# introduction to AspectJ

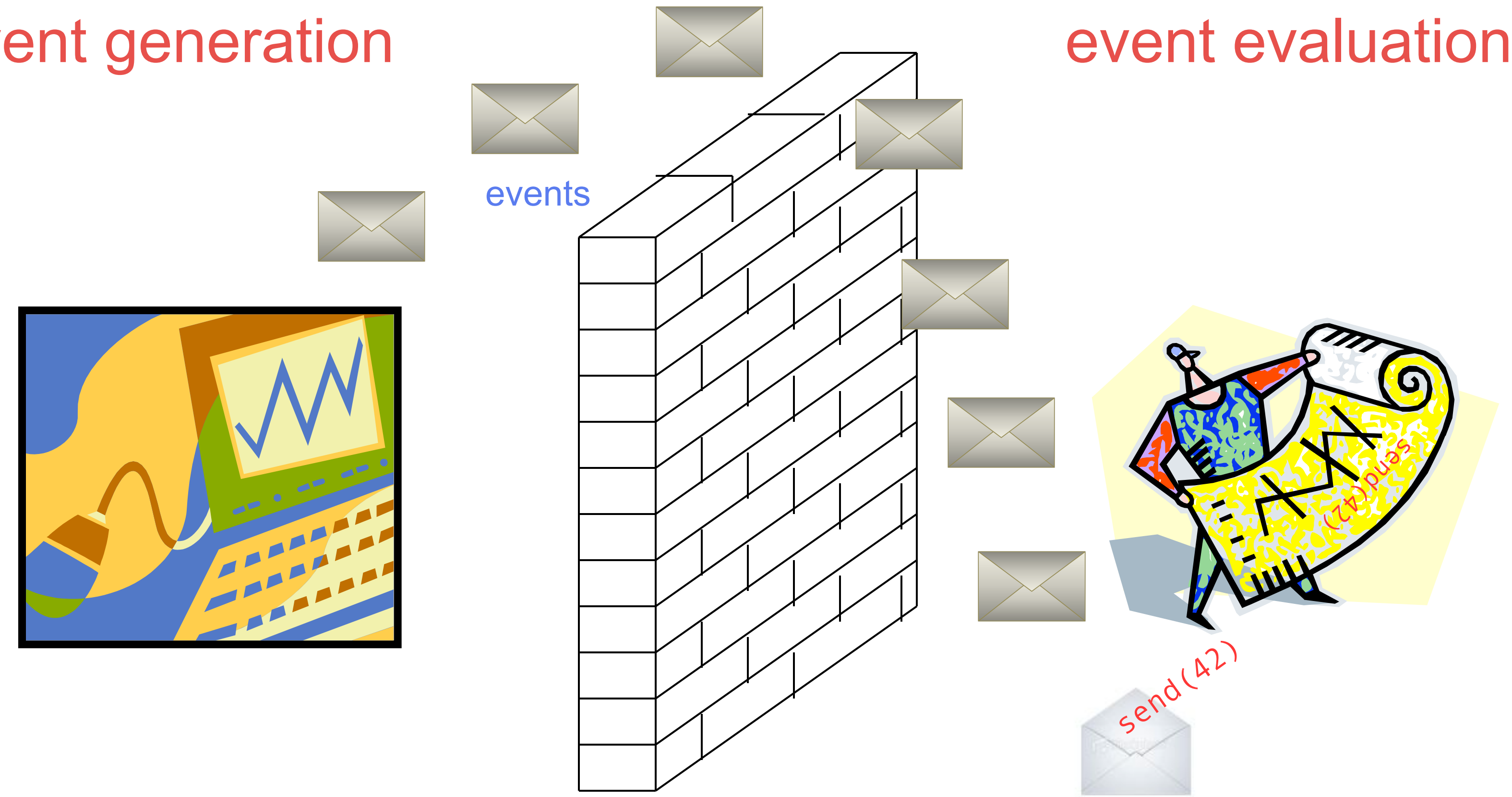
CS 119

```
here viewed as a:
- program instrumentation and
- monitoring
framework
```

# monitoring

event generation

event evaluation




instrumentation

specification

# why AspectJ?

- so, … monitoring a program's execution requires these two elements:
  - instrumentation
  - specification

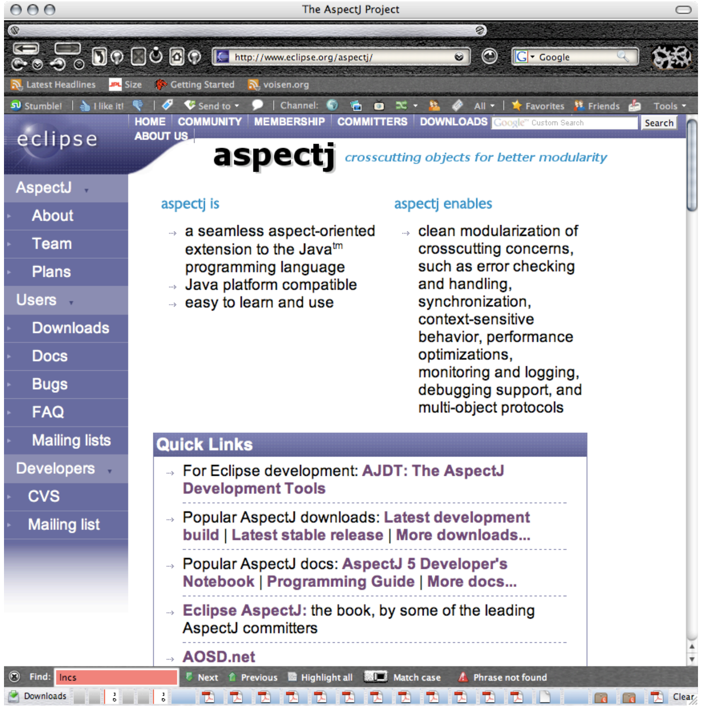
- both elements are provided by AspectJ:
  - instrumentation
    - AspectJ's extension to Java
  - specification
    - Java

# outline

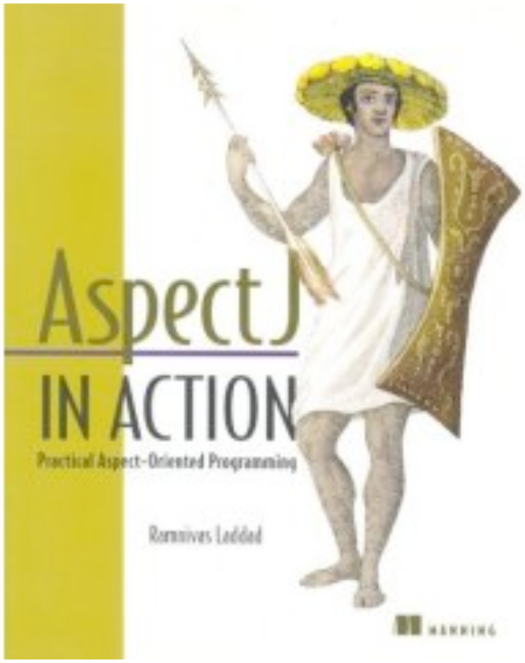
- this lesson : introducing the language
- next lesson : monitoring with AspectJ

# resources

- http://www.eclipse.org/aspectj



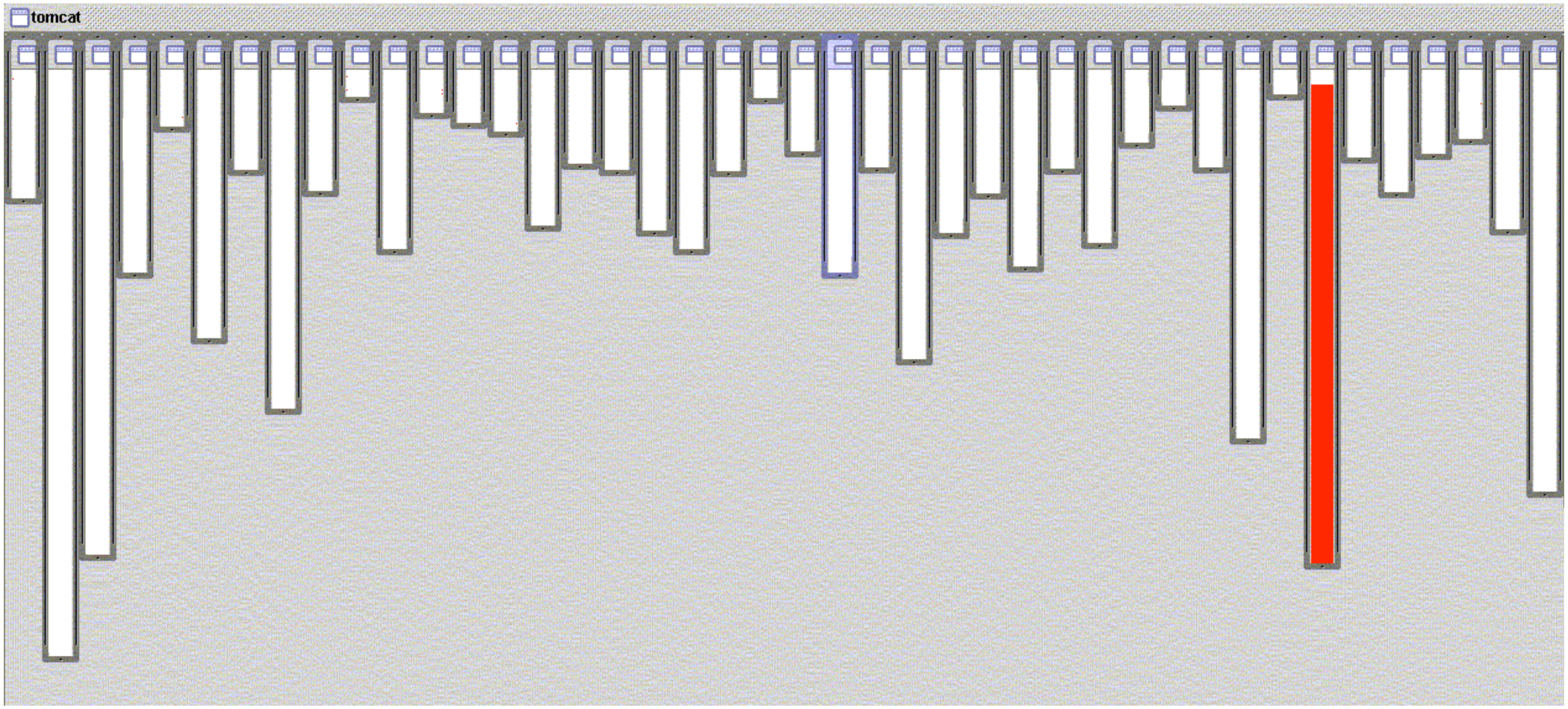

optional reading



# AspectJ

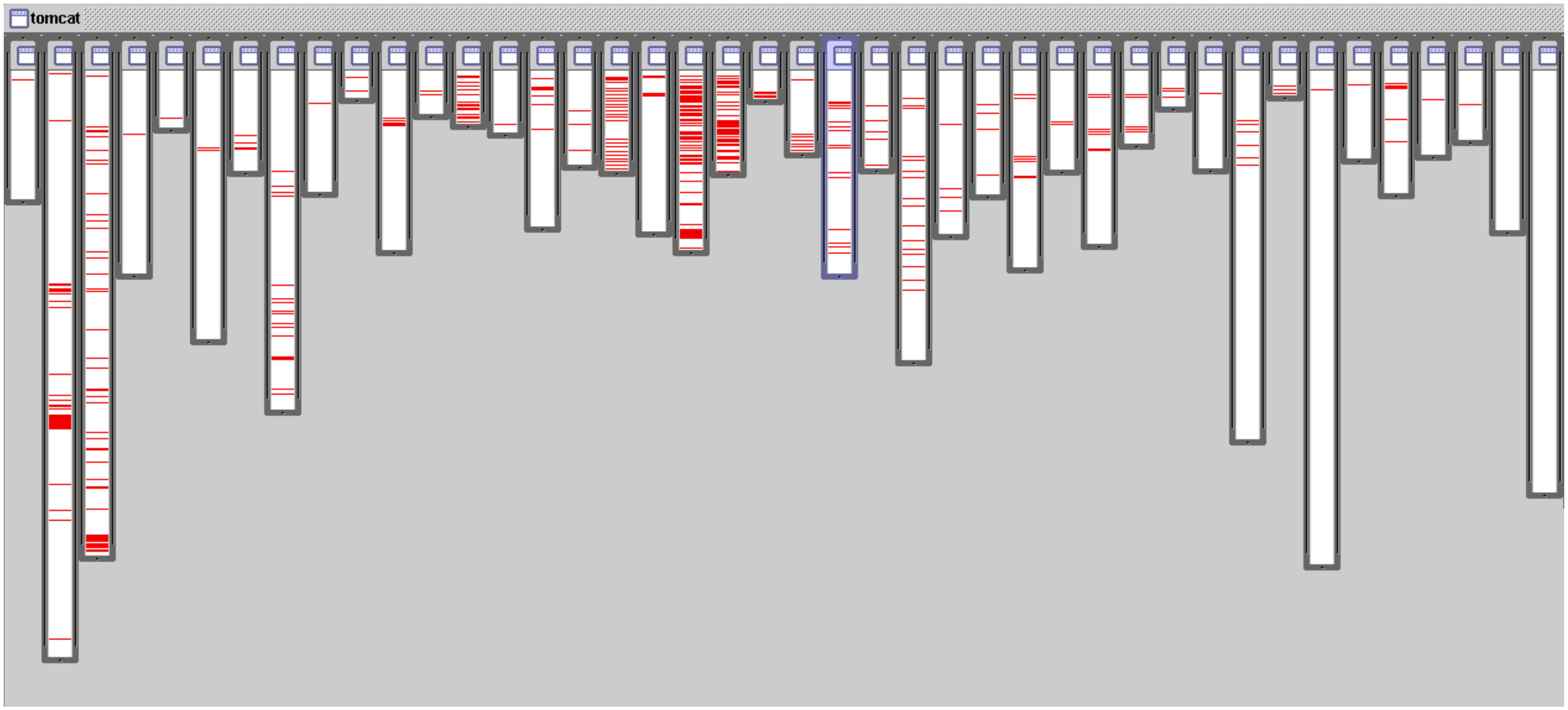
- AspectJ, launched 1998 at Xerox PARC
- an extension of Java
- a new way of modularizing programs compared to object oriented programming
- emphasis on separating out cross-cutting concerns. Logging for example is a concern. That is, code for one *aspect* of the program is collected together in one place
- we shall use it purely for monitoring, and we do not focus on the broader application of AOP as a programming paradigm
- we will, however, briefly explain the more general purpose of AOP
- the AspectJ compiler is free and open source, very mature
- AspectJ works with Eclipse, and other IDEs
- outputs .class files compatible with any JVM

# good modularity




- XML parsing in org.apache.tomcat
  - red shows relevant lines of code
  - nicely fits in one box

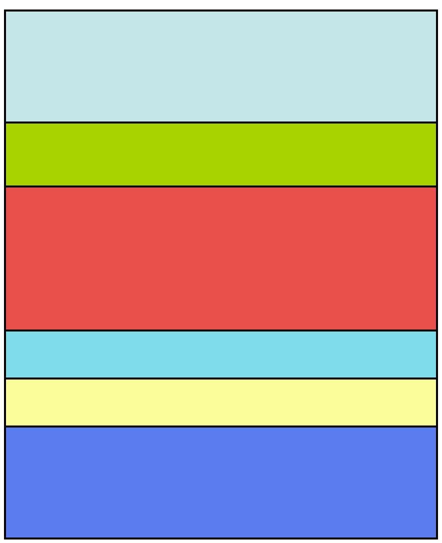
# bad modularity




- where is logging in org.apache.tomcat
  - red shows lines of code that handle logging
  - not in just one place
  - not even in a small number of places

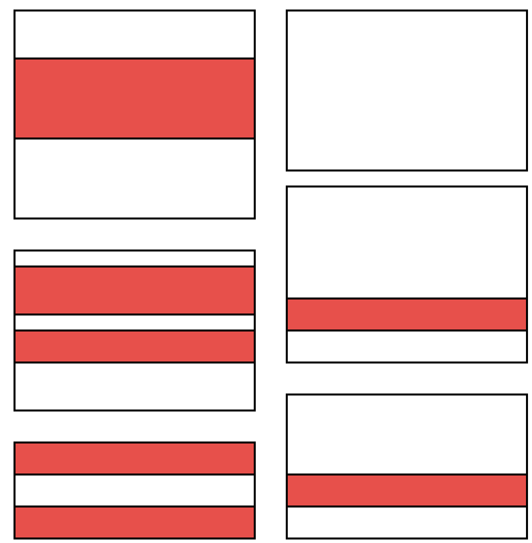
# two central problems AOP tries to solve

**code trangling:**
one module
many concerns



example:
logging

**code scattering:**
one concern
many modules

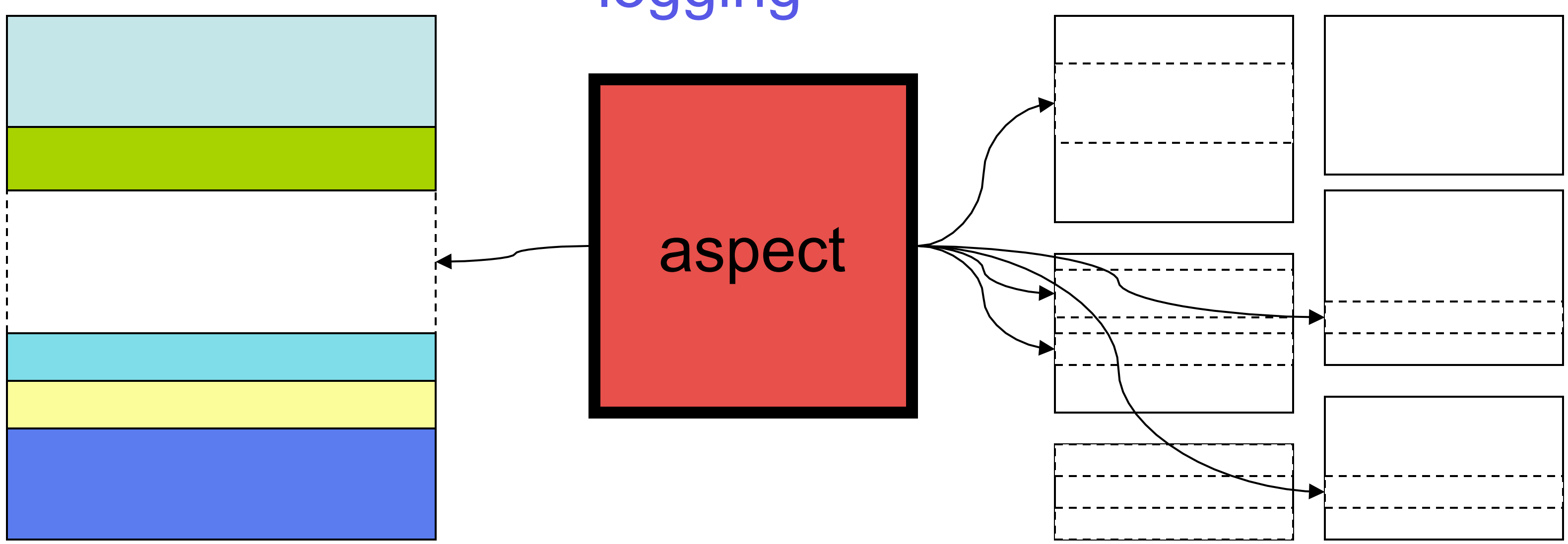


# two central problems AOP tries to solve

**code trangling:**
one module
many concerns

**code scattering:**
one concern
many modules

example:
logging



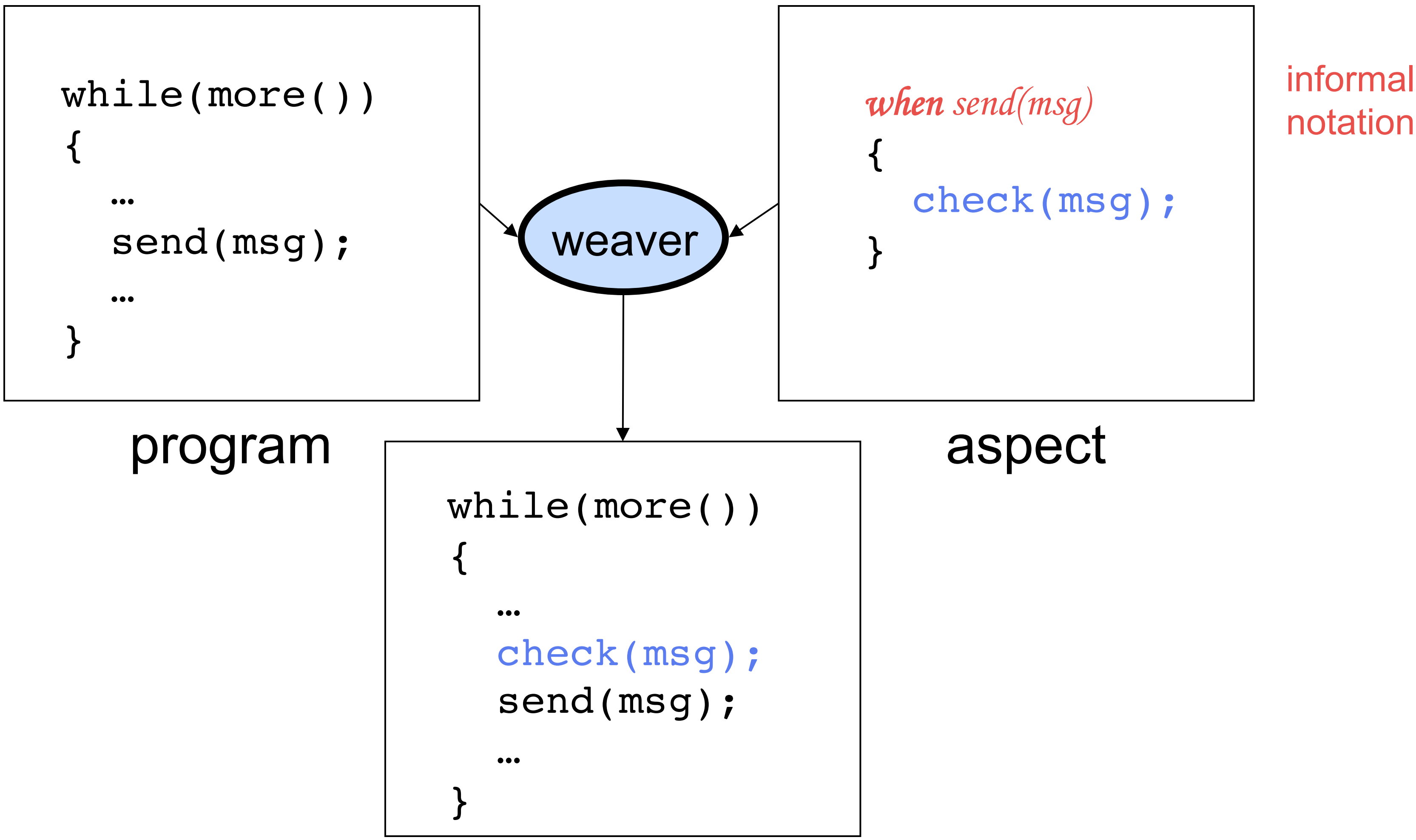
# examples of crosscutting code

- logging (tracking program behavior)
- verification (checking program behavior)
- policy enforcement (correcting behavior)
- security management (preventing attacks)
- profiling (exploring where a program spends its time)
- memory management
- visualization of program executions
- …

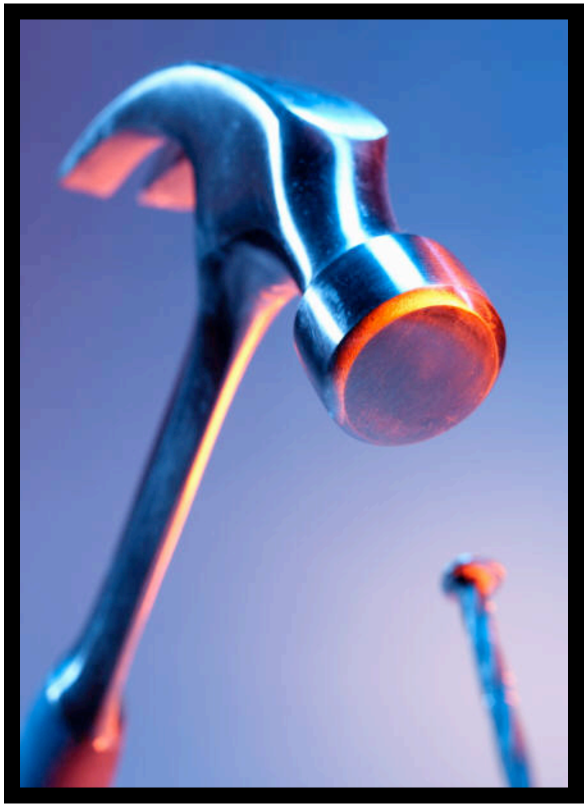
# the problem

- the flow of the core logic gets obscured, harder to follow, the core logic is tangled with the new code.
- the new code code gets scattered throughout the code base
  - lots of typing
  - big picture (in one place) is missing
  - difficult to find what is new code and how it works
  - difficult to change new code
  - increases probability of consistency errors

# very simplified view of AOP



# that’s it



except for
notation,
all the
details,
usage,
…

# basic mechanisms

- join points
    - points in a Java program
- three main additions to Java
  - pointcut
    - picks out join points and values at those points
      - primitive and user-defined pointcuts
  - advice
    - additional action to take at join points matching a pointcut
  - aspect
    - a modular unit of crosscutting behavior
      - normal Java declarations
      - pointcut definitions
      - advice

- inter-type declarations
add fields, methods to classes

# terminology as equations

**`Program:`**

Joinpoint = well-defined point in the program

**`AspectJ:`**

Pointcut = Joinpoint-set

Advice = Kind × Pointcut × Code

  **`where`** Kind = {before, after, around}

Aspect = Advice-list

# example

```
class Power {
  int balance;

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

  boolean withdraw(int amount) {
    if (balance - amount > 0) {
      balance = balance - amount;
      return true;
    } else return false;
  }
}
```

# logging class

```
class Logger {
  private PrintStream stream;

  Logger() {
    … create stream
  }

  void log(String message) {
    stream.println(message);
  }
}
```

# logging the traditional way

logging

```
class Power {
  int balance;
  Logger logger = new Logger();

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

  boolean withdraw(int amount) {
    logger.log("withdraw amount: " + amount);
    if (balance - amount >= 0) {
      balance = balance – amount;
      return true;
    } else return false;
  }
}
```

# logging the AOP way

```
aspect Logging {
  Logger logger = new Logger();

  when deposit(amount) {
    logger.log("deposit amount : " + amount);
  }

  when withdraw(amount) {
    logger.log("withdraw amount : ” + amount);
  }
}
```

that’s not quite how it is written though

# logging the AOP way

advice kind

advice parameter

```
aspect Logging {
  Logger logger = new Logger();

  before(int amount) :
    call(void Power.deposit(int)) && args(amount) {
      logger.log("deposit amount : ” + amount);
  }

  before(int amount) :
    call(boolean Power.withdraw(int)) && args(amount) {
      logger.log("withdraw amount : ” + amount);
  }
}
```

call pointcut

args pointcut

advice body

the AspectJ way

# primitive pointcuts

a pointcut is a predicate on join points that:

- can match or not match any given join point and
- optionally, can pull out some of the values at that join point

**Example:**

```
call(void Power.deposit(int))
```

matches any join point that is a:
call of a method with this signature

# explaining parameters…

**of advice**

- variable is bound by advice declaration
  - pointcut supplies value for variable
  - value is available in advice body

typed variable in place of type name

advice parameter

```
before(int amount) :
    call(void Power.deposit(int)) && args(amount) {
      logger.log("deposit amount : ” + amount);
  }
```

# parameter data flow

- value is ‘pulled’
  - right to left across ‘:’ from pointcuts to advice
  - and then to advice body

```
before(int amount) :
    call(void Power.deposit(int)) && args(amount) {
      logger.log("deposit amount : ” + amount);
  }
```

# pointcut naming and patterns

named pointcut

```
aspect Balance {

  pointcut powerChange(Power power) :
    (call(* deposit(..)) || call(* withdraw(..)))
    && target(power);

  after(Power power) : powerChange(power) {
    System.out.println("balance = " + power.balance);
  }

}
```

pointcut patterns

"after" advice

target pointcut

# privileged aspects

can access private fields and methods

```
privileged aspect Balance {

  pointcut powerChange(Power power) :
    (call(* deposit(..)) || call(* withdraw(..)))
    && target(power);

  after(Power power) : powerChange(power) {
    System.out.println("balance = " + power.balance);
  }
}
```

suppose power.balance is a private variable. Then the aspect must be privileged.

# args, this and target pointcuts

```
before(Rover rover, Power power, int amount) :
    call(void Power.deposit(int))
    && args(amount) && this(rover) && target(power) {…}
```

Object R

```
class Rover {
  …
  void execute(…) {
    …
    power.deposit(500);
    …
  }
  …
}
```

Object P

```
class Power {
  …

  void deposit(int amount){
    …
  }
  …
}
```

# target pointcut

`target( TypeName | VariableName )`

does two things:

- predicate on join points - any join point at which target object is an instance of *`TypeName`* or of the same type as *`VariableName`*.
  "any join point " can be:
  - method call join points
  - field get & set join points
  - …
- exposes target if argument is a variable name

`target(Power) :`

- matches when target object is of type `Power`

`target(power) :`

- ditto, since power is of type `Power`
- in addition it binds the target object to `power`

`Power` is a type

`power` is a variable

# parameter data flow again

- value is ‘pulled’
  - right to left across ‘:’ from pointcuts to user-defined pointcuts
  - from pointcuts to advice
  - and then to advice body

```
pointcut powerChange(Power power) :
    (call(* deposit(..)) || call(* withdraw(..)))
    && target(power);

  after(Power power) : powerChange(power) {
    System.out.println("balance = " + power.balance);
  }
```

# contract checking

- pre-conditions
  - check that parameter is valid
- post-conditions
  - check that result is correct
- policy enforcement
  - check, and correct if check fails
- invariants
  - check that some condition on the state "always" holds

# pre-condition

fictive notation

```
boolean withdraw(int amount) {
  pre balance - amount > 50;
  …
  // implementation:
  …
}
```

# pre-condition

```
aspect WithDrawPreCond {
  final int MIN_BALANCE  = 50;

  before(Power power, int amount) :
    call(boolean Power.withdraw(int)) &&
    target(power) && args(amount)
  {
    assert power.balance - amount > MIN_BALANCE :
           "withdrawal too big: " + amount;
  }
}
```

# post condition

fictive notation

```
boolean withdraw(int amount) {
  pre balance - amount > 50;
  post result == (old(balance) - amount) >= 0
       &&
       balance ==
         (result ? old(balance) - amount
                 : old(balance))
  …
  // implementation:
  …
}
```

# post-condition

```
public aspect WithDrawPostCond {
  int old_balance;

  before(Power power)  :
      call(boolean Power.withdraw(int)) && target(power)
  {
    old_balance = power.balance;
  }

  after(Power power, int amount) returning(boolean changed) :
      call(boolean Power.withdraw(int)) &&
      target(power) && args(amount)
  {
    assert changed == (old_balance - amount) >= 0 &&
           power.balance ==
             (changed ? old_balance-amount : old_balance);
  }
}
```

# post-condition

around advice

```
aspect WithDrawPostCondAround {
  int old_balance;

  boolean around(Power power, int amount) :
      call(boolean Power.withdraw(int)) &&
      target(power) && args(amount)
  {
    old_balance = power.balance;
    boolean changed = proceed(power,amount);
    assert changed == (old_balance - amount) >= 0;
    assert power.balance ==
            (changed ? old_balance-amount : old_balance);
    return changed;
  }
}
```

proceed statement

# the proceed “method”

**for each around advice with the signature:**

***T* around(*T1* arg1, *T2* arg2, …)**

**there is a special method with the signature:**

***T* proceed(*T1*, *T2*, …)**

**calling this method means:**

**“run what would have run if this around advice had not been defined”**

# policy enforcement

fictive notation

```
boolean withdraw(int amount) {
  pre balance - amount > 50 {
      System.out.println("withdrawal rejected");
      return false;
  }
  …
  // implementation:
  …
}
```

# policy enforcement

around advice

```
aspect WithdrawCorrect {
  final int MIN_BALANCE  = 50;

  boolean around(Power power, int amount) :
    call(boolean Power.withdraw(int)) &&
    target(power) && args(amount)
  {
    if(power.balance - amount >= MIN_BALANCE)
      return proceed(power,amount);
    else {
      System.out.println("withdrawal rejected");
      return false;
    }
  }
}
```

proceed statement

# invariant checking

fictive notation

```
class Power {
  int balance;

  invariant balance >= 500;

  void deposit(int amount) {
    …
  }

  boolean withdraw(int amount) {
    …
  }
}
```

# invariant checking

```
aspect Invariant {
  boolean invariant(int balance) {
    return balance >= 500;
  }

  pointcut write(int balance) :
    set(int Power.balance) && args(balance);

  before(int balance) : write(balance) { //every update
    if (!invariant(balance))
      System.out.println("invariant violated");
    }
  }
}
```

```
after(Power power) :
  execution(* Power.*(..)) && target(power)
{
  if (!invariant(power.balance))
    System.out.println("invariant violated");
} // at method bounderies
```

# examples of patterns

**Type names:**

```
Command
*Command
java.*.Date
Java..*
Javax..*Model+
```

**Combined Types:**

```
!Vector
Vector || HashTable
java.util.RandomAccess+
    && java.util.List+
```

**Method Signatures:**

```
public void Power.set*(*)
boolean Power.withdraw(int)
bo* Po*.wi*w(i*)
!static * *.*(..)
rover..command.Command+.check(int,..)
```

# reflexive information available at **all** joinpoints

- thisJoinPoint
  - getArgs() : Object[]
  - getTarget() : Object
  - getThis() : Object
  - getStaticPart() : JoinPointStaticPart
- thisJoinPointStaticPart
  - getKind() : String
  - getSignature() : Signature
  - getSourceLocation() : SourceLocation

# logging exceptions

## using thisJoinPoint

```
aspect LogExceptions {
  Logger logger = new Logger();

  after() throwing (Error e): call(* *(..)) {
    logger.log("exception thrown " +
         thisJoinPoint + ":" + e);
    }
}
```

logged information in the case of an assertion error in call of withdraw:

…

exception thrown call(boolean core.Power.withdraw(int)):java.lang.AssertionError

… thisJoinPoint

# checking object creation

```
class CmdFactory {
  static Command mkTurnCommand(int budget, int degrees) {
    return new TurnCommand(budget, degrees);
  }
  …
}
```

*want to ensure that any creation of commands goes through the factory methods mk…*

```
aspect FactoryCheck {
  pointcut illegalNewCommand():
    call(Command+.new(..)) &&
    !withincode(* CmdFactory.mk*(..));

  before(): illegalNewCommand() {
    throw new Error("Use factory method instead.");
  }
}
```

# checking object creation

```
class CmdFactory {
  static Command mkTurnCommand(int budget, int degrees) {
    return new TurnCommand(budget, degrees);
  }
  …
}
```

*want to ensure that any creation of commands goes through the factory methods mk…*

```
aspect FactoryCheckStatic {
  pointcut illegalNewCommand():
    call(Command+.new(..)) &&
    !withincode(* CmdFactory.mk*(..));

  declare error : illegalNewCommand() :
    "Use factory method instead.";
}
```

*must be a "static pointcut"*

static declare

causes check to be performed at compile time

# inter-type declarations

- inside an aspect:
  adding declarations to a class C

```
aspect A {
  int     counter = 0;
  void    count() {counter++;}
  …
}
```

```
class C {
   …
   …
}
```

# inter-type declarations

- one must indicate what class:

```
aspect A {
   int  C.counter = 0;
   void C.count() {counter++;}
   …
}
```

```
class C {
   …
   …
}
```

# inserting fields and methods

verify that a command is executed no more than once!

requires a counter per Command object.

field and method inserted in Command object but accessible only to aspect.

```
aspect ExecuteOnlyOnce {
  private int Command.counter = 0;
  private void Command.count() {counter++;}

  before(Command cmd) :
      call(void Command+.execute()) && target(cmd)
  {
    assert cmd.counter == 0 : "command executed again";
    cmd.count();
  }
}
```

# same property

verify that a command is executed no more than once!

**eliminating:** **`private`**, +, count method, assert message

```
aspect ExecuteOnlyOnce {
  int Command.counter = 0;

  before(Command cmd) :
      call(void Command.execute()) && target(cmd)
  {
    assert cmd.counter++ == 0;
  }
}
```

it does not get much shorter than this

# aspect association

- instances of aspects:
  - one per virtual machine (the default)
  - one per object (`perthis`, `pertarget`)
  - one per control-flow (`percflow`, `percflowbelow`)

```
aspect <AspectName> <association>(<pointcut>){
  pointcut … : …;
  …
}                          pointcut defined here


<association> ::=
  perthis | pertarget | percflow | percflowbelow
```

# aspect association

- perthis(pc):
  - when a pointcut satisfying pc is reached, and this(x) holds, and x does not already have an associated aspect instance of this type, a new instance is created for x (to track x)
- pertarget(pc):
  - similar, except we use target(x)
- percflow(pc):
  - when a pointcut satisfying pc is reached, a new instance is created, which lasts as long as the control flow under this pc does

# same property

verify that a command is executed no more than once!

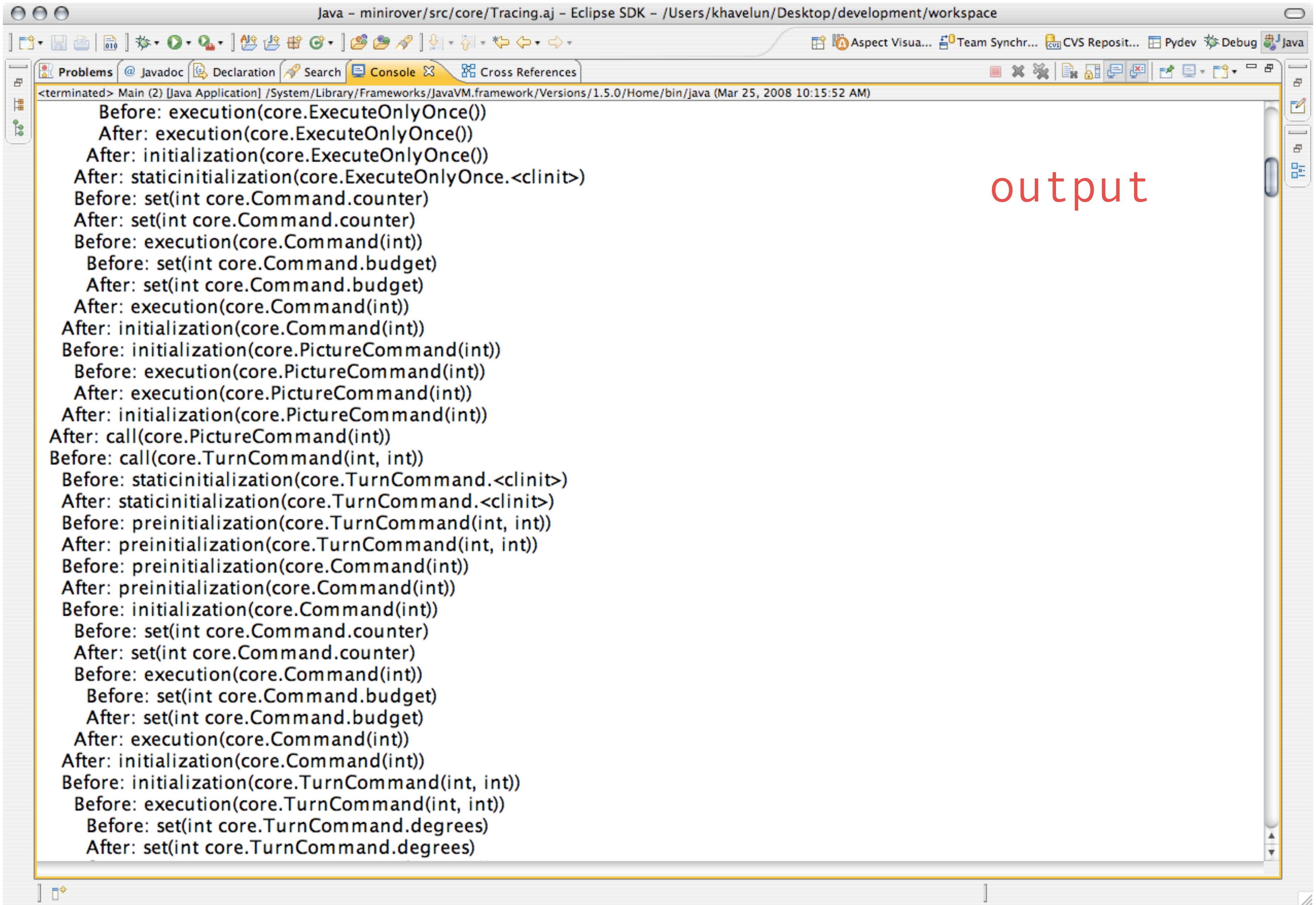
**this time using object association : one aspect per Command target of the execute command.**

```
aspect ExecuteOnlyOnce2 pertarget(execute()){
  int counter = 0;

  pointcut execute() : call(void Command.execute());

  before() : execute() {
    assert counter++ == 0;
  }
}
```

# Tracing aspect

**all pointcuts**
except within
Tracing aspect

```
aspect Tracing {
    private int callDepth = -1;

    pointcut tracePoint() : !within(Tracing);

    before() : tracePoint() {
      callDepth++; print("Before", thisJoinPoint);
    }

    after() : tracePoint() {
      print("After", thisJoinPoint); callDepth--;
    }

    private void print(String prefix, Object message) {
      for(int i = 0, spaces = callDepth * 2; i < spaces; i++)
        System.out.print(" ");
      System.out.println(prefix + ": " + message);
    }
}
```



Java – minirover/src/core/Tracing.aj – Eclipse SDK – /Users/khavelun/Desktop/development/workspace
Aspect Visua...
Team Synchr...
CVS Reposit...
Pydev
Debug
Java
Problems
Javadoc
Declaration
Search
Console
Cross References
<terminated> Main (2) [Java Application] /System/Library/Frameworks/JavaVM.framework/Versions/1.5.0/Home/bin/java (Mar 25, 2008 10:15:52 AM)
Before: execution(core.ExecuteOnlyOnce())
After: execution(core.ExecuteOnlyOnce())
After: initialization(core.ExecuteOnlyOnce())
After: staticinitialization(core.ExecuteOnlyOnce.<clinit>)
Before: set(int core.Command.counter)
After: set(int core.Command.counter)
Before: execution(core.Command(int))
Before: set(int core.Command.budget)
After: set(int core.Command.budget)
After: execution(core.Command(int))
After: initialization(core.Command(int))
Before: initialization(core.PictureCommand(int))
Before: execution(core.PictureCommand(int))
After: execution(core.PictureCommand(int))
After: initialization(core.PictureCommand(int))
After: call(core.PictureCommand(int))
Before: call(core.TurnCommand(int, int))
Before: staticinitialization(core.TurnCommand.<clinit>)
After: staticinitialization(core.TurnCommand.<clinit>)
Before: preinitialization(core.TurnCommand(int, int))
After: preinitialization(core.TurnCommand(int, int))
Before: preinitialization(core.Command(int))
After: preinitialization(core.Command(int))
Before: initialization(core.Command(int))
Before: set(int core.Command.counter)
After: set(int core.Command.counter)
Before: execution(core.Command(int))
Before: set(int core.Command.budget)
After: set(int core.Command.budget)
After: execution(core.Command(int))
After: initialization(core.Command(int))
Before: initialization(core.TurnCommand(int, int))
Before: execution(core.TurnCommand(int, int))
Before: set(int core.TurnCommand.degrees)
After: set(int core.TurnCommand.degrees)
output

# abstract pointcuts

- what if we want to trace specific events? do we edit the Tracing aspect? no, we can define the pointcut as abstract
- a pointcut can be defined as abstract without a “right-hand” side:

```
abstract pointcut something(T x);
```

- advices can be defined on the abstract pointcut
- specialization of aspect can later define the pointcut
- this resembles parameterization with poincuts
- similar to the way methods can be defined abstract and later defined in sub-classes

# abstract Tracing aspect

```
abstract aspect AbstractTracing {
    private int callDepth = -1;

    abstract pointcut tracePoint();

    before() : tracePoint() {
      callDepth++; print("Before", thisJoinPoint);
    }

    after() : tracePoint() {
      print("After", thisJoinPoint); callDepth--;
    }

    private void print(String prefix, Object message) {
      for(int i = 0, spaces = callDepth * 2; i < spaces; i++)
        System.out.print(" ");
      System.out.println(prefix + ": " + message);
    }
}
```

aspect and pointcut are now abstract, the rest is the same!

# concrete tracing aspect

we just define
the pointcut

```
aspect ConcreteTracing extends AbstractTracing {
  pointcut tracePoint() :
    call(* Power.*(..)) || withincode(* Command+.*(..));
}
```

It's a bit like function application:

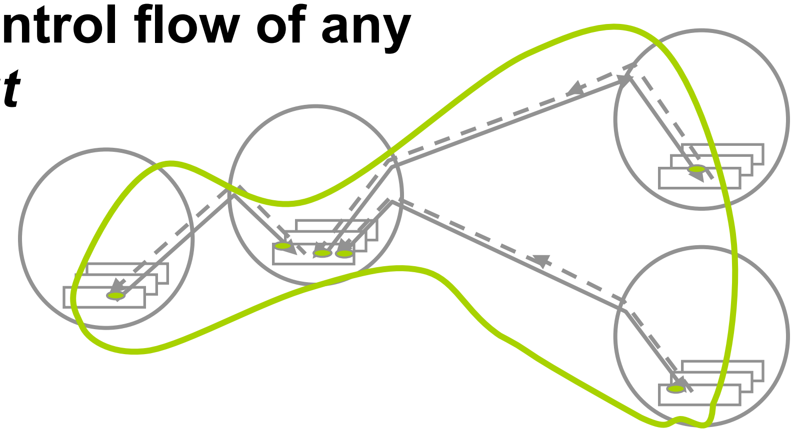
```
aspect ConcreteTracing =
   AbstractTracing(
       call(* Power.*(..)) || withincode(* Command+.*(..))
   )
```

not AspectJ syntax

# control flow pointcuts

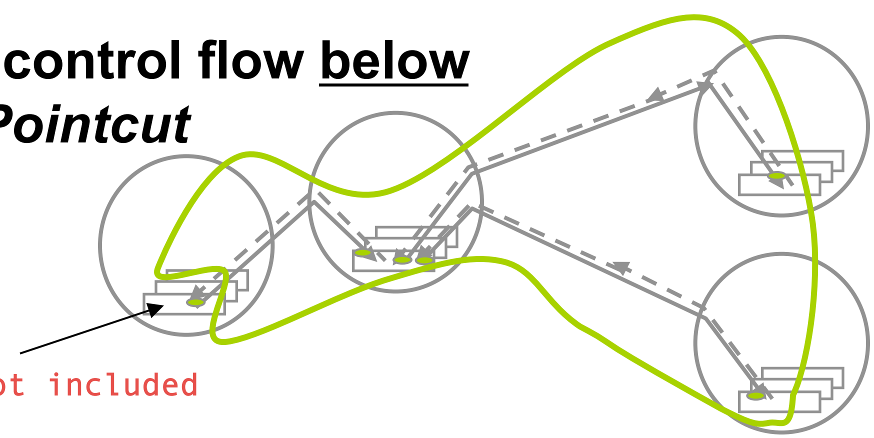
`cflow(`***`Pointcut`***`)`

**all join points in the dynamic control flow of any join point picked out by *Pointcut***

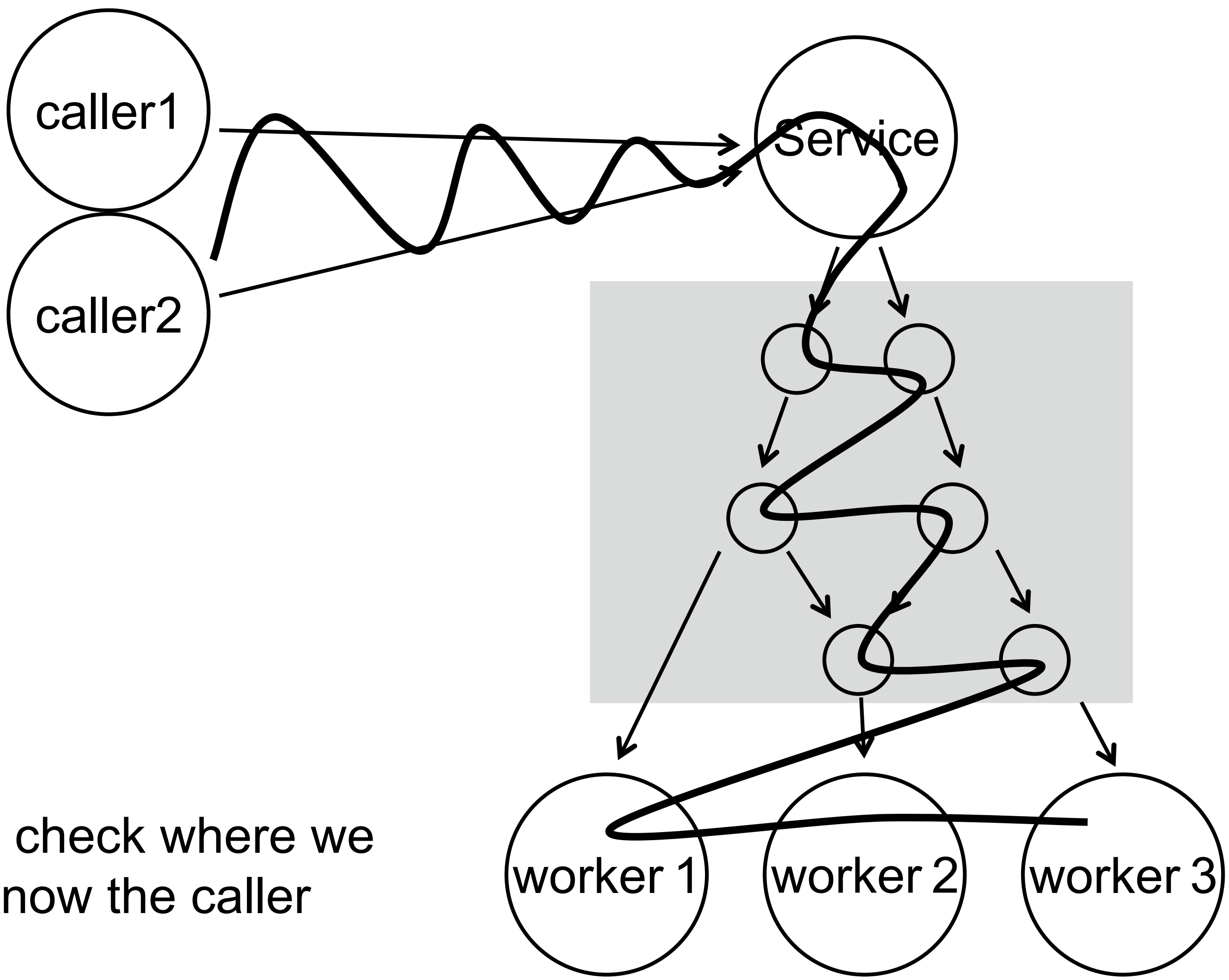


`cflowbelow(`***`Pointcut`***`)`

**all join points in the dynamic control flow <u>below</u> any join point picked out by *Pointcut***

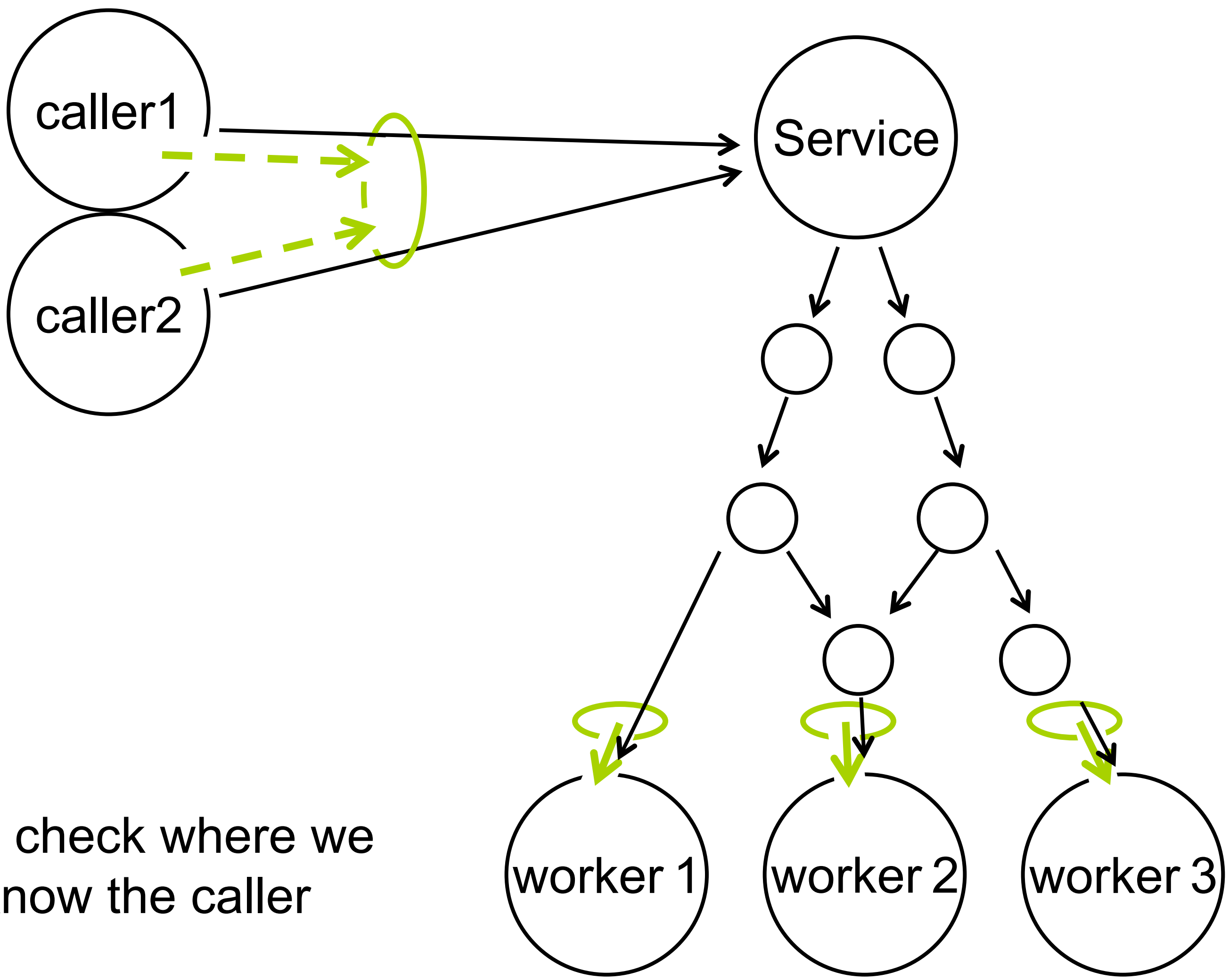


# example




introduce check where we need to know the caller

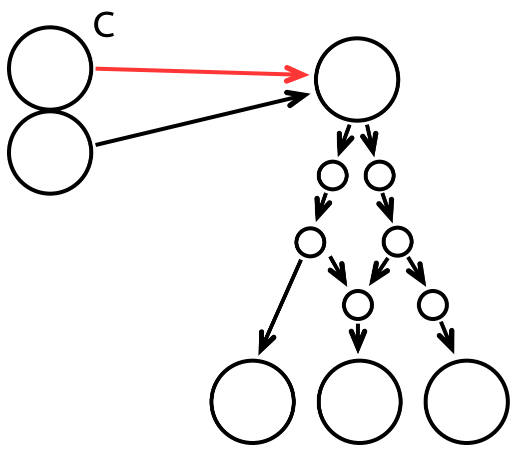
# example




introduce check where we need to know the caller

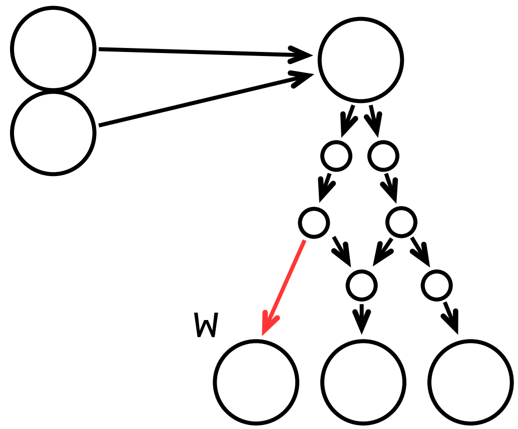
# context-passing aspects

```
pointcut invocation(Caller c):
  this(c) && call(void Service.doService(String));
```



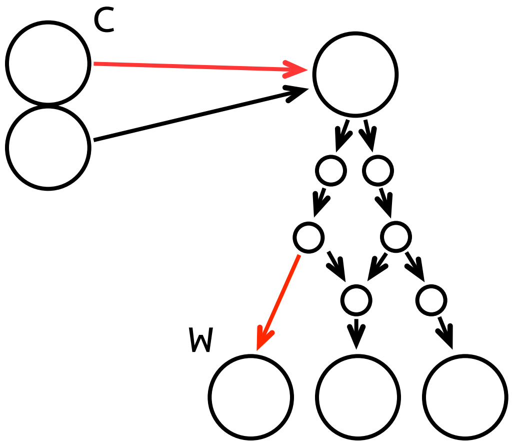
# context-passing aspects

```
pointcut invocation(Caller c):
  this(c) && call(void Service.doService(String));

pointcut workPoint(Worker w):
  target(w) && call(void Worker.doTask(Task));
```



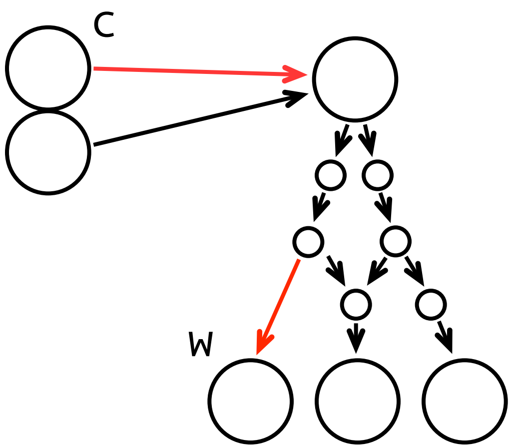
# context-passing aspects

```
pointcut invocation(Caller c):
  this(c) && call(void Service.doService(String));

pointcut workPoint(Worker w):
  target(w) && call(void Worker.doTask(Task));

pointcut calledWork(Caller c, Worker w):
  cflow(invocation(c)) && workPoint(w);
```



# context-passing aspects

```
abstract aspect CapabilityChecking {

  pointcut invocation(Caller c):
    this(c) && call(void Service.doService(String));

  pointcut workPoint(Worker w):
    target(w) && call(void Worker.doTask(Task));

  pointcut calledWork(Caller c, Worker w):
    cflow(invocation(c)) && workPoint(w);



  before (Caller c, Worker w): calledWork(c, w) {
    verifyCalledWork(c,w);
  }
}
```



# advice precedence

what happens if two pieces of advice apply to the same join point?

```
aspect Policy {
  pointcut scope() : !cflow(adviceexecution());
  …
  before(): call(* *.*(..)) && scope() {
    if (!isAllowed(thisJoinPoint))
      error("invalid ");
  }

  declare precedence: Policy, *;
}
```

order undefined unless:

- in same aspect,
- in sub-aspect, or
- using declare precedence...

```
aspect LogIt {
  pointcut scope() :!cflow(adviceexecution());

  before(): call(* *.*(..)) && scope() {
    System.out.println("Entering " + thisJoinPoint);
  }
}
```

# advice precedence rules

```
assume that aspect L has
lower priority than aspect H (L < H)
and consider a particular joinpoint
```

- H executes its before advice before

  L's before advice

- H executes its after advice after

  L's after advice

- H's around advice encloses

  L's around advice

# beginner mistake

## not controlling circularity of advice

pointcuts sometimes match more than expected

```
aspect A {
  before(): call(String toString()) {
    System.err.println(thisJoinPoint);
  }
}
```

use within, cflow, adviceexecution() to control

```
aspect A {
  before(): call(String toString()) && !within(A) {
    System.err.println(thisJoinPoint);
  }
}
```

# summary

## pointcuts

**primitive**

call
execution
handler
get set
initialization
this target args
within withincode
cflow cflowbelow

**user-defined**

pointcut

## advice

before
after
around

## inter-type decls

Type.field
Type.method()

## declare

error
parents
precedence

## reflection

thisJoinPoint
thisJoinPointStaticPart

## pointcut overview (see aspect next two slides)

```
class Rover {
  Power power = new Power();
  boolean error = false;

  void execute(Command[] plan) {
    power.deposit(500);
    for(Command cmd : plan)  {
      if(power.withdraw(cmd.getBudget()))
        try {cmd.execute();}
        catch(ExecException e) {
          e.printStackTrace();
        }
      else {
        error = true;
        System.out.println("terminating");
        break;
      }
    }
  }
}
```

within(Rover)

call(Power.new())

withincode(* Rover.execute(..))

call(void deposit(int))

get(Power Rover.power)

call(boolean Power.withdraw(int))

cflow(call(* Power.withdraw(..)))

handler(ExecException)

set(boolean Rover.error)

execution(void Rover.execute(Command[]))

# an aspect that gets “around”

```
public aspect Monitor {
  static boolean tracingOn = true;

  pointcut scope() : if(tracingOn) && !cflow(adviceexecution());

  pointcut handlethrow(ExecException e) : handler(ExecException) && args(e);
  before(ExecException e) : handlethrow(e) && scope() {
    print("*** bad luck: " + e);
  }

  after() returning (Power power) : call(Power.new()) && scope() {
    print("power object created " + power);
  }

  before(int amount) : call(void deposit(int)) && args(amount) && scope() {
    print("depositing: " + amount);
  }

  after(int amount) returning (boolean success):
    call(boolean Power.withdraw(int)) && args(amount) && scope() {
    print("withdrawing " + amount + ":" + success);
  }
```

```
void around(Command[] plan) :
   execution(void Rover.execute(Command[])) && args(plan) && scope() {
   if (!validatePlan(plan))
     proceed(correctPlan(plan));
   else
     proceed(plan);
 }

after() returning(Power power):
   get(Power Rover.power) && within(Rover) && scope() {
   print("reading power " + power);
 }

 before(boolean value) :
   set(boolean Rover.error) && args(value) && if(value)
   && withincode(* Rover.execute(..)) && scope() {
   print("error flag being set to " + value);
 }

 before() : call(* *.*(..)) && cflow(call(* Power.withdraw(..))) && scope() {
   print("function call " + thisJoinPointStaticPart.getSignature());
 }

 before(Rover rover, Command command) :
   call(* Command.execute()) &&
   this(rover) && target(command) && scope() {
   print("Rover " + rover + " executing command " + command);
 }
}
```

… continued

# abstract syntax for AspectJ

- contains most elements of language
- look at quick guide
- look at examples

```
AspectDecl ::=
  [ privileged ] [ Modifiers ] aspect Id
      [ extends Type ] [ implements TypeList ]
      [ PerClause ]
  { BodyDecl* }

PerClause ::=
    pertarget ( Pointcut ) | perthis ( Pointcut )
  | percflow ( Pointcut )  | percflowbelow ( Pointcut ) | issingleton ()

BodyDecl ::=
   JavaBodyDecl
 | IntertypeDecl
 | PointcutDecl
 | AdviceDecl
```

AspectJ syntax
intertype declarations

InterTypeDecl ::=
  [ Modifiers ] Type Type . Id ( Formals ) [ throws TypeList ] { Body }
| [ Modifiers ] Type . new ( Formals ) [ throws TypeList ] { Body }
| [ Modifiers ] Type Type . Id [ = Expression ] ;
| declare warning : Pointcut : String ;
| declare error : Pointcut : String ;
| declare precedence : TypePatList ;

## AspectJ syntax
## pointcut and advice declarations

PointcutDecl ::=
abstract [Modifiers] pointcut Id ( Formals ) ;
| [Modifiers] pointcut Id ( Formals ) : Pointcut ;

AdviceDecl ::=
AdviceSpec [ throws TypeList ] : Pointcut { Body }

AdviceSpec ::=
before ( Formals )
after ( Formals )
after ( Formals ) returning [ ( Formal ) ]
after ( Formals ) throwing [ ( Formal ) ]
Type around ( Formals )

## AspectJ syntax
## pointcuts

Pointcut ::=
  call(MethodPat) | call(ConstructorPat)
  | execution(MethodPat) | execution(ConstructorPat)
  | initialization(ConstructorPat) | preinitialization(ConstructorPat)
  | staticinitialization(TypePat)
  | get(FieldPat) | set(FieldPat)
  | handler(TypePat)
  | adviceexecution()
  | within(TypePat) | withincode(MethodPat) | withincode(ConstructorPat)
  | cflow(Pointcut) | cflowbelow(Pointcut)
  | if(Expression)
  | this(Type | Var) | target(Type | Var) | args(Type | Var , …)

AspectJ syntax
patterns

MethodPat ::=
 [ModifiersPat] TypePat [TypePat . ] IdPat ( TypePat | .., … )
 [ throws ThrowsPat ]

ConstructorPat ::=
 [ModifiersPat ] [TypePat . ] new ( TypePat | .. , …)
 [ throws ThrowsPat ]

FieldPat ::= [ModifiersPat] TypePat [TypePat . ] IdPat

TypePat ::=
  IdPat [ + ] [ [] … ]
 | ! TypePat
 | TypePat && TypePat
 | TypePat || TypePat
 | ( TypePat )

IdPat ::=
 Java id with `*'s mixed in

## special expressions and statements

```
Expression ::=
    thisJoinPoint
  | thisJoinPointStaticPart
  | thisEnclosingJoinPointStaticPart

StatementExpression ::=
  proceed ( Arguments )
```

end