Aspect-Oriented Programming and Aspect-J

TDDD05 / DF14900

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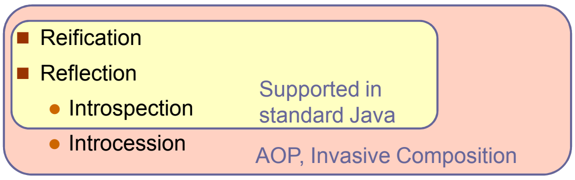
Outline: Aspect-Oriented Programming

- New concepts introduced
  - Crosscutting concern
  - Aspect
  - Dynamic aspect weaving
  - Static aspect weaving
  - Join point
  - Dynamic join point model
  - Static join point model
- Pros and cons
- Case study: Aspect-J (also Lesson 3 + Lab 3)

Recall: Reification, Reflection etc.



- Reification
- Reflection
  - Introspection
  - Introcession

Supported in standard Java

AOP, Invasive Composition

Object-Oriented Programming …

- Objects model the real world
  - Data and operations combined
  - Encapsulation
  - Objects are self contained
- Separation of concerns ?

Example (1)

```
class Account {
    private int balance = 0;

    public void deposit(int amount) {
        balance = balance + amount;
    }

    public void withdraw(int amount) {
        balance = balance - amount;
    }
}
```

Example (2)

```
class Logger {
    private OutputStream stream;

    Logger() {
        // Create stream
    }

    void log(String message) {
        // Write message to stream
    }
}
```

Example (3)

```
class Account {
    private int balance = 0;
    Logger logger = new Logger();

    public void deposit(int amount) {
        balance = balance + amount;
        logger.log("deposit amount: " + amount);
    }

    public void withdraw(int amount) {
        balance = balance - amount;
        logger.log("withdraw amount: " + amount);
    }
}
```

What is Crosscutting

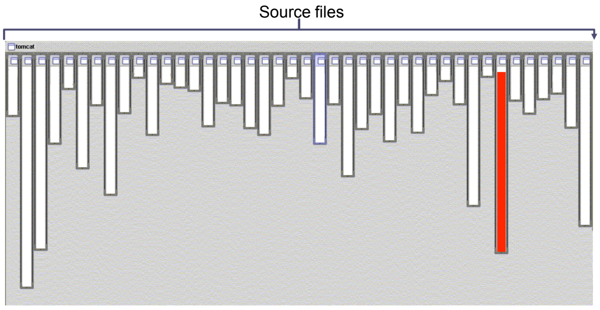
- Code in objects (components, programs) not directly related to the core functionality
  - User authentication
  - Persistence
  - Timing
- Mixing of concerns leads to
  - Code scattering
  - Code tangling

Problems: Intermixed Concerns

- Correctness
  - Understandability
  - Testability
- Maintenance
  - Find code
  - Change it consistently
  - No help from OO tools
- Reuse

Case Study: Apache Tomcat

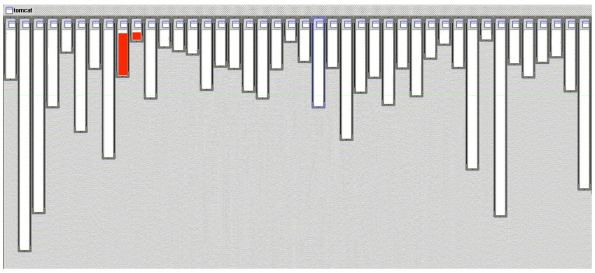
- Concern: XML Parsing



From org.apache.tomcat

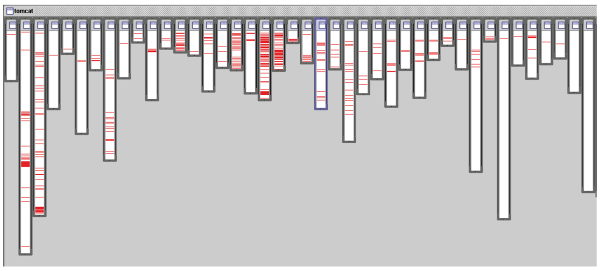
Case Study (2): Apache Tomcat

- Concern: URL Pattern Matching



Case Study (3): Apache Tomcat

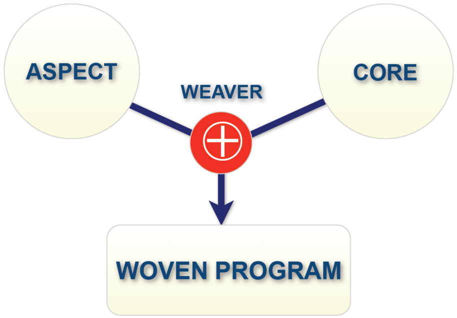
- Concern: Logging



Aspect-Oriented Programming

- Aspect = Implementation of a crosscutting concern
- Components and component language
- Aspects and aspect language
- Does not replace OOP
- Code does not have to be OO based

Aspect Weaving



Back to the Examples

```
class Account {
    private int balance = 0;

    public void deposit(int amount) {
        balance = balance + amount;
    }

    public void withdraw(int amount) {
        balance = balance - amount;
    }
}
```

Weave on Demand

```
aspect Logging {

    Logger logger = new Logger();

     WHENEVER ANY METHOD IS CALLED () {
          logger.log(“Method is called”);
     }
}
```

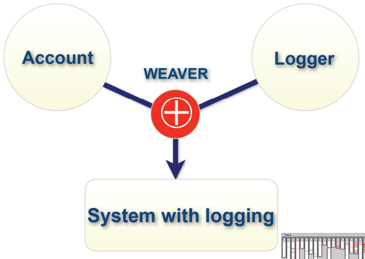
A weaving rule
(code execution pattern
→ execution modification)

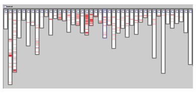
Weaving, Example

```
aspect Logging {

    Logger logger = new Logger();

     WHENEVER ANY METHOD IS CALLED () {
          logger.log(“Method is called”);
     }
}
```

```
class Account {
    private int balance = 0;

    public void deposit(int amount) {
        balance = balance + amount;
    }

    public void withdraw(int
        balance = balance - amc
    }
}
```

```
class Logger {
    private OutputStream stream;

    Logger() {
        // Create stream
    }

    void log(String message) {
        // Write message to stream
    }
}
```





Weaving Time

- Preprocessor
- Compile time
- Link time
- Load time
- Run time

New Concepts

(using Aspect-J terminology)

- **Weaving**
- **Aspect** (= weaving rule)
  - **Join point**
  - **Pointcut**
  - **Advice**

Join Point

- **Static join point model** (Invasive Composition)
  - A *location* in (a component) code where a concern crosscuts
  - Example: A method or class definition
- **Dynamic join point model** (AspectJ)
  - A well-defined *point in the program flow*
  - Example: A call to a method

Pointcut

- A **pointcut is a predicate that matches join points**
  - The “pattern” part of a weaving rule
  - Is a predicate that matches join points
  - Picks out certain join points
  - Exposes parameters at join points
- Example
  - The `balanceAltered` pointcut picks out each join point that is a call to either the `deposit()` or the `withdraw()` method of an `Account` class

```
pointcut balanceAltered() :
   call(public void Account.deposit(int)) ||
        call(public void Account.withdraw(int));
```

Pointcut, Further Examples

- `call ( void SomeClass.make*(..) )`
  - picks out each join point that's a call to a void method defined on `SomeClass` whose name begins with "`make`“ regardless of the method's parameters
- `call ( public * SomeClass.* (..) )`
  - picks out each call to `SomeClass` public methods
- `cflow ( somePointcut )`
  - picks out each pointcut that occurs in the dynamic context of the join points picked out by *`somePointcut`*
  - pointcuts in the control flow, e.g., in a chain of method calls

Advice

- The modification part of a weaving rule
- Code executed at a pointcut
  - join point reached
  - joint point matched

```
before(int i) : balanceAltered(i) {
  System.out.println("The balance changed");
}
```

Aspect

- **The unit of modularity for a crosscutting concern**
  - Implements join points, pointcuts, advice

```
public aspect LoggingAspect {
     pointcut balanceAltered(int i) :
       call(public void Account.deposit(int)) ||
           call(public void Account.withdraw(int));

     before(int i) : balanceAltered(i) {
        System.out.println("The balance changed");
     }
}
```

So far we have …

- Agreed that *tangled, scattered* code that appears as a result of *mixing different crosscutting concerns* in (OO) programs is a problem
- Sketched a feasible solution - AOP
- Introduced
  - Join points
  - Pointcuts
  - Advice
  - Aspects
  - Weaving
- Tools?

AspectJ

- Xerox Palo Alto Research Center
- Gregor Kiczales, 1997
- Goal: Make AOP available to developers
  - Open Source
  - Tool integration Eclipse
- Java with aspect support
- Current focus: industry acceptance

Join Points in AspectJ

- Method call execution
- Constructor call execution
- Field get
- Field set
- Exception handler execution
- Class/object initialization

Patterns as Regular Expressions

- Match any type: `*`
- Match 0 or more characters: `*`
- Match 0 or more parameters: `(..)`
- All subclasses: `Person+`
- Call: `call (private void Person.set*(*)`
- Call: `call (* * *.*(*))`
- Call: `call (* * *.*(..))`

Logical Operators

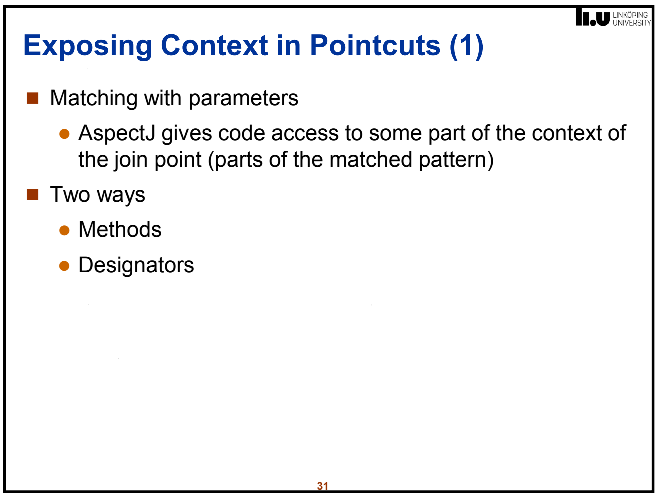
- Match all constructor-based instantiations of subclasses of the `Person` class:

```
call((Person+ && ! Person).new(..))
```

Pointcut Example

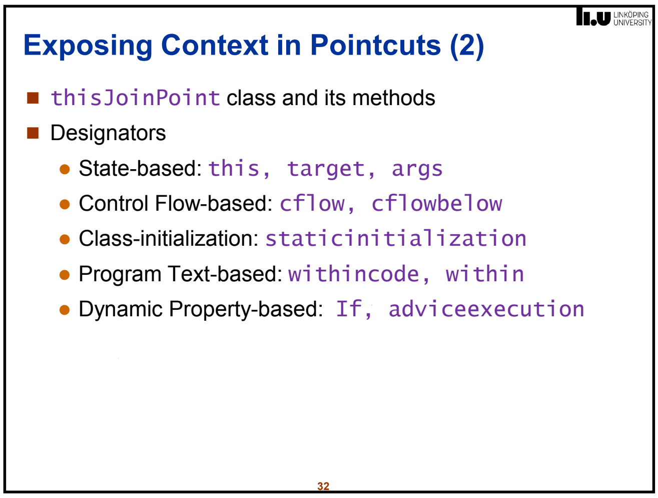
- Match all attempts to retrieve the `balance` variable of the `Account` class:

```
pointcut balanceAccess() :
    get(private int Account.balance);
```



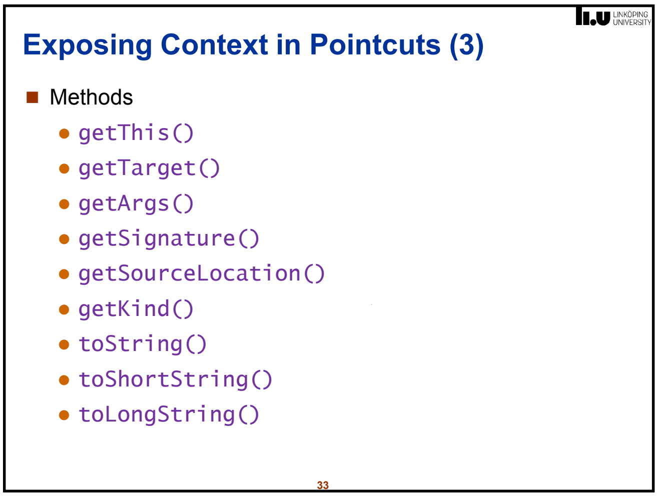
Exposing Context in Pointcuts (1)

- Matching with parameters
  - AspectJ gives code access to some part of the context of the join point (parts of the matched pattern)
- Two ways
  - Methods
  - Designators



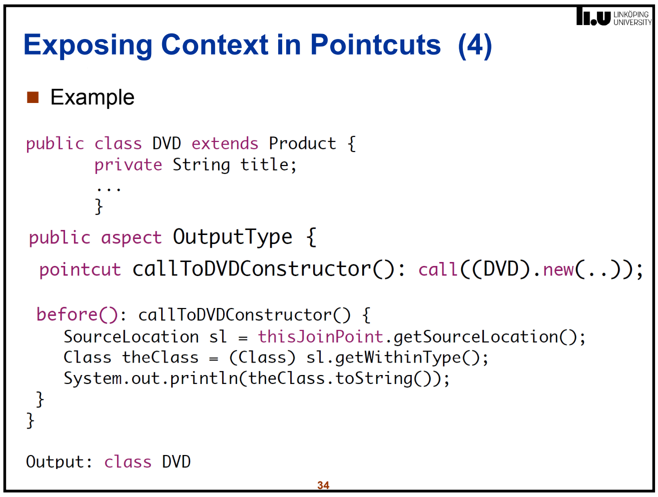
Exposing Context in Pointcuts (2)

- `thisJoinPoint` class and its methods
- Designators
  - State-based: `this, target, args`
  - Control Flow-based: `cflow, cflowbelow`
  - Class-initialization: `staticinitialization`
  - Program Text-based: `withincode, within`
  - Dynamic Property-based: `If, adviceexecution`



Exposing Context in Pointcuts (3)

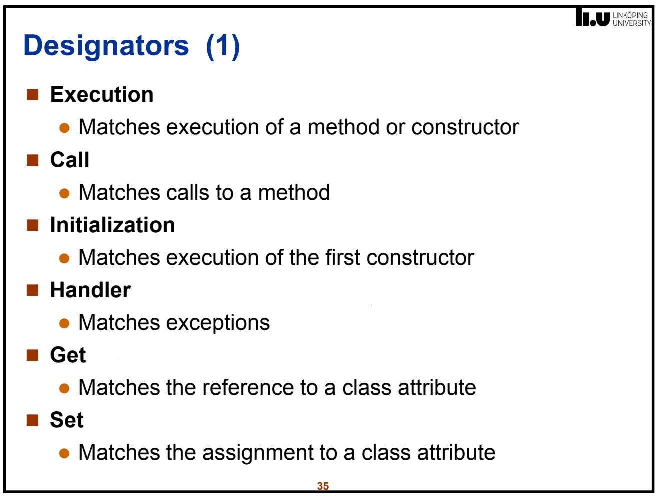
- Methods
  - `getThis()`
  - `getTarget()`
  - `getArgs()`
  - `getSignature()`
  - `getSourceLocation()`
  - `getKind()`
  - `toString()`
  - `toShortString()`
  - `toLongString()`



Exposing Context in Pointcuts (4)

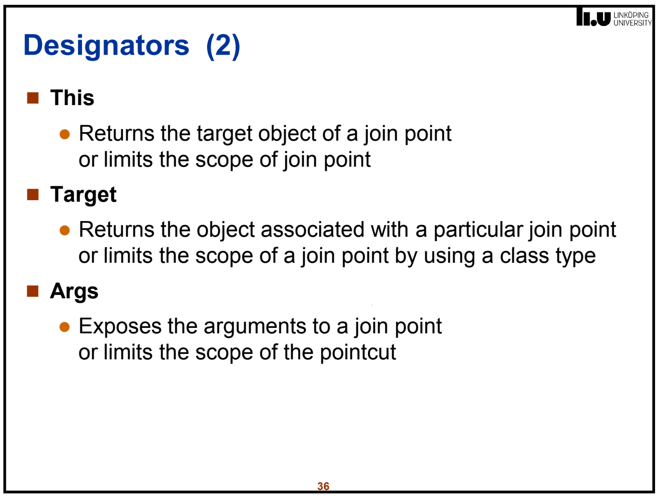
- Example

```
public class DVD extends Product {
       private String title;
       ...
       }
public aspect OutputType {
 pointcut callToDVDConstructor(): call((DVD).new(..));

 before(): callToDVDConstructor() {
    SourceLocation sl = thisJoinPoint.getSourceLocation();
    Class theClass = (Class) sl.getWithinType();
    System.out.println(theClass.toString());
 }
}

Output: class DVD
```



Designators (1)

- **Execution**
  - Matches execution of a method or constructor
- **Call**
  - Matches calls to a method
- **Initialization**
  - Matches execution of the first constructor
- **Handler**
  - Matches exceptions
- **Get**
  - Matches the reference to a class attribute
- **Set**
  - Matches the assignment to a class attribute



Designators (2)

- **This**
  - Returns the target object of a join point or limits the scope of join point
- **Target**
  - Returns the object associated with a particular join point or limits the scope of a join point by using a class type
- **Args**
  - Exposes the arguments to a join point or limits the scope of the pointcut

Designators (3)

- **Cflow**
  - Returns join points in the execution flow of another join point
- **Cflowbelow**
  - Returns join points in the execution flow of another join point but including the current join point
- **Staticinitialization**
  - Matches the execution of a class's static initialization

Designators (4)

- **Withincode**
  - Matches within a method or a constructor
- **Within**
  - Matches within a specific type (class)
- **If**
  - Allows a dynamic condition to be part of a pointcut
- **Adviceexecution**
  - Matches on advice join points
- **Preinitialization**
  - Matches pre-initialization join points

One more Exposing Context Example

```
pointcut setXY(FigureElement fe, int x, int y):
          call(void FigureElement.setXY(int, int))
                           && target(fe) && args(x, y);

...

after(FigureElement fe, int x, int y) returning: setXY(fe, x, y)
{
    System.out.println(fe +
                " moved to (" + x + ", " + y + ").");
}
```

Exposing Context, Comment

- Prefer designators over method calls
- Higher cost of reflection associated with `get*`

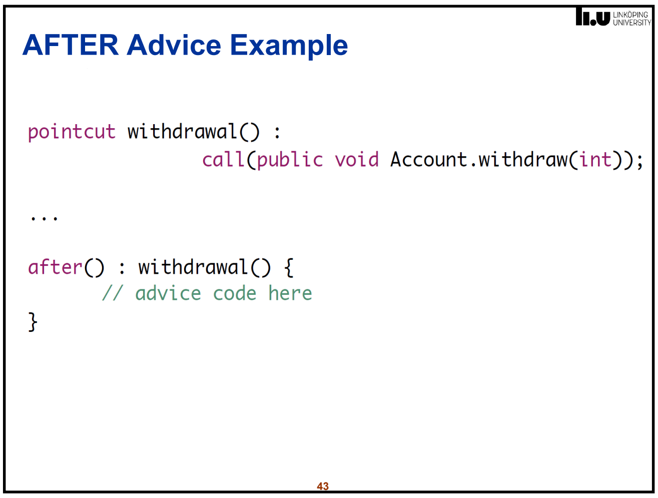
```
pointcut setXY():
    call(void FigureElement.setXY(int, int));
after() returning: setXY() {
    FigureElement fe = thisJoingPoint.getThis();
    ...
    System.out.println(fe + " moved to (" + x + ", " + y + ").");
}
```

Advice

- Before
- After
  - Unqualified
  - After returning
  - After throwing
- Around

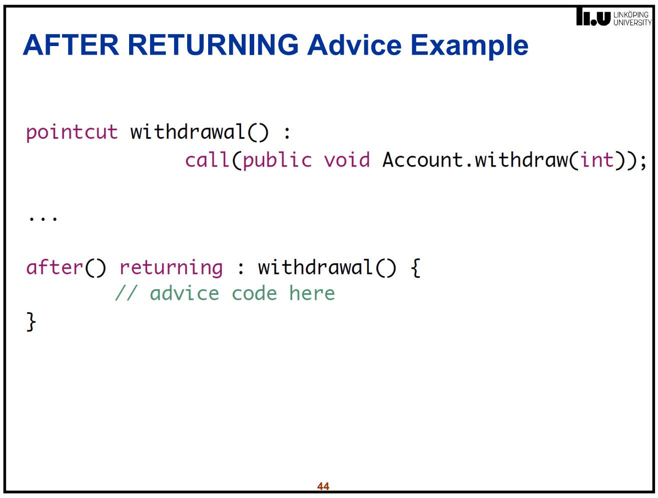
BEFORE Advice Example

```
pointcut withdrawal() :
         call(public void Account.withdraw(int));

...

before() : withdrawal() {
          // advice code here
}
```



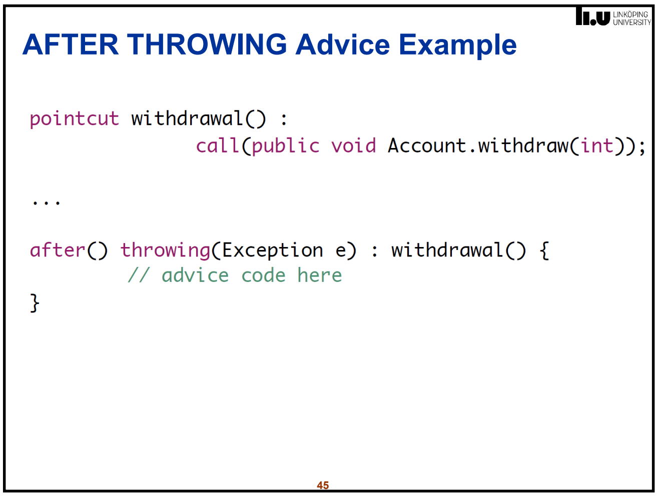
AFTER Advice Example

```
pointcut withdrawal() :
                call(public void Account.withdraw(int));

...

after() : withdrawal() {
       // advice code here
}
```



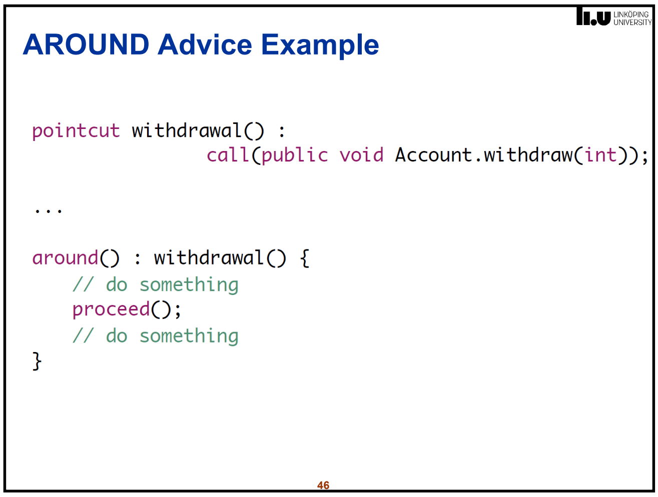
AFTER RETURNING Advice Example

```
pointcut withdrawal() :
               call(public void Account.withdraw(int));

...

after() returning : withdrawal() {
        // advice code here
}
```



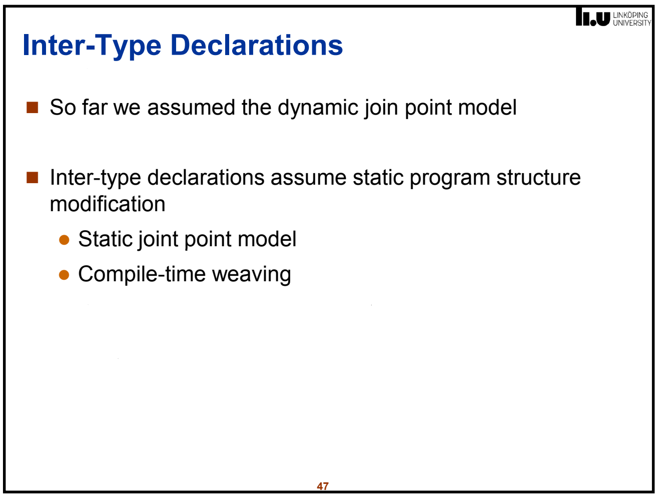
AFTER THROWING Advice Example

```
pointcut withdrawal() :
               call(public void Account.withdraw(int));

...

after() throwing(Exception e) : withdrawal() {
         // advice code here
}
```



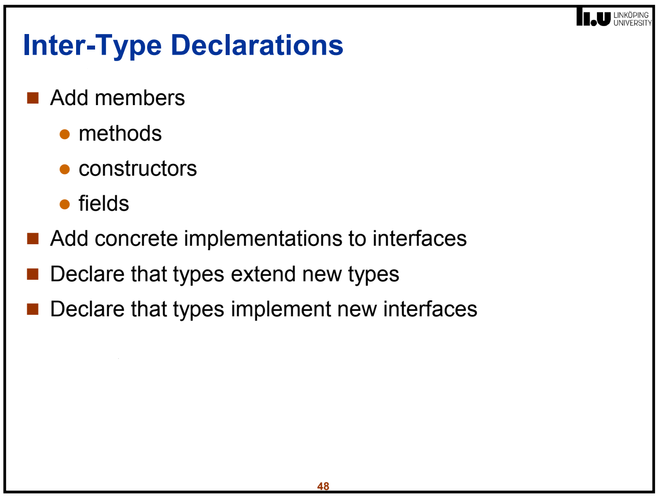
AROUND Advice Example

```
pointcut withdrawal() :
               call(public void Account.withdraw(int));

...

around() : withdrawal() {
    // do something
    proceed();
    // do something
}
```



Inter-Type Declarations

- So far we assumed the dynamic join point model
- Inter-type declarations assume static program structure modification
  - Static joint point model
  - Compile-time weaving



Inter-Type Declarations

- Add members
  - methods
  - constructors
  - fields
- Add concrete implementations to interfaces
- Declare that types extend new types
- Declare that types implement new interfaces

Other AOP Languages

- AspectWerkz
- JAC
- JBoss-AOP
- Aspect#
- LOOM.NET
- AspectR
- AspectS
- AspectC
- AspectC++
- Pythius

Possible Applications

- Resource pooling connections
- Caching
- Authentication
- Design by contract
- Wait cursor for slow operations
- Inversion of control
- Runtime evolution
- Consistent exception management
  - (Byte) code size reduction ☺

Acknowledgements

- Most slides courtesy Jens Gustafsson and Mikhail Chalabine