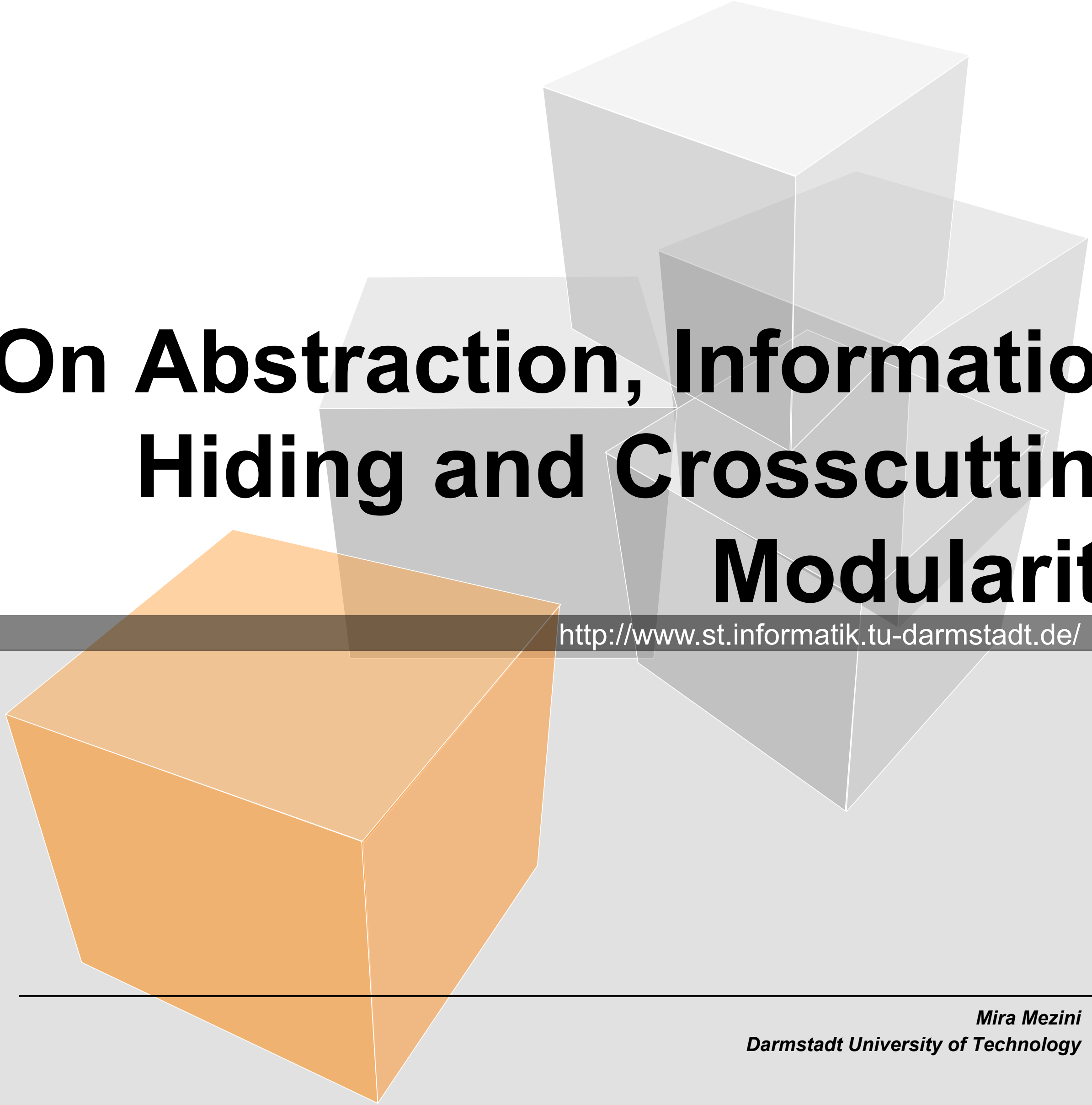
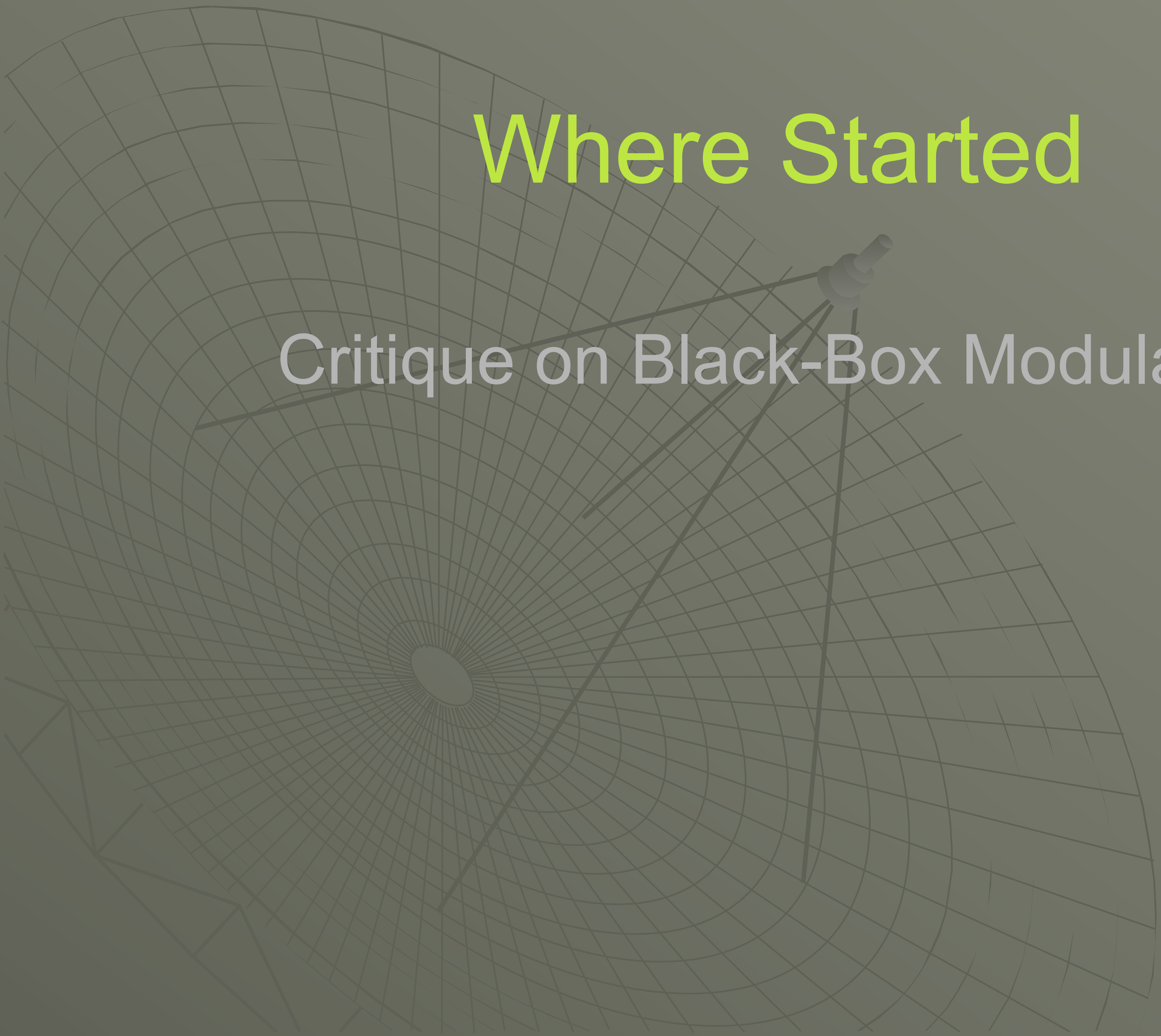


On Abstraction, Information Hiding and Crosscutting Modularity

http://www.st.informatik.tu-darmstadt.de/

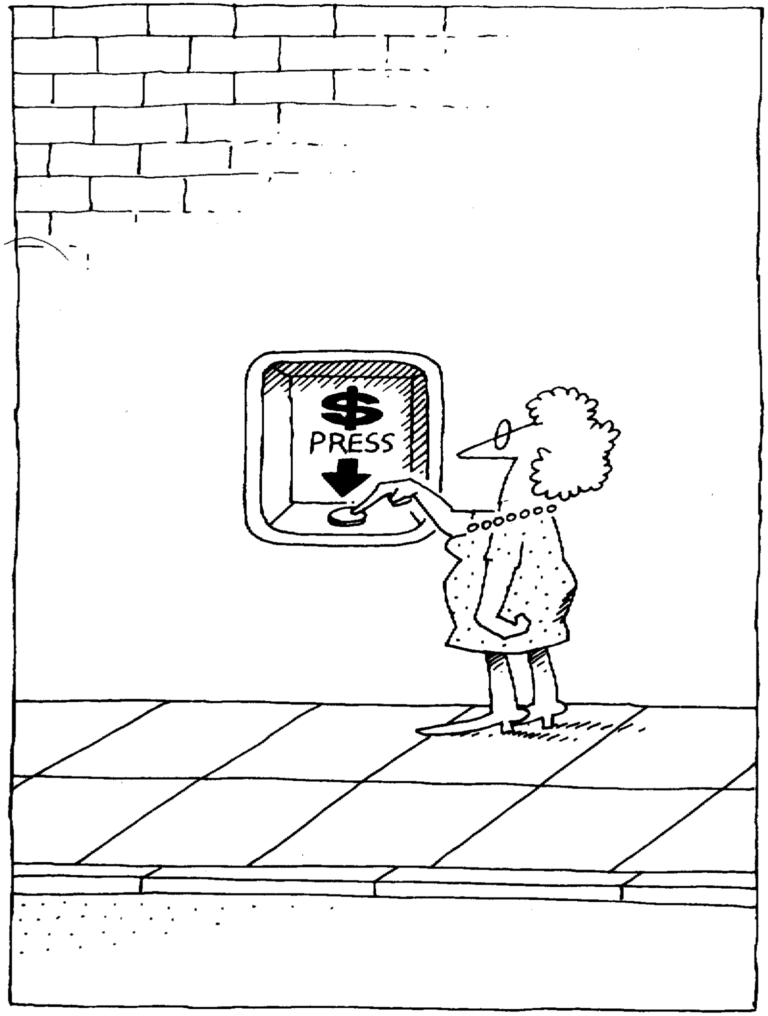
Mira Mezini
Darmstadt University of Technology

Where Started



Critique on Black-Box Modularity

Black-Box Abstraction



HIDE!

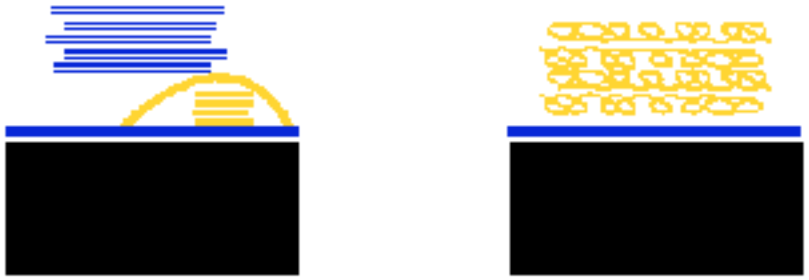
BUT, WHAT?

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

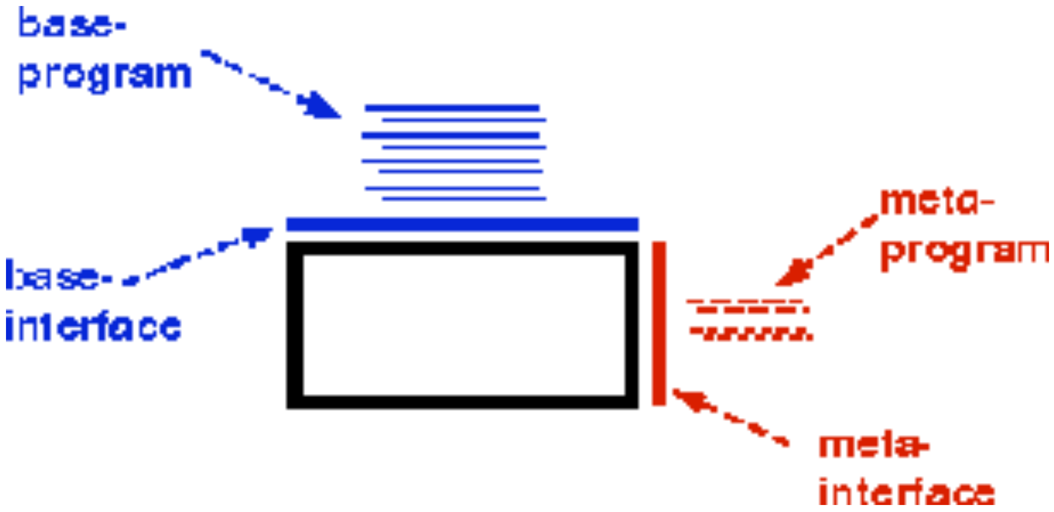
Parnas

WHATEVER IS LIKELY TO CHANGE!

Kiczales: Beyond the Black-Box



Clients confront an issue that the interface claimed to hide.



An open implementation presents two interfaces

Harrison & Ossher on Subjectivity

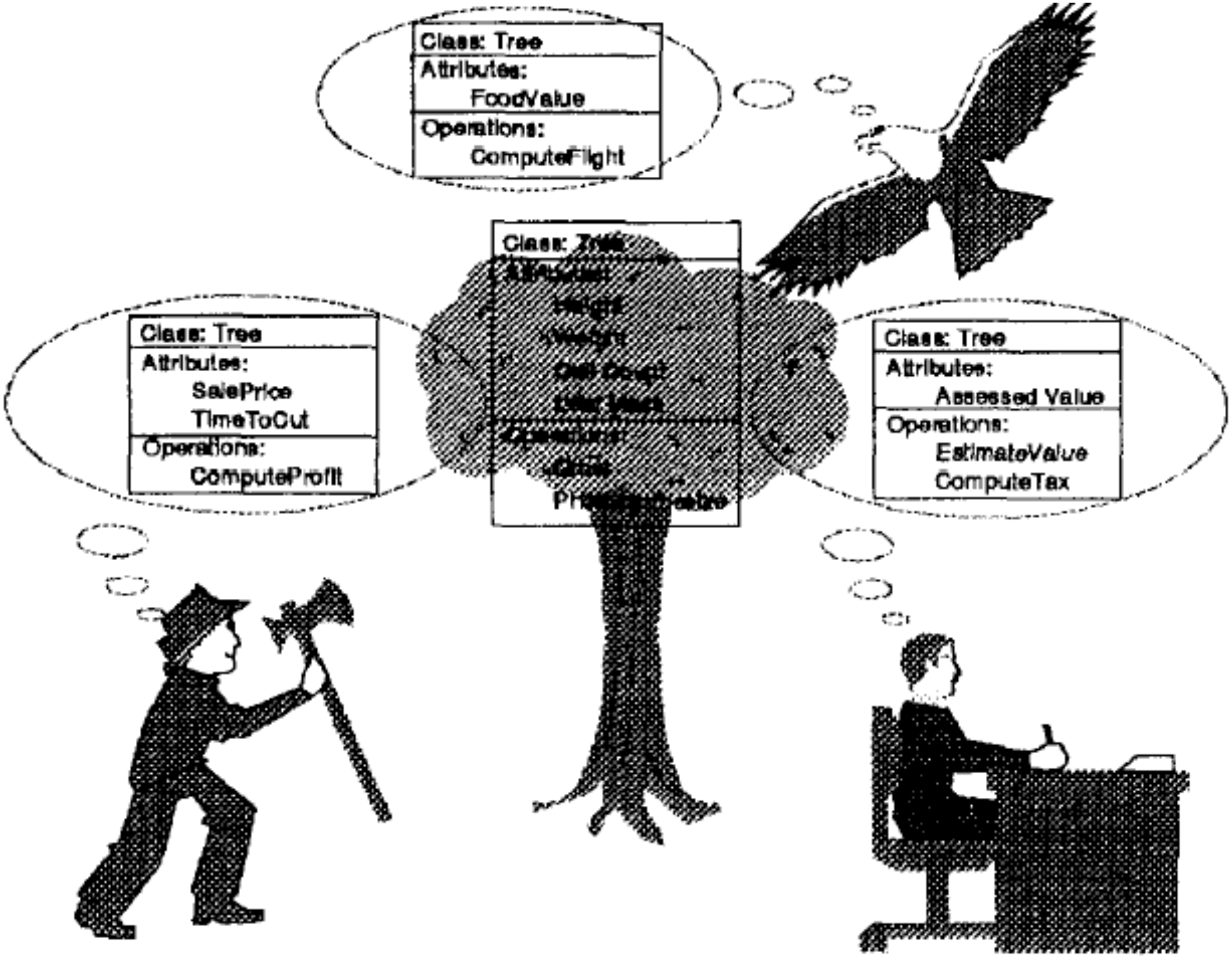
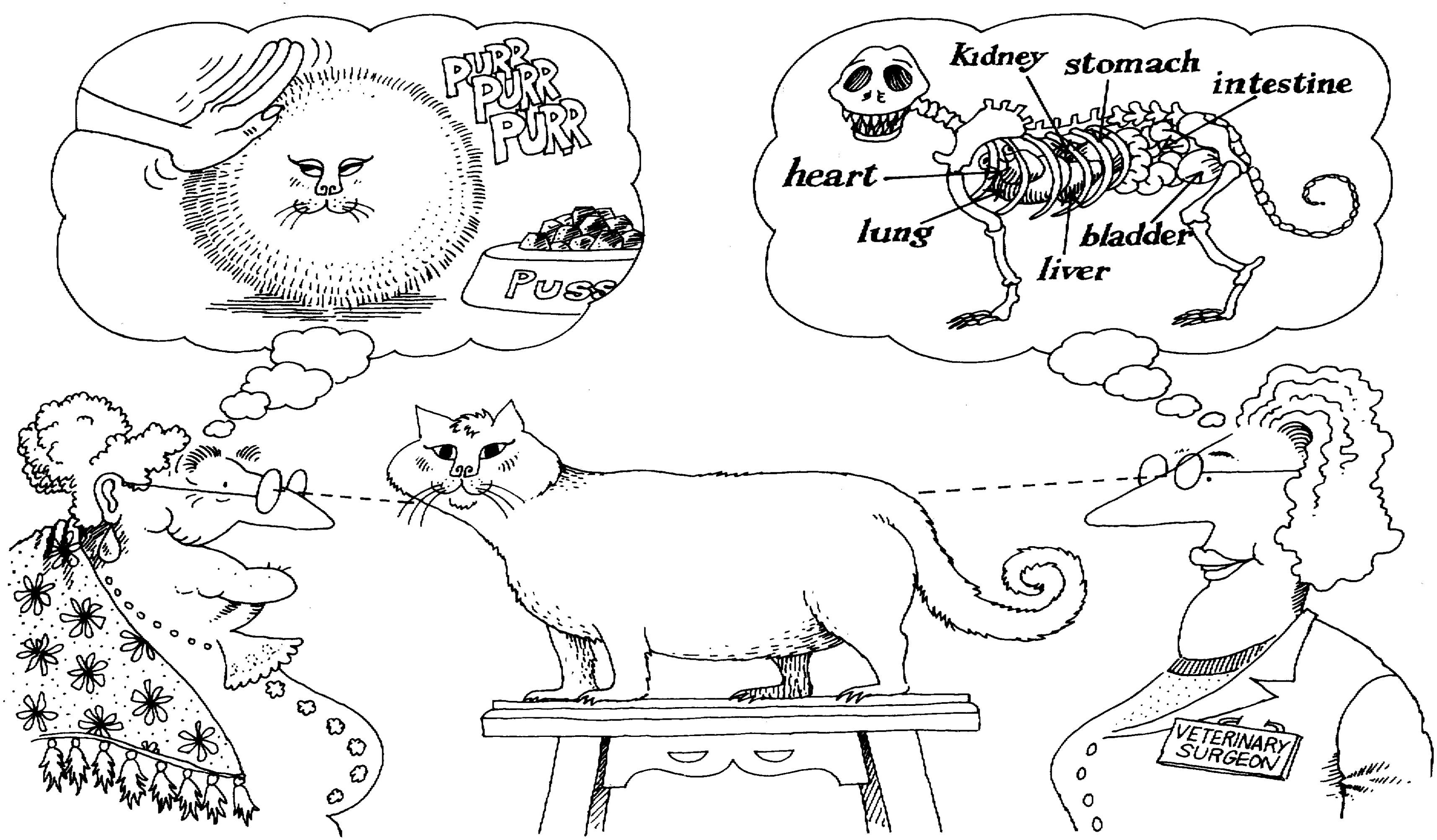


Figure 3 - Many Subjective Views of an Object-Oriented Tree

Grady Booch on Subjectivity



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

Where we are

AOP improves software modularity

- anonymous AOP researcher

AOP is anti-modular.

- anonymous non-AOP researcher

Questions Addressed in [KiczalesMezini05]

- **Does AOP improve or harm modularity?**
  - in presence of crosscutting concerns (CCC) improves modularity of aspects and non-aspects
  - does not harm modularity otherwise

- **If AOP is modular, what is modularity?**
  - nearly the same idea and mechanisms as before
  - except for how interfaces are determined
    - aspect-aware interfaces
    - interface depends on overall system configuration

Form of Argument

- Start with
  - simple definitions of modularity and modular reasoning
  - Java and AspectJ implementations of a simple example

- For both implementations
  - analyze static modularity
  - consider interfaces for both implementations
  - analyze ability to do modular reasoning

- Discussion of *aspect-aware interfaces*

Definitions:

Code implementing a concern is ***modular*** if:

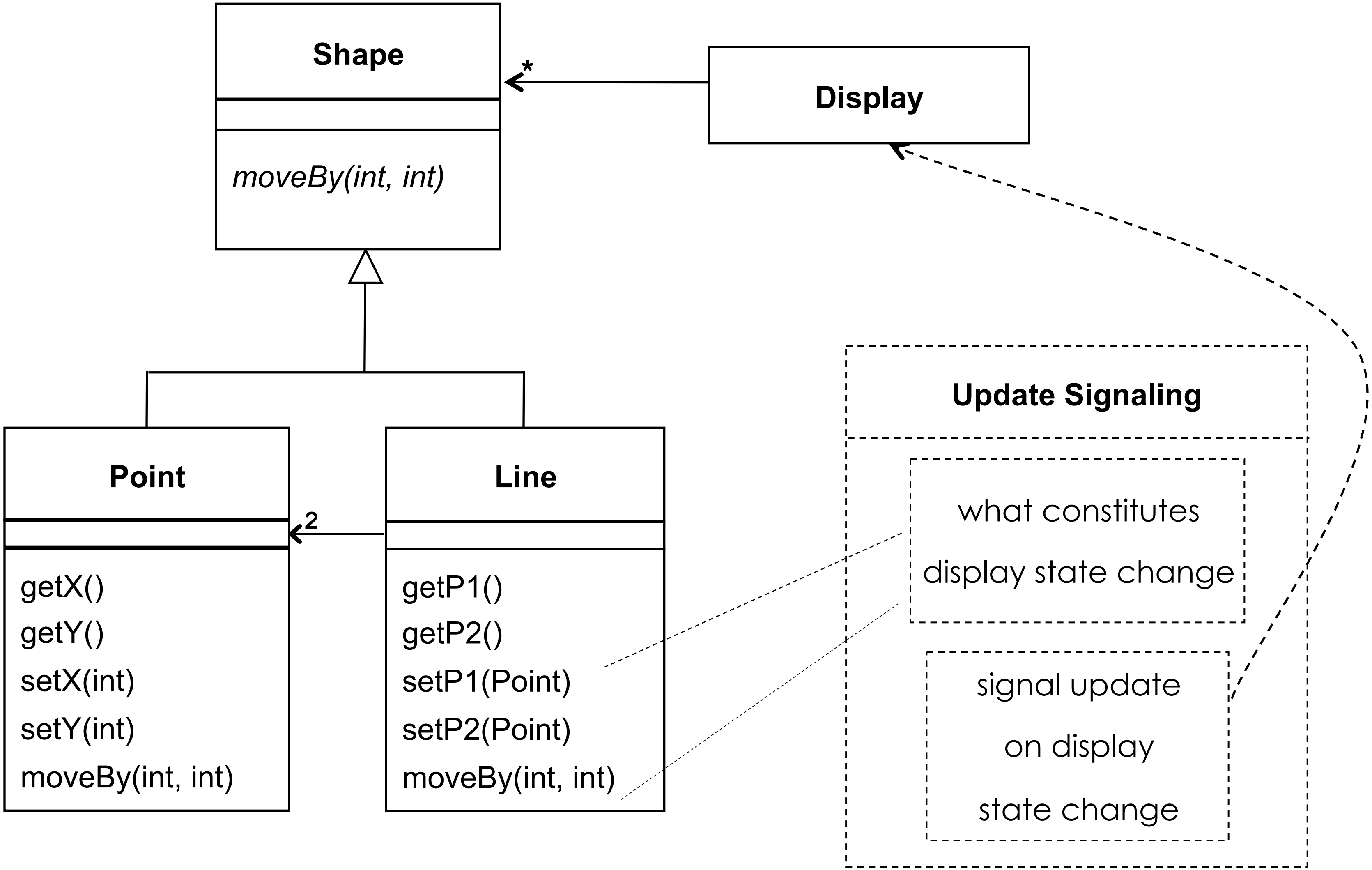
- it is textually local
- It has a well-defined interface
- the interface is an abstraction of the implementation
- interface is enforced
- the module can be automatically composed

- ***Modular reasoning***: make decisions about a module by studying only
  - its implementation and interface
  - interfaces of other modules referenced in the module’s implementation or interface

- ***Expanded modular reasoning***: also study implementations of referenced modules

- ***Global reasoning:*** have to examine all the modules in the system

Example



Shape

moveBy(int, int)

Display

*

Point

getX()
getY()
setX(int)
setY(int)
moveBy(int, int)

Line

getP1()
getP2()
setP1(Point)
setP2(Point)
moveBy(int, int)

2

Update Signaling

what constitutes
display state change

signal update
on display
state change

Java Implementation

```
class Point {
  int x, y;
  ...
  void setX(int nx) {
    x = nx;
    Display.update();
  }
}
```

```
class Line {
  Point p1, p2;
  ...
  void moveBy(int dx, int dy) {
    p1.x += dx; p1.y += dy;
    p2.x += dy; p2.y += dy;
    Display.update();
  }
}
```

AspectJ Implementation

```
class Point {
  int x, y;
   ...
  void setX(int nx) {
    x = nx;
  }
}
```

```
class Line {
  Point p1, p2;
  ...
  void moveBy(int dx, int dy) {
    p1.x += dx; p1.y += dy;
    p2.x += dy; p2.y += dy;
  }
}
```

```
aspect UpdateSignaling {
  pointcut change():    execution(void Point.setX(int))
                     || execution(void Point.setY(int))
                     || execution(void Shape.moveBy(int, int));
  after() returning: change() {
    Display.update();
  }
}
```

Modularity Assessment

		localized	interface	abstraction	enforced	composable
non AOP	display updating	no	n/a	n/a	n/a	n/a
	Point, Line	medium	medium	medium	yes	yes

```
class Line {
  ...
  void moveBy(int dx, int dy) {
    p1.x += dx; p1.y += dy;
    p2.x += dy; p2.y += dy;
    Display.update();
  }
}
```

```
class Point {
   ...
  void setX(int nx) {
     x = nx;
     Display.update();
  }
}
```

Modularity Assessment

		localized	interface	abstraction	enforced	composable
non AOP	display updating	no	n/a	n/a	n/a	n/a
	Point, Line	medium	medium	medium	yes	yes
AOP	display updating	high	high	medium	yes	yes
	Point, Line	high	high	high	yes	yes

```
class Line {
  ...
  void moveBy(int dx, int dy) {
    p1.x += dx; p1.y += dy;
    p2.x += dy; p2.y += dy;
  }
}
```

```
class Point {
   ...
  void setX(int nx) {
     x = nx;
  }
}
```

OO Interfaces

```
Point implements Shape
  int getX();
  int getY();
  void setX(int);
  void setY(int);
  void moveBy(int, int);

Line
  <similar>
```

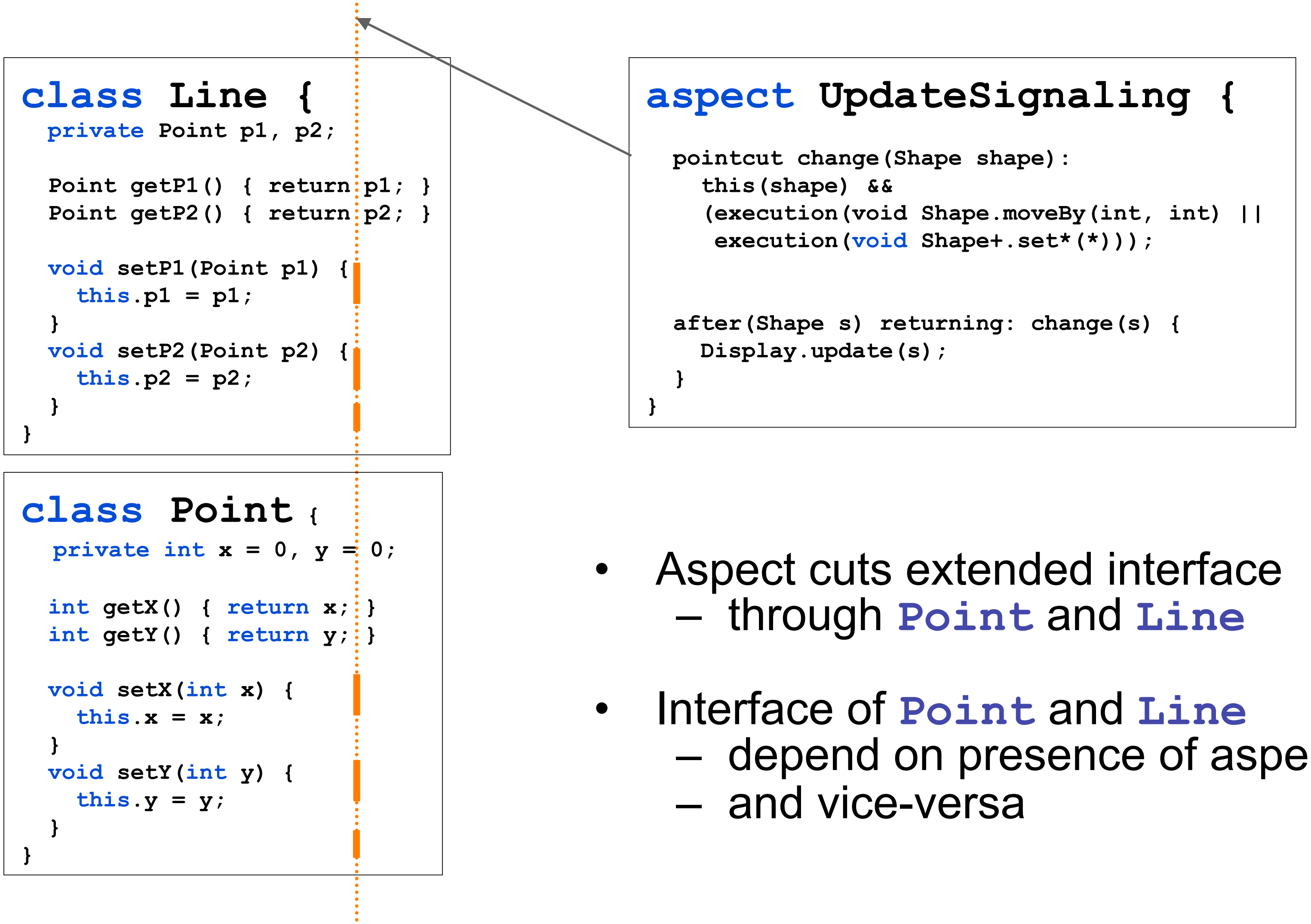
Aspect Aware Interfaces

```
Point implements Shape
  int getX();
  int getY();
  void setX(int): UpdateSignaling – after returning change();
  void setY(int): UpdateSignaling – after returning change();
  void moveBy(int, int): UpdateSignaling – after returning change();

Line
  Point p1, p2;
  Point getP1();
  Point getP2();
  void moveBy(int, int): UpdateSignaling – after returning change();

UpdateSignaling
   after returning: change():
    Point.setX(int), Point.setY(int), Point.moveBy(int, int),
    Line.moveBy(int, int);
```

Interface Depends on Deployment



```
class Line {
  private Point p1, p2;

  Point getP1() { return p1; }
  Point getP2() { return p2; }

  void setP1(Point p1) {
    this.p1 = p1;
  }
  void setP2(Point p2) {
    this.p2 = p2;
  }
}
```

```
class Point {
   private int x = 0, y = 0;

  int getX() { return x; }
  int getY() { return y; }

  void setX(int x) {
    this.x = x;
  }
  void setY(int y) {
    this.y = y;
  }
}
```

```
aspect UpdateSignaling {

  pointcut change(Shape shape):
    this(shape) &&
    (execution(void Shape.moveBy(int, int) ||
     execution(void Shape+.set*(*)));


  after(Shape s) returning: change(s) {
    Display.update(s);
  }
}
```

- Aspect cuts extended interface
  - through `Point` and `Line`
- Interface of `Point` and `Line`
  - depend on presence of aspects
  - and vice-versa

Modular Reasoning Scenario

- The example has a weakness
  - `x` and `y` fields of `Point` are public
- The programmer decides to make `x` and `y` private.
- When doing this (s)he must ensure the system works as before.

```
class Point {
  int x, y;
   ...
  void setX(int nx) {
    x = nx;
  }
}
```

We compare :

- reasoning with traditional interfaces about the non-AOP code against
- reasoning with AAIs about the AOP code.

Reasoning About Change

Both implementations start out the same

- define accessors
- global reasoning to find references to fields
- change to use accessors
- simple change to **`Line.moveBy`** method

```
void moveBy(int dx  int dy) {
  p1.x += dx;
  p1.y += dy;
  p2.x += dy;
  p2.y += dy;
}
```

```
void moveBy(int dx, int dy) {
  p1.setX(p1.getX() + dx);
  p1.setY(p1.getY() + dy);
  p2.setX(p2.getX() + dx);
  p2.setY(p2.getY() + dy);
}
```

Is this change reasonable? Does it affect other concerns?
What kind of reasoning do I need to reach a conclusion?

Reasoning About Change

To discover the effect of this potential change – violation of the display updating invariant - the programmer needs to pieces of information:

- a specification of the invariant: *“update the display after any top-level change of a figure element”*
- structure of update signaling to infer that the invariant would be violated by the change.

Reasoning in OOP

- Discovering the invariant description
  - Nothing in **`Line`** is likely to describe the invariant.
  - Due to explicit call to **`Display.update()`**, the programmer might go look at the **`Display`** class.
    - We assume, optimistically, that **`update()`**’s documentation contains the invariant.
  - Expanded modular reasoning with one step leads the programmer to the invariant

- Discovering the structure of update signaling requires at least further expanded modular reasoning and in general global reasoning

Recovering in OOP

- Add non-update-signaling setter methods to `Point` for the sole purpose of calling them from `Line.moveBy`?

  … **maintenance nightmare**

- The best I can do is probably to let `x` and `y` public… this is probably the reason why they were package public at first place!
- **Information hiding is broken not by accident!**

Reasoning and Recovering in the AOP

- The interface of `UpdateSignaling` includes the complete structure of what method executions will signal updates.
  - modular reasoning provides this information

- Once the programmer understands that the change is invalid, the proper fix is to use `cflowbelow`:

```
after() returning: change() && !cflowbelow(change())
  { Display.update(); }
```

Intermediate Conclusions

Current modularity is not as good as claimed.

- With AOP,
  - its interface cuts through the classes,
  - the structure of that interface is captured declaratively,
  - the actual implementation is modularized
- Without AOP,
  - the structure is implicit
  - the actual implementation is not modular.
  - In presence of crosscutting concerns static modularity and modular reasoning are impaired

Intermediate Conclusions

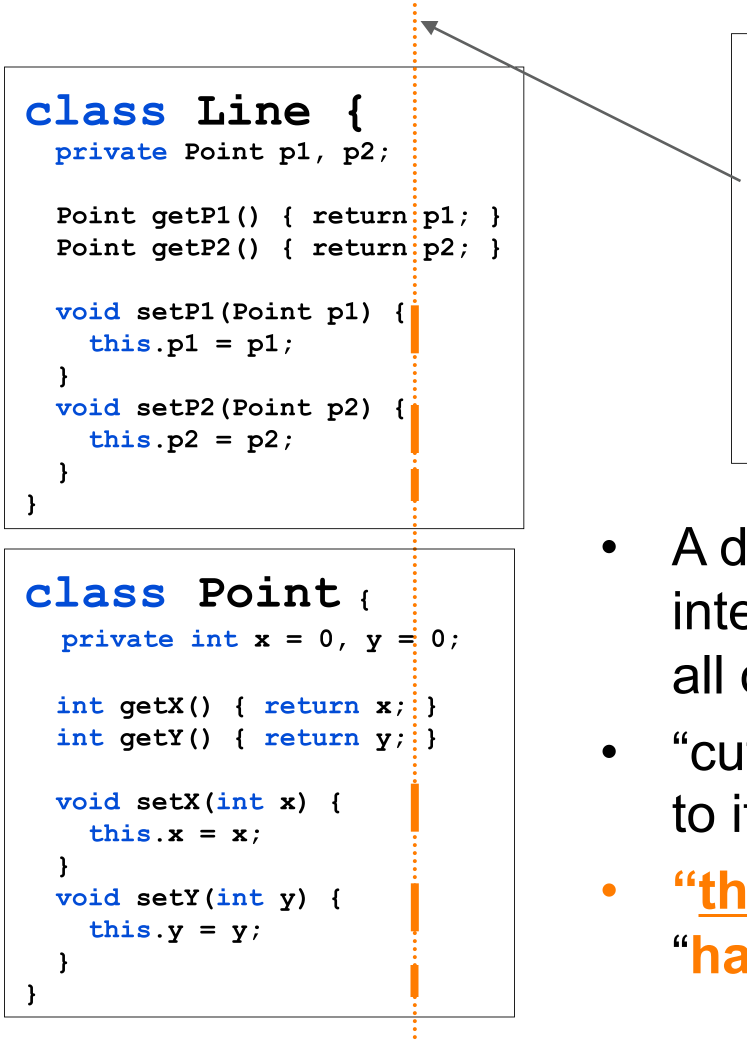
The cost: We must know the deployment setting to know the interface of a module.

- But, for CCCs we inherently have to pay the main cost of AOP.
- We have to know something about the total deployment configuration, in order to do the global reasoning required to reason about crosscutting concerns.

- By using AOP, we get modular reasoning benefits back, whereas not using AOP we do not.
- constructing aspect-aware interfaces is simple: pointcuts (or other mechanisms) can be declarative

To Hide or Not to Hide?

AGILE INFORMATION HIDING



```
class Line {
  private Point p1, p2;

  Point getP1() { return p1; }
  Point getP2() { return p2; }

  void setP1(Point p1) {
    this.p1 = p1;
  }
  void setP2(Point p2) {
    this.p2 = p2;
  }
}
```

```
class Point {
   private int x = 0, y = 0;

  int getX() { return x; }
  int getY() { return y; }

  void setX(int x) {
    this.x = x;
  }
  void setY(int y) {
    this.y = y;
  }
}
```

```
aspect UpdateSignaling {

  pointcut change(Shape shape):
    this(shape) &&
    (execution(void Shape.moveBy(int, int) ||
     execution(void Shape+.set*(*)));


  after(Shape s) returning: change(s) {
    Display.update(s);
  }
}
```

- A disciplined way to establish additional interface properties without explicitly stating all of them in the interface.
- “cut an interface through there and program to it”
- “**there is** a well-defined interface” versus “**has** a well-defined interface”

What Else Have We Done

A Quick Tour on “my” AOP

The Caesar Story

Critique on AspectJ-like Languages

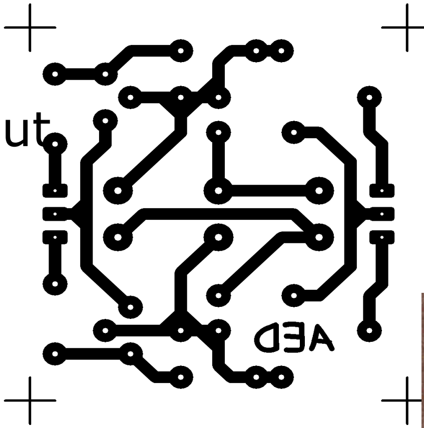
- Physical separation of aspect from base code

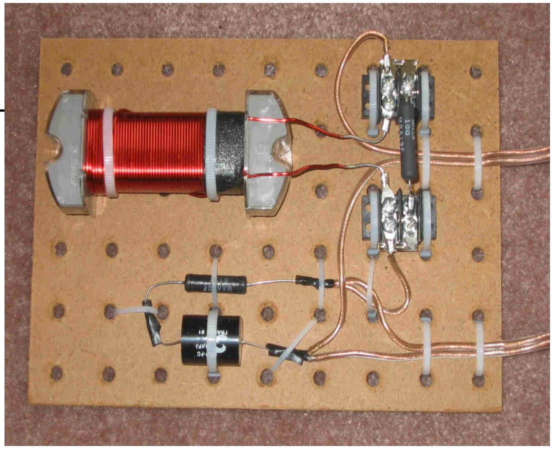
- Aspect described in terms of base application
- Unfair description: “Aspect = specification of how to patch the code such that an aspect is supported”

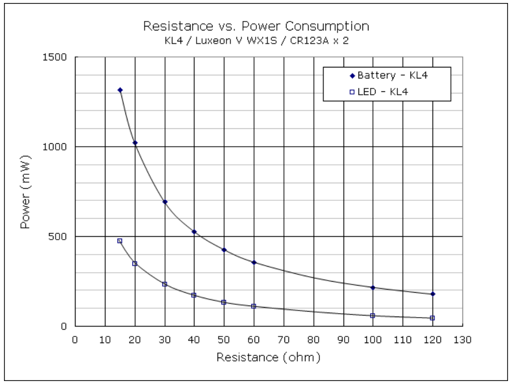
- Difficult:
  - reusable aspects
  - assignment of domain experts to aspects
- Aspects are “tangled”: use names from base application
- Physical separation is not enough!

The Goal by Analogy

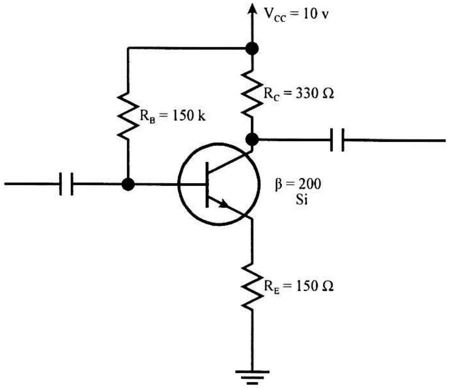
layout



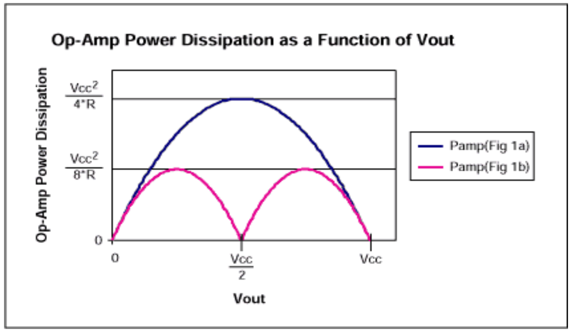




power consumption

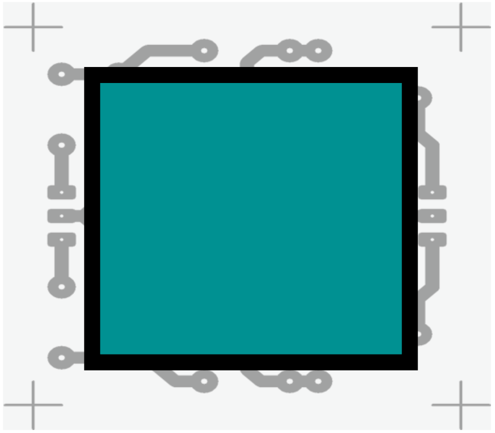


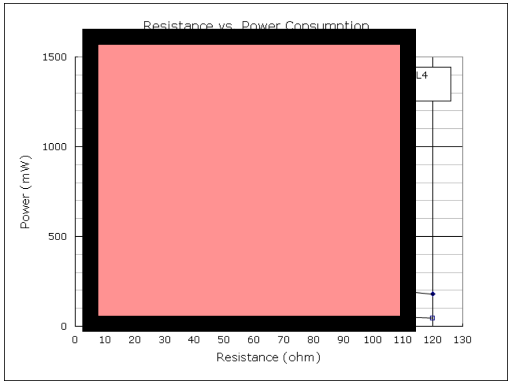
circuit structure

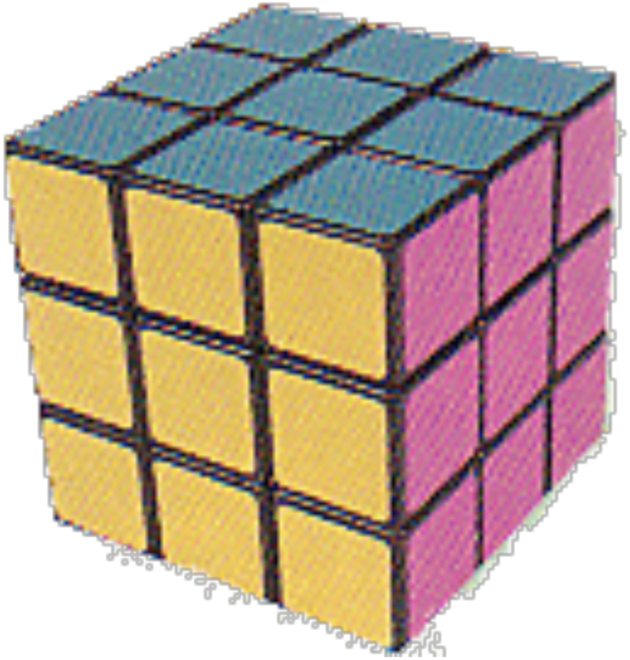


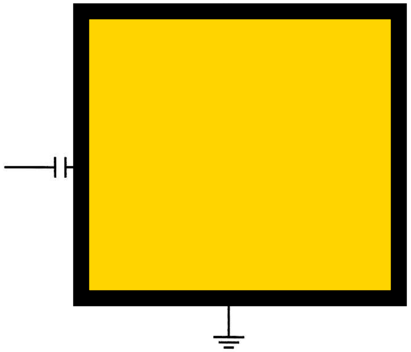
heat emission

The Goal by Analogy



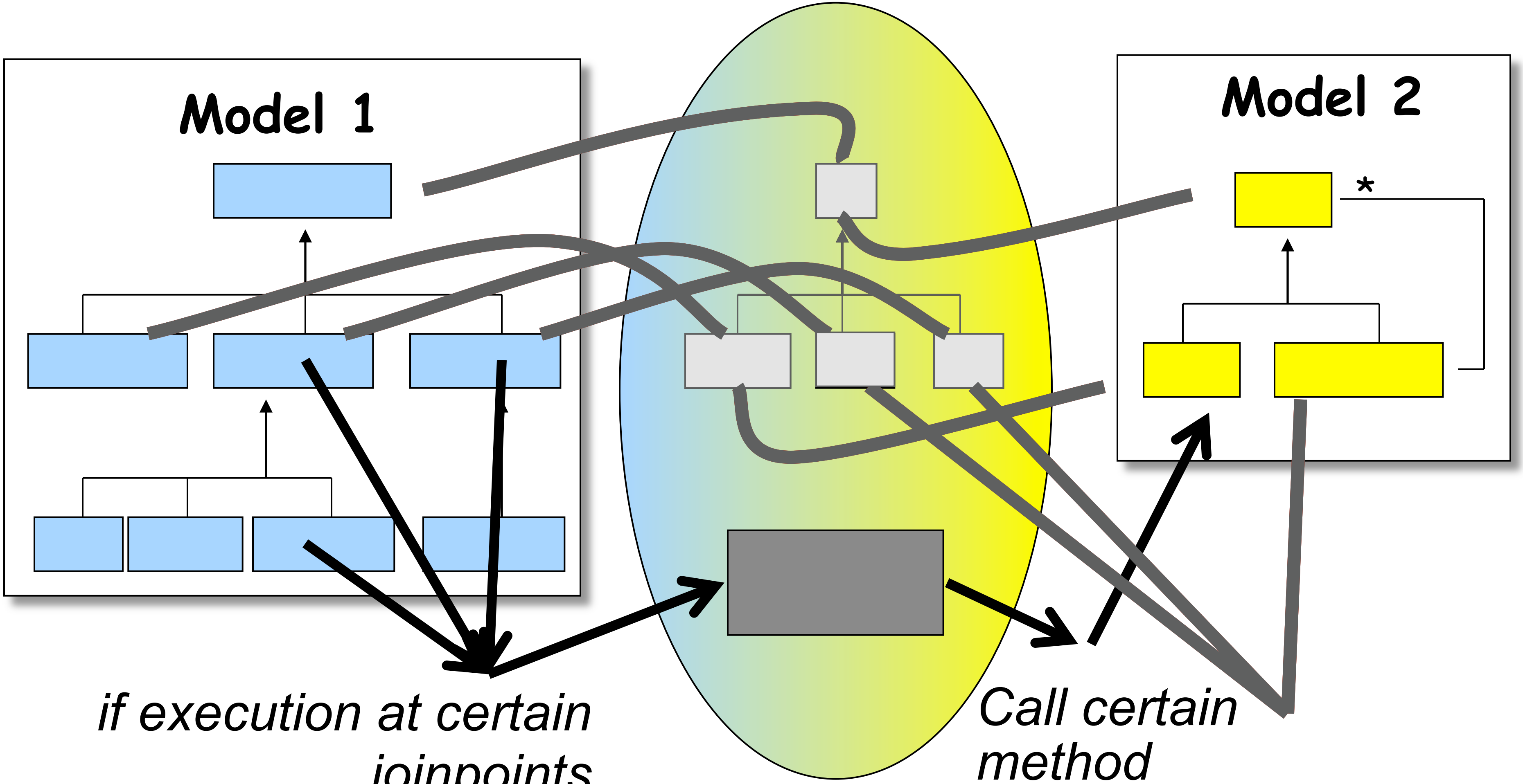






Crosscutting Models in CaesarJ

model superimposition by
structural and behavioral mapping



if execution at certain joinpoints

Call certain method

The ALPHA Story

Critique on AspectJ-like Pointcuts

```
pointcut change():
        call(Point.setX(int))
    || call(void Point.setY(int))
    || call(void Shape+.moveBy(int, int));
```

instead of specifying *WHAT* the crosscutting structure is,

this pointcut describes *HOW* it appears in the concrete syntax of the program

Wanted

> ***"after data changes that was previously read during the most recent draw of a display, update that display"***

Robust.

Minimal knowledge about implementation details of figures.

Precise.

Avoids unnecessary updates, e.g., after calls to `setX` modifying an **`x`** not read in control flow of **`draw`**.

Wanted …

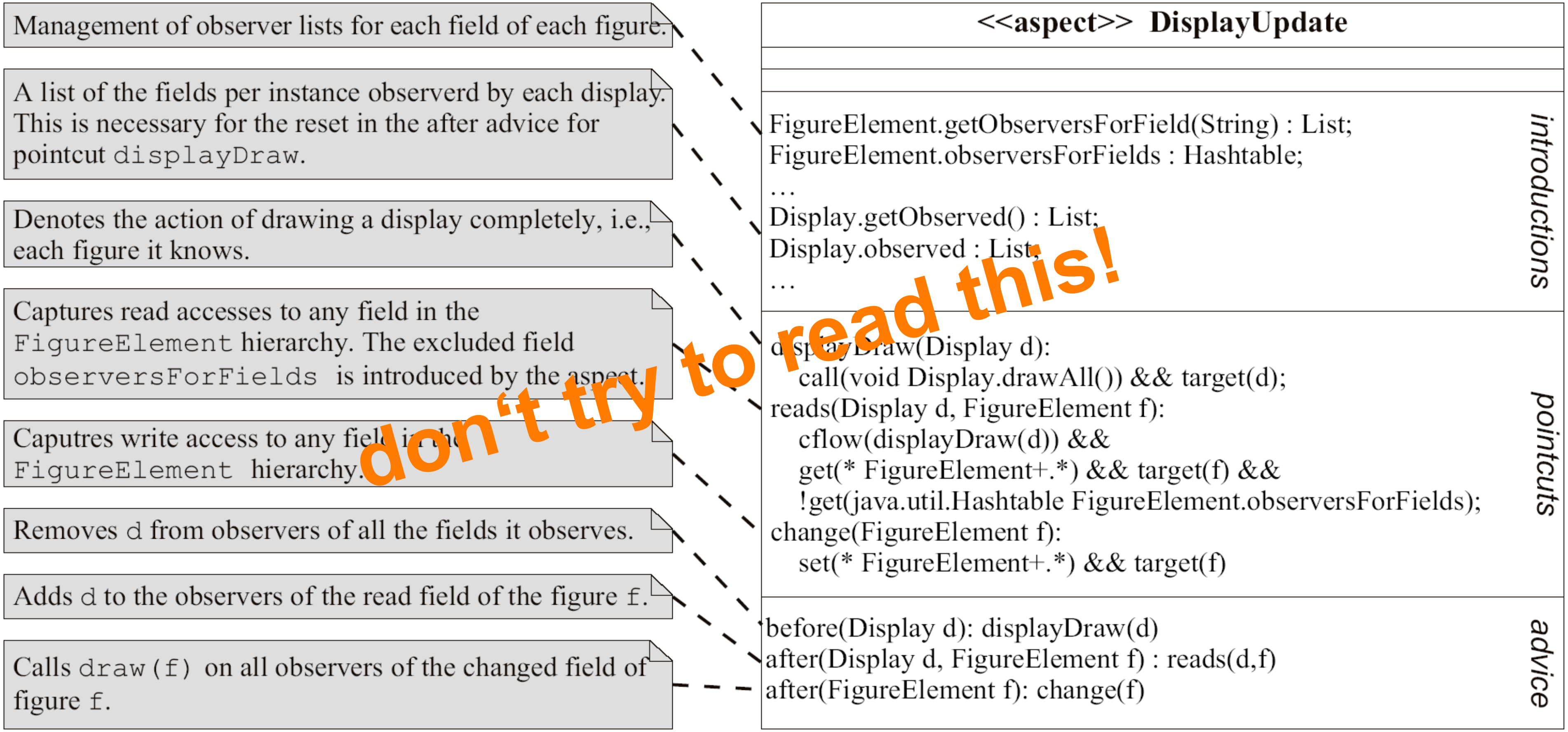
> ***"after data changes that was previously read during the most recent draw of a display, update that display"***

Can we express something like this in AspectJ?

Yes: Aspect constructs an automaton making extensive use of reflection

less dependent on names, but … complex

Problems with Current Pointcuts …



Management of observer lists for each field of each figure.

A list of the fields per instance observerd by each display. This is necessary for the reset in the after advice for pointcut `displayDraw`.

Denotes the action of drawing a display completely, i.e., each figure it knows.

Captures read accesses to any field in the `FigureElement` hierarchy. The excluded field `observersForFields` is introduced by the aspect.

Caputres write access to any field in the `FigureElement` hierarchy.

Removes `d` from observers of all the fields it observes.

Adds `d` to the observers of the read field of the figure `f`.

Calls `draw(f)` on all observers of the changed field of figure `f`.

<<aspect>> DisplayUpdate

introductions

```
FigureElement.getObserversForField(String) : List;
FigureElement.observersForFields : Hashtable;
…
Display.getObserved() : List;
Display.observed : List;
…
```

pointcuts

```
displayDraw(Display d):
   call(void Display.drawAll()) && target(d);
reads(Display d, FigureElement f):
   cflow(displayDraw(d)) &&
   get(* FigureElement+.*) && target(f) &&
   !get(java.util.Hashtable FigureElement.observersForFields);
change(FigureElement f):
   set(* FigureElement+.*) && target(f)
```

advice

```
before(Display d): displayDraw(d)
after(Display d, FigureElement f) : reads(d,f)
after(FigureElement f): change(f)
```

don't try to read this!

Abstractions for Behavioral Mapping

> ***“after data changes that was previously read during the most recent draw of a display, update that display”***

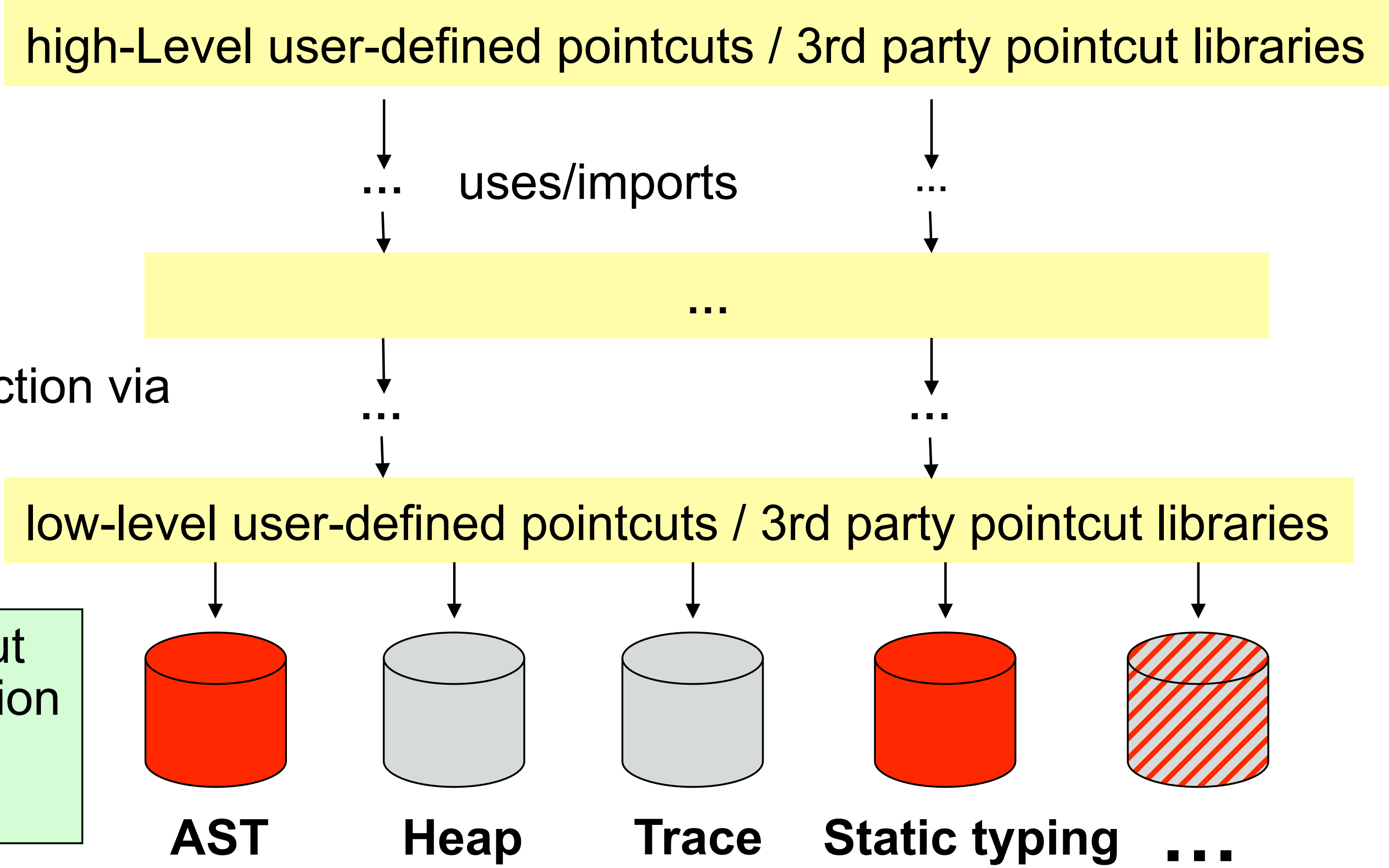
Challenges

Need knowledge about the execution: “previously read”, “most recent draw”…

Need powerful abstraction mechanisms similar to functional abstraction

The Programming Model of Alpha

encode pointcuts as logic queries; pointcut "fires" if query has non-empty result



high-Level user-defined pointcuts / 3rd party pointcut libraries

… uses/imports …

…

… …

low-level user-defined pointcuts / 3rd party pointcut libraries

AST **Heap** **Trace** **Static typing** **…**

pointcut abstraction via inference rules

Store facts about program execution in an extensible list of logic DBs

Pointcuts in ALPHA

dule really “talks” elf … about “its slice” of the execution.

Object specific pointcut

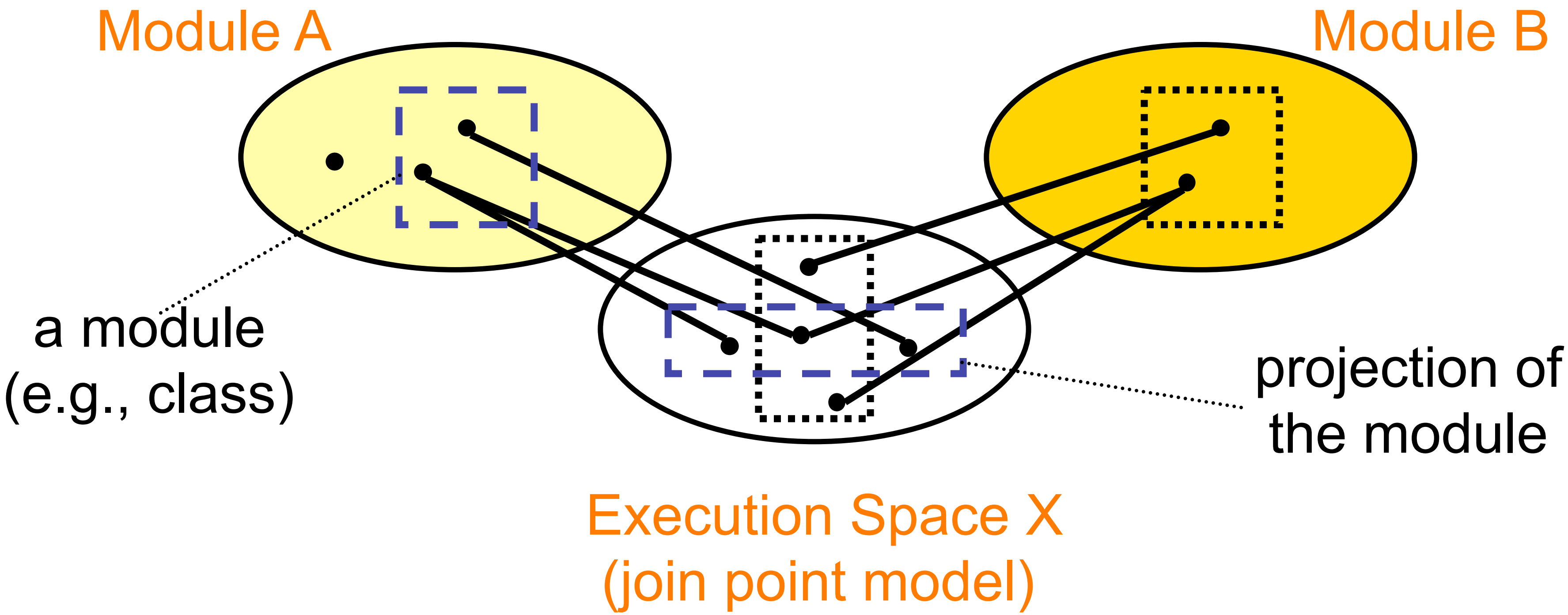
```
class Main {
  display d;

  before set (P, F, _),
         get (T1, _, P, F, _),
         calls (T2, _, @this.d, draw, _),
         cflow(T1, T2),
         reachable (P, d)
    { ... }
    ...
}
```

Control flows in the past

“after data changes that was read during the most recent draw of d, update d”

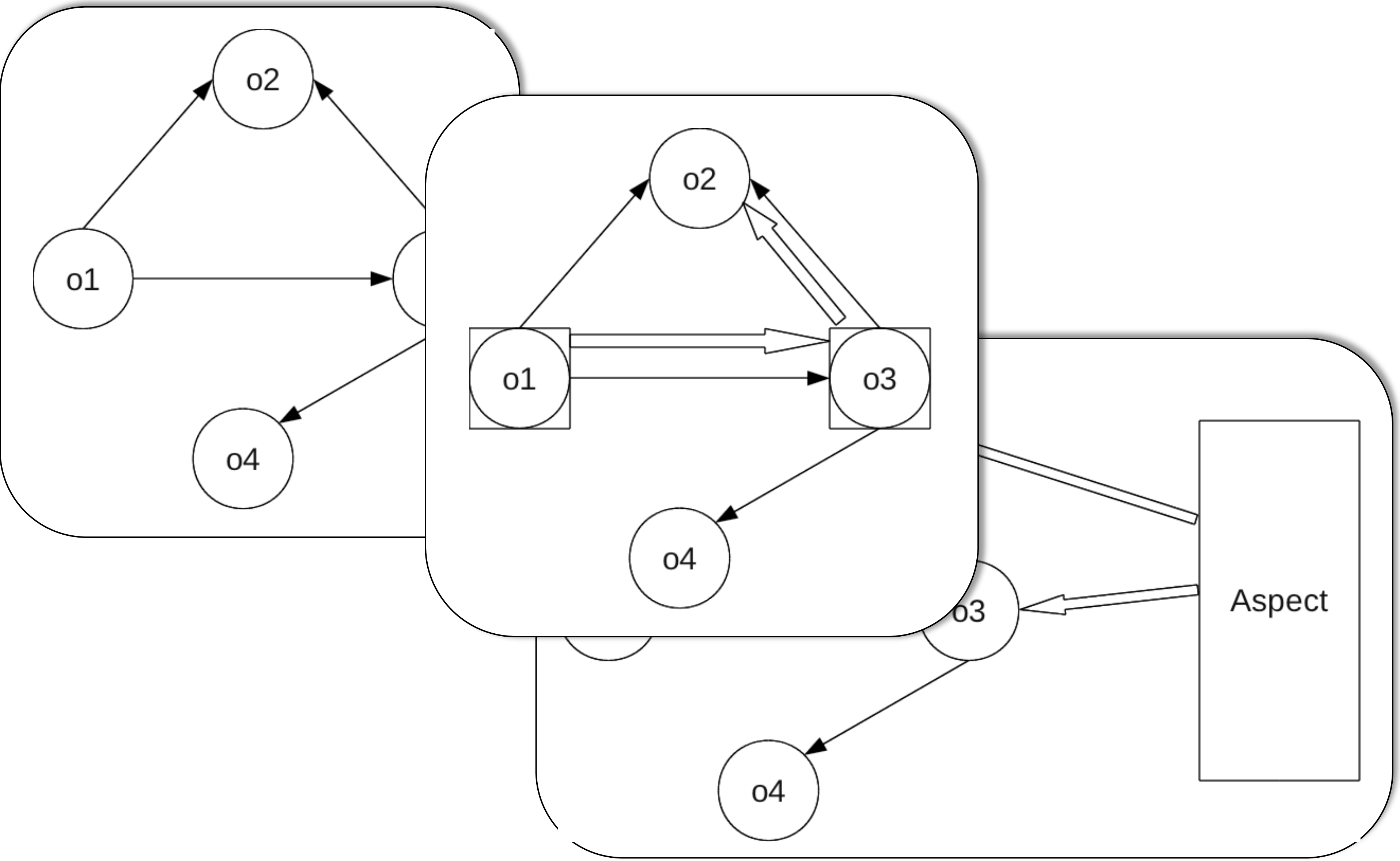
[Masuhara/Kiczales, ECOOP 2003]



two modules in A&B crosscut when ***projections of the modules into X intersect & neither is a subset of the other***

The EScala Story

EScala in a Nutshell



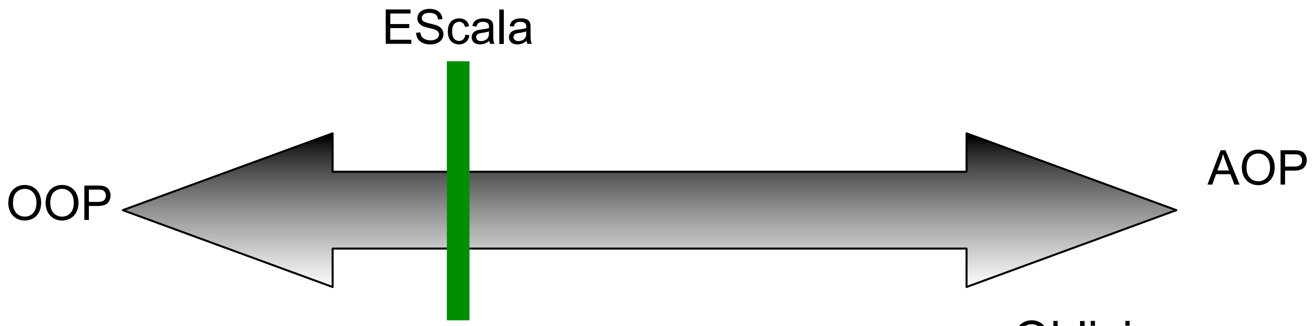
EScala in a Nutshell

EBS

decoupled producer/consumer

Larger-scale object modules

A la Newspeak



Abstraction
Encapsulation
Modular compilation/loading
Dynamic structure

Obliviousness
Implicit events
Global quantification

FRP

streams
data-driven programming

Where We Might Go

Classical vs. Non-Classical Modularity

- “modularity = information hiding” point of view is rooted in classical logic.
- Well-known limitations of classical logic as a representation formalism for human knowledge.
- Yet, information hiding is a undisputed dogma in programming

- Programmers use non-classical reasoning in meaningful ways, they are humans too ☺
- Classical information hiding has its limitations

Ostermann at al., Revisiting Information Hiding
ECOOP 11

Classical vs. Non-Classical Modularity

- Generally, it might be worth investigating notions of modularity based on non-classical logic.

- Some notions of modularity that escape classical modularity can be understood based on non-classical logics:
  - **AOP and default logic**
  - State, mutation, aliasing and separation logic
  - Error handling and para-consistent logics

Ostermann at al., Revisiting Information Hiding
ECOOP 11

Aspects and Default Logic

- One can **reason by default** that the semantics of a method call is to execute the corresponding method body,

- **Aspects** that intercept such method calls are considered **exceptions to** that **default rule**.

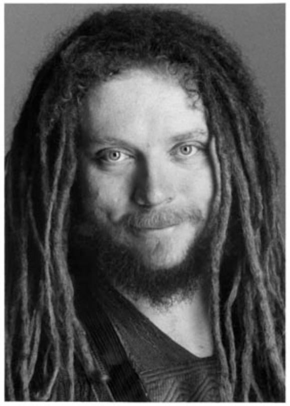
- In this setting, one can - using defaults - reason locally about the program behavior.
- In case one learns later that the default assumption turns out to be wrong, there is a controlled process of updating the conclusions one has drawn from the invalid default assumption

Ostermann, Reasoning About Aspects with Common Sense
ECOOP 11

Lanier on Black-Box Abstraction

- Each module - statement, expression, function, object - is a little “black box” - relates to the rest through a well-defined I/O interface (IO-wires).
- Intuition underlying communication between modules:
  - “sending pulses down a wire” - passing messages
  - “single-point sampling of the world at the end of the wire” by algorithmic protocols

> Lanier: “world as a planet of the help desks in which human race will be largely engaged in maintaining very large software systems …”



EDITED BY JOHN BROCKMAN

THE NEXT FIFTY YEARS

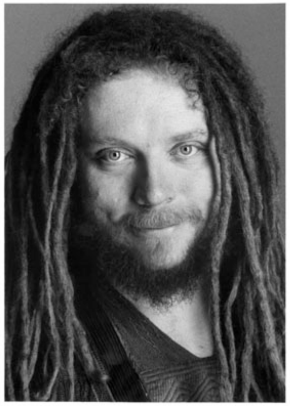
Science in the First Half of the Twenty-First Century

Lanier on Black-Box Abstraction

- Programmers forced to stream intentions into sequential steps aligned with this pipeline view of the world
- Complex algorithmic protocols needed to give meaning to sequences of pulses
  - accidental complexity!
- Pure hierarchical structuring
  - hard to accommodate different perspectives into pure hierarchical systems (crosscutting concerns)

Surface Binding

- Components probe “measurable fundamental” properties of program execution and take decisions based on some evolving model of the world
  - components connected by “surfaces” sampled at several points in parallel instead of “wires sampled at single points”
  - pattern classification and automatic maintenance of implicit confirmatory and predictive models instead of sampling algorithmic protocols



Heterarchy

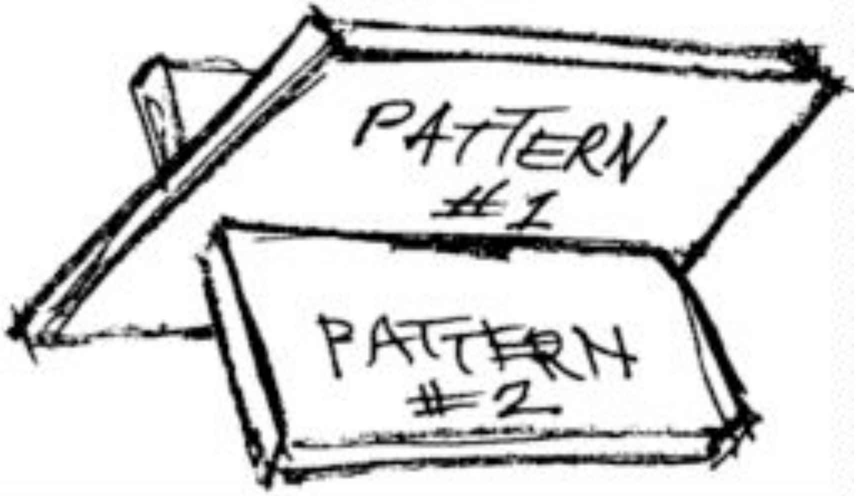
There always exist different (hierarchical) logical sub-trees of origination, each of which is reigned by a principle (=archae) that cannot be subsumed under the guiding principles of the other trees.

Diversity of organizing principles is the basis of adaptability. In addition, adaptability if promoted by the organization of diversity.

> "[T]he sphere of complexity is that of organized diversity, of the organization of diversity."
> Morin, Edgar. 1974. "Complexity." International Social Science Journal, 26(4):555-82.

Crosscutting Models in Art and Creativity

Arthur Koestler. The Art of Creation



Looking at problems from different frames of references is argued to be at the core of the creativity process

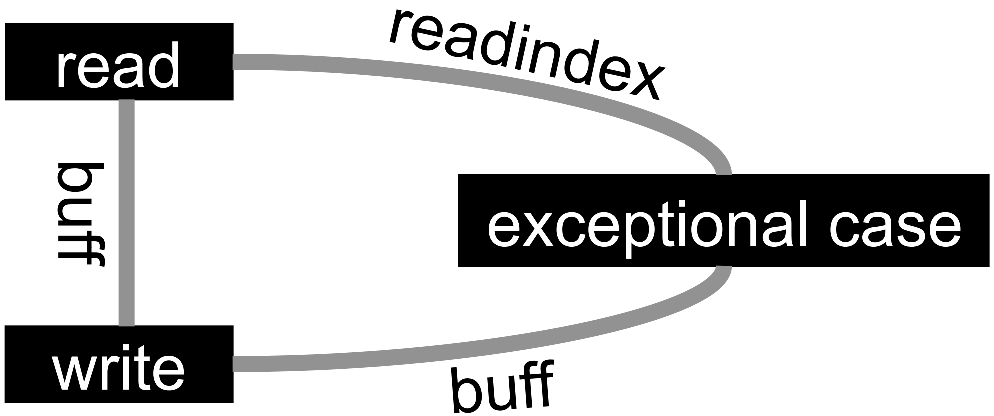
Lopes et al. Onward 03

```
static void encodeStream(InputStream in, OutputStream out) {
  int readindex = 0;

  byte[] buff = new byte[N];

  while ( (readindex = in.read(buff)) == N) {
            out.write( Encoder.encodeDuration(buff) );
  }

  if (readindex > 0) {
     for (int i = readindex; i < N; i++) buff[i] = 0;
     out.write( Encoder.encodeDuration(buff) );
  }
}
```



Lopes et al. Onward 03

```
static void encodeStream(InputStream in, OutputStream out) {
  int readindex = 0;

  byte[] buff = new byte[N];

  while ( (readindex = in.read(buff)) == N) {
     out.write( Encoder.encodeDuration(buff) );
  }

  if (readindex > 0) {
     for (int i = readindex; i < N; i++) buff[i] = 0;
     out.write( Encoder.encodeDuration(buff) );
  }
}
```

The problem aggravated if one has to write things like

“after data changes that was read during the most recent draw of a display, update that display”

Lopes et al. Onward 03

```
/**
* encodeStream converts stream of bytes into sounds.
* @param in stream of bytes to encode
* @param out stream of audio samples representing input
*/

encodeStream(InputStream input, OutputStream output) {

  while there is data in input: read N bytes from it,
       perform encodeDuration on those bytes, and write
       result into output

  if, however, after reading the input, the number of
       bytes read is less than N, then, before continuing
       with writing out, patch it with zeros.

}
```

refining a statement at a later point in the program text happens pervasively in written discourse.

END