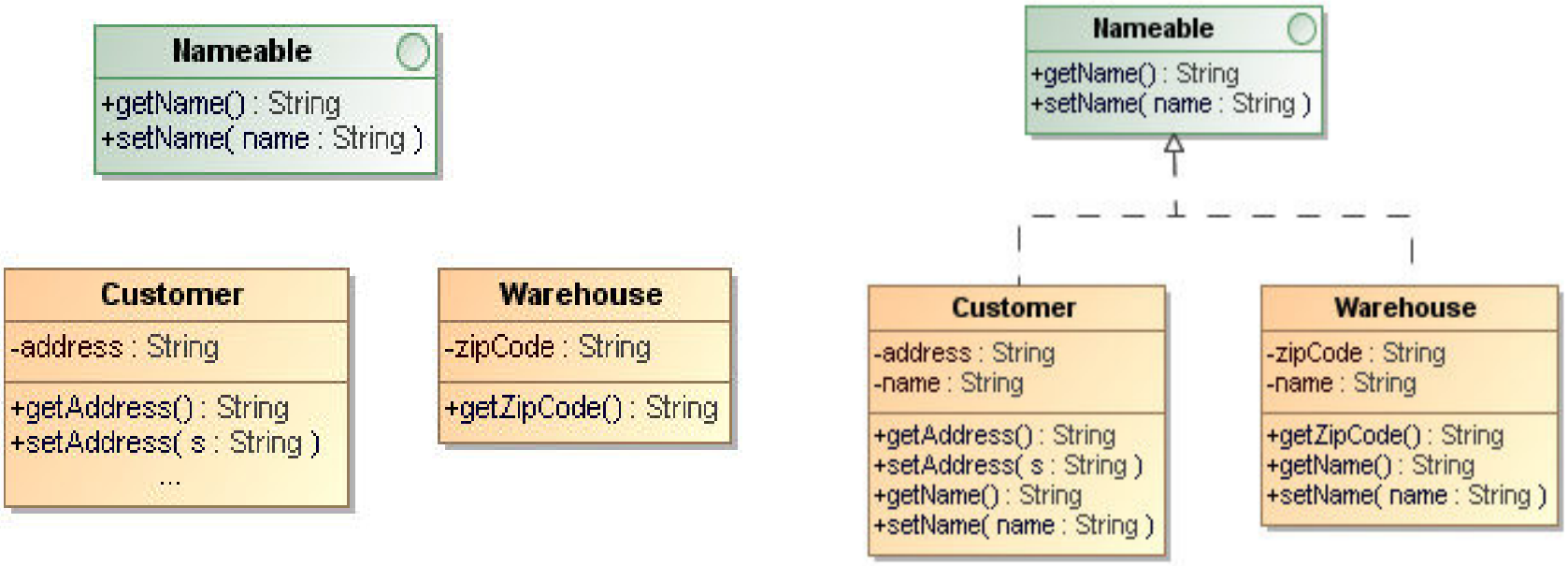
```
public class Customer  {
    private String address;
    public String getAddress() {
        return address;
    }
    public void setAddress(String address) {
        this.address = address;
    }
}
```

# Inter-type declarations - Examples

```
public aspect CustomerIdentifiable  {
    private int Customer.id;
    private static int idGen;
    public int Customer.getId() {return id;}

    public void Customer.setId(int idn) {id = idn;}

    pointcut customerCreation(Customer c):
         initialization(Customer.new(..)) && this(c);

    after (Customer c) returning: customerCreation(c){
         c.setId(idGen++);
    }
}
//... main
    Customer c1=new Customer(), c2=new Customer();
    System.out.println("c1.id="=c1.getId()+" c2.id="+c2.getId());

Output: c1.id=0 c2.id=1
```

# Idiom: default interface implementation

- Java does not allow interfaces to contain implementation code; only classes can implement methods.
- Sometimes, it would be useful to have a default implementation for interfaces as well.



# Idiom: default interface implementation

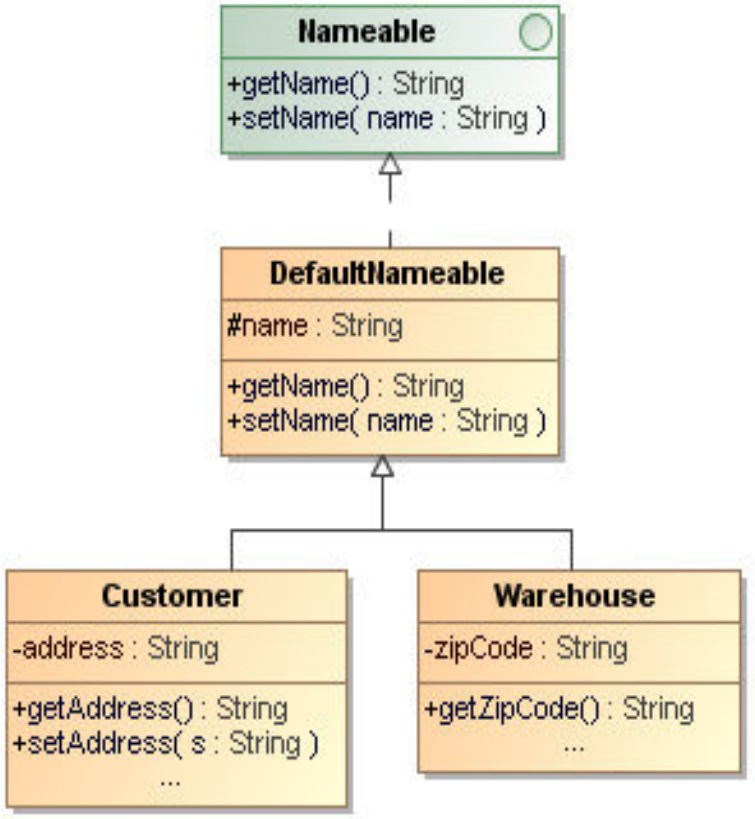
```
public interface Nameable {
    public void setName(String name);
    public String getName();
}
//Java solution
public class Customer implements Nameable {
    private String name;
    public void setName(String name) {
         this.name = name;
    }
    public String getName() {
         return this.name;
    }
 //... other members (methods, attributes)
}
```

# Idiom: default interface implementation

Solution without AspectJ: to create a default implementation class for the interface and let the classes extend this class.

Disadvantages:

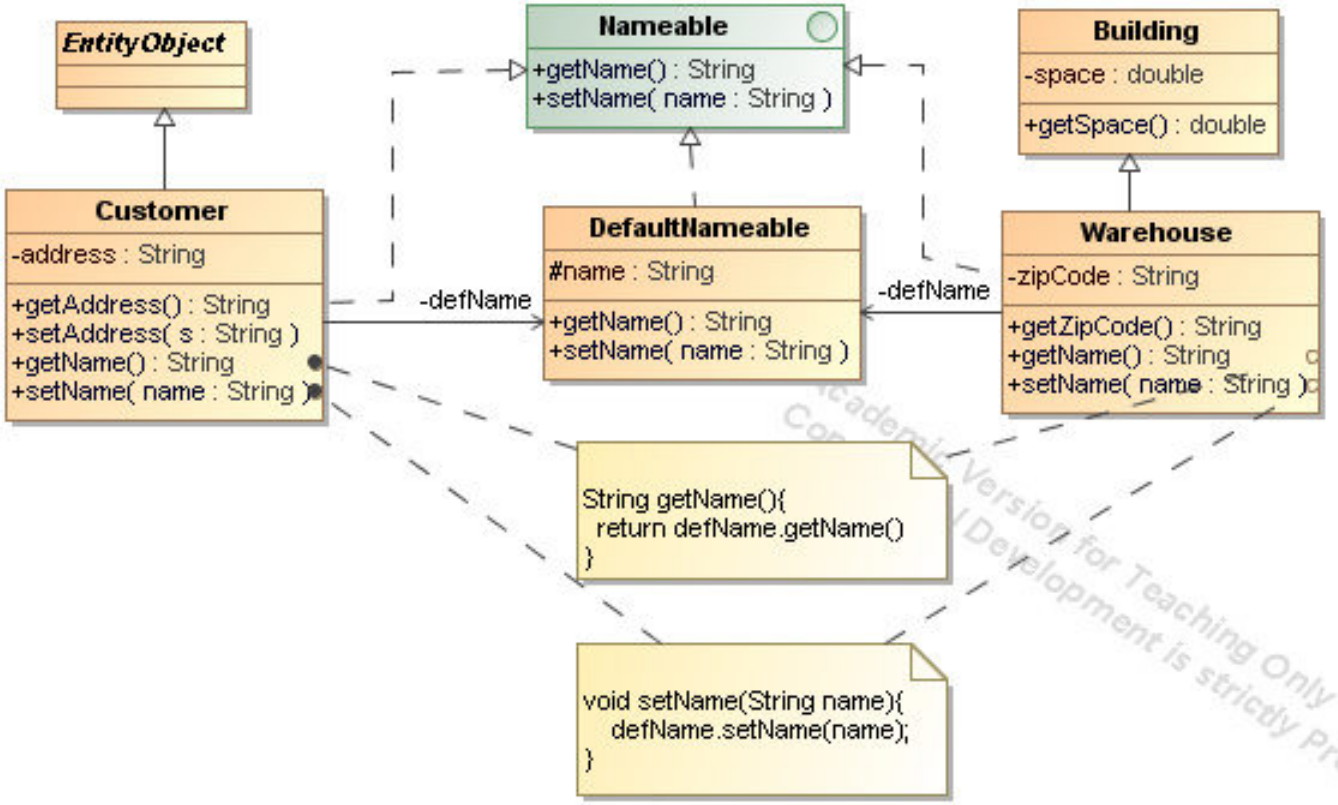
- It works well as long as the implementing classes need to extend only this class, but the solution does not work if you need to implement two or more such interfaces.
- It breaks down if you need to extend another class and implement an interface using its default implementation.



# Idiom: default interface implementation

Alternatives:

- Use the delegation pattern by delegating each method to an instance of the default implementation class.
  - You end up with several one-line methods, which causes code scattering (one of the symptoms of a crosscutting concern).



# Idiom: default interface implementation

```
//AspectJ solution
public interface Nameable {
    public void setName(String name);
    public String getName();
    static aspect Impl {
        private String Nameable.name;
        public void Nameable.setName(String name) {
                this.name = name;
        }
        public String Nameable.getName() {
                return this.name;
        }
    }
}
public class Customer implements Nameable {
    //... other members (methods, attributes)
}
```

# Idiom: default interface implementation

Remarks:

- This solution  saves you from writing a lot of code.
- It facilitates making changes. If you need to modify the default implementation, all you need to do is change the nested aspect.
- Although the classes that implement these interfaces no longer have to implement their methods, in some cases you may need to customize a few methods.
  - When such methods are directly implemented in classes, they override the default implementation introduced by the aspect.
- Another variation that can be used provides only a partial default implementation for an interface.

# Modifying the Type Hierarchy

- The inheritance hierarchy of existing classes and interfaces can be modified using the `declare parents` construct.
- It has two forms:

```
declare parents : [TypePattern] implements [InterfaceList];
```

or

```
declare parents : [TypePattern] extends [Class or InterfaceList];
```

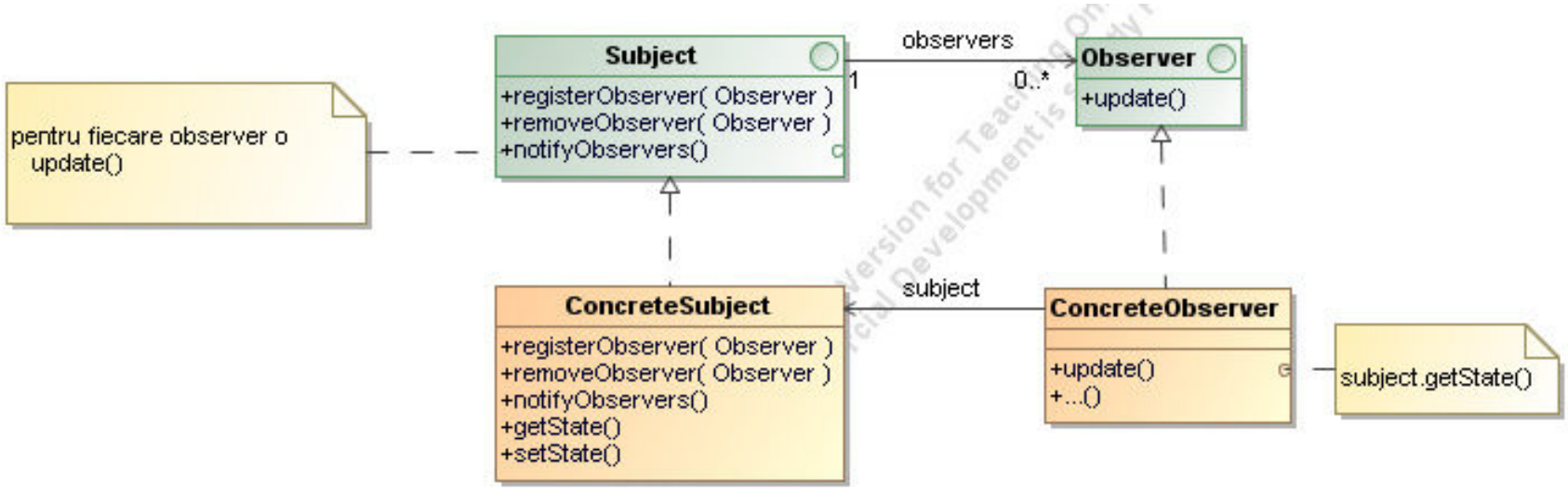
- The declaration of parents must follow the regular Java object-hierarchy rules:
  - You cannot declare a class to be the parent of an interface.
  - You cannot declare parents in such a way that it results in multiple inheritance.

# Modifying the Type Hierarchy

- Evaluation order: static and dynamic crosscutting
- AspectJ applies all static crosscutting prior to dynamic crosscutting.
- It applies all `declare parents` statements before evaluating matches for a pointcut.
- Matching is not affected by how a static structure came to be: it could be due to the way classes were written or due to a static crosscutting construct.

# Modifying the Type Hierarchy

- Observer design pattern



# Introducing Members to Multiple Types

- A combination of member introduction and type-hierarchy modification provides a useful idiom to introduce members to multiple types.
- You create an interface, introduce members to it, and declare it the parent of the target types.
- It is similar to creating default implementations of interfaces.
- Example: To trace the last-accessed time for each service class.
  - We assume that a service class is marked with the @Service annotation.
  - You need to introduce a field for the last-accessed time in all service classes. (We cannot use wildcards in a member-introduction statement.)

# Introducing Members to Multiple Types

```
public aspect TimeTracker {
   private static interface LastAccessedTimeHolder {
     static aspect Impl {
       private long LastAccessedTimeHolder.lastAccessedTime;
       public long LastAccessedTimeHolder.getLastAccessedTime() {
         return lastAccessedTime;
       }
      public void LastAccessedTimeHolder.setLastAccessedTime(long time) {
         lastAccessedTime = time;
       }
     }
  }
declare parents : @Service * implements LastAccessedTimeHolder;
before(LastAccessedTimeHolder service)
: execution(* LastAccessedTimeHolder+.*(..)) && this(service) &&
    !within(TimeTracker) {
      service.setLastAccessedTime(System.currentTimeMillis());
    }
}
```

# Supplying Annotations

- AspectJ provides support for selecting join points based on annotations carried by the program elements.
- It also offers static crosscutting constructs to supply annotations in a crosscutting manner.
- You can associate annotations with methods, constructors, fields, and types. The constructs for supplying annotations share the following general form:

```
declare @<target-kind>: <Target-element-pattern>: @<Annotation-
    type>[Annotation-properties];
```

- Program elements annotated using the `declare` statement can be used the same way as normally annotated program elements.
- Eg. if a pointcut specifies an annotation as part of the matching specification, program elements annotated using a `declare` statement will match the same way as program elements directly marked with an annotation.

# Supplying Annotations

- The declaration has three parts:
  - `declare @<target-kind>` declares the kind of elements annotated by the statement
  - `<Target-element-pattern>` uses a signature pattern to select the program elements to be annotated
  - `@<Annotation-type>[Annotation-properties]` declares the annotation, which may contain any properties available for the annotation.
- Like normal annotations, `declare` statements must use annotations that are compatible with the elements being annotated.

# Supplying Annotations

- Method:

```
declare @method: <Method signature pattern>: <Annotation>;
```

Eg.
```
declare @method: * AccountService.*(..):
    @Transactional(Propagation.Required);
```

- Constructor:

```
declare @constructor: <Constructor signature pattern>: <Annotation>
```

Eg.
```
declare @constructor: AccountService+.new():@ConfigurationOnly;
```

- Field:

```
declare @field:<Field signature pattern>: <Annotation>;
```

Eg.
```
declare @field:* MissileInformation.*: @Classified;
```

- Type:

```
declare @type:<Type signature pattern>: <Annotation>;
```

Eg.
```
declare @type: banking..* :@PrivacyControlled;
```

# Declaring weave-time errors and warnings

- AspectJ provides a static crosscutting mechanism to declare weave-time errors and warnings based on certain usage patterns.
- This mechanism is often used with the AspectJ compiler as the weaver and therefore is also referred to as a compile-time error and warning construct.
- With this mechanism, you can implement behavior similar to the #error and #warning preprocessor directives supported by some C/C++ compilers.
- `declare error`
- `declare warning`

# Declaring weave-time errors and warnings

- The **`declare error`** construct provides a way to declare a weave-time error when the compiler detects the presence of a join point matching a given pointcut. The compiler issues an error, prints the given message for each detected use, and aborts the compilation process:

```
declare error : <pointcut> : <message>;
```

- The **`declare warning`** construct provides a way to declare a compile-time warning, but it doesn't abort the compilation process:

```
declare warning : <pointcut> : <message>;
```

Remark:

You cannot use the pointcuts that use runtime checks to select the matching join points—**`this(), target(), args(), @this(), @target(), @args(), if(), cflow(), and cflowbelow()`**— in their declaration.

# Declaring weave-time errors and warnings

- A typical use of these constructs is enforcing rules, such as prohibiting calls to certain unsupported methods, or issuing a warning about such calls.

```
declare error : callToUnsafeCode() : "This third-party code is known
   to result in a crash";

declare warning : callToBlockingOperation() : "Please ensure you are
   not calling this from an AWT thread";
```

# Softening Checked Exceptions

- Java specifies two categories of exceptions that a method may throw: checked and unchecked.
  - Checked - callers must deal with it either by catching exception or by declaring that they can throw it.
  - Unchecked (it directly or indirectly extends `RuntimeException` or `Error`) - callers need not deal with it explicitly and the exception is automatically propagated up the call stack.
- Exception softening lets you treat checked exceptions thrown by specified pointcuts as unchecked ones.
- It eliminates the need to explicitly deal with them in the caller code.
- The exception-softening feature helps modularize the crosscutting concerns of exception handling.

# Softening Checked Exceptions

- To soften exceptions, you use the `declare soft` construct, which takes the following form:

```
declare soft : <ExceptionTypePattern> : <pointcut>;
```

- If a method is throwing more than one checked exception, you must soften each one individually.
- Exception softening is a quick way to avoid tangling the concern of exception handling with the core logic.

Remark:

Do not overuse this technique. One of the reasons to use checked exceptions is that it forces you to handle them by making a conscious decision about processing the exceptions or propagating them to the caller.

# Softening Checked Exceptions

```
import java.rmi.RemoteException;
public class TestSoftening {
   public static void main(String[] args) {
     TestSoftening test = new TestSoftening();
     test.perform();
   }
   public void perform() throws RemoteException {
     throw new RemoteException();
   }
}
```

Compilation error: **`main`** does not catch the **`RemoteException`**, nor does it specify that it throws the exception.

# Softening Checked Exceptions

```
import java.rmi.RemoteException;
public class TestSoftening {
   public static void main(String[] args) {
     TestSoftening test = new TestSoftening();
     test.perform();
   }
   public void perform() throws RemoteException {
     throw new RemoteException();
   }
}
import java.rmi.RemoteException;
public aspect SofteningTestAspect {
    declare soft : RemoteException : call(void
   TestSoftening.perform());
}
ajc TestSoftening.java SofteningTestAspect.aj
    //no compilation errors
```