Formal Specification of Software

The Object Contraint Language by Example

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The Classifier Context

context (c :)? typeName

inv expressionName? : OclExpression

context (c :)? typeName

inv expressionName$_1$? : OclExpression$_1$

...

...

inv expressionName$_n$? : OclExpression$_n$

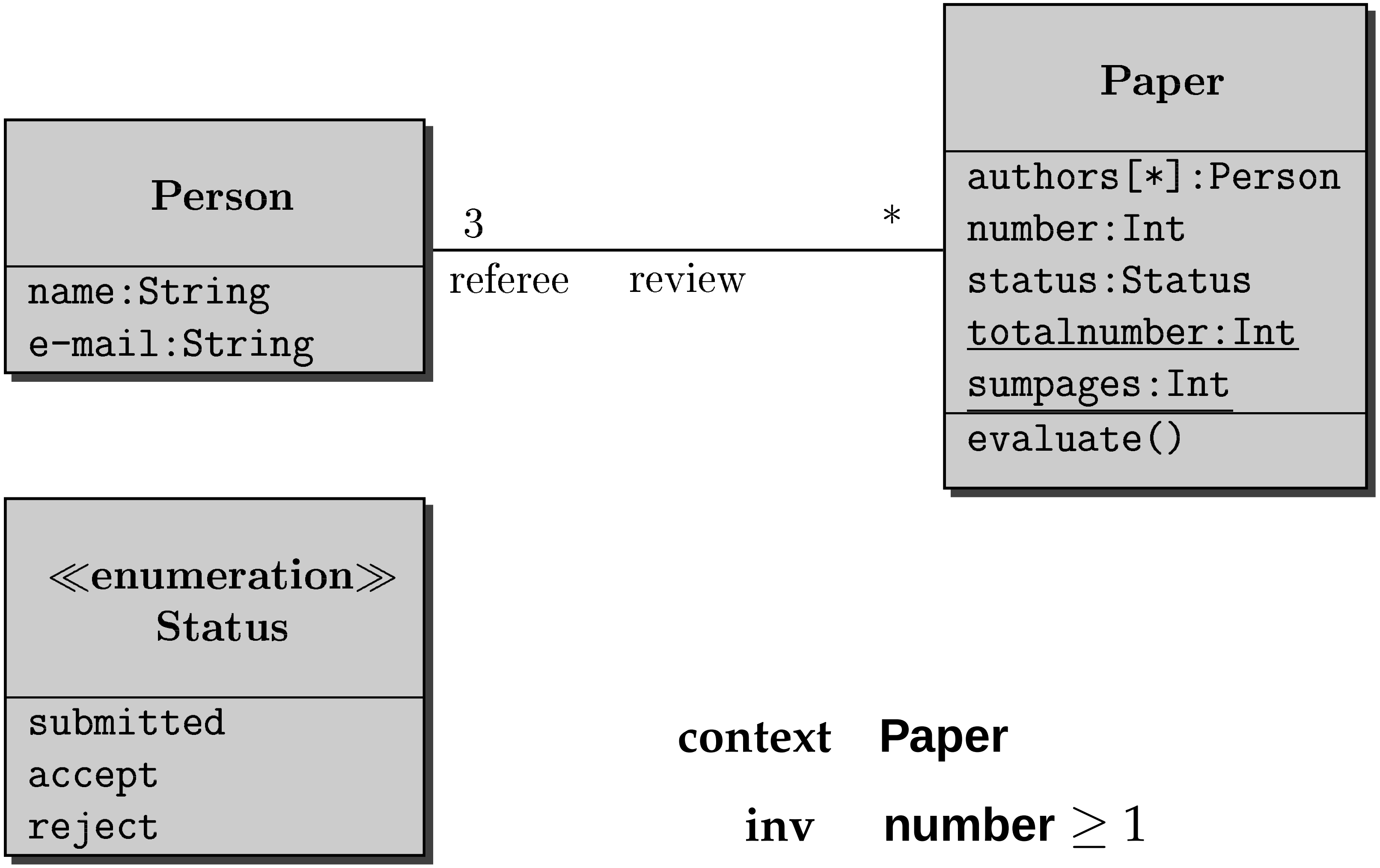
The Operator Context

context **(** c **:)?**

typeName ::opName(p_1**: type**$_1$**; . . . ;**p_k**: type**$_k$ **):rtype**

{pre ,post } **expressionName? : OclExpression**

Constraints with Attributes



context **Paper**

inv **number** ≥ 1

Equivalent notational variations

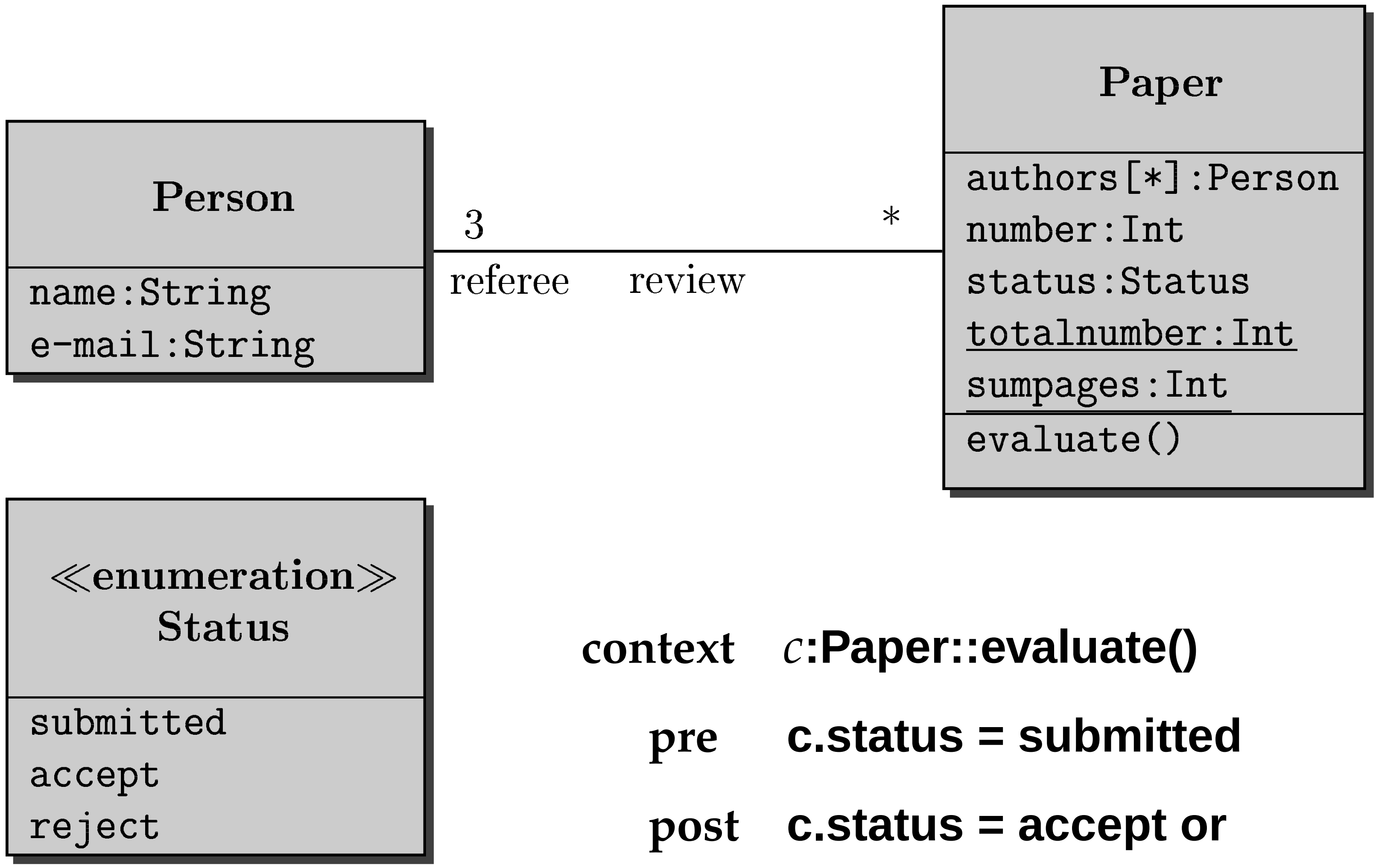
context Paper
  inv self.number ≥ 1

context c:Paper
  inv c.number ≥ 1

context c:Paper
  inv startCount : c.number ≥ 1

context Paper
  inv startCount : number ≥ 1

Operator Constraint



context c**:Paper::evaluate()**

pre **c.status = submitted**

post **c.status = accept or**

c.status = reject

Types

Model types

The classes form the context diagram of an OCL constraint

Basic types

$Integer$, $Real$, $Boolean$ **and** $String$

Enumeration types

The user defined enumeration types

Collection types

Set, Bag, $Sequence$

Special types

e.g. $OclAny$, $OclType$

Subtyping

- **T_1, T_2 model types:**

  $T_1 < T_2$ holds exactly if T_1 is a subclass of T_2

- $\mathit{Integer} < \mathit{Real}$

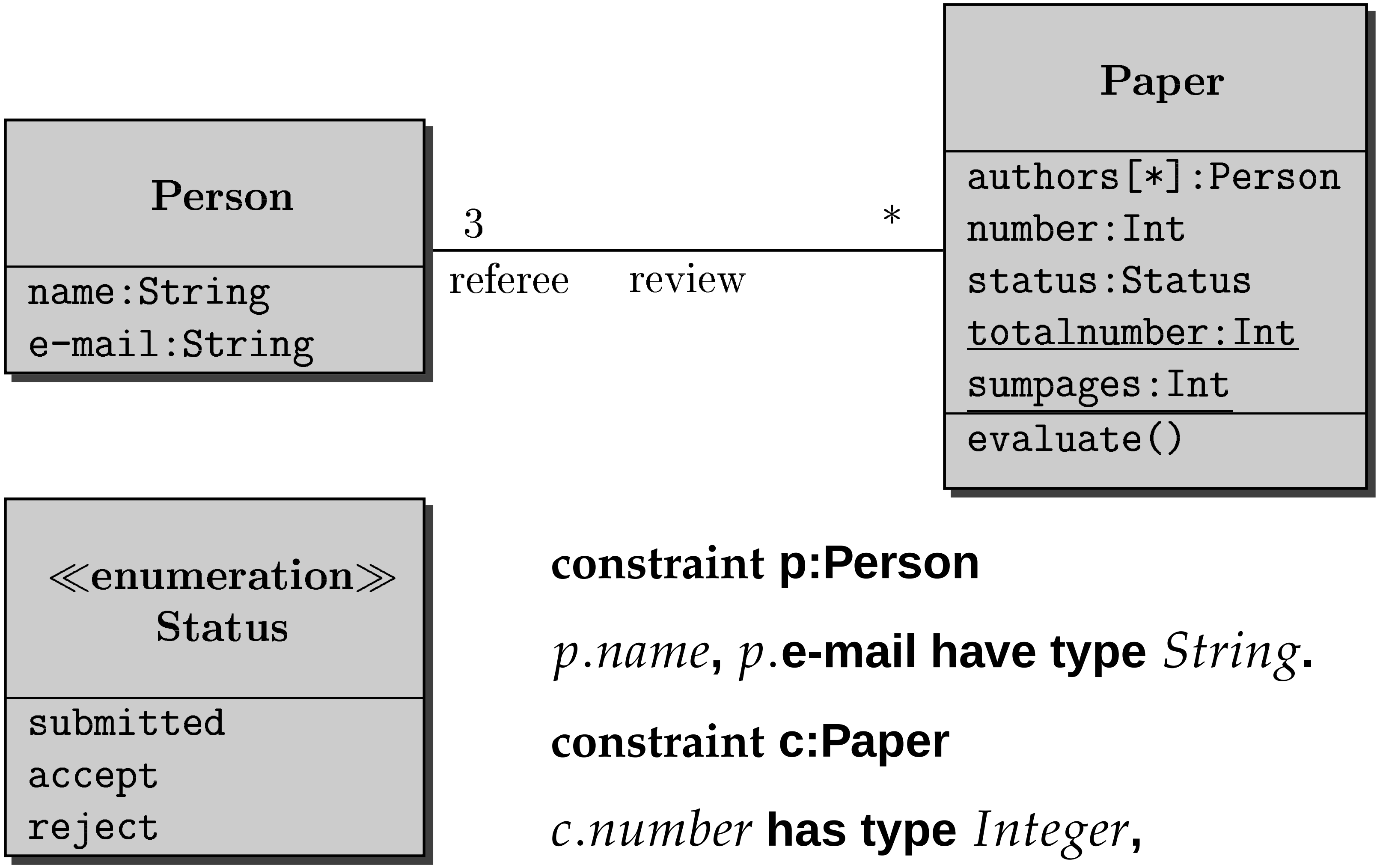
- **For all type expressions T, not denoting a collection type:**
  - $\mathit{Set}(T) < \mathit{Collection}(T)$
  - $\mathit{Bag}(T) < \mathit{Collection}(T)$
  - $\mathit{Sequence}(T) < \mathit{Collection}(T)$

- **If T is a model, basic, or enumeration type: $T < OCLAny$**

- **If $T_1 < T_2$ and C is any of the type constructors $\mathit{Collection}$, Set, Bag, $\mathit{Sequence}$:**

  $C(T_1) < C(T_2)$.

Typing Examples



constraint p:Person

$p.name$, p.**e-mail have type** $String$.

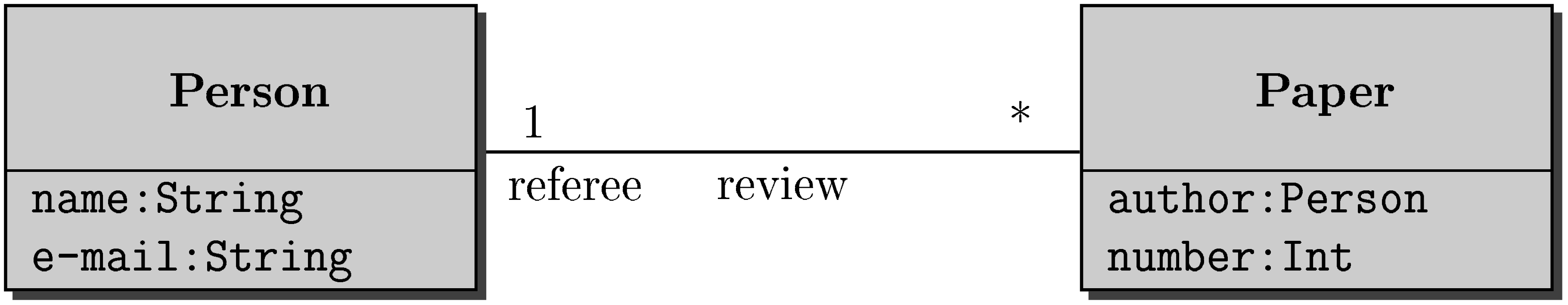
constraint c:Paper

$c.number$ **has type** $Integer$,

$c.status$ **has type** $Status$,

$c.authors$ **has type** $Set(Person)$

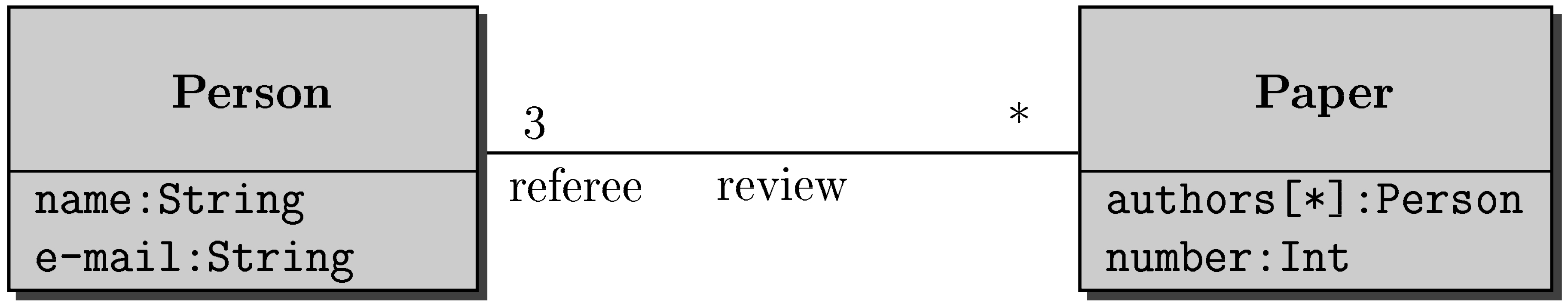
Constraints with Associations



context **c:Paper**

inv **c.author $<>$ c.referee**

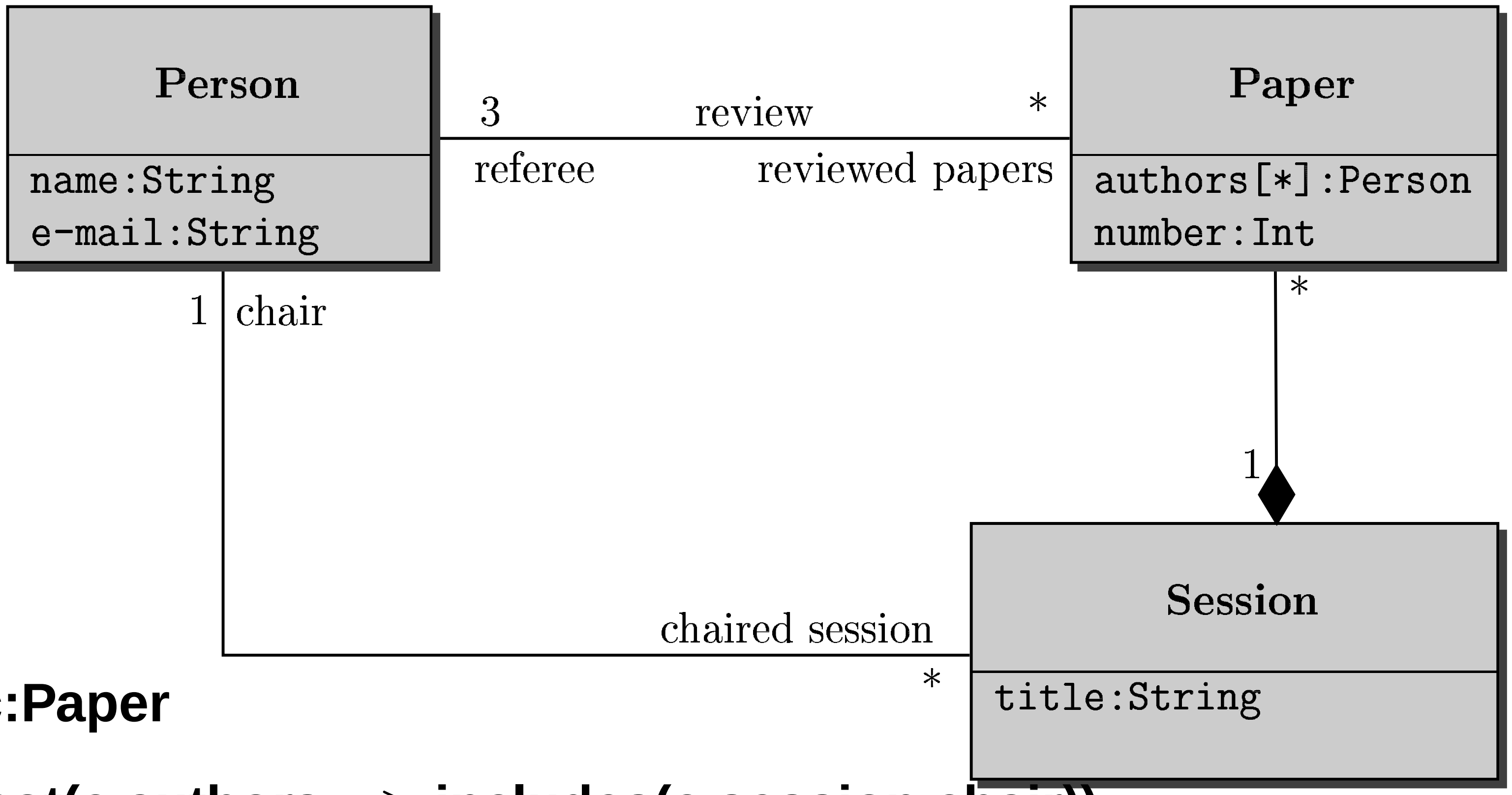
Constraints with Associations



context **c:Paper**

inv **c.authors –> intersection(c.referee) –> isEmpty**

Constraints and Navigation



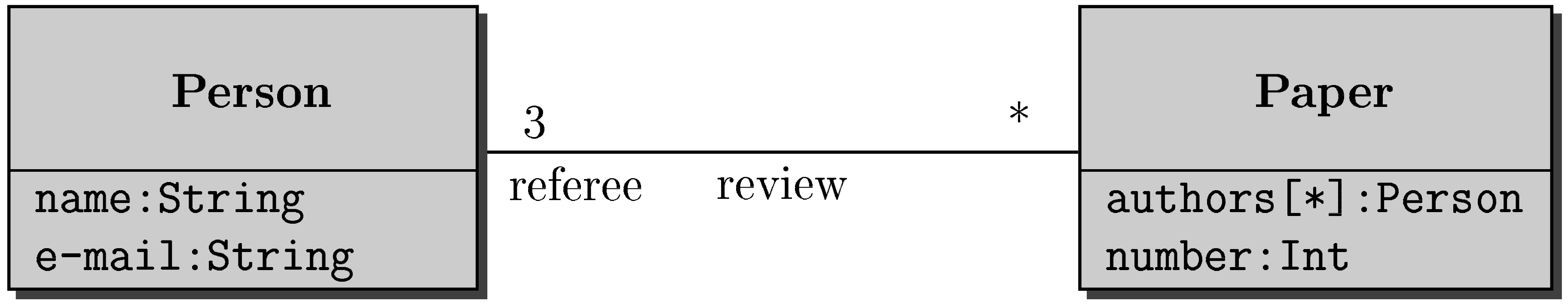
context **c:Paper**

inv **not(c.authors –> includes(c.session.chair))**

context **p:Person**

inv **p.reviewed_papers.session.chair –> includes(p)**

allInstances



context **Person**

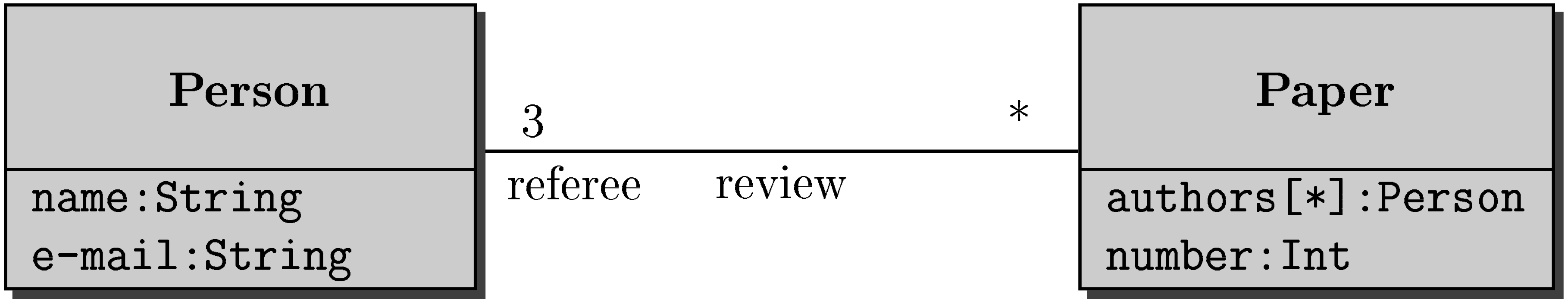
inv **Person.allInstances –> forAll(p | p.e-mail.size $\geq$ 3)**

context **Paper**

inv **Paper.allInstances –> forAll(p1, p2 |**

p1 <> p2 implies p1.number <> p2.number)

Avoiding *allInstances*



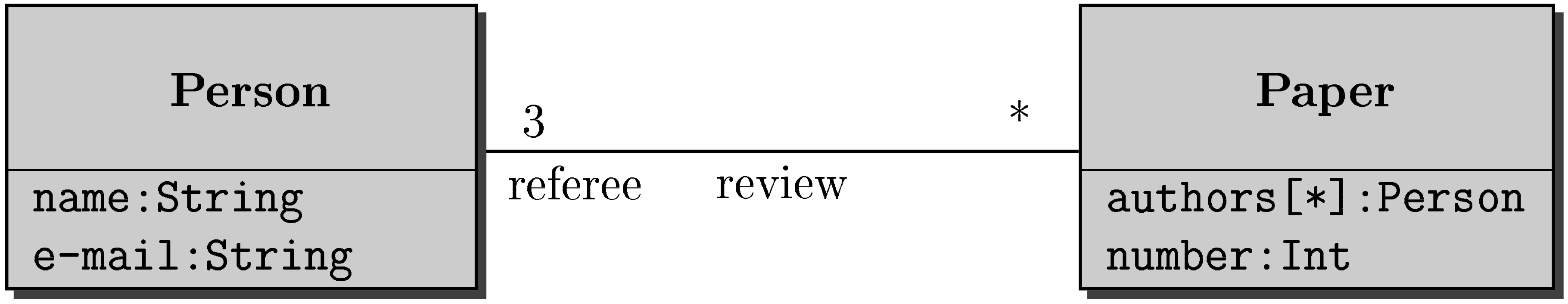
context **Person**

inv **Person.allInstances –> forAll(p | p.e-mail.size $\geq$ 3)**

Can be equivalently replaced by:
context **p:Person**

inv **p.e-mail.size $\geq$ 3**

Avoiding *allInstances*



context **Paper**

inv **Paper.allInstances –> forAll(p1, p2 |**

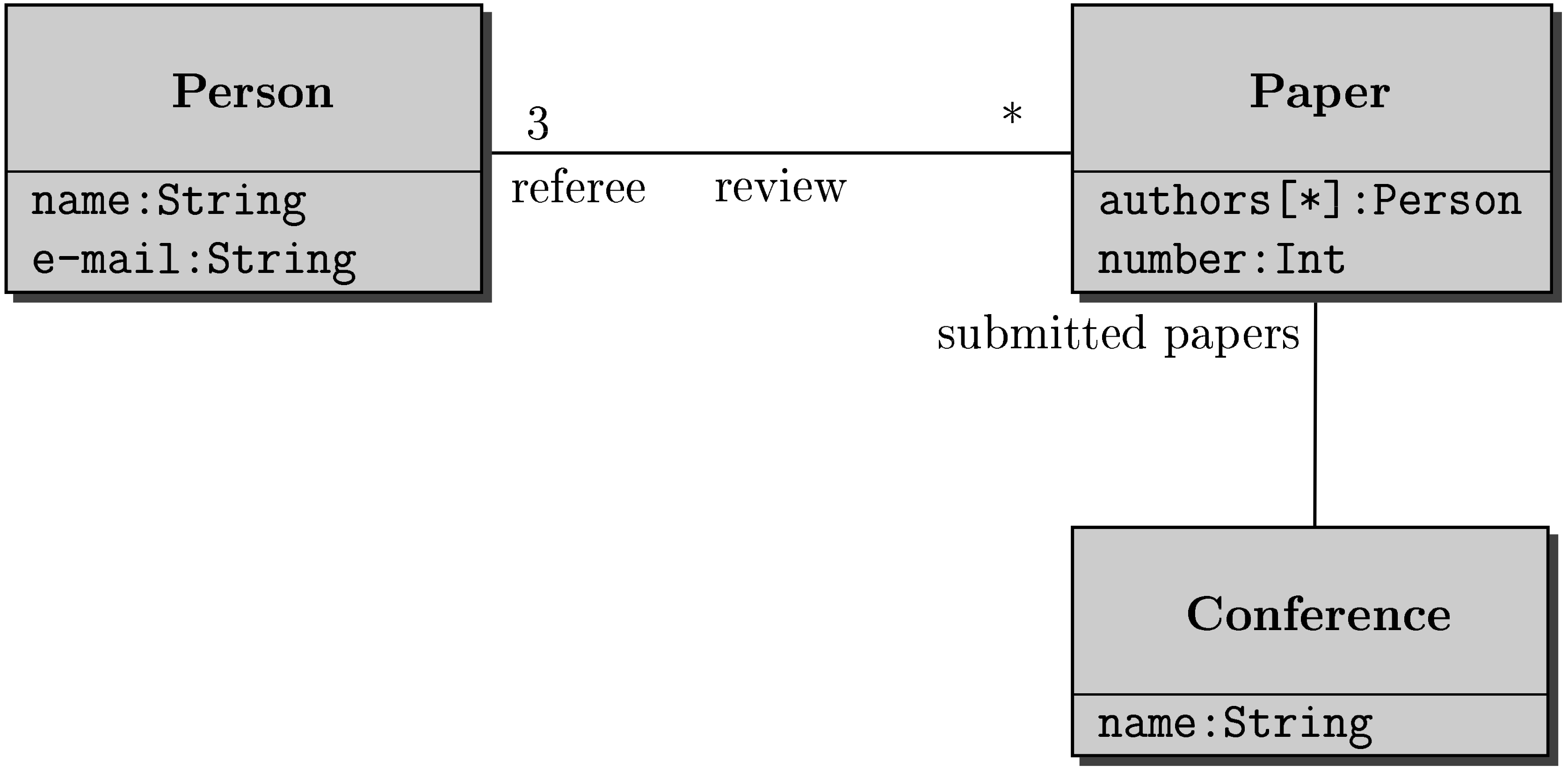
p1 <> p2 implies p1.number <> p2.number)

Can be equivalently replaced by:

context **p1,p2:Papers**

inv **p1 <> p2 implies p1.number <> p2.number)**

Avoiding *allInstances*

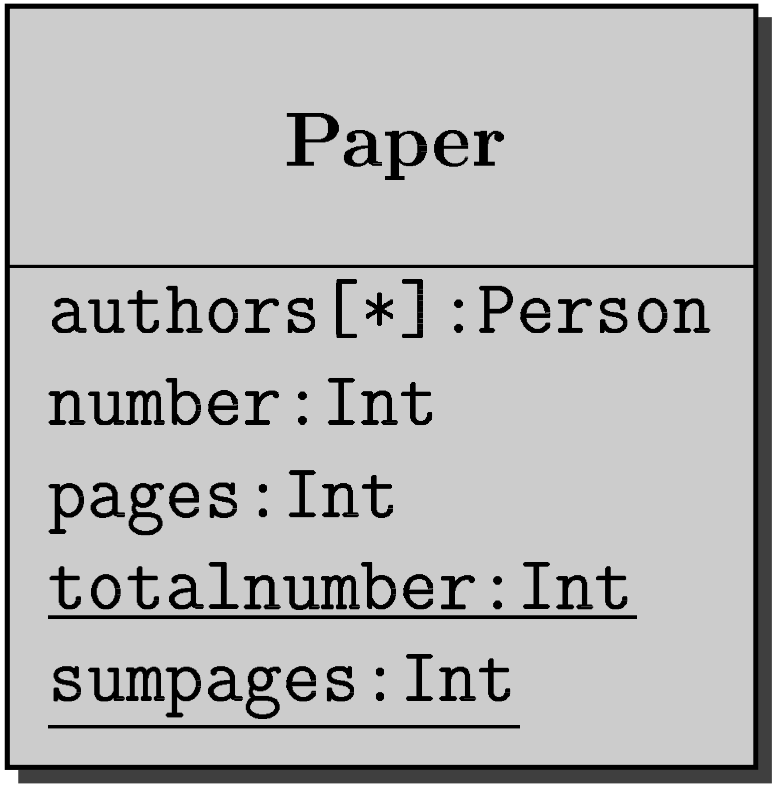


context **Conference**

inv **self.submitted_papers $->$ forAll(p1, p2 $|$**

p1 $<>$ p2 implies p1.number $<>$ p2.number)

Introducing the *iterate* Operation



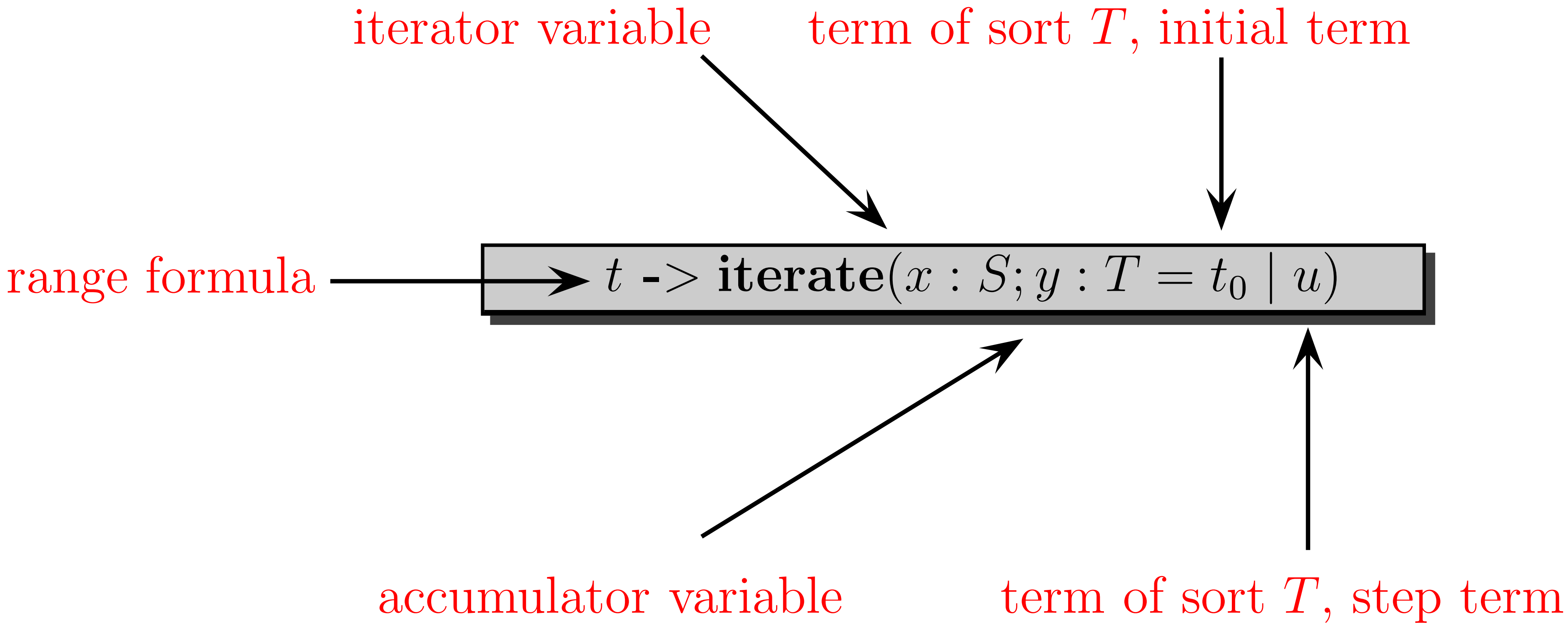
context p:Papers

inv Papers.allInstances –>

iterate(x:Paper ; y:Int = 0 | y+x.pages)

= Papers.sumpages

Syntax of the *iterate* construct


iterator variable
term of sort T, initial term
range formula
t **->** **iterate**$(x : S; y : T = t_0 \mid u)$
accumulator variable
term of sort T, step term

iterate: Example 1

Adding a new operation *occurences* to the built-in OCL type $String$

string.occurences(string2:String):Set(Integer) **The set of positions in string where an occurence of string2 as a substring starts. Strings start with position 0.**

```
pre  : string2.size =< string.size
post :  result  =  { 0 .. (string.size - string2.size) } ->
                   iterate(x;  y:Set(Integer)=Set{} |
                   if string.substring(x,x+string2.size) = string2
                   then y  -> including(x) else y)
```

iterate: Example 2

Adding a new operation *substringOcc* to the built-in OCL type $String$

string.substringOcc(string2:String):Boolean **True if string2 occurs at least once as a substring in string.**

post : **result = (string2.size =$<$ string.size) and not (string.occurences(string2) –$>$ isEmpty)**

Quantifiers

$$t \text{->} iterate(x; y : Boolean = true \mid y \textbf{ and } a)$$

- t **is an expression of type** $Set(T)$
- x **is a variable of type** T
- a **is an expression of type** $Boolean$

Can be equivalently expressed by

$$t \text{->} forAll(x \mid a)$$

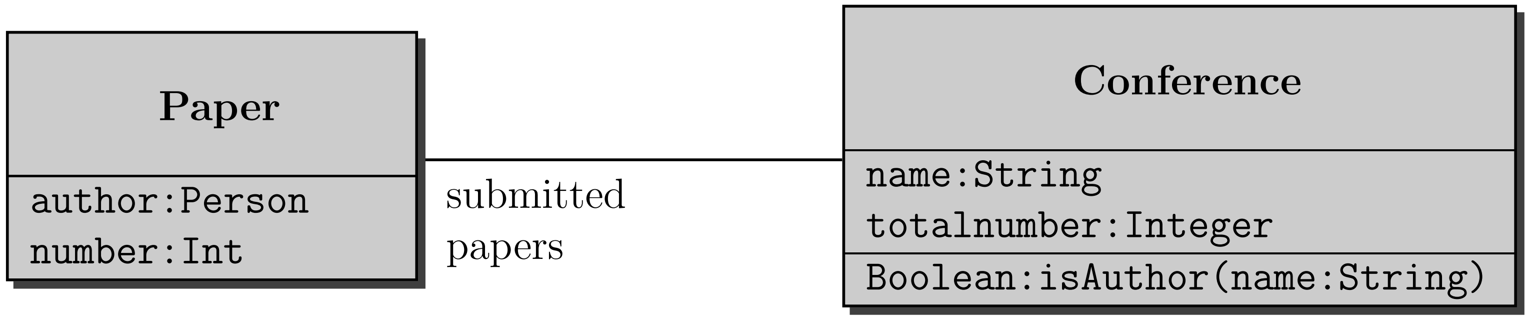
Likewise

$$t \text{->} iterate(x; y : Boolean = false \mid y \textbf{ or } a)$$

Can be expressed by

$$t \text{->} exists(x \mid a)$$

Collecting Elements



context *c*:**Conference::isAuthor(name:String)**

pre **true**

post **result =**
c.sp –> collect(p | p.author.name) –> includes(name)

Reducing *collect* to *iterate*

set $->$ collect(x $|$ expr) : Bag(T)

=

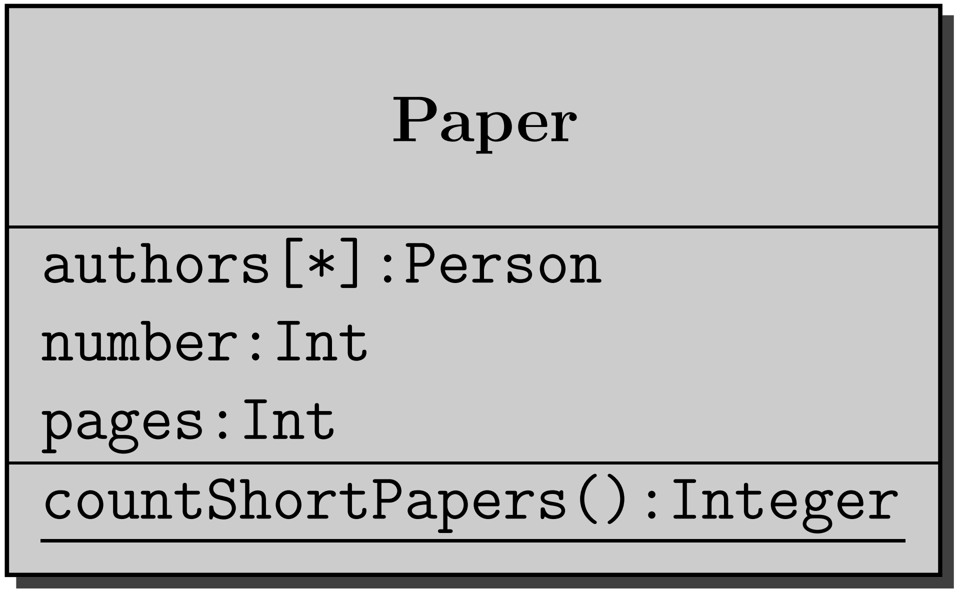
set $->$ iterate(x; acc : Bag(T) = Bag$\{\}$ $|$ acc $->$ including(expr))

Evaluation of

c.sp $->$ collect(p $|$ p.authors.name)

involves implicit flattening.

Selecting Elements



context **Paper::countShortPapers():Integer**

pre **true**

post **result =**
Paper.allInstances –>
select(p | p.pages < 10) –> size

Reducing *select* to *iterate*

s $->$ select(x $|$ expr) : Set(T) =

s $->$ iterate(x; acc : Set(T) = Set$\{\}$ $|$

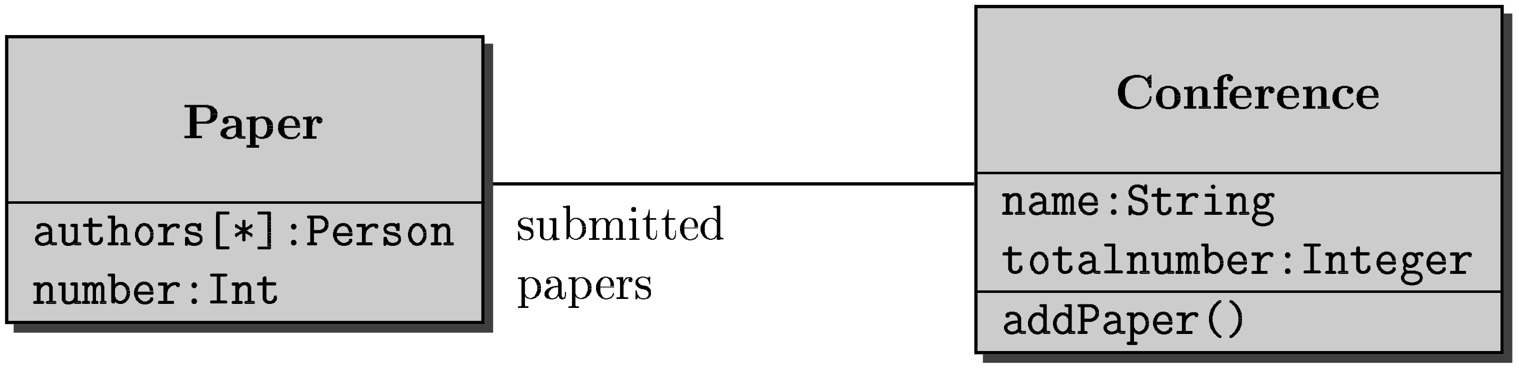
if expr then acc $->$ including(x)

else acc)

where

- **s is of type $Set(T)$**
- ***expr* is an OCL expression of type *Boolean***

Refering to Previous Values

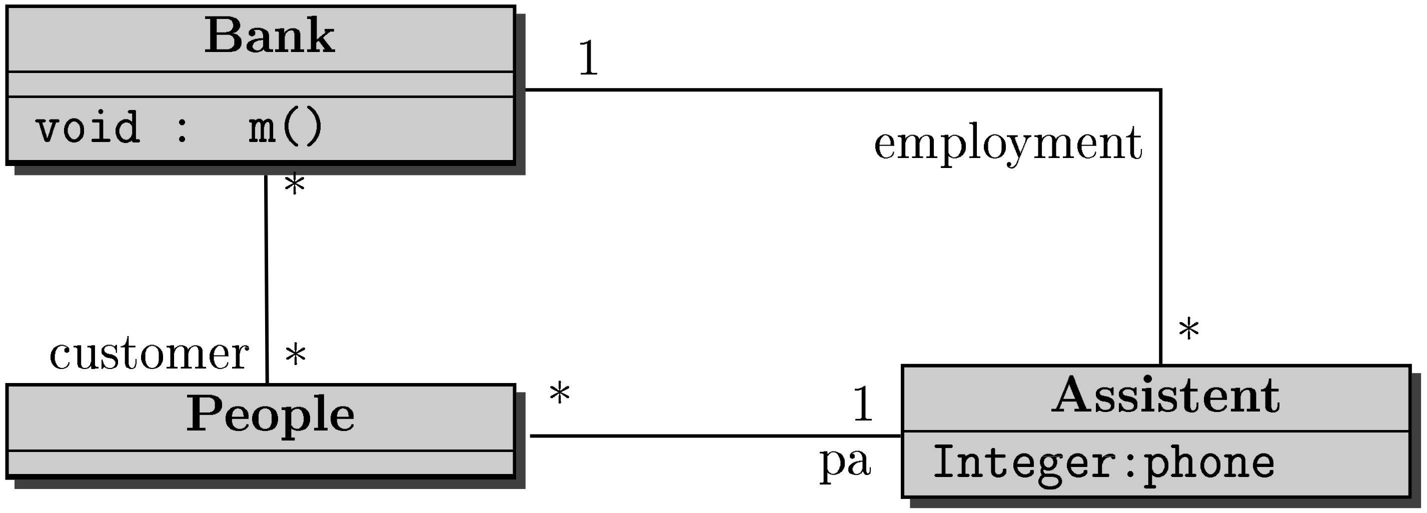


context c:**Conference::addPaper()**

pre **true**

post **totalnumber = totalnumber@pre + 1**

Multiple Occurences of @pre



$c.pa.phone$	**the new phone number of the current p.a.**
$c.pa@pre.phone$	**the new phone number of the previous p.a.**
$c.pa.phone@pre$	**the old phone number of the current p.a.**
$c.pa@pre.phone@pre$	**the old phone number of the previous p.a.**