Fondamenti della Programmazione: Metodi Evoluti

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Lezione 11: Genericity

What we have seen in the previous lecture

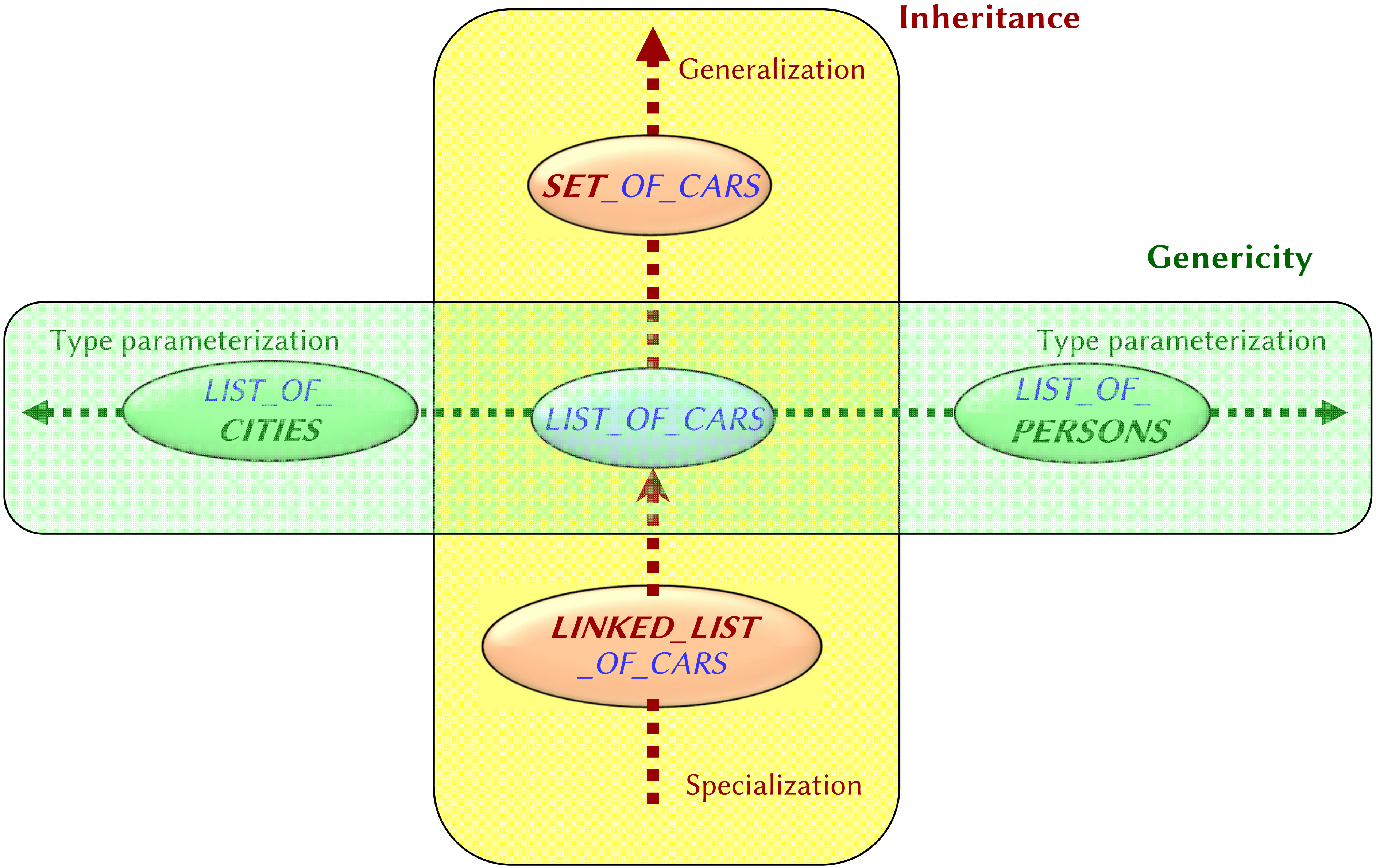
The basics of fundamental O-O mechanisms:

- Inheritance
- Polymorphism
- Dynamic binding
- Static typing

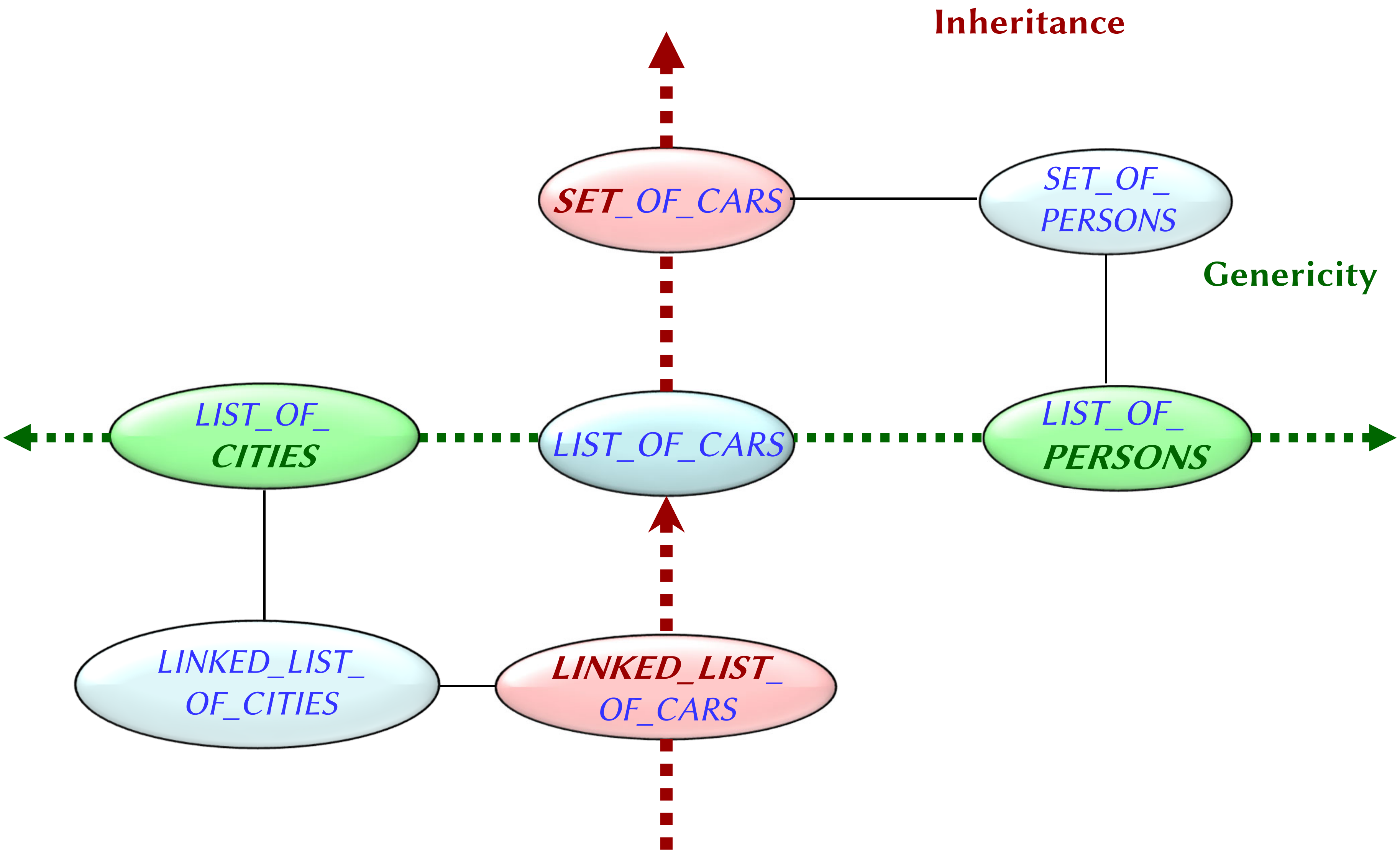
In this lecture we extends them with another key mechanism:

- Genericity

Extending the basic notion of class



Extending the basic notion of class



Ensuring type safety

How could we define consistent "container" data structures, for various types, e.g. list of accounts, list of points?

Something like this:

c : CITY ; p : PERSON

cities : LIST ;

people : LIST ;

---

people.extend (p)

cities.extend (c)

What if arguments are wrong?

c := cities.last

c.some_city_operation

Possible approaches

1. Duplicate code, manually or with help of macro processor

2. Wait until run time; if types don't match, trigger a run-time failure (Smalltalk)

3. Convert ("cast") all values to a universal type, such as "pointer to void" in C

4. **Parameterize the class**, giving an explicit name *G* to the type of container elements. This is the Eiffel approach, also found in recent versions of Java, .NET and others.

A generic class

Formal generic parameter

Definition

```
class LIST [G] feature
        extend (x : G ) ...
        last : G ...
end
```

Declaration

Use: obtain a generic derivation, e.g.

Actual generic parameter

```
cities : LIST [CITY ]
```

Use

Using generic derivations

cities : LIST [CITY]

people : LIST [PERSON]

c : CITY

p : PERSON

...

cities.extend (c)

people.extend (p)

c := cities.last

c.some_city_operation

STATIC TYPING

The compiler will reject:

- *people.extend (c)*
- *cities.extend (p)*

Static typing (reminder)

Type-safe call:

A feature call *x.f* such that any object attached to *x* during execution has a feature corresponding to *f*

[Generalizes to calls with arguments, *x.f* (*a*, *b*)]

Static type checker:

A program-processing tool (such as a compiler) that guarantees, for any program it accepts, that any call in any execution will be *type-safe*

Statically typed language:

A programming language for which it is possible to write a *static type checker*

Using genericity

Not only

LIST [CITY]

But also

LIST [LIST [CITY]]

And so on...

Many types can be derived from a same class:

a type is no longer exactly the same thing as a class!

(But every type remains **based** on a class.)

What is a type?

(To keep things simple let's assume that a class has zero or one generic parameter)

A $\boxed{\text{type}}$ is of one of the following two forms:

- C, where C is the name of a non-generic class

- $D\ [T]$, where D is the name of a generic class and T is a $\boxed{\text{type}}$

Have you seen the recursion?

Types (reminder)

We use types to declare entities, as in

x : *SOME_TYPE*

With the mechanisms defined so far, a type is one of:

- A non-generic class

  e.g. *x* : METRO_STATION

- A generic derivation, i.e. the name of a class followed by a list of ***types***, the actual generic parameters, in brackets

  e.g. *x* : *LIST* [*METRO_STATION*]

  x : *LIST* [*ARRAY* [*METRO_STATION*]]

Genericity: summary

Type extension mechanism

Reconciles flexibility with type safety

Enables us to have parameterized classes

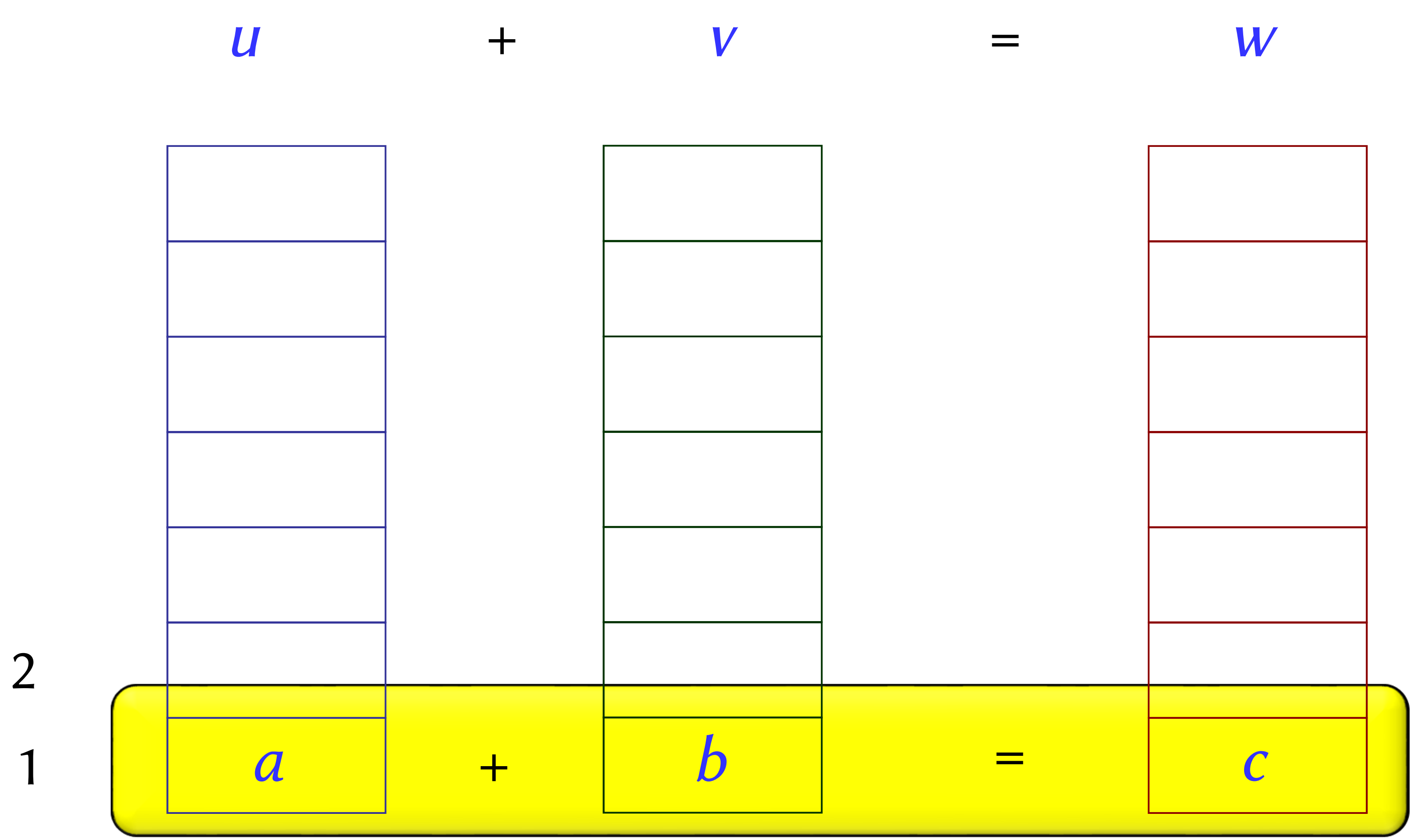
Useful for container data structures: lists, arrays, trees, ...

"Type" now a bit more general than "class"

Adding two vectors (1)


```
class VECTOR [G ]
feature
        plus alias "+" (other: VECTOR [G ]): VECTOR [G ]
                        -- Sum of current vector and other.
                require
                        lower = other.lower
                        upper = other.upper
                local
                        a, b, c : G
                do
                        ... See next ...
                end
        ... Other features ...
end
```

Adding two vectors (2)



Adding two vectors (3)

Body of *plus* **alias** "+" in *VECTOR* [*G*] :

```
create Result.make (lower, upper)
from
        i := lower
until
        i > upper
loop
        a := item (i )
        b := other.item (i )
        c := a + b         -- Requires "+" operation on G!
        Result.put (c, i )
        i := i + 1
end
```

The solution

Declare class *VECTOR* as

class *VECTOR* [*G* –> *NUMERIC*] **feature**

... The rest as before ...

end

Class *NUMERIC* (from the Kernel Library) provides features *plus* **alias** "+", *minus* **alias** "-"and so on.

Constrained genericity (1)

Unconstrained

LIST [G]

e.g. *LIST* [*INTEGER*], *LIST* [*PERSON*]

Constrained

HASH_TABLE [*G* —> *HASHABLE*]

VECTOR [*G* —> *NUMERIC*]

Constrained genericity (2)

Unconstrained

- the generic class
  LIST [G]
  can be used by substituting G with any class, e.g.:
  LIST [*INTEGER*], *LIST* [*PERSON*]

  as in:

  prices : *LIST* [*INTEGER*]

  candidates : *LIST* [*PERSON*]

Constrained

- the generic **constrained** class
  HASH_TABLE [*G* —> *HASHABLE*]
  can be used by substituting G only with a class inheriting from (i.e., a subclass of) *HASHABLE*
- unconstrained genericity is constrained to *ANY*
- multiple constraints can be specified
  VECTOR [*G* —> {*COMPARABLE*, *NUMERIC* }]

  and then all constraint must be satisfied, e.g.:

Correct! *prices* : *VECTOR* [*INTEGER*]

Wrong! *candidates* : *VECTOR* [*STRING*]

Improving the solution

Can we have *VECTOR* of *VECTOR* ... ?
Remember we need operation "+" on single items...

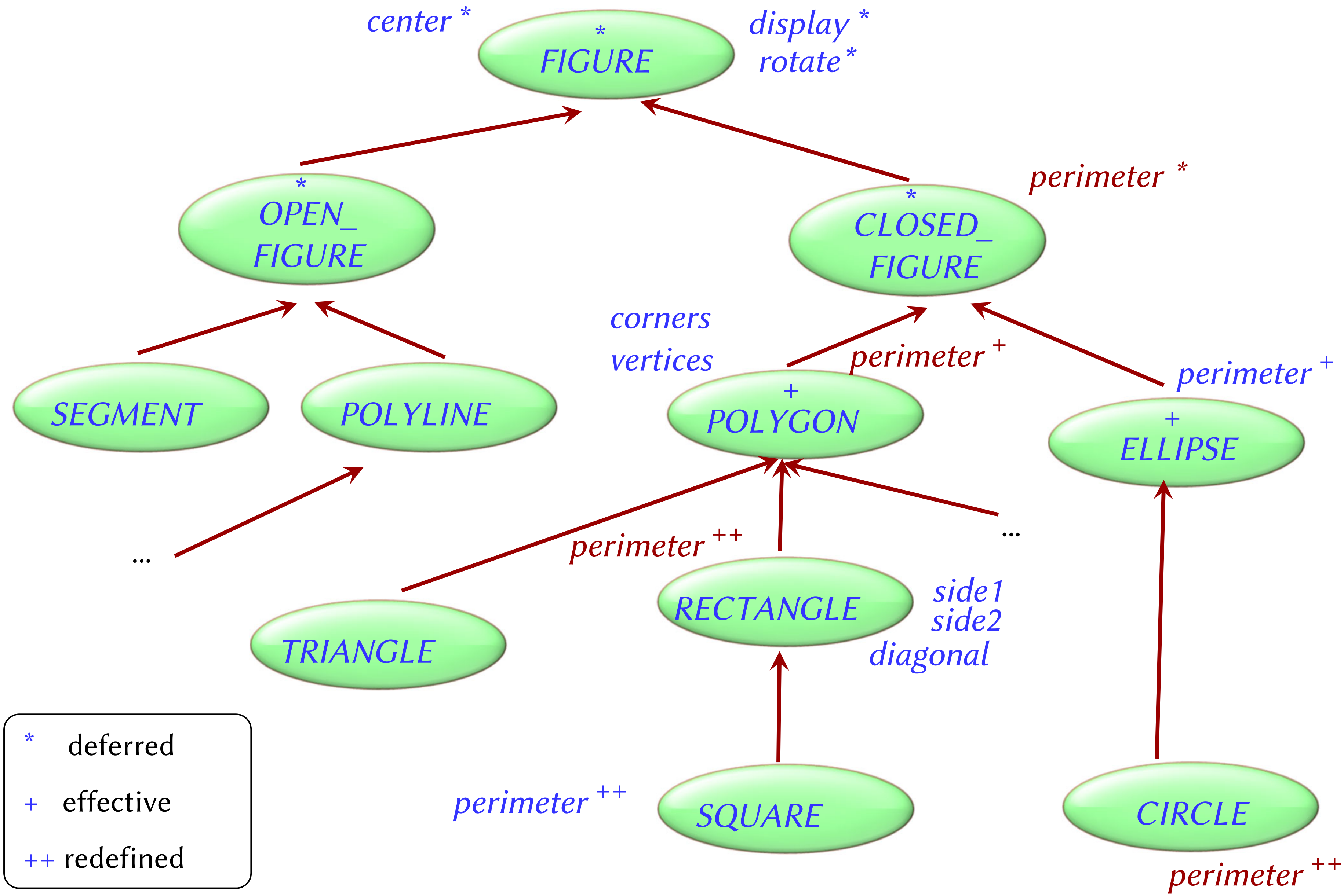
Make *VECTOR* itself a descendant of *NUMERIC*,
effecting the corresponding features:

```
class VECTOR [G -> NUMERIC] inherit
        NUMERIC
feature
        ... Rest as before, including infix "+"...
end
```

Then it is possible to define

```
v :   VECTOR [INTEGER]
vv :  VECTOR [VECTOR [INTEGER]]
vvv : VECTOR [VECTOR [VECTOR [INTEGER]]]
```

A more realistic example of inheritance hierarchy

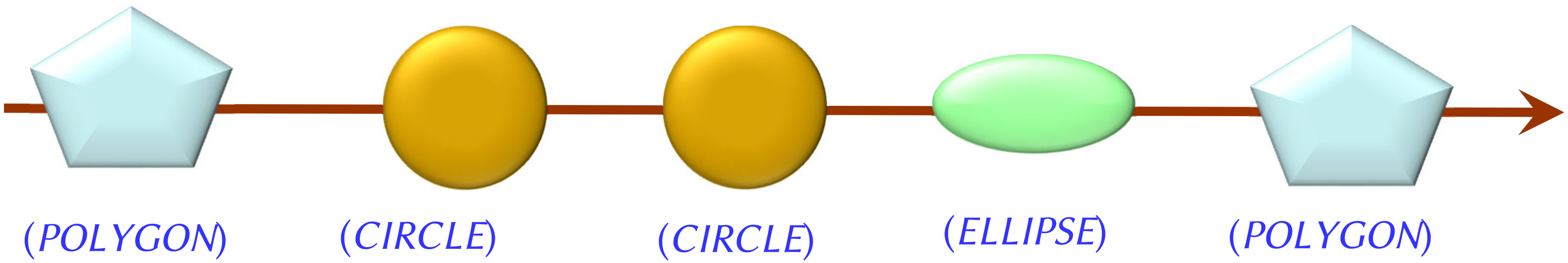


Polymorphic data structures

figs : *LIST* [*FIGURE*]
p1, *p2*: *POLYGON*
c1, *c2*: *CIRCLE*
e: *ELLIPSE*

```
class LIST [G]
feature
    extend (v : G)
        do … end
    …
end
```

figs.*extend* (*p1*) ; *figs*.*extend* (*c1*) ; *figs*.*extend* (*c2*)
figs.*extend* (*e*) ; *figs*.*extend* (*p2*)



Working with polymorphic data structures

figs: *LIST* [*FIGURE*]

…

across *figs* **as** *c* **loop**

c.*item*.*display*

end

from *figs.start*

until *figs.after*

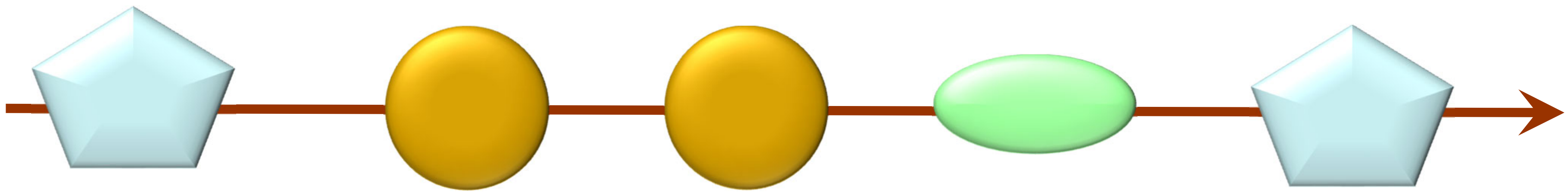
loop

figs.item.display

figs.forth

end

Dynamic binding



(*POLYGON*) (*CIRCLE*) (*CIRCLE*) (*ELLIPSE*) (*POLYGON*)

Polymorphic data structures (one more example)

fleet: LIST [VEHICLE]

a_cab: TAXI

a_tram: TRAM

a_house: HOUSE

Not a subclass of *VEHICLE*

Using genericity you can provide an implementation of type safe containers. This helps avoiding object-tests

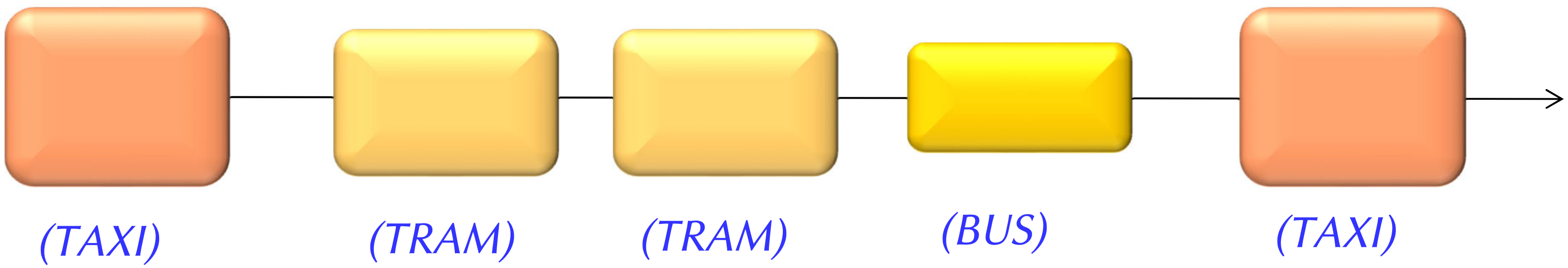
fleet.extend (a_tram)

fleet.extend (a_cab)

fleet.extend (a_house)

Allowed?

No!



Definition: polymorphism (adapted)

An **attachment** (assignment or argument passing) is **polymorphic** if its target entity and source expression have different types.

An **entity** or **expression** is **polymorphic** if – as a result of polymorphic attachments – it may at runtime become attached to objects of different types.

A **container data structure** is **polymorphic** if it may contain references to objects of different types.

Polymorphism is the existence of these possibilities.

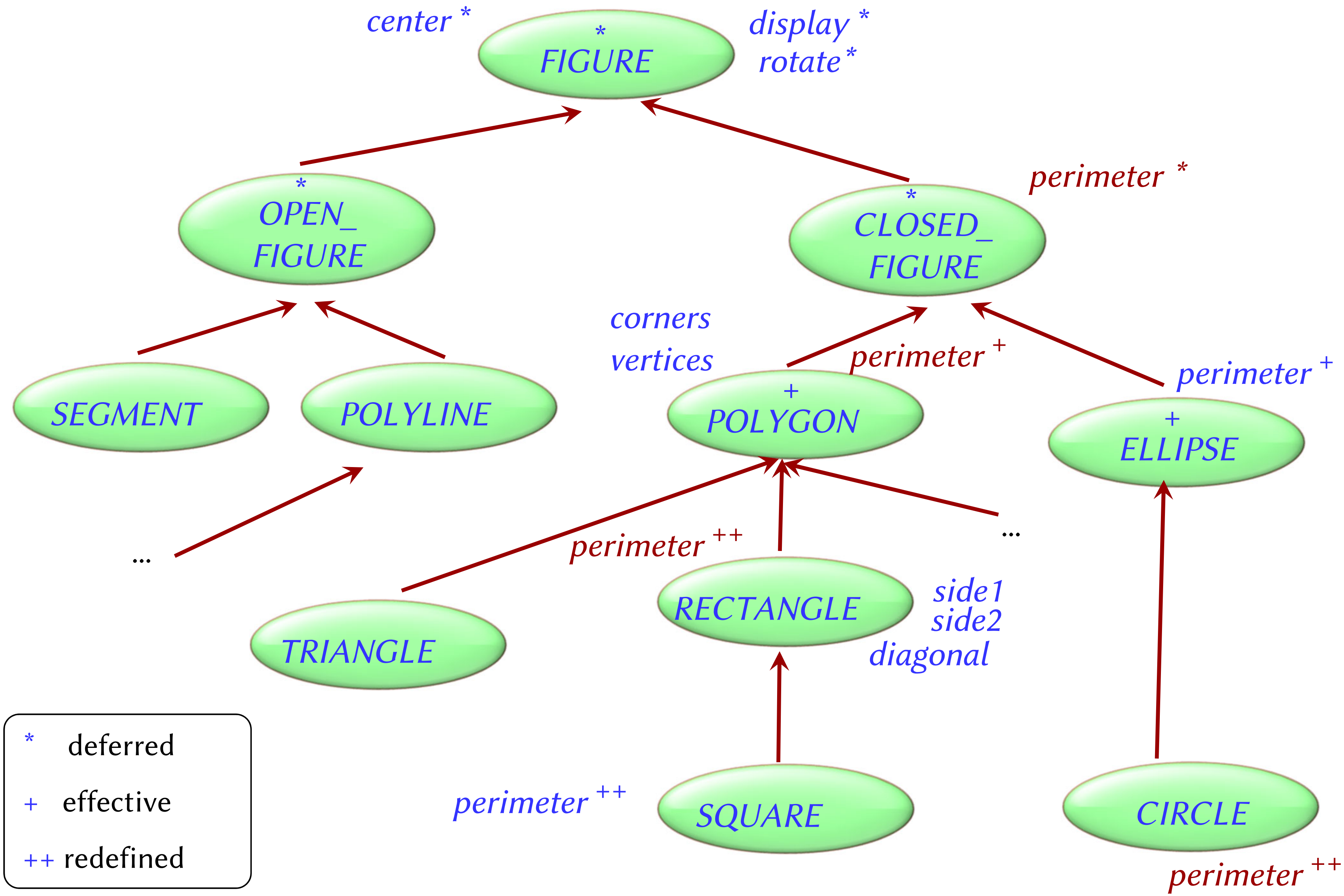
Conformance: full definition

An expanded type conforms only to itself.

A reference type *U* **conforms** to a reference type *T* if either:

- Both have no generic parameters, and *U* is a descendant of *T*.
- They are both generic derivations with the same number of actual generic parameters, and
  - the base class of *U* is a descendant of the base class of *T*,
  - and every actual parameter of *U* (recursively) **conforms** to the corresponding actual parameter of *T*.

A more realistic example of inheritance hierarchy

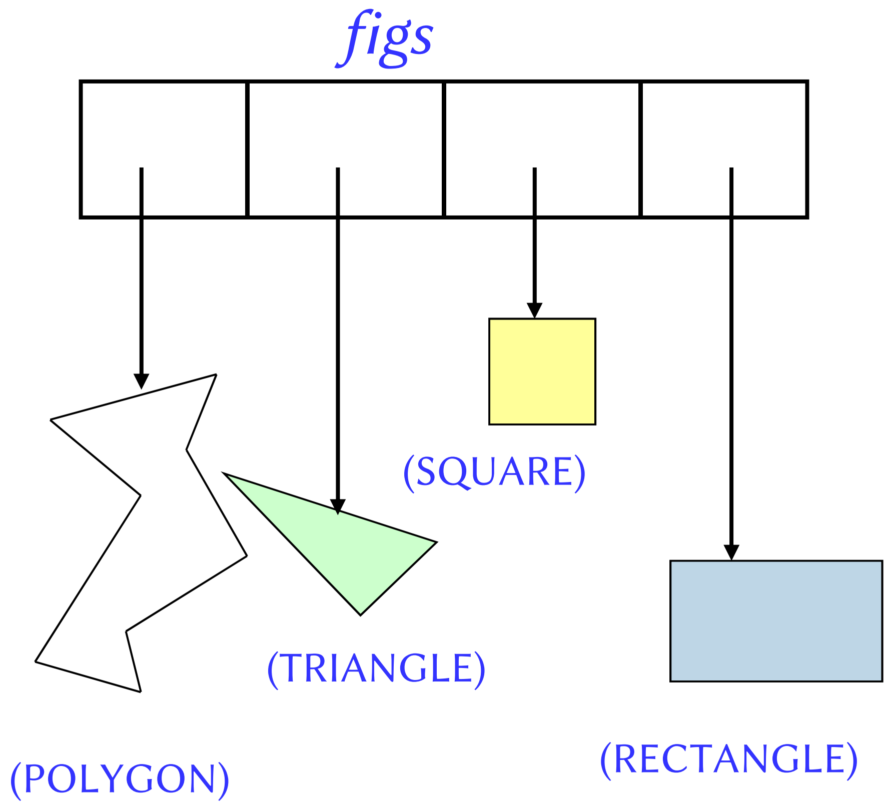


*	deferred
+	effective
++	redefined

Reminder: the list of figures

class
LIST [*G*]
feature
...
last : *G* **do** ...
extend (*x* : *G*) **do** ...
end

figs : *LIST* [*FIGURE*]
r : *RECTANGLE*
s : *SQUARE*
t : *TRIANGLE*
p : *POLYGON*



figs.extend (*p*); *figs.extend* (*t*); *figs.extend* (*s*); *figs.extend* (*r*)

figs.last.display

Enforcing a type: the problem

figs.store ("FN") -- Save on disk (from class *STORABLE*)

…

-- Two years later:

figs := *retrieved* ("FN") -- Read from disk

…

x := *figs.last* -- [1]

print (*x.diagonal*)-- [2]

Is there anything wrong with this?
Which is the type of *x* ?

- If *x* is declared of type *FIGURE*, [2] is invalid.
- If *x* is declared of type *RECTANGLE*, [1] is invalid.

Enforcing a type: the Object Test

Expression to be tested

Object-Test Local

if **attached** {*RECTANGLE*} *figs.retrieved.last* ("FN") **as** r **then**

print (*r.diagonal*)

...Do anything else with *r*, guaranteed

...to be non void and of dynamic type *RECTANGLE*

else

print ("Too bad.")

end

SCOPE of the Object-Test Local

Earlier mechanism: assignment attempt


```
f: FIGURE
r: RECTANGLE

...
figs.retrieve ("FN")
f := figs.last

r ?= f

if r /= Void then
        print (r.diagonal)
else
        print ("Too bad.")
end
```

Assignment attempt

$$x \mathrel{?=} y$$

with

$$x : A$$

Semantics:

- If y is attached to an object whose type conforms to A, perform normal reference assignment.
- Otherwise, make x void.