Java & Eiffel:

An objective personal assessment

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Topics

1. Background
2. Common elements
3. Contracts
4. Type system
5. Inheritance
6. Agents
7. Other mechanisms
8. Syntax, ease of learning; conclusion

Background: Eiffel

Eiffel 1: 1986 (contracts, multiple inheritance,
genericity, deferred classes…)

Eiffel 2: 1988 (exceptions, constrained genericity)

Eiffel 3: 1991 (uniform type system,
infix/prefix features, …)

1997: Agents, Precursor

2005-2006: ECMA/ISO standard: attached types, numerous clarifications and simplifications

2008-now: Void safety, concurrency (SCOOP)

In progress: advanced functional features, safe covariance

Background: Java

1995: 1.0
1997: 1.1
Microsoft JVM, Swing
1999: 1.2 (*Java 2*)
Java Foundation Classes
2000: 1.3
Performance improvements, Hotspot
2004: 1.5 (5.0):
Metadata , genericity
2006: Java SE 6, support for scripting languages
2011: Java SE 7, support for dynamic languages
2014 (expected): Java SE 8, lambda expressions

C#

- Originally 1999 (COOL), part of .NET
- 2002: C# 1.0
- 2006: C# 2.0, generics, partial types
- 2007: C# 3.0, extension methods, lambda expressions
- 2010: C# 4.0, generic co- and contravariance
- 2012: C# 5.0, asynchronous methods

What's common

Not C++

Not backward-compatible with C (but Java closer to C, especially syntax)

Object-oriented languages

Statically typed languages

Dynamic binding by default

Type system permits garbage collection

Genericity (built-in in Eiffel, late addition in Java)

Portable implementations

Overall structure

Java: classes, but also static methods

Eiffel: classes throughout – unit of both type and module decomposition

The problem with attribute export status

If an attribute is exported, clients can both read it and assign any value that they want to it.

Ex: *heater.temperature* = 19;

Information hiding

In Java:

Can still do $x.a := v$

This design mistake (in my opinion) comes from C++: designers did not understand the Uniform Access principle

Exporting an attribute means exporting it read-write

Eiffel approach (Uniform Access):

- Query can be attribute or function
- Client does not know which – only that it's a query
  (difference not visible in "contract view" of class)
- Exporting a query means exporting it to read; there's nothing wrong or dangerous with this
- To provide setter privileges: write procedure
- Can use assignment-like syntax for setter

Language style

Consistency principle

The language should offer **one good way** to do anything useful

Language style

Compatibility principle

Traditional notations should be supported with an O-O semantics

Infix and prefix operators

In

$$a - b$$

the – operator is "infix"
(written between operands)

In

$$- b$$

the – operator is "prefix"
(written before the operand)

The object-oriented form of call

some_target.some_feature (some_arguments)

For example:

my_figure.display

my_figure.move (3, 5)

x := a.plus (b)   ???????

Operator features

```
expanded class INTEGER feature

        plus alias "+" (other: INTEGER): INTEGER
                        -- Sum with other
            do ... end

      times alias "*" (other: INTEGER): INTEGER
                        -- Product by other
            do  ... end

      minus alias "-" : INTEGER
                        -- Unary minus
            do  ... end
      ...
      end
```

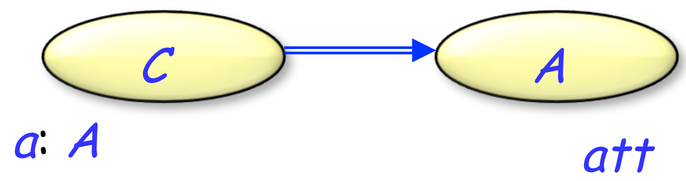
Calls such as *i.plus (j)* can now be written *i + j*

Possible client privileges in Eiffel

If class *A* has an attribute *att* : *SOME_TYPE*, what may a client class *C* with

a : *A*

do with *a*.*att* ?



The attribute may be:

Secret

Read-only

Read,
restricted write

Full write

a.*att*
invalid

Modify through
a.*some_procedure*

Modify through
a.*set_att*(*v*)

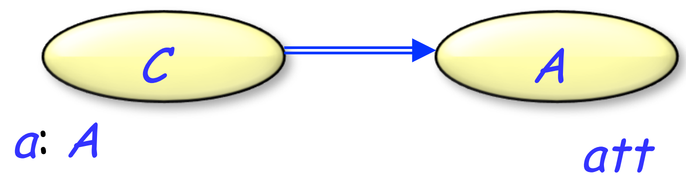
a • *att* permitted in *C* (for access)

Abstraction and client privileges

If class *A* has an attribute *att* : *SOME_TYPE*, what may a client class *C* with

a : *A*

do with *a.att* ?



Read access if attribute is exported

- *a.att* is an expression.
- An assignment ~~*a.att := v*~~ would be syntactically illegal!

(It would assign to an expression, like ~~*x + y := v*~~.)

Applying abstraction principles

Beyond read access: full or restricted write, through exported procedures.

Full write privileges: *set_attribute* procedure, e.g.

```
set_temperature (u : REAL) is
            -- Set temperature value to u.
    do
            temperature := u
    ensure
            temperature = u
    end
```

Client will use e.g. *x.set_temperature (21.5)*

Other uses of a setter procedure

```
set_temperature (u : REAL) is
                -- Set temperature value to u.
        require
                not_under_minimum: u >=  -273
                not_above_maximum: u <= 2000
        do
                temperature := u
                update_database
        ensure
                temperature_set: temperature = u
        end
```

Having it both ways: assigner commands

Make it possible to call a setter procedure

temperature: *REAL* **assign** *set_temperature*

Then the syntax

x.*temperature* := 21.5

is accepted as a shorthand for *x*.*set_temperature* (21.5)

Retains contracts etc.

Eiffel: providing an assigner command

class *C* [*G*] **feature**

```
	item : G

	put (x: G)
		require
			...
		do
			item := x
		ensure
			item = x
		end
end
```

Client code:

```
	n : INTEGER
	x : C [INTEGER]
```

Information hiding

```
class
    A

feature
        f ...
        g ...

feature {NONE}

        h, i ...

feature {B, C}

        j, k, l ...

feature {A, B, C}
        m, n...
end
```

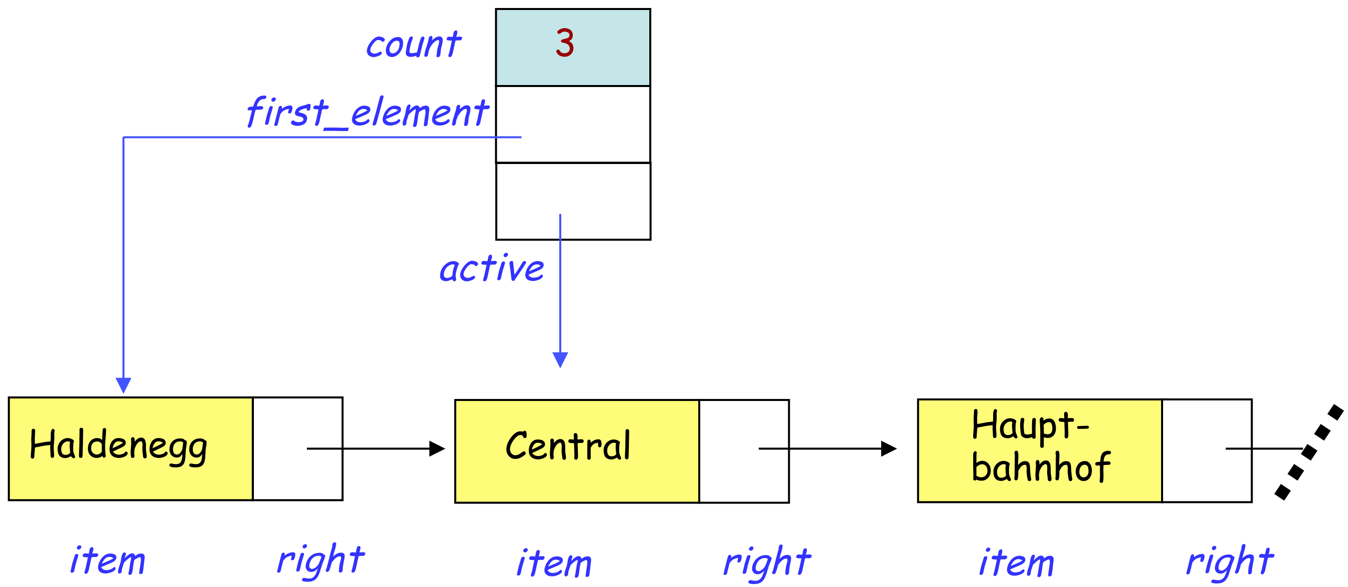
Status of calls in a client with *a1*: *A*:

- *a1.f*, *a1.g* : valid in any client
- *a1.h* : invalid everywhere
  (including in *A*'s own text!)
- *a1.j* : valid only in *B*, *C* and their descendants
  (not valid in *A*!)
- *a1.m* : valid in *B*, *C* and their descendants,
  as well as in *A* and its descendants

An example of selective export

LINKABLE exports its features to *LINKED_LIST*

- Does not export them to the rest of the world
- Clients of *LINKED_LIST* don't need to know about *LINKABLE* cells.



Exporting selectively

```
class
    LINKABLE [G]
feature {LINKED_LIST}

        put_right (...) is do ... end

        right: G is do ... end

        ...
end
```

These features are selectively exported to *LINKED_LIST* and its descendants (and no other classes)

Information hiding

Information hiding only applies to use by clients, using dot notation or infix notation, as with *a1.f* (***Qualified*** calls).

Unqualified calls (within class) not subject to information hiding:

```
class A feature {NONE}
      h is ... do ... end
feature

      f is
            do
                  ...; h; ...
            end
end
```

Possible client privileges in Java

Access specifiers (placed in front of each definition for each member of the class):

- **`public`**
- **`protected`**
- Package access (no keyword)
- **`private`**

Access specifiers

`public`

- The member declared to be public is available to everyone

`private`

- No one can access that member except the class that contains that member, inside methods of that class

`protected`

- Member can be accessed by
  - Descendants of the class
  - Classes in the same package

Package access

- Default
- Also called "friendly"
- All other classes in current package have access to that member
- To all classes outside of current package, the member appears to be **`private`**

Access modifiers at the class level

Either **`public`** or default (no access modifier)

- **`public`**
  - Appears before the **`class`** keyword
  - Makes the class available to a client programmer
- No access modifier
  - Makes the class available only within the package

No **`private`** and **`protected`**!

Comparison: Eiffel vs. Java

Access level	Eiffel	Java
only current class	-	**private**
only current class and its descendants	**feature** {NONE}	-
current class + "friends"	**feature** {B,C} ("friends" = B, C and their descendants)	default ("friends" = classes in the same package)
current class + its descendants + "friends"	**feature** {A,B,C} ("friends" = B, C and their descendants, A = current class)	**protected** ("friends" = classes in the same package)
everyone	**feature** {ANY}	**public**

More comparison: Eiffel vs. Java

Eiffel - no `package` mechanism

Eiffel - no way of hiding a feature from your descendants

- Module viewpoint: If B inherits from A, all the services of A are available in B (possibly with a different implementation).

Java - no way of exporting a member only to self and descendants

Java - no language rule to distinguish between access to attributes for reading and for writing

Java - additional way of making a class available outside its package or not

Access control more fine grained in Eiffel

C# access modifiers

C# adds the **`internal`** access modifier, which restricts access within the assembly

Classes can be:

- **`public`**
- **`internal`**

Class members can be:

- **`public`** – accessible to everyone
- **`internal`** – accessible only from current assembly
- **`protected`** – accessible only from containing class or types derived from containing class (a.k.a. "family" export status)
- **`protected internal`** – accessible only from current assembly or types derived from the containing class
- **`private`** – accessible only from containing type

The problem with attribute export status

If an attribute is exported, clients can both read it and assign any value that they want to it.

Ex: *heater.temperature* := 19

The C# solution: properties

```
public class Heater {
    private int TemperatureInternal;
        public int Temperature {
            get {return TemperatureInternal;}
            set {
                if (! InRange(value)) {
                    throw new ArgumentException
                    ("Temperature out of range");
                }

                Temperature Internal = value;

            NotifyObservers();
            }
        }
```

attribute

property

Assignment commands

It is possible to define a query as

temperature: *REAL* **assign** *set_temperature*

Then the syntax

x.*temperature* := 21.5

Not an assignment, but a procedure call

is accepted as an abbreviation for

x.*set_temperature* (21.5)

Retains **contracts** and any other supplementary operations

Contracts

Elements of specification associated with the code

Help in: analysis, design, debugging, testing, maintenance, management

Eiffel: Built-in

Java: additions (iContract, JML)

JML example (www.eecs.ucf.edu/~leavens/JML-release/org/jmlspecs/samples/dbc/Polar.java)

```
public /*@ pure @*/ strictfp class Polar extends ComplexOps
    /** The angle of this number. */
    private double ang;
    /** Initialize this polar coordinate number …  */
    /*@ requires mag >= 0 && Double.NEGATIVE_INFINITY < ang
    @ && ang < Double.POSITIVE_INFINITY;
    @ ensures this.magnitude() == mag;
    @ ensures this.angle() == standardizeAngle(ang);
  @ also
    @ requires mag < 0 && Double.NEGATIVE_INFINITY < ang
    @ && ang < Double.POSITIVE_INFINITY;
    @ ensures this.magnitude() == - mag;
    @ ensures this.angle() == standardizeAngle(ang+StrictMath.PI);
 @ also @ requires Double.isNaN(mag) || Double.isNaN(ang)
    @ || Double.NEGATIVE_INFINITY == ang
    @ || ang == Double.POSITIVE_INFINITY;
    @ signals_only IllegalArgumentException; @*/
```

Type system

Java:

- "Primitive" types are special, e.g. int, bool, float
- Special class types: Integer, Float, …

Eiffel: every type is based on a class

e.g. INTEGER, REAL, BOOLEAN

Conversions in Java

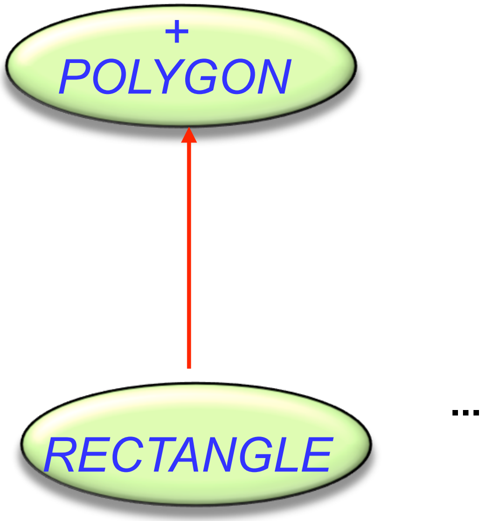
Built-in conversions between primitive types

For reference types: type narrowing (equivalent of object test)

Conversions

What is the difference between the following (in Eiffel syntax)?

- *my_polygon := my_rectangle*
- *my_real := my_integer*



Conversion

Try to avoid having a special rule for e.g.

$$3 + 5.0$$

Can we generalize conversion?

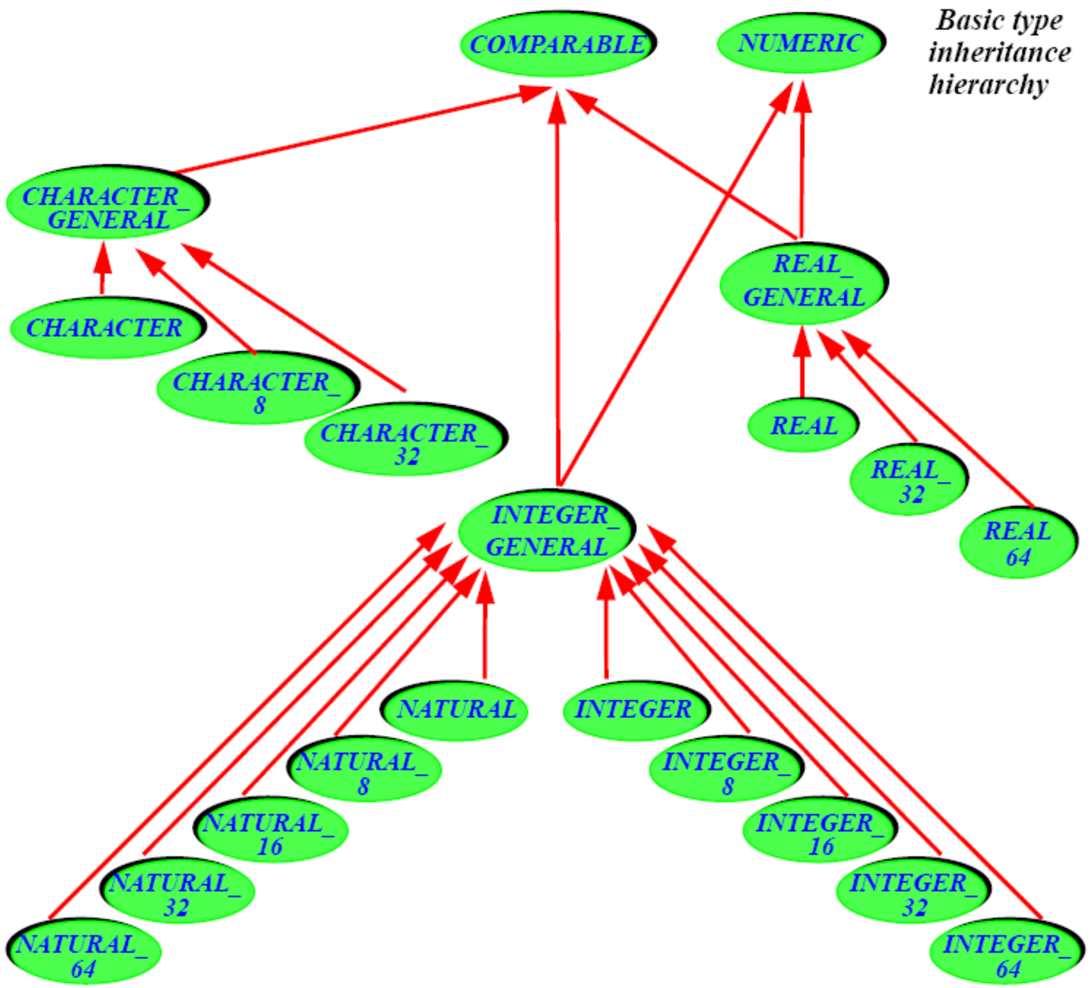
Without conversion: we exchange strings with .NET as

- **create** *my_string.from_dotnet (her_dotnet_string)*
- *dotnet_routine (("ABCDE").to_dotnet)*

With conversions: convert to out-of-control type:

- *my_string := her_dotnet_string*
- *dotnet_routine ("ABCDE")*

Basic type hierarchy



Resolution

Introduce explicit conversion mechanism

As in rest of language, governs all forms of "*attachment*" (assignment or argument passing)

First change

```
class STRING create
        make, from_dotnet
convert
    from_dotnet ({DOTNET_STRING})
feature
        from_dotnet (s: DOTNET_STRING)
            do
                ...
            end
```

Second change

```
class STRING create
        make, from_dotnet

convert
    from_dotnet ({DOTNET_STRING})
    to_dotnet: {DOTNET_STRING }
feature
    to_dotnet: DOTNET_STRING
        do
            ...
        end
```

Can we generalize conversion?

Without conversion: we exchange strings with .NET through

- **create** *my_string.from_dotnet (her_dotnet_string)*
- *dotnet_routine (("ABCDE").to_dotnet)*

Now: abbreviation for this

With conversions:

- *my_string := her_dotnet_string*
- *dotnet_routine ("ABCDE")*

First change

```
class STRING create
        make, from_dotnet
convert
        from_dotnet ({DOTNET_STRING})
feature
        from_dotnet (s: DOTNET_STRING)
            do
                ...
            end
```

The other way around?

Without conversion: we exchange strings with .NET through

- **create** *my_string* . *from_dotnet* (*her_dotnet_string*)
- *dotnet_routine* (("*ABCDE*") . *to_dotnet*)

With conversions:

- *my_string* := *her_dotnet_string*
- *dotnet_routine* ("*ABCDE*")

Now: abbreviation for this

Second change

```
class STRING create
        make, from_dotnet

convert
    from_dotnet ({DOTNET_STRING})
    to_dotnet : {DOTNET_STRING }
feature
    to_dotnet: DOTNET_STRING
        do
            ...
        end
```

Keeping things simple and clear

Conversion principle

No type may both conform and convert to another.

Conversion Non-Transitivity principle

That *V* converts to *U* and *U* to *T* does not imply that *V* converts to *T*.

Conversion Asymmetry principle

No type *T* may convert to another through both a conversion procedure and a conversion function.

For programmer-defined types

```
my_date := [13, " May" , 2013]
```

Related change

Allow 5.0 + 3 and 3 + 5.0

5.0 + 3 is a shortcut for (5.0).*plus* (3)

But we want 3 + 5.0 to be a shortcut for

((3).*to_real*).*plus* (5.0) !

Target conversion

In class *REAL*:

```
plus alias "+" convert
        do
                ...
        end
```

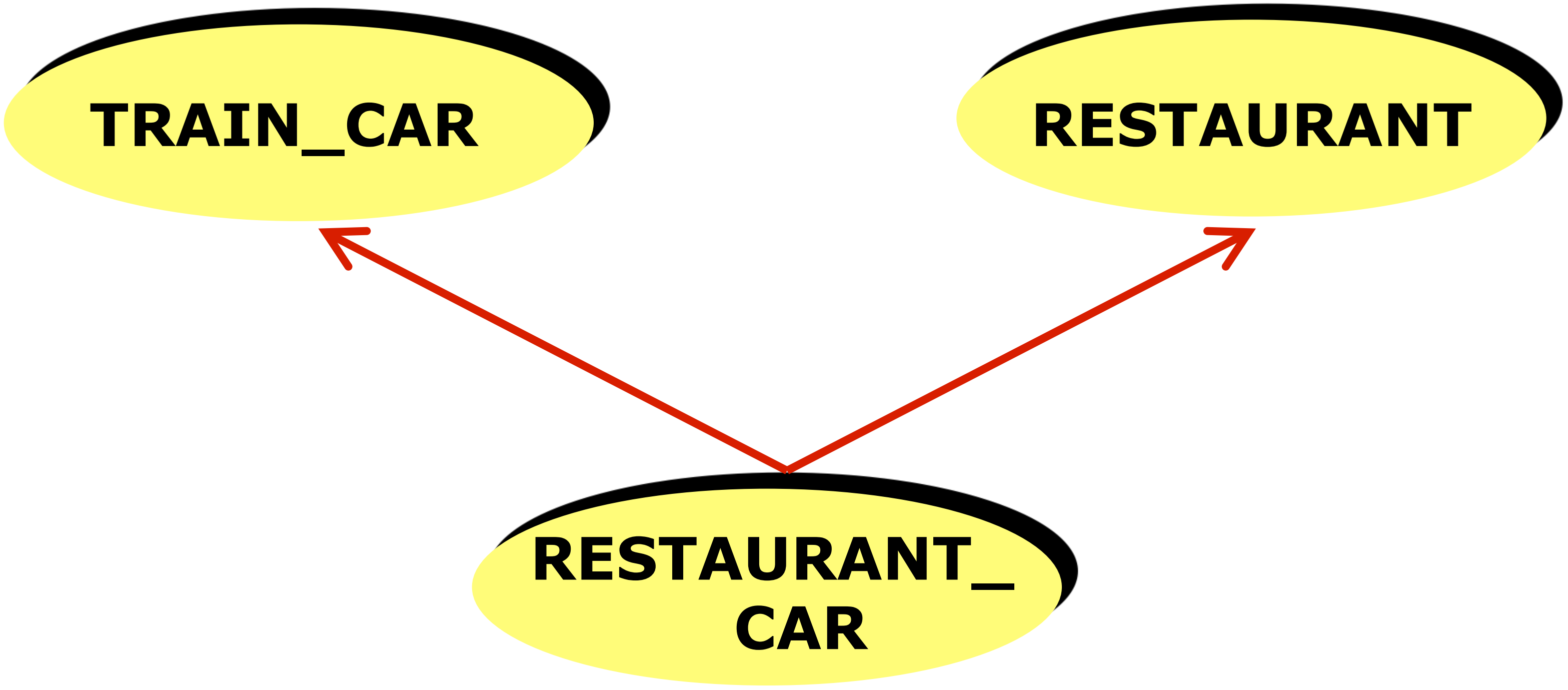
Control structures

```
across my_list as l loop
        op (l.item)
end

require
        across emplist as e all e.item.is_full_time end
```

For **across** to be applicable, it suffices that the type of the structure inherit from *ITERABLE*

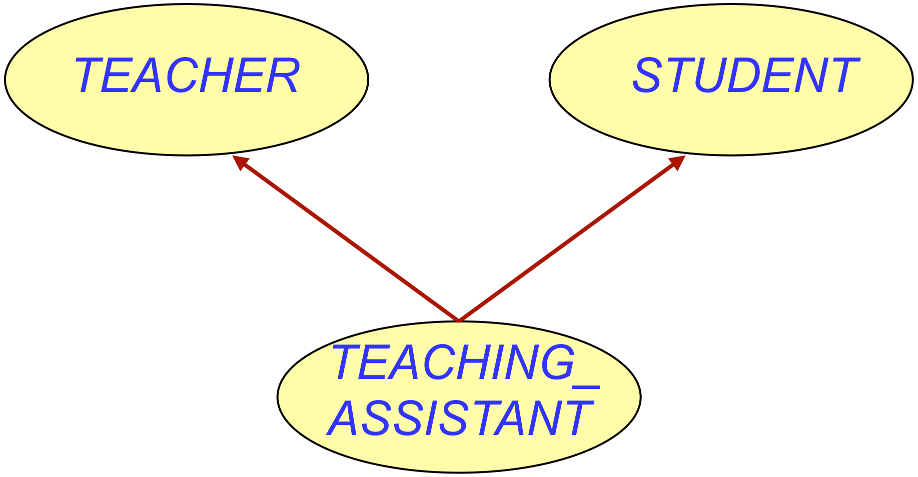
Multiple inheritance in Eiffel



Multiple inheritance

A class may have two or more parents.

What not to use as an elementary example: *TEACHING_ASSISTANT* inherits from *TEACHER* and *STUDENT*.



Examples of multiple inheritance

Combining separate abstractions:

- Restaurant, train car
- Calculator, watch
- Plane, asset
- Home, vehicle
- Tram, bus

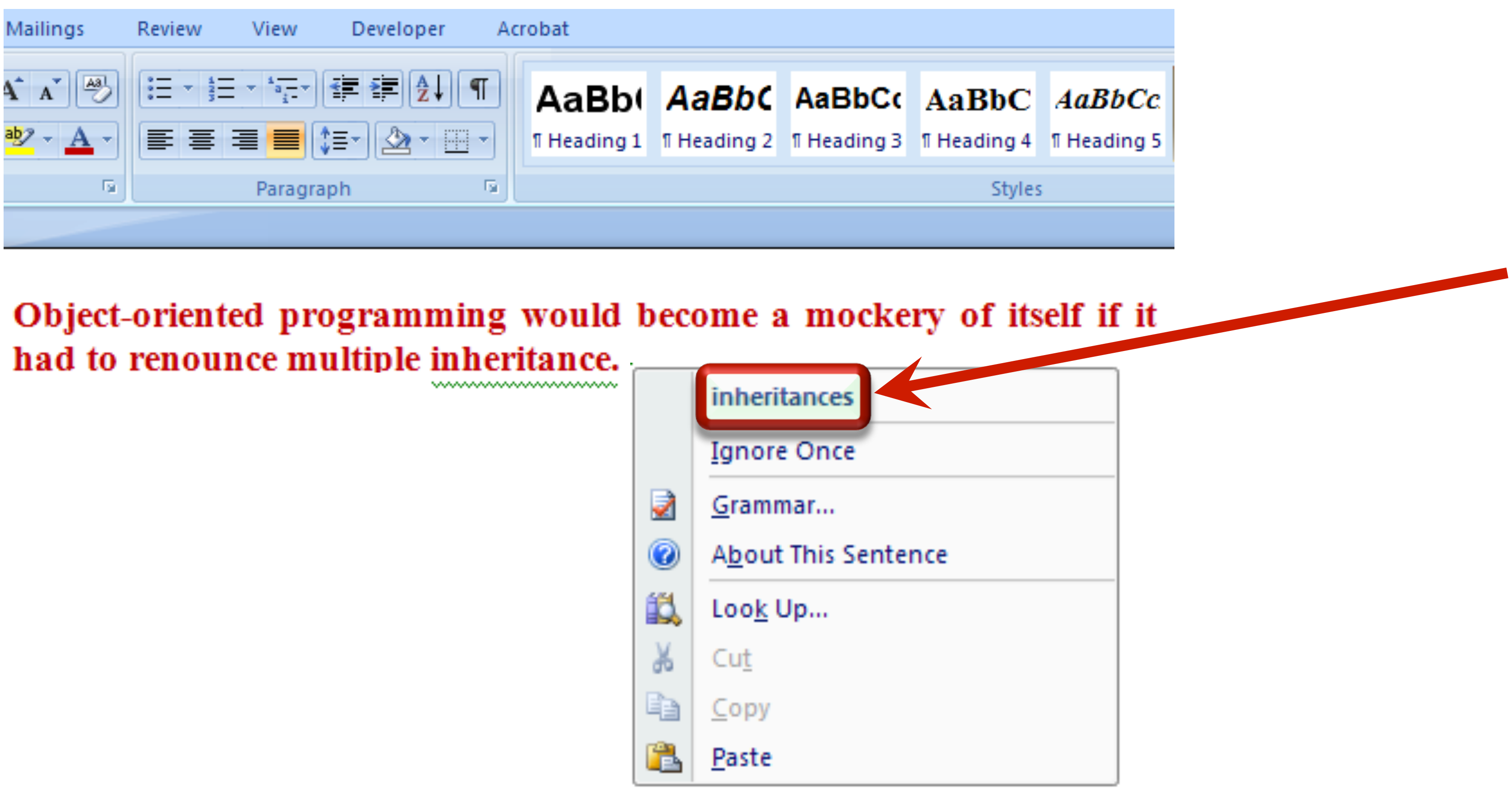
Warning

Forget all you have heard!

Multiple inheritance is **not** the works of the devil

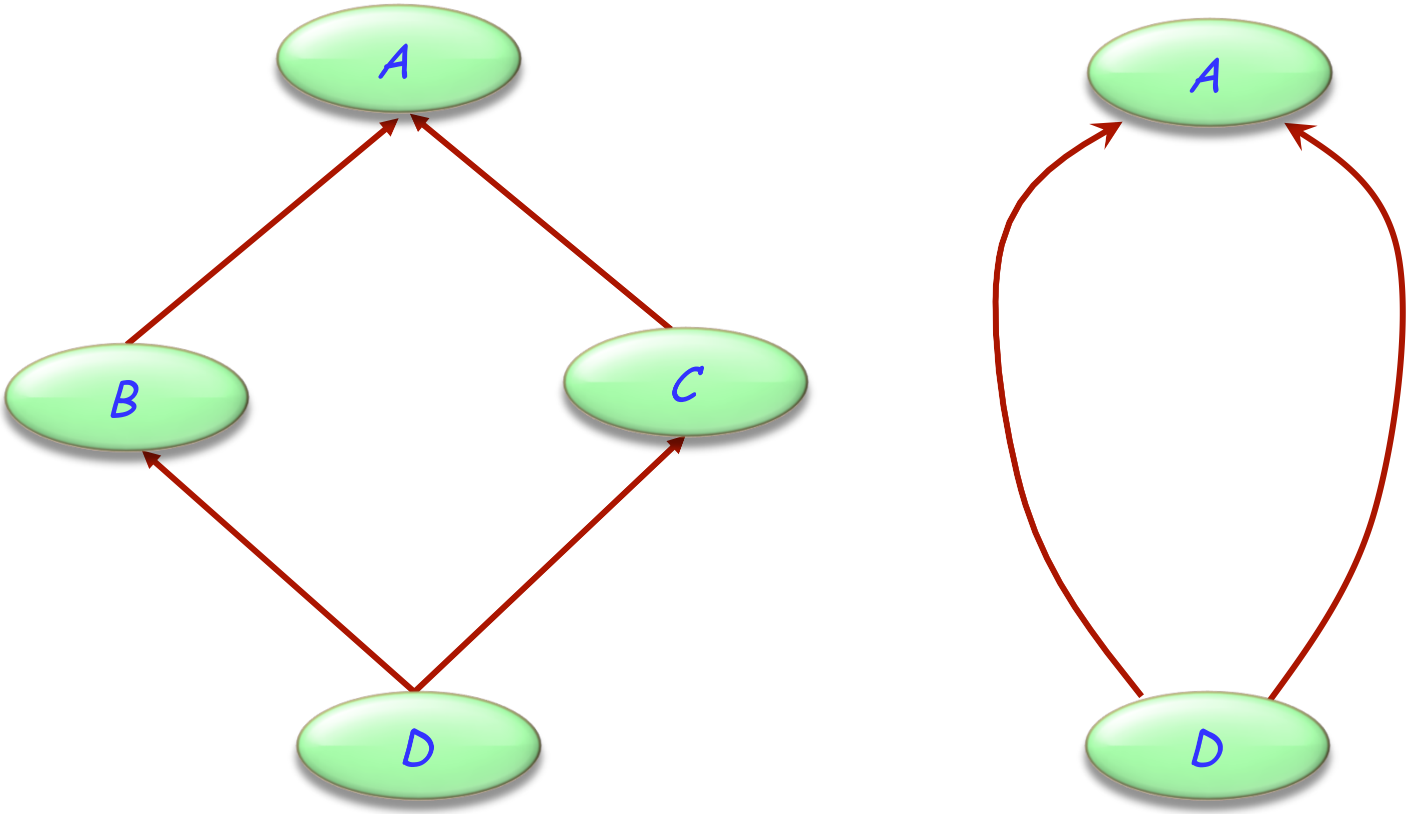
Multiple inheritance is **not** bad for your teeth

(Even though Microsoft Word apparently does not like it:



)

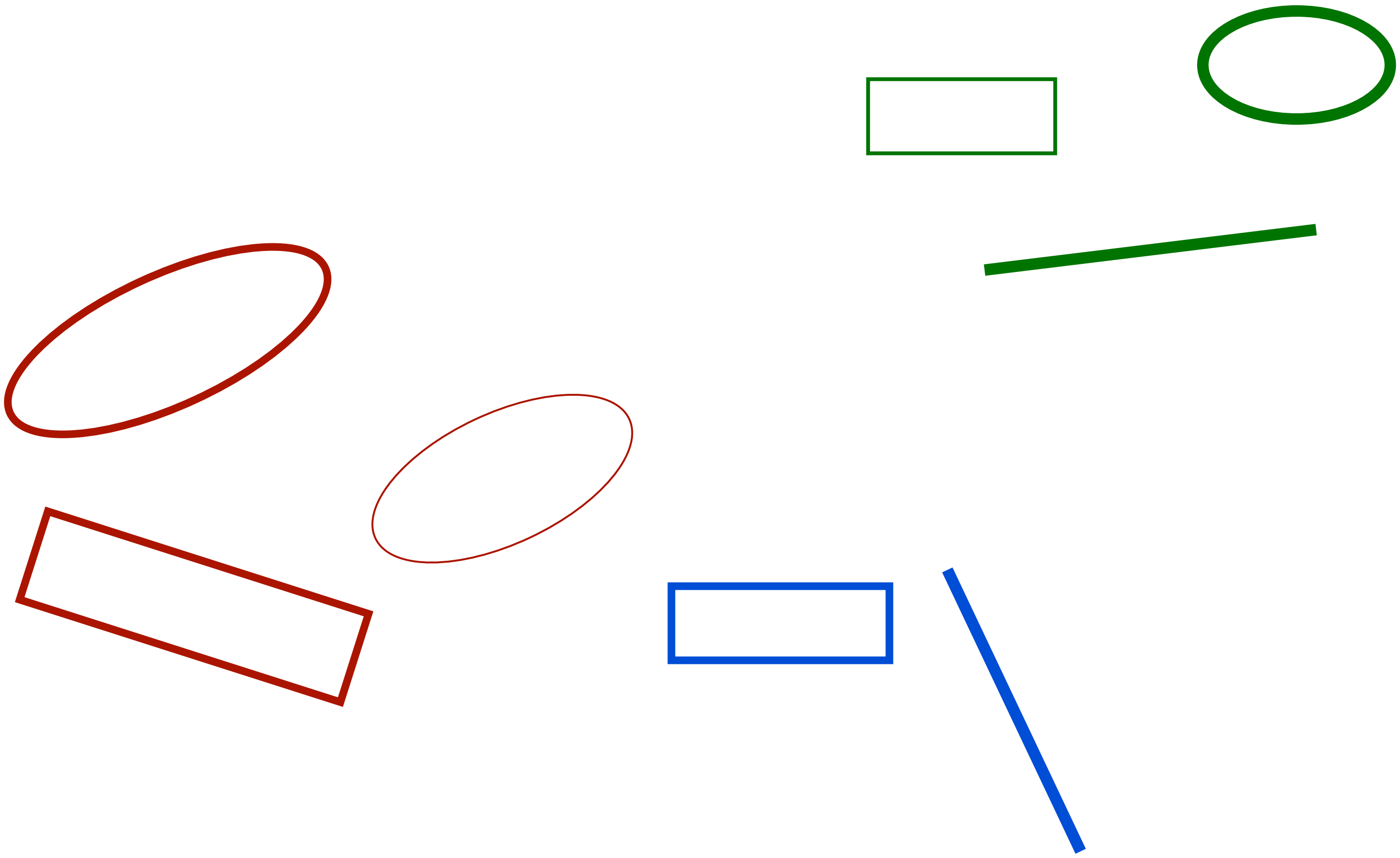
This is **repeated**, not just multiple inheritance



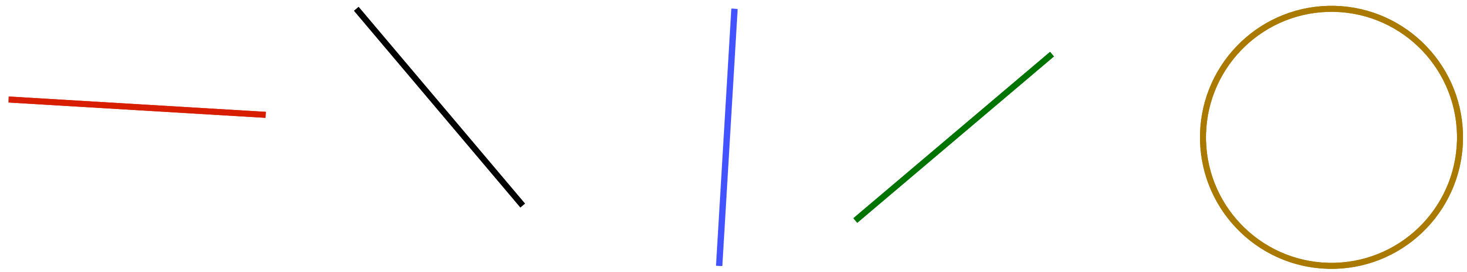
Not the basic case!

(Although it does arise often; why?)

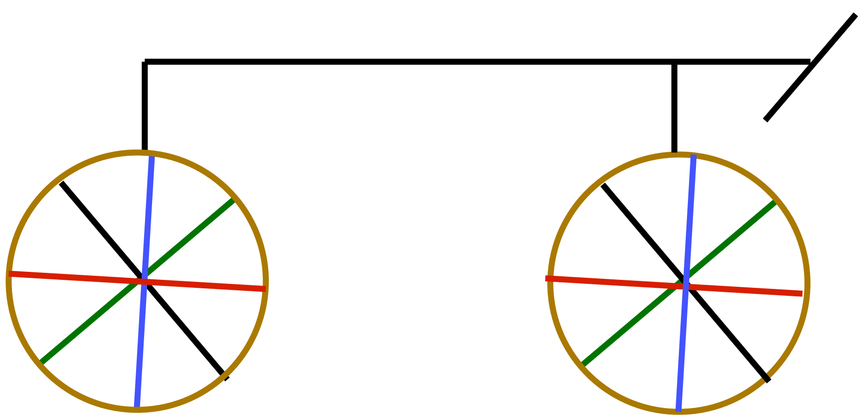
Composite figures



Multiple inheritance: Composite figures

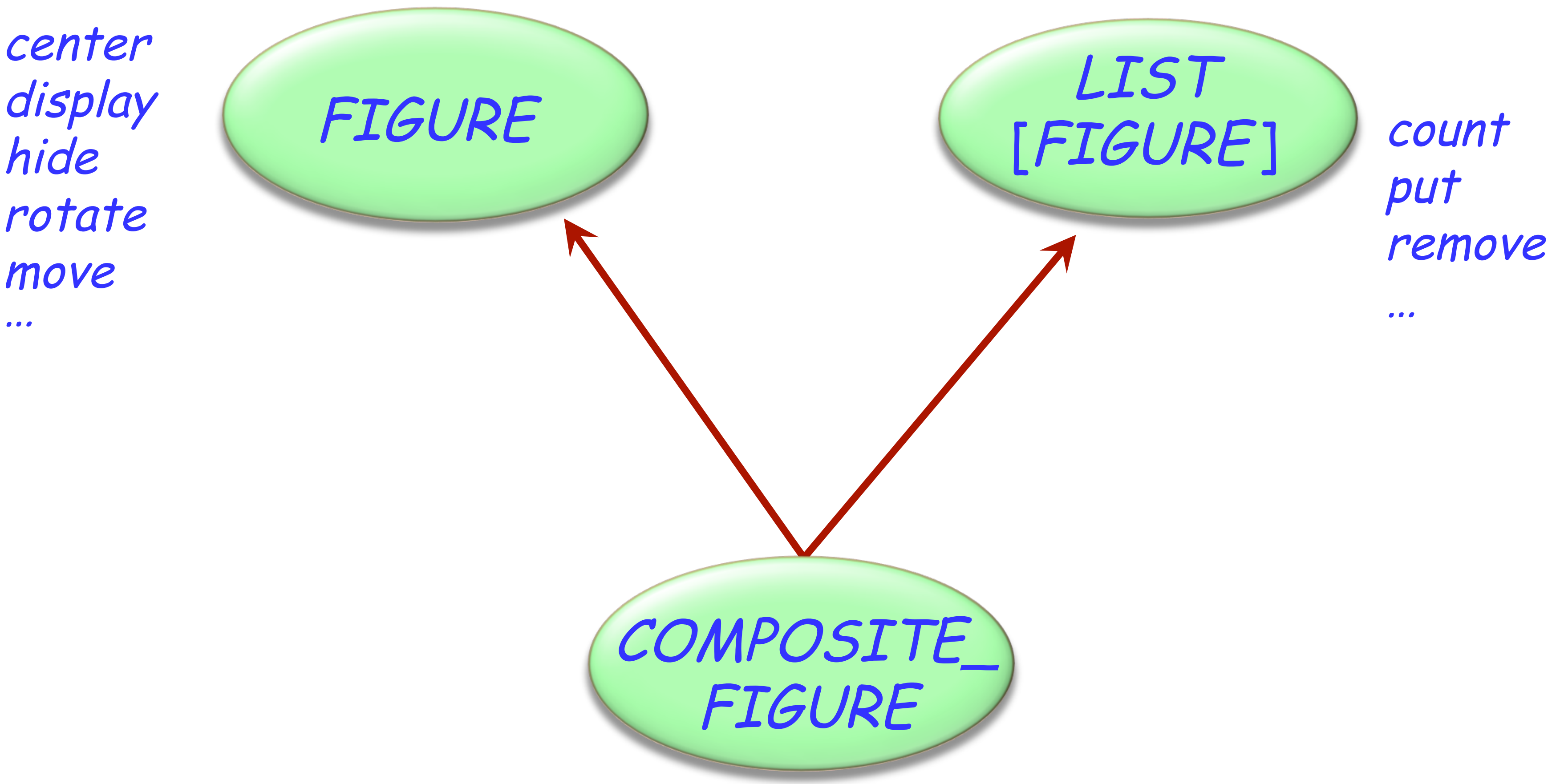


Simple figures

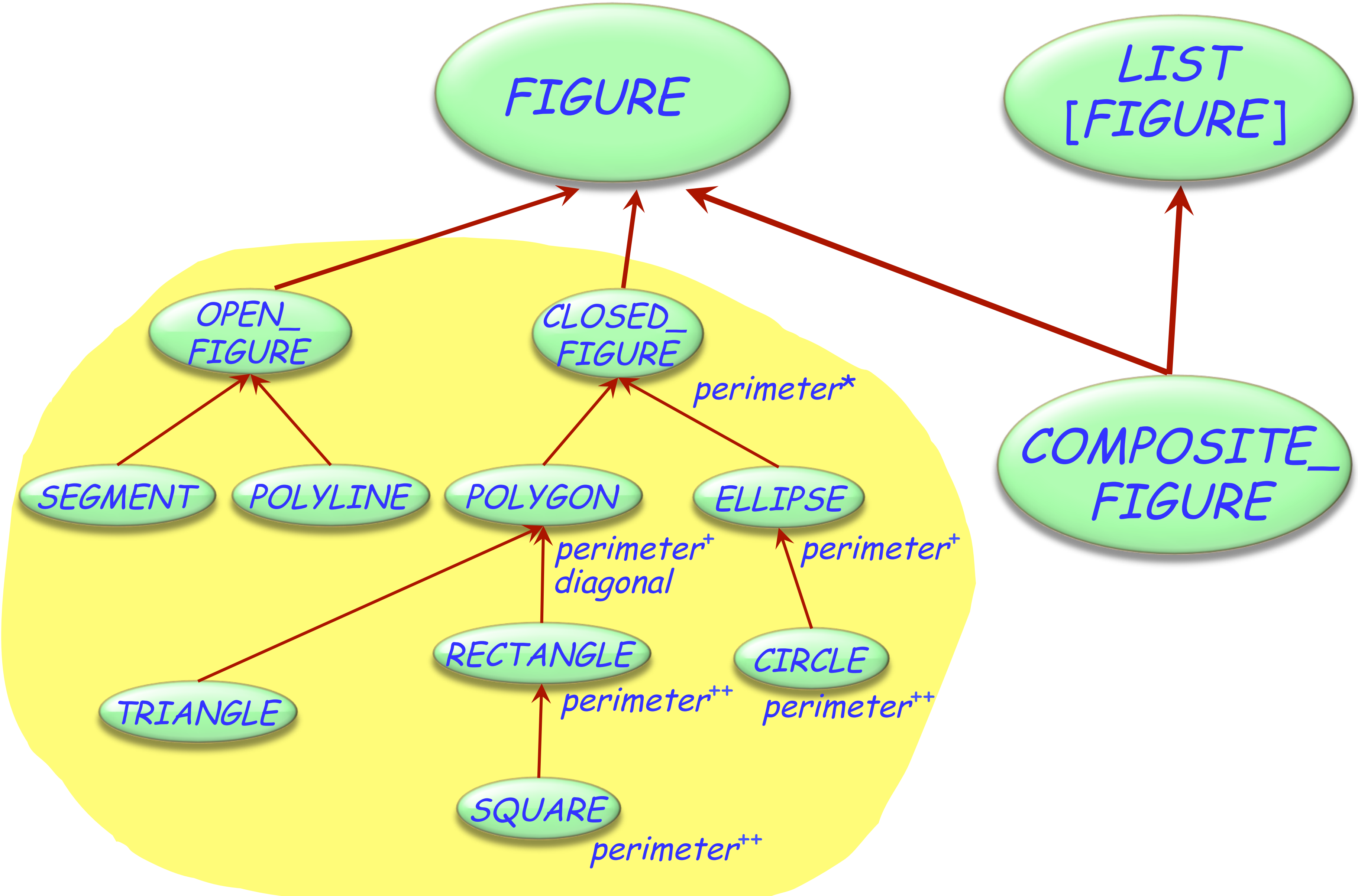


A composite figure

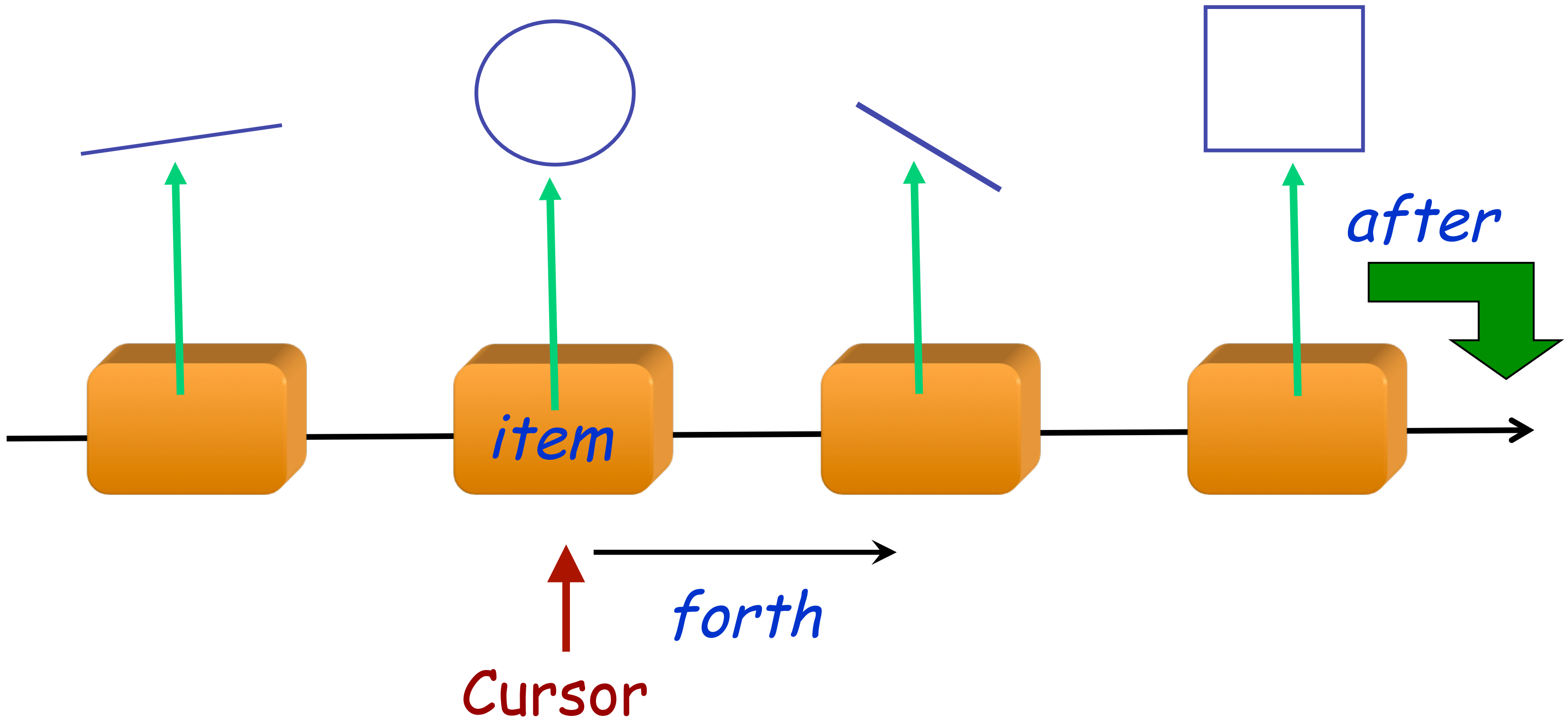
Defining the notion of composite figure



In the overall structure



A composite figure as a list



Composite figures

```
class COMPOSITE_FIGURE inherit
        FIGURE

        LIST [FIGURE]
feature
        display
                -- Display each constituent figure in turn.
        do
                from start until after loop
                        item.display

                        forth
                end
        end
        ... Similarly for move, rotate etc. ...
end
```

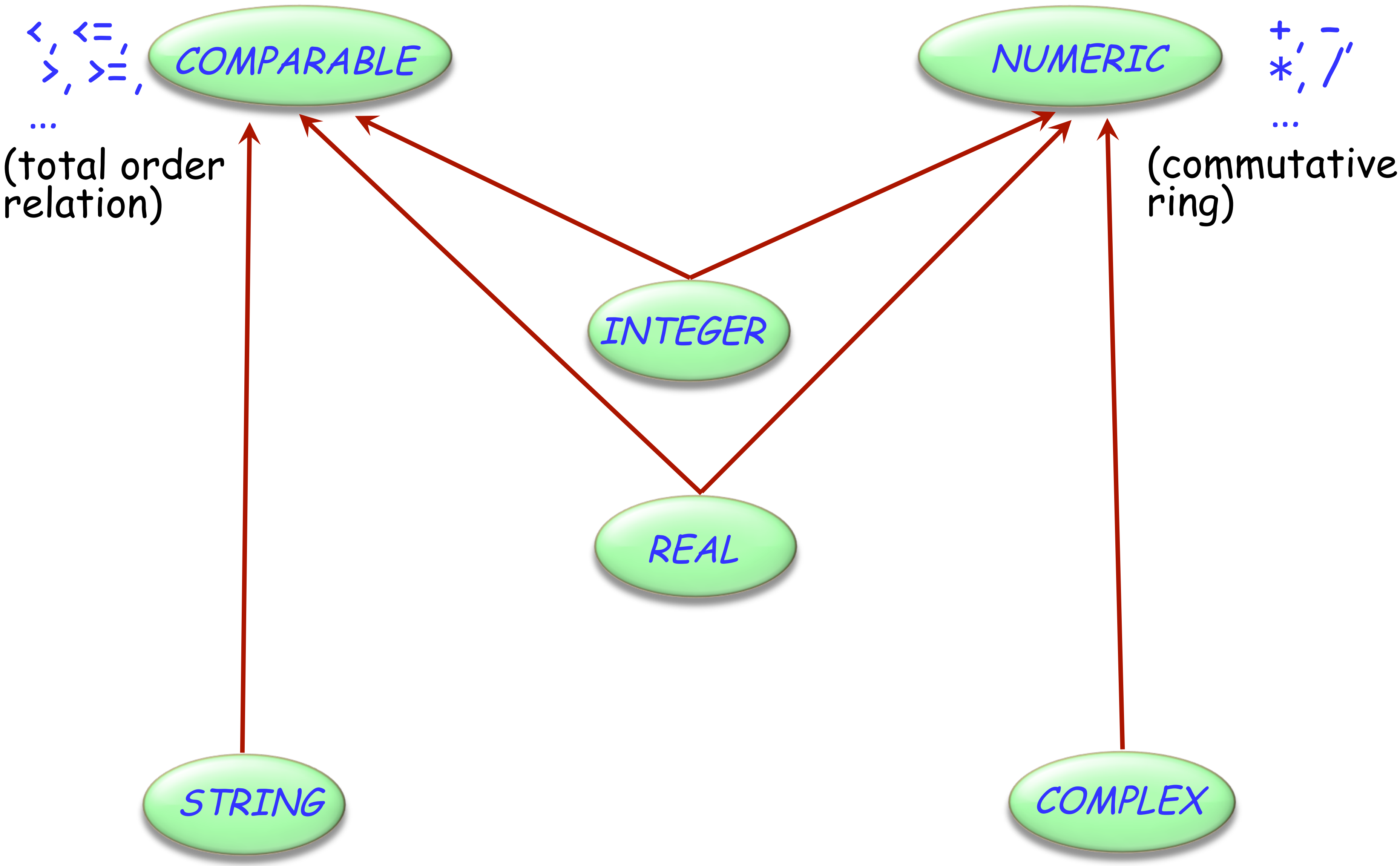
Requires dynamic binding

Going one level of abstraction higher

A simpler form of procedures *display*, *move* etc. can be obtained through the use of iterators

Use agents for that purpose

Multiple inheritance: Combining abstractions



The Java-C# solution

No multiple inheritance for classes

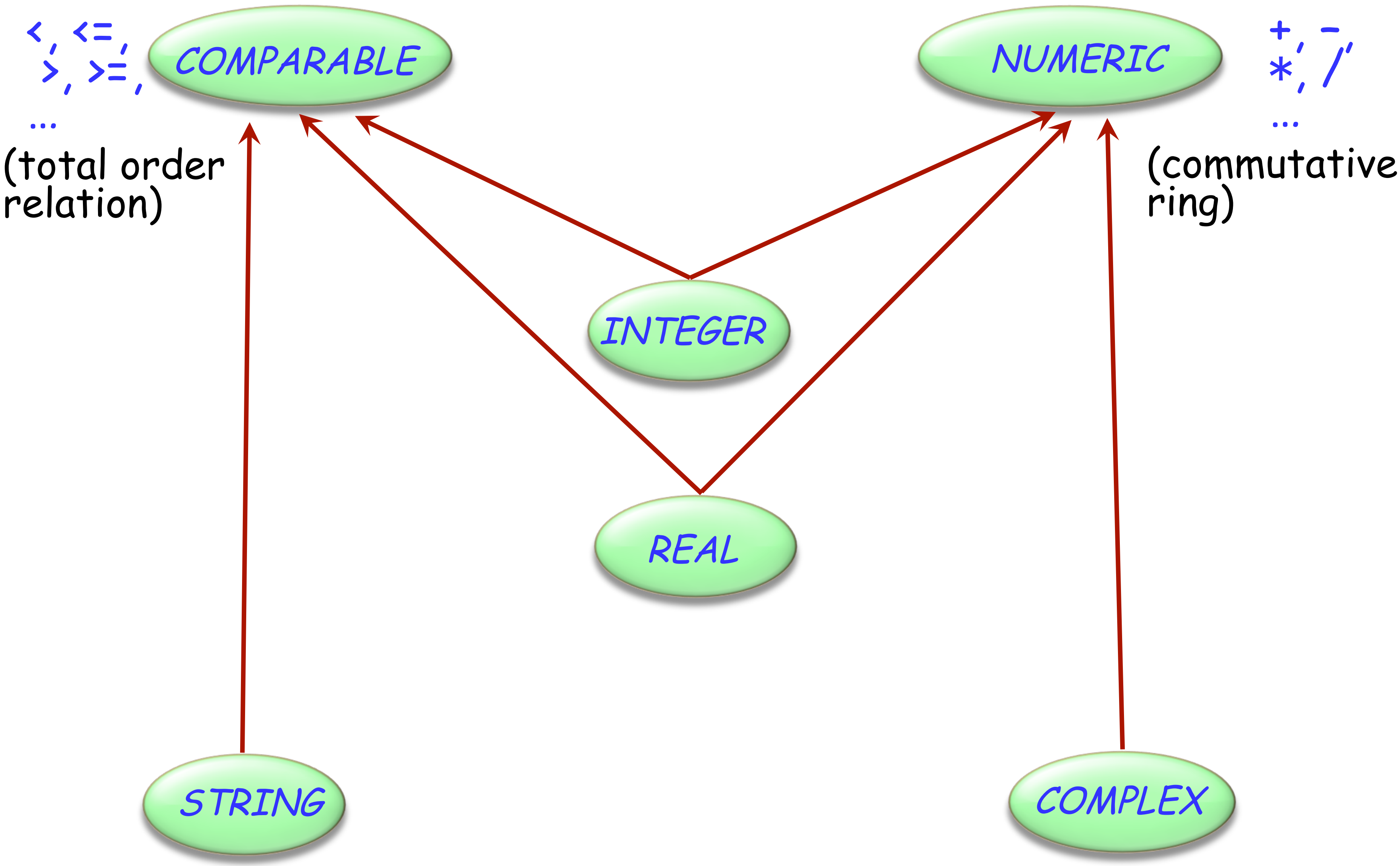
"Interfaces": specification only (but no contracts)

- Similar to completely deferred classes (with no effective feature)

A class may inherit from:

- At most one class
- Any number of interfaces

Multiple inheritance: Combining abstractions



How do we write *COMPARABLE*?

```
deferred class COMPARABLE feature

    less alias "<" (x: COMPARABLE [G]): BOOLEAN
        deferred
        end

    less_equal alias "<=" (x: COMPARABLE): BOOLEAN
        do
            Result := (Current < x or (Current = x))
        end

    greater alias ">" (x: COMPARABLE): BOOLEAN
        do Result := (x < Current) end

    greater_equal alias ">=" (x : COMPARABLE ): BOOLEAN
        do Result := (x <= Current) end
end
```

Lessons from this example

Typical example of *program with holes*

We need the full spectrum from fully abstract (fully deferred) to fully implemented classes

Multiple inheritance is there to help us combine abstractions

Non-conforming inheritance

class

ARRAYED_LIST [*G*]

inherit

LIST [*G*]

inherit {*NONE*}

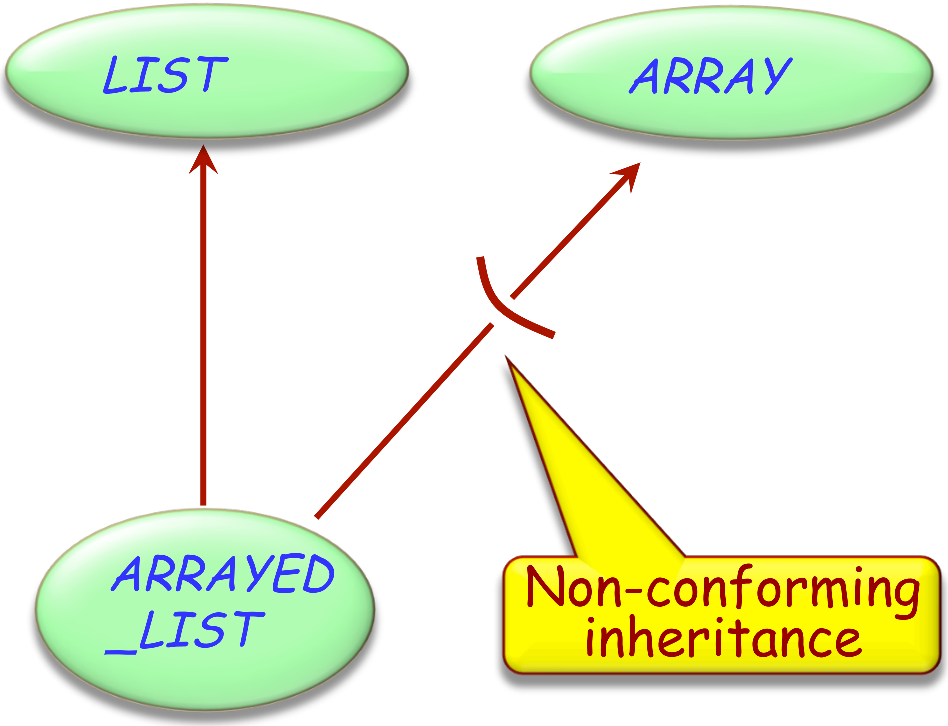
ARRAY [*G*]

feature

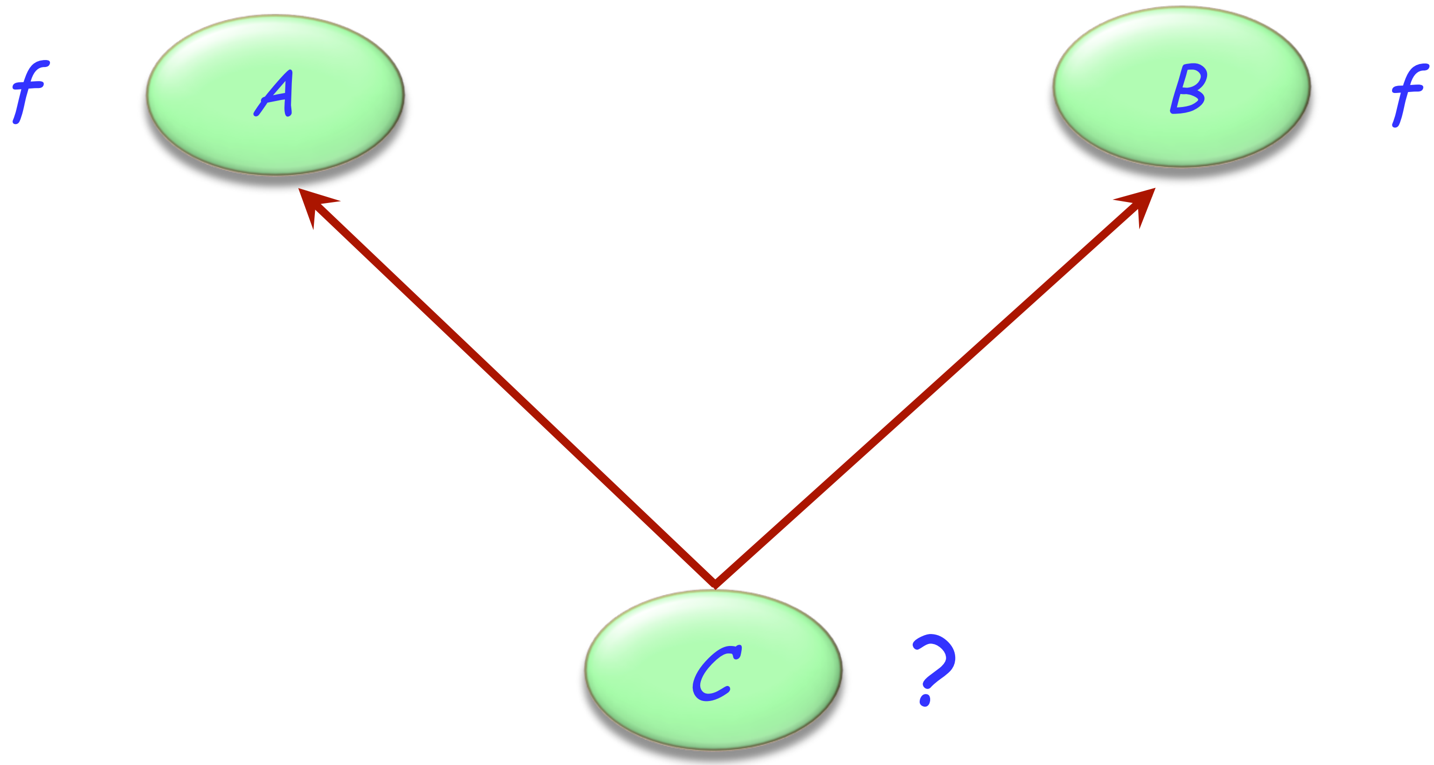
… Implement *LIST* features using *ARRAY* features

…

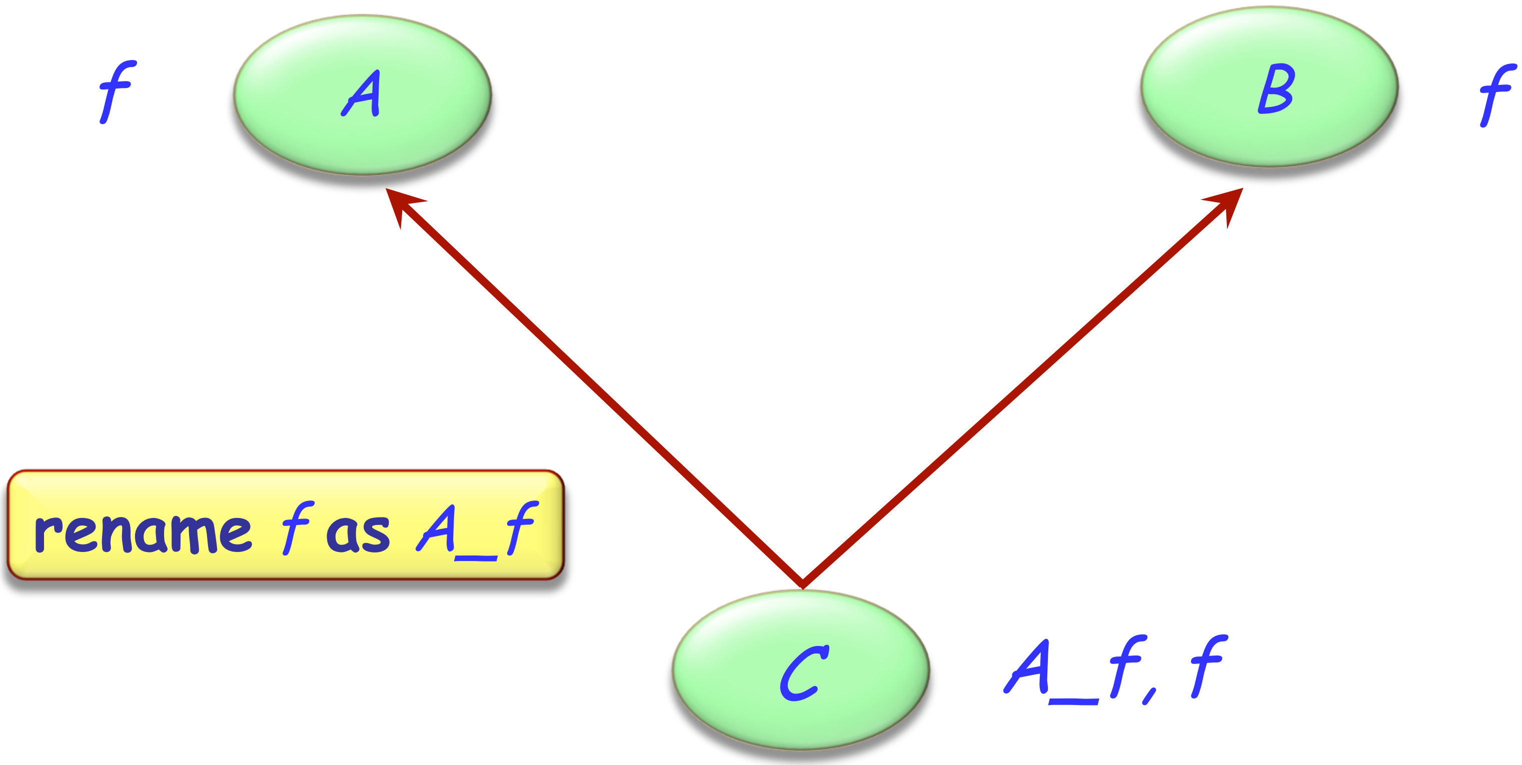
end



Multiple inheritance: Name clashes



Resolving name clashes



Consequences of renaming

a1: *A*
b1: *B*
c1: *C*

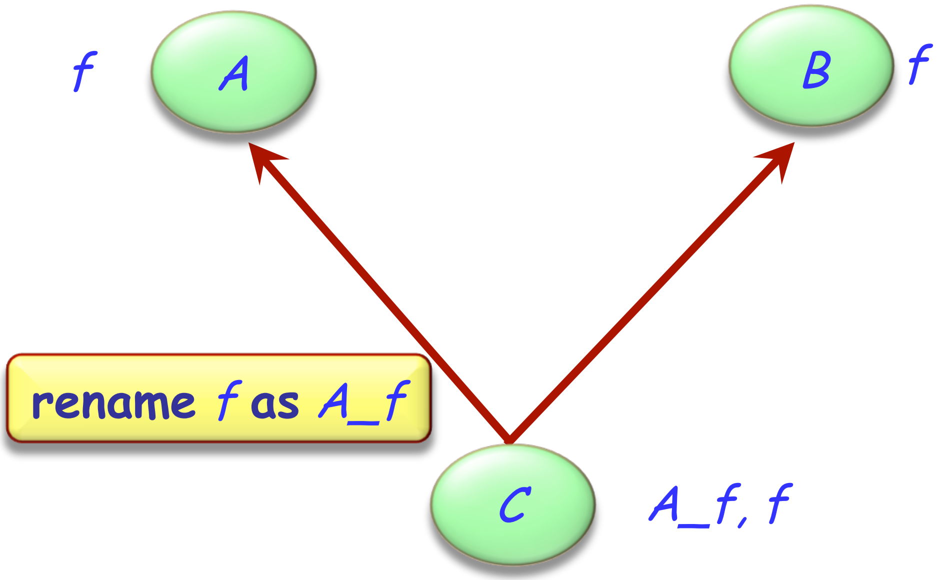
...

c1.f

c1.A_f

a1.f

b1.f



Invalid:

- *a1.A_f*
- *b1.A_f*

Are all name clashes bad?

A name clash must be removed unless it is:

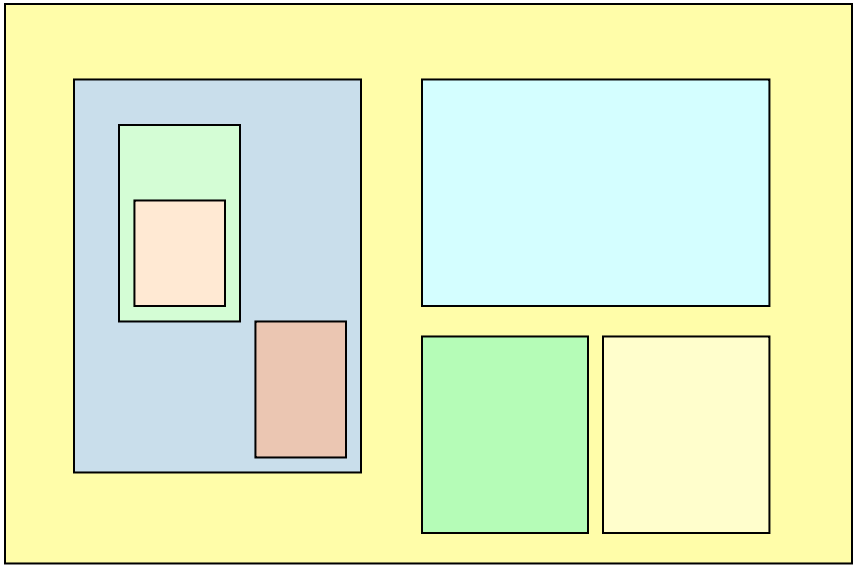
- Under repeated inheritance (i.e. not a real clash)

- Between features of which at most one is effective (i.e. others are deferred)

Another application of renaming

Provide locally better adapted terminology.

Example: *child (TREE); subwindow (WINDOW)*



Overloading

Present in C++, Java, C#, not in Eiffel

Java rule: several features may have the same name if signature (argument types and numbers) are different

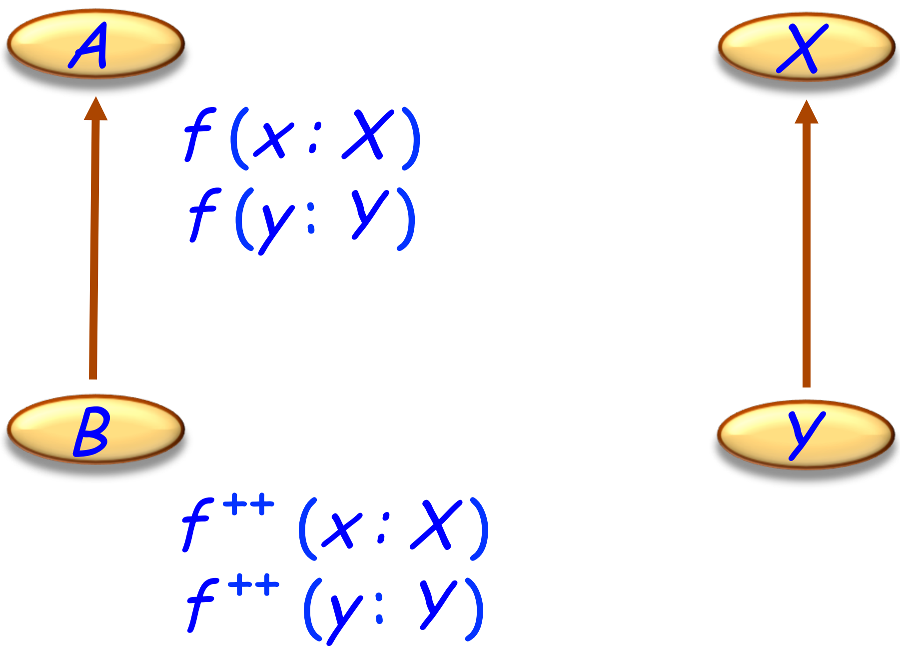
Example

```
print (x: INTEGER)
print (x: INTEGER; f: FORMAT)
print (x: REAL)
```

Risks of overloading

Conflicts with inheritance, polymorphism, dynamic binding

Causes confusion: what does $a.f(xx)$ mean?



See: *Overloading vs Object Technology*, in in *JOOP (Journal of Object-Oriented Programming)*, vol. 14, no. 4, Oct-Nov 2001, se.ethz.ch/~meyer/publications/publications/joop/overloading.pdf

Where is overloading when we need it?

```
class POINT feature
        …
        set_cartesian (x : REAL ; y : REAL) do … end

        set_polar (ro : REAL ; theta : REAL) do … end

        …
end
```

Constructors

C++, Java: name of class, overloaded

```
x = new POINT (1, 0, "cartesian");
```

Eiffel: specific creation procedures

create *x.set_cartesian* (1, 0)

Can be used as normal procedures: *x.set_cartesian* (1, 0)

No special rules for inheritance; each class's constructors are independent from those of parents.

Exception handling: C++/Java

Try operation and provide alternative mechanism:

```
try {
        instructions_1
} catch (A a1) {
        instructions_A
} catch (B b1)
        instructions_B
...
finally {
        cleanup}
```

Raising and specifying exceptions

```
public static int f (...) throws my_exception
        {
        ... throw my_exception
        }
```

Then any caller must catch or throw my_exception.

But: only for programmer exceptions.

Agents

Mechanism to encapsulate operations into objects
Example: Eiffel Event Library

On the publisher side, e.g. GUI library:

- (Once) declare event type:

  click: EVENT_TYPE [TUPLE [INTEGER, INTEGER]]

- (Once) create event type object:

  create *click*

- To trigger one occurrence of the event:

  click.publish ([x_coordinate, y_coordinate])

On the subscriber side, e.g. an application:

click.subscribe (**agent** *my_procedure*)

Another example of using agents

$$\int_a^b my\_function\ (x)\ dx$$

$$\int_a^b your\_function\ (x, u, v)\ dx$$

my_integrator.*integral* (**agent** *my_function* , *a*, *b*)

my_integrator.*integral* (**agent** *your_function* ? , *u*, *v*), *a*, *b*)

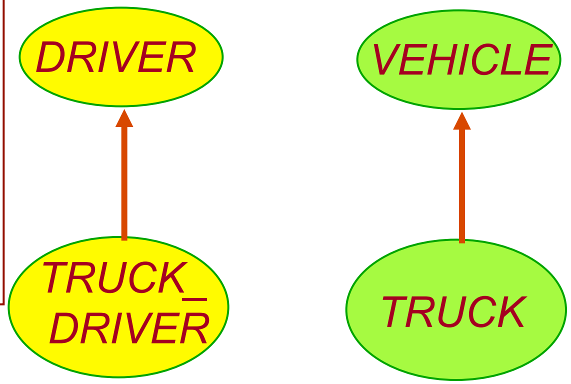
No agents ("closures") in Java

Use inner classes

See: java.sun.com/docs/white/delegates.html

Covariance

```
class DRIVER feature
    transport : VEHICLE
    set_transport (v : VEHICLE) do … end
        …
end
```




```
class TRUCK_DRIVER inherit
     DRIVER
         redefine transport, set_transport end
feature
    transport : TRUCK
    set_transport (t : TRUCK) do … end
    …
end
```

Anchored types

```
class DRIVER feature
    transport : VEHICLE
    set_transport (v : like transport )  do… end
        …
end
```

```
class TRUCK_DRIVER inherit
        COMPANY
            redefine transport end
feature
        transport : TRUCK
        -- No need to redefine set_transport
        …
end
```

Type redefinition rule

May redefine argument or result to a descendant of the original type

Covariance pros and cons

Covariance (Eiffel):

Realistic modeling

But:

Type checking issues

For that reason Java and many other languages are novariant

This is safer but pushes the problem to the programmer

The problem with covariance

```
c: COMPANY
bc: BLOOMBERG_COMPANY

v: VALUATION

...
c := bc
c.set_valuation (v)
```

Catcall!

```
class COMPANY feature
    valuation: VALUATION
    set_valuation (v: like valuation) is
        do ... end
end
```

```
class BLOOMBERG_COMPANY inherit
    COMPANY
        redefine valuation end
feature
    valuation: VALUATION
    -- No need to redefine set_valuation
        ...
end
```

Catcalls

Follow from combination of:

- Polymorphism
- Covariant redefinition

CAT stands for "Changed Availability or Type"

The attached mechanism of ISO Eiffel removes all catcall possibilities

Once routines

If instead of

```
r is
        do
                ... Instructions ...
        end
```

you write

```
r is
        once
                ... Instructions ...
        end
```

then *Instructions* will be executed only for the first call by any client during execution. Subsequent calls return immediately.

In the case of a function, subsequent calls return the result computed by the first call.

Implementation

Java: virtual machine

Eiffel: translation to C or .NET virtual machine

Melting Ice Technology

Syntax

Java:

- Symbol-oriented, C-like

Eiffel:

- Basic structures use keywords, lower-level elements use some symbols
- Keyword consistency: simplest applicable word (**require**, not *requires*; **feature**, not *features*).

Ease of learning

Usenet posting by David Clark, U. Canberra, taught both Eiffel & Java:

My experience has been that students do not find Java easy to learn. Time and again the language gets in the way of what I want to teach....The first thing they see is

```
public static void main (String [ ] args) throws IOException;
```

There are about six different concepts in that one line which students are not yet ready to learn...."