

Object-Oriented Design Heuristics

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Source

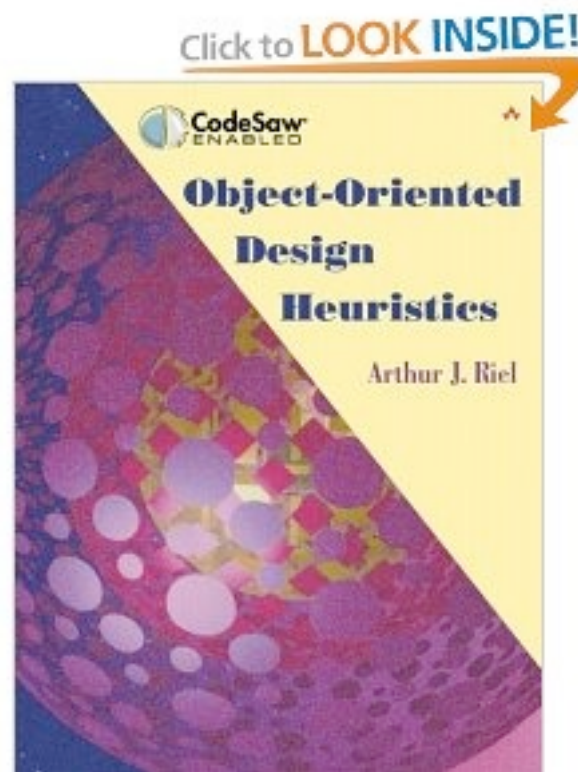
Book from Arthur J. Riel

Addison-Wesley Professional (May 10, 1996)

978-0201633856

Java 1.6

Pharo 1.0



Goal of this lecture

Provide useful and simple programming “rules”

Insight into object-oriented design improvement

Intended to

- Increase the readability and the quality of your code

- Facilitate software maintenance

Goal of this lecture

This lecture can be considered as the continuation of CC3002

This lecture provides good hints to not make people throw stones at you when they will look at your code

Classes and Objects

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Classes and Objects

The building blocks of the object-oriented paradigm

An object will always have four important facets

- its own identify (e.g., its address in memory)

- the attributes of its class (usually static) and values for those attributes (usually dynamic)

- the behavior of its class (the implementor's view)

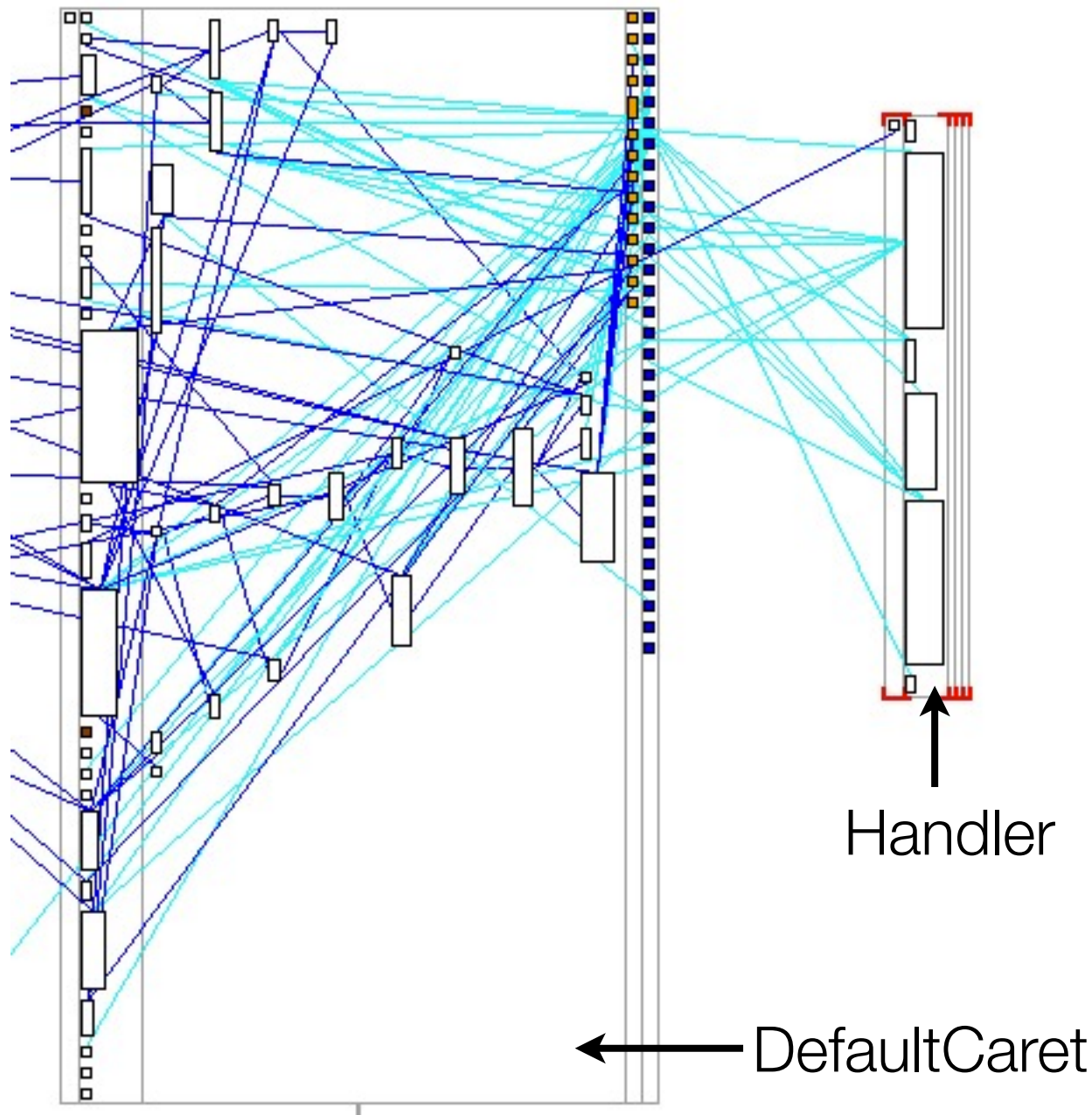
- the published interface (the user's view)

All data should be hidden within its class

```
public class DefaultCaret extends Rectangle implements Caret,  
FocusListener, MouseListener, MouseMotionListener {  
  
    ...  
    int updatePolicy = UPDATE_WHEN_ON_EDT;  
    boolean visible;  
    boolean active;  
    int dot;  
    int mark;  
    Object selectionTag;  
    boolean selectionVisible;  
    Timer flasher;  
    Point magicCaretPosition;  
    transient Position.Bias dotBias;  
    transient Position.Bias markBias;  
    boolean dotLTR;  
    boolean markLTR;  
    transient Handler handler = new Handler();  
    transient private int[] flagXPoints = new int[3];  
    transient private int[] flagYPoints = new int[3];  
    private transient NavigationFilter.FilterBypass filterBypass;  
    static private transient Action selectWord = null;  
    static private transient Action selectLine = null;  
  
    ...  
}
```

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Piece of code extracted from the JDK 1.6. The class DefaultCaret belongs to the package javax.swing.text. It contains 15 public attributes



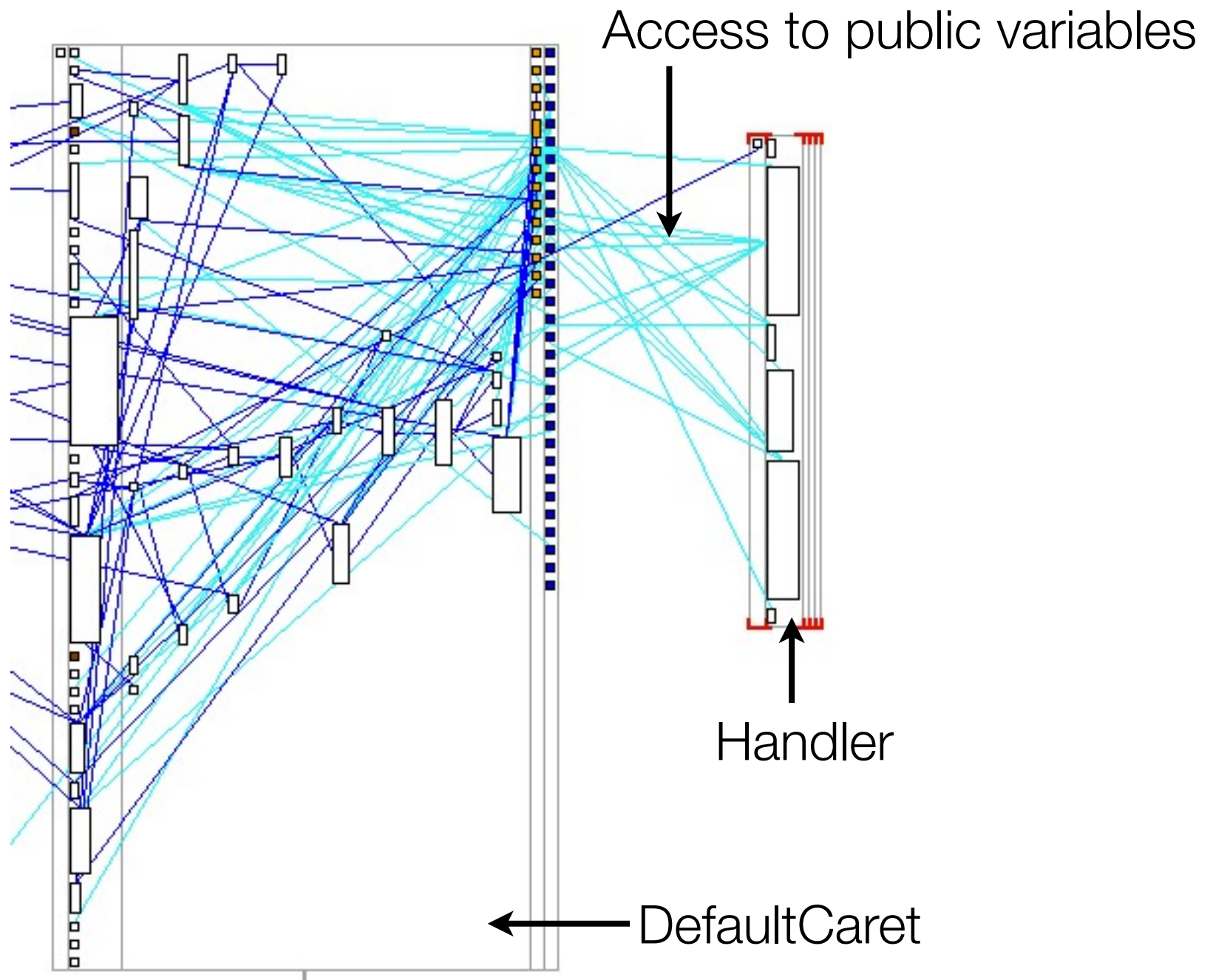
Class blueprint [Lanza 2003]

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We will make heavy use of visualization along the semester. Visualizing software is a very handy and intuitive mechanism for getting a quantitative and qualitative impression about a system.

Class blueprint is a visualization that shows class internal. A class is represented as a box. Each box is composed of 5 part. Each part correspond to some particular elements that composes the class. From left to right: constructors, public methods, private methods, variable accessors and mutators (get and set methods), attributes.

Blue edges represent methods invocations. Cyan edges represent variable accesses.



Class blueprint [Lanza 2003]

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The class `DefaultCaret` contains 15 public attributes. These attributes are accessed by other classes. `Handler` for example. This shows a poor programming style. Never make field public or package visible.

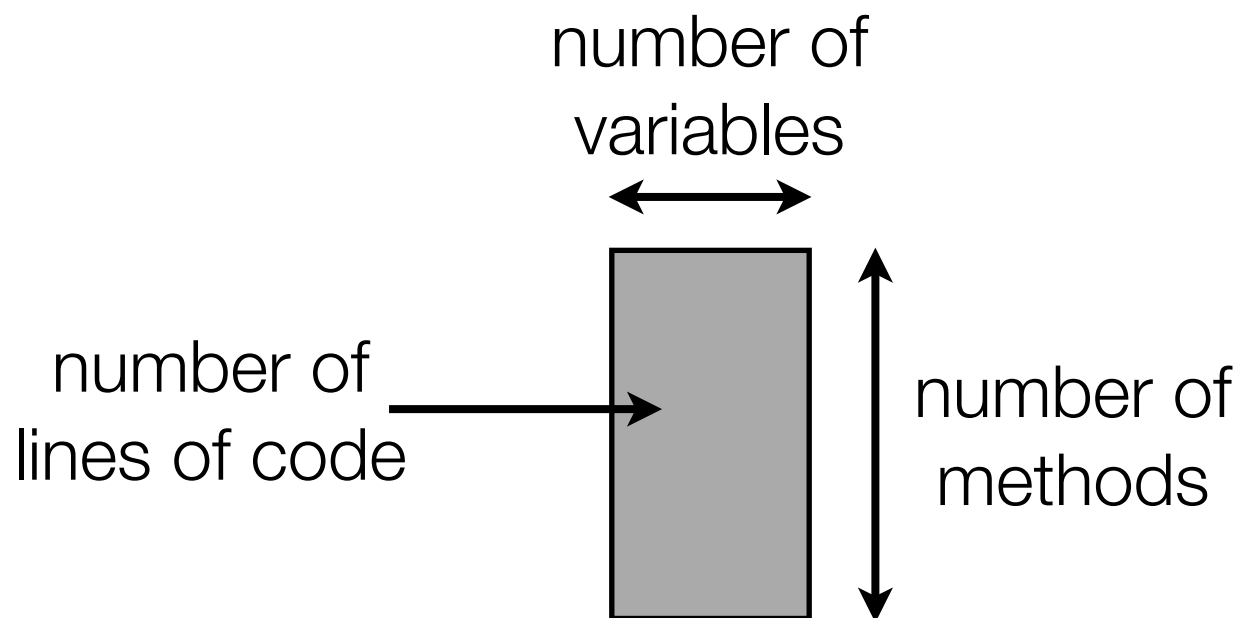
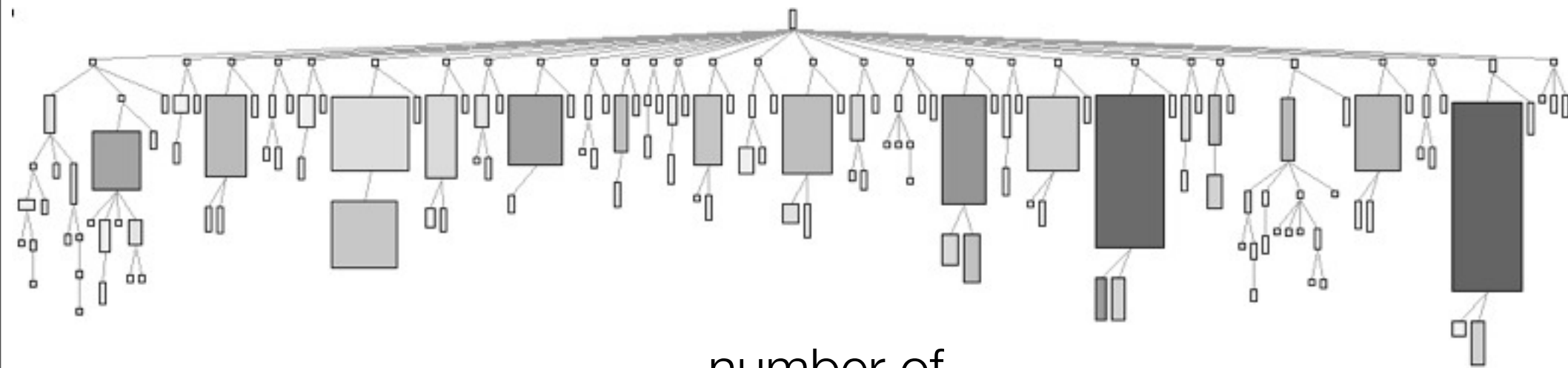
One may argue that for optimization reason, it may be preferable to have public variables instead of accessors. It was true some time ago when virtual machines and compiler were not that sophisticated. Today, making variable public is hardly considered as an efficient way to optimize your program.

How to hide data?

Visibility of variables should be set to private or protected

Define accessors and mutators when necessary

Minimize the number of messages in the protocol of a class

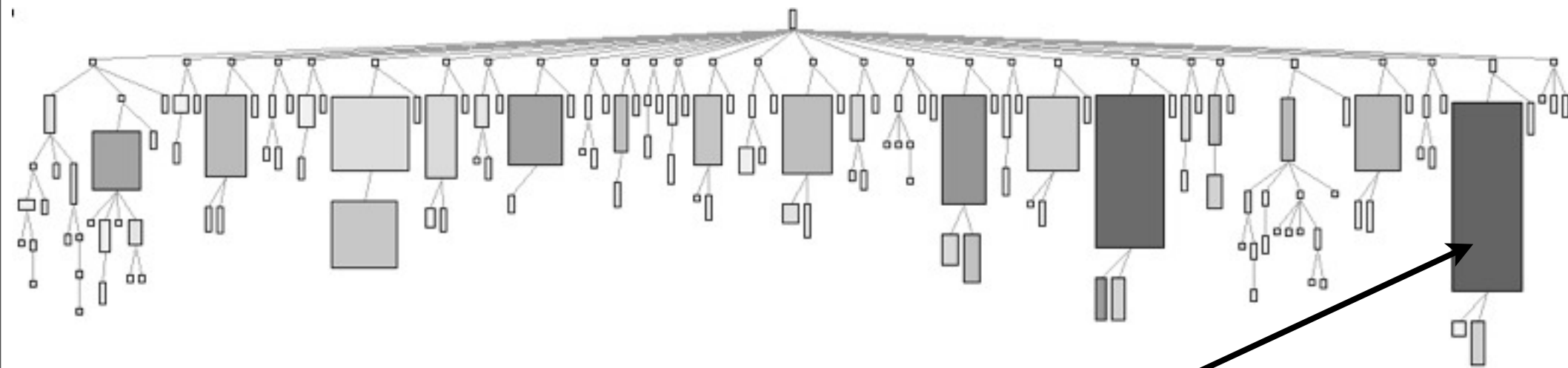


System complexity [Lanza 2003]

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We can see another visualization, called System complexity. This visualization is about class hierarchies. Each class is represented as a box, shaped with three metrics: number of variables, number of methods and number of lines of code.

The hierarchy represented here is PLAF, the pluggable look and feel of Java. You can notice the irregularity of the hierarchies, which probably hide some missing functionalities.



javax.swing.plaf.basic.BasicTreeUI

1636 lines of code

49 variables

131 methods

System complexity [Lanza 2003]

JComponent

1888 LOC

169 methods

73 attributes



JTable

2691 LOC

185 methods

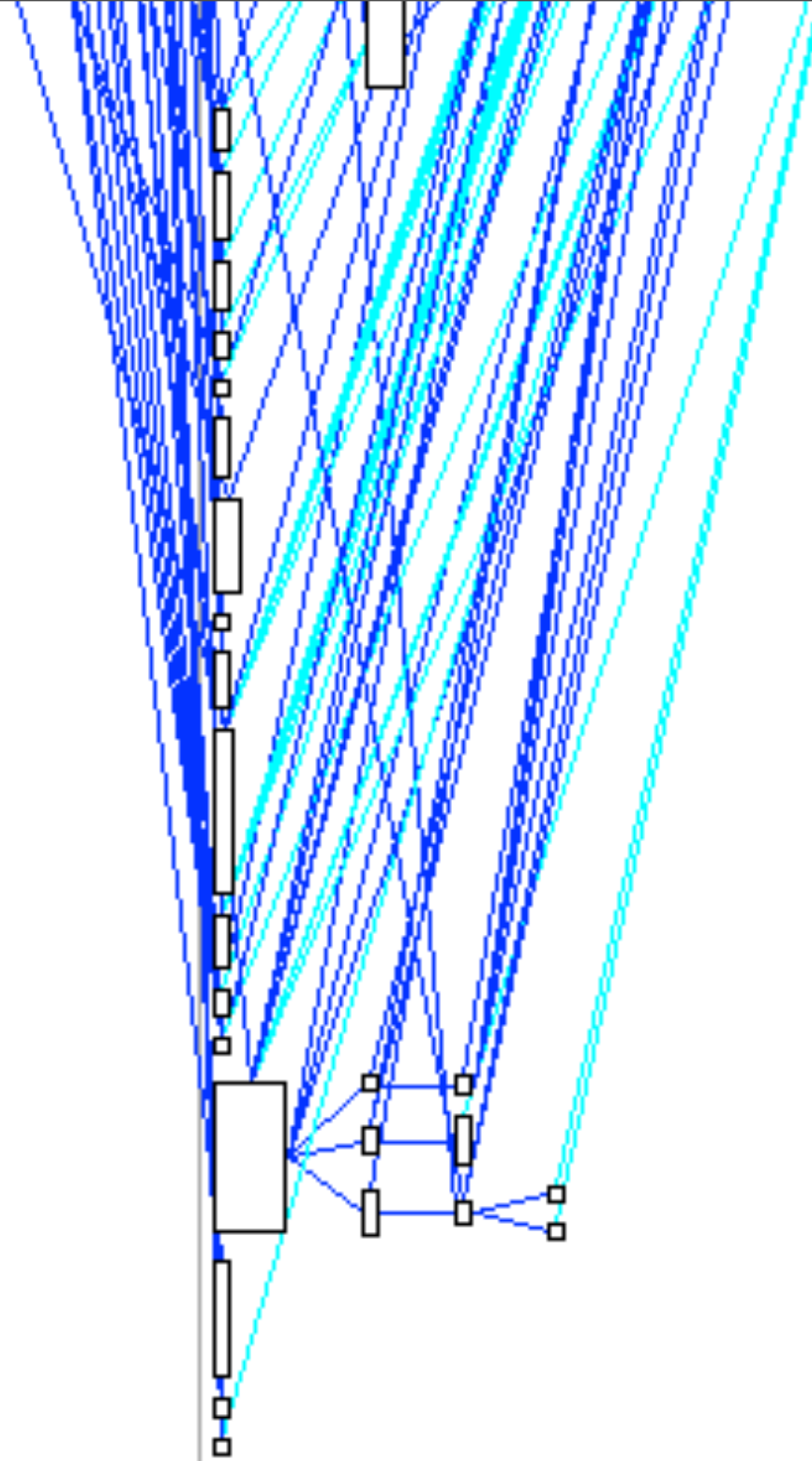
44 attributes



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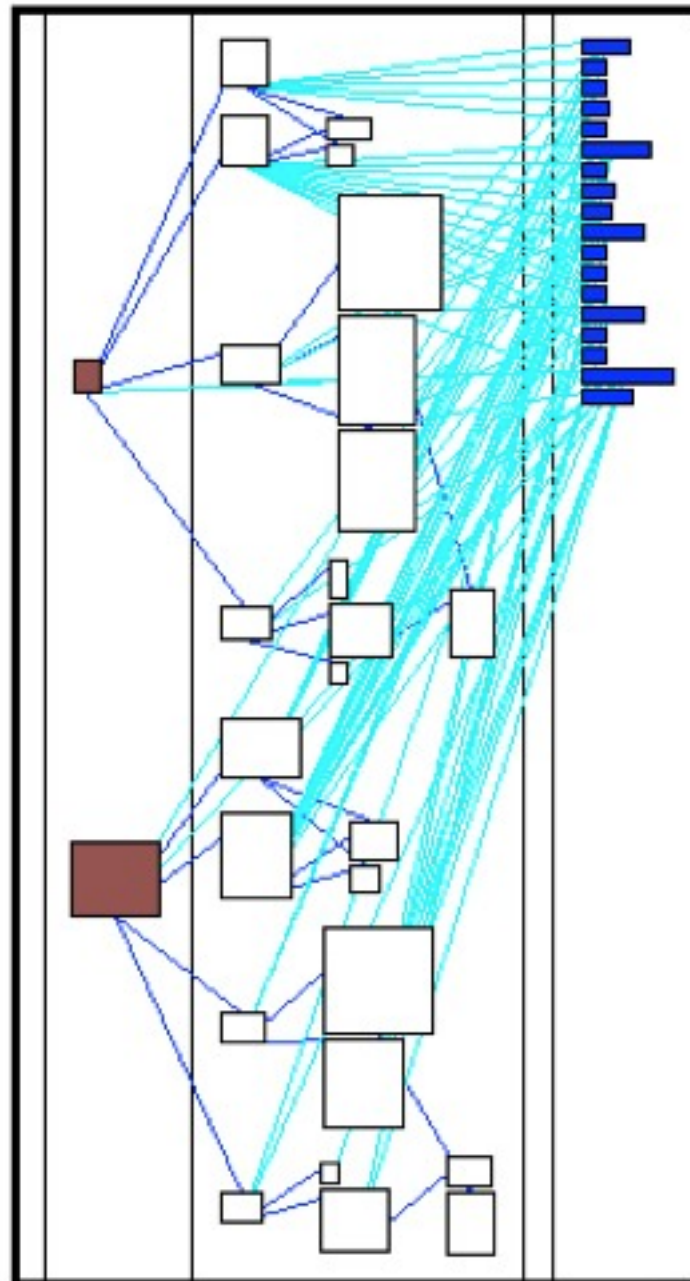
We can merely observe the two biggest classes of Swing: JComponent and JTable. However, we should not blame their developers. The root of a graphical user interface framework is inherently complex and difficult to implement. To convince yourself, have a look at the root class of any serious GUI framework.

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A class should capture one and only one key abstraction



Example in ArgoUML

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We can observe a class which has 2 public methods and many private methods. This class is quite particular in the sense that its private methods are divided into two distinct groups. Each group of private method is used by one public method.

This is an example of a class that offers two distinct functionalities.

Action-Oriented vs Object-Oriented

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The god class problem

A “god” class performs most of the work, leaving minor details to a collection of trivial classes

*Do not create god classes/objects in your system.
Be very suspicious of a class whose name contains
Driver, Manager, System, Subsystem, Utility*

```
* @version 1.158, 03/13/06
* @since   JDK1.0
*/
public final class System {

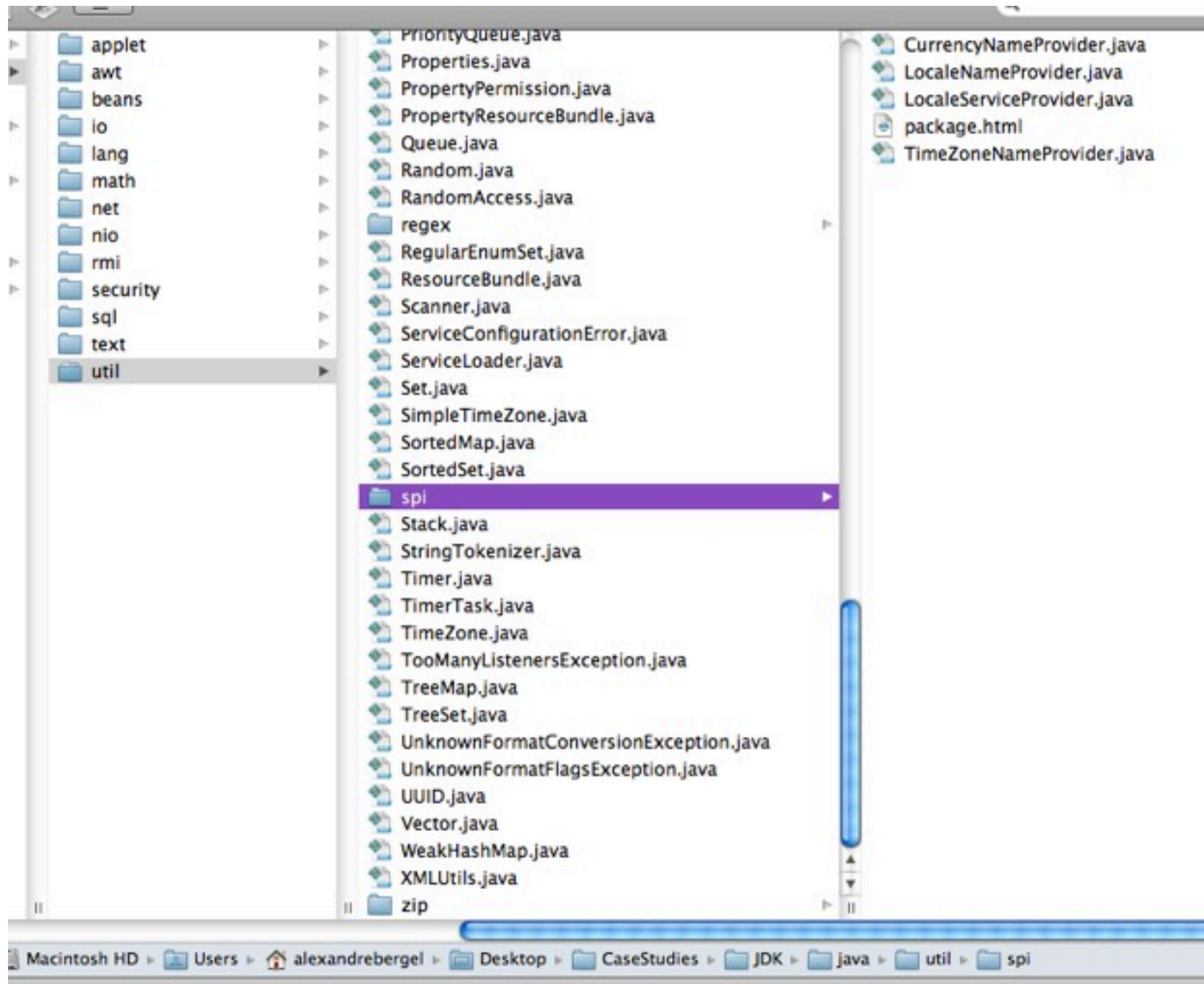
    /* First thing---register the natives */
    private static native void registerNatives();
    static {
        registerNatives();
    }

    /** Don't let anyone instantiate this class */
    private System() {
    }

    /**
     * The "standard" input stream. This stream is already
     * open and ready to supply input data. Typically this stream
     * corresponds to keyboard input or another input source specified by
```

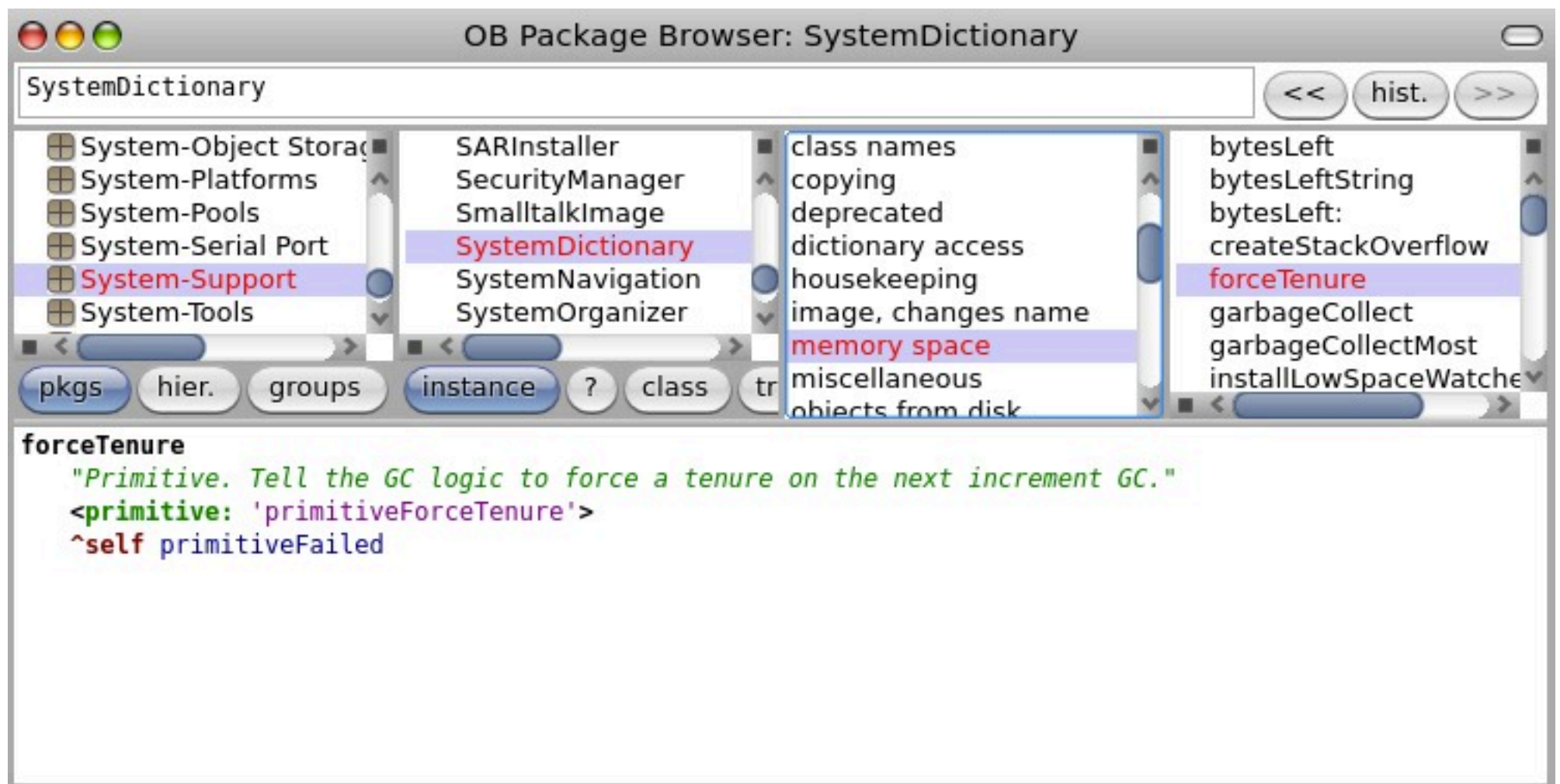
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java.lang.System is the perfect example. It offers methods ranging from writing on the standard streams to copying arrays and managing security.



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Note that the heuristic given before is also valid for packages. Consider the package `java.util`. This package contains 229 classes, most of them are collections. But it also contains the classes `Data`, `JapaneseImperialCalendar`, `Locale`, `Random`, `XMLUtils` and many more unrelated classes.



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In the Pharo and Squeak Smalltalk languages, the class SystemDictionary is another example of a god class.

SystemDictionary enables one to control the garbage collectors, streaming objects, accessing classes, querying the systems. It has little to do with the notion of dictionary!

In application that consist of an object-oriented model interaction with a user interface, the model should never be dependent on the interface.

The interface should be dependent on the model

In Mozilla:

dom/base/nsDOMWindowUtils.cpp

```
/* -*- Mode: C++; tab-width: 2; indent-  
tabs-mode: nil; c-basic-offset: 2 -*- */  
/* ***** BEGIN LICENSE BLOCK *****  
 * Version: MPL 1.1/GPL 2.0/LGPL 2.1  
 * . . .  
#include "nsIDOMHTMLCanvasElement.h"  
#include "nsICanvasElement.h"  
#include "gfxContext.h"  
#include "gfxImageSurface.h"  
 * . . .
```

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Have a look at the definition of the class nsDOMWindowUtils, which is central to the DOM component of Mozilla.

This class has references to some graphical packages, which goes against the idea of having a clean and modular DOM.

**belong to
the core**

In Mozilla:

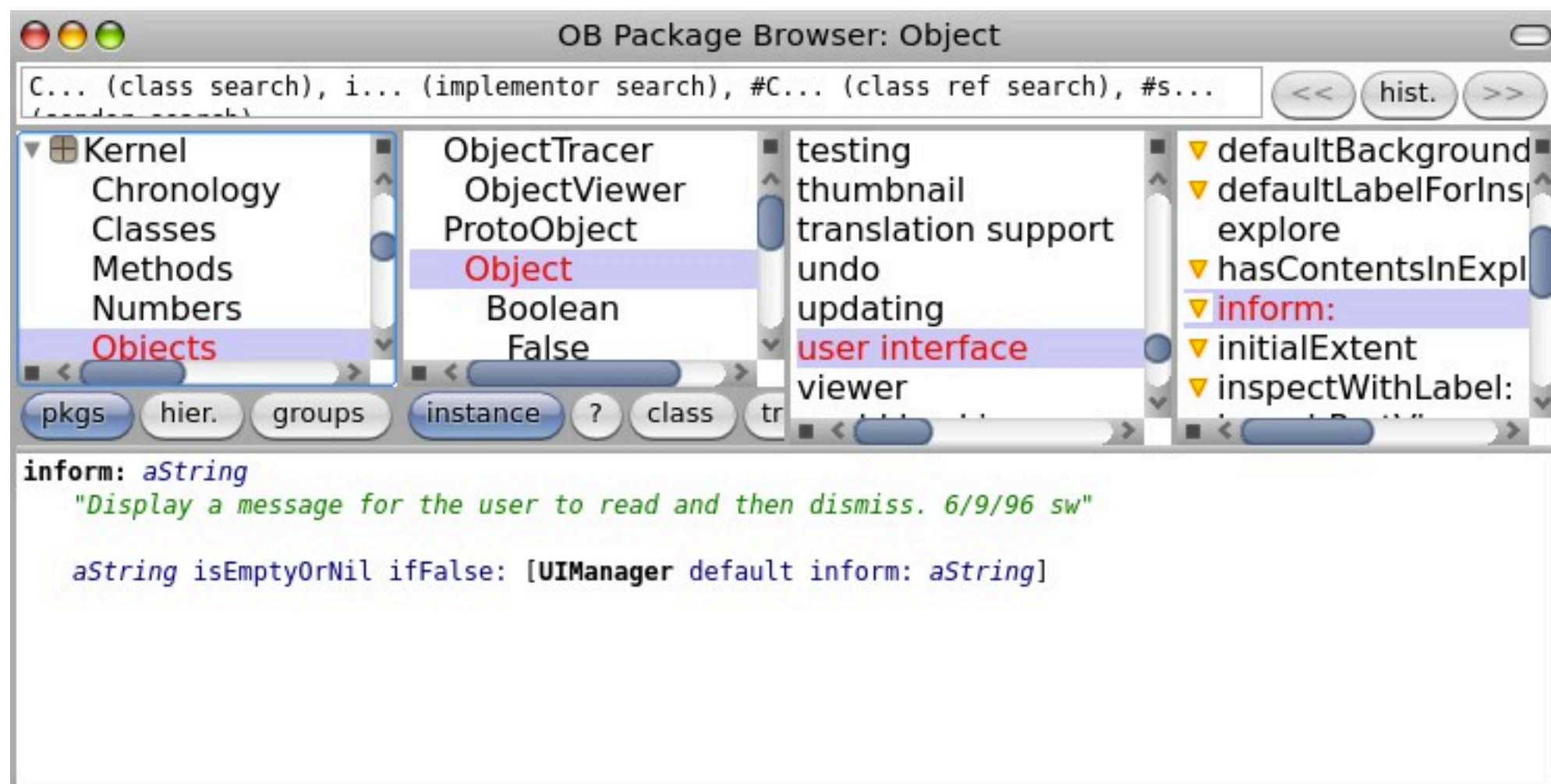


`dom/base/nsDOMWindowUtils.cpp`

```
/* -*- Mode: C++; tab-width: 2; indent-  
tabs-mode: nil; c-basic-offset: 2 -*- */  
/* ***** BEGIN LICENSE BLOCK *****  
 * Version: MPL 1.1/GPL 2.0/LGPL 2.1  
...  
#include "nsIDOMHTMLCanvasElement.h"  
#include "nsICanvasElement.h"  
#include "gfxContext.h"  
#include "gfxImageSurface.h"  
...
```

**belong to
gfx package**

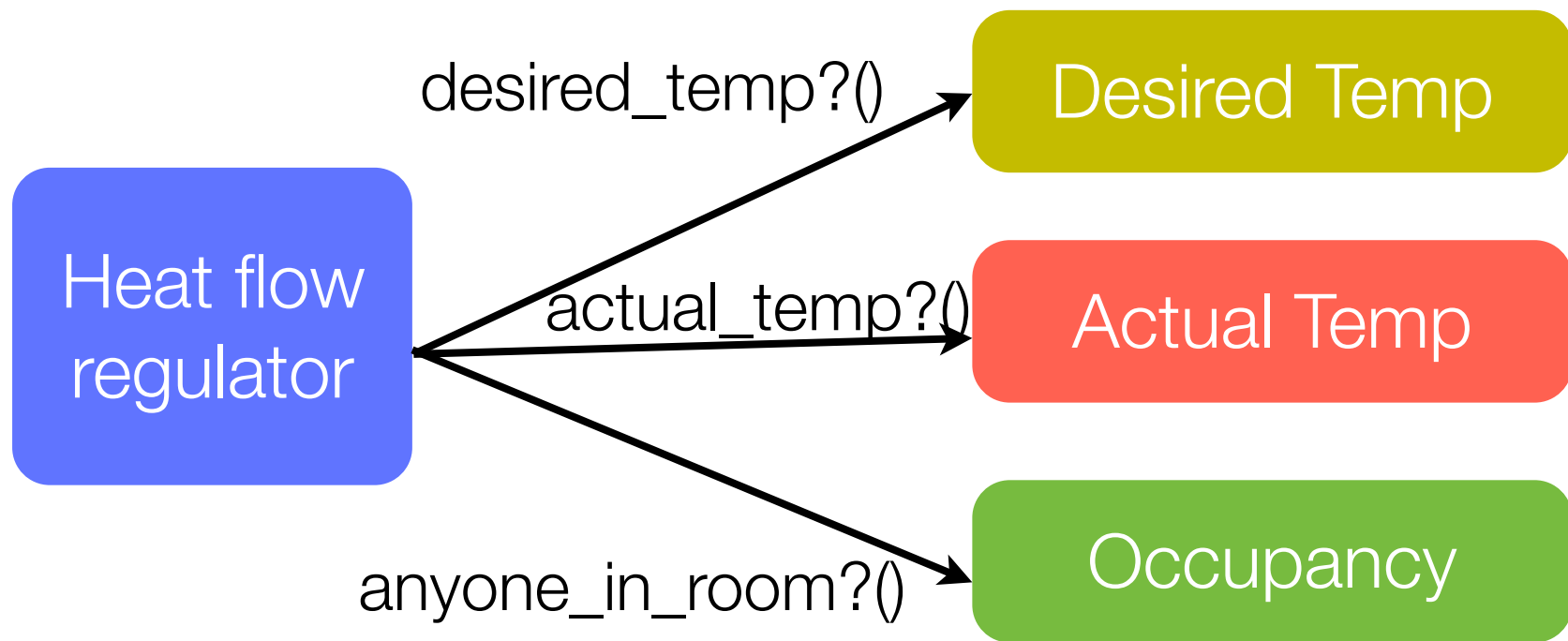




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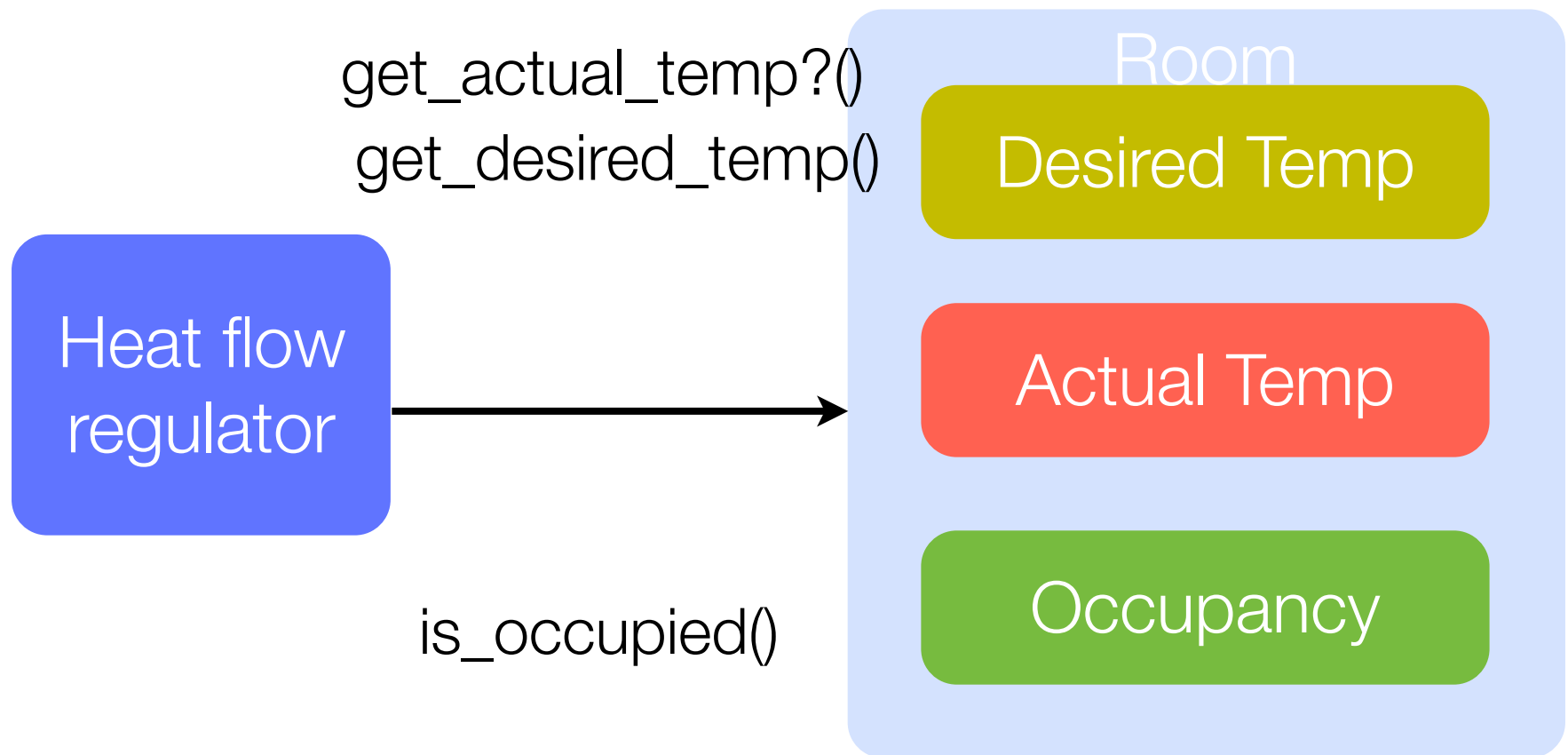
Another example of the kernel of Pharo. The class Object contains a reference to the UIManager, which belongs to the package ToolBuilder. The method #inform: is clearly wrongly packaged

About encapsulation



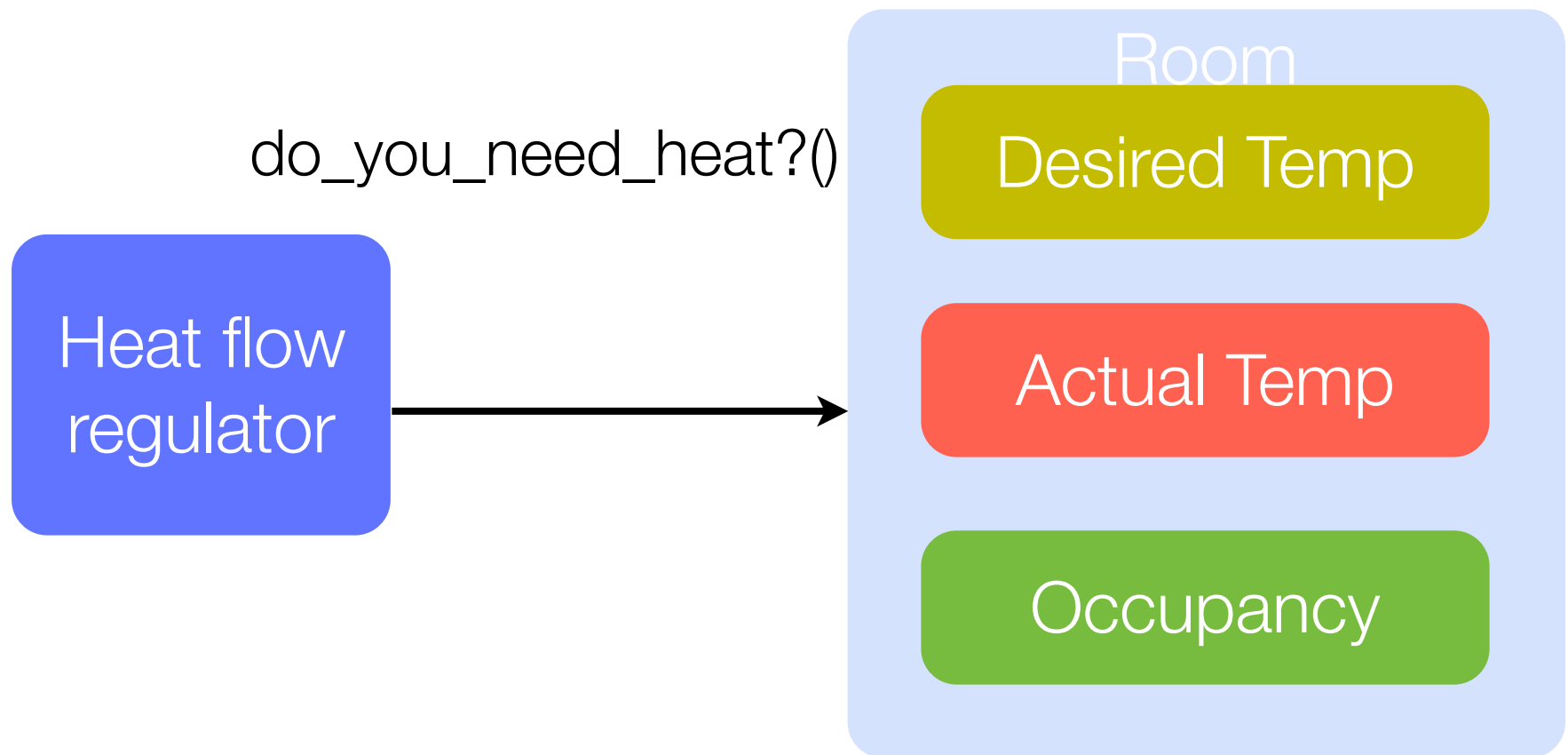
Home heating system without encapsulation

About encapsulation



Home heating system with encapsulation

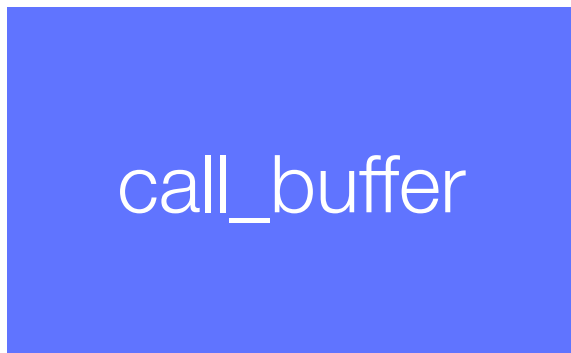
About encapsulation



Home heating system with distributed intelligence

Do not turn an operation into a class. Be suspicious of any class whose name is a verb or is derived from a verb.

DigitCollector



call_buffer

DialToneInitiator



connector

Classes which should be operations

TelephoneCall



call_buffer
connector

A better design for telephone services

The relationship between classes and objects

Minimize the number of classes with which another class collaborates

```
public class JTable extends JComponent implements TableModelListener,  
Scrollable,  
    TableColumnModelListener, ListSelectionListener, CellEditorListener,  
    Accessible, RowSorterListener  
{  
    ...  
    /** The <code>TableModel</code> of the table. */  
    protected TableModel      dataModel;  
  
    /** The <code>TableColumnModel</code> of the table. */  
    protected TableColumnModel columnModel;  
  
    /** The <code>ListSelectionModel</code> of the table, used to keep  
track of row selections. */  
    protected ListSelectionModel selectionModel;  
  
    /** The <code>TableHeader</code> working with the table. */  
    protected JTableHeader      tableHeader;  
    ...  
}
```

```

public class JTable extends JComponent implements TableModelListener,
Scrollable,
    TableColumnModelListener, ListSelectionListener, CellEditorListener,
    Accessible, RowSorterListener
{
    ...
    /** The <code>TableModel</code> of the table. */
    protected TableModel tableModel;

    /** The <code>TableColumnModel</code> of the table. */
    protected TableColumnModel tableColumnModel;

    /** The <code>ListSelectionModel</code> of the table, used to keep
    track of row selections. */
    protected ListSelectionModel selectionModel;

    /** The <code>JTableHeader</code> working with the table. */
    protected JTableHeader tableHeader;
    ...
}

```

JTable depends on more
than 50 different classes

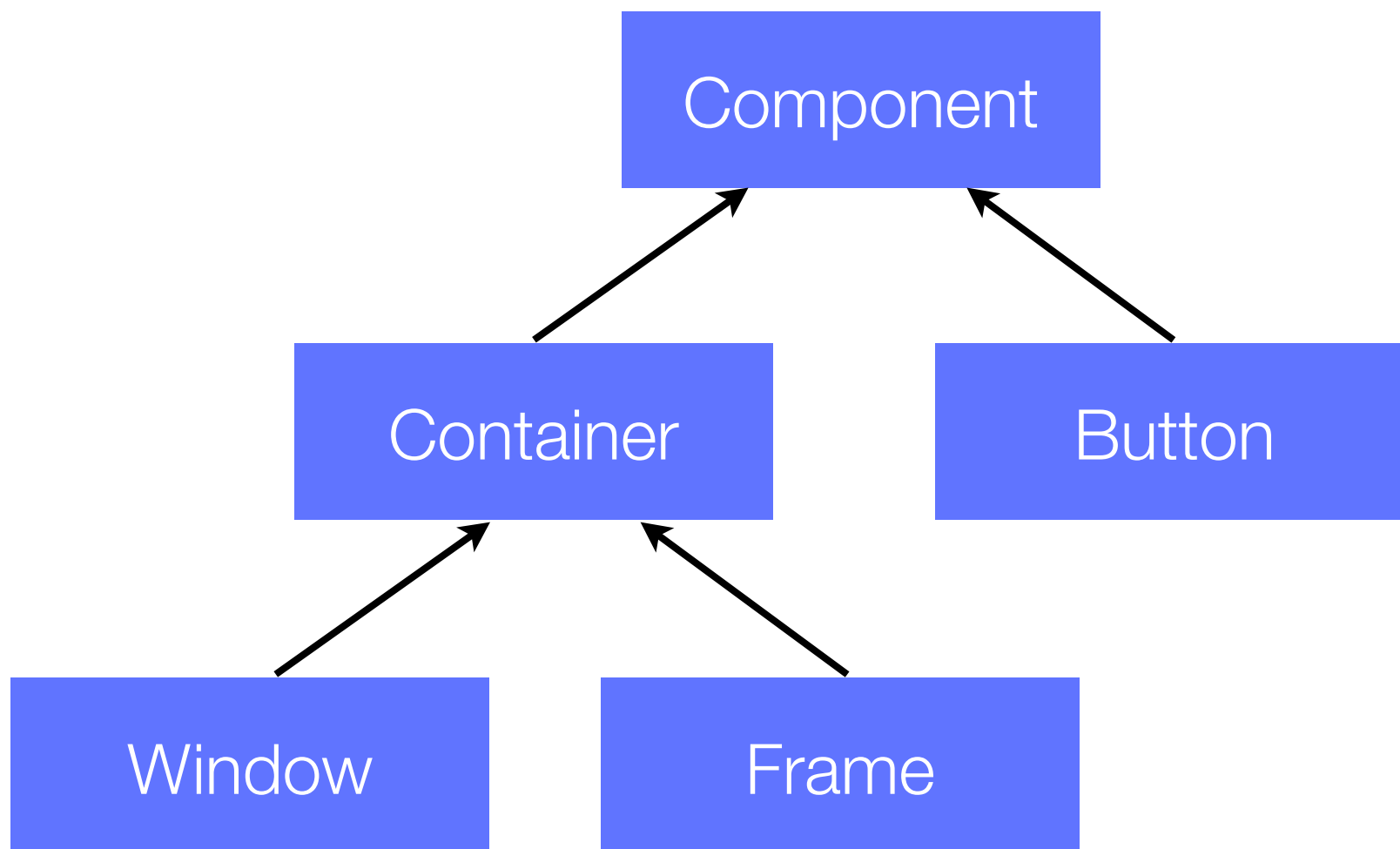
The inheritance relationship

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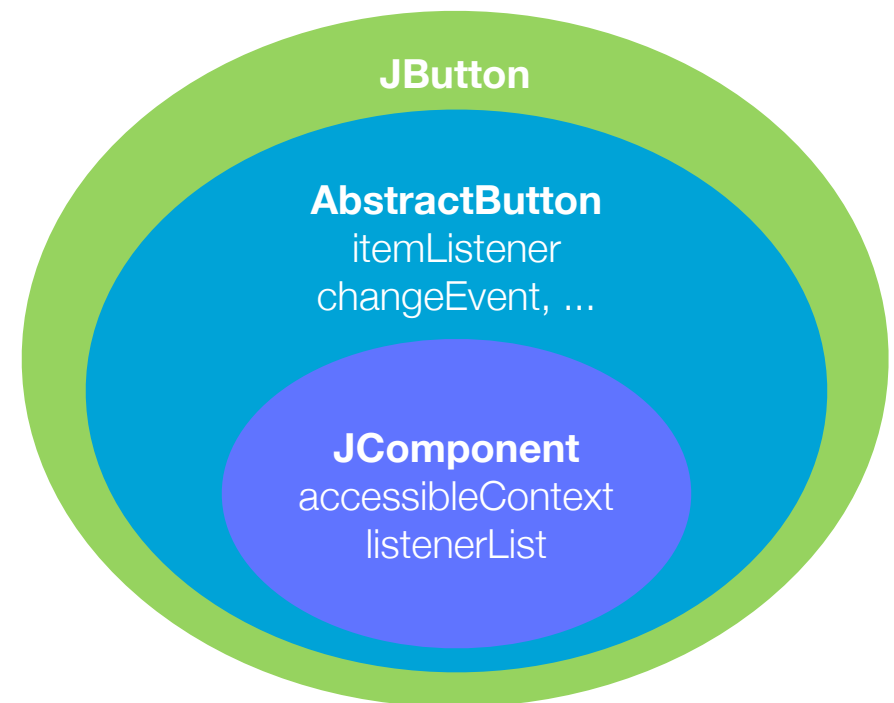
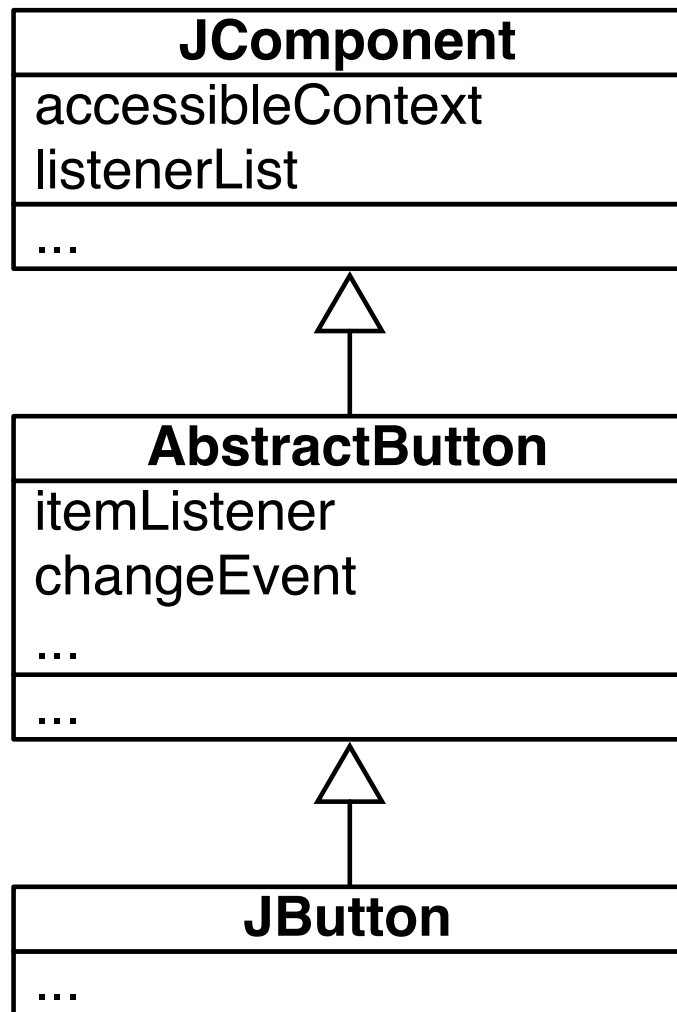
Inheritance

The Inheritance relationship is one of the most important relationships within object-orientation

It is best used to capture the *a-kind-of* relationship between classes



Example of the core of java.awt



Virtual Classes

A powerful mechanism in object-oriented programming

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Abstract

The notions of class, subclass and virtual procedure are fairly well understood and recognized as some of the key concepts in object-oriented programming. The possibility of modifying a virtual procedure in a subclass is a powerful technique for specializing the general properties of the superclass.

In most object-oriented languages, the attributes of an object may be references to objects and (virtual) procedures. In Simula and BETA it is also possible to have class attributes. The power of class attributes has not yet been widely recognised. In BETA a class may also have *virtual class attributes*. This makes it possible to defer part of the specification of a class attribute to a subclass. In this sense virtual classes are analogous to virtual procedures. Virtual classes are mainly interesting within strongly typed languages where they provide a mechanism for defining general parameterised classes such as set, vector and list. In this sense they provide an alternative to generics.

Although the notion of virtual class originates from BETA, it is presented as a general language mechanism.

Keywords: languages, virtual procedure, virtual class, strong typing, parameterized class, generics, BETA, Simula, Eiffel, C++, Smalltalk

1 Introduction

The notions of class and subclass are some of the key language concepts associated with object-oriented pro-

gramming. Classes support the classification of objects with the same properties, and subclassing supports the specialisation of the general properties. A class defines a set of attributes associated with each instance of the class. An attribute may be either an object reference (or just reference for short) or a procedure.

In a subclass it is possible to specialize the general properties defined in the superclass. This can be done by adding references and/or procedures. However, it is also possible to modify the procedures defined in the superclass. Modification can take place in different ways. In Simula 67 [4] a procedure attribute may be declared virtual. A virtual procedure may then be redefined in a subclass. A non-virtual procedure cannot be redefined¹. This is essentially the same scheme adapted by C++ [16] and Eiffel [13]. In Smalltalk [6] any procedure is virtual in the sense that it can be redefined in a subclass, and even the parameters of a procedure may be redefined.

In BETA [8] a virtual procedure cannot be redefined in a subclass, but it may be further defined by an *extended* definition. The extended procedure is a "sub-procedure" (in the same way as for subclass) of the procedure defined in the superclass. This implies that the actions of a virtual procedure definition are automatically combined with the actions of the extended procedure in a subclass. This is the case for all levels of subclasses that further defines a virtual procedure. In Smalltalk and C++ it is the responsibility of the programmer to combine a redefined virtual procedure with the corresponding virtual procedure of the superclass. This is of course more flexible, since the programmer can ignore the procedure in the superclass. However, it is also a potential source of error since the programmer may forget to execute the virtual procedure from the superclass.

Using the terminology from [18] a class in BETA

¹In Simula a subclass may declare a new procedure with the same name as a procedure defined in a superclass. This does not have the effect of a redefinition as in Smalltalk.

@OOPSLA'89

```
Window: class Stream
  (# UpperLeft,LowerRight: @ Point;
   Label: ~ Text;
   Move: proc (# ... #);
   Display: virtual proc (# ... #);
  #)
```

Figure 2: Example of class declaration

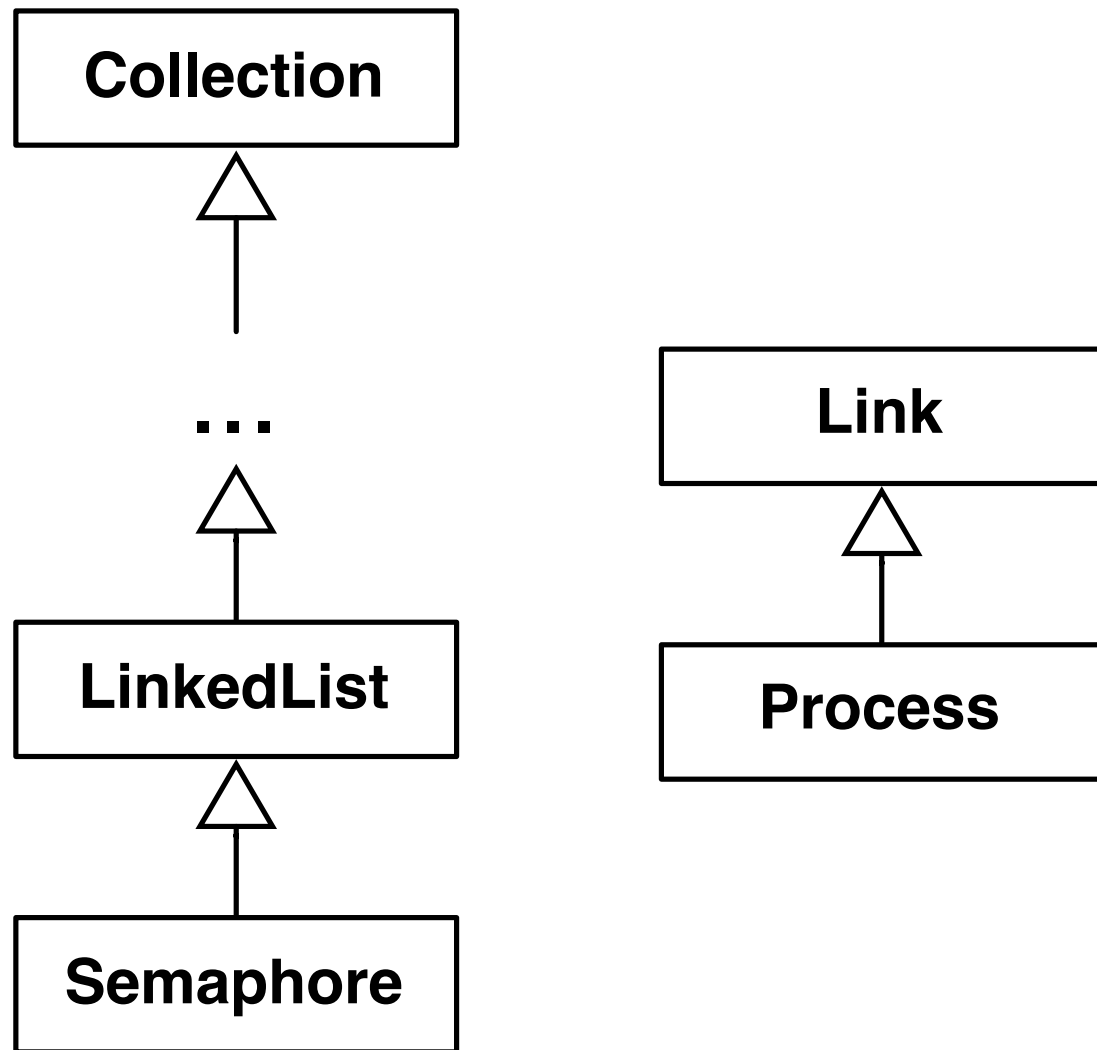
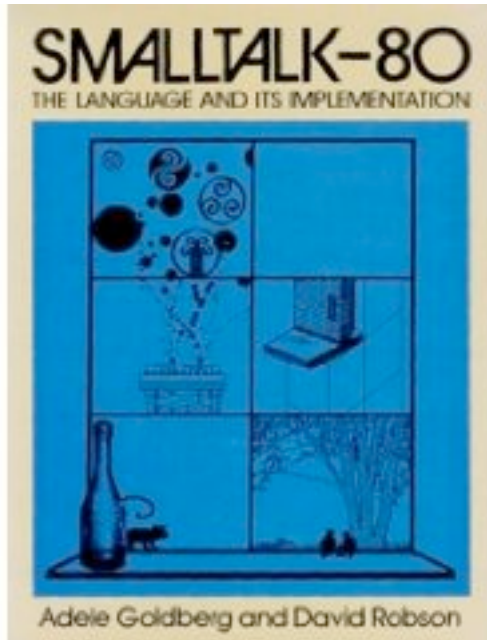
“In Figure 2 an example of a class is given. Class Window is described as a subclass of class Stream. ...”

```
Window: class Stream
  (# UpperLeft,LowerRight: @ Point;
   Label: ~ Text;
   Move: proc (# ... #);
   Display: virtual proc (# ... #);
  #)
```

Figure 2: Example of class declaration

“In Figure 2 an example of a class is given. Class Window is described as a subclass of class Stream. ...”

Do you think a window can be considered as a stream?



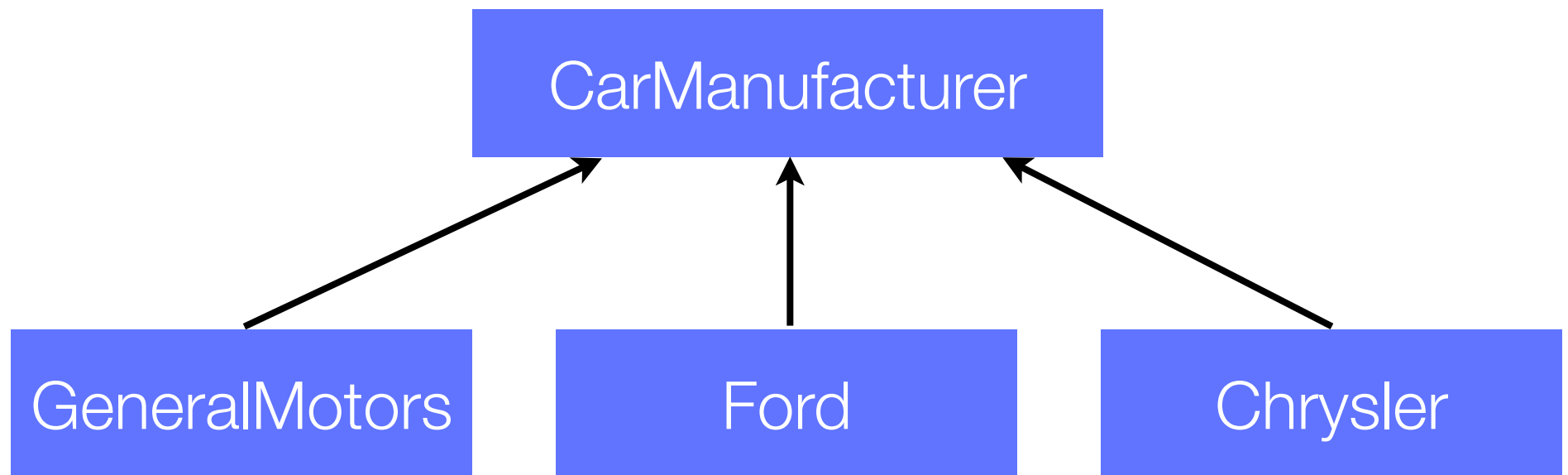
Probably a semaphore can be seen as a collection, but is it worth subclassing `LinkedList` in that case?

All abstract classes must be base classes

All abstract classes must be base classes

Since an abstract class cannot be instantiated, does it make sense to have an abstract class leaf?

Mistaking objects for derived classes



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Consider the inheritance hierarchy given on this slide. At first view the inheritance hierarchy looks correct. GeneralMotors, Ford and Chrysler are all special types of car manufacturers. On second thought, is GeneralMotors really a special type of car manufacturer? Or is it an example of a car manufacturer? This is a classic error and it causes proliferation of classes.

how many GeneralMotors objects are there? Ford objects? Chrysler objects? The answer for all three classes is one. In this case they should have been objects.

Keep in mind that not all derived classes that have only one instance in your system are manifestations of this error, but many will be.

It should be illegal for a derived class to override a base class method with a NOP method, that is, a method that does nothing



What is wrong with this design?

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Consider a class `Dog`. The behaviors that all `Dogs` know how to carry out is `bark`, `chase_cats` and `wag_tail`. Consider that we want to have a dog that does not wag its tail, let's say `DogNoWag`. This new class is exactly like a `Dog` except it doesn't know how to wag its tail. A solution could be to have `DogNoWag` inherit from `Dog` and override the `wag_tail` method with an empty method (NOP).



This design does not capture a logical relationship

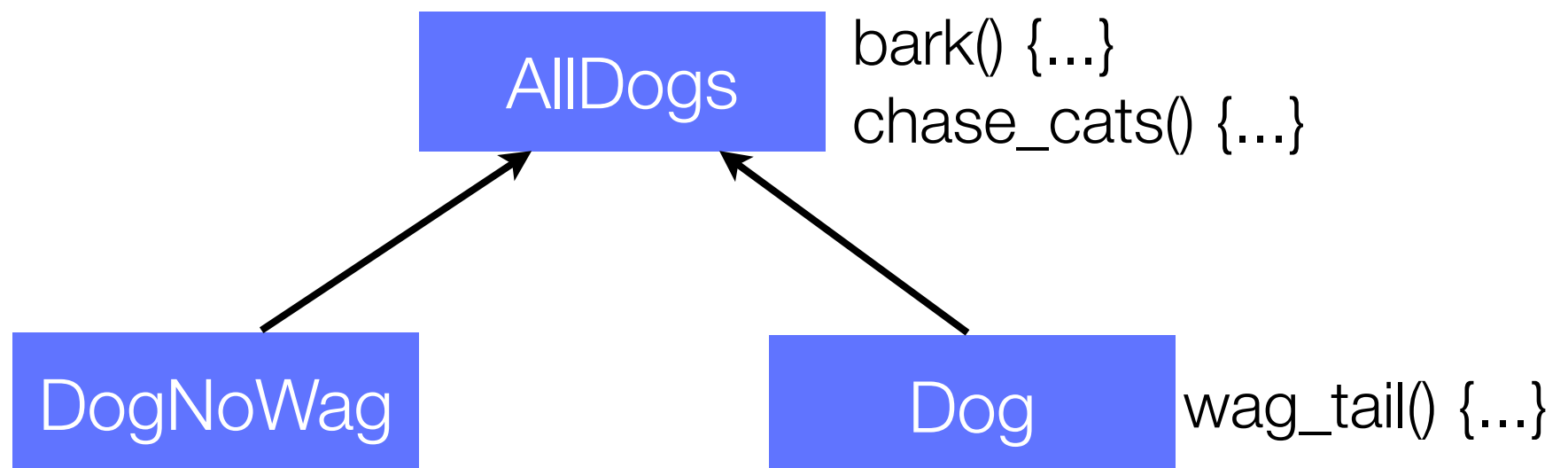
It implies the following statements:

All dogs know how to wag their tails

DogNoWag is a special type of dog

DogNoWag does not know how to wag its tail

The rules of classic logic are not being obeyed



Dogs and their tails...

Some other heuristics

When building an inheritance hierarchy, try to construct reusable frameworks rather than reusable components

Users of a class must be dependent on its public interface, but a class should not be dependent on its users

Minimize the number of message sends between a class and its collaborator

A class must know what it contains, but it should not know who contains it

All base classes should be abstract classes

All base classes should be abstract classes

*Not everybody will agree with this one (including me),
but this heuristic deserves some attention*