Enforcing Information Hiding in Interface Specifications:

with

The AspectJML specification language

A Client-Aware checking Approach

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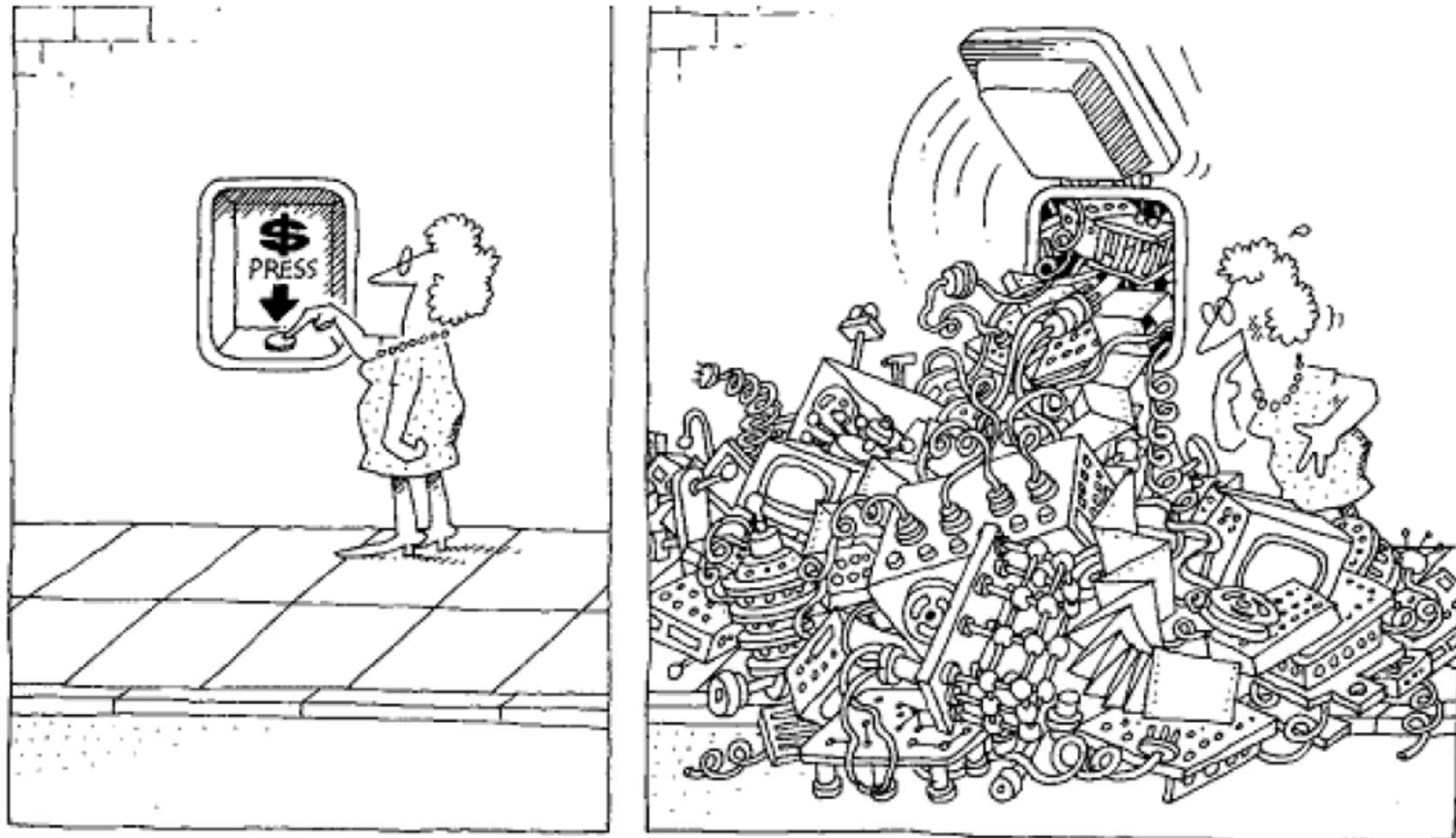
What is information hiding?

How to abstract away the details?



The task of the software development team is to engineer the illusion of simplicity.

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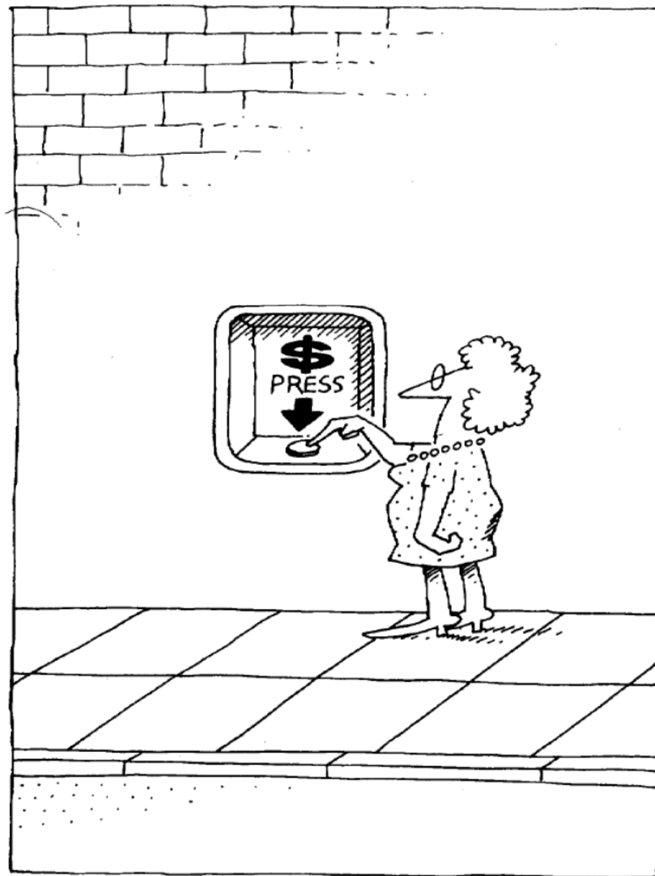
Black-box abstraction



The task of the software development team is to engineer the illusion of simplicity.

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Parnas

Whatever is likely to change!

Hiding the secret of a module behind an interface

Abstraction is an important key

Abstraction allows you to take a simpler view of a complex concept.

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Encapsulation helps in the process

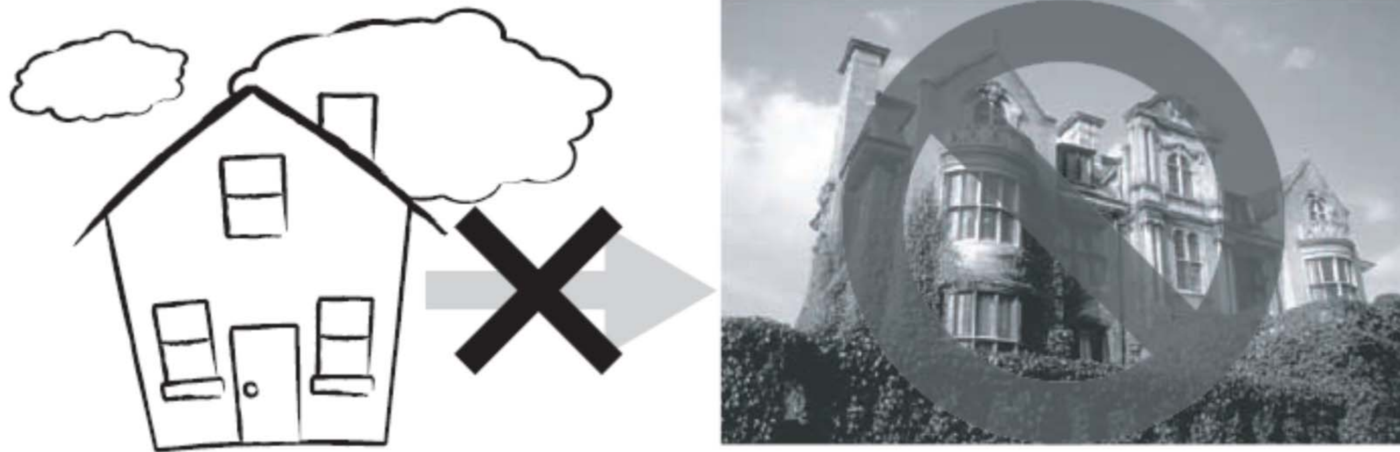

Figure 5-8 Encapsulation says that, not only are you allowed to take a simpler view of a complex concept, you are *not* allowed to look at any of the details of the complex concept. What you see is what you get—it's all you get!

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Is Encapsulation equivalent to Information Hiding ?

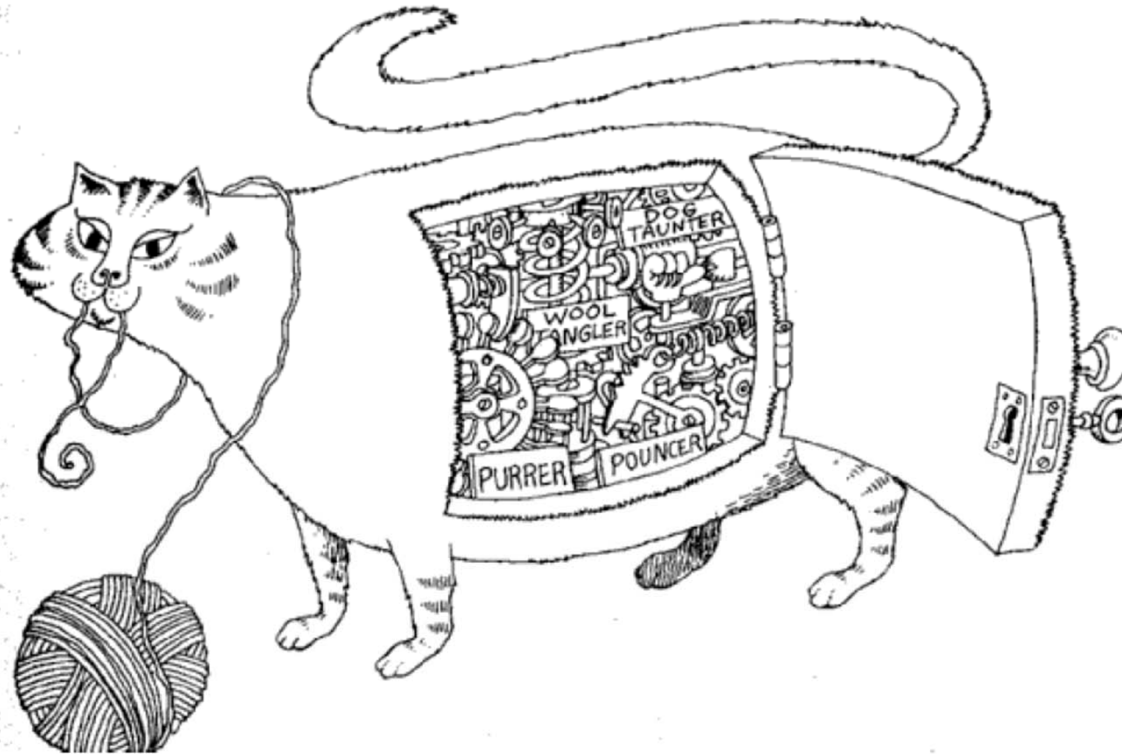
Think about these examples

```
class EncapsulationWithoutInformationHiding {
  private ArrayList list = new ArrayList();

  public ArrayList getList() {
    return this.list;
  }
}
```

```
class InformationHidingWithoutEncapsulation {
  public List list = new ArrayList();
}
```

Avoid exposure implementation details



Encapsulation hides the details of the implementation of an object.

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Information hiding for other artifacts
(Leavens and Muller. ICSE, 2007)

- Visibility modifiers on specifications
- Some specifications hidden from some clients
- Some specifications say more to privileged clients

```
class Package {
  //@ public model JMLDouble pWeight;
  private double weight;
  //@ private represents weight = pWeight;

  /*@ public normal_behavior
    @   requires weight <= 5;
    @   ensures this.pWeight == weight;
    @ also
    @ private normal_behavior
    @   requires weight <= 5;
    @   ensures this.weight == weight;
  public void setWeight(double weight) {
    this.weight = weight;
  }
  /* other methods omitted */
}
```

Design by Contract

- Specifications (contracts) in OO programming Language
  - preconditions
  - postconditions

```
decrement is
        -- Decrease counter by one.
    require
        item > 0
    ensure
        item = old item - 1
```

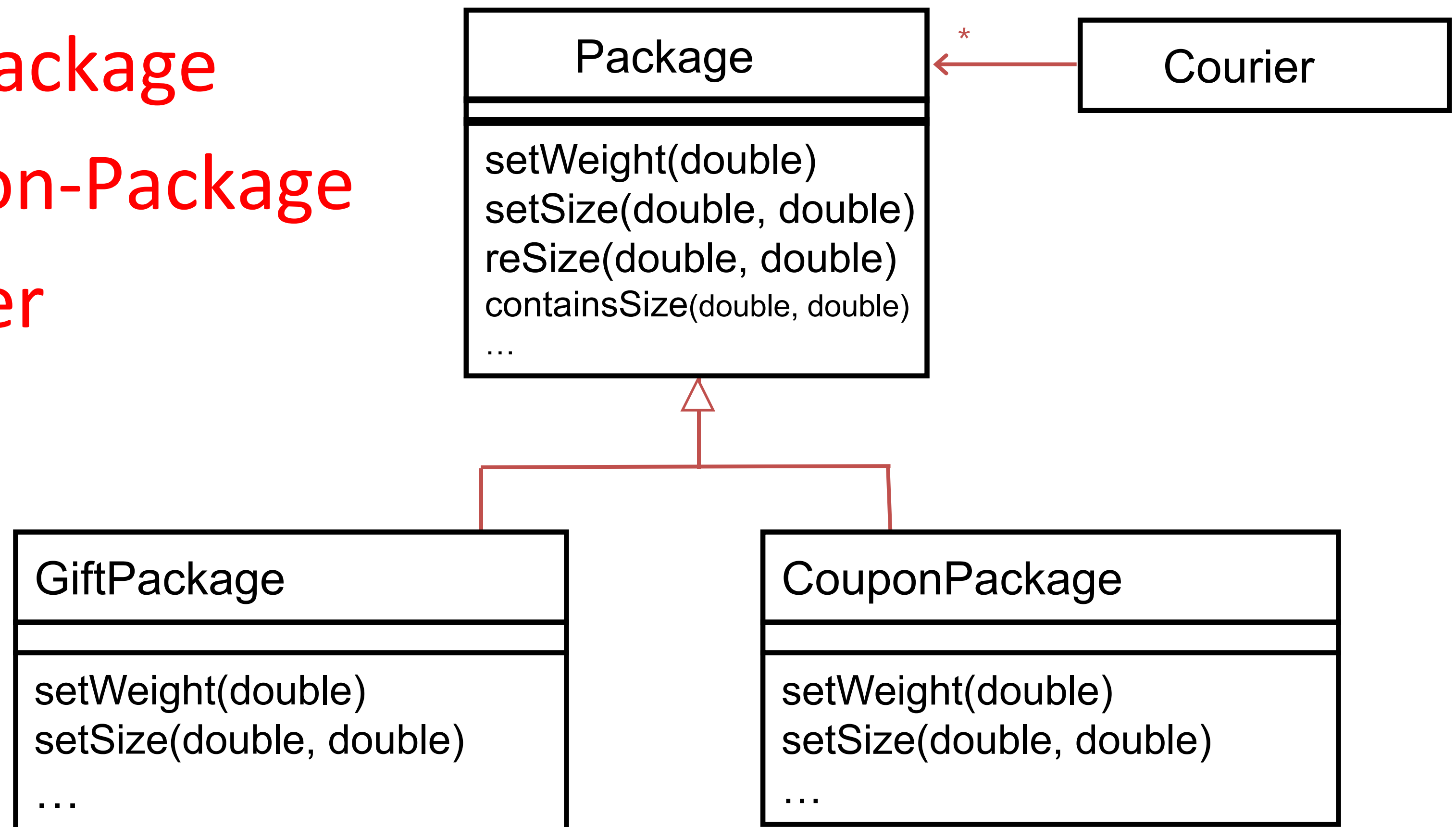
Running example

(Package delivery system)

https://www.google.com.br/search?q=Package+delivery

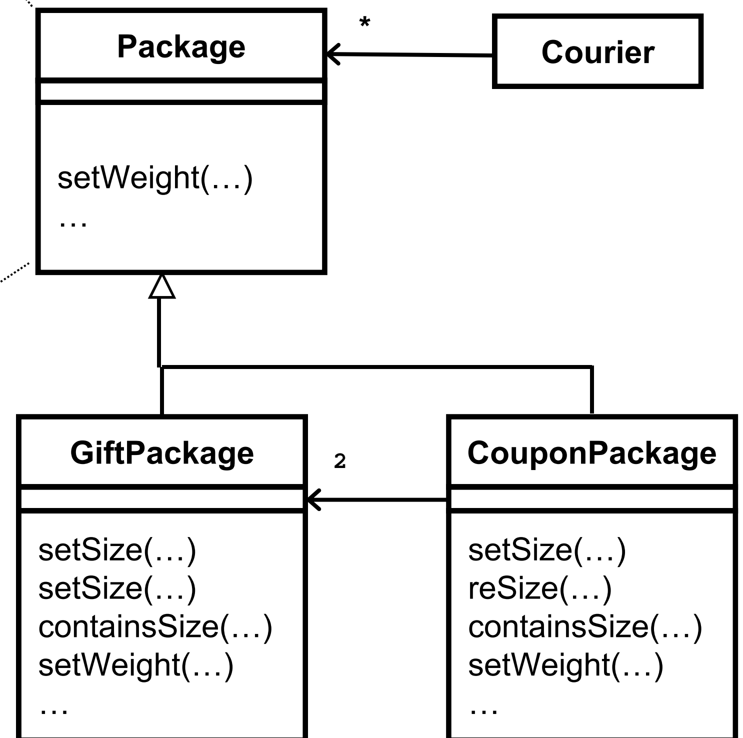
Delivery package classes…

- Package,
- Gift-Package
- Coupon-Package
- Courier
- …



Package contracts with a DbC language

```
class Package {
  /* intentionally public */
  public double weight;

  public void setWeight(double weight)
   @pre weight <= 5;
   @post this.weight == weight;
 {
    this.weight = weight;
  }

/* other methods omitted */
}
```



Consider the following Package's client

Written by Cathy

```
class ClientClass {

  public void clientMeth(Package p) {
    p.setWeight(5);
  }
}
```

Written by Alice

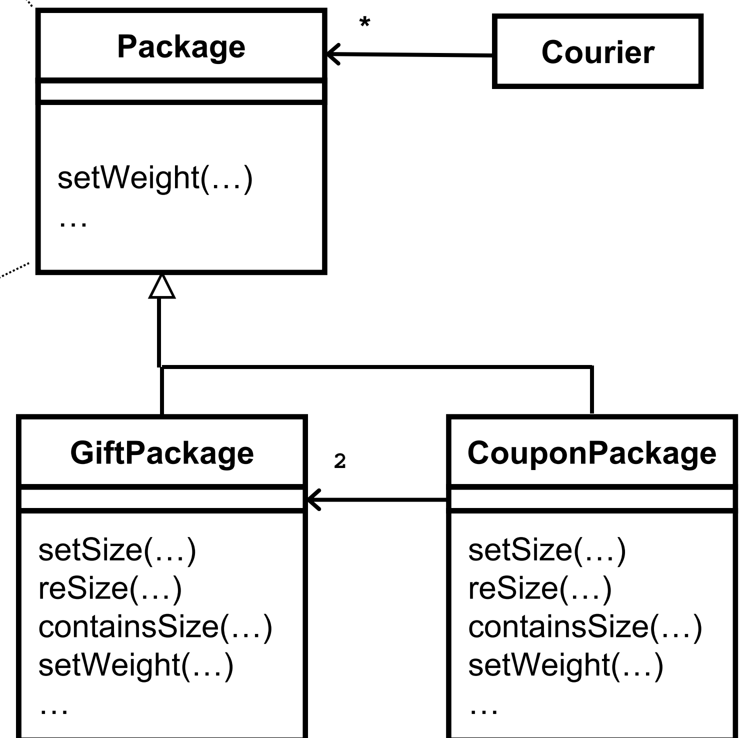
```
class Package {
  /* intentionally public */
  public double weight;

  public void setWeight(double
weight)
   @pre weight <= 5;
   @post this.weight == weight;
 {
   this.weight = weight + 1;
 }

/* other methods omitted */
}
```

RAC

PostconditionError:
this.weight is 6.0
weight is 5.0

Consider now the following change by Alice

```
class Package {
  private double weight;

  public void setWeight(double weight)
   @pre weight <= 5;
   @post this.weight == weight;
 {
    this.weight = weight;
  }

/* other methods omitted */
}
```



But now RAC breaks information hiding!

Written by Cathy

```
class ClientClass {

  public void clientMeth(Package p) {
    p.setWeight(5);
  }
}
```

Written by Alice

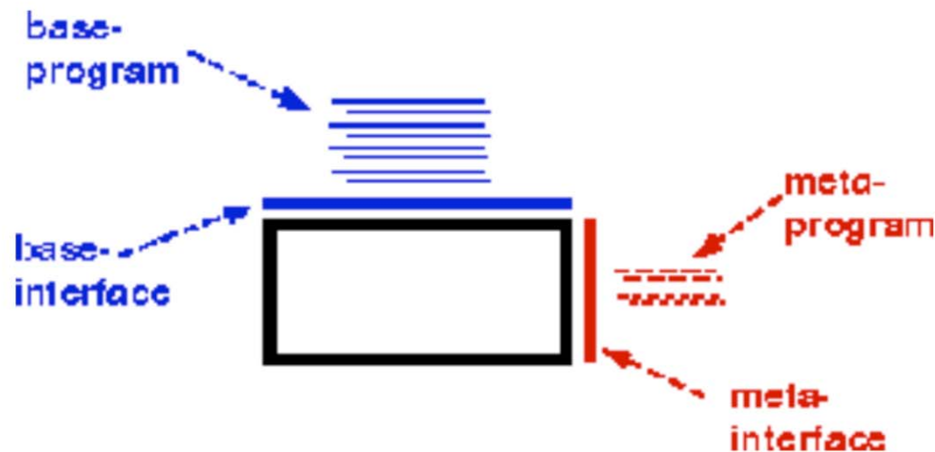
```
class Package {
 private double weight;

  public void setWeight(double weight)
   @pre weight <= 5;
   @post this.weight == weight;
 {
   this.weight = weight + 1;
 }

/* other methods omitted */
}
```

RAC

PostconditionError:
this.weight is 6.0
weight is 5.0

Kiczales: Beyond the black-box

Clients confront an issue that the interface claimed to hide.



An open implementation presents two interfaces

Do DbC languages present this information hiding problem?

code contracts

Microsoft Research

Is this program correct?

```
 1 using System;
 2 using System.Diagnostics.Contracts;
 3
 4 class Package {
 5
 6   private double weight;
 7
 8   public void setWeight(double weight) {
 9     Contract.Requires(weight <= 5);
10     Contract.Ensures(this.weight == weight);
11     this.weight = weight + 1;
12   }
13 }
14
15 class ClientClass {
16
17   public void clientMeth(Package p) {
18     p.setWeight(5);
19   }
20 }
21
```

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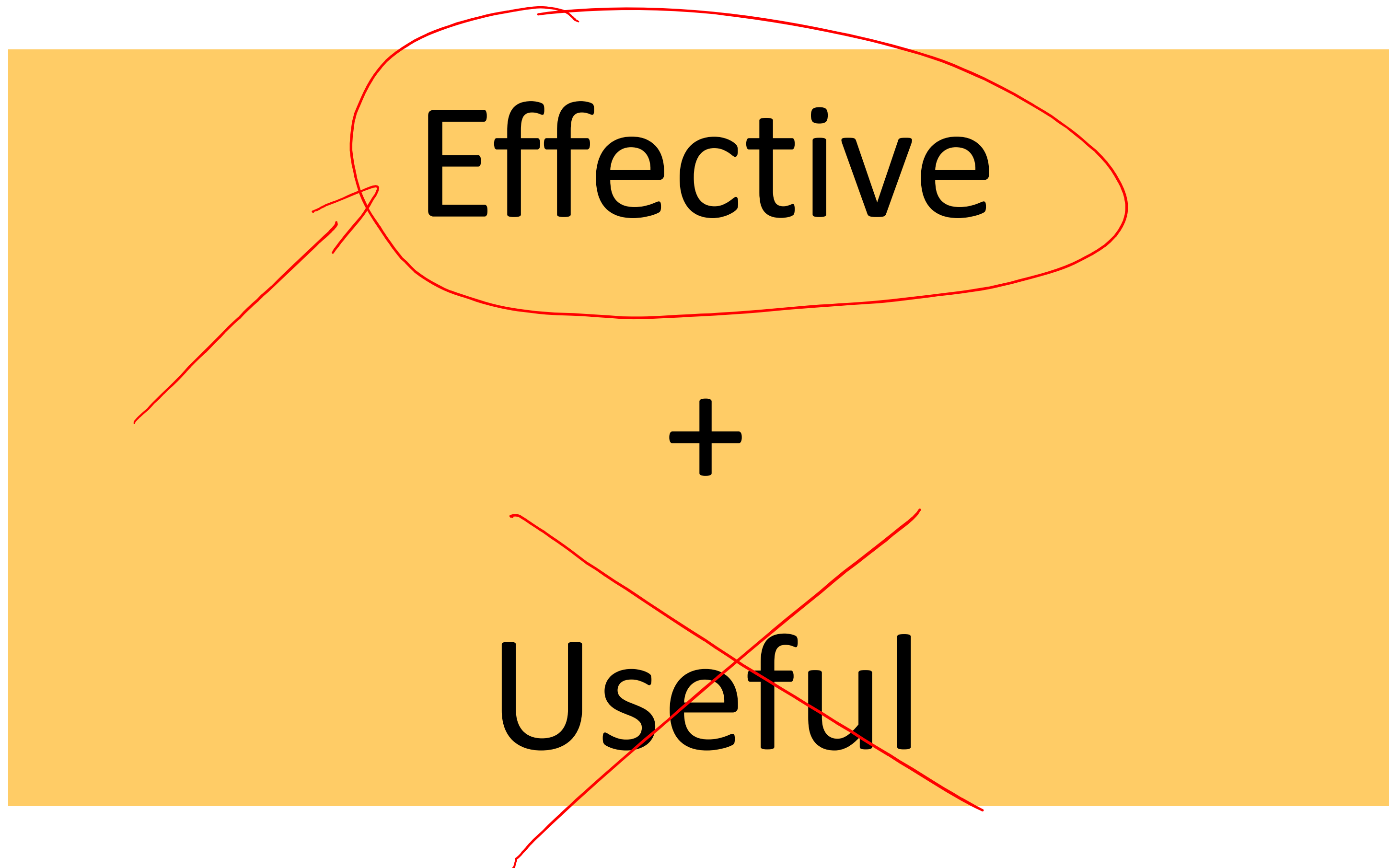
'►' shortcut: Alt+B

		Description
	1	Possible precision mismatch for the arguments of ==
	2	ensures is false: this.weight == weight

In this scenario, we can say that…

… standard DbC/RAC tools are **NOT**…



But the DbC language JML starting fixing the problem…

Java modeling language—JML

- Formal specification language for Java
  - behavioral specification of Java modules
- Adopts design by contract based on Hoare-style with assertions
  - pre-, postconditions and invariants
  - {P} C {Q}

- Main goal → Improve functional software correctness of Java programs

Information Hiding and Visibility in Interface Specifications

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Abstract

Information hiding controls which parts of a class are visible to non-privileged and privileged clients (e.g., subclasses). This affects detailed design specifications in two ways. First, specifications should not expose hidden class members. As noted in previous work, this is important because such hidden members are not meaningful to all clients. But it also allows changes to hidden implementation details without invalidating correctness proofs for client code, which is important for maintaining verified programs. Second, to enable sound modular reasoning, certain specifications must be visible to clients. We present rules for information hiding in specifications for Java-like languages, and demonstrate their application to the specification language JML. These rules restrict proof obligations to only mention visible class members, but retain soundness. This allows maintenance of implementations and their specifications without affecting client reasoning.

1 Introduction

When following information hiding, clients (including subclasses) of each class are provided with the information they need to use that class, but nothing more [28]. This aids maintenance because hidden implementation details can be changed without affecting clients. However, information hiding and its benefits apply not only to code but also to other artifacts, such as documentation and specifications.

In this paper, we focus on formal interface specifications and correctness proofs. Formal interface specifications include contracts written in Eiffel [22], the Java Modeling Language (JML) [14], and Spec# [3]. We use JML examples for concreteness, but the rules we present can also be applied to Eiffel and Spec#. We mainly discuss JML since its syntax has visibility modifiers for specification constructs, such as invariants and method specification cases. These modifiers allow one to specify a class's public (non-privileged client), protected (subclass), package (friend), and private (implementation) interfaces [10, 13, 29, 30].

Our contribution is a set of rules for the modular use of visibility modifiers in specifications. Formalization allows us to precisely describe the subtle interactions between programs, specifications, and proofs and to prove soundness.

Our rules could also be applied to similar artifacts. For example, they could be applied to the weak (incomplete) specifications embodied in unit test cases and to the informal specifications embodied in documentation. Like formal specifications they could also be specialized for different visibility levels. For example, a unit test case could be marked as public, which would imply that changes to hidden implementation details would not affect its type correctness or meaning. Hence, it would not have to be changed when hidden details change. Similarly, a class could have documentation marked as protected, which describes how its methods affect its protected members.

Information hiding affects specifications in two ways. First, specifications should not expose hidden implementation details. Such details cannot be fully understood by all clients [23]. Also they should not be used in a client's correctness proof, since otherwise the proof would be invalidated when they change. For example, suppose method `add` of a class `BoundedList` has a public precondition `count < capacity`, where `count` and `capacity` are protected fields. Then non-privileged clients do not know what this precondition means exactly; for instance, they do not know whether `count` is the number of elements in the list (counting from one) or an array index (counting from zero). Such details are hidden from clients to enhance maintainability, which includes maintainability of correctness proofs.

Second, to enable sound modular reasoning, certain specifications must be visible to clients. For instance, specifications of virtual (overrideable) methods must be visible to overriding subclass methods, otherwise the overriding method cannot respect behavioral subtyping [1, 5, 15, 21].

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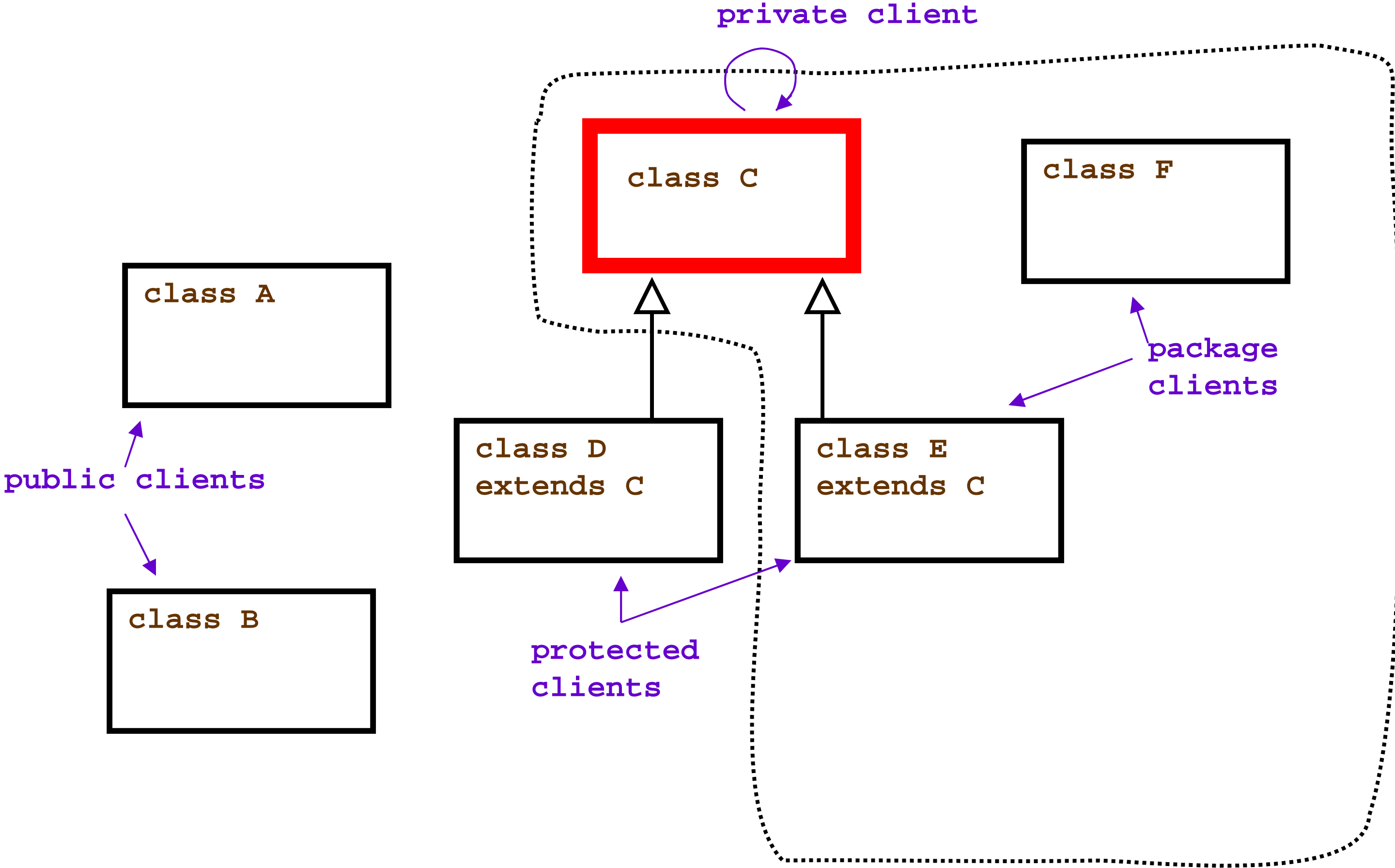
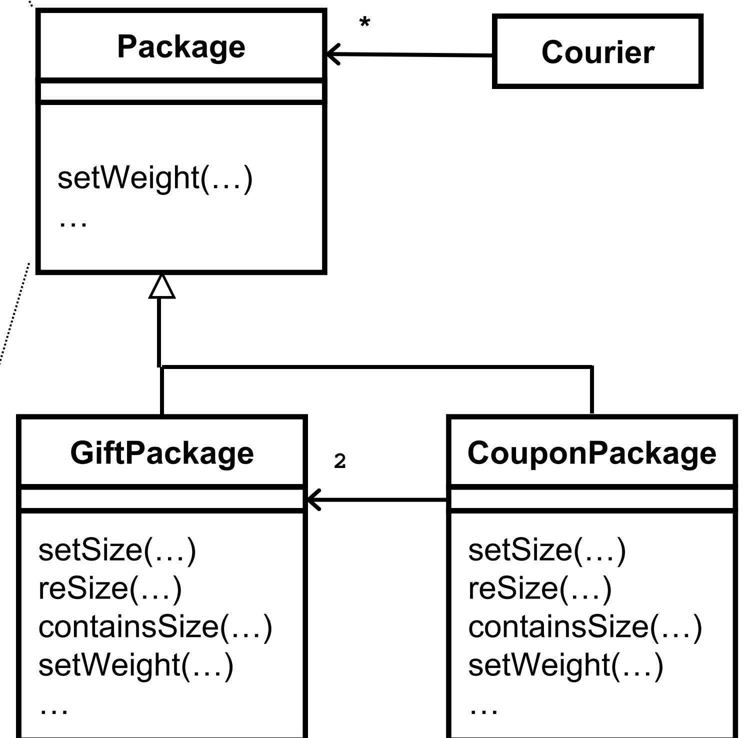
Kinds of clients in Java and JML



Package contracts with JML

```
class Package {
  //@ public model JMLDouble pWeight;
  private double weight;
  //@ private represents weight = pWeight;

  /*@ public normal_behavior
    @   requires weight <= 5;
    @   ensures this.pWeight == weight;
    @ also
    @ private normal_behavior
    @   requires weight <= 5;
    @   ensures this.weight == weight;
  public void setWeight(double weight) {
    this.weight = weight;
  }

  /* other methods omitted */
}
```



JML RAC still breaks information hiding!

Written by Cathy

```
class ClientClass {

  public void clientMeth(Package p) {
   p.setWeight(5);
  }
}
```

RAC

JMLPostconditionError: when
this.weight is 6.0
weight is 5.0

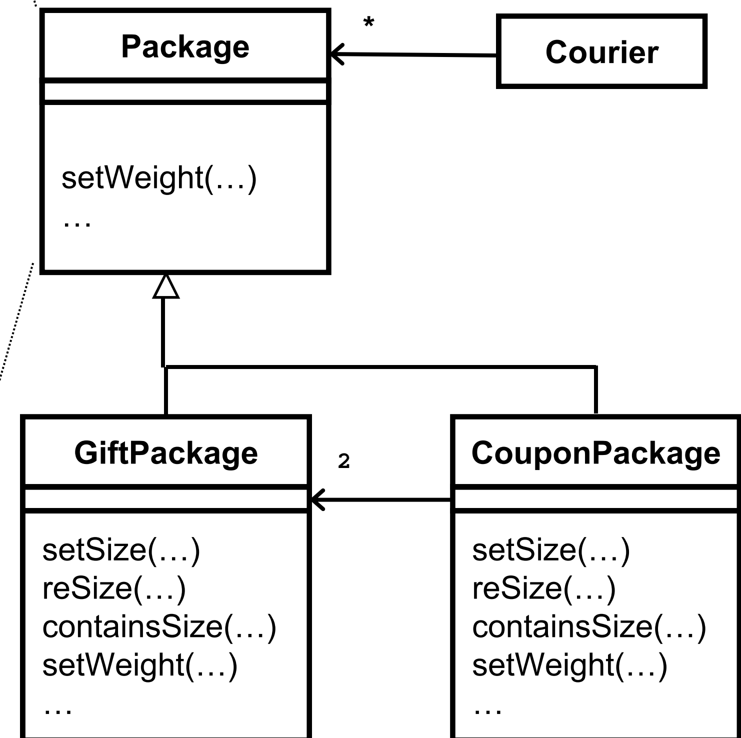
Written by Alice

```
class Package {
  //@ public model JMLDouble pWeight;
  private double weight;
  //@ private represents weight = pWeight;

  /*@ public normal_behavior
    @   requires weight <= 5;
    @   ensures this.pWeight == weight;
    @ also
    @ private normal_behavior
    @   requires weight <= 5;
    @   ensures this.weight == weight;
  public void setWeight(double weight) {
    this.weight = weight + 1;
  }

  /* other methods omitted */
}
```

The problem can become even worse…

Package contracts for subtypes

```
class Package {
  //@ public model JMLDouble pWeight;
  protected double weight;
  //@ protected represents weight = pWeight;

  /*@ public normal_behavior
    @   requires weight <= 5;
    @   ensures this.pWeight == weight;
    @ also
    @ protected normal_behavior
    @   requires weight <= 8;
    @   ensures this.weight == weight;
  public void setWeight(double weight) {
    this.weight = weight;
  }

  /* other methods omitted */
}
```



JML RAC misses a precondition violation!

Written by Cathy

```
class ClientClass {

  public void clientMeth(Package p) {
    p.setWeight(8);
  }
}
```

RAC

Returns successfully!

Written by Alice

```
class Package {
  //@ public model JMLDouble pWeight;
  protected double weight;
  //@ protected represents weight = pWeight;

  /*@ public normal_behavior
    @   requires weight <= 5;
    @   ensures this.pWeight == weight;
    @ also
    @ protected normal_behavior
    @   requires weight <= 8;
    @   ensures this.weight == weight;
public void setWeight(double weight) {
    this.weight = weight;
  }

  /* other methods omitted */
}
```

```
class GiftPackage extends Package {
}
```

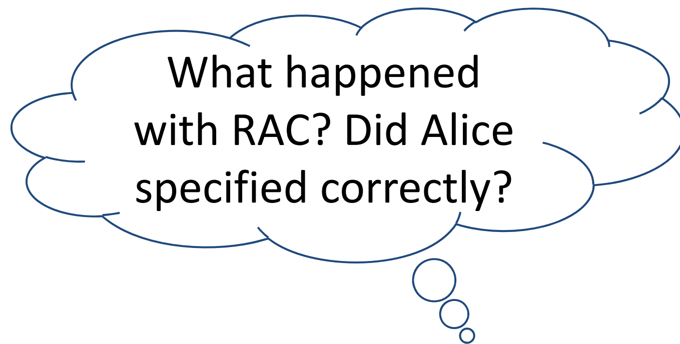
JML/RAC is **NOT**...

Effective

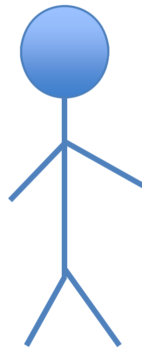
+

Useful

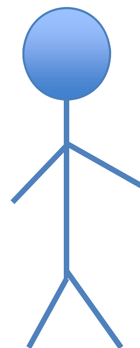
Unanswered questions can arise

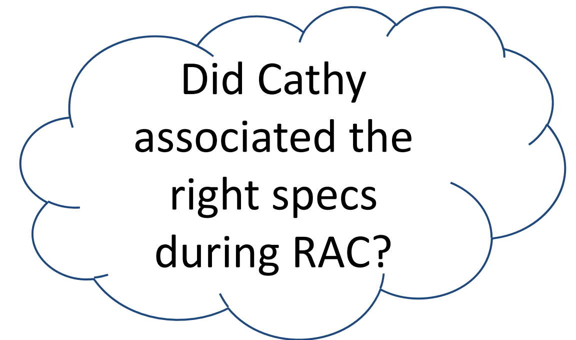


Cathy



Alice





This is caused by the…

…supplier-side instrumentation of contracts in JML and any other RAC

```
class Package {
  //@ public model JMLDouble pWeight;
  protected double weight;
  //@ protected represents weight = pWeight;

  /*@ public normal_behavior
    @   requires weight <= 5;
    @   ensures this.pWeight == weight;
    @ also
    @ protected normal_behavior
    @   requires weight <= 8;
    @   ensures this.weight == weight;
  public void setWeight(double weight) {
    this.weight = weight;
  }

  /* other methods omitted */
}
```

```
class Package {
  …
  public void setWeight(double weight) {
   //@ assume w <= 5 || w <= 8 ;
     …
   //@ assert this.pWeight == weight
            && this.weight == weight;
  }

  /* other methods omitted */
}
```

Information hiding problem statement

we say that a RAC compiler that checks specifications based at supplier-side as overly-dynamic

The AspectJML Language

is one

solution

to the illustrated problem

Client-aware checking approach

```
class GiftPackage extends
Package {

 public void setWeight(double w){
    …
 }
```

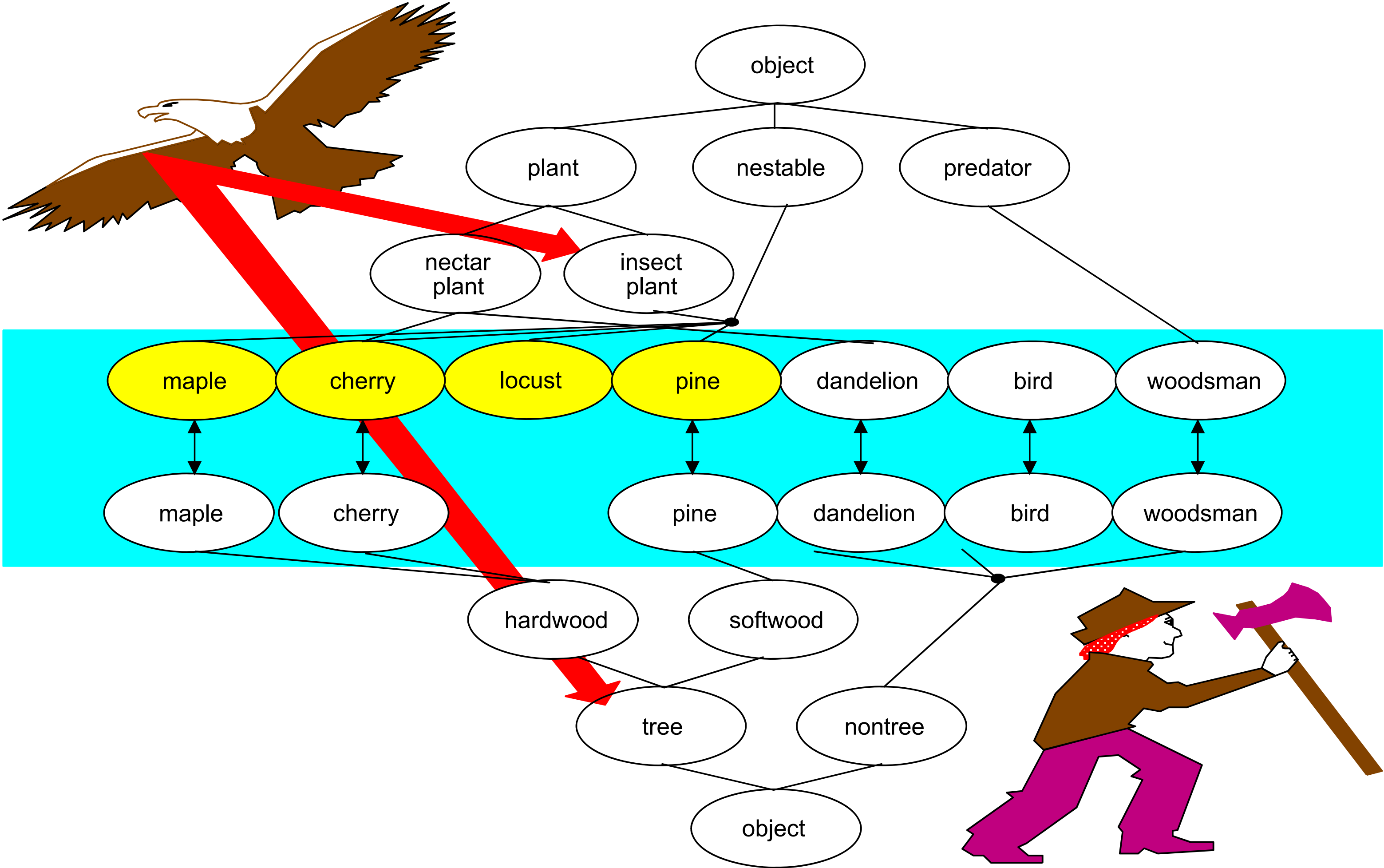
```
class Courier

 public void deliver(double w){
    …
 }
}
```

```
class OtherClient{

  void clientMeth(Package p) {
    p.setWeight(-1);
    p.setY(-1);
  }
  void helper(…) {
    …
  }
}
```

```
class Package {

/*@ public behavior
   @  requires w <= 5;
   @  ensures this.pWeight == w;
   @ also
   @ protected behavior
   @  requires w <= 8;
   @  ensures this.weight == w;
   @*/
 public void setWeight(double w) {…}
 …
}
```

- CAC cuts through clients
  - with proper runtime checks
- Runtime checking itself is modular
  - based on privacy-kind of clients

Harrison & Harold Ossher on Subjectivity



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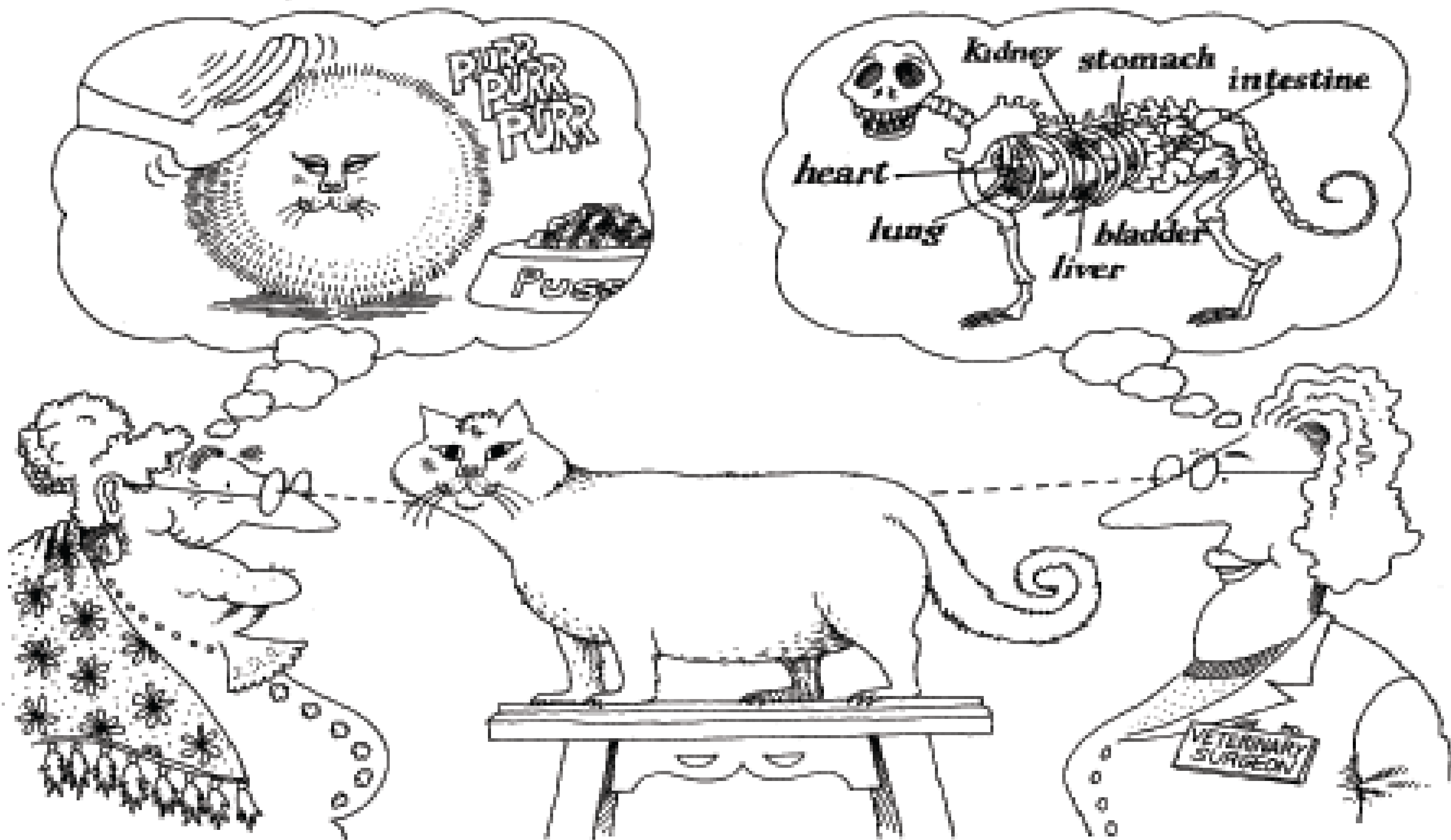
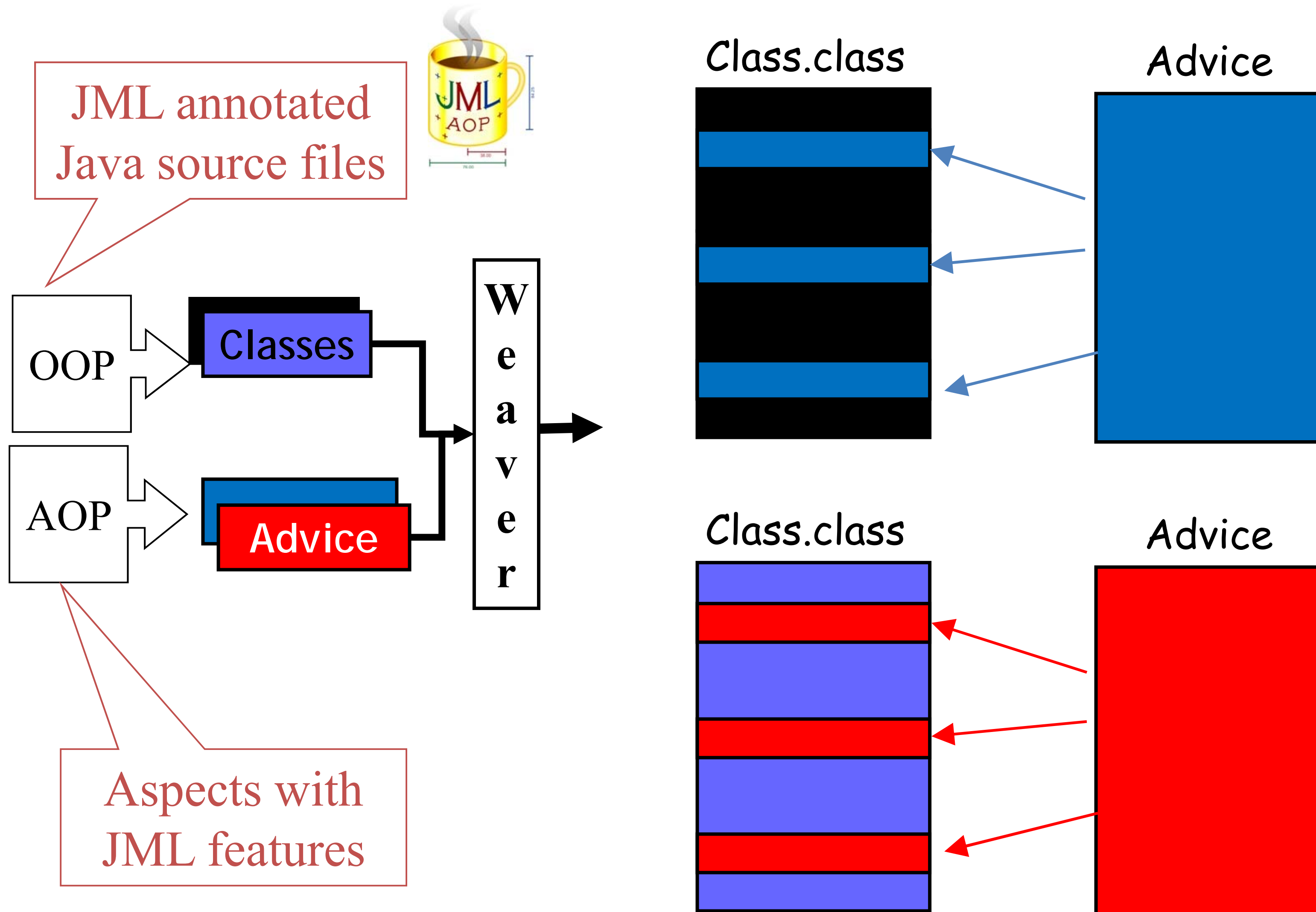
Grady Booch on Subjectivity



Abstraction focuses upon the essential characteristics of some object, relative to the perspective of the viewer.

CAC implementation with AspectJML



To hide or not to hide?

```
class GiftPackage extends
Package {

 public void setWeight(double w){
    …
 }
```

```
class Courier

 public void deliver(double w){
    …
 }
}
```

```
class OtherClient{

  void clientMeth(Package p) {
    p.setWeight(-1);
    p.setY(-1);
  }
  void helper(…) {
    …
  }
}
```

```
class Package {

/*@ public behavior
   @  requires w <= 5;
   @  ensures this.pWeight == w;
   @ also
   @ protected behavior
   @  requires w <= 8;
   @  ensures this.weight == w;
   @*/
 public void setWeight(double w) {…}
 …
}
```

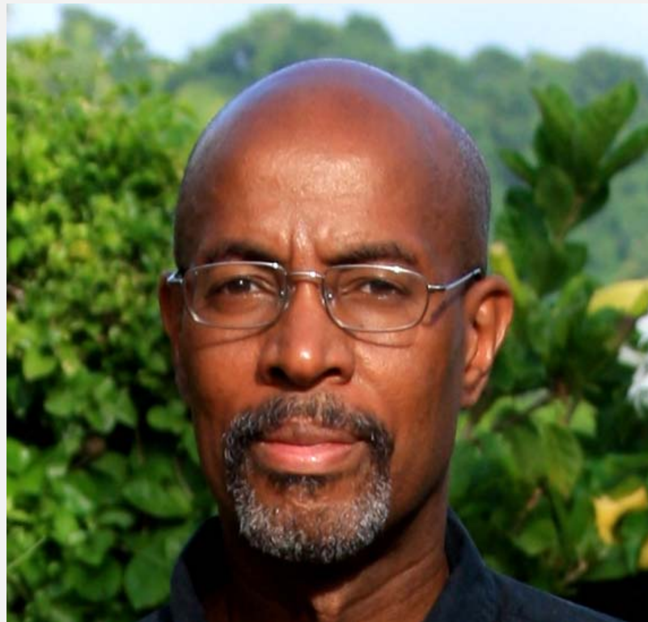
- CAC cuts through clients
  - with proper runtime checks
- Runtime checking itself is modular
  - based on privacy-kind of clients

Future work

- Find case studies
- More study on the problems caused by overly-dynamic checking
  - dynamic-dispatch

AspectJML/CAC in action…

Dedicated to the Memory of



Robert France