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Fondamenti della Programmazione: Metodi Evoluti

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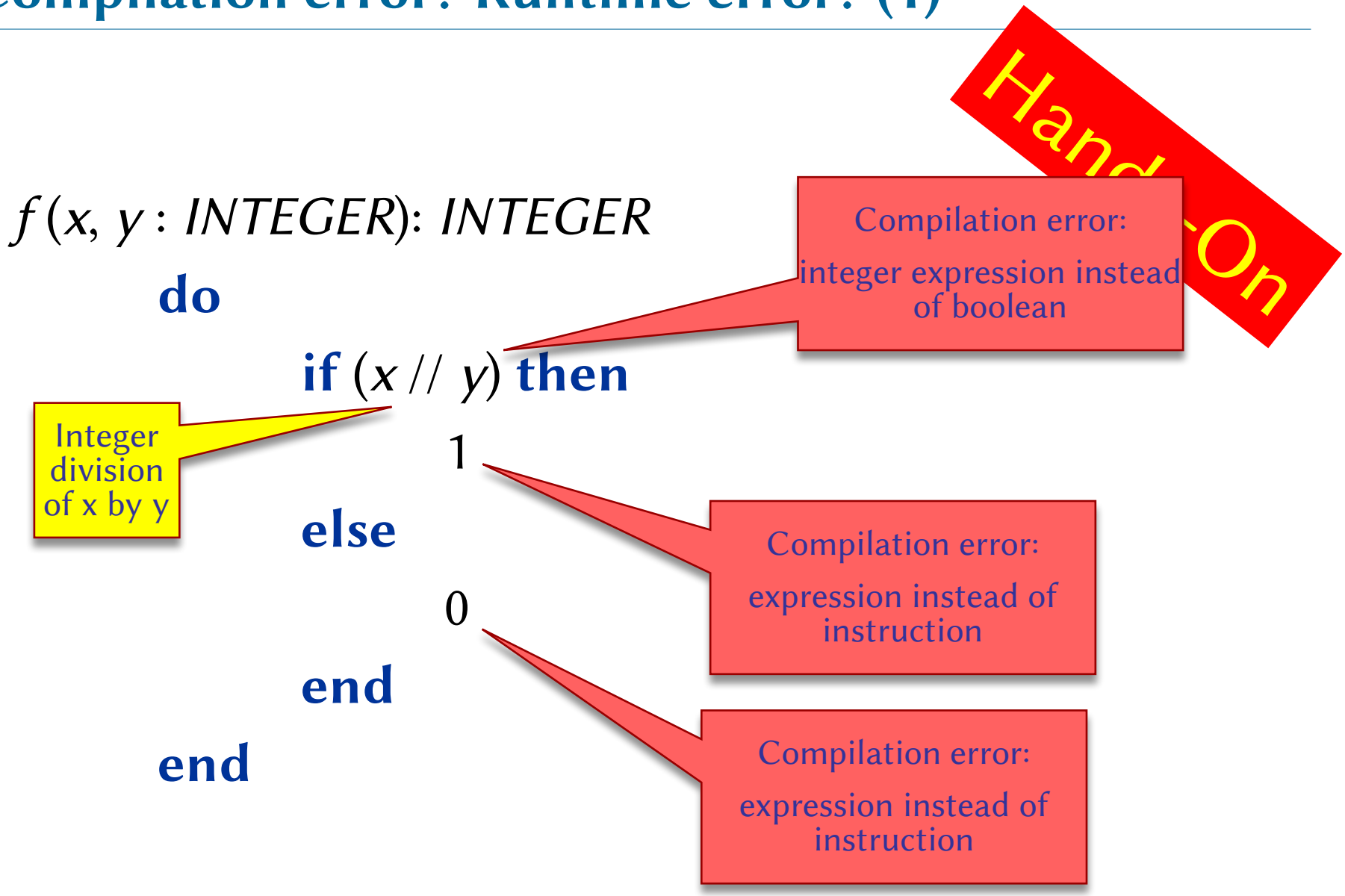
Esercitazione 5

Compilation error? Runtime error? (1)



Compilation error? Runtime error? (2)


```
f (x, y : INTEGER): INTEGER
        do
                if (False) then
                        Result := x // y
                end
                if (x /= 0 ) then
                        Result := y // x
                end
        end
```

Everything is OK

(during both compilation and runtime)

Calculating function's value

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Hands-On

```
f (max : INTEGER; s : STRING): STRING
        do
                if s.is_equal ("Java") then
                        Result := "J**a"
                else
                        if s.count > max then
                                Result := "<an unreadable German word>"
                        end
                end
        end
```

Calculate the value of:

- $f(3, \text{"Java"})$ → "J**a"
- $f(20, \text{"Immatrikulationsbestätigung"})$ → "<an unreadable German word>"
- $f(6, \text{"Eiffel"})$ → **Void**

What does this routine do?


```
abs (x : REAL): REAL
        do
                if (x >= 0) then
                        Result := x
                else
                        Result := -x
                end
        end
```

Write a routine...

- ... that increases time by one second inside class *TIME*:

```
class TIME
        hour, minute, second : INTEGER

        second_forth
                do ... end
        ...
end
```

Increasing seconds...

```
class TIME
    second_forth
        do
            if second = max_second then
                second := 0
                minute_forth
            else
                second := second + 1
            end
        ensure
            old second = max_second implies second = 0
            old second < max_second implies second = old
second + 1
        end
end
```

Increasing minutes... and so on...

```
class TIME
    minute_forth
        do
            if minute = max_minute then
                minute := 0
                hour_forth
            else
                minute := minute + 1
            end
        ensure
            old minute = max_minute implies minute = 0
            old minute < max_minute implies minute = old
minute + 1
        end
end
```

Simple loop (1)

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Hands-On

How many times will the body of the following loop be executed?

i: *INTEGER*

...

from

In Eiffel we usually start counting from 1

i := 1

until

i > 10

loop

print ("I will not say bad things about assistants")

i := *i* + 1

end

10

Simple loop (2)

And what about this one?

i : *INTEGER*

...

from

i := 10

until

i < 1

loop

print ("I will not say bad things about assistants")

end

∞

Caution!
Loops can be infinite!

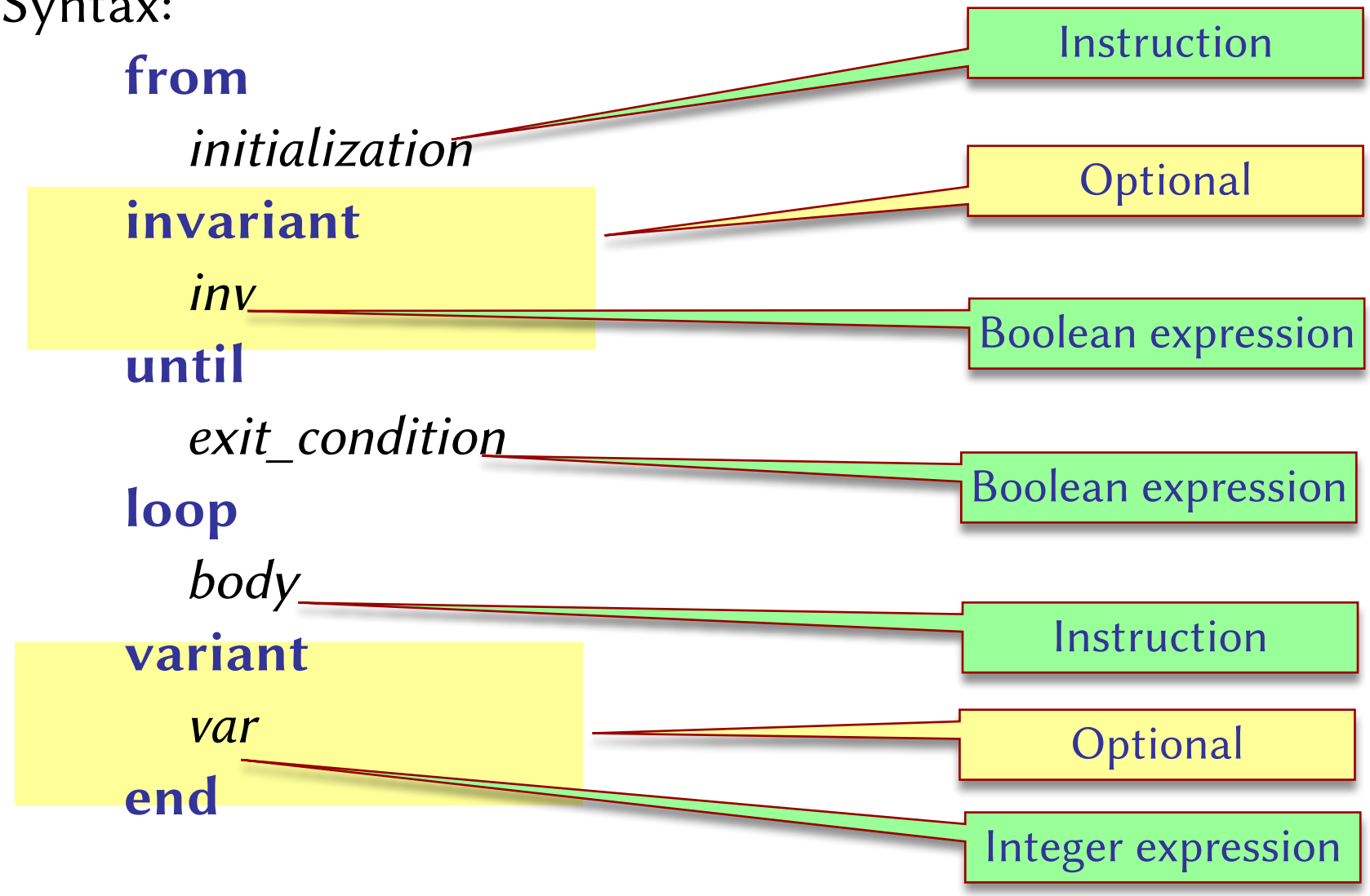
What does this function do?


```
factorial (n : INTEGER): INTEGER
        local
            i : INTEGER
        do
            from
                i := 2
                Result := 1
            until
                i > n
            loop
                Result := Result * i
                i := i + 1
            end
        end
```

Loop, full form

Syntax:

```
from
    initialization
invariant
    inv
until
    exit_condition
loop
    body
variant
    var
end
```



Invariant and variant

Loop invariant (do not mix with class invariant)

- holds after execution of **from** clause and after each execution of **loop** clause
- captures how the loop iteratively solves the problem: e.g. "to calculate the sum of all *n* elements in a list, on each iteration *i* (*i* = 1..*n*) the sum of first *i* elements is obtained"

Loop variant

- integer expression that is nonnegative after execution of **from** clause and after each execution of **loop** clause and strictly decreases with each iteration
- a loop with a variant can not be infinite (why?)

Invariant and variant

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Hands-On

What are the invariant and variant of the "factorial" loop?

```
from
    i := 2
    Result := 1
invariant
    Result = factorial (i - 1)
until
    i > n
loop
    Result := Result * i
    i := i + 1
variant
    n − i + 2
end
```

i = 4; **Result** = 6 = 3!

When features are used in contracts, ***their*** contracts are **NOT** checked

n - *i* + 1
it's enough, if we call factorial with *n* > 0

Contracts

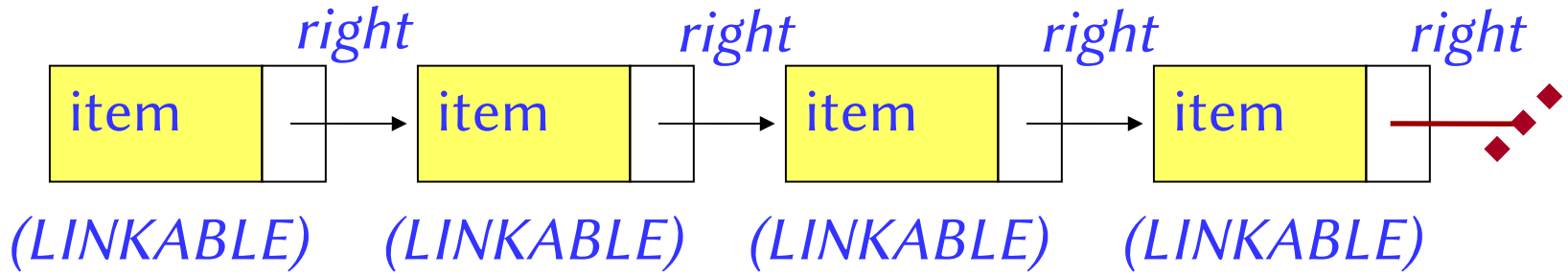
Which are the contracts?

```
require
    n >= 0
do
    from
        i := 2
        Result := 1
    invariant
        Result = factorial (i - 1)
    until
        i > n
    loop
        Result := Result * i
        i := i + 1
    variant
        n − i + 2
    end
ensure
    n > 0  implies Result = n * factorial (n - 1)
end
```

LINKABLE (a predefined Eiffel class)

To make it possible to link infinitely many similar elements together, each element should contain a reference to the next element

```
class LINKABLE
        feature
                ...
                right : LINKABLE
end
```



INT_LINKABLE

```
class INT_LINKABLE
create set_value
feature -- Access
        value : INTEGER
        next : detachable INT_LINKABLE
feature -- Initialization
        set_value (a_value : INTEGER)
                do value := a_value
                ensure value = a_value
                end
feature -- Processing
        link_to (other : detachable INT_LINKABLE)
                -- connect to `other'
                do next := other
                ensure next = other
                end
end
```

No need of requiring *other* /= **Void**

INT_LINKED_LIST

```
class INT_LINKED_LIST
feature -- Access
        first_element : detachable INT_LINKABLE
                -- First element of the list

        last_element : detachable INT_LINKABLE
                -- Last element of the list

        active_element : detachable INT_LINKABLE
                -- Current element of the list

        count : INTEGER
                -- Number of elements in the list
        ...
invariant
        ...
end
```

INT_LINKED_LIST

```
class INT_LINKED_LIST
feature – Cursor movement
        start
                -- Set `active_element' to the first element
                do
                        active_element := first_element
                ensure active_element = first_element
                end
        last
                -- Set `active_element' to the last element
                do
                        active_element := last_element
                ensure active_element = last_element
                end
        forth
                -- Set `active_element' to the next element, if exists
                do
                        if attached active_element as ae then
                                active_element := ae.next
                        end
                ensure attached old active_element as ae implies active_element = ae.next
                end
end
```

INT_LINKED_LIST class invariant

Is it Void Safe?

invariant

count >= 0

last_element /= **Void implies** *last_element.next* = **Void**

...

...

...

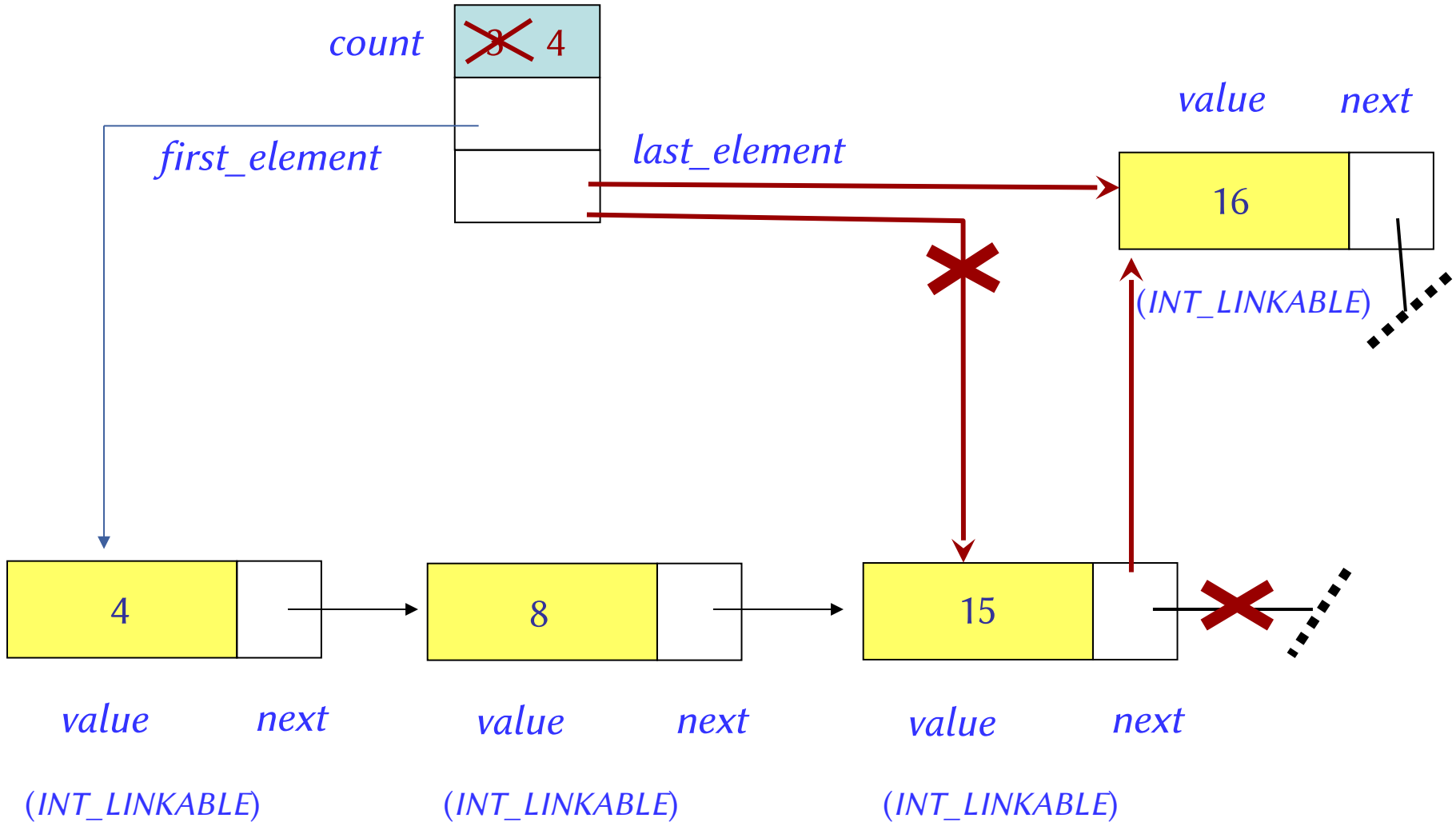
Look here!

end

INT_LINKED_LIST class invariant

```
invariant
    count >= 0
    attached last_element as le implies le.next = Void
    count = 0  implies
        (first_element = last_element) and
        (first_element = Void) and
        (first_element = active_element)
    count = 1  implies
        (first_element = last_element) and
        (first_element /= Void) and
        (attached active_element as ae implies ae = first_element)
    count = 2  implies
        (first_element /= Void) and
        (last_element /= Void) and
        (attached active_element as ae implies ae = first_element or ae = last_element) and
        (attached first_element as fe implies fe.next = last_element)
    count > 2  implies
        (first_element /= last_element) and
        (first_element /= Void) and
        (last_element /= Void) and
        (attached first_element as fe implies fe.next /= last_element)
end
```

INT_LINKED_LIST: inserting at the end



INT_LINKED_LIST: inserting at the end

```
append (a_value : INTEGER)
        -- Add `a_value' after `last_element'.
    local
        new_element: like first_element
    do
        create new_element.set_value (a_value)
        if count = 0 then
            first_element := new_element
        else
            if attached last_element as le then
                le.link_to (new_element)
            end
        end
        last_element := new_element
        count := count + 1
    ensure
        count = old count + 1
        attached last_element as le implies le.value = a_value
        attached old last_element as ole implies ole.next = last_element
    end
```

Is it Void Safe?

INT_LINKED_LIST: searching for an item

```
has (a_value: INTEGER): BOOLEAN
        -- Does list contain `a_value'?
    local
        previous_element, current_element : like first_element
    do
        from
            current_element := first_element
            previous_element := Void
        invariant
            not Result implies
                (previous_element /= Void implies
                                        previous_element.value /= a_value )
            Result implies
                (previous_element /= Void implies
                                        previous_element.value = a_value )
        until
            (current_element = Void) or Result
        loop
            if current_element.value = a_value then
                Result := True
            end
            previous_element := current_element
            current_element := current_element.next
        end
    end
```

For the **variant** contract
k: INTEGER

k := 0

Are these calls Void Safe?

k := k+1

variant
count - k

INT_LINKED_LIST: finding an item

```
get_element (a_value: INTEGER): detachable INT_LINKABLE
    -- Return the first element containing `a_value', if exists
local
    previous_element, current_element : like first_element
do
    from
        current_element := first_element;
        previous_element := Void
    invariant
        Result = Void implies
            (previous_element /= Void implies previous_element.value /= a_value )
        Result /= Void implies
            (previous_element /= Void implies previous_element.value = a_value )
        until
            current_element = Void or else current_element.value = a_value
        loop
            previous_element := current_element
            current_element := current_element.next
        end
        Result := current_element
ensure
        Result /= Void implies Result.value = a_value
        Result = Void implies not has(a_value)
end
```

Are these calls Void Safe?

For the **variant** contract introduce the same changes as in previous slide

INT_LINKED_LIST

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Write a routine that

- inserts value *a_value* after the first occurrence of a value *target* and add *a_value* at the end if the value *target* is not found
- do not reuse in the code existing feature *has* and *get_element* (generally not a good choice!) – but they may be used in contracts

insert_after (*a_value, target*: *INTEGER*)

do ... **end**

INT_LINKED_LIST: insert_after (1)

```
insert_after (a_value, target : INTEGER)
    -- Insert `a_value' right after first occurrence of `target', if exists,
    -- otherwise add `a_value' after `last_element'.
    local
        current_element, new_element : like first_element
    do
        create new_element.set_value (a_value)
        from current_element := first_element
        until current_element = Void or else current_element.value = target
        loop current_element := current_element.next
        end
        if current_element /= Void then
            new_element.link_to (current_element.next)
            current_element.link_to (new_element)
            if current_element = last_element then
                last_element := new_element
            end
        else – list does not contain `target'
            ...
        end
        count := count + 1
    ensure
        count = old count + 1
        not old has(target) implies
                (attached last_element as le implies le.value = a_value)
        old has(target) implies (attached get_element(target) as ge implies
                    (attached ge.next as gen implies gen.value = a_value) )
    end
```

Refactor into feature *link_after*

INT_LINKABLE (final version)

```
class INT_LINKABLE
create set_value
feature -- Access
    value : INTEGER
    next : detachable INT_LINKABLE
feature -- Initialization
    set_value (a_value : INTEGER)
        do value := a_value
        ensure value = a_value
        end
feature -- Processing
    link_to (other : detachable INT_LINKABLE)
        -- Connect to `other'.
        do next := other
        ensure next = other
        end
    link_after (other : INT_LINKABLE)
        -- insert after `other' preserving what was after it.
        do
            link_to (other.next)
            other.link_to (Current)
        ensure
            next  = old other.next
            other.next  = Current
        end
end
```

Same as *next* := *other.next* ?

Yes!

Same as *other.next* := **Current** ?

No!

INT_LINKED_LIST: insert_after (2)

```
insert_after (a_value, target : INTEGER)
    -- Insert `a_value' right after first occurence `target', if exists,
    -- otherwise add `a_value' after `last_element'.
    local
        current_element, new_element : like first_element
    do
        create new_element.set_value (a_value)
        from current_element := first_element
        until current_element = Void or else current_element.value = target
        loop current_element := current_element.next
        end
        if current_element /= Void then
            new_element.link_after (current_element)
            if current_element = last_element then
                last_element := new_element
            end
        else – list does not contain `target'
            ...
        end
        count := count + 1
    ensure
        count = old count + 1
        not old has(target) implies
                (attached last_element as le implies le.value = a_value)
        old has(target) implies (attached get_element(target) as ge implies
                    (attached ge.next as gen implies gen.value = a_value) )
    end
```

INT_LINKED_LIST: insert_after (3)

```
insert_after (a_value, target : INTEGER)
    -- Insert `a_value' right after first occurence `target', if exists,
    -- otherwise add `a_value' after `last_element'.
    local
        current_element, new_element : like first_element
    do
        create new_element.set_value (a_value)
        ...
        if current_element /= Void then
        ...
        else – list does not contain `target'
            if count = 0 then
                first_element := new_element
            else
                if attached last_element as le then
                    new_element.link_after(le)
                end
            end
            last_element := new_element
        end
        count := count + 1
    ensure
        ...
    end
```

Same as

le.link_to (new_element) ?

Yes!

INT_LINKED_LIST

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Write a routine that

- calculates the sum of all positive values in a list

sum_of_positive: *INTEGER*

do ... **end**

INT_LINKED_LIST: sum_of_positive

```
sum_of_positive: INTEGER
        -- The sum of positive elements
    local
        current_element : like first_element
    do
        from
            current_element := first_element
        until
            current_element = Void
        loop
            if current_element.value > 0 then
                Result := Result + current_element.value
            end
            current_element := current_element.next
        end
    ensure
        Result >= 0
    end
```