Aspect-Oriented Programming and AspectJ

CUGS

Mikhail CHALABINE
mikch@ida.liu.se

Outline

- Introduction to AOP
- AspectJ

Look for answers

- What are the new concepts introduced?
  - What is a crosscutting concern?
  - What is an aspect?
  - What is dynamic aspect weaving?
  - What is static aspect weaving?
  - What is a join point?
  - What is a dynamic join point model?
  - What is a static join point model?
- What are the problems, benefits?

A Big Picture

- Reification
- Reflection
  - Introspection
  - Introcession

Java

Compost, AOP, etc.

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);
    }
}
```

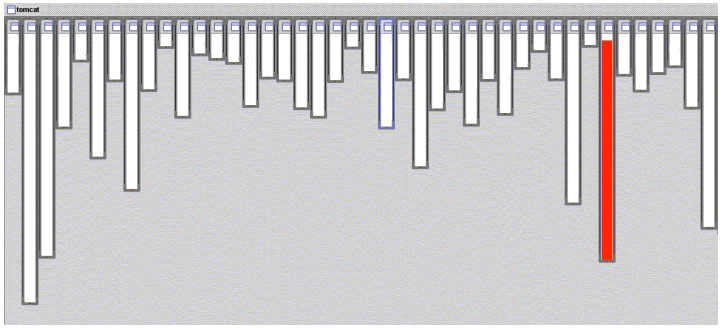
What is Crosscutting

- 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)

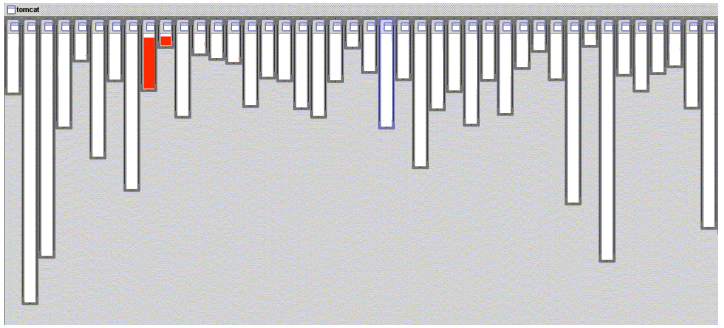
- Correctness
  - Understandability
  - Testability
- Maintenance
  - Find code
  - Change it consistently
  - No help from OO tools
- Reuse

XML parsing



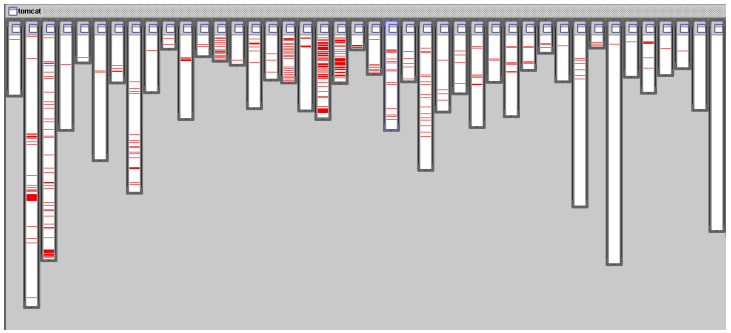
- XML parsing in org.apache.tomcat

URL pattern matching



- URL pattern matching in org.apache.tomcat

Logging

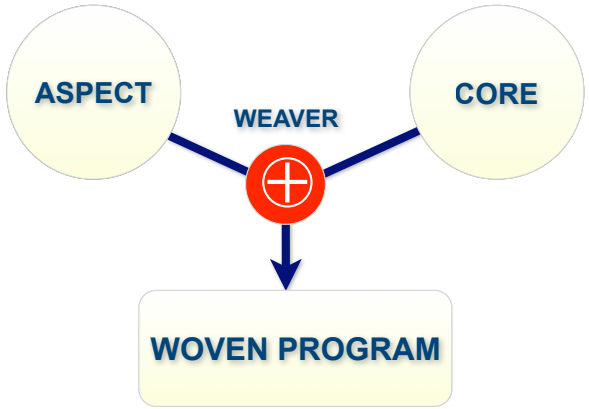


- logging in org.apache.tomcat

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

BIG PICTURE



Back to the example

```
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

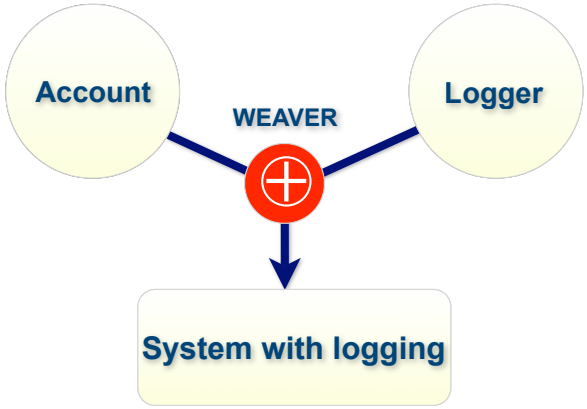
Automatically transform given (program) code

```
aspect Logging {

    Logger logger = new Logger();

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


Example big picture



Weaving Time

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

New concepts

- Weaving
- Join point
- Pointcut
- Advice
- Aspect

Join Point

- **Static join point model**
  - A location in (a component) code where a concern crosscuts
- **Dynamic join point model** (AspectJ)
  - A well-defined point in the program flow
- Examples:
  - Method / class declaration
  - A call to a method

```
public void Account.deposit(int)
```


Pointcut

- A **pointcut** picks out certain join points
  - Specifies join points
  - Exposes parameters at join points
  - Is a predicate that matches 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

Code executed at a pointcut (join point reached, joint point is 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

- 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 object associated with a particular join point or limits the scope of a join point by using a class type
Target	Returns the target object of a join point or limits the scope of join point
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 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

Inter-type Declarations Demo

CUGS
Mikhail CHALABINE
mikch@ida.liu.se

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