2017-2018

POLYTECH PARIS-SUD

Cycle Ingénieur – 2ème année

Département Informatique

Verification and Validation

Part III : Formal Specification with UML/MOAL

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Plan of the Chapter

- Syntax & Semantics of our own language

  MOAL

  - mathematical
  - object-oriented
  - UML-annotation
  - language

  (conceived as the „essence" of annotation languages like OCL, JML, Spec#, ACSL, ...)

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- Concepts of MOAL
  - Basis: Logic and Set-theory
  - MOAL is a Typed Language
  - Basic Types, Sets, Pairs and Lists
  - Object Types from UML
  - Navigation along UML attributes and associations (Idea from OCL and JML)
- Purpose :
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  - Method Contracts with Pre- and Post-Conditions
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- Ultimate Goal:
  Specify system components to improve analysis, design, test and verification activities
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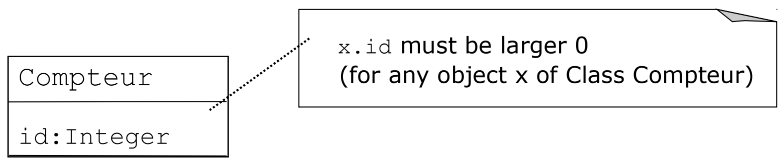
- More precision needed
  (like JML, VCC) that constrains an underlying state σ



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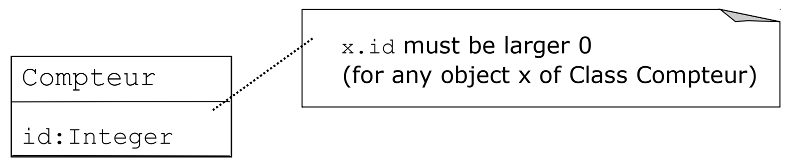

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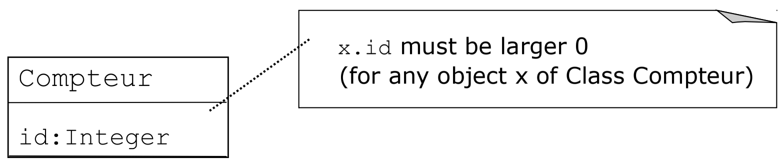

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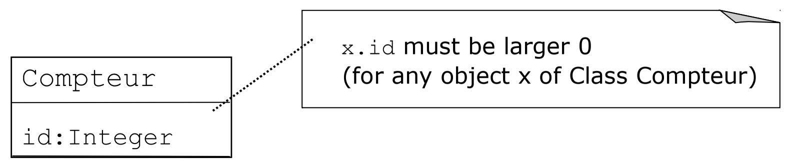

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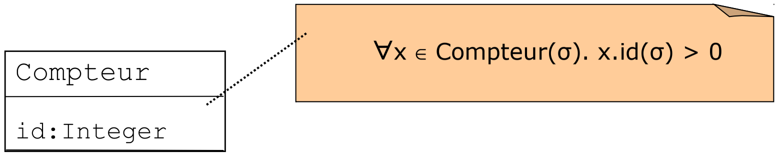

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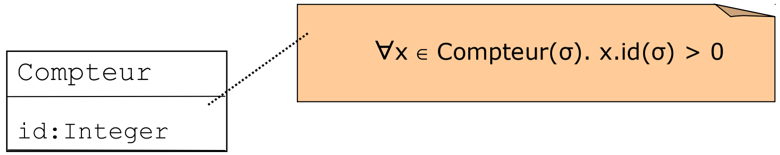

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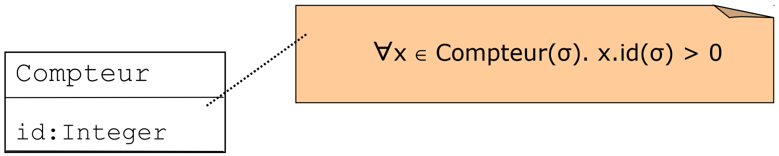

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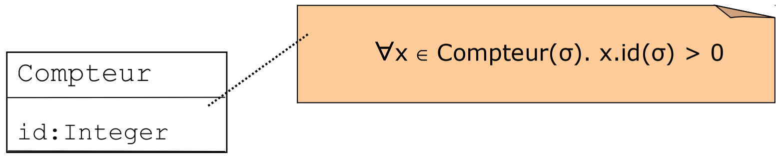

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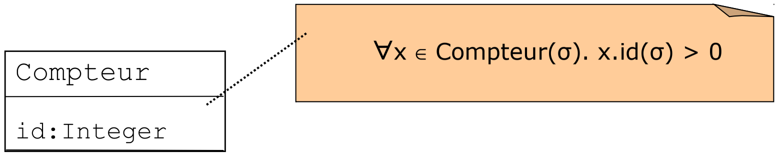

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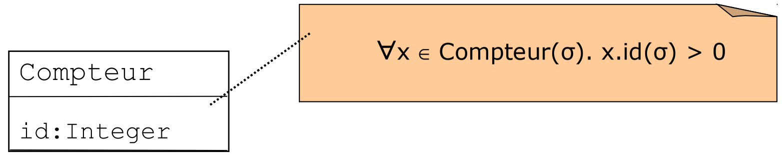

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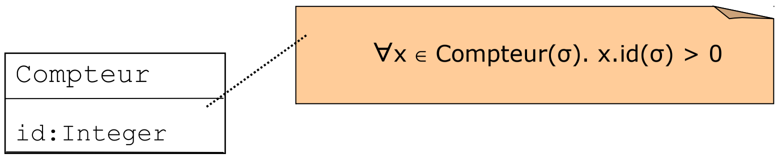

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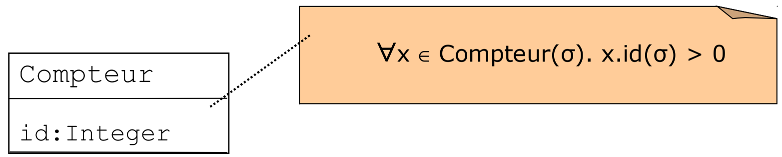

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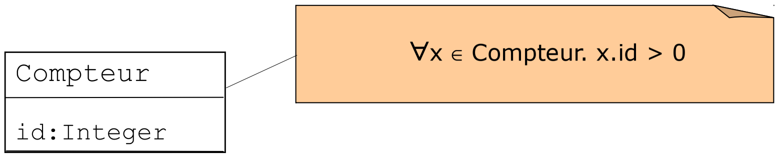

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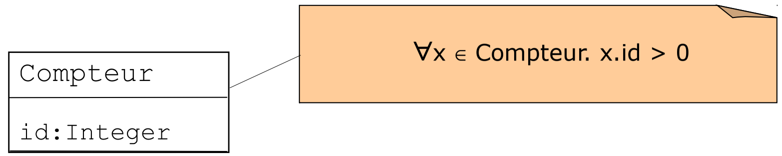

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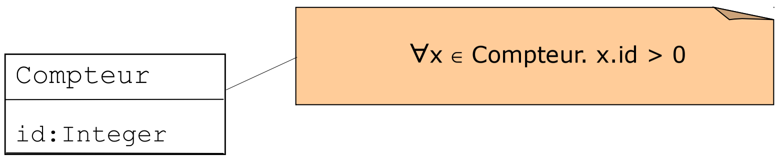

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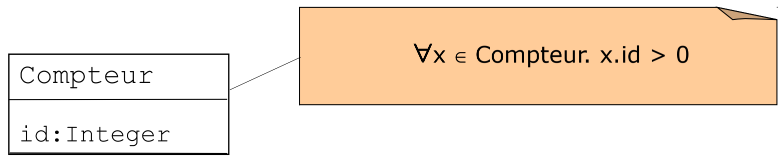

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Compteur
id:Integer

definition $inv_{Compteur}(\sigma) \equiv \forall x \in Compteur(\sigma).\ x.id(\sigma) > 0$

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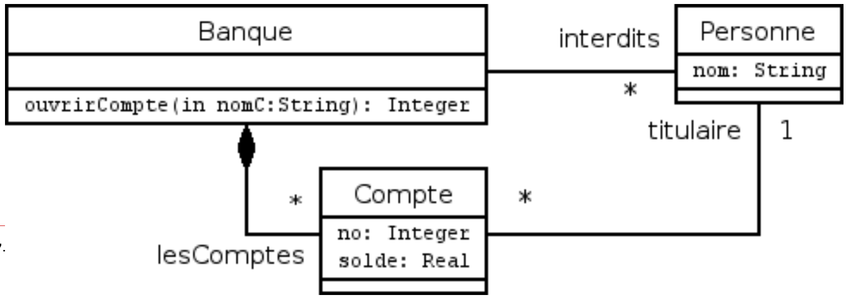
A first Glance to an Example: Bank

Opening a bank account. Constraints:

- there is a blacklist
- no more overdraft than 200 EUR
- there is a present of 15 euros in the initial account
- account numbers must be distinct.



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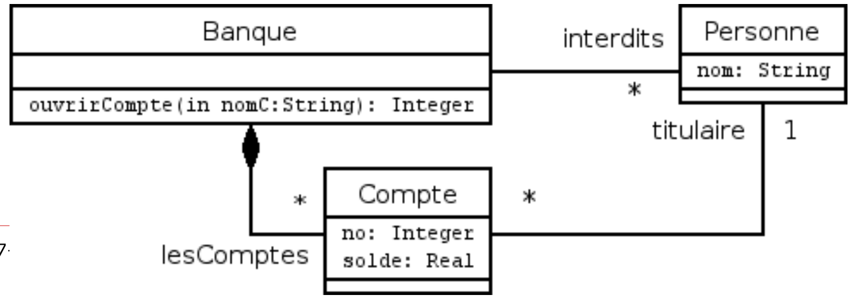

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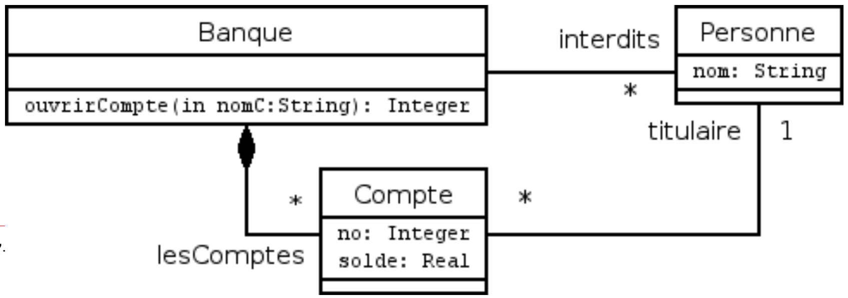

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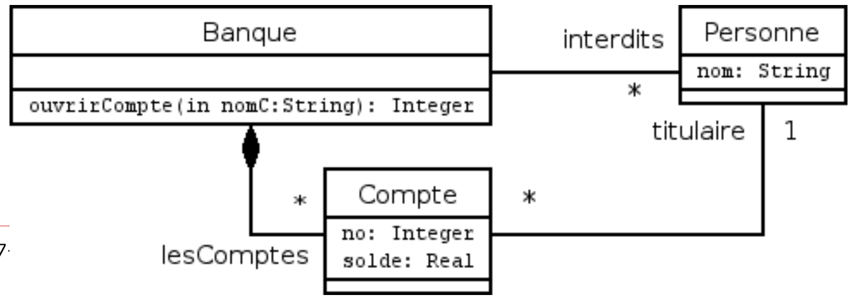

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A first Glance to an Example: Bank (2)

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definition unique ≡ isUnique(.no)(Compte)
definition noOverdraft ≡ ∀c ∊ Compte. c.id ≥ -200

definition pre_ouvrirCompte(b:Banque, nomC:String)≡
                      ∀p ∊ Personne. p.nom ≠ nomC

definition post_ouvrirCompte(b:Banque,nomC:String,r::Integer)≡
     |{p ∊ Personne | p.nom = nomC ∧ isNew(p)}|  = 1
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Syntax and Semantics of MOAL

- The usual logical language:
  - True, False
  - negation : $\neg E$,
  - or: $E \lor E'$, and: $E \land E'$, implies: $E \longrightarrow E'$
  - $E = E'$, $E \neq E'$,
  - if C then E else E' endif
  - let x = E in E′
  - Quantifiers on sets and lists:

    ∀x ∈ Set. P(x)   ∃x ∈ Set. P(x)

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Syntax and Semantics of MOAL

- The arithmetic core language.
  expressions of type `Integer` or `Real`:
  - `1,2,3 ...   resp. 1.0, 2.3, pi.`
  - `- E, E + E',`
  - `E * E', E / E',`
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Syntax and Semantics of MOAL Sets

- | S | size as Integer
- isUnique(*f*)(S) ≡ ∀x,y ∈ S. f(x)=f(y)⟶ x=y
- {}, {a,b,c} *empty and finite sets*
- e∈S, e∉S is element, not element
- S⊆ S' is subset
- {x ∈ S | P(S)} filter
- S ∪ S',S ∩ S' union , intersect between sets of same type
-
- Integer, Real, String ... are symbols for the set of all Integers,Reals, ...

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Lists *S* have the following operations:

- x ∈ L -- is element (overload!)
- |S| -- length as Integer
- head(L),last(L)
- *nth*(L,*i*) -- for i between 0 et |S|-1
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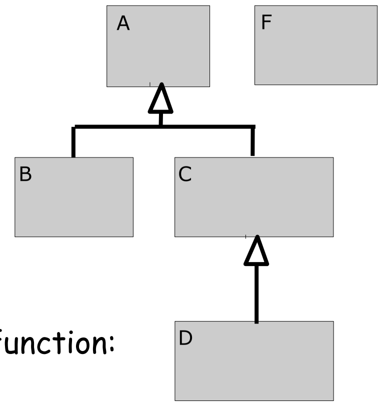
Syntax and Semantics of Objects

- Objects and Classes follow the semantics of UML
  - inheritance / subtyping
  - casting
  - objects have an id
  - NULL is a possible value in each class-type
  - for any class A, we assume a function:

    $A(\sigma)$

    which returns the set of objects of class A in state σ (the « instances » in σ).



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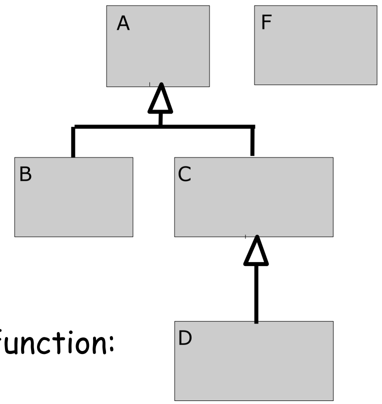

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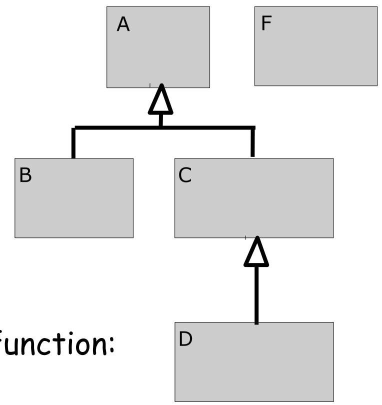

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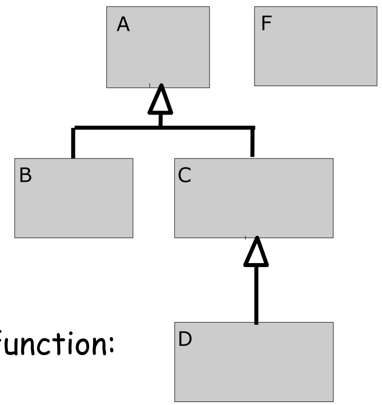

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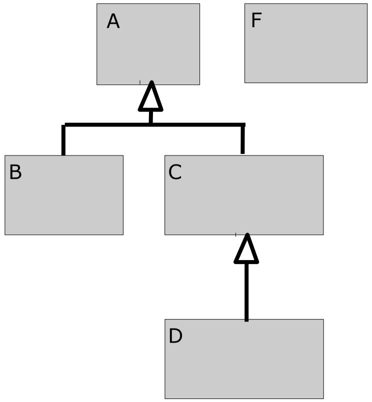

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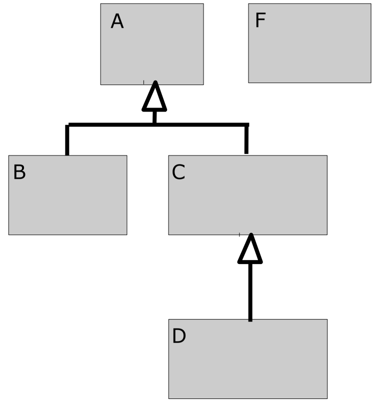

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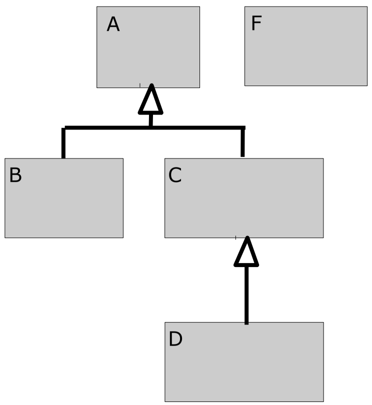

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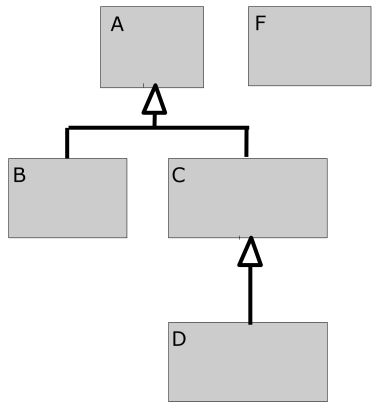

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- As in all typed object-oriented languages casting allows for converting objects.
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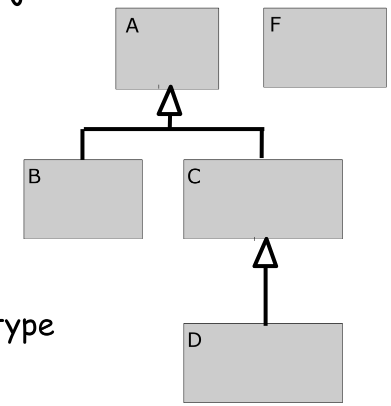

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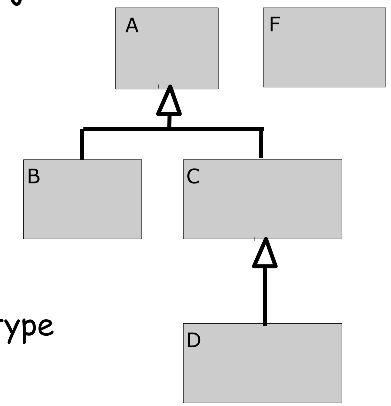

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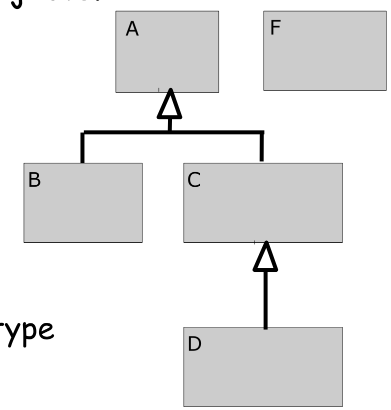

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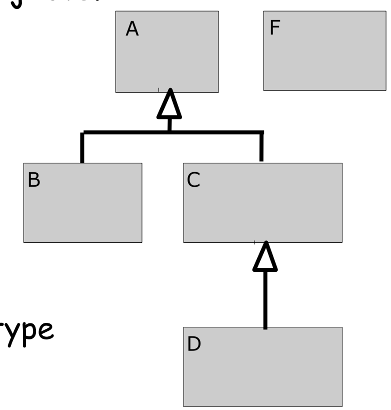

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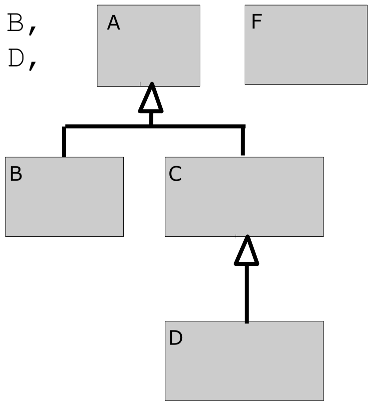

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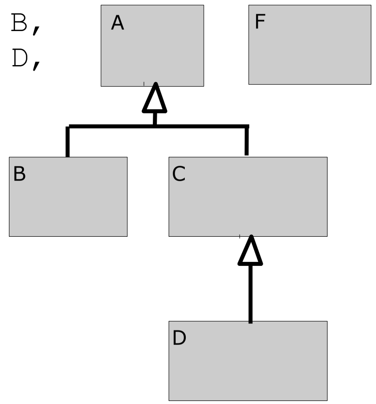

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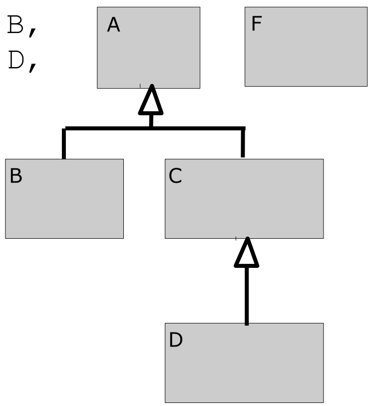

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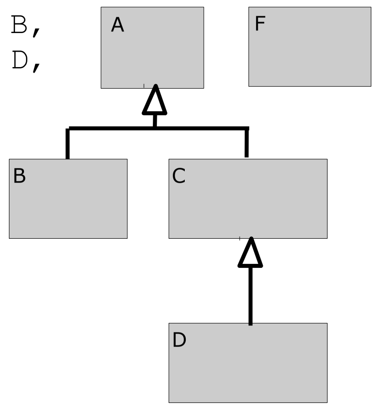

Syntax and Semantics of OCL / UML

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  $\langle A\rangle B(\sigma)$ (or just: $\langle A\rangle B$) is the set of instances of B casted to A.

  We have:

  $\langle A\rangle B \cup \langle A\rangle C \subseteq A$

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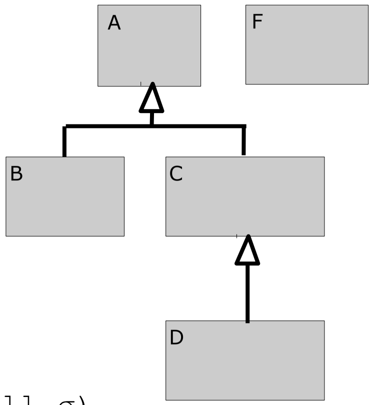

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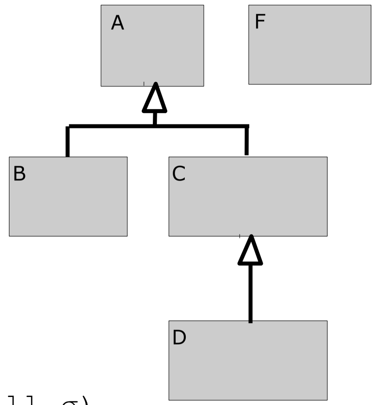

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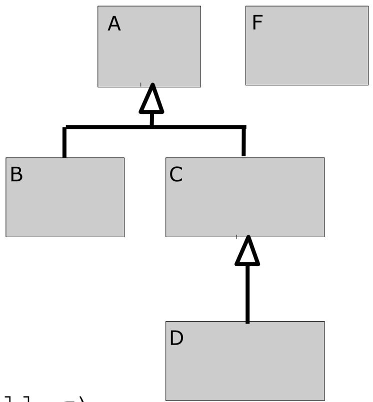

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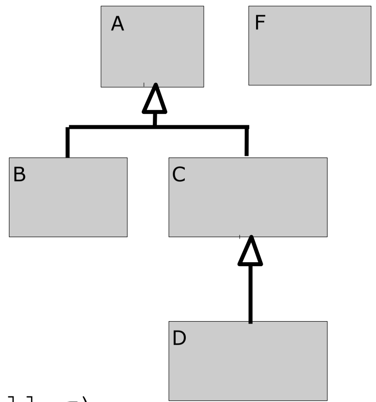

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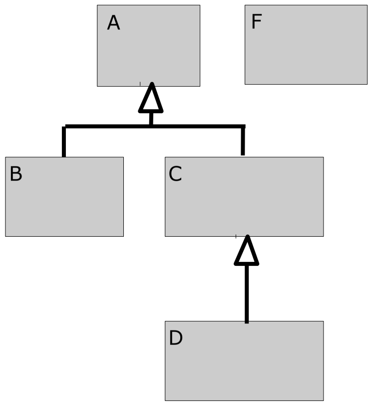

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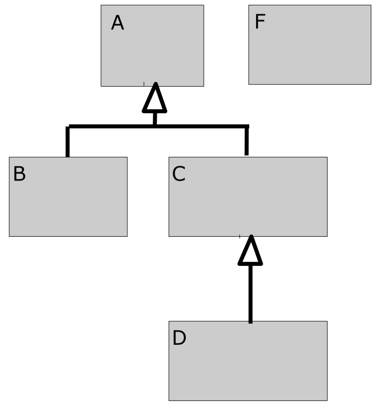

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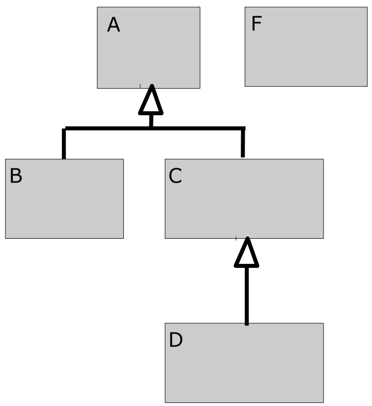

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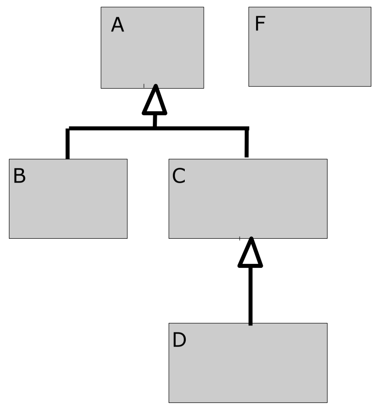

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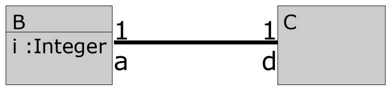

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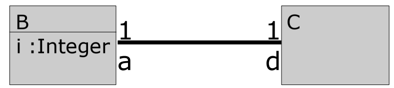

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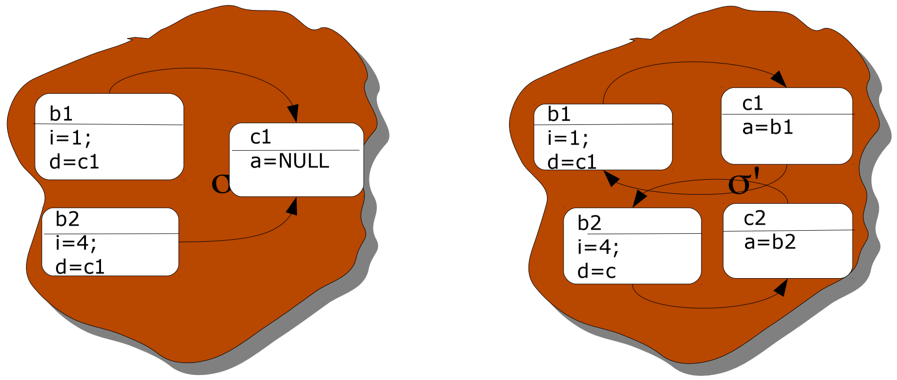

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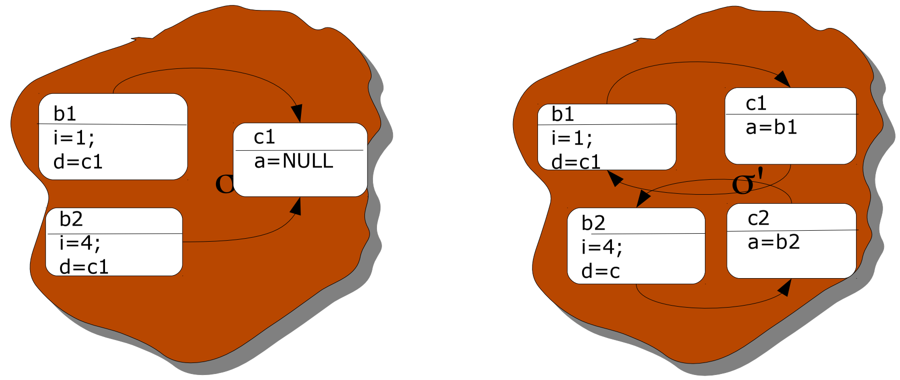

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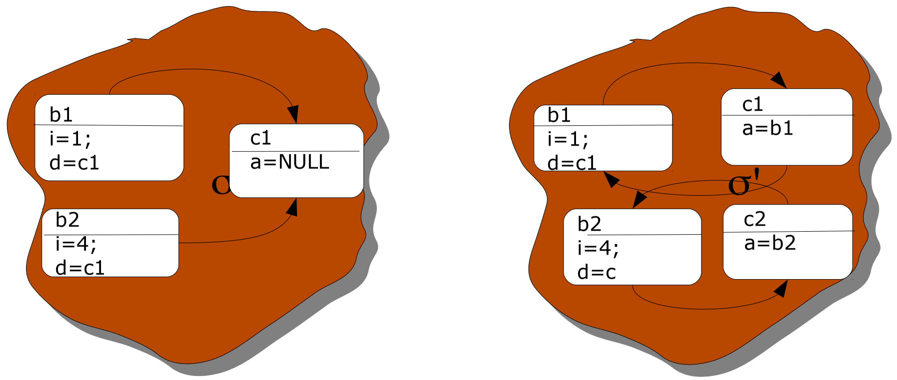

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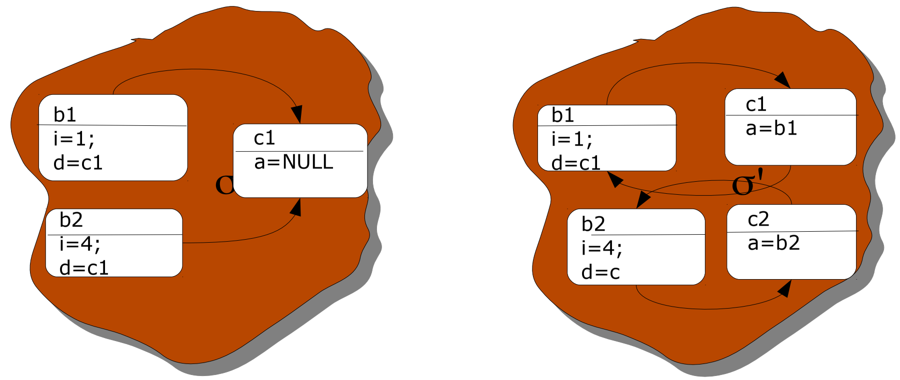

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- each attribute is represen-ted by a function in MOAL. The class diagram right corresponds to delaration of accessor functions:

  .i(σ) :: B -> Integer
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  .d(σ) :: B -> C

- Applying the σ-convention, this makes navigation expressions possible:
  - b1.d :: C
    c1.a :: B   b1.d.a.d.a ...

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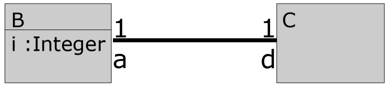

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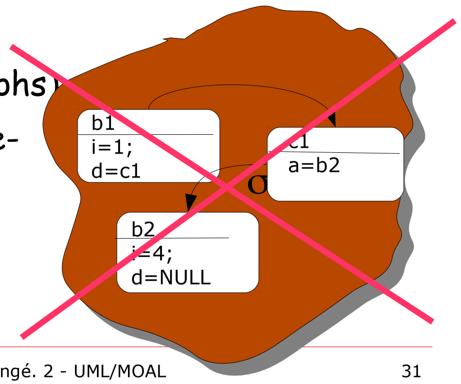

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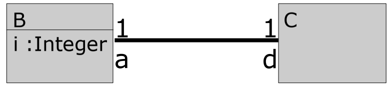

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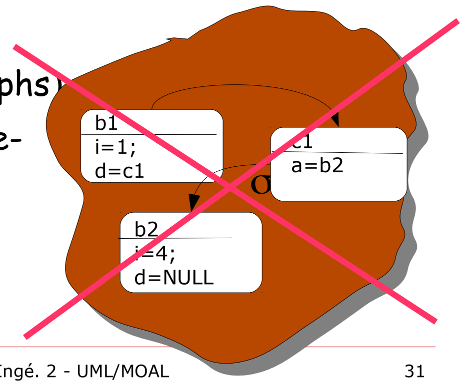

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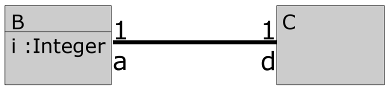

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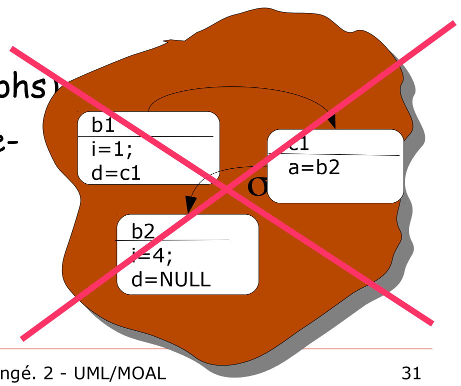

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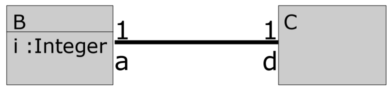

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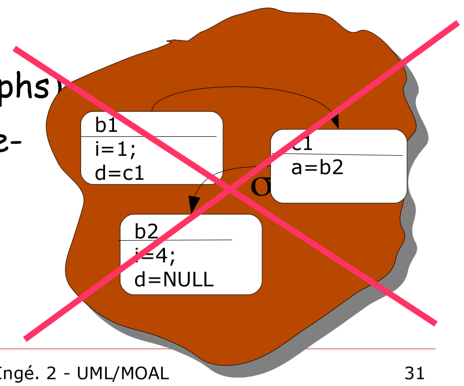

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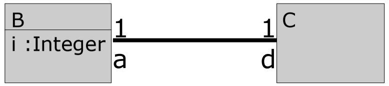
  For the 1-1-case, they are:



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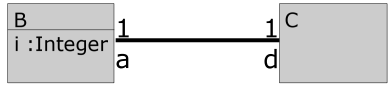

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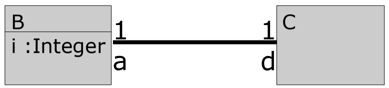

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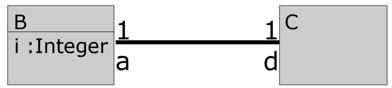

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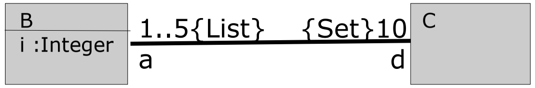

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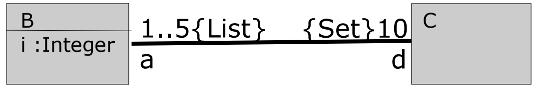

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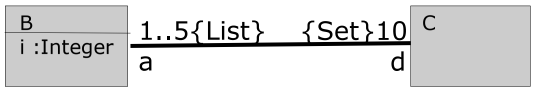

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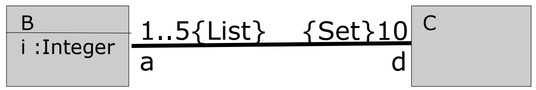

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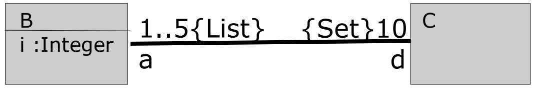

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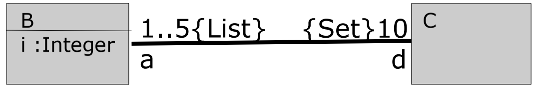

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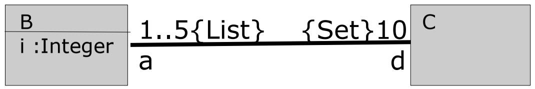

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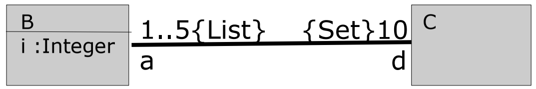

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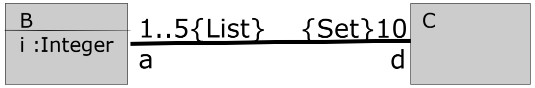

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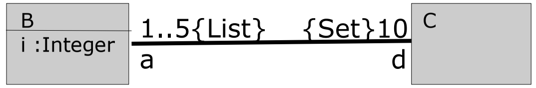

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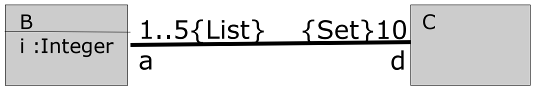

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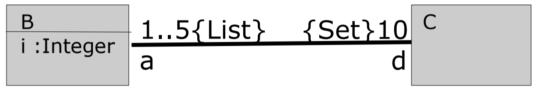

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- This appears for the first time in so-called contracts for (Class-model) methods:

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i : Integer
m(k:Integer) : Integer

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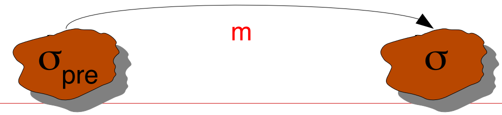

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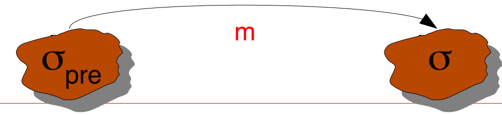

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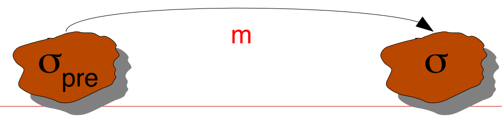

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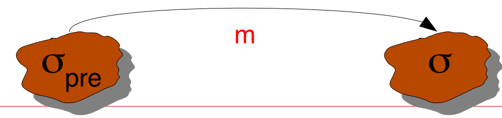

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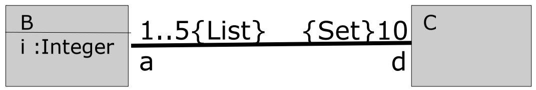

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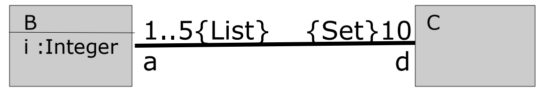

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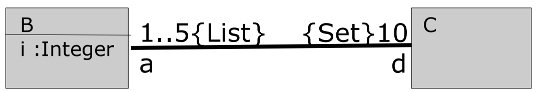

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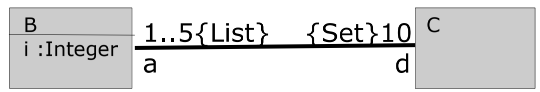

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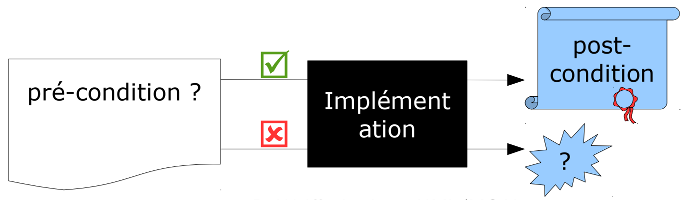
Pré et post-conditions (piqué de Delphine !)

Principe de la conception par contrats : contrat entre l'opération appelée et son appelant

- Appelant responsable d'assurer que la pré-condition est vraie
- Implémentation de l'opération appelée responsable d'assurer la terminaison et la post-condition à la sortie, si la pré-condition est vérifiée à l'entrée

Si la pré-condition n'est pas vérifiée, aucune garantie sur l'exécution de l'opération



Pré et post-conditions (piqué de Delphine !)

Principe de la conception par contrats : contrat entre l'opération appelée et son appelant

- Appelant responsable d'assurer que la pré-condition est vraie
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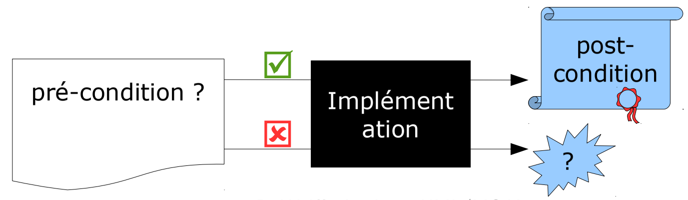

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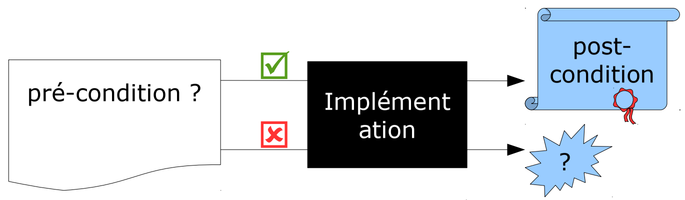

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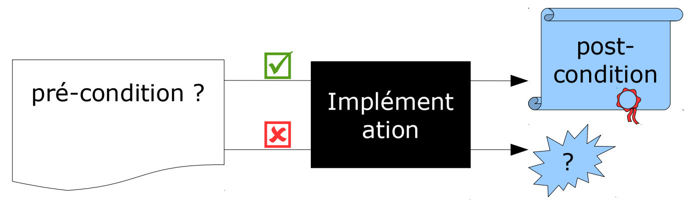

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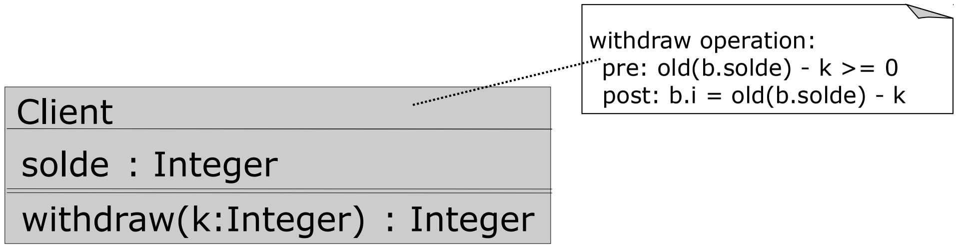
Operations in UML and MOAL

- Syntactically, contracts are annotated like this (JML-ish):



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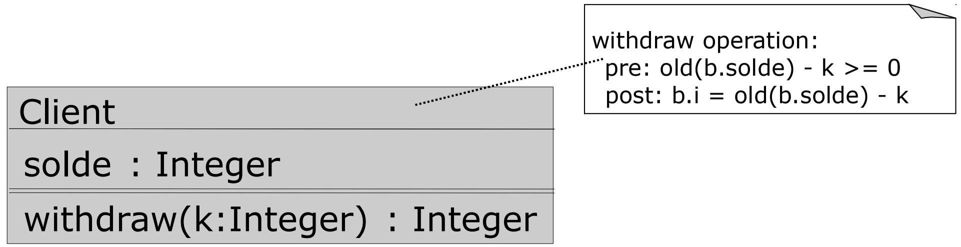

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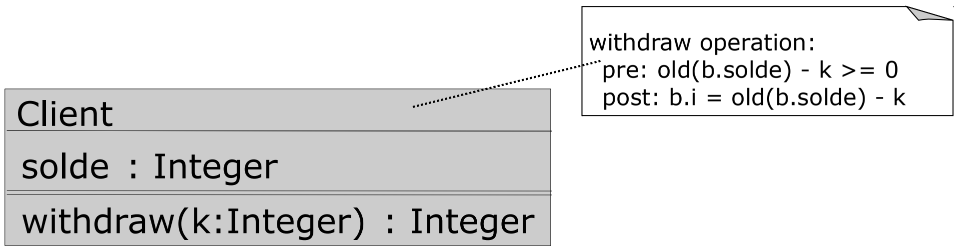

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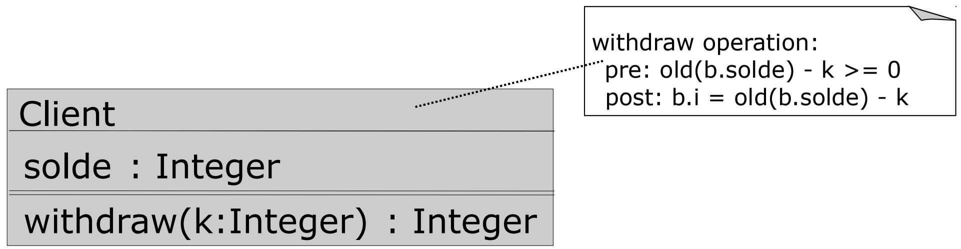

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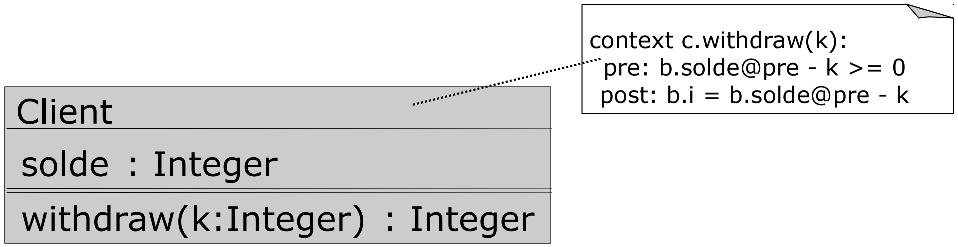
Operations in UML and MOAL

- ... or like this (OCL-ish):



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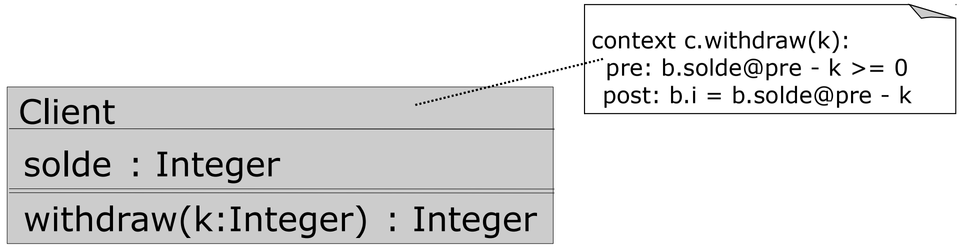

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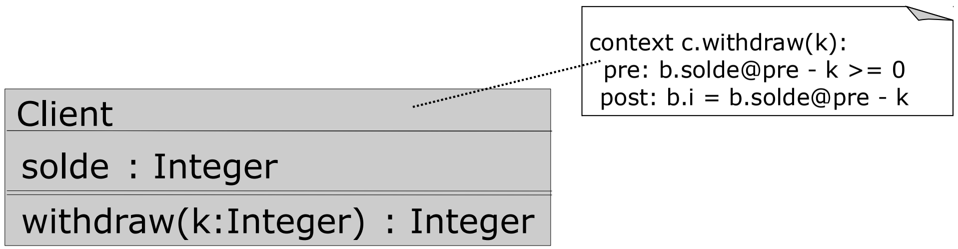

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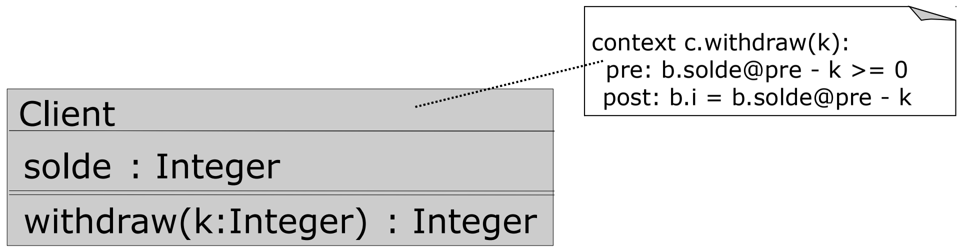

Operations in UML and MOAL Contracts

- This appears for the first time in so-called contracts for (Class-model) methods:

B
i : Integer
add(k:Integer) : Integer

- The « method » add can be seen as a « transaction » of a B object transforming the underlying pre-state σ_{pre} in the state « after » add yielding a post-state σ.

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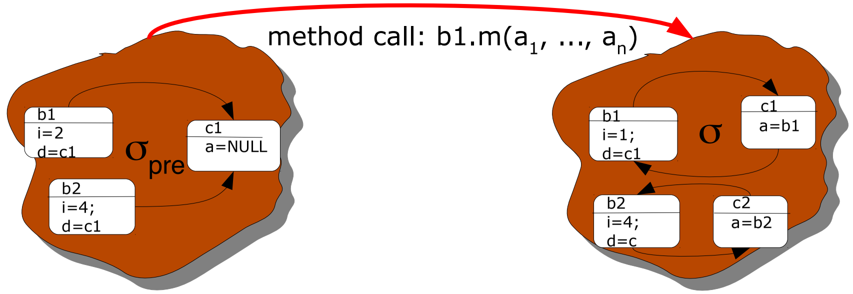
Syntax and Semantics of MOAL Contracts

- Again: This is the view of a transaction (like in a data-base), it completely abstracts away intermediate states or time. (This possible in other models/calculi, like the Hoare-calculus, though).



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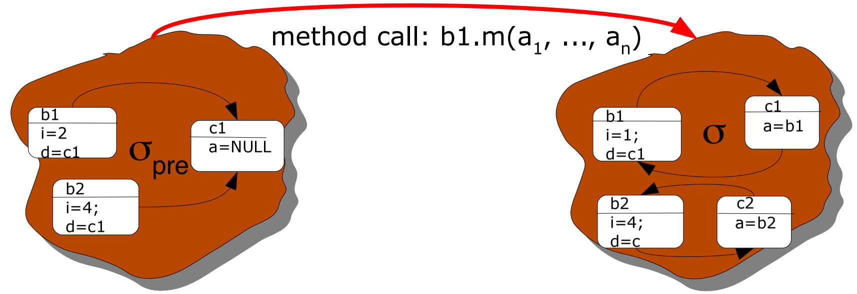

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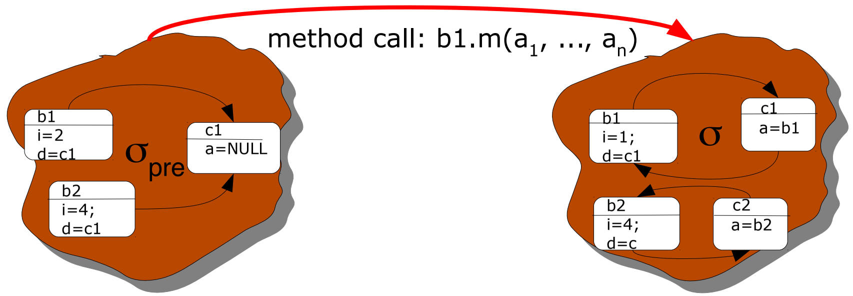

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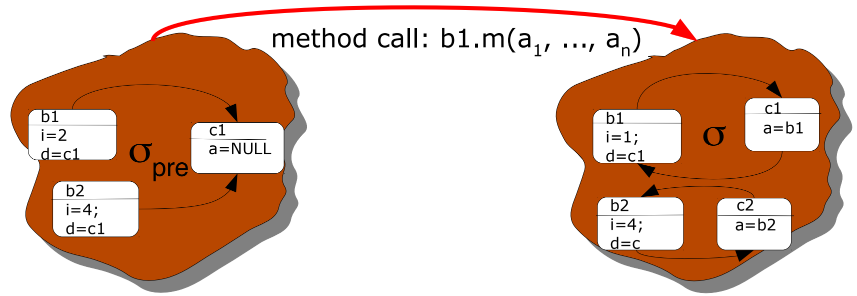

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Syntax and Semantics of MOAL Contracts

- Consequence:
  - The pre-condition is a formula referring to the σ_{pre} and the method arguments b1, a_1, ..., a_n only.
  - the post-condition is only assured if the pre-condition is satisfied
  - otherwise the method
    - ...may do anything on the state and the result, may even behave correctly , may non-terminate !
    - raise an exception (recommended in Java Programmer Guides for public methods to increase robustness)

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Syntax and Semantics of MOAL Contracts

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  - The post-condition is a formula referring to both σ_{pre} and σ, the method arguments b1, a_1, ..., a_n and the return value captured by the variable result.
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Syntax and Semantics of MOAL Contracts

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  - The semantics of a method call:

    $b1.m(a_1, ..., a_n)$

    is thus:

    $$pre_m(b1,a_1, ..., a_n)(\sigma_{pre}) \longrightarrow post_m(b1,a_1, ..., a_n,result)(\sigma_{pre},\sigma)$$

  - Note that moreover all global class invarants have to be added for both pre-state σ_{pre} and post-state σ !
    For an entire transition, the following must hold:

$$Inv(\sigma_{pre}) \wedge pre_m ... (\sigma_{pre}) \wedge post ... (\sigma_{pre},\sigma) \wedge Inv(\sigma)$$

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- Example:

Client
solde : Integer
withdraw(k:Integer) : {ok,nok}

class invariant:
c.solde >= 0 for all clients c.

operation c.withdraw(k) :
pre: k >= 0 ∧ old(c.solde) - k>=0
post: c.solde = old(c.solde) - k

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  $\forall c \in Client(\sigma).\ 0 \le c.solde(\sigma)$
- definition $pre_{withdraw}(c, k)(\sigma) \equiv$
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Syntax and Semantics of MOAL Contracts

- Notation:
  - In order to relax notation, we will use for applications to σ_{pre} the old-notation:

    Client(σ_{pre}) becomes old(Client)

    `c.solde`(σ_{pre}) becomes old(`c.solde`)

    etc.

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Client(σpre) becomes old(Client)
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Syntax and Semantics of MOAL Contracts

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Semantics of MOAL Contracts

- Two predicates are helpful when defining contracts. They exceptionally refer to both (σ_{pre},σ)
  - `isNew(p)` (σ_{pre},σ) is true only if object p of class C does not exist in σ_{pre} but exists in σ
  - modifiesOnly(S)(σ_{pre},σ) is only true iff
    - all objects in σ_{pre} are except those in S identical in σ
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With this predicate, one can express : „and nothing else changes". It is also called «framing condition».

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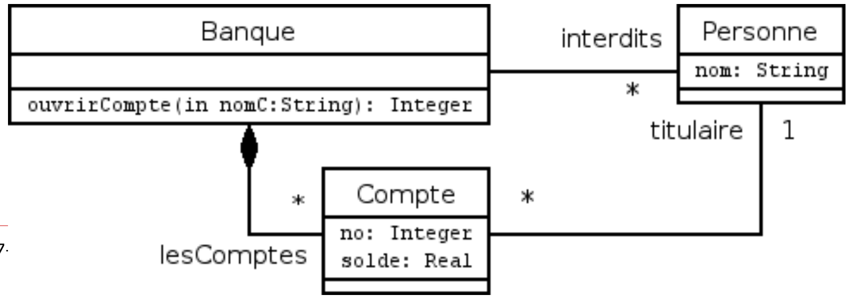
A Revision of the Example: Bank

Opening a bank account. Constraints:

- there is a blacklist
- no more overdraft than 200 EUR
- there is a present of 15 euros in the initial account
- account numbers must be distinct.



A Revision of the Example: Bank

Opening a bank account. Constraints:

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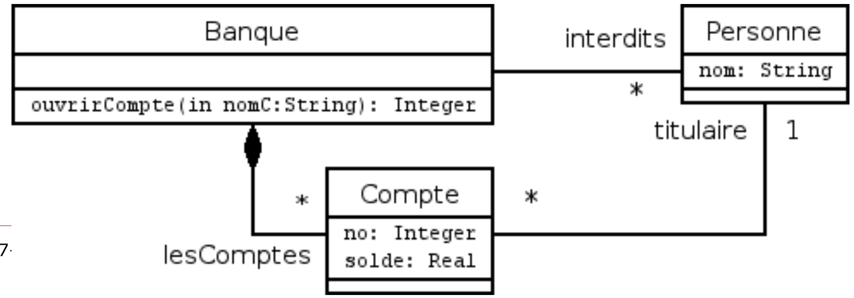

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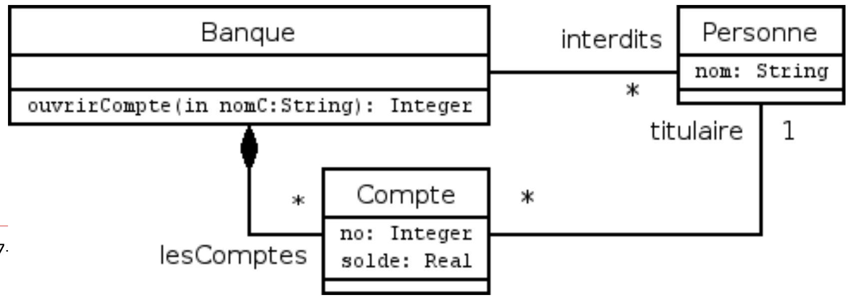

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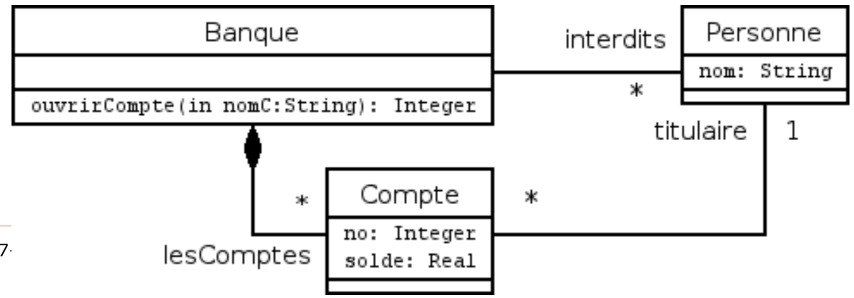

A Revision of the Example: Bank (2)

```
definition pre_ouvrirCompte(b:Banque, nomC:String)≡
                    ∀p ∊ Personne. p.nom ≠ nomC
definition post_ouvrirCompte(b:Banque,nomC:String,r:Integer)≡
     |{p ∊ Personne | p.nom = nomC| = 1
   ∧  ∀p ∊ Personne. p.nom = nomC ⟶ isNew(p)
   ∧ |{c∊Compte | c.titulaire.nom = nomC}| = 1
   ∧ ∀c∊Compte. c.titulaire.nom = nomC ⟶ c.solde = 15
                                        ∧ isNew(c)
   ∧ b.lesComptes=old(b.lesComptes)∪
                {c∊Compte | c.titulaire.nom = nomC}
    ∧ b.interdits=old(b.interdits)∪
                {c∊Compte | c.titulaire.nom = nomC}
   ∧ modifiesOnly({b}∪{c∊Compte c.titulaire.nom = nomC}
                ∪ {p ∊ Personne | p.nom = nomC})
```


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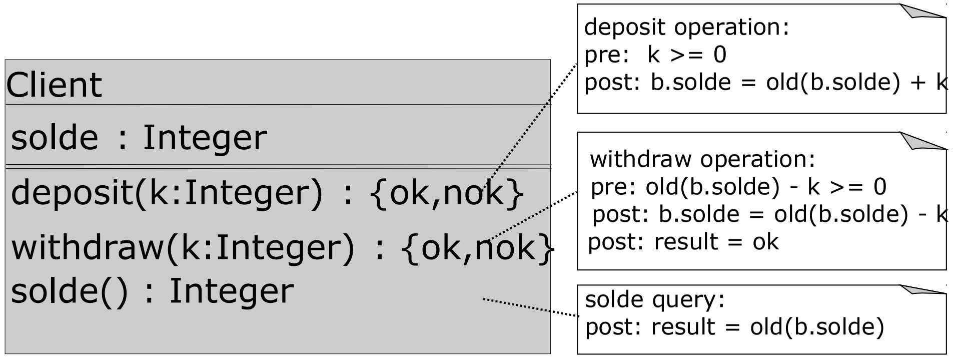
Operations in UML and MOAL

- Example:



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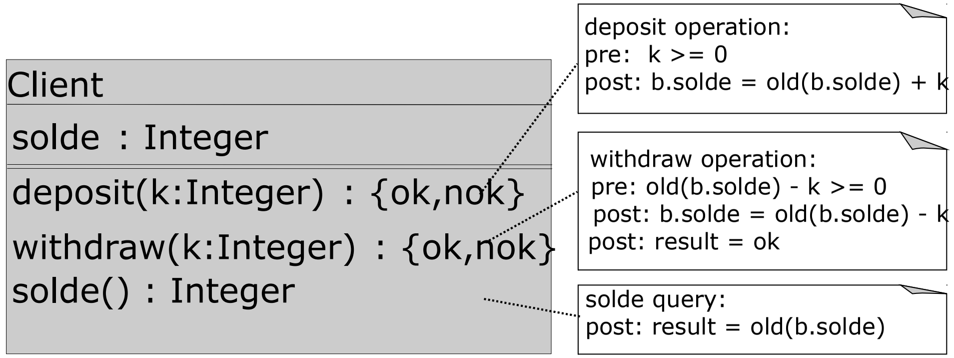

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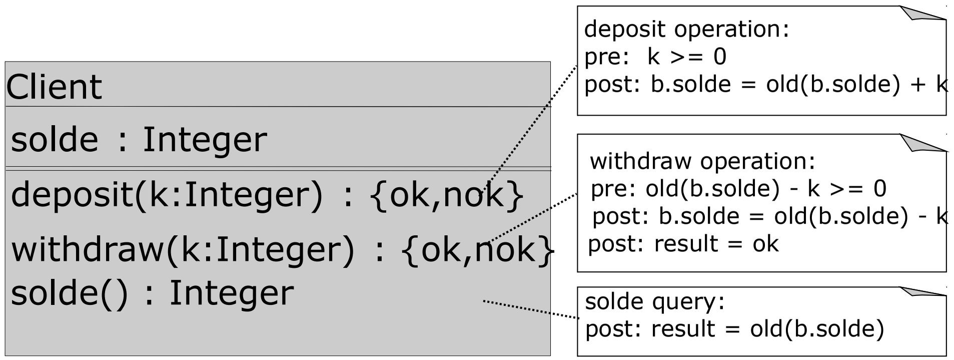

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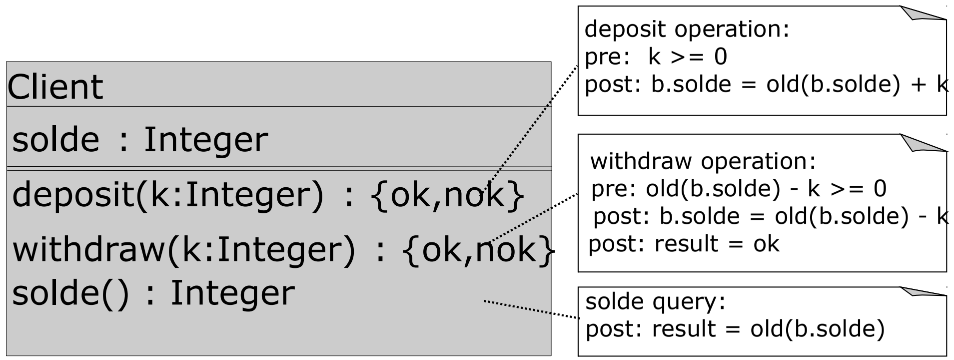

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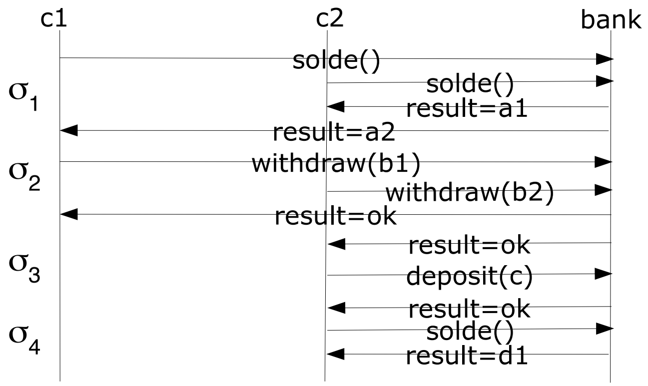
Operations in UML and MOAL

- Abstract Concurrent Test Scenario:



assert c1.solde(σ_4)=a2-b1 ∧ b1 ≥ 0 ∧ a2 ≥ b1

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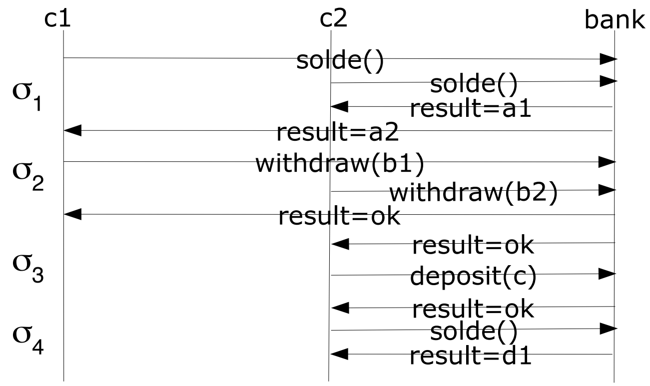

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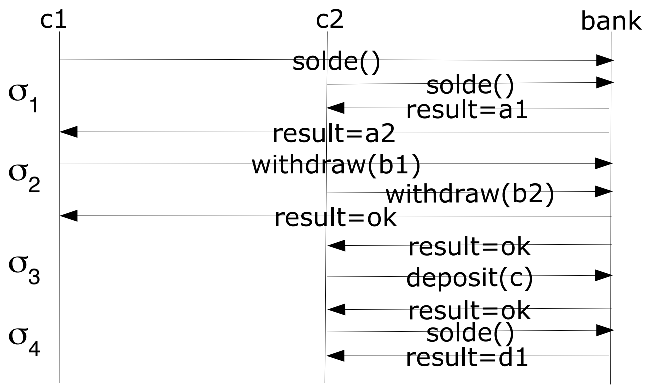

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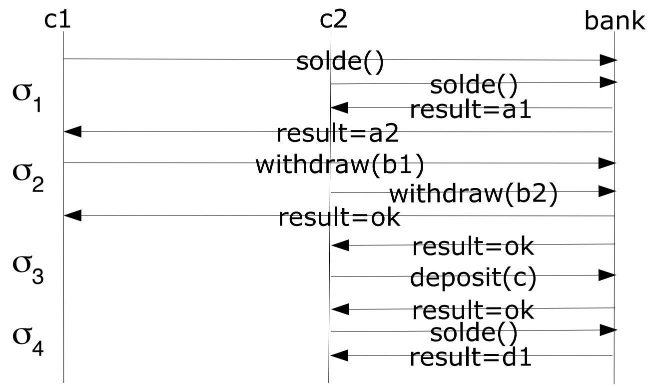

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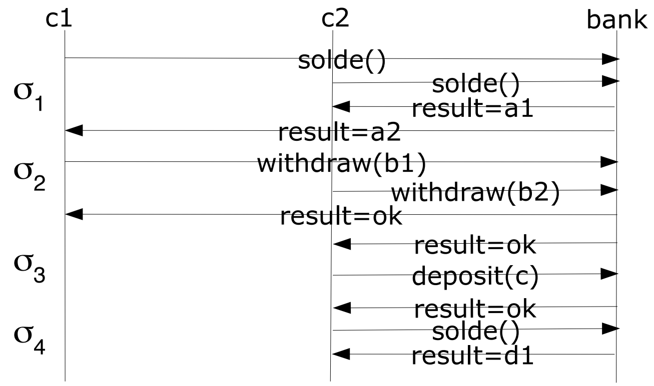

Any instance of b1 and a1 is a test ! This is a „Test Schema“ !
Note: b1 can be chosen dynamically during the test !

Operations in UML and MOAL

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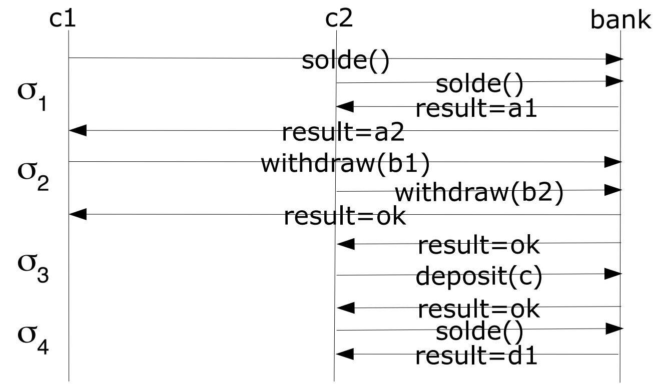

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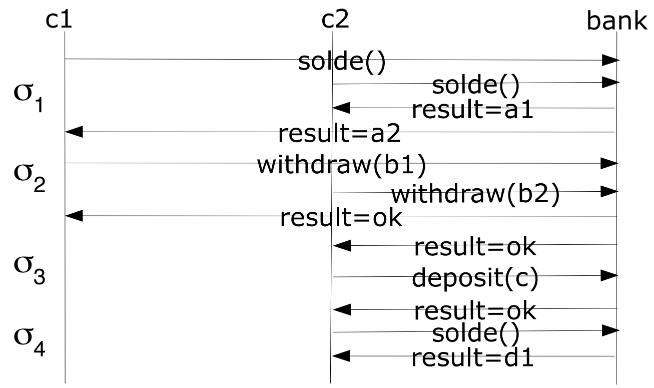

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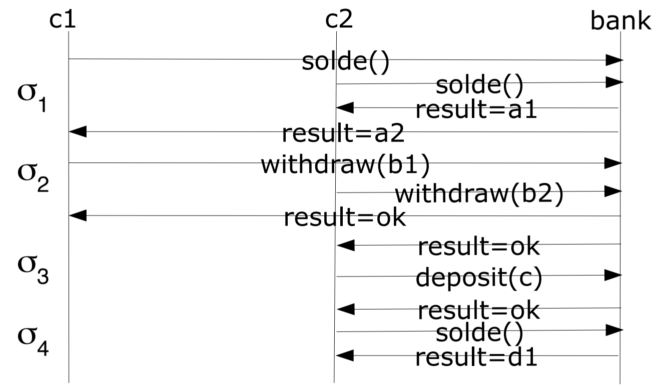

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Summary

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- MOAL can be used to annotate Class Models, Sequence Diagrams and State Machines
- Working out, making explicit the constraints of these Diagrams is an important technique in the transition from Analysis documents to Designs.

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