Advance Software Engineering OCL

By:

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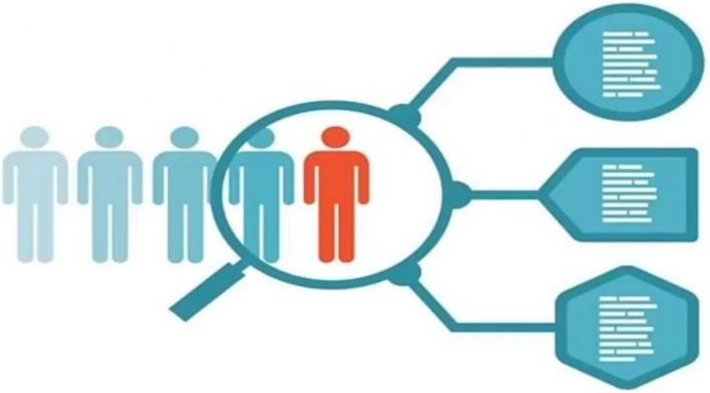
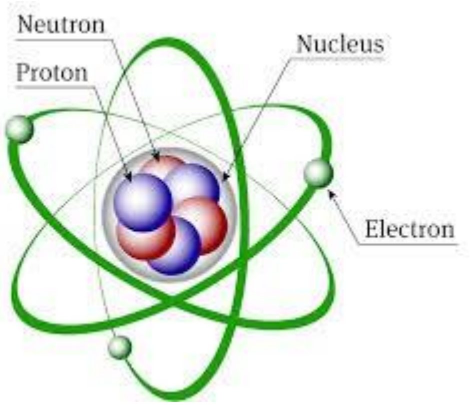
Any model

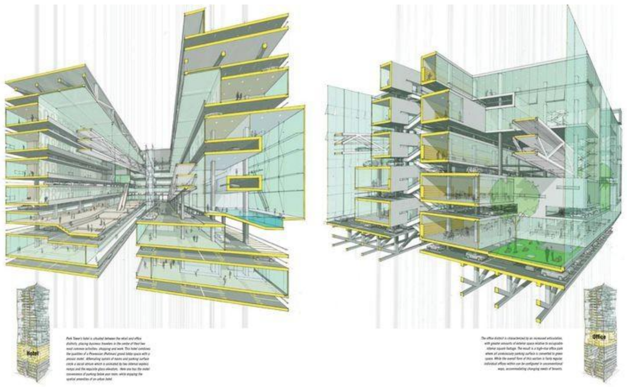
- Any model is splits into three types:
  1. Predictive model: Analyze the past for the future
  2. Descriptive model: creating the relationship in the data - grouping
  3. Perspective model: decision based on all the elements -prescribing



Predictive model



Descriptive model



Perspective model

Model Driven Engineering

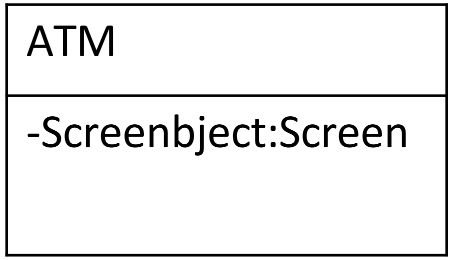
- Using Perspective models as programs
- Engineering domain-specific languages for capturing such models:
  - Precise abstract syntax.
  - Supporting graphical/textual modeling tool
- Expressing and checking validity constrains for models.
- Analyzing and simulating models
- Transformation models into:
  - Other types of models
  - Software products

Why Model Driven Engineering?

- When the abstractions provided by implementation-level technologies are not satisfactory
    - Engineers need to copy/past similar boilerplate content/code too often
    - To make change engineers need to modify several inter-related artefacts in a similar way.
- When reasoning about properties of the system is too hard/expensive at the implementation level.

Example1: Boilerplate code

```
public class ATM {

        private String Screen;

        public String getScreen() {
                // TODO - implement ATM.getScreen
                throw new UnsupportedOperationException();
        }

        /**
         *
         * @param Screen
         */
        public void setScreen(String Screen) {
                // TODO - implement ATM.setScreen
                throw new UnsupportedOperationException();
        }

}
```



ATM

-Screenbject:Screen

Using Visual Paradigm

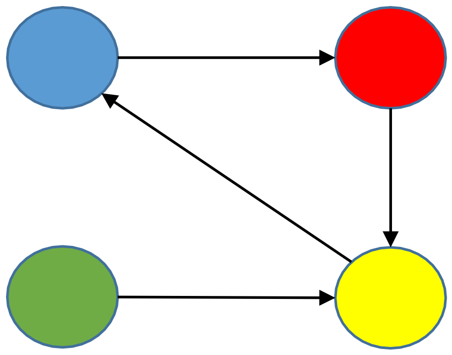
Example2: Property analysis and verification

- The following code controls the change of colors in tree lights.

```
switch(color){
        case "blue":{color="red"; break;}
        case "green":{color="yellow"; break;}
        case "yellow":{color="blue"; break;}
        case "red":{color="yellow"; break;}
     }
```

Example2: Property analysis and verification

- The following code controls the change of colors in tree lights.
- The code in previous slide can be trivially from this model.
- For larger state machine models we probably need automated reachability analysis



Modeling Languages

- Large number of off-the-shelf modeling languages
- Each language focuses on specific class of domains, problems and systems
  - UML (object oriented systems)
  - Simulink (control systems)
  - Archimate (enterprise architecture)
  - BPMN (business modeling)
  - ER (rational databases)

Domain-Specific Languages

- Often models are useful for the problem at hand, but existing language lack appropriate abstraction
- Example; Organizing conferences

Conference Organization

- A conference runs over a number of days
- On every day, there are several talks organized in (potentially parallel) tracks.
- There are breaks between tracks (e.g. for lunch, coffee etc.)
- Each talk can be delivered by one or more speakers
- Each talk ha a pre-defined duration

Artefacts Involved

Booklet

Website

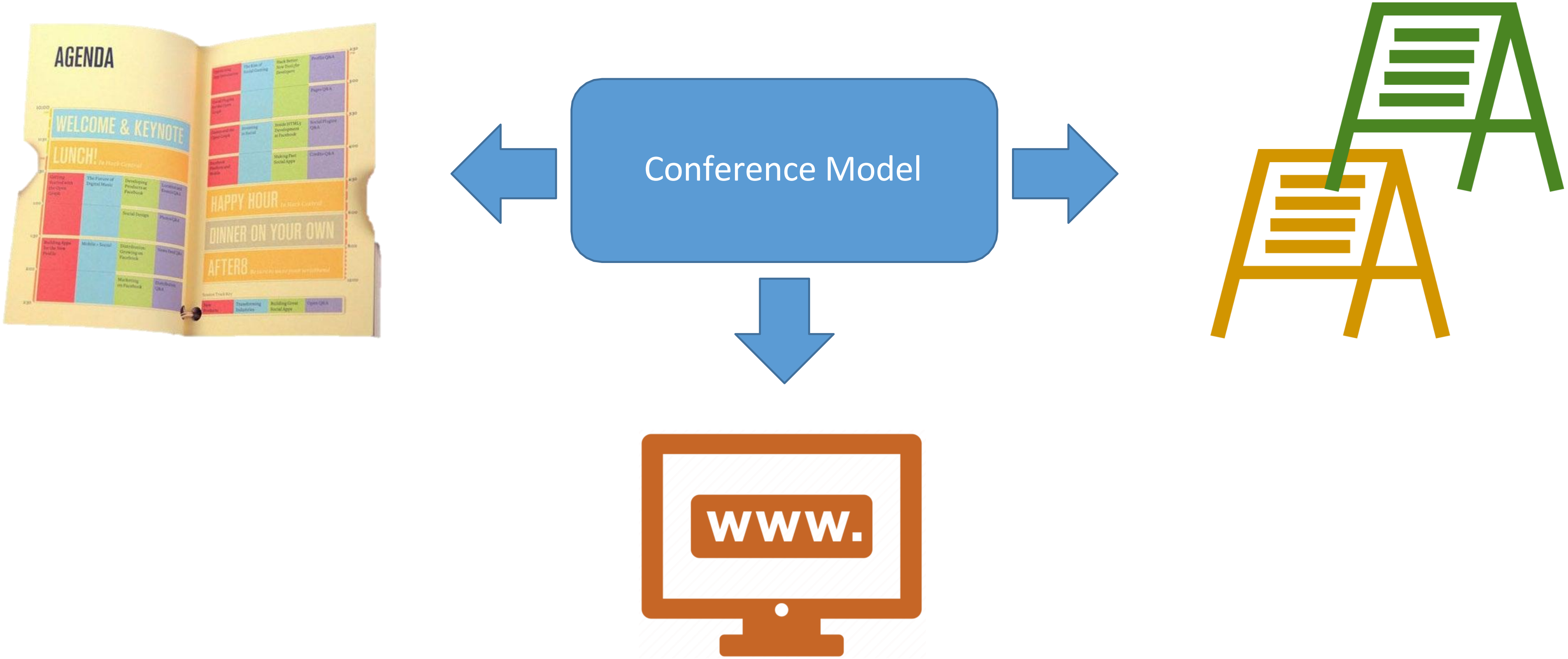
Track Posters

Challenges

- Consistency/maintainability
    - Same content appears in different artefacts
- Correctness
    - Parallel tracks must be located in different rooms
    - The total duration of the talks of track must not exceed the duration of the tracks
    - Breaks must not overlap with tracks.

Domain-specific models to the rescue

Conference modeling language



Conference Model

UML Diagrams are NOT Enough!

- We need a language to help with the spec.
- We look for some “add-on” instead of a brand new language with full specification capability.
- Why not first order logic? – Not OO.
- OCL is used to specify constraints on OO systems.
- OCL is not the only one.
- But OCL is the only one that is standardized.

OCL

- OCL is The Object Constraint Language in UML
- First developed in 1995 as IBEL by IBM’s Insurance division for business modelling.
- OCL was used to define UML 1.2 itself.
- Companies behind OCL:
    - Rational Software, Microsoft, Hewlett-Packard, Oracle, Sterling Software, MCI Systemhouse, Unisys, ICON Computing, IntelliCorp, i-Logix, IBM, ObjecTime, Platinum Technology, Ptech, Taskon, Reich Technologies, Softeam

Textbook: “The Objection Constraint Language: Precise Modeling with UML”, by Jos Warmer and Anneke Kleppe

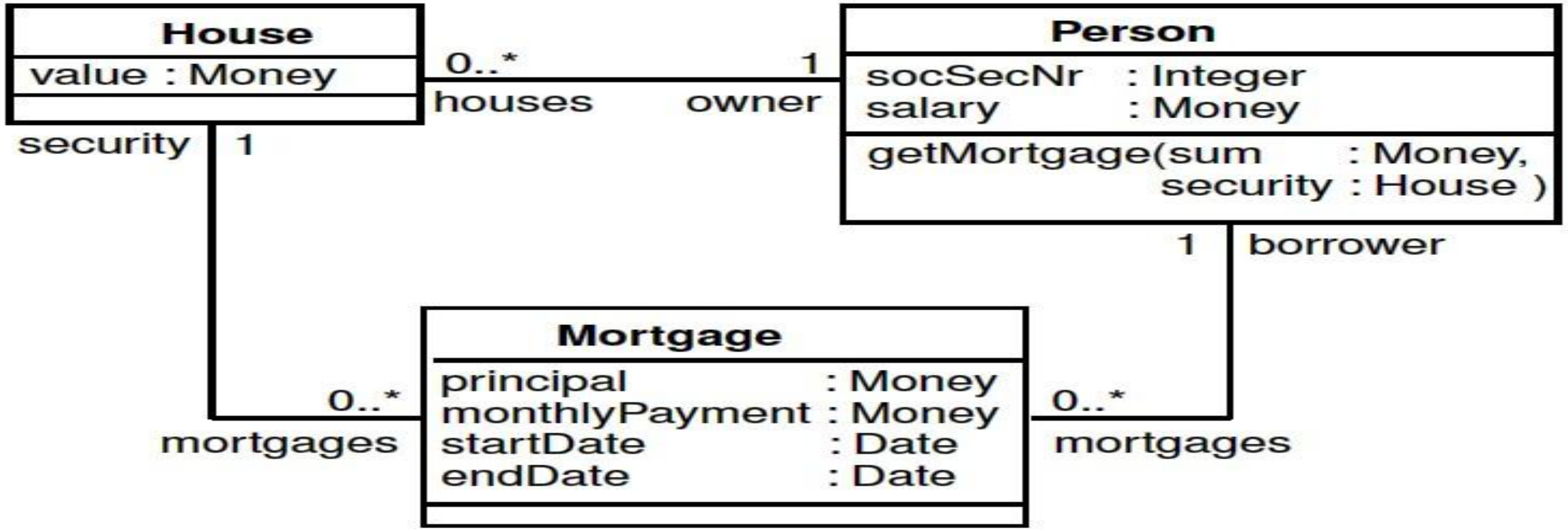
Advantages of Formal Constraints

- Better documentation
  - Constraints add information about the model elements and their relationships to the visual models used in UML
  - It is way of documenting the model
- More precision
  - OCL constraints have formal semantics, hence, can be used to reduce the ambiguity in the UML models
- Communication without misunderstanding
  - UML models are used to communicate between developers, Using OCL constraints modelers can communicate unambiguously

Where to use OCL?

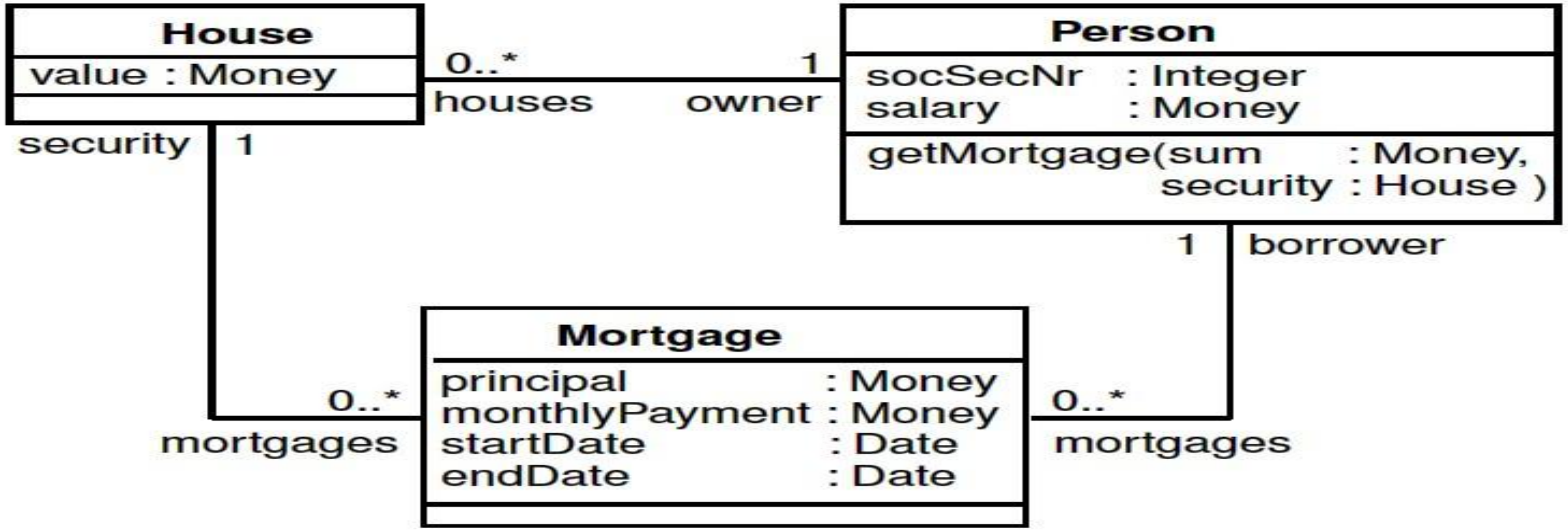
- Specify invariants for classes and types
- Specify pre- and post-conditions for methods
- As a navigation language
- To specify constraints on operations
- Test requirements and specifications

Example: A Mortgage System



1. A person may have a mortgage only on a house he/she owns.
   The start date of a mortgage is before its end date.

OCL specification of the constraints:



1. **context** *Mortgage*
   invariant: *self.security.owner = self.borrower*

context *Mortgage*
invariant: *security.owner = borrower*

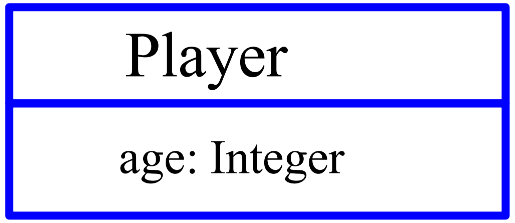
2. **context** *Mortgage*
   invariant: *self.startDate < self.endDate*

context *Mortgage*
invariant: *startDate < endDate*

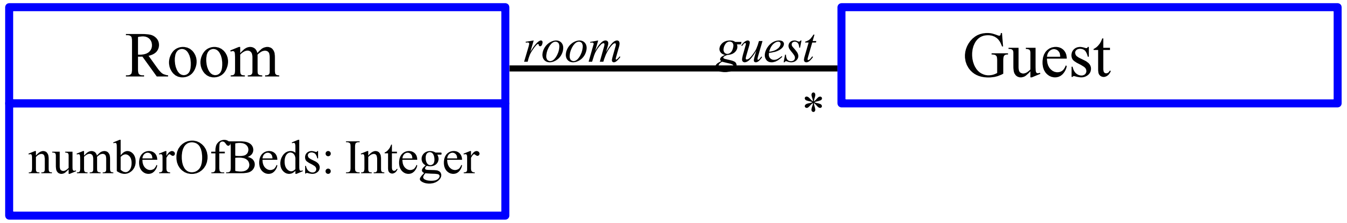
More Constraints Examples

- All players must be over 18.

context Player **invariant:**
self.age >=18



- The number of guests in each room doesn’t exceed the number of beds in the room.



context Room **invariant:**
guests -> size <= numberOfBeds

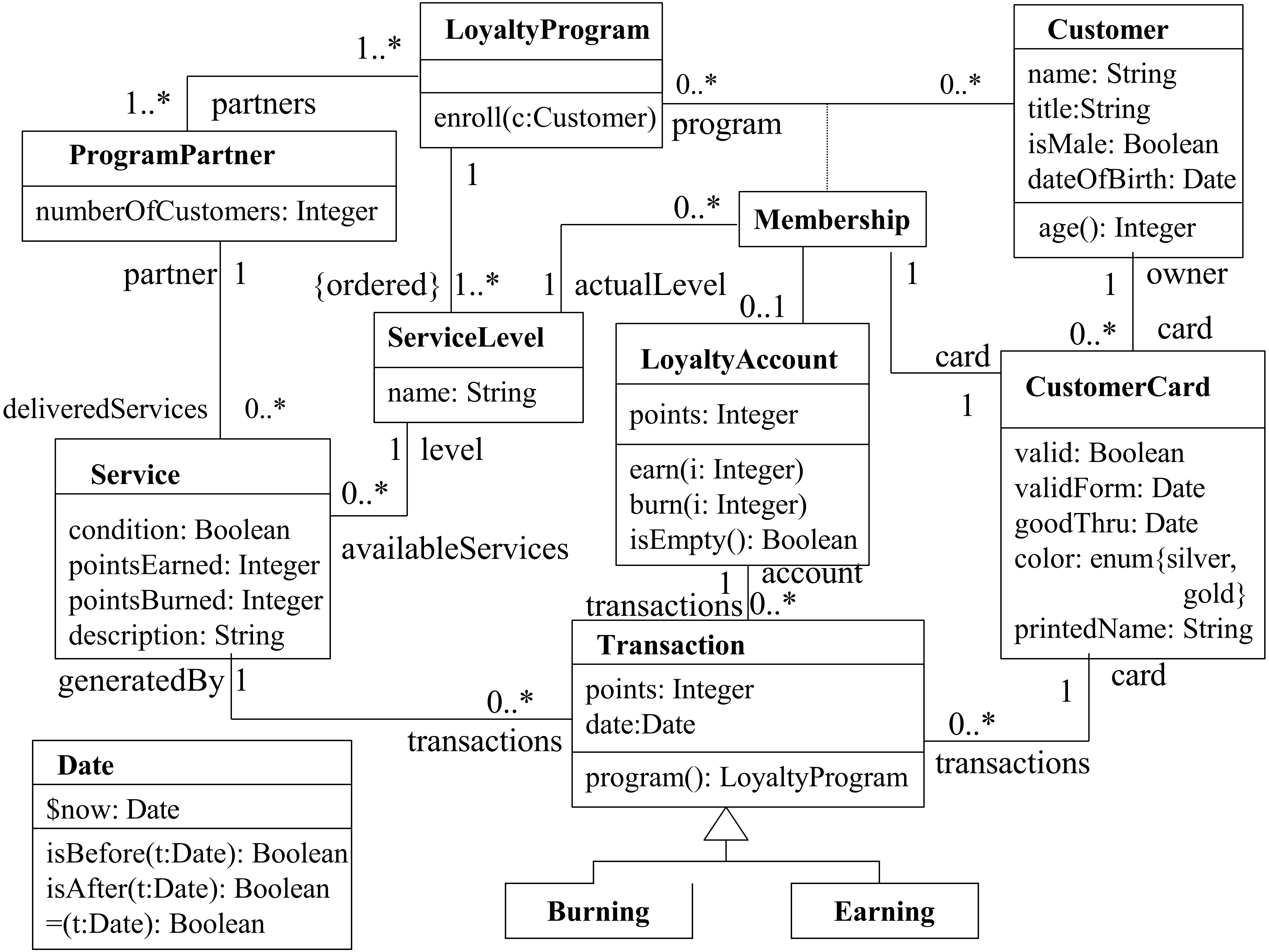
Constraints (invariants), Contexts and Self

- A constraint (invariant) is a boolean OCL expression – evaluates to true/false.
- Every constraint is bound to a specific type (class, association class, interface) in the UML model – its context.
- The context objects may be denoted within the expression using the keyword 'self'.
- The context can be specified by:
  - Context <context name>
  - A dashed note line connecting to the context figure in the UML models
- A constraint might have a name following the keyword **invariant**.

Example of a static UML Model

Problem story:

A company handles loyalty programs (class LoyaltyProgram) for companies (class ProgramPartner) that offer their customers various kinds of bonuses. Often, the extras take the form of bonus points or air miles, but other bonuses are possible. Anything a company is willing to offer can be a service (class Service) rendered in a loyalty program. Every customer can enter the loyalty program by obtaining a membership card (class CustomerCard). The objects of class Customer represent the persons who have entered the program. A membership card is issued to one person, but can be used for an entire family or business. Loyalty programs can allow customers to save bonus points (class loyaltyAccount) , with which they can “buy” services from program partners. A loyalty account is issued per customer membership in a loyalty program (association class Membership). Transactions (class Transaction) on loyalty accounts involve various services provided by the program partners and are performed per single card. There are two kinds of transactions: Earning and burning. Membership durations determine various levels of services (class serviceLevel).



LoyaltyProgram

enroll(c:Customer)

Customer

name: String
title:String
isMale: Boolean
dateOfBirth: Date

age(): Integer

ProgramPartner

numberOfCustomers: Integer

Membership

ServiceLevel

name: String

LoyaltyAccount

points: Integer

earn(i: Integer)
burn(i: Integer)
isEmpty(): Boolean

CustomerCard

valid: Boolean
validForm: Date
goodThru: Date
color: enum{silver, gold}
printedName: String

Service

condition: Boolean
pointsEarned: Integer
pointsBurned: Integer
description: String

Transaction

points: Integer
date:Date

program(): LoyaltyProgram

Burning

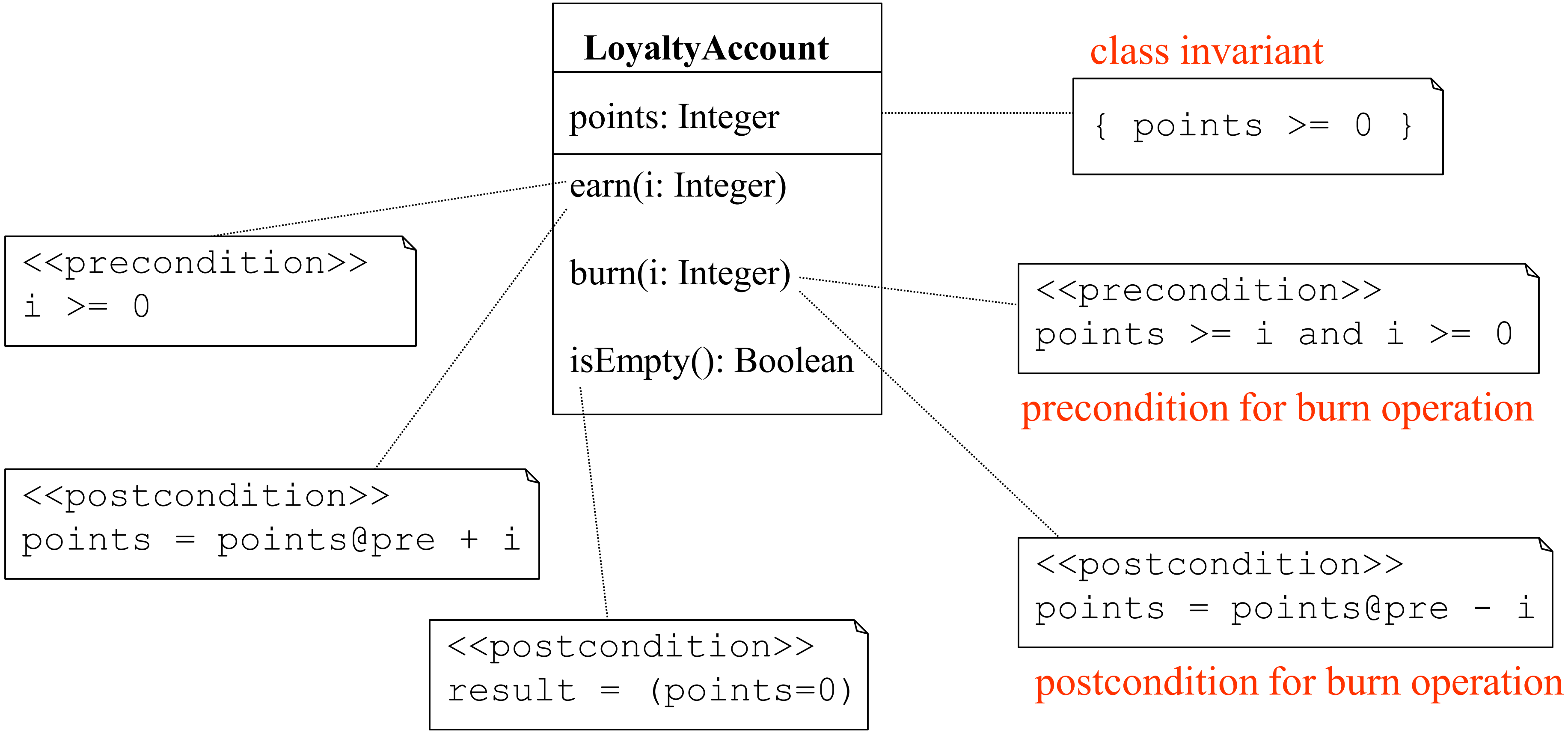
Earning

Date

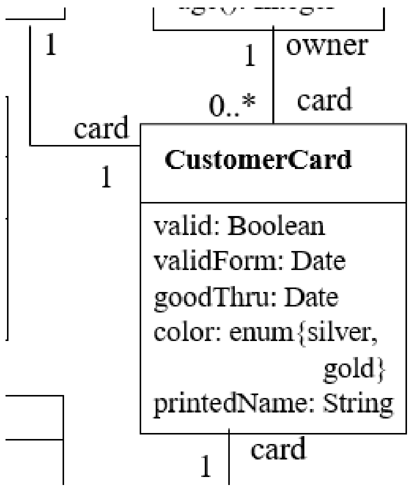
$now: Date

isBefore(t:Date): Boolean
isAfter(t:Date): Boolean
=(t:Date): Boolean

Using OCL in Class Diagrams



Invariants on Attributes



- Invariants on attributes:

```
context Customer
invariant agerestriction: age >= 18

context CustomerCard
invariant correctDates: validFrom.isBefore(goodThru)
```

The type of *validFrom* and *goodThru* is *Date*.
isBefore(*Date*):*Boolean* is a *Date* operation.

- The class on which the invariant must be put is the invariant context.

- For the above example, this means that the expression is an invariant of the Customer class.

Invariants using Navigation over Association Ends – Roles (1)

Navigation over associations is used to refer to associated objects, starting from the context object:

```
    context CustomerCard
    invariant: owner.age >= 18
```

```
owner → a Customer instance.
owner.age → an Integer.
```

Invariants using Navigation over Association Ends – Roles (2)

```
context CustomerCard
invariant printedName:
printedName =
owner.title.concat(‘ ‘).concat(owner.name)
```

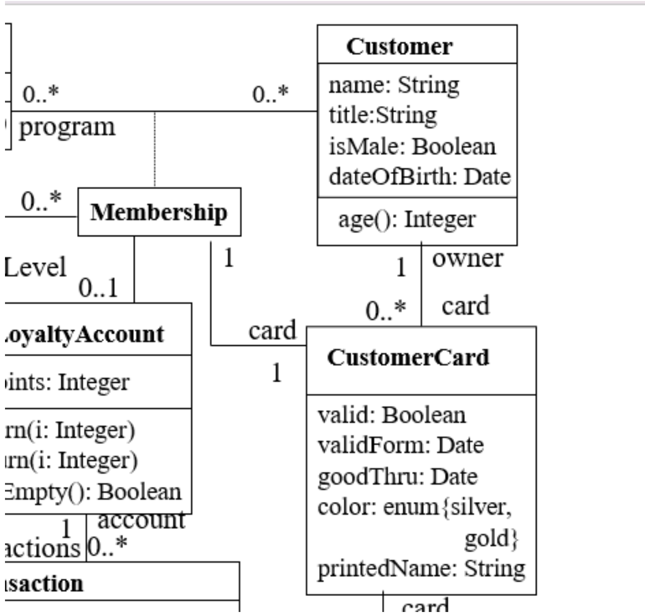
printedName →a String.
owner → a Customer instance.
owner.title →a String.
owner.name → a String.
String is a recognized OCL type.
concat is a String operation, with the
signature *concat*(*String*): *String*.

Invariants using Navigation through Associations with “Many” Multiplicity

Navigation over associations roles with multiplicity greater than 1 yields a Collection type. Operations on collections are accessed using an arrow ->, followed by the operation name.

“A customer card belongs only to a membership of its owner”:

```
context CustomerCard
invariant correctCard:
owner.Membership->includes(membership)
```



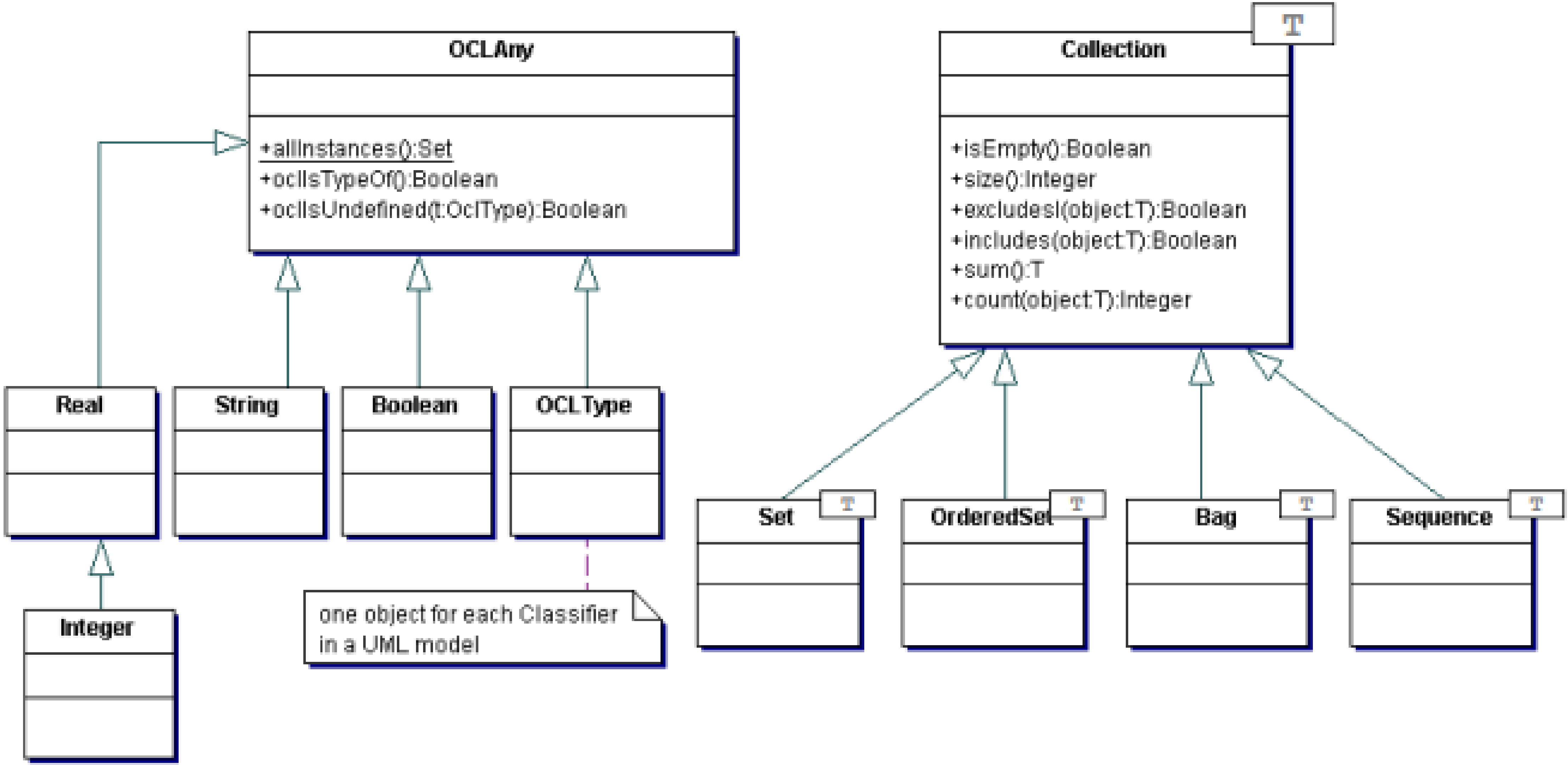
a set of *Membership instances.*

membership →*owner* → a *Customer* instance.

owner.Membership → a *Membership instance.*

includes is an operation of the OCL *Collection* type.

OCL Type Hierarchy



Recap

Models

- Predictive, Descriptive, Perspective

OCL- Context

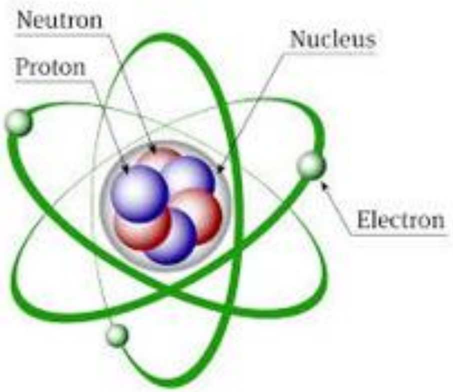
OCL - Pre-Post Condition

OCL – Navigation

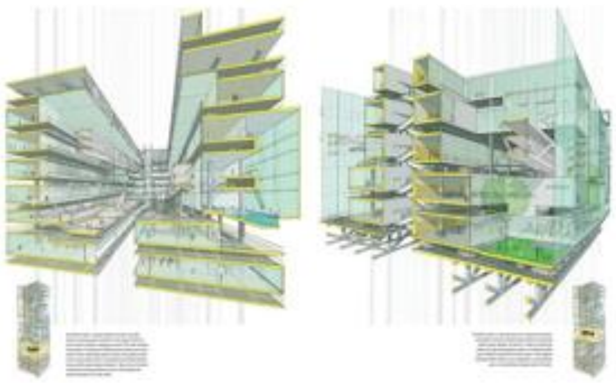
OCL - Types

OCL – Collections

Predictive model



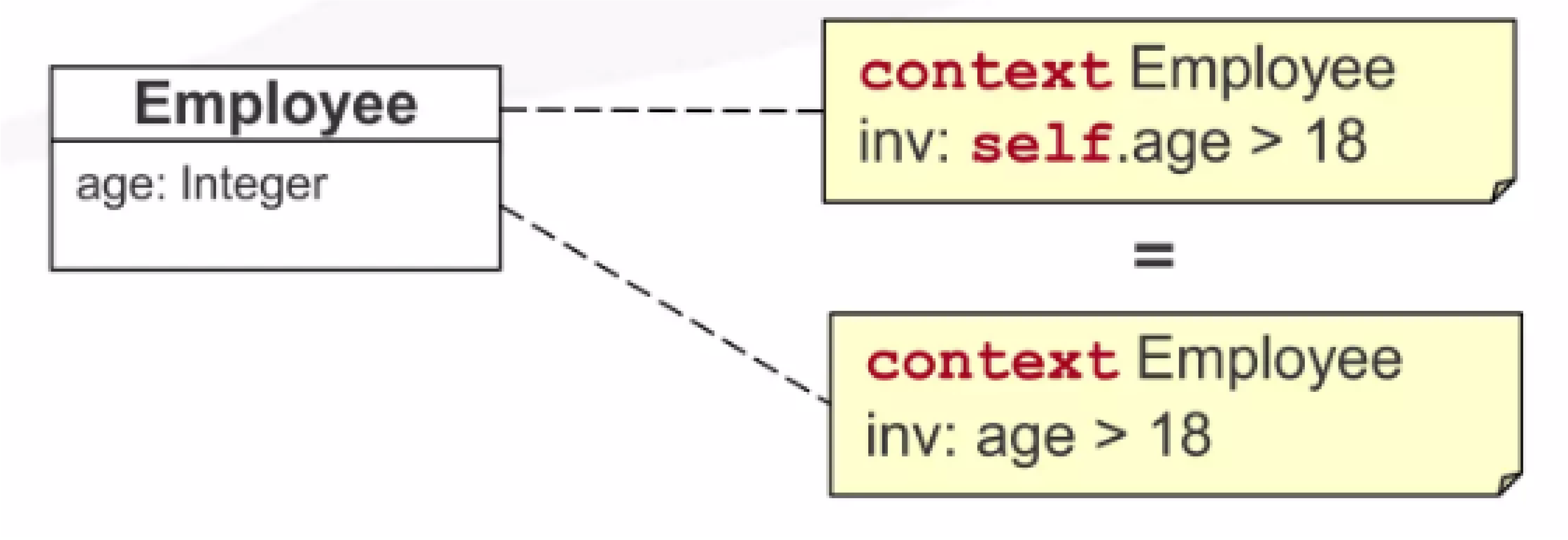
Descriptive model



Perspective model

Models

Context

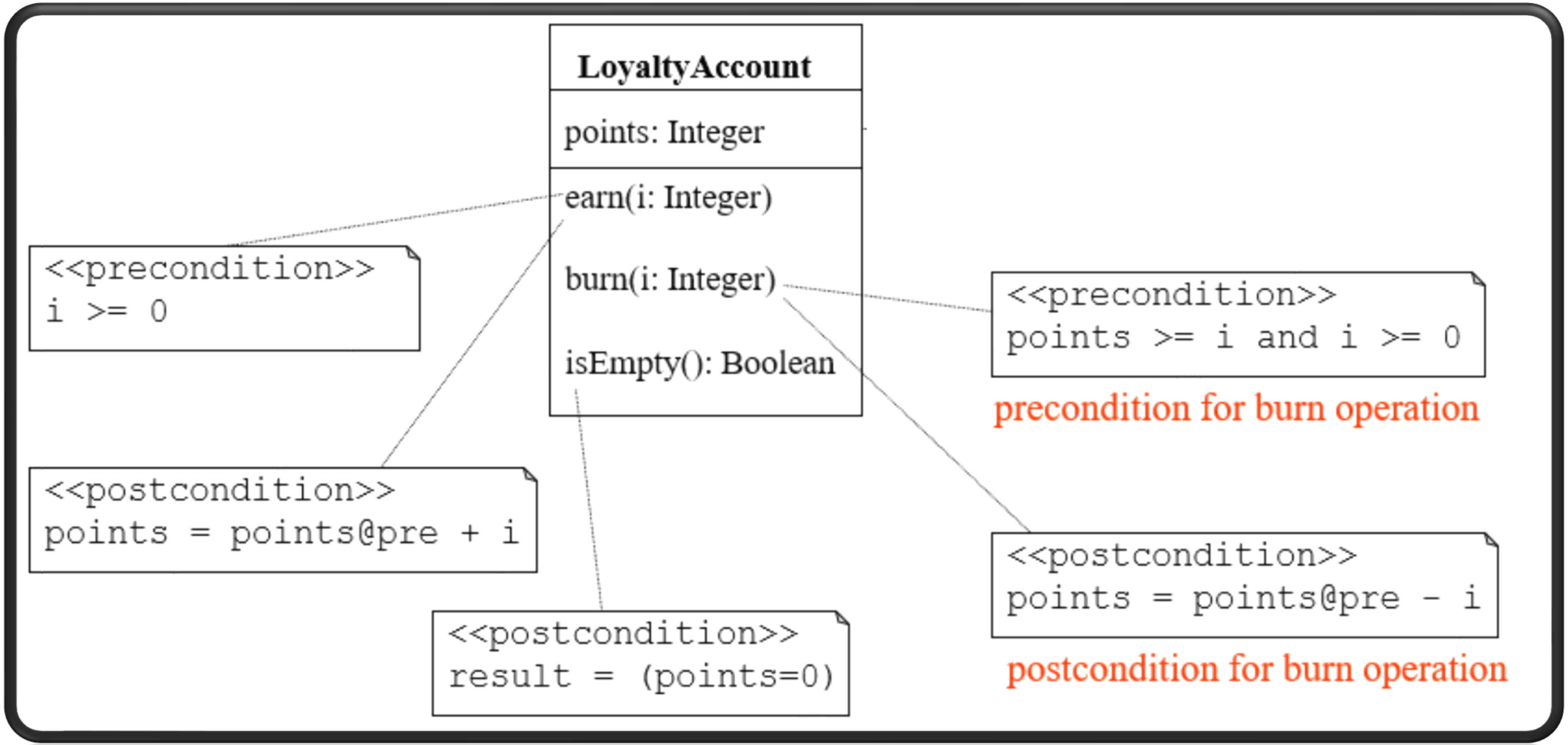


```
context Employee
inv: self.age > 18
```

=

```
context Employee
inv: age > 18
```

Pre, post- Conditions



LoyaltyAccount

points: Integer

earn(i: Integer)

burn(i: Integer)

isEmpty(): Boolean

```
<<precondition>>
i >= 0
```

```
<<postcondition>>
points = points@pre + i
```

```
<<postcondition>>
result = (points=0)
```

```
<<precondition>>
points >= i and i >= 0
```

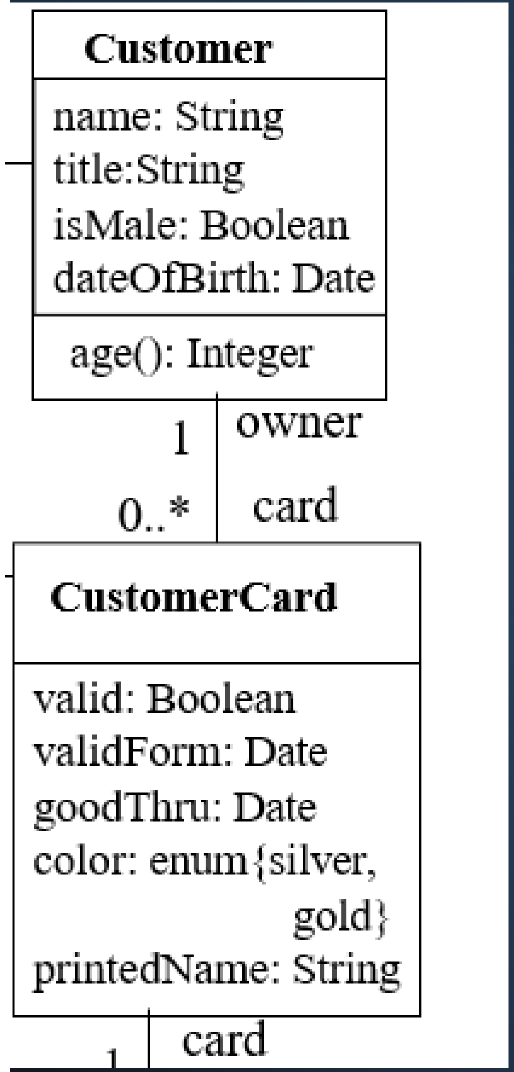
precondition for burn operation

```
<<postcondition>>
points = points@pre - i
```

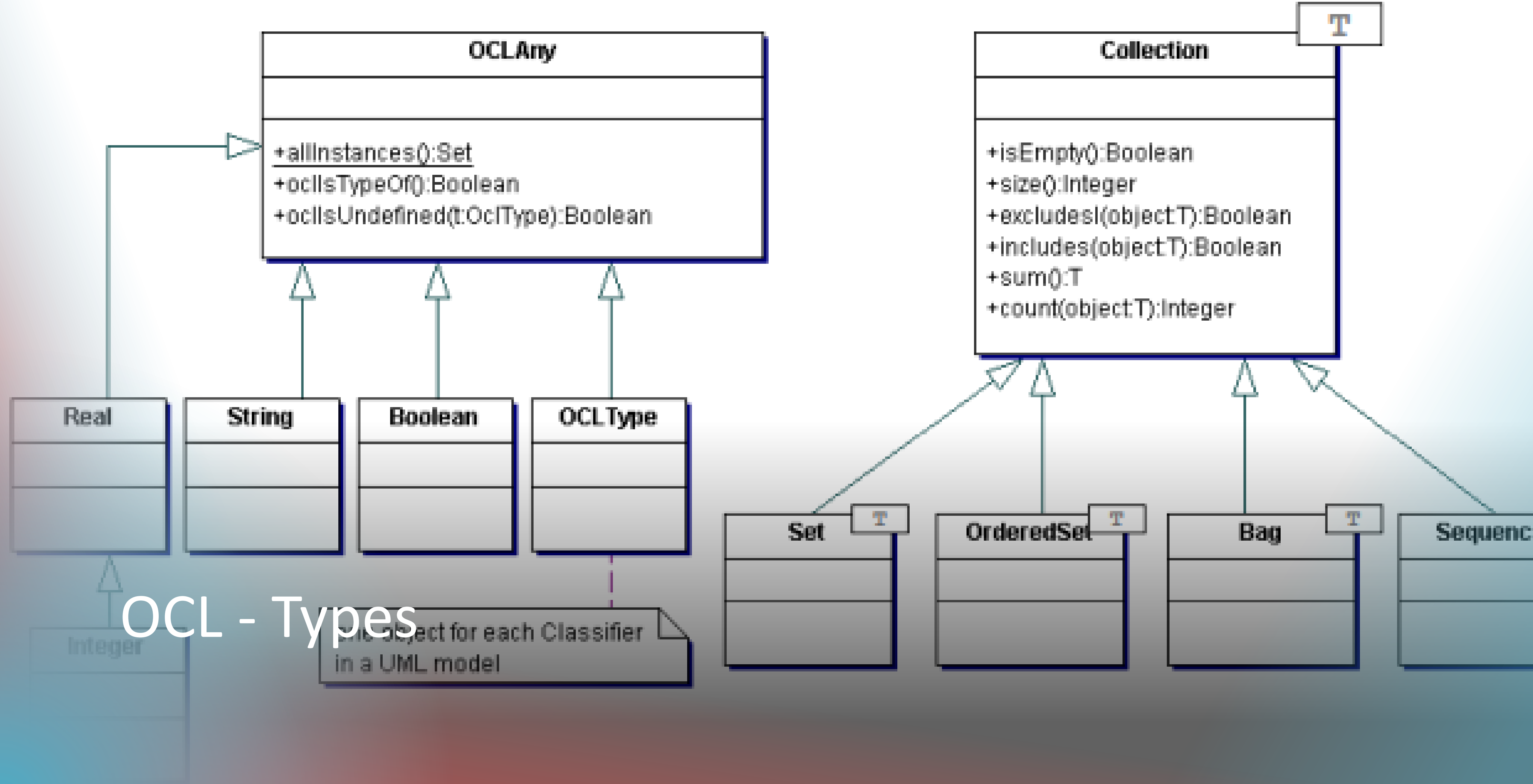
postcondition for burn operation

Navigation

```
context CustomerCard
invariant printedName:
printedName =
owner.title.concat(‘ ‘).concat(owner.name)
```



OCL - Types



OCLAny

+allInstances():Set
+oclIsTypeOf():Boolean
+oclIsUndefined(t:OclType):Boolean

Real

String

Boolean

OCLType

Integer

One object for each Classifier
in a UML model

Collection

T

+isEmpty():Boolean
+size():Integer
+excludesl(object:T):Boolean
+includes(object:T):Boolean
+sum():T
+count(object:T):Integer

Set

T

OrderedSet

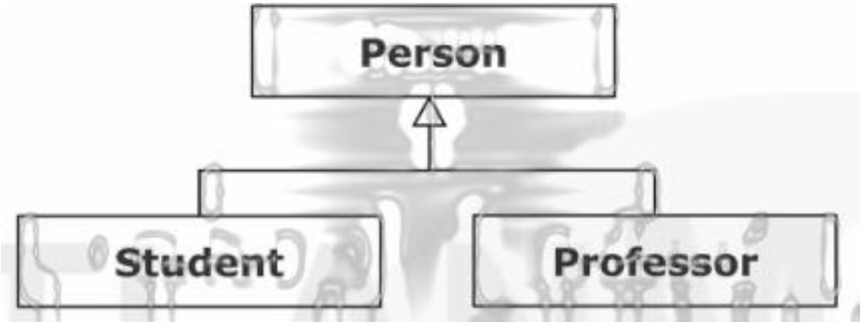
T

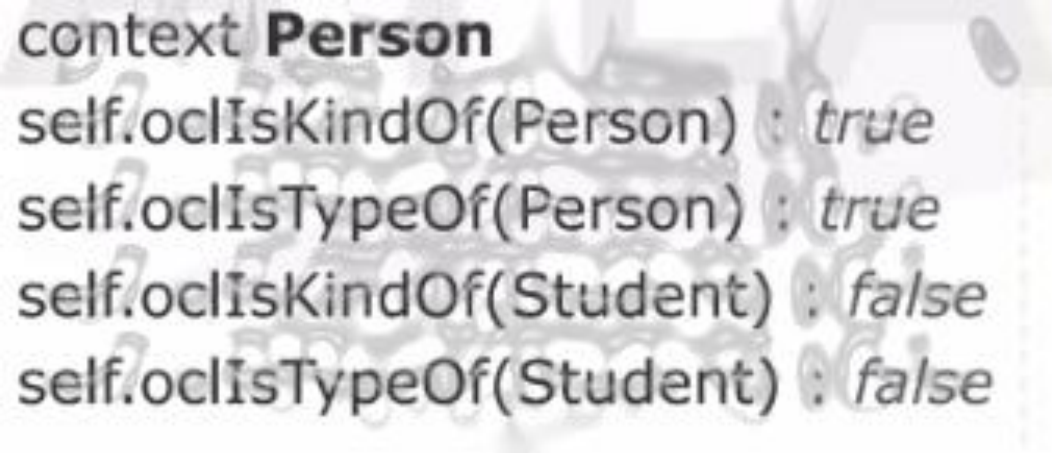
Bag

T

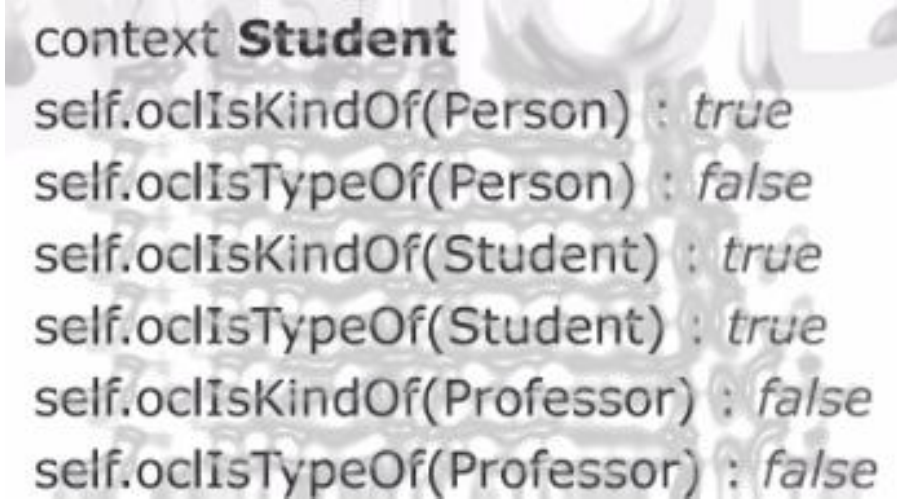
Sequenc

OCL ANY

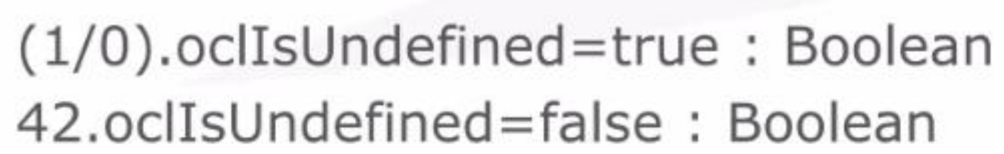




```
context Person
self.oclIsKindOf(Person) : true
self.oclIsTypeOf(Person) : true
self.oclIsKindOf(Student) : false
self.oclIsTypeOf(Student) : false
```

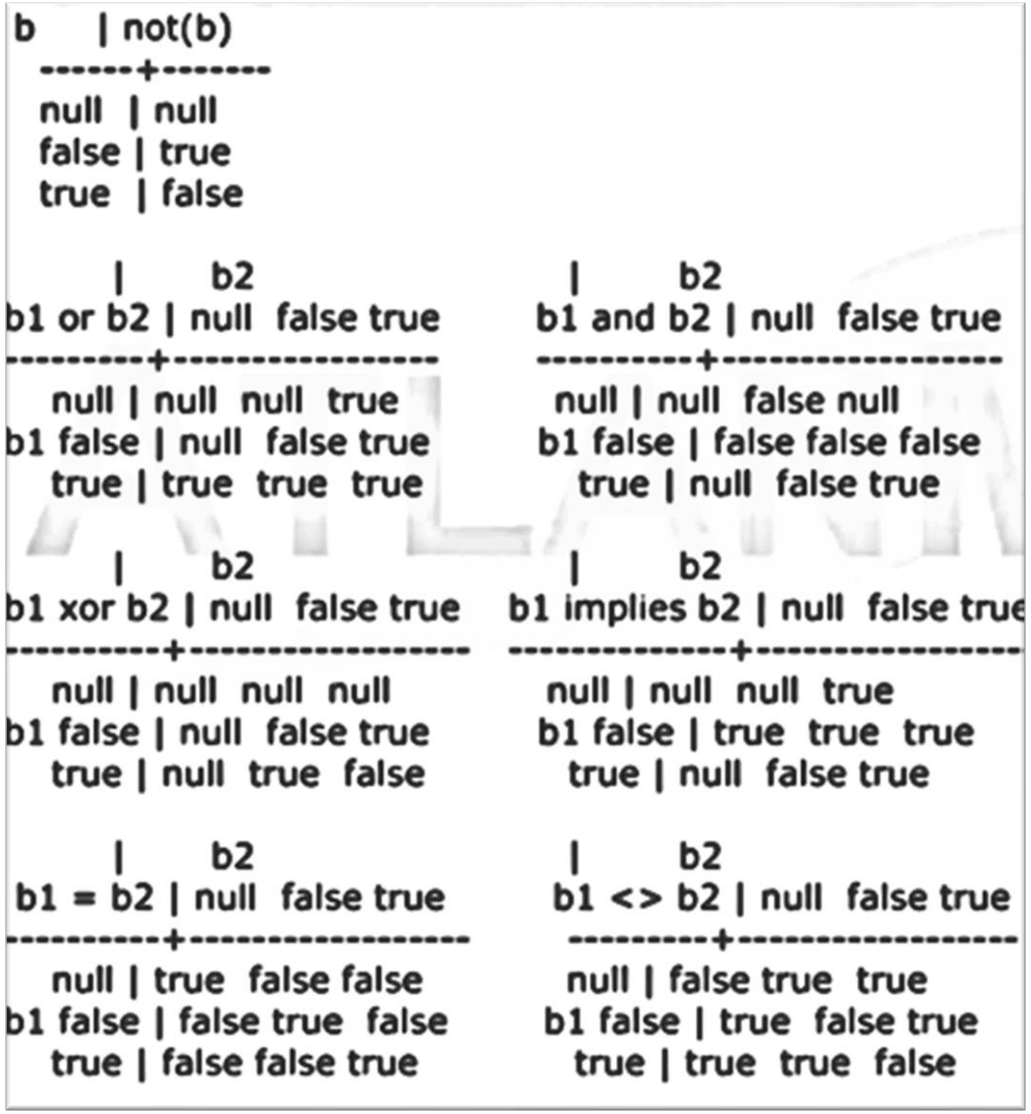


```
context Student
self.oclIsKindOf(Person) : true
self.oclIsTypeOf(Person) : false
self.oclIsKindOf(Student) : true
self.oclIsTypeOf(Student) : true
self.oclIsKindOf(Professor) : false
self.oclIsTypeOf(Professor) : false
```



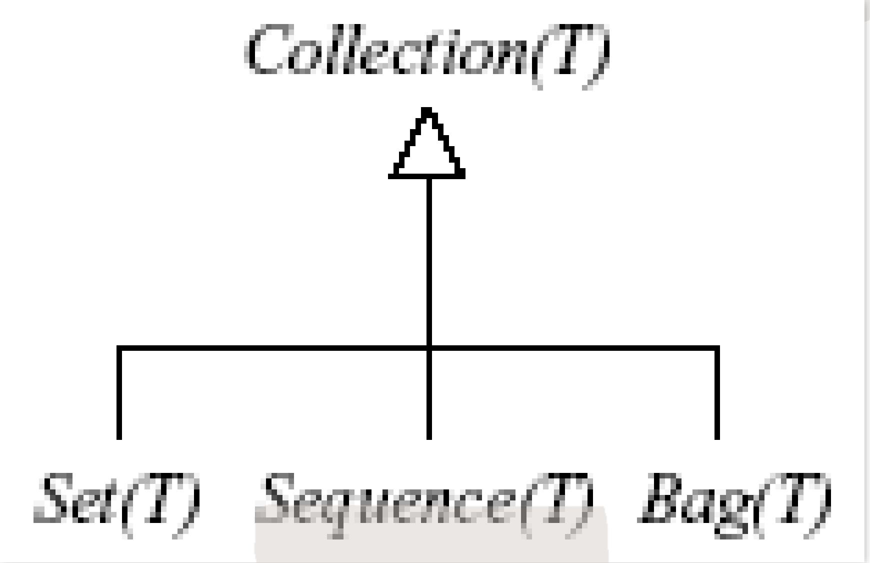
```
(1/0).oclIsUndefined=true : Boolean
42.oclIsUndefined=false : Boolean
```

Valued logic for OCL



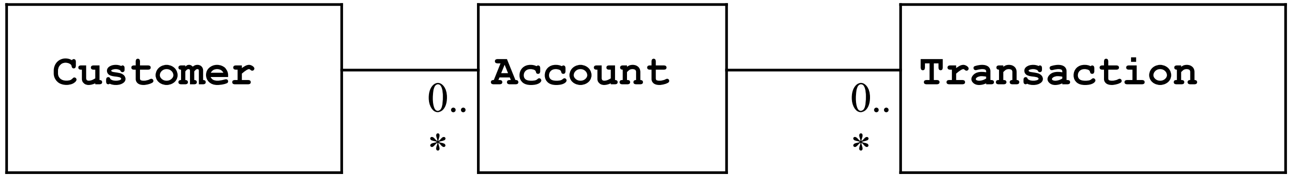
```
b      | not(b)
 ------+-------
 null  | null
 false | true
 true  | false

         |      b2                       |       b2
b1 or b2 | null  false true     b1 and b2 | null  false true
---------+----------------     ----------+-----------------
   null | null  null  true        null | null  false null
b1 false | null  false true     b1 false | false false false
   true | true  true  true         true | null  false true

          |      b2                         |       b2
b1 xor b2 | null  false true   b1 implies b2 | null  false true
----------+-----------------   --------------+----------------
   null | null  null  null        null | null  null  true
b1 false | null  false true     b1 false | true  true  true
   true | null  true  false       true | null  false true

        |      b2                        |       b2
 b1 = b2 | null  false true       b1 <> b2 | null  false true
---------+------------------      ---------+----------------
   null | true  false false        null | false true  true
b1 false | false true  false      b1 false | true  false true
   true | false false true         true | true  true  false
```

OCL Collections



- Collection is a predefined OCL type
  - Operations are defined for collections
  - They never change the original
- Three different collections:
  - Set (no duplicates)
  - Bag (duplicates allowed)
  - Sequence (ordered Bag)
  - OrderSet (ordered Set)
- With collections type, an OCL expression either states a fact about all objects in the collection or states a fact about the collection itself, e.g. the size of the collection.
- Syntax:
  - collection->operation

OCL Collections

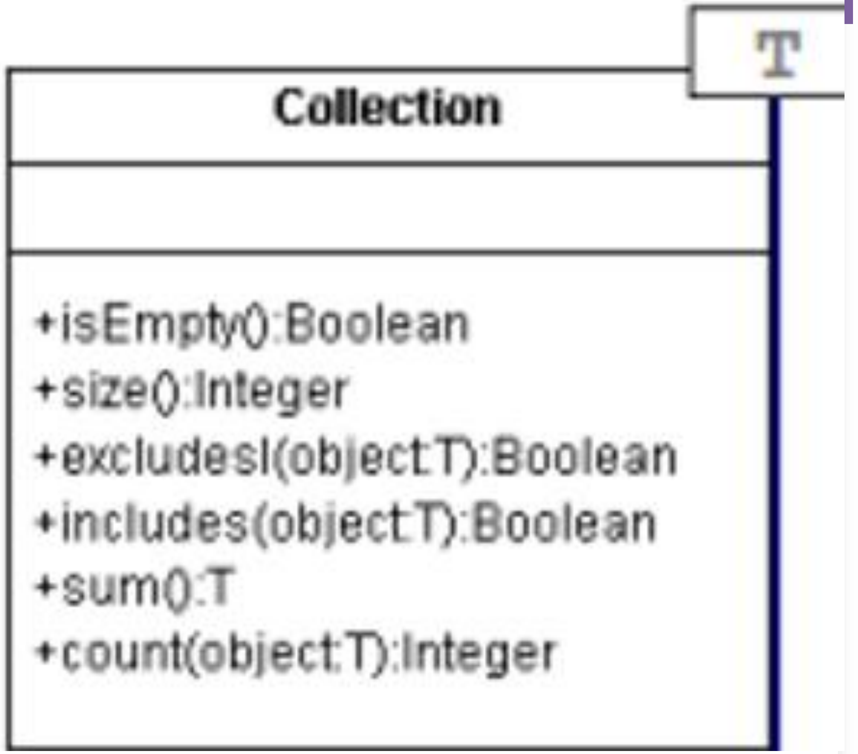


context *Customer*
`account` produces a **set** of Accounts

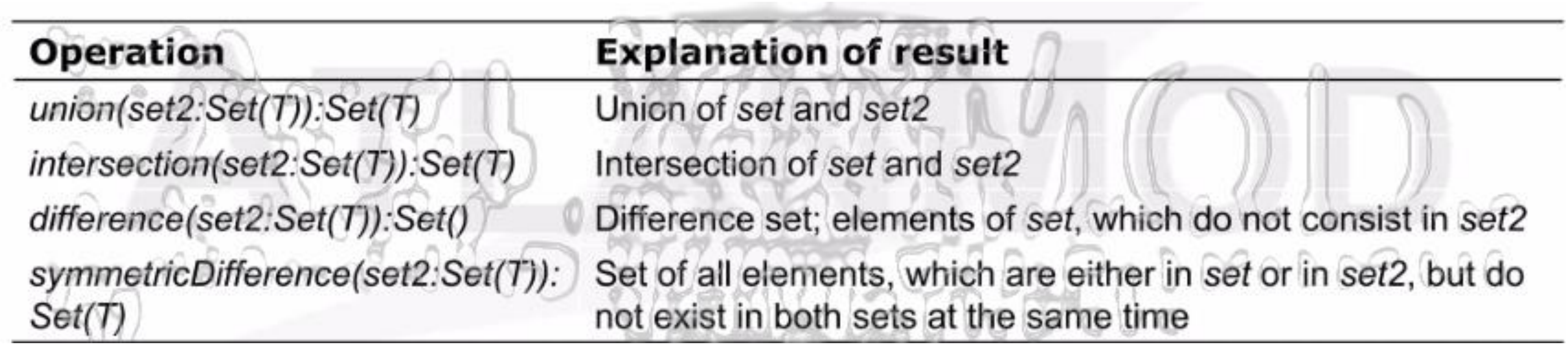
context *Customer*
`account.transaction` produces a **bag** of transactions

If we want to use this as a set we have to do the following

`account.transaction -> asset()`

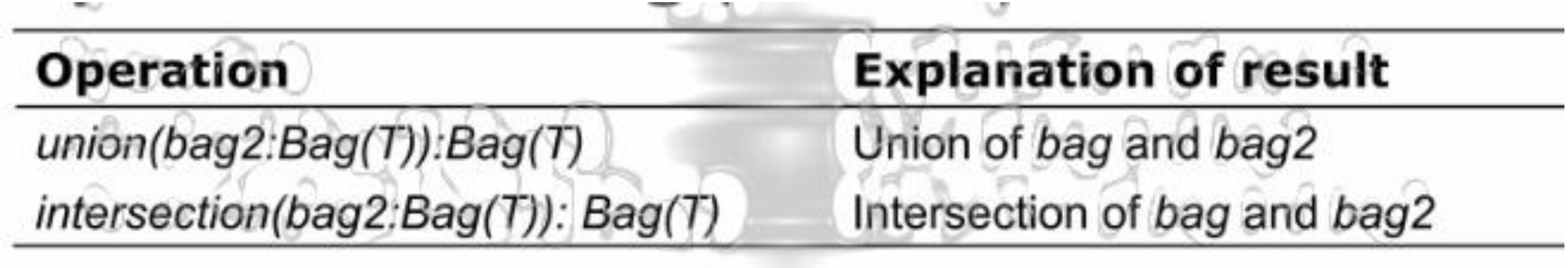


Operations of Set



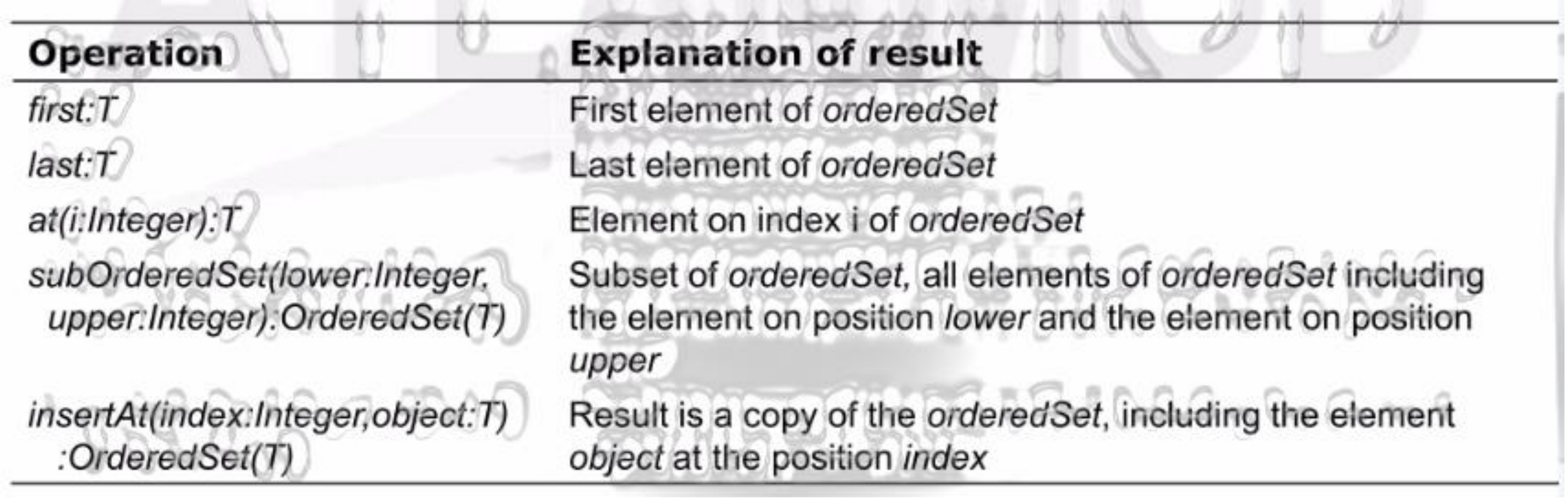
Operation	**Explanation of result**
union(set2:Set(T)):Set(T)	Union of *set* and *set2*
intersection(set2:Set(T)):Set(T)	Intersection of *set* and *set2*
difference(set2:Set(T)):Set()	Difference set; elements of *set*, which do not consist in *set2*
symmetricDifference(set2:Set(T)): Set(T)	Set of all elements, which are either in *set* or in *set2*, but do not exist in both sets at the same time

Operations of Bag



Operation	**Explanation of result**
union(bag2:Bag(T)):Bag(T)	Union of *bag* and *bag2*
intersection(bag2:Bag(T)): Bag(T)	Intersection of *bag* and *bag2*

Operations of Orderset/Sequence



Operation	**Explanation of result**
first:T	First element of *orderedSet*
last:T	Last element of *orderedSet*
at(i:Integer):T	Element on index i of *orderedSet*
subOrderedSet(lower:Integer, upper:Integer):OrderedSet(T)	Subset of *orderedSet*, all elements of *orderedSet* including the element on position *lower* and the element on position *upper*
insertAt(index:Integer,object:T) :OrderedSet(T)	Result is a copy of the *orderedSet*, including the element *object* at the position *index*

Collection Operations

- 22 operations with variant meaning depending on the collection type such as:

1. equals (=) and not equals operation (<>)
2. Transformations (asBag(), asSet(), asOrderedSet(), asSequence())
3. including(object) and excluding(object)
4. flatten() for example Set{Bag{1,2,2},Bag{2}} asSet{1,2}

Note: If we have two bags Bag{1,2,2} and Bag{2}

- Set{Bag{1,2,2}, Bag{2}}->flatten()

  Result **Bag{1,2,2,2}**

- Set{Bag{1,2,2}, Bag{2}}->flatten()->asSet()

  Result **Set{1,2}**

Collection Operations

<collection> → size
→ isEmpty
→ notEmpty
→ sum ( )
→ count (object)
→ excludes (object)
→ includes (object)
→ includesAll (collection)

<collection> → select (e:T | <b.e.>)
→ reject (e:T | <b.e.>)
→ collect (e:T | <v.e.>)
→ forAll (e:T* | <b.e.>)
→ exists (e:T | <b.e.>)
→ iterate (e:T_1; r:T_2 = <v.e.> | <v.e.>)

b.e. stands for: boolean expression

v.e. stands for: value expression

Examples

- Select (select or ->select): Returns a collection containing the elements that satisfy a specified condition.

```
context Library
inv: books->select(b | b.available =
false)->isEmpty()
```

This OCL expression checks if there are no unavailable books in the library

Examples

Collect (collect or ->collect): Applies a transformation to each element of a collection, producing a new collection.

```
context ShoppingCart
inv: items->collect(i | i.product.price *
i.quantity)->sum() <= user.balance
```

This OCL expression calculates the total cost of items in the shopping cart and checks if it's within the user's balance.

Examples

Reject (reject or ->reject): Returns a collection containing the elements that do not satisfy a specified condition.

```
context TaskList
inv: tasks->reject(t | t.completed)->isEmpty()
```

This OCL expression checks if there are no incomplete tasks in the task list.

Examples

ForAll Checks if a condition is true for all elements in a collection.

```
context ShoppingCart
inv: items->forAll(i | i.quantity > 0)
```

This OCL expression ensures that the quantity of each item in the shopping cart is greater than zero.

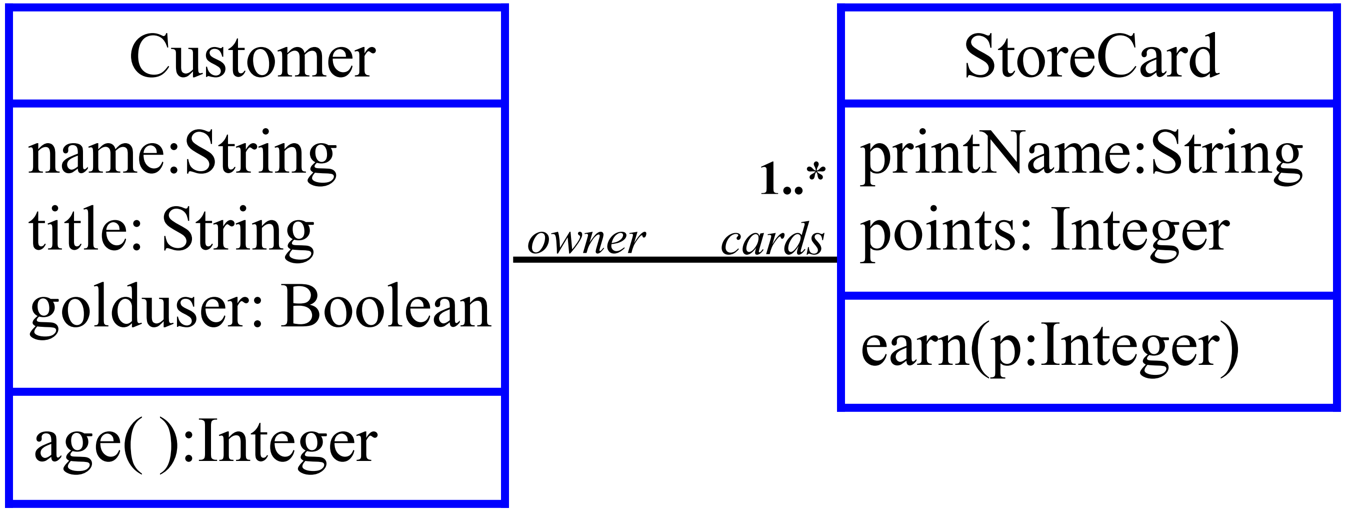
Examples

Exists checks if there is at least one element in a collection that satisfies a specified condition.

```
context Library
inv: books->exists(b | b.popularity > 100)
```

This OCL expression checks if there is at least one book in the library with a popularity score greater than 100.

Changing the context



Customer

name:String
title: String
goldUser: Boolean

age( ):Integer

owner

1..*

cards

StoreCard

printName:String
points: Integer

earn(p:Integer)

context *StoreCard*

invariant: *printName* = *owner.title.concat*(*owner.name*)

context *Customer*

cards → *forAll* (

printName = *owner.title.concat*(*owner.name*))

Note switch of context!

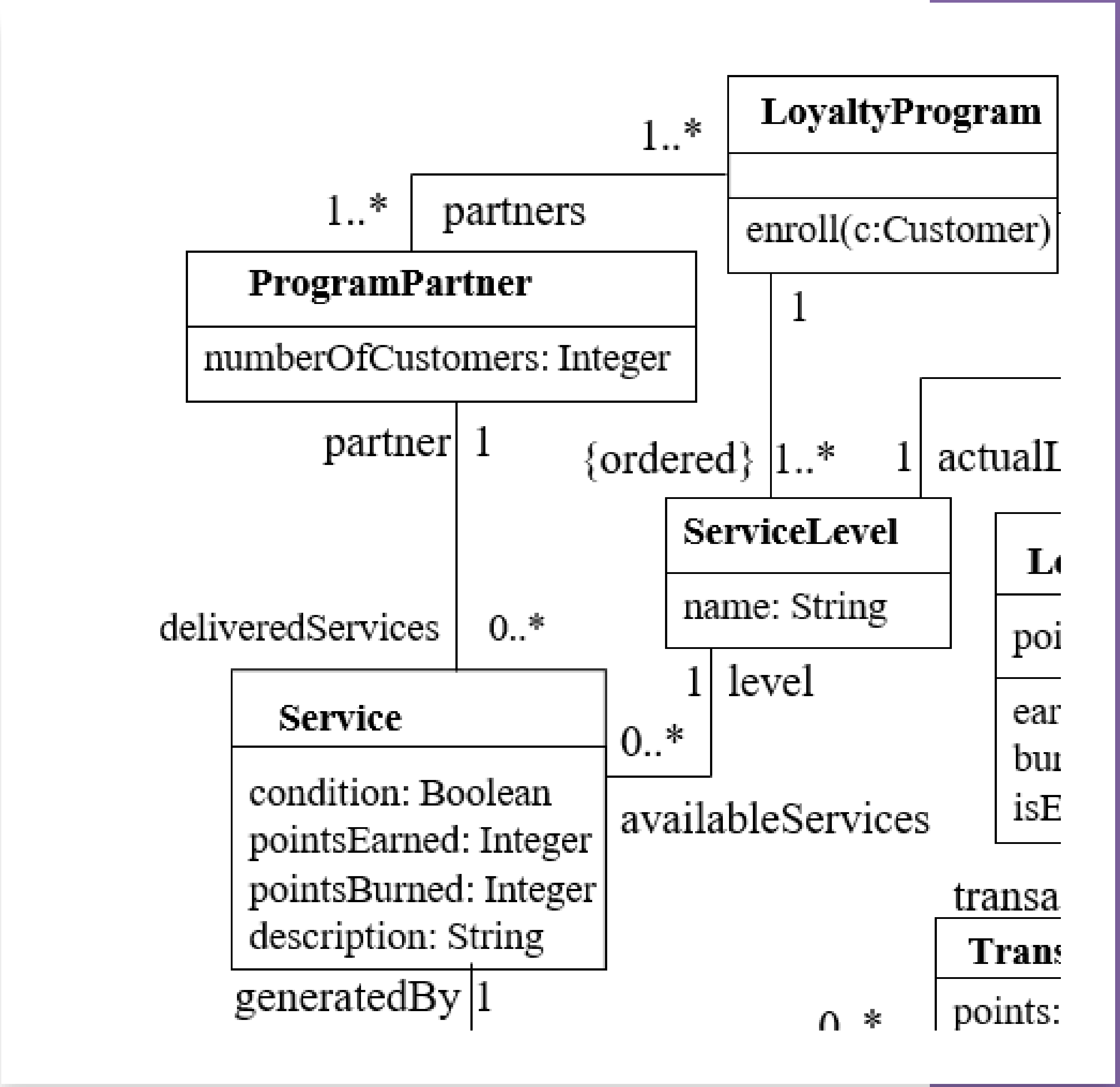
Example

“The partners of a loyalty program have at least one delivered service”:

- **context** *LoyaltyProgram*
- **invariant** minServices**:** *partners.deliveredservices->size*() >= 1

“The number of a customer’s programs is equal to that of his/her valid cards”:

- **context** *Customer*
- **invariant** sizesAgree**:** *Programs->size*() = *cards->select*(*valid=true*)*->size*()



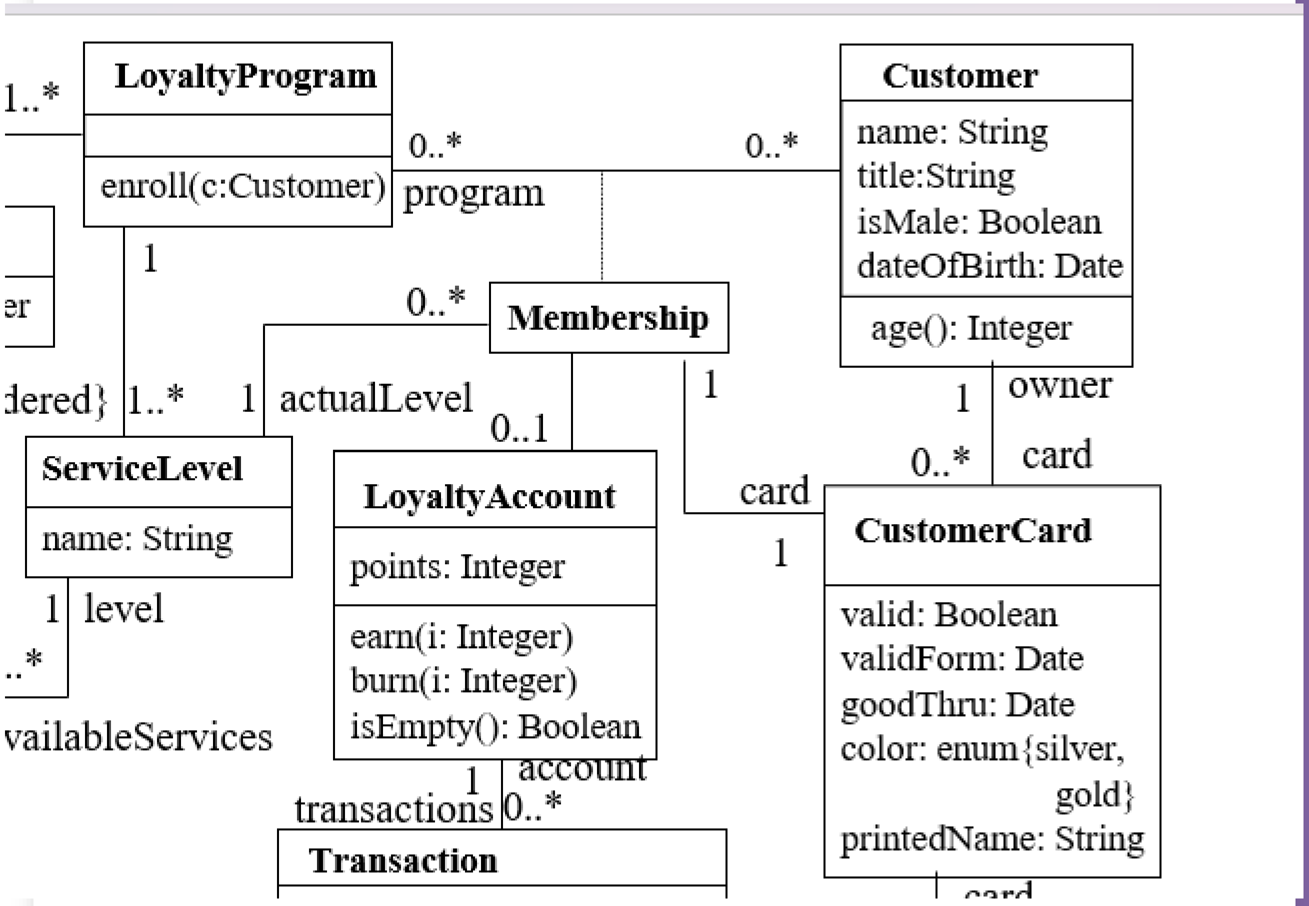
Example

“The partners of a loyalty program have at least one delivered service”:

- **context** *LoyaltyProgram*
- **invariant** minServices**:** *partners.deliveredservices->size*() >= 1

“The number of a customer’s programs is equal to that of his/her valid cards”:

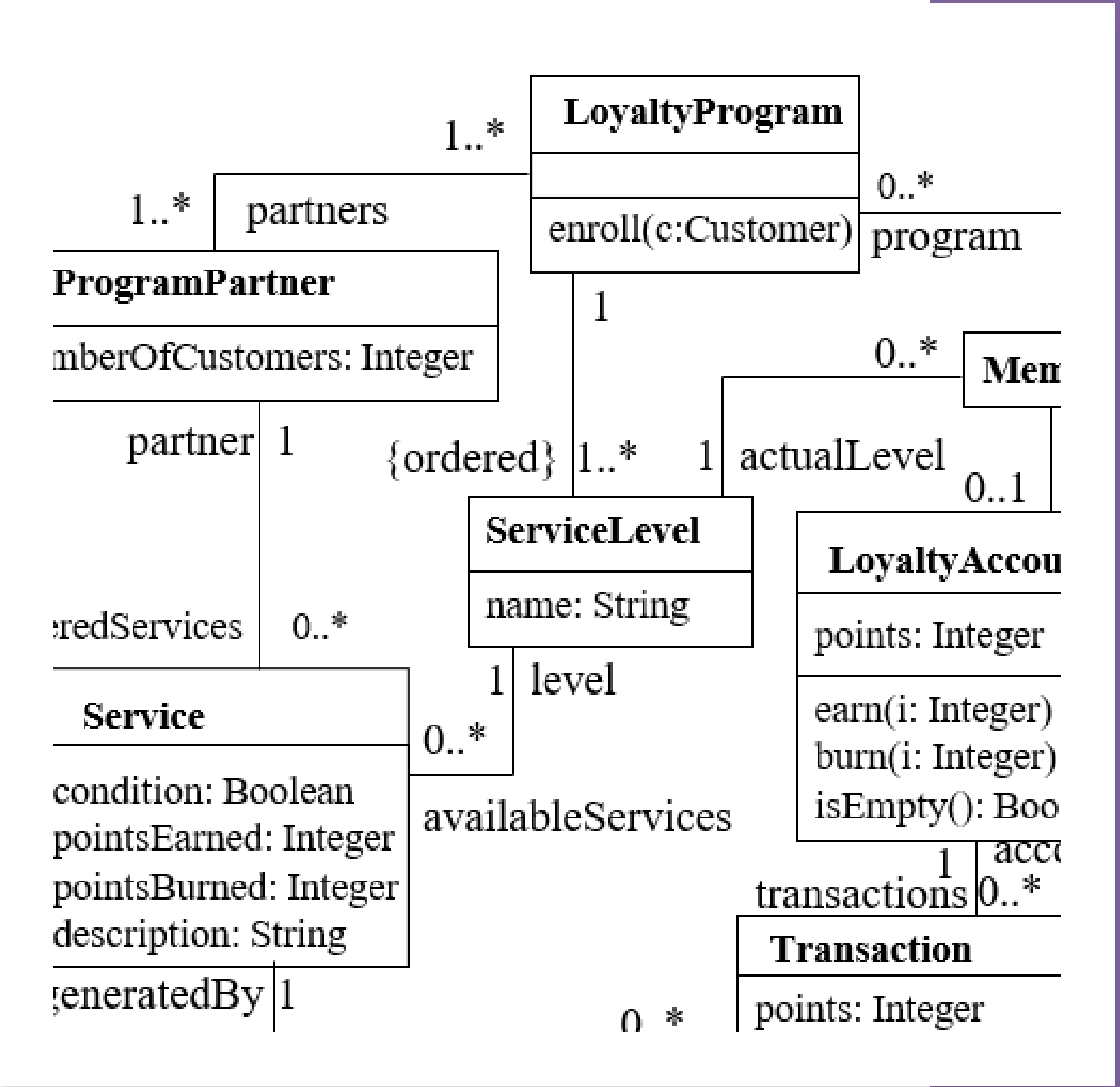
- **context** *Customer*
- **invariant** sizesAgree**:** *Programs->size*() = *cards->select*(*valid=true*)*->size*()



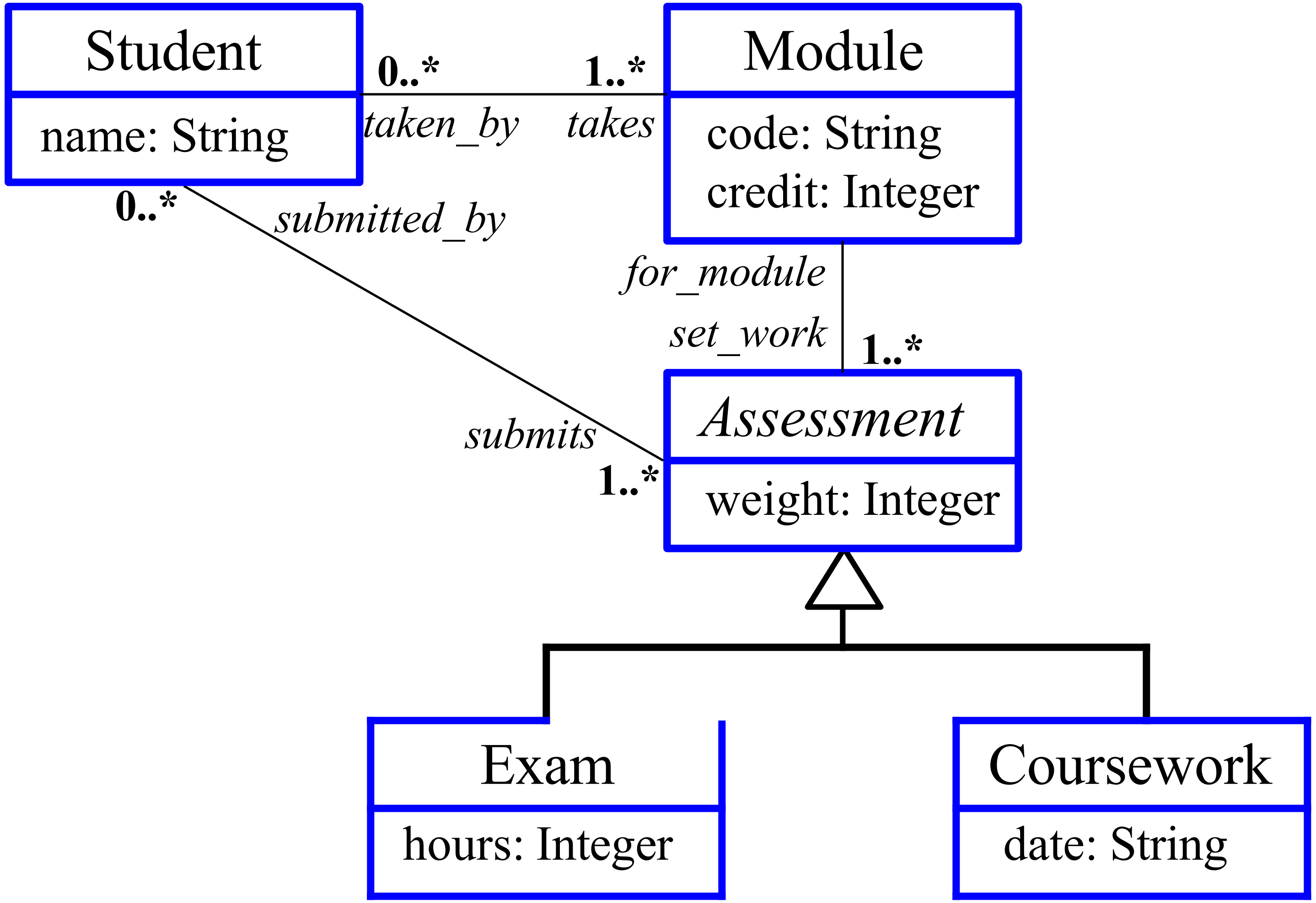
Example

“When a loyalty program does not offer the possibility to earn or burn points, the members of the loyalty program do not have loyalty accounts. That is, the loyalty accounts associated with the Memberships must be empty”:

-
  ```
  context LoyaltyProgram invariant
  noAccounts:
  partners.deliveredservices->
  forAll(pointsEarned = 0 and
  pointsBurned = 0) implies
  Membership.account->isEmpty()
  ```



Example UML diagram



Constraints

a) Modules can be taken iff they have more than seven students registered

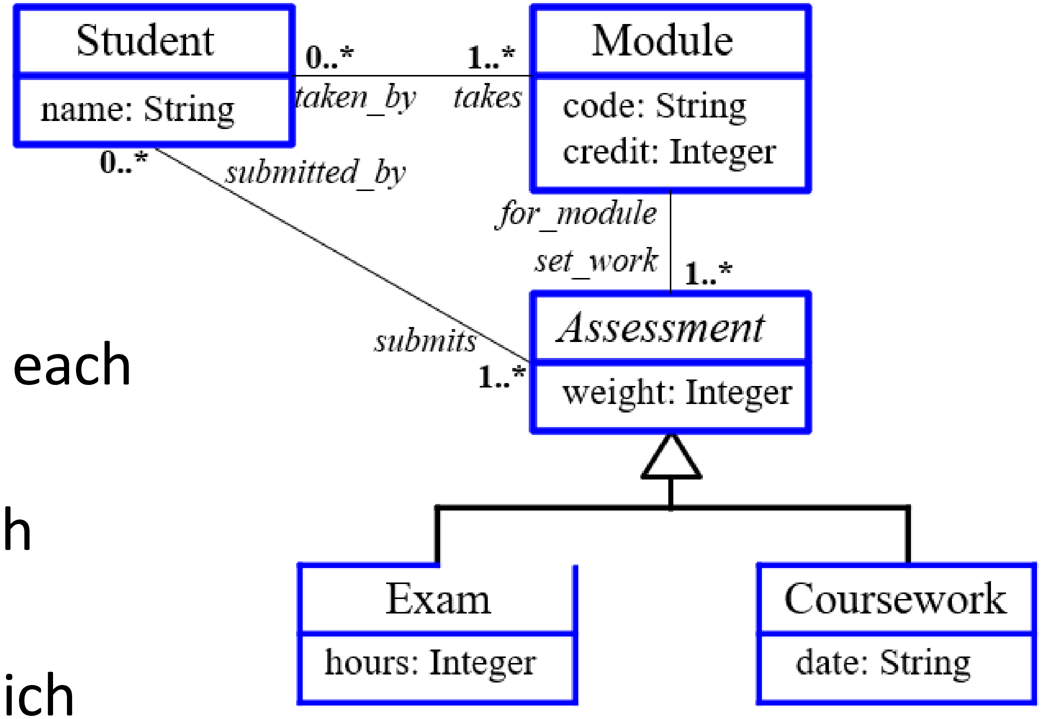
b) The assessments for a module must total 100%

c) Students must register for 120 credits each year

d) Students must take at least 90 credits of CS modules each year

e) All modules must have at least one assessment worth over 50%

f) Students can only have assessments for modules which they are taking



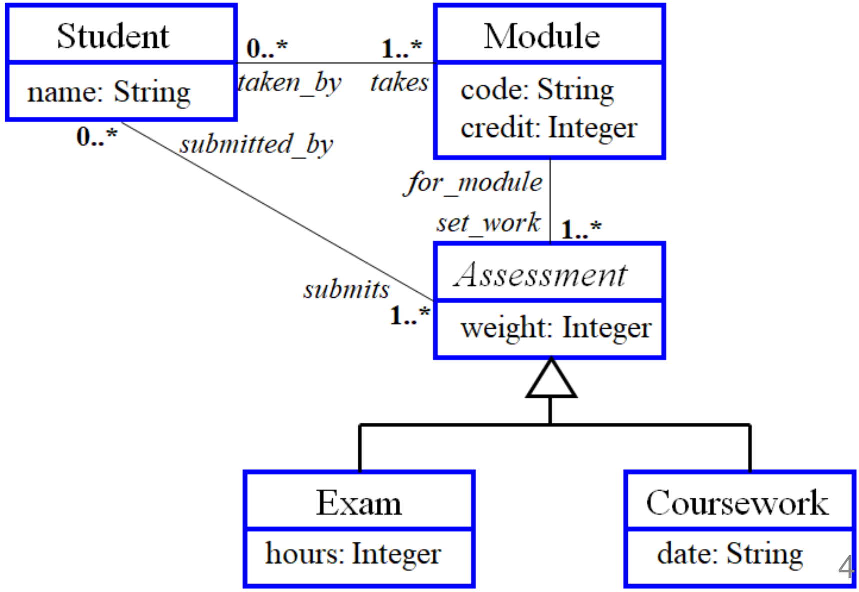
Constraint (a)

a) Modules can be taken iff they have more than seven students registered

Note: when should such a constraint be imposed?

context *Module*

invariant: *taken_by→size() > 7*



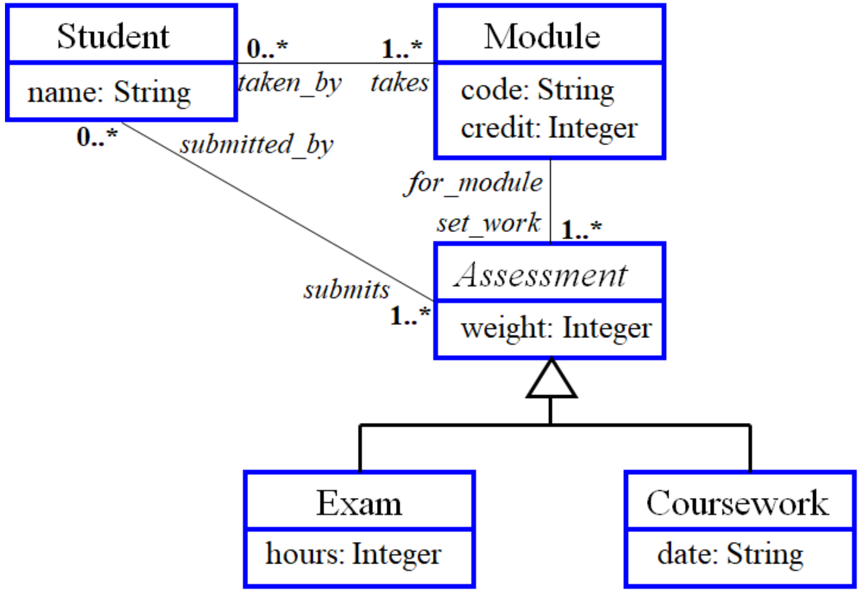
Constraint (b)

b) The assessments for a module must total 100%

context *Module*

invariant:

set_work.weight→sum( ) = 100

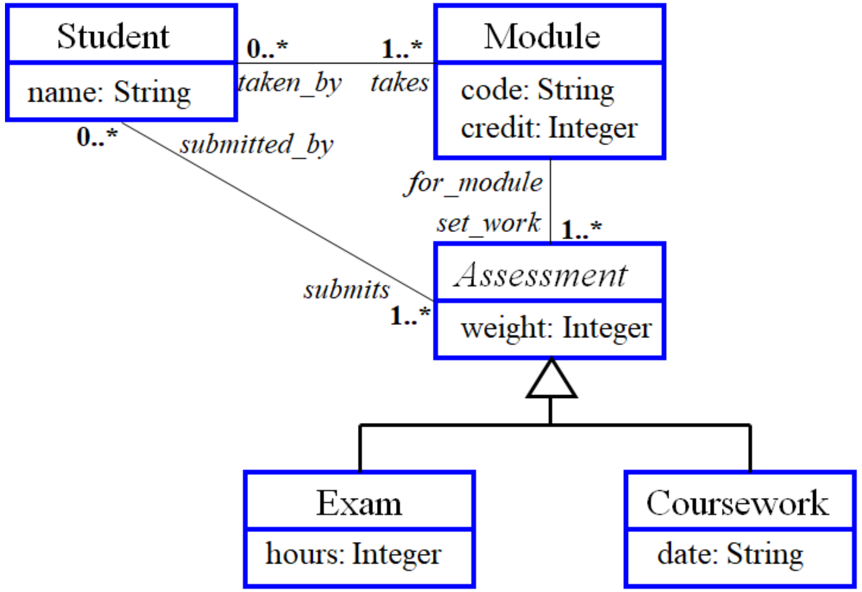


Constraint (c)

c) Students must register for 120 credits each year

context *Student*

invariant: *takes.credit*⟶*sum( ) = 120*



Constraint (d)

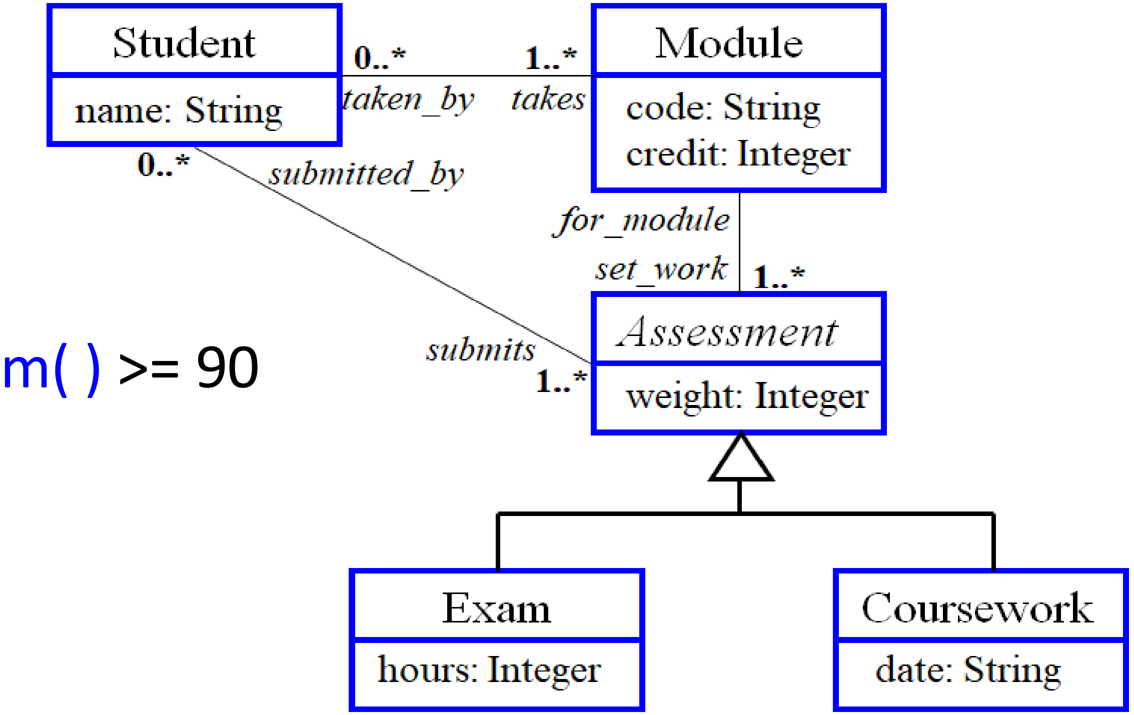
d) Students must take at least 90 credits of CS modules each year

context *Student*

invariant:

takes →

select(*code.substring*(*1,2*) = ‘*CS*’).credit→sum( ) >= 90

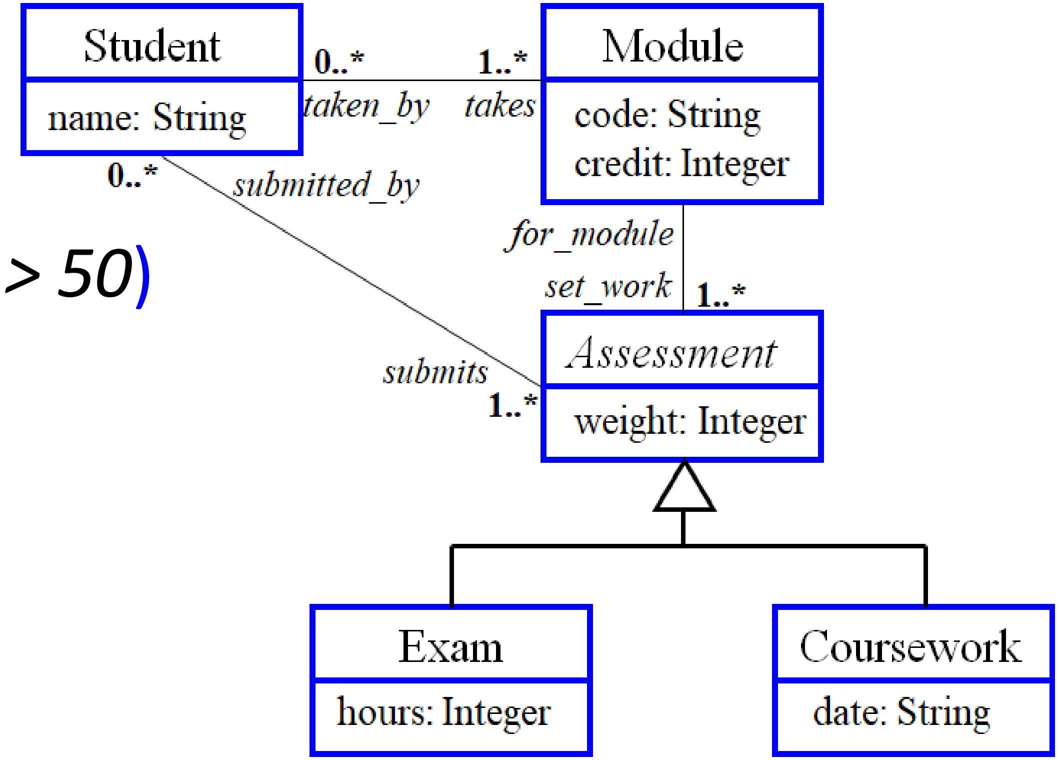


Constraint (e)

e) All modules must have at least one assessment worth over 50%

context *Module*

invariant: *set_work*→*exists*(*weight > 50*)

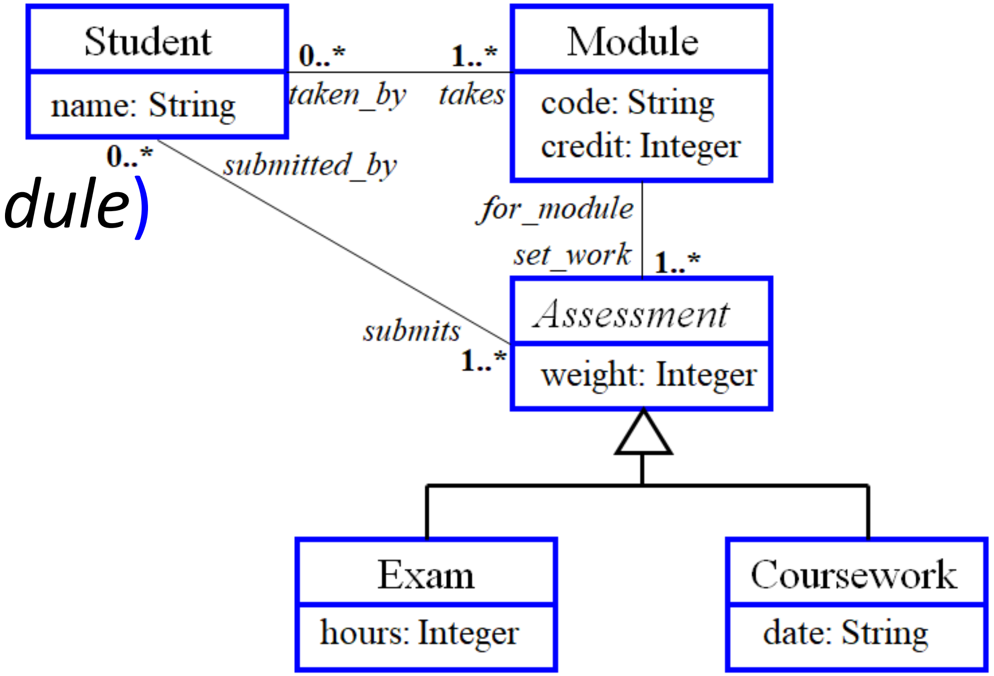


Constraint (f)

f) Students can only have assessments for modules which they are taking

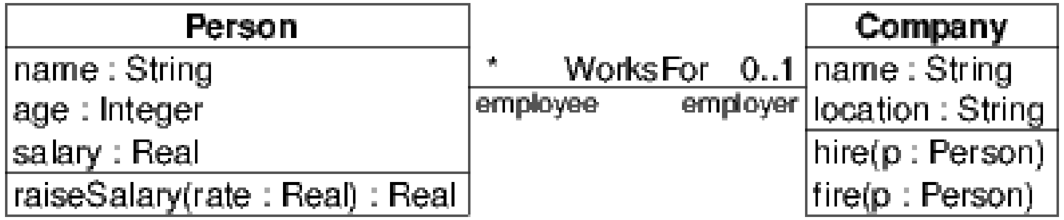
context *Student*

invariant: *takes*→*includesAll*(*submits.for_module*)



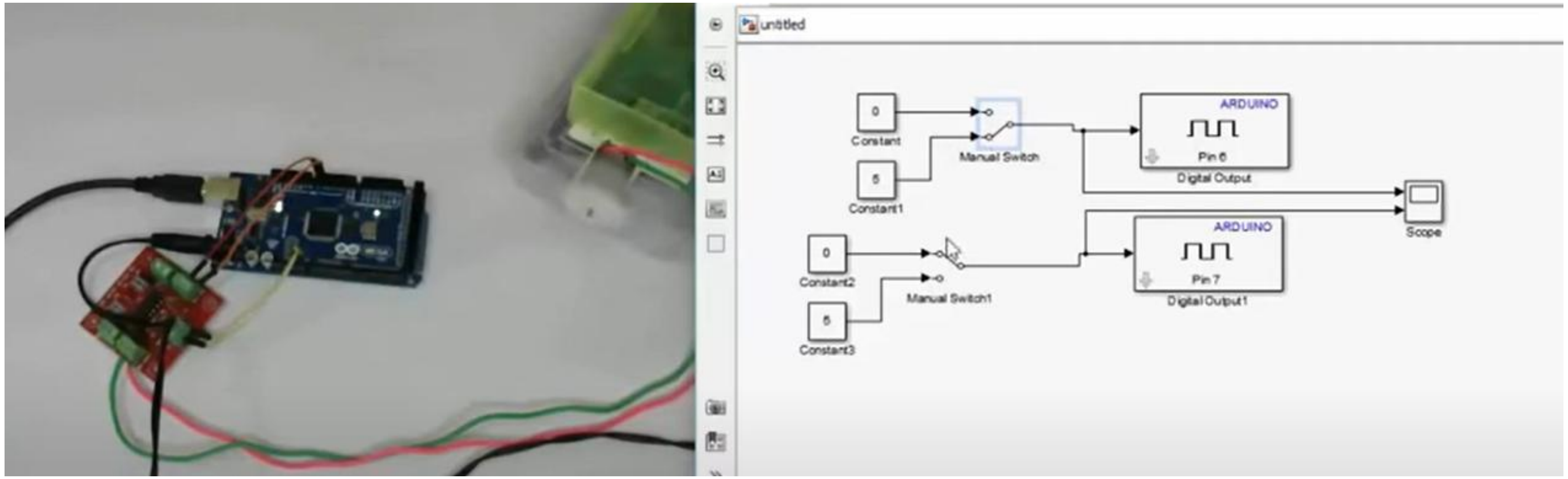
Pre, Post Conditions

```
context Company::hire(p : Person)
  pre  hirePre1: p.isDefined()
  pre  hirePre2: employee->excludes(p)
  post hirePost: employee->includes(p)

context Company::fire(p : Person)
  pre  firePre:  employee->includes(p)
  post firePost: employee->excludes(p)
```



THANK YOU!

Simulink


untitled
0
Constant
5
Constant1
Manual Switch
ARDUINO
Pin 6
Digital Output
Scope
0
Constant2
5
Constant3
Manual Switch1
ARDUINO
Pin 7
Digital Output1