HY 351: Ανάλυση και Σχεδίαση Πληροφοριακών Συστημάτων
CS 351: Information Systems Analysis and Design

HY351:
Ανάλυση και Σχεδίαση Πληροφοριακών Συστημάτων
Information Systems Analysis and Design

OCL: Object Constraint Language

Γιάννης Τζίτζικας

Διάλεξη : 14
Ημερομηνία :

Διάρθρωση

- Στόχοι της OCL
- Γιατί να χρησιμοποιήσουμε την OCL
- Παρουσίαση της OCL
- Διαβεβαιώσεις και Γλώσσες Προγραμματισμού
  - (Assertions and Programming Languages)

Τι είναι η OCL (Object Constraint Language)?

- Μια τυπική γλώσσα (formal language) για την προδιαγραφή περιορισμών (constraints) σε αντικειμενοστρεφή μοντέλα
- Είναι δηλωτική (declarative) (περιγράφει το *τι* αντί του *πως*)
- Είναι μια γλώσσα με τύπους (typed)
  - Και πιο φιλική από άλλες τυπικές γλώσσες

Περί *περιορισμών*

- Κάποιοι περιορισμοί μπορούν να εκφραστούν γραφικά με τη γραφική γλώσσα UML (π.χ. η πολλαπλότητα των συσχετίσεων, partition subclasses, κλπ).
- Για κάποιους άλλους αυτό δεν είναι εύκολο/εφικτό, π.χ.:
  - Περιορισμοί που εμπλέκουν >2 κλάσεις
  - Περιορισμοί που εμπλέκουν τιμές γνωρισμάτων (και συνδυασμούς αυτών)
  - Προϋποθέσεις και Μετα-συνθήκες (pre/post-conditions) λειτουργιών

Η OCL μπορεί να τους εκφράσει με τυπικό τρόπο

Γιατί να γράφουμε περιορισμούς σε OCL;
Why to write OCL constraints?

Γιατί να εκφράσουμε ρητώς τέτοιους περιορισμούς;

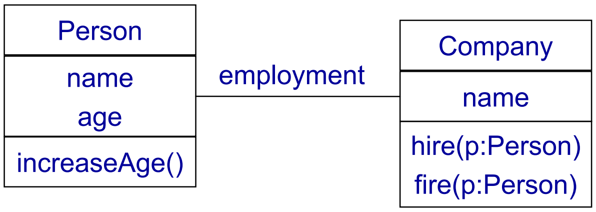
Γιατί κάνουν τα μοντέλα μας πιο ακριβή

- Ώστε να τα καταλαβαίνουμε καλύτερα
- Ώστε οι προγραμματιστές να τα υλοποιούν (σωστά)
- Ώστε να μπορούμε να έχουμε μια τυπική επαλήθευση (formal validation) του μοντέλου πριν την υλοποίηση
  - και δοκιμασίες (tests) για τη φάση της υλοποίησης

Μπορούν να μεταφραστούν σε «διαβεβαιώσεις» (assertions) στις γλώσσες προγραμματισμού

- Μερικά εργαλεία CASE προσφέρουν τέτοιες μεταφραστικές και επαληθευτικές υπηρεσίες

Τα διαγράμματα κλάσεων δεν είναι πολύ ακριβή



Person
name
age
increaseAge()

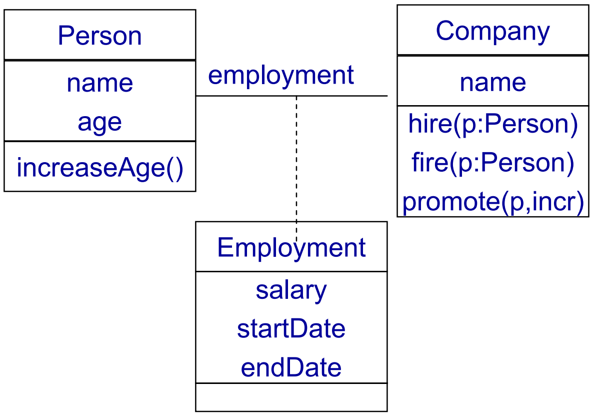
employment

Company
name
hire(p:Person)
fire(p:Person)

- *Μπορεί ένας ανήλικος να εργαστεί σε μια εταιρία;*
- *Μπορεί μια εταιρία να προσλάβει ένα άτομο που είναι ήδη εργαζόμενος της;*

Το παραπάνω διάγραμμα δεν μας αποτρέπει τίποτα από τα παραπάνω

Τα διαγράμματα κλάσεων δεν είναι πολύ ακριβή (II)



Person
name
age
increaseAge()

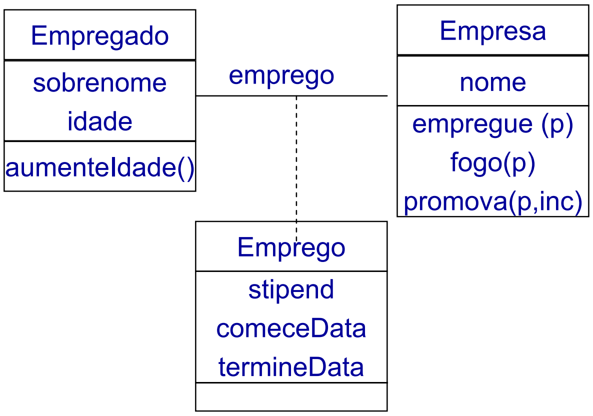
employment

Company
name
hire(p:Person)
fire(p:Person)
promote(p,incr)

Employment
salary
startDate
endDate

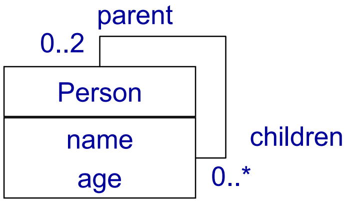
- *Μπορεί ένα πρόσωπο να αρχίσει να εργάζεται πριν τη γέννησή του;*
- *Μπορεί μια προαγωγή να μειώσει το μισθό ενός εργαζομένου;*
- *Υπάρχει κάποιο κατώτερο όριο στους μισθούς για αυτούς που εργάζονται στην εταιρία πάνω από 10 έτη;*

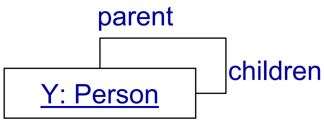
Τα διαγράμματα κλάσεων δεν είναι πολύ ακριβή (ΙΙΙ)
… Η σπουδαιότητα της γνώσης υποβάθρου



- *Θα μπορούσατε να αναπτύξετε ένα σύστημα (στον οποίο να είχατε λάβει υπόψη τους προηγούμενους περιορισμούς) αν τα διαγράμματα κλάσεων ήταν σε μια γλώσσα που δεν γνωρίζατε (π.χ. στα Ισπανικά);*

Τα διαγράμματα κλάσεων δεν είναι πολύ ακριβή (IV)





Επιτρεπτό διάγραμμα αντικειμένων (object diagram)

Object Constraint Language (OCL)

- OCL is a formal language used to describe expressions on UML models.
- OCL expressions typically specify invariant conditions that must hold for the system being modeled.
- They can also specify queries over objects described in a model.
- OCL is a typed language, so that each OCL expression has a type. To be well formed, an OCL expression must conform to the type conformance rules of the language. For example, you cannot compare an Integer with a String.
- When OCL expressions are evaluated, they do not have side effects; i.e. their evaluation cannot alter the state of the corresponding executing system.
  - However, OCL expressions could be used to specify operations / actions that, when executed, do alter the state of the system.

Πότε τη χρησιμοποιούμε;
Where to use OCL?

OCL can be used for a number of different purposes:

- To specify invariants on classes and types in the class model
- To describe pre- and post conditions on Operations and Methods
- To specify derivation rules for attributes for any expression over a UML model.
- To describe Guards in State Diagrams
- To specify target (sets) for messages and actions
- To specify type invariant for Stereotypes
- As a query language

UML modelers can use OCL to

- to specify application-specific constraints in their models.
- to specify queries on the UML model, which are completely programming language independent

Οι κυριότεροι τύποι περιορισμών της OCL
The main types of OCL Constraints

- **Invariants on classes** (αναλλοίωτες συνθήκες στις κλάσεις)
  - συνθήκες που πρέπει να ικανοποιούνται από όλα τα στιγμιότυπα μιας κλάσης
    - Π.χ.. salary > 1000 Euro
- **pre-conditions on operations** (προ-συνθήκες στις λειτουργίες)
  - συνθήκες που πρέπει να ικανοποιούνται πριν την εκτέλεση μιας λειτουργίας
    - Π.χ. η λειτουργία «Απόλυση()» μπορεί να εκτελεστεί μόνο σε έναν άτομο που έχει ήδη προσληφθεί
- **post-conditions on operations** (μετα-συνθήκες στις λειτουργίες)
  - συνθήκες που πρέπει να ικανοποιούνται μετά την εκτέλεση μιας λειουτργίας
    - Π.χ. μετά την εκτέλεση της «Ανάληψη(ποσό)» το υπόλοιπο του τραπεζικού λογαριασμού πρέπει να έχει μειωθεί κατά «ποσό».

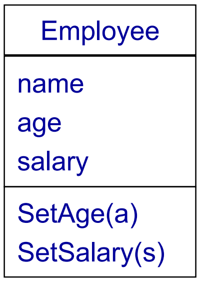
Πως μπορούμε να προδιαγράψουμε έναν περιορισμό;
How we can specify a constraint?

- Declaration of the **context** of a constraint by referencing the model element that a constraint applies to
- Declaration of the type of a constraint (**`inv`**, **`pre`**, **`post`**)
- Expressing the desired condition by referencing properties of model elements and using various operations that are supported.

Δήλωση Συμφραζομένων (Συγκειμένων)
Context Declaration

- Προσδιορίζει το στοιχείο στο οποίο αφορά ο περιορισμός
- Το **context** μπορεί να είναι
  - a class (for invariants)
  - an operation (for pre/post-conditions)

- Παράδειγμα:

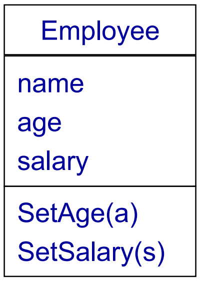


Context Employee **inv: self.**salary > 1000

Context Employee::SetSalary(salary) **pre:** salary > 1000

Δεν είναι ισοδύναμα. Γιατί;

Ονόματα και σχόλια περιορισμών
Constraint names and comments



Context Employee::SetAge (age)
pre: age > 0

Context Employee::SetAge (age)
pre positive_age **:** age > 0

Optional constraint name

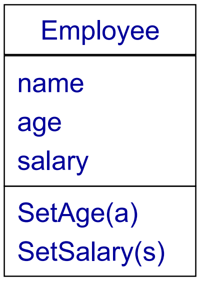
Allowing the constraint to be referenced by name.

Context Employee::SetAge (age)
pre positive_age **:** age > 0
-- the age should always be positive

Comment

Everything immediately following the two dashes up to and including the end of line is part of the comment.

self



Context Employee
inv: self.salary > 1000

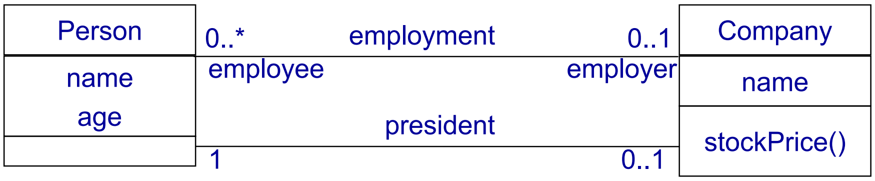
Context Employee
inv: salary > 1000

equivalent

In most cases, the keyword self can be dropped because the context is clear. As an alternative for self, a different name can be defined playing the part of self.

Context e: Employee
inv: e.salary > 1000

Επιλογείς (πώς να αναφέρουμε στοιχεία)
Selectors (how we reference elements)



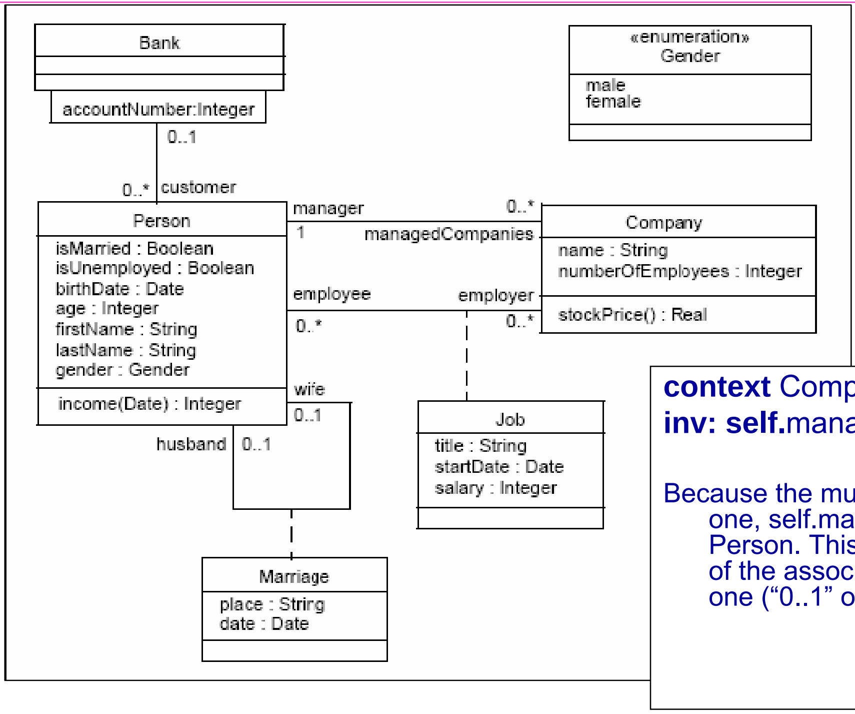
context

context

self.age // returns the age of a particular person
self.employment// returns the employer (company) of a person
self.employer // as before

self.employment// returns the set of all employees of a company
self.president // returns the singleton with the president of a company
self.stockPrice() // returns the value this method would return

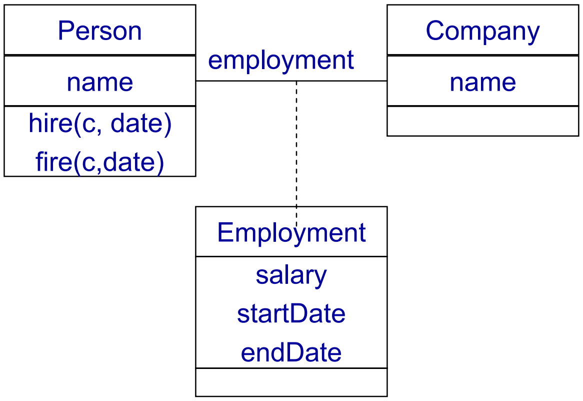
Selectors (how we reference elements)



context Company
inv: self.manager.isUnemployed = false

Because the multiplicity of the role manager is one, self.manager is an object of type Person. This happens when the multiplicity of the association-end has a maximum of one (“0..1” or “1”) .

Selectors
Referencing Association Classes



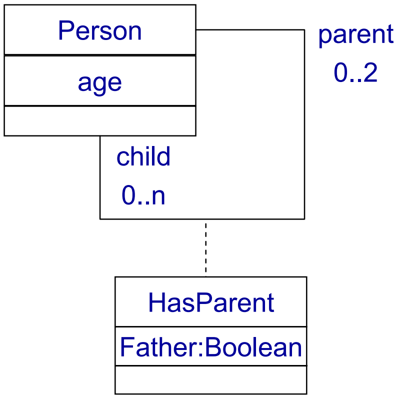
The salary should be > 1000

Context Person **inv:** self.employment.salary > 1000

Για όλους τους εργαζομένους;
Για έναν;
Περισσότερα αργότερα
(αυτή η έκφραση δεν είναι πάντα σωστή).

We use dot and the name of the association class starting with a lowercase letter

Selectors
Referencing Recursive Associations



The age of a children should be less than the age of its parents.

Here the name of the association class alone is not enough.

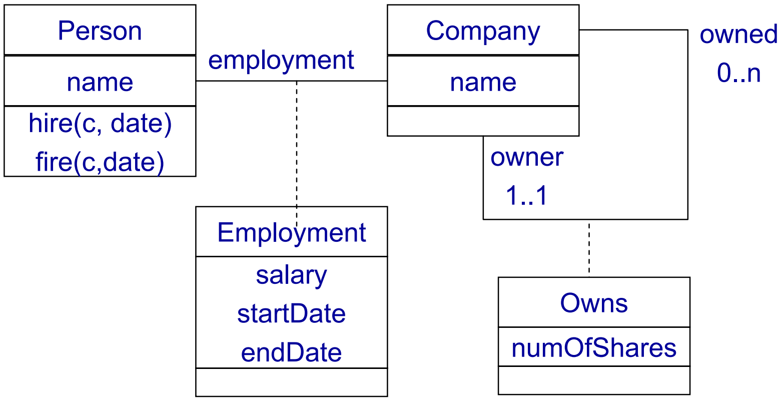
We need to distinguish the direction in which the association is navigated.

To make the distinction, the rolename of the direction in which we want to navigate is added to the association class name, enclosed in square brackets.

Context Person **inv:** self.hasParent[parent].age > self.age

self.hasParent.age is invalid

Selectors
Referencing Recursive Associations



Let c be a company. The name of the company that owns c should be different than the name of c.

Context Company **inv:** self.owns[owner].name <> self.name

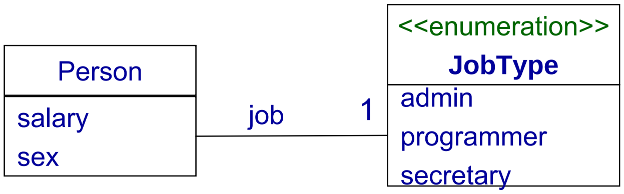
Πράξεις
Operations

- Boolean Operations
  - **and** // ∧
  - **or** // ∨
  - **not** // ¬
  - **implies** // →
  - **xor**
- Comparison operations
  - **<, >, <=, >=, <>, ==**
- Arithmetic
  - **+, -, *, /, abs(), div, floor(), round()**
- String operations
  - **concat**(s1, s2), **toUpper**(s),

- Nil
  - if an attribute **attr** of an object **obj** has no value then **obj.attr** returns **nil**
- Empty
  - if there are no associated objects to an object **obj** through an association **assoc** then **obj.assoc** returns the empty bag {}.
- Nil <> Empty

Αναφορά σε απαριθμητούς τύπους
Referring to enumerations

- Enumerations

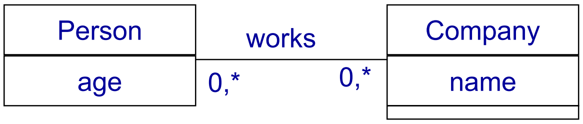

Person
salary
sex
job
1
<<enumeration>>
JobType
admin
programmer
secretary

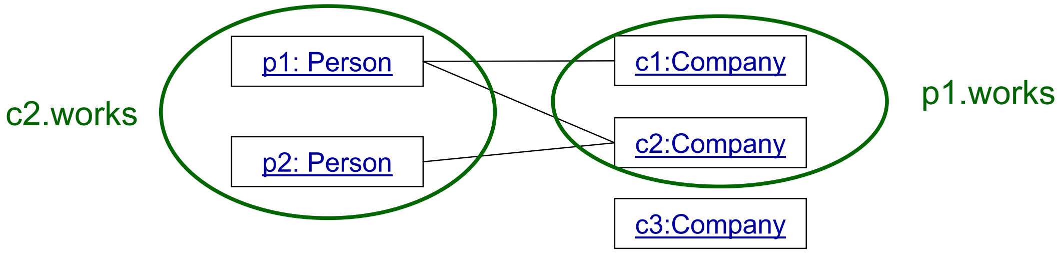
Context Person **inv:** self.job==JobType::admin **implies** self.salary > 10.000

Context Person **inv:** self.name==“Yannis” **implies** self.sex::Male

Συλλογές στην OCL
Collections in OCL

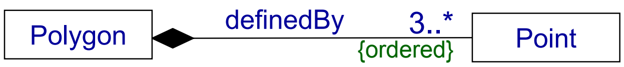
- Allow us to refer to the objects that are referred using associations (typically in those with upper multiplicity > 1)



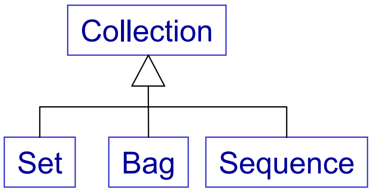


Collections in OCL (II)

Single navigation of an association results in a **Set**,
combined navigations in a **Bag**, and
navigation over associations adorned with {ordered} results in an **OrderedSet**.

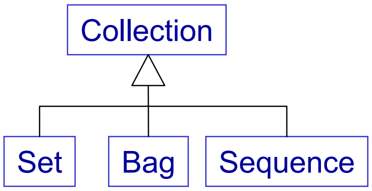


Collection is an abstract type, with the concrete collection types (Set, Sequence, and Bag) as its subtypes.



Αντικείμενα και Συλλογές
Objects and Collections

- Objects
  - are instances of classes, including the predefined ones (e.g. Integer)
- Sets
  - a “set” of objects
  - example: Set { p1, p2}
- Bag
  - duplicates allowed
  - example: Bag { p1, p1, p1, p2, p1}
- Sequence
  - is a bag of ordered elements
  - example: Sequence {p1, p2, p3, p1 } // <p1, p2, p3, p1>



Collection

Set

Bag

Sequence

Πράξεις σε Συλλογές
Collection Operations

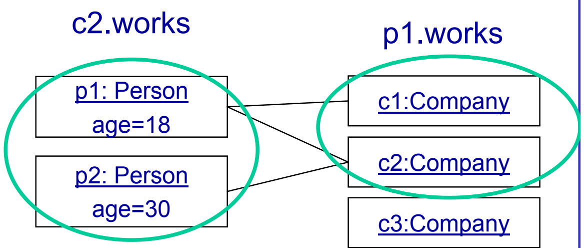
The type Collection defines a large number of predefined operations to enable the modeler to manipulate collections.

As OCL is an expression language, collection operations never change collections (rather than changing the original collection they project the result into a new one).

- c1->**Size**()   // number of elements of c1
- c1->**count**(*elem*)   // counts the number of occurrences of *elem* in c1
- c1->**includes**(*elem*)   // checks if *elem* is member of c1
- c1->**includesAll**(*coll*)   // checks if *coll* is contained in c1
- c1->**excludes**(*elem*)   // returns True if *elem* is not member of in c1
- c1->**isEmpty**()   // checks if c1={}

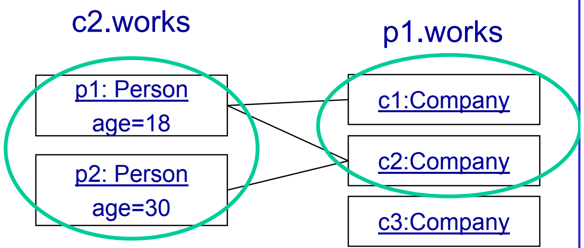
- c1->**forAll**(*expr*)   // returns True if *expr* is true for all elements of c1
- c1->**exists**(*expr*)   // returns True if *expr* is true for at least one element of c1
- c1->**select** (*expr*)   // returns the elements of c1 that satisfy *expr*
- c1->**reject** (*expr*)   // returns the elements of c1 that do not satisfy *expr*
- SET OPERATIONS:
  - c1->**union**(c2), c1->**intersection**(c2), c1**-**c2

Παραδείγματα
Collection Operations: Examples



- p1.works->**size**() is 2
- p1.works->**count**(c3) is 0
- p1.works->**includes**(c2)
  - is True
- p1.works->**includes**(c3) is False
- c2.works->**includesAll**(c1.works)
  - is True
- c1.works->**includesAll**(c2.works)
  - is False
- c3.works->**isEmpty**()
  - is True

Collection Operations: Examples (II)

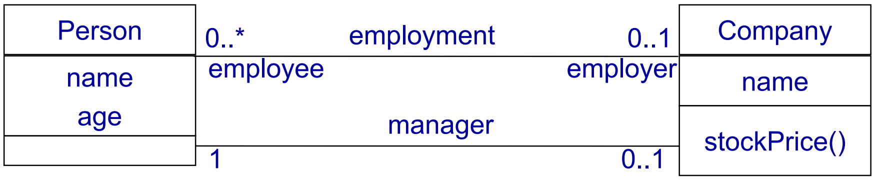


- c2.works->**forAll**{ x | x.age>20 **and** x.age < 70}
  - is False
- c2.works->**exists**{ x | x.age>20 **and** x.age < 70}
  - is True
- c2.works->**select**{ x | x.age>20 **and** x.age < 70}
  - will return {p2}
- p1.works->**intersection**(p2.works)
  - will return {c2}
- p1.works **-** p2.works
  - will return {c1}

Ένα αντικείμενο μπορεί να αντιμετωπιστεί ως μονοσύνολο
A single object can be treated as a singleton

A single object can be used as a Set as well. It then behaves as if it is a Set containing the single object. The usage as a set is done through the arrow followed by a property of Set.

context Company
inv: self.manager->**size()** = 1



Select / Reject

The reject operation is available in OCL for convenience, because each reject can be restated as a select with the negated expression. Therefore, the following two expressions are identical:

collection->reject(v : Type | boolean-expression-with-v)

collection->select(v : Type | not (boolean-expression-with-v))

The collection of all the employees who are not married is empty:

context Company
inv: self.employee**->reject(** isMarried **)->isEmpty()**

Collect operation

The select and reject operations always result in a sub-collection of the original collection.

When we want to specify a collection which is derived from some other collection, but which contains different objects from the original collection (i.e., it is not a sub-collection), we can use a collect operation.

The collect operation uses the same syntax as the select and reject and is written as one of:

collection->collect(v : Type | expression-with-v)

collection->collect(v | expression-with-v)

collection->collect(expression)

The value of the reject operation is the collection of the results of all the evaluations of expression-with-v.

An example: specify the collection of birthDates for all employees in the context of a company. This can be written in the context of a Company object as one of:

self.employee->collect(birthDate)

self.employee->collect(person | person.birthDate)

self.employee->collect(person : Person | person.birthDate)

Collect (2)

Shorthand for Collect

Because navigation through many objects is very common, there is a shorthand notation for the collect that makes the OCL expressions more readable.

Instead of

self.employee->collect(birthdate)

we can also write:

self.employee.birthdate

In general, when we apply a property to a collection of Objects, then it will automatically be interpreted as a collect over the members of the collection with the specified property. For any property name that is defined as a property on the objects in a collection, the following two expressions are identical:

collection.propertyname

collection->collect(propertyname)

and so are these if the property is parameterized:

collection.propertyname (par1, par2, ...)

collection->collect (propertyname(par1, par2, ...))

Collect (3)

When the source collection is a **Set** the resulting collection is not a Set but a **Bag**.

If the source collection is a **Sequence** or an **OrderedSet**, the resulting collection is a **Sequence**.

When more than one employee has the same value for birthDate, this value will be an element of the resulting Bag more than once.

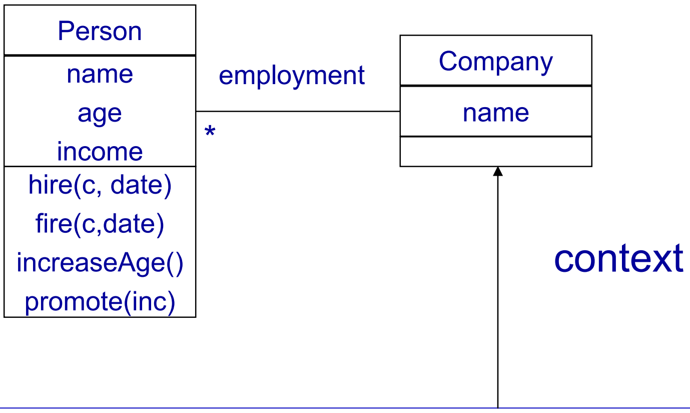
The Bag resulting from the collect operation always has the same size as the original collection.

It is possible to make a Set from the Bag, by using the **asSet** property on the Bag.
Example:

self.employee**->collect(** birthDate **)->asSet()**

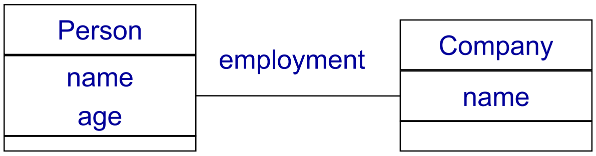
Results in the Set of different birthDates from all employees of a Company

Examples with Bags and other operations



- **employment.age** is a <u>bag</u>
- **employment.income** is a <u>bag</u>
- **employment.income->asSet()** returns all distinct incomes of the employees

Παραδείγματα με Αναλλοίωτες Συνθήκες
Examples of Invariants (using collection operations)



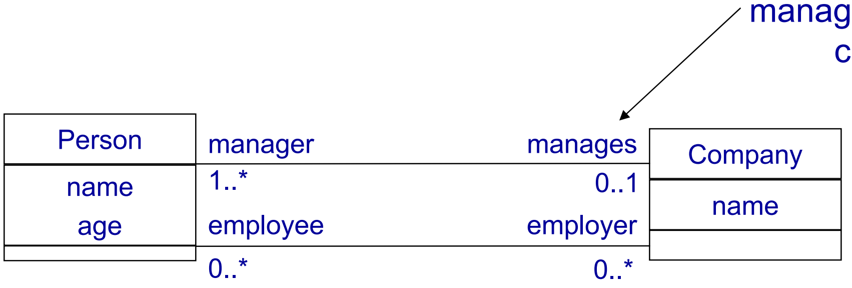
All persons should have positive age

Context Person **inv:** self.age >0

All persons that work for a company should be adults

Context Company **inv:** self.employment->**forall**(x | x.age > 18)

Examples of Invariants (using collection operations)



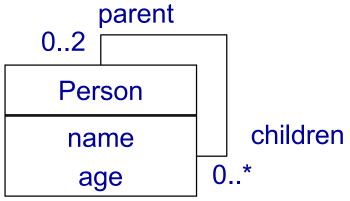
A person can be a manager of only one company

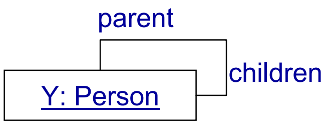
All companies should have managers that are not employers of other companies

Context Company **inv:** **not** (self.manager->**exists**(x| x.employer->**exists**(y|y<>self))

Context Company **inv:** self.manager.employer->**forall**(x | x = **self**)

Another example





Context Person
inv: self.parent->**excludes**(**self**) and **self**.children->**excludes**(**self**)

Forall

context Company
inv: self.employee**->forAll(** age <= 65 **)**
inv: self.employee**->forAll(** p | p.age <= 65 **)**
inv: self.employee**->forAll(** p : Person | p.age <= 65 **)**

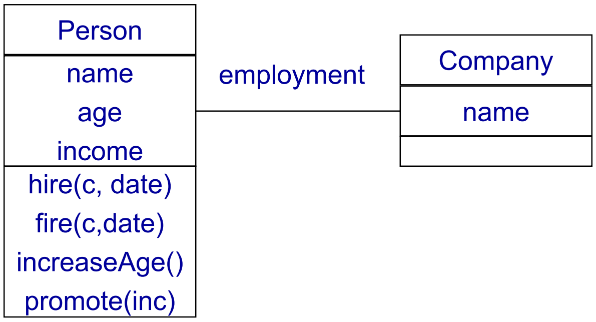
These invariants evaluate to true if the age property of each employee is less or equal to 65.

The forAll operation has an extended variant in which more then one iterator is used.
Both iterators will iterate over the complete collection.
Effectively this is a forAll on the Cartesian product of the collection with itself.

context Company **inv:**
self.employee**->forAll(** e1, e2 : Person | e1 <> e2 **implies** e1.forename <> e2.forename**)**

This expression evaluates to true if the forenames of all employees are different.
It is semantically equivalent to:
context Company **inv:**
self.employee**->forAll (**e1 | **self.**employee->**forAll** (e2 | e1 <> e2 **implies** e1.forename <> e2.forename))

Examples of Constraints (using collection operations) Pre/Post-Conditions



Person

name
age
income

hire(c, date)
fire(c,date)
increaseAge()
promote(inc)

employment

Company

name

Context Person::hire(c:Company)
pre: **not** employment->**includes**(c)
post: employment->**includes**(c)

Context Person::fire(c:Company)
pre: employment->**includes**(c)
post: **not** employment->**includes**(c)

Context Person::increaseAge ()
post: age = age@pre +1

@pre: the value of an attribute/association before the execution of the operation

Context Person::Promote (inc) **post: self.**income = income@pre * (1+inc)

@Pre

When the pre-value of a property evaluates to an object, all further properties that are accessed of this object are the new values (upon completion of the operation) of this object.

a.b@pre.c -- takes the old value of property b of a, say object18,
-- and then the new value of c of object18.

a.b@pre.c@pre -- takes the old value of property b of a, say object18
-- and then the old value of c of object18.

The '@pre' postfix is allowed only in OCL expressions that are part of a Postcondition.

Asking for a current property of an object that has been destroyed during execution of the operation results in OclUndefined. Also, referring to the previous value of an object that has been created during execution of the operation results in OclUndefined.

Post-conditions
Result, out-parameters

The reserved word **result** denotes the result of the operation, if there is one.

Context Person::getIncome(d:Date): Integer
post: result = 1000

The right-hand-side of this definition may refer to the operation being defined (i.e., the definition may be recursive) as long as the recursion is not infinite.

When the operation has no out or in/out parameters (like in this example), then the type of result is the return type of the operation (here Integer).

When the operation has out or in/out parameters, the return type is a **Tuple.**

The postcondition for the income operation with an out parameter *bonus* could be:

Context Person::getIncome(d:Date, bonus:Integer): Integer
post: result = **Tuple**{bonus=300, result=1000}

The return type of operation calls is Tuple(bonus: Integer, result: Integer).

Post-conditions
Result, out-parameters (2)

Context Person::getIncome(d:Date, bonus:Integer): Integer
post: result = **Tuple**{bonus=300, result=1000}

The out parameters need not be included in the operation call (we have to provide values only for the in or in/out parameters).

Let *Yannis* be an object of the class Person, and let d1 be a Date.
Then, **Yannis.getIncome(d1)** is a valid operation call.

The type of the result of this operation call is Tuple(bonus: Integer, result: Integer).

We can access these values using the names of the out parameters, and the keyword result, for example:
Yannis.getIncome(d1).bonus = 300 and
Yannis. getIncome(d1).result = 1000

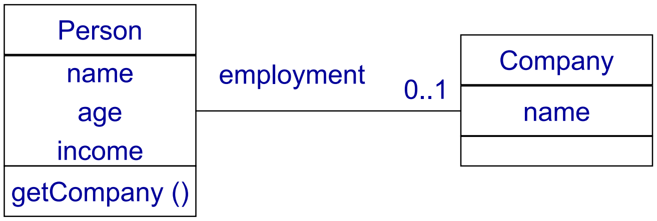
Body: Indicating the result of a query operation

An OCL expression may be used to indicate the result of a query operation.

The expression must conform to the result type of the operation.

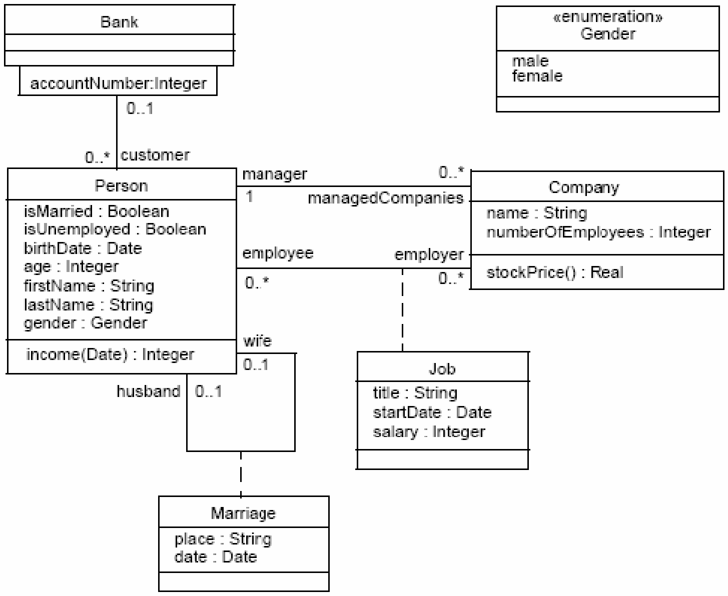
Like in the pre/post-conditions, the parameters may be used in the expression.

Pre/post-conditions, and body expressions may be mixed together after one operation context.



Context Person::getCompany():Company
pre: self.employment->size()>0
body: self.employment

Body: Indicating the result of a query operation (II)



Context Person::getCurrentSpouse():Person
pre: self.isMarried = true
body: self.marriage ->select(m| m.ended = false).spouse

(to be continued)