Fondamenti della Programmazione: Metodi Evoluti

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Lezione 14: Agenti

Numerical programming

Hands-On

1. Given a set of predefined functions, allow the user to choose one of them to be numerically integrated, according to user provided interval and integration step

2. Allow the user to input a polynomial function to be numerically integrated, as above

Integration: a first solution

compute_integral (*f*: *INTEGRATABLE_FUNCTION* ;
a, *b*, *step* : *REAL*): *REAL*

-- Integral of function *f*
-- over Interval [*a*, *b*]

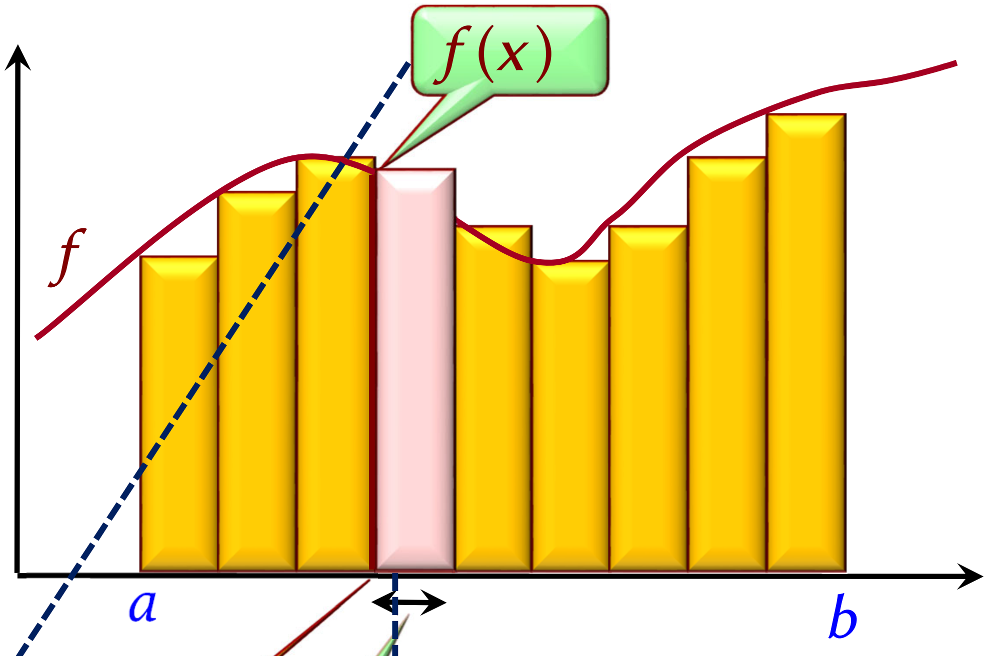
local
x: *REAL*; *i* : *INTEGER*

do

from *x* :=*a* *i* :=0 **until** *x* ≥ *b* **loop**

Result := **Result** + *f*.*item* (*x*) * step
i := *i* + 1
x := *a* + *i* * *step*

end
end



Numerical question: why not
x := *x* + *step* ?

Solution highlights and problems (see demo)


```
deferred class INTEGRATABLE_FUNCTION feature
    item (x: REAL): REAL
...
```

For each function to be integrated one has to define an appropriate **class**, subclass of *INTEGRATABLE_FUNCTION* and implementing the required feature *item* which provides the current value of the function

```
class CALCULUS feature
    compute_integral (f: INTEGRATABLE_FUNCTION; a, b, step: REAL): REAL
...
my_calculus: CALCULUS
...
r := my_calculus.compute_integral (f_to_integrate, start, end, step)
```

Solution demo

See demo…

Solution highlights and problems (2)

Need to define a *wrapper class* (*INTEGRATABLE_FUNCTION*) **only** to provide the common ancestor for all functions to be integrated.

It has just one instance

It has no attributes

A better approach is to directl pass the function to be integrated as an argument to the integration procedure

The mechanism allowing this has to be provided by the programming language: in Eiffel it is the *agent mechanism*

Agents (1)

Agents are objects whose unique purpose is to describe an operation

In Eiffel an operation is represented by a routine: a command (procedure) or a query (function)

Given a routine *r* the corresponding agent is defined by the espression

agent *r*

An agent can be assigned to an object (of an appropriate type to be seen next)

a := **agent** *r*

Now we can ask *a* to execute routine *r* through a predefined feature *call* (of an appropriate type: to be seen next)

a.call

like if we just wrote

r

Agents (2)

If routine *r* takes two arguments then writing

a.call (*x*, *y*)

is the agent call producing the same effect as

r (*x*, *y*)

The old syntax used ***a.call([x,y])***

Here ***(x,y)*** is indeed a tuple but with a simpler syntax

In such a way we can pass a routine *r* as an argument to another routine *t* so that the passed routine *r* is known inside *t* just through its formal name ***a***

Agents (3)

Agents provide to **operations** the separation between

definition of the operation (agent definition)

execution of the operation (agent call)

Useful whenever an object has to apply an operation to other objects without prior knowledge of the specific operation

- **providing new operations to existing objects**

e.g.: iterating over a list and applying an action to every item, without knowing the action in advance

Application of agents

Numerical programming: Applying a calculus operation to a function

Iteration: Applying an operation to all elements of a data structures

Event-driven programming: Applying a program reaction to an event (and being able to undo it)

User interaction: Being able to undo user actions

A first kind of agent: function (1)

Assume class

MY_CLASS

has feature

my_function (*x: REAL*): REAL **do** ... **end**

and consider

my_object : *MY_CLASS*

We want to *agent*-ize *my_object.my_function*

Which is the language mechanism allowing to write

a := **agent** *my_object.my_function* ? ? ?

A first kind of agent: function (2)

In general:

which is the type of an "*agent*-ized" function?

Described by EIFFEL generic class

FUNCTION [*A*, *R*]

A is constrained to be a type conforming to *TUPLE*

R denotes the type of the result returned by the function

The old syntax used ***FUNCTION*** **(B, A, R)** where *B* denoted the class providing the function passed as an agent, or its ancestor; often *ANY* was used.

A first kind of agent: function (3)

Declaring variable

a : ***FUNCTION*** [*REAL*, *REAL*]

allows to write (agent definition)

a := **agent** *my_object.my_function*

The old syntax used
FUNCTION **(ANY, TUPLE[REAL], REAL)**

Then the request to the agent to execute feature call

a.call (*x*)

has the same effect as

my_object.my_function (*x*)

...but for the fact that *a.call* (*x*) does not return a result !

A first kind of agent: function (4)

Feature *call* of class *FUNCTION* [*A*, *R*] just executes the *agent*-ized routine and store its result in feature *last_result*

Therefore

a.call (*x*)

s := *a.last_result*

produces the same effect as

s := *my_object.my_function* (*x*)

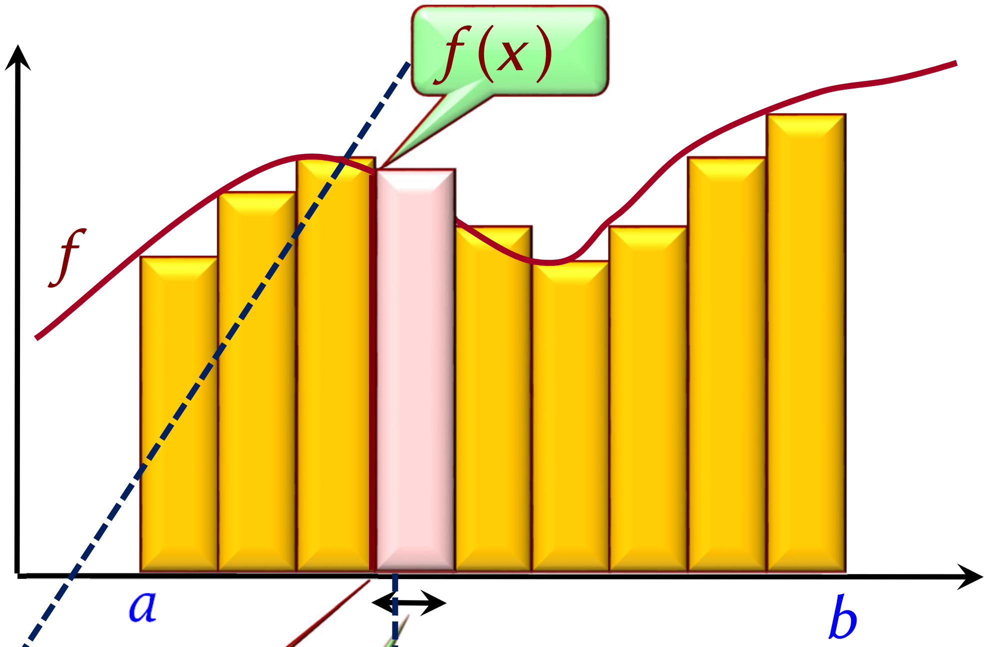
A shortcut is to write (keeping the convention for accessing a generic item of a structure)

s := *a.item* (*x*)

Integration: agent based solution

compute_integral (*f*: *FUNCTION* [*REAL*, *REAL*]; *a*, *b*, *step* : *REAL*): *REAL*

-- Integral of function *f*
-- over Interval [*a*, *b*]



local
x: *REAL*; *i* : *INTEGER*

do

from *x* :=*a* *i* :=0 **until** *x* ≥ *b* **loop**

Result := **Result** + *f*.*item* (*x*) * step
i := *i* + 1
x := *a* + *i* * *step*

end
end

Numerical question: why not
x := *x* + *step* ?

Agent-based solution highlight and comparison

```
class CALCULUS feature
    compute_integral (f: FUNCTION [REAL, REAL]; a, b, step: REAL): REAL
...
my_calculus: CALCULUS
...
r := my_calculus.compute_integral (agent f_to_integrate, start, end, step)
```

a feature

Previous solution without agents

```
class CALCULUS feature
    compute_integral (f: INTEGRATABLE_FUNCTION; a, b, step: REAL): REAL
...
deferred class INTEGRATABLE_FUNCTION feature
    item (x: REAL): REAL
...
my_calculus: CALCULUS
...
r := my_calculus.compute_integral (f_to_integrate, start, end, step)
```

a class instance

Agent-based solution demo

See demo...

One more issue (1)

Declaring variable

a : ***FUNCTION*** [*REAL*, *REAL*]

allows to write (agent definition)

a := **agent** *my_object.my_function*

and we can then ask the agent *a* to compute *my_function* with an argument *x* assigned by the routine using the agent itself

s := *a.item* (*x*)

What if we have a function with two arguments and we want the agent to compute it with one fixed parameter *p* defined by us?

One more issue (2)

We declare variable

a2 : ***FUNCTION*** [*REAL*, *REAL*, *REAL*]

and write (agent definition)

a2 := **agent** *my_object.my_function* (?, *p*)

and we can then ask the agent *a2* to compute *my_function* with first argument *x* assigned by the routine using the agent itself and second argument assigned to *p* by the agent definition

s := *a2.item* (*x*)

The old syntax used

FUNCTION **(ANY, TUPLE[REAL, REAL], REAL)**

and we get the same effect as

s := *my_object.my_function* (*x*, *p*)

If no argument is used in the agent definition, then all the routine arguments have to be assigned by the routine using the agent

Iteration examples

- Perform the following actions on a list of persons with name and age
    1. Print the name of each
    2. Increment age of each by a given amount

Implementation for each is straightforward

Iteration examples (2)

See demo...

Iteration examples (3)

For each problem the same “pattern” (loop-and-for-each-do-something) is applied again and again: can we abstract?

Towards a generalization (1)

Assume *MY_LIST_CLASS* has a procedure able to iterate over all elements

```
do_for_each_item (action-on-some-argument ...)
    from start
    until after
    loop
        apply action-on-some-argument to current item
        forth
    end
```

A routine passed as argument to a routine...

... so that it can be executed at run-time

Towards a generalization (2)

Then for

my_list : *MY_LIST_CLASS*

writing

my_list.do_for_each_item (*my_procedure*)

would apply *my_procedure* to each element in *my_list*

The old syntax used ***PROCEDURE*** **(ANY, TUPLE[G])**

Descendants of *LINEAR* [*G*], like *LINKED_LIST* [*G*], have such a routine!
(a mechanism of this kind is often called **iterator**)

```
do_all (action : PROCEDURE [G ] )
        from start
        until after
        loop
                action.call (item)
                forth
        end
```

The mechanism to *agent*-ize a procedure...

The argument passed to the *agent*-ized procedure is *item*, the *LINKED_LIST* attribute denoting the current element of the list

A second kind of agent: procedure (1)

In general:

which is the type of an "*agent*-ized" procedure?

Described by EIFFEL generic class

PROCEDURE [*A*]

A is constrained to be a type conforming to *TUPLE*

The old syntax used ***PROCEDURE*** **(B,A)** where *B* denoted the class providing the procedure passed as an agent, or its ancestor; often *ANY* was used.

A second kind of agent: procedure (2)

Declaring object

a : ***PROCEDURE*** [*G*]

allows to attach to *a* the object (agent definition)

agent *my_object.my_procedure*

either by assignment (as seen for *agent*-ized functions) or by parameter passing.

Then the request to the agent to execute feature call

a.call (*p*)

has exactly the same effect as

my_object.my_procedure (*p*)

A second kind of agent: procedure (3)

Then for

my_list : *LINKED_LIST* [*PERSON*]

writing

my_list.do_all (*my_procedure*)

would apply *my_procedure* to each element in *my_list* , as if it were written

```
from start
until after
loop
    my_procedure (item)
    forth
end
```

Iteration solution with agents: first approach

How to use this with

my_list : *LINKED_LIST* [*PERSON*]

so that the iterator

my_list.do_all(...)

has the required behavior?

Which is the *my_procedure* to be passed in an agent form so as to print or increment_age ?

It has to be a procedure such that the current item of the list (an instance of *PERSON*) is its **argument**

And which is the **target** that has to call such a procedure?

Iteration solution with agents: first approach

The answer is in the syntax of *agent*-ized procedure and *do_all*

my_list.do_all(**agent** *my_object.my_procedure*)

my_procedure has to be such that the current item of *my_list* (which is an instance of *PERSON*) is its **argument**

my_object cannot be a specific instance of *PERSON* since *my_procedure* will have to be applied to each item of the list (and this is taken care by *do_all*)

Hence *my_object* has to be the current object (*Current*), which has to have a procedure able to call the appropriate procedure of *PERSON*

Iteration examples

Given *my_list* : *LINKED_LIST* [*PERSON*]

we can write *my_list.do_all* (...) so as to implement:

- Perform the following actions on a list of persons with name and age
    1. Print the name of each
    2. Increment age of each by a given amount

The argument of action (print, increment_age) is the current person, possibly with parameter(s) (amount)

But how to pass the proper argument?

Iteration examples with agents

Hands-On

1. Perform the following operations on a list of persons with name and age
    1. Print the name of each
    2. Increment age of each by a given amount

Iteration example solution (1st approach)

See demo…

Agent-based solution (1st approach) highlight

Previous solution for integration was

class *CALCULUS* **feature**

integral (*f*: *FUNCTION* [*REAL*, *REAL*]; *a*, *b*, *step*: *REAL*): *REAL*

…

my_calculus: *CALCULUS*

a feature

…

r := *my_calculus.integral* (**agent** *f_to_integrate*, *start*, *end*, *step*)

same as **agent** *print_person*(?)

In this case solution is

my_list.do_all (**agent** *print_person*)

…

feature *print_person* (*p*: *PERSON*) **do** *p.print_me* **end**

…

class *PERSON* **feature**

print_me **do** *print* (‘*my name is:*’ , *name*); … **end**

Feature needed to use the *PERSON* feature *print_me*

Agent-based solution (1st approach) highlight

Also for case 2. the solution has the same structure

my_list.do_all (**agent** *increment_age* (?, *delta_age*))

...

feature *increment_age* (*p* : *PERSON* ; *delta_age*: INTEGER)
    do *p.set_age* (*age* + *delta_age*) **end**

...

class *PERSON* **feature**
    p.set_age (*new_age*: INTEGER) **do** *age* := *new_age*; ... **end**

Feature needed to use the *PERSON* feature *set_age*

Keeping arguments open

An agent can have both "closed" and "open" arguments

closed arguments are set at time of agent definition; ***open*** arguments are set when requesting the agent to execute feature call

To keep an argument open, just replace it by a question mark:

u := **agent** *a0*.*f* (*a1*, *a2*, *a3*) -- All closed

w := **agent** *a0*.*f* (*a1*, *a2*, ?)

x := **agent** *a0*.*f* (*a1*, ?, *a3*)

y := **agent** *a0*.*f* (*a1*, ?, ?)

z := **agent** *a0*.*f* (?, ?, ?) -- All open. Same as *z* := **agent** *a0*.*f*

Calling an agent with open/closed arguments

f (x1: T1 ; x2: T2 ; x3: T3)

a1: T1 ; a2: T2 ; a3: T3

u := **agent** *a0.f (a1, a2, a3)* — *u.call ([])*

v := **agent** *a0.f (a1, a2, ?)* — *v.call ([a3])*

w := **agent** *a0.f (a1, ? , a3)* — *w.call ([a2])*

x := **agent** *a0.f (a1, ?, ?)* — *x.call ([a2, a3])*

y := **agent** *a0.f (?, ?, ?)* — *y.call ([a1, a2, a3])*

z := **agent** *a0.f* — *z.call ([a1, a2, a3])*

Agent-based solution (1st approach) discussion


```
my_list.do_all (agent print_person)
...
feature print_person (p : PERSON ) do p.print_me  end
...
class PERSON feature
    print_me   do print (‘my name is:’ , name); ... end
-----------------------------------------------------
my_list.do_all (agent increment_age (?, delta_age) )
...
feature increment_age (p : PERSON ; delta_age: INTEGER)
    do p.set_age (age + delta_age) end
...
class PERSON feature
     p.set_age (new_age: INTEGER) do age := new_age); ... end
```

In both cases we had to ***wrap*** the feature defined on PERSON (*print_me*, *set_age*) in a new feature (defined at the same level of the object on which iterator is applied) to be passed as an agent to the iterator

Can we avoid this wrapping and pass directly the original feature?

Avoid wrapping procedures

We need a mechanism to pass, as an agent, a procedure defined for instances of a class *G* without *agent*-izing it by means of making reference to a specific instance *x* of *G*

(remember the agent definition is **agent** *my_object*.*my_procedure*)

Otherwise we cannot use that *agent*-ized procedure for arbitrary instances of *G*

Given procedure *my_procedure* defined in class *G*, the agent definition

agent {*G*}.*my_procedure*

does the job.

It is called **agent definition with open target**

Iteration examples with agents

Hands-On

- Perform the following operations on a list of persons with name and age
  1. Print the name of each
  2. Increment age of each by a given amount

Agent-based solution (2nd approach) discussion (1)


```
my_list.do_all (agent {PERSON}.print_me)
...
class PERSON feature
    print_me
    do print ('my name is:' , name); ... end
```

Agent mechanism allows to reuse *print_me* (an existing procedure of ***PERSON***) without having to wrap it

Previous solution (1st approach)

```
my_list.do_all (agent print_person)
...
feature print_person (p: PERSON) do p.print_me  end
...
class PERSON feature
    print_me
    do print ('my name is:' , name); ... end
```

Agent-based solution (2nd approach) discussion (2)


```
my_list.do_all (agent {PERSON}.increment_age (delta_age) )
…
class PERSON feature
    increment_age (delta_age: INTEGER)
      do age := age + delta_age end
```

Agent mechanism allows to reuse *set_age* (an existing procedure of ***PERSON***)

Here wrapping is required because *set_age* is not exactly the procedure we need

Previous solution (1st approach)

```
my_list.do_all (agent increment_age (?, delta_age) )
…
feature increment_age (p : PERSON ; delta_age: INTEGER)
    do p.set_age (age + delta_age) end
…
class PERSON feature
    set_age (new_age: INTEGER)
      do age := new_age; … end
```

Agent-based solution (2nd approach) discussion (3)

But if we cannot modify the code of the class PERSON then we have to use the 1st approach

Previous solution (1st approach)

```
my_list.do_all (agent increment_age (?, delta_age) )
...
feature increment_age (p : PERSON ; delta_age: INTEGER)
    do p.set_age (age + delta_age) end
...
class PERSON feature
    set_age (new_age: INTEGER)
      do age := new_age; ... end
```

Agents with open/closed target/arguments

x.a_feature (**agent** *y*.*f*) -- closed/open

x.a_feature (**agent** *y*.*f* (?, ?)) -- closed/open

x.a_feature (**agent** *y*.*f* (a, ?)) -- closed/partial

x.a_feature (**agent** *y*.*f* (a, b)) -- closed/closed

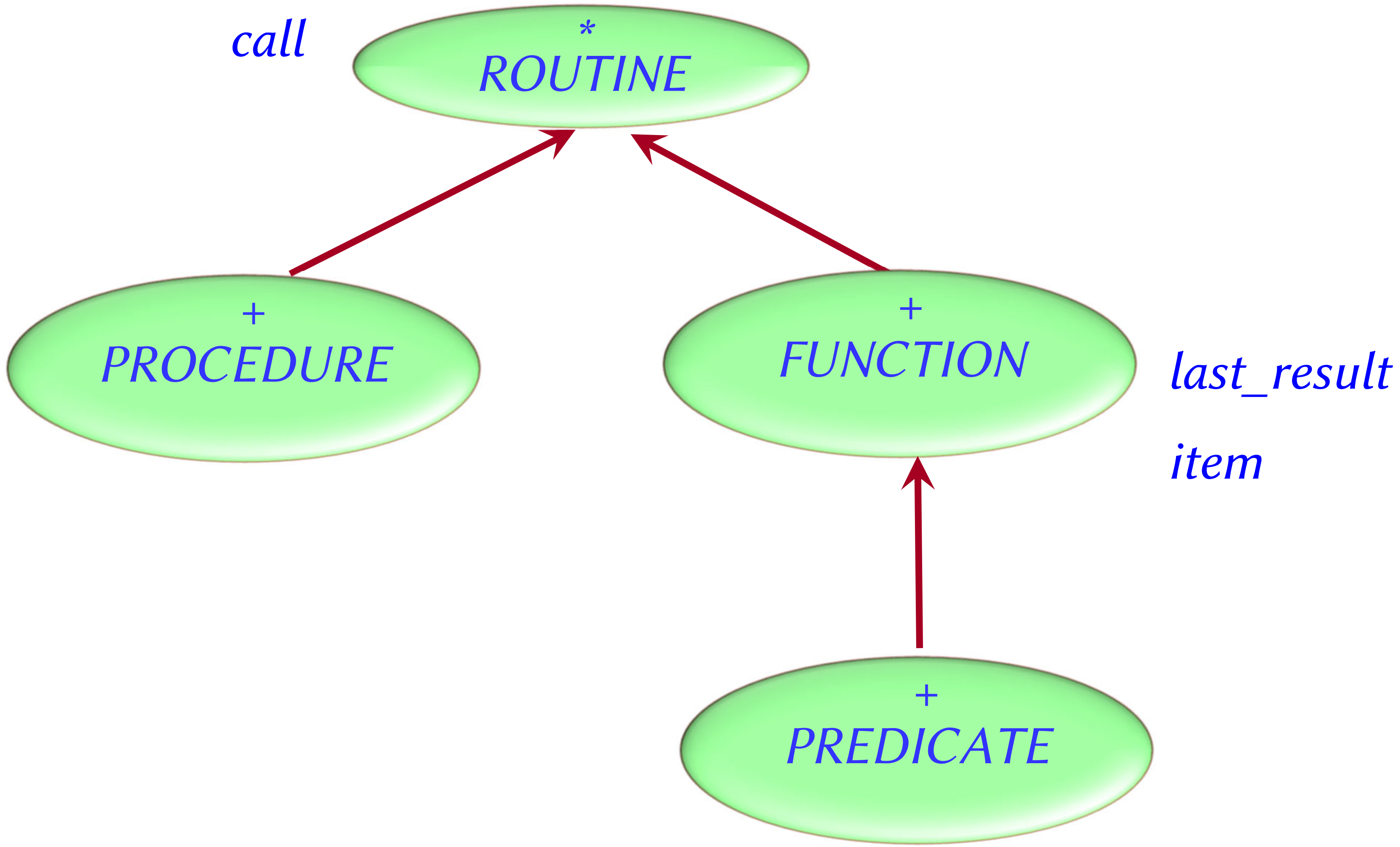
x.an_iterator (**agent** {*C*}.*f*) -- open/open

x.an_iterator (**agent** {*C*}.*f* (?, ?)) -- open/open

x.an_iterator (**agent** {*C*}.*f* (a, ?)) -- open/partial

x.an_iterator (**agent** {*C*}.*f* (a, b)) -- open/closed

Kernel library classes representing agents



Further iterator routines in TRAVERSABLE

Other interesting iterators defined in *TRAVERSABLE* [*G*], parent of *LINEAR* [*G*]

Execute on all elements satisfying a given condition

do_if (*action* : *PROCEDURE* [*G*];
    test : *PREDICATE* [*G*])

where *PREDICATE* [*G*] is a
subclass of *FUNCTION* [*G*, *BOOLEAN*]

Test whether a property hold for **all** elements

for_all (*test* : *PREDICATE* [*G*])

Test whether a property hold for **at least one** element

there_exists (*test* : *PREDICATE* [*G*])

Agent-like mechanisms in other languages

In non-O-O languages, e.g. C and Matlab, there is no notion of agent, but you can pass a routine as argument to another routine, as in

integral (& *f*, *a*, *b*)

where *f* is the function to integrate. & *f* (C notation for *function pointers*, one among many possible ones) is a way to refer to the function f. (We need some such syntax because just `*f*' could be a function call.)

Agents (or *delegates* in C# or *closures* in functional languages) provide a higher-level, more abstract and safer technique by wrapping the routine into an object with all the associated properties.

Iteration examples

1. Perform the following actions on a list of persons with name and age
    1. Print the name of each
    2. Increment age of each by a given amount

2. Perform the following actions on a list of persons with name and salary
    1. Increment by a given amount each salary which is below a given level

Implementation for each is straightforward

Iteration examples

Given *my_list* : *LINKED_LIST* [*PERSON*]
we can write *my_list.do_all* (...) so as to implement:

- Perform the following actions on a list of persons with name and age
  - Print the name of each
  - Increment age of each by a given amount

The argument of action (print, increment_age) is the current person, possibly with parameter(s) (amount)

- Perform the following actions on a list of persons with name and salary
  - Increment by a given amount each salary which is below a given level

The argument of action (increment_salary) is the current person, possibly with parameter(s) (amount, level)

But how to pass the proper argument?