POLYTECH
PARIS-SUD

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Cycle Ingénieur – 2ème année
Département Informatique

Verification and Validation

Part III : Formal Specification with UML/MOAL

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Plan of the Chapter

Plan of the Chapter

- Syntax & Semantics of our own language

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MOAL

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  - mathematical

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  - object-oriented
  - UML-annotation
  - language

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

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  - Basis: Logic and Set-theory

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  - Method Contracts with Pre- and Post-Conditions
  - Annotated Sequence Diagrams for Scenarios, . . .

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  (like JML, VCC) that constrains an underlying state σ

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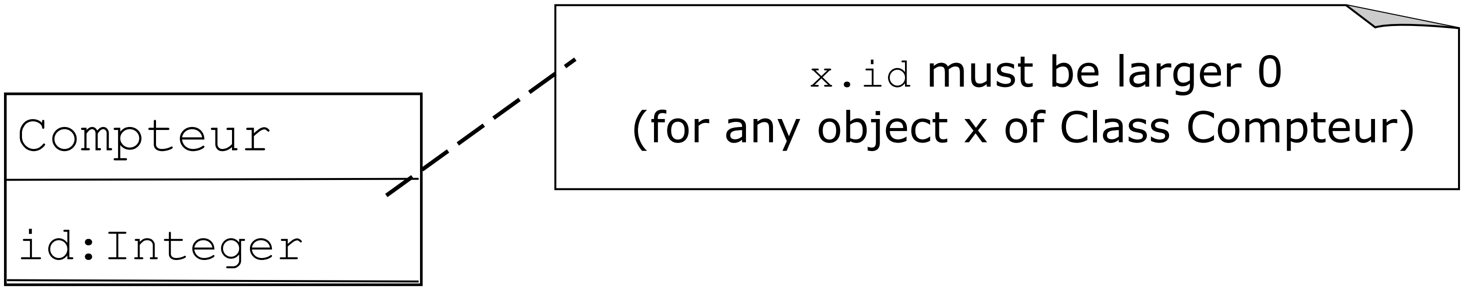

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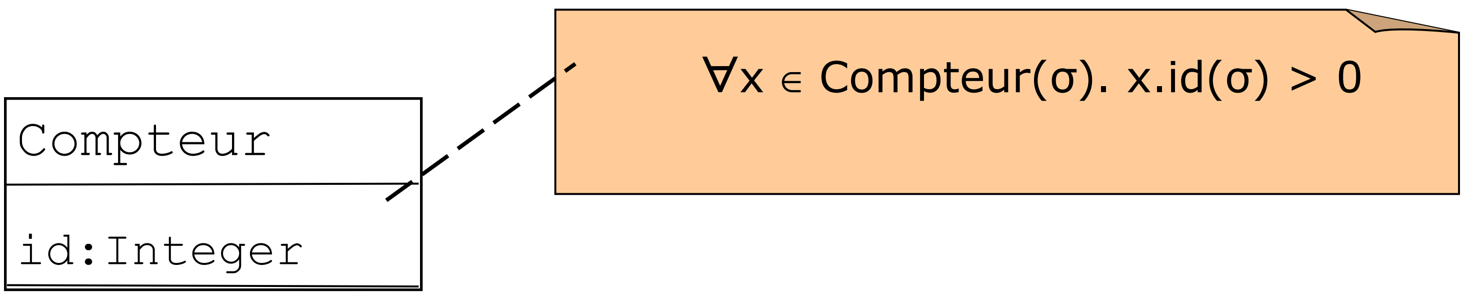

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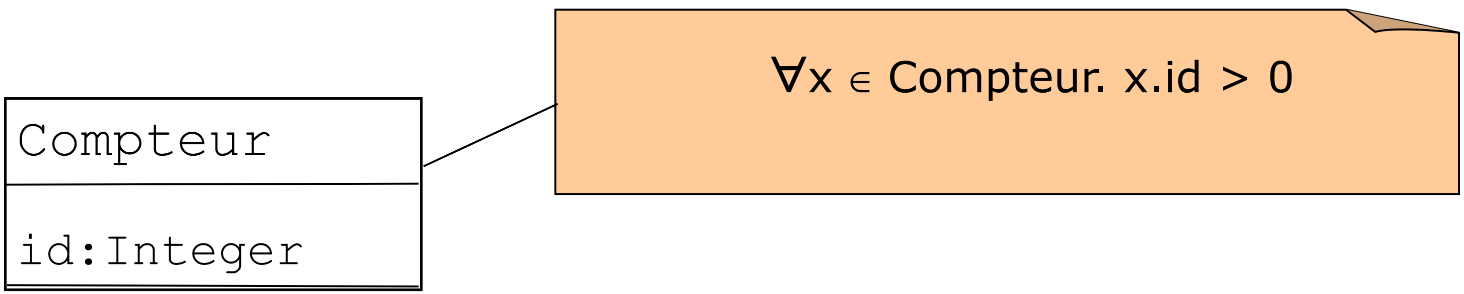

... by abbreviation convention if no confusion arises.

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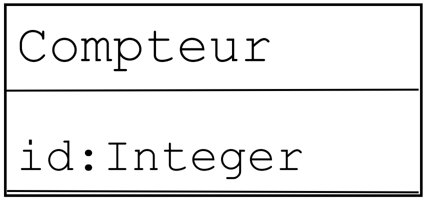

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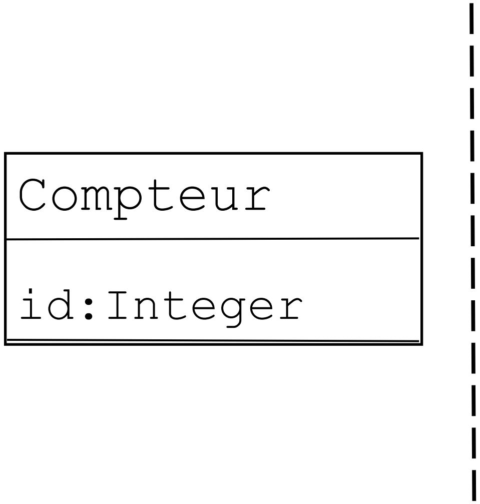

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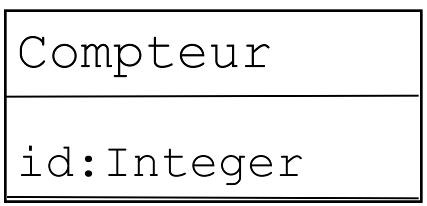

definition $inv_{Compteur}(\sigma) \equiv \forall x \in Compteur(\sigma).$
$x.id(\sigma) > 0$

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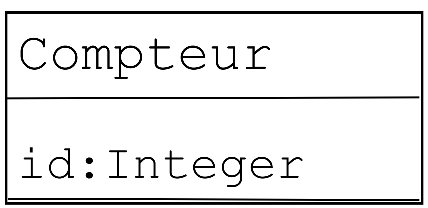

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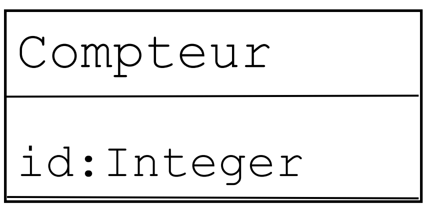

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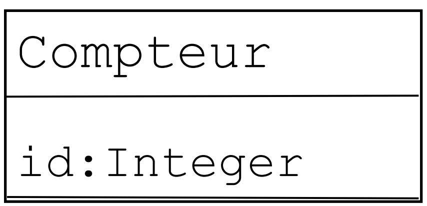

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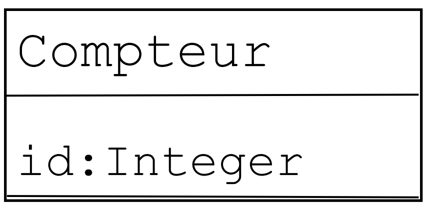

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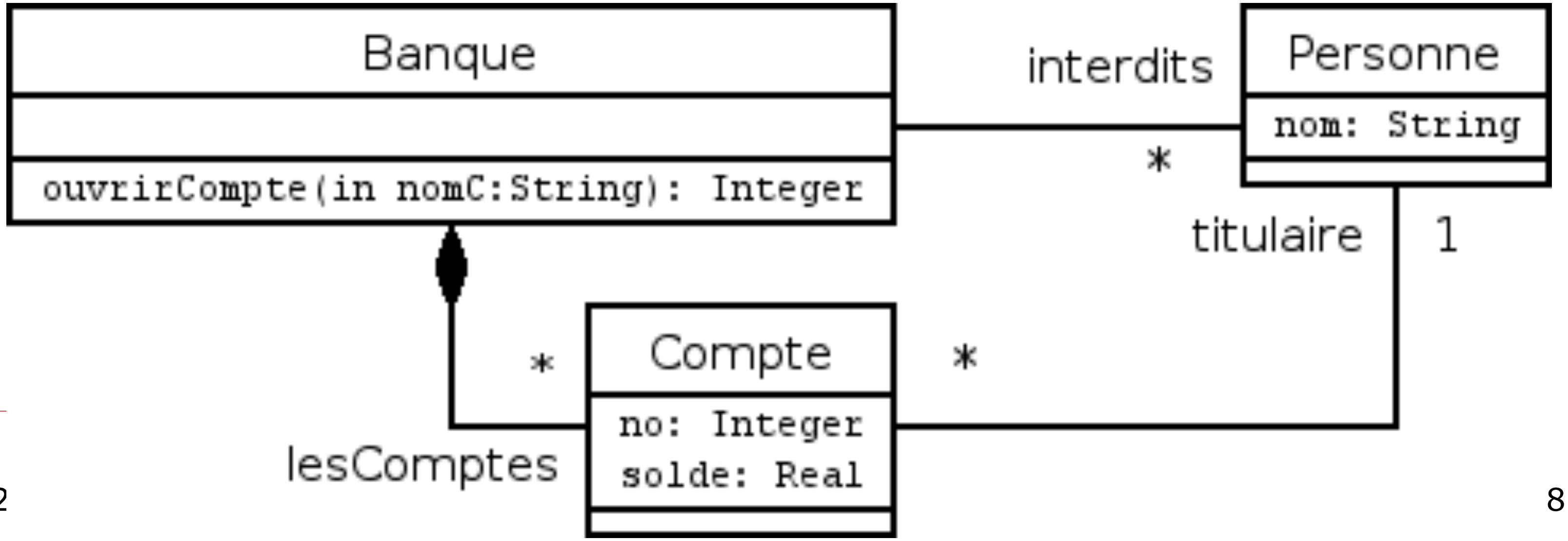
... or as mathematical definition in a separate document

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.



A first Glance to an Example: Bank (2)

definition unique ≡ isUnique(.no)(Compte)

definition noOverdraft ≡ $\forall$c ∈ Compte. c.id ≥ -200

definition $pre_{ouvrirCompte}$(b:Banque, nomC:String)≡
$\forall$p ∈ Personne. p.nom ≠ nomC

definition $post_{ouvrirCompte}$(b:Banque,nomC:String,r::Int)≡
|{p ∈ Personne | p.nom = nomC ∧ isNew(p)}| = 1
∧ |{c∈Compte | c.titulaire.nom = nomC}| = 1
∧ $\forall$c∈Compte. c.titulaire.nom = nomC
⟶ c.solde = 15 ∧ isNew(c)

MOAL: a specification langage?

- In the following, we will discuss the MOAL Language in more detail ...

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  - Quantifiers on sets and lists:

$\forall x \in Set.\ P(x)$ $\exists x \in Set.\ P(x)$

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  - *E* `*` *E*', *E* `/` *E*',

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  - `E * E', E / E',`
  - `abs(E), E div E', E mod E'...`

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  - `substring(i,j,S)`
  - `'Hello'`

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- `| S |`   `size as Integer`

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- $|\ S\ |$ size as Integer
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- 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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- `(X,Y)` `pairing`

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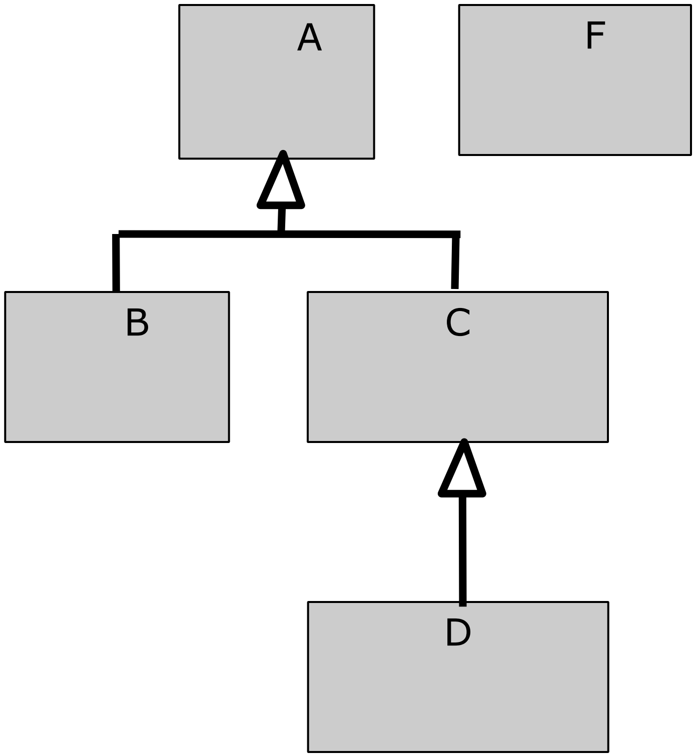
- [1,2,3] -- denotations of lists

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 instances of class A in state σ



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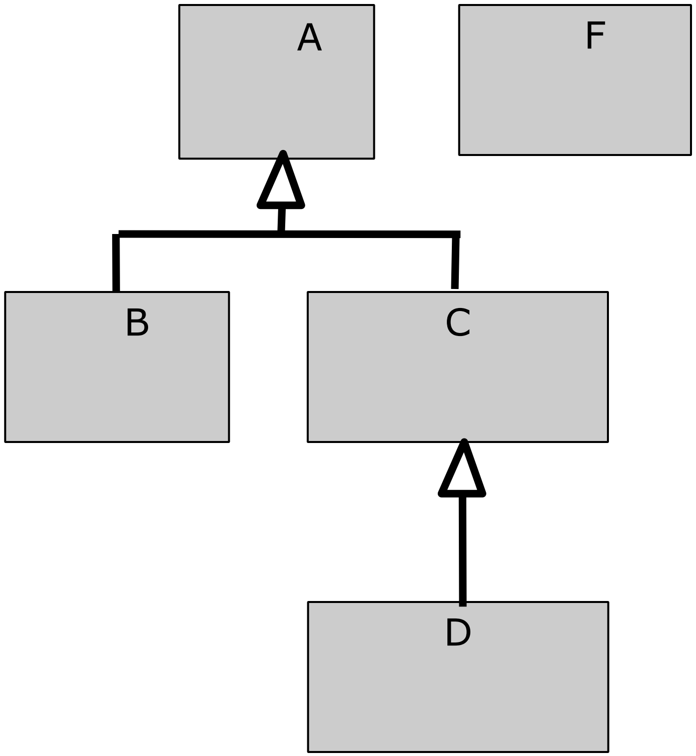
  Recall that we will drop the index (σ) whenever it is clear from the context



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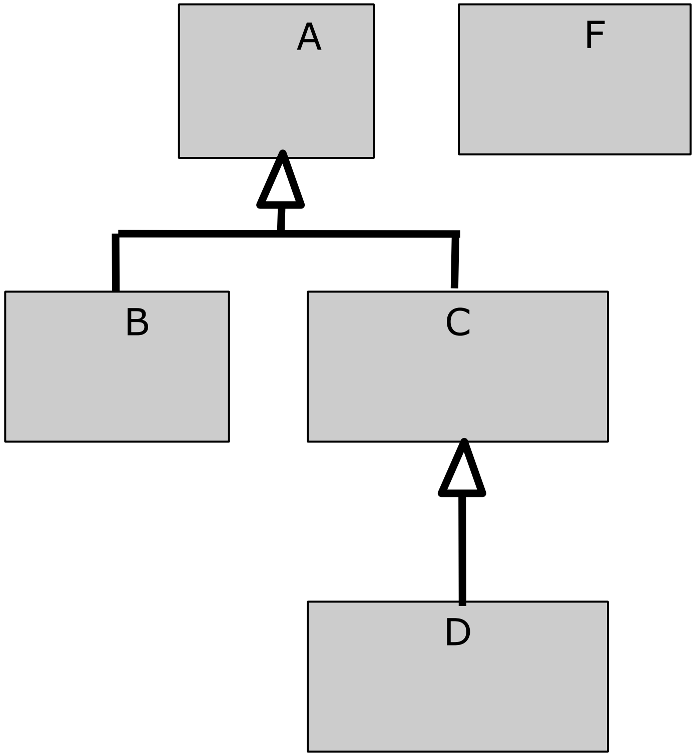

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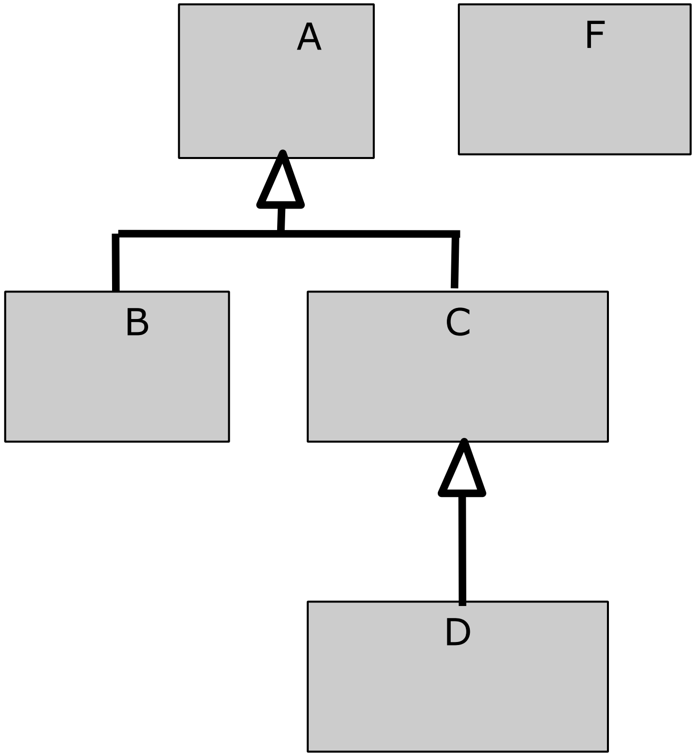

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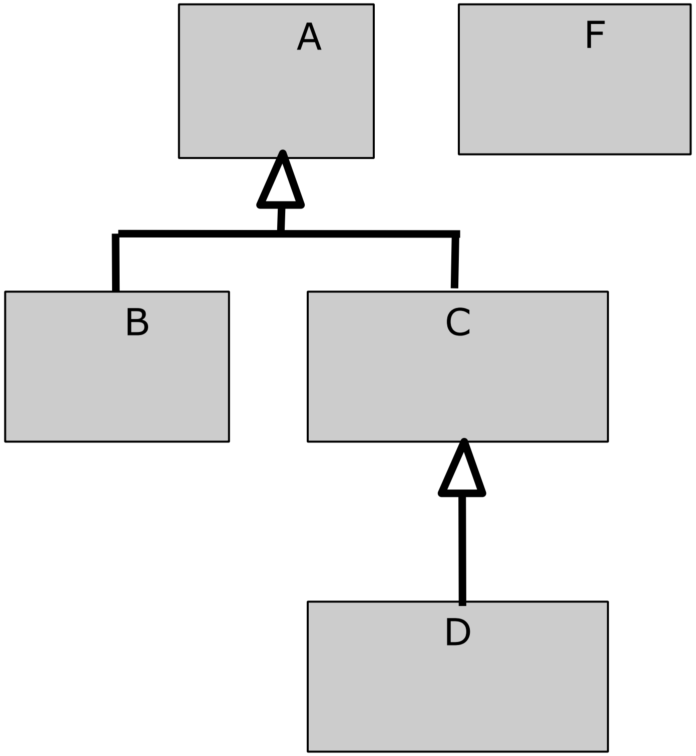

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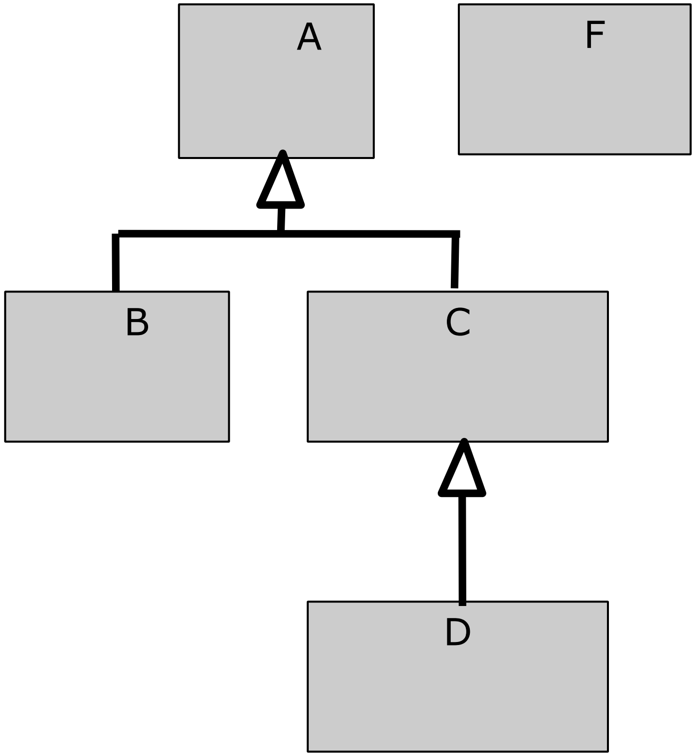

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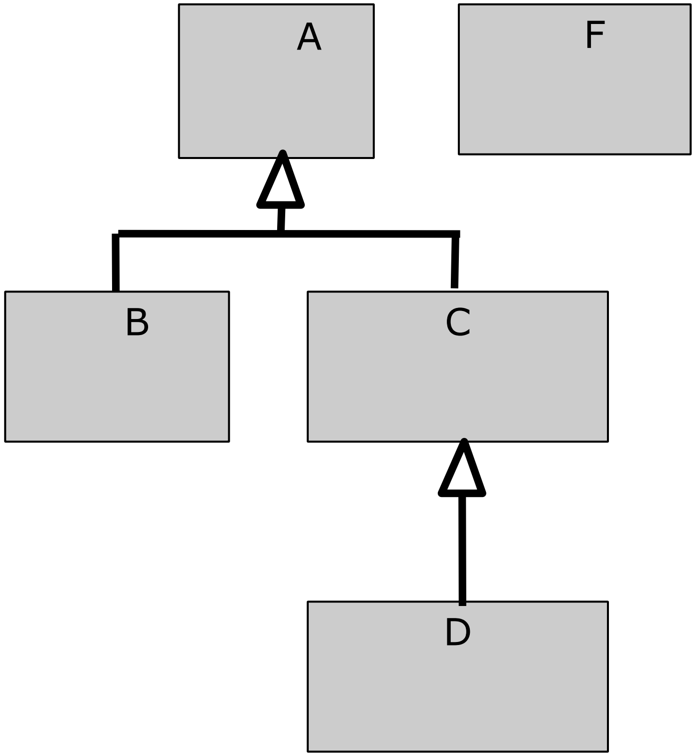

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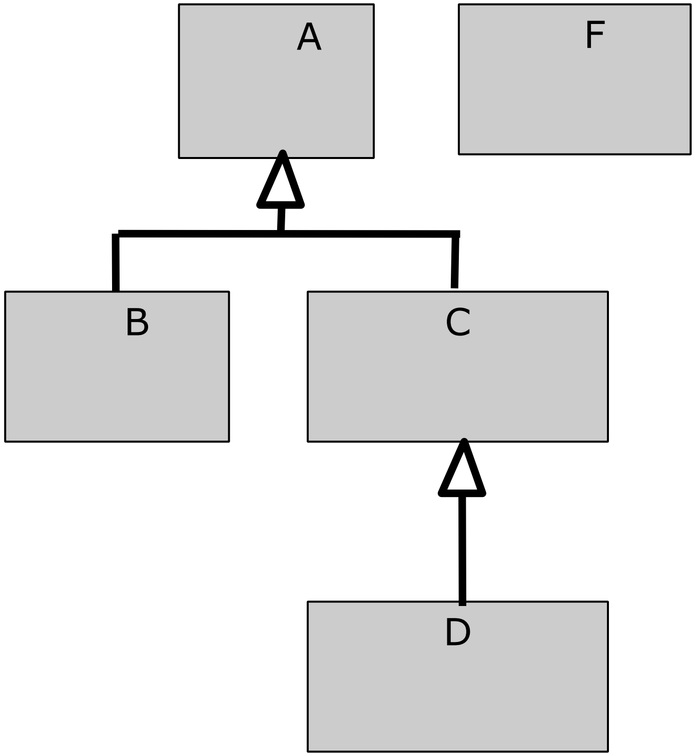

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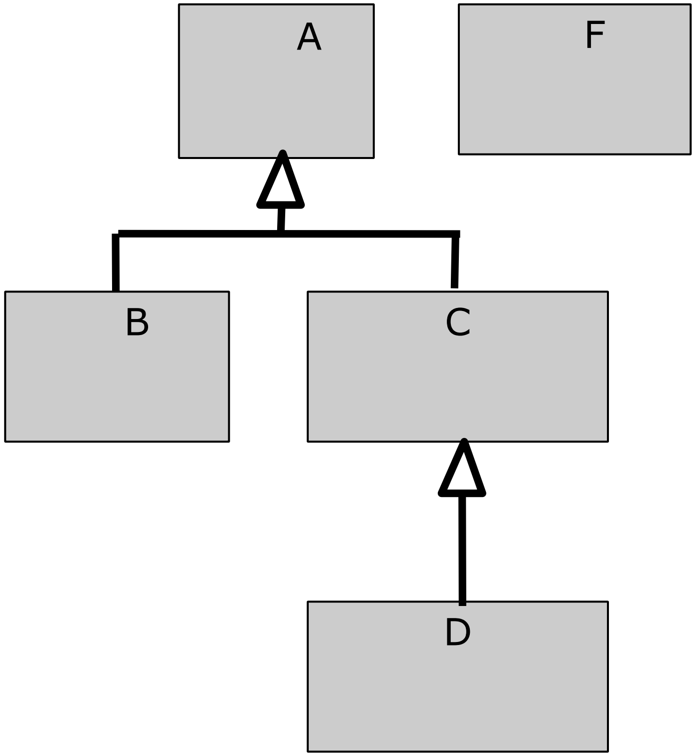
- Objects have two types:
  - the « apparent type » (also called static type)
  - the « actual type » (the type at creation)
  - casting changes the apparent type along the class hierarchy, but not the actual type



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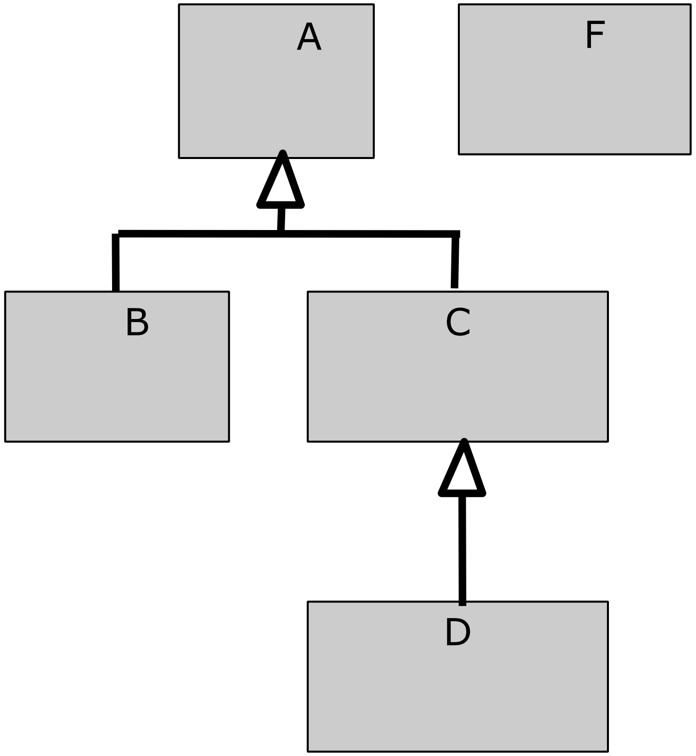

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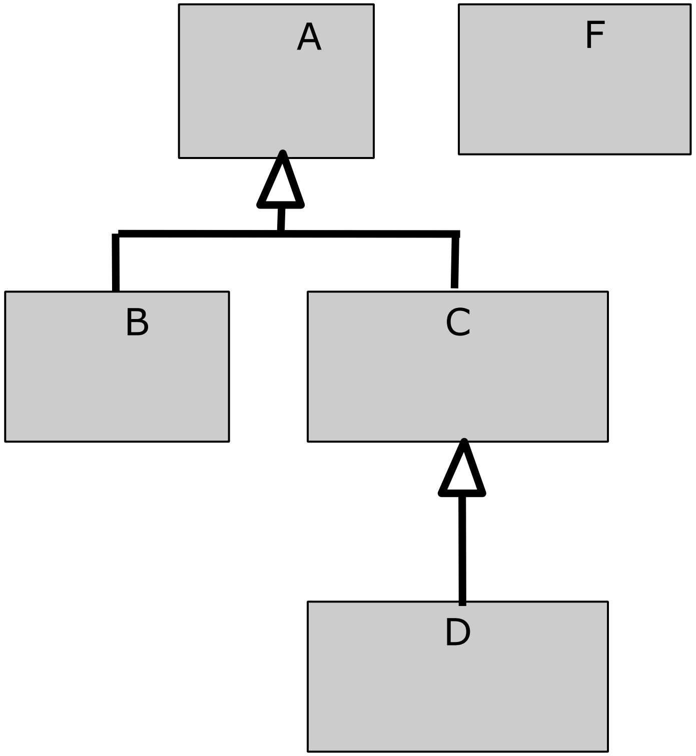
- Assume the creation of objects

  `a in class A,b in class B,`
  `c in class C,d in class D,`



Syntax and Semantics of Objects

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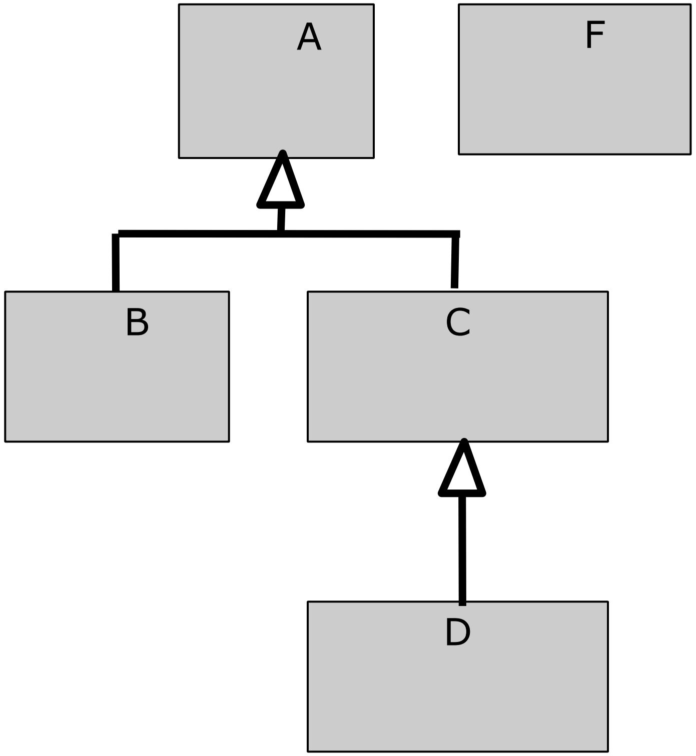
- Then casting:

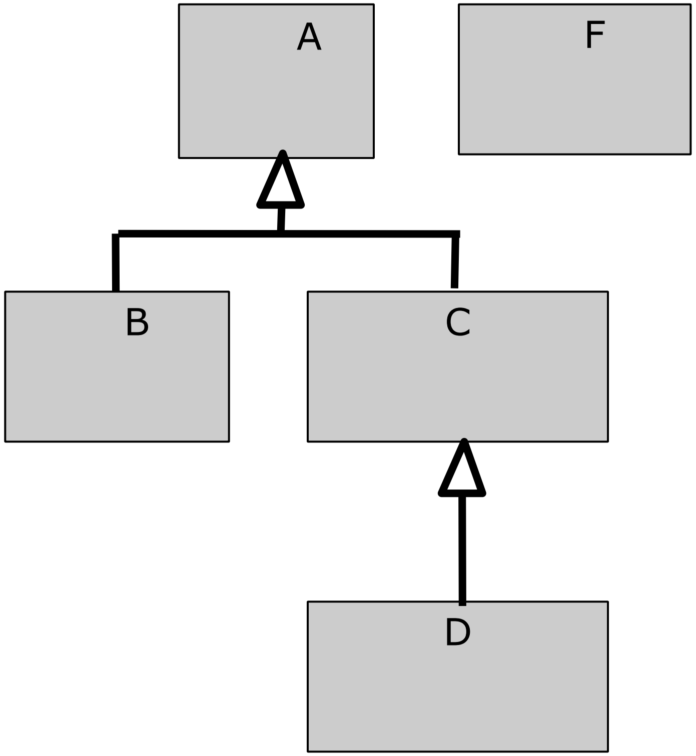
```
⟨F⟩b is illtyped

⟨A⟩b has apparent type A,
    but actual type B

⟨A⟩d has apparent type A,
    but actual type D
```



Syntax and Semantics of OCL / UML



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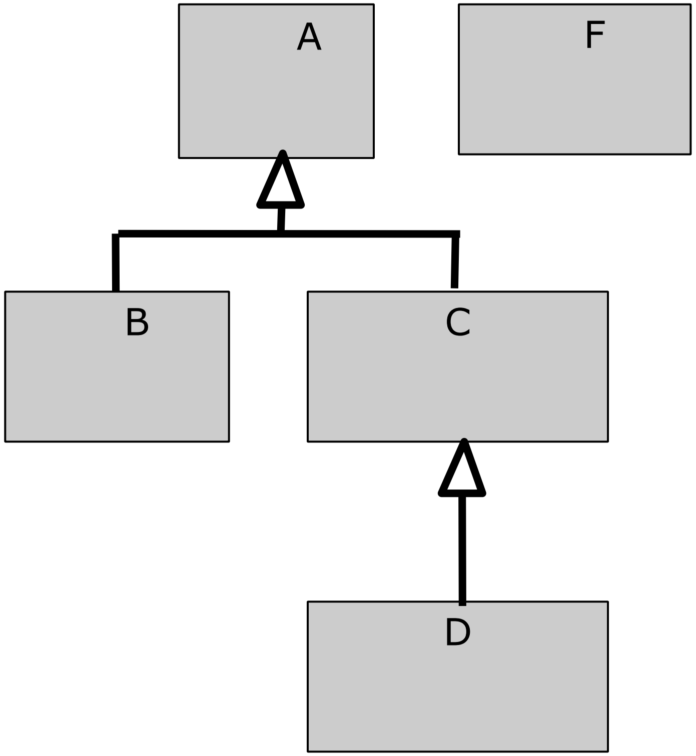

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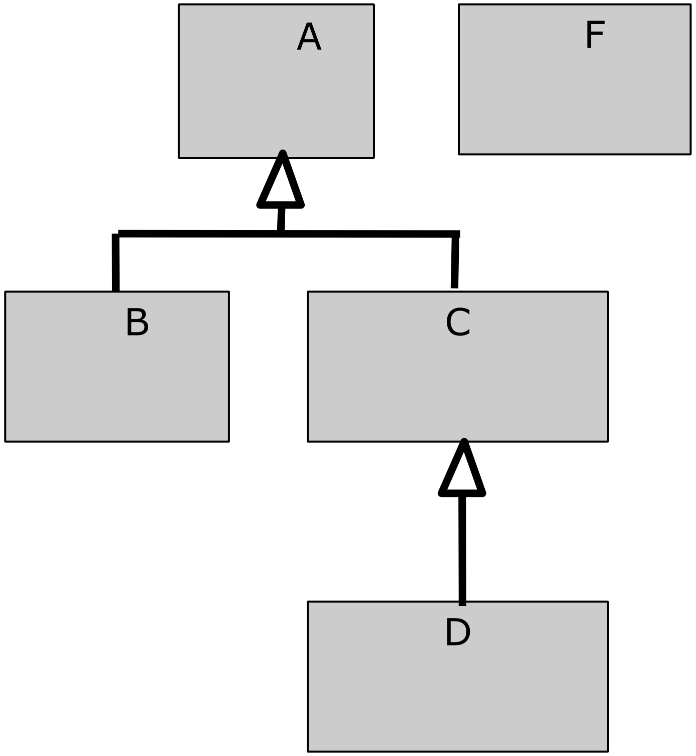

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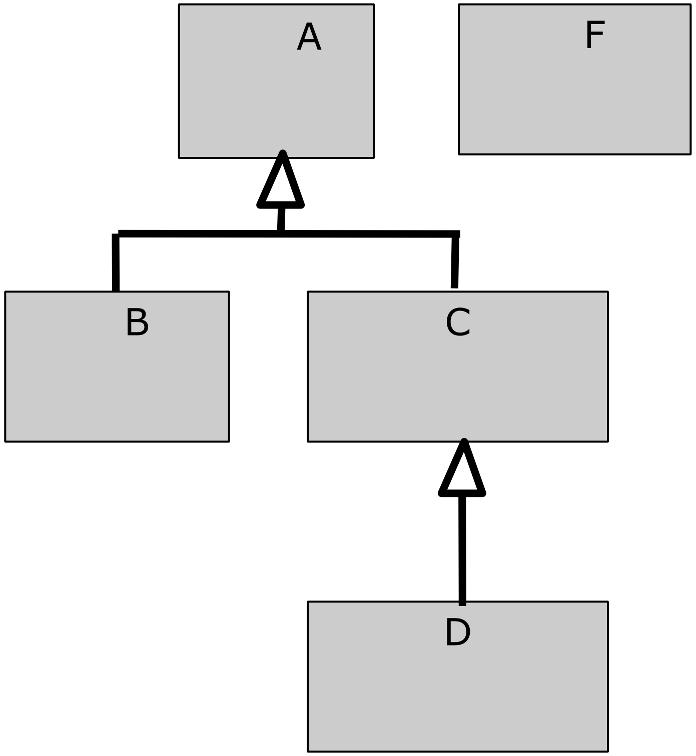

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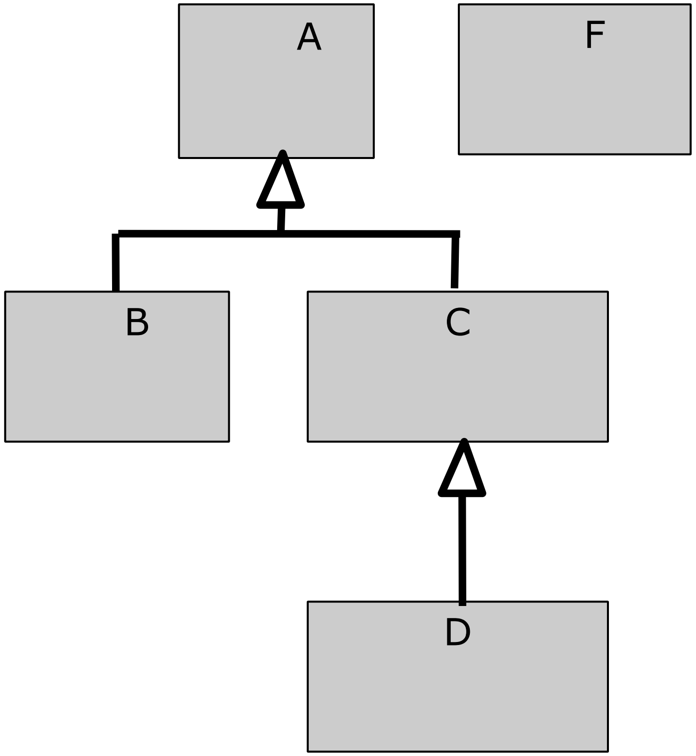

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    $\langle A \rangle B \cup \langle A \rangle C \subseteq A$

    but:

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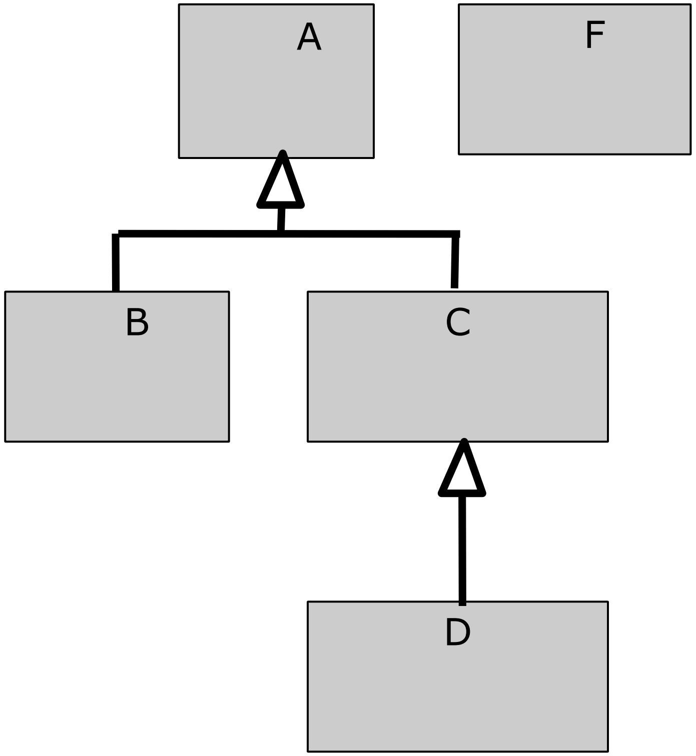
    and also: $\langle A \rangle D \subseteq A$ (for all states σ)



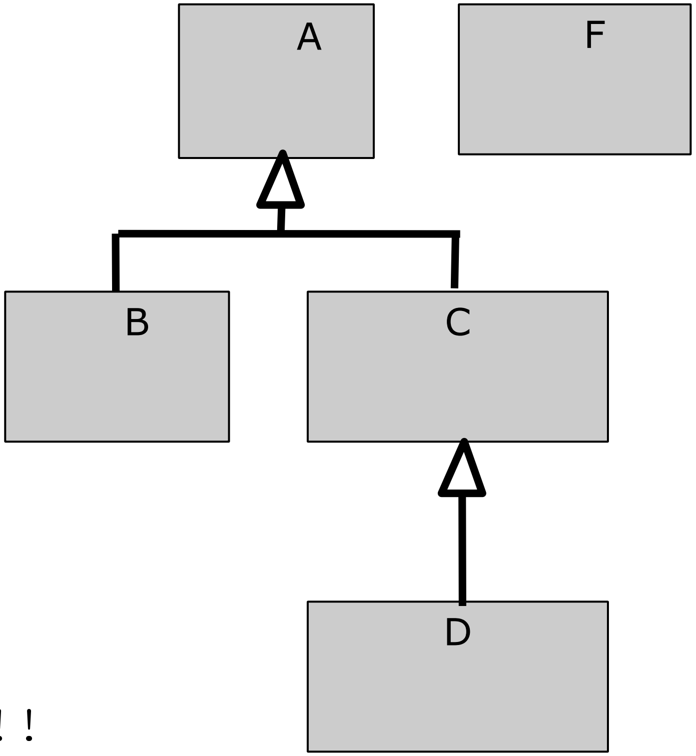
Syntax and Semantics of Objects

- Instance sets can be used to determine the actual type of an object:

  $b \in B$

  corresponds to Java's `instanceof` or `OCL's isKindOf`. Note that casting does NOT change the actual type:

  $\langle A \rangle b \in B$, and $\langle B \rangle \langle A \rangle b = b$!!!



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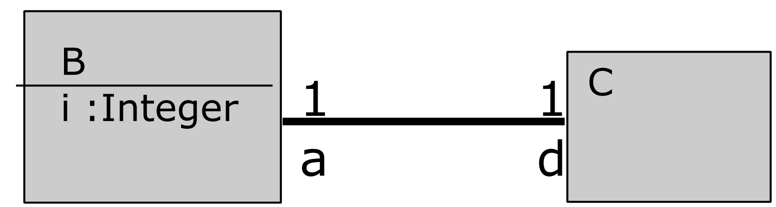
  - consequence:
    up-down casts are identities.

Syntax and Semantics of Object Attributes



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- Objects represent structured, typed memory in a state σ. They have attributes.

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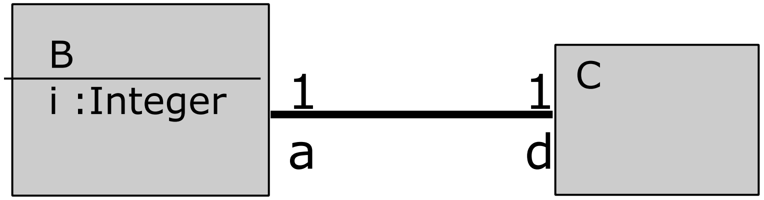

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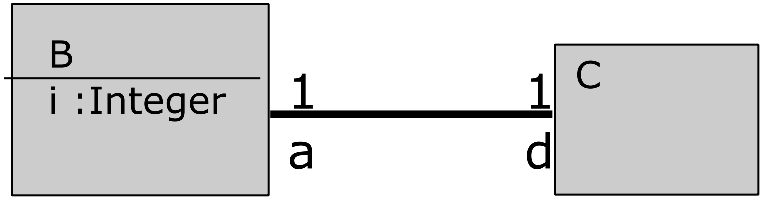
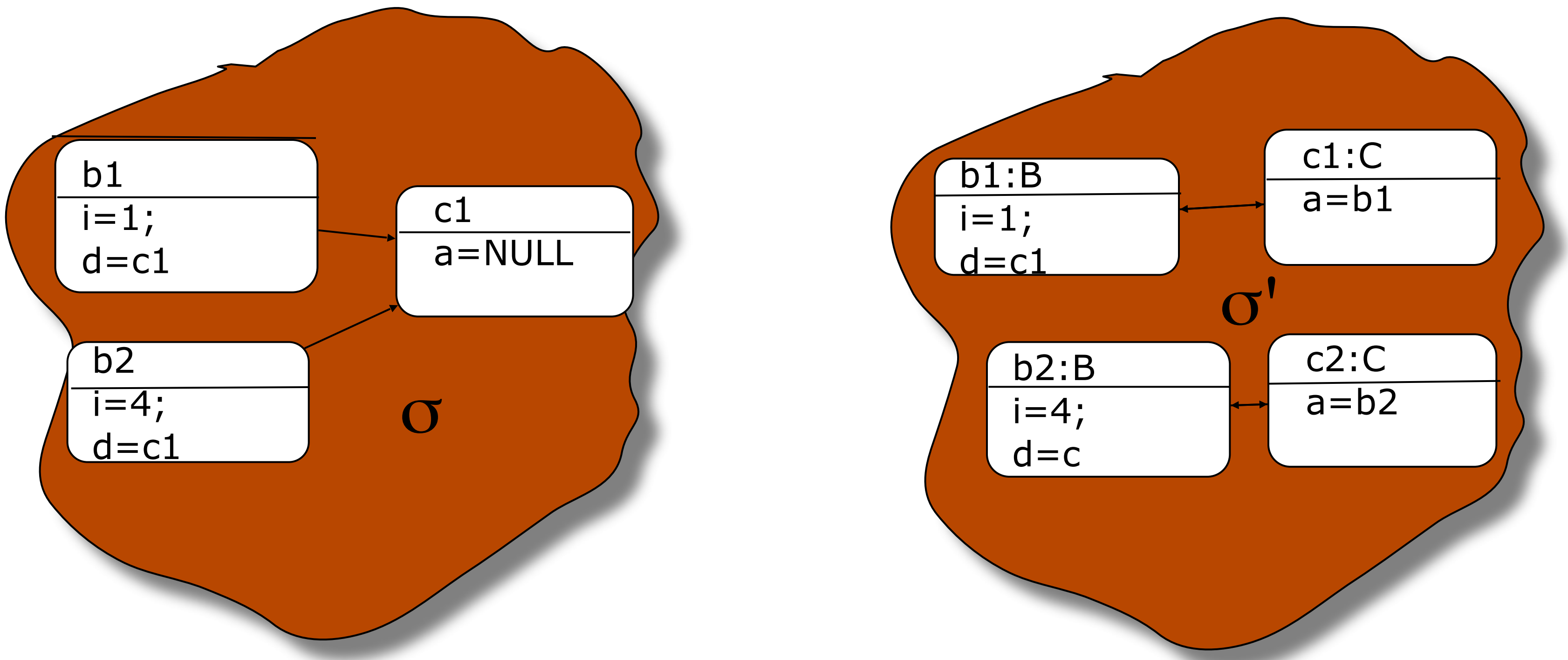


Syntax and Semantics of Object Attributes

- Example:

attributes of class type in states σ' and σ.



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

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  - ➢ `b1.d :: C`
    `c1.a :: B` `b1.d.a.d.a ...`

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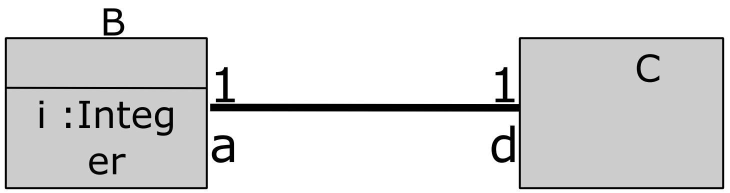
  - Note that navigation expressions depend on their underlying state:
    b1.d(σ).a(σ).d(σ).a(σ) = NULL
    b1.d(σ').a(σ').d(σ').a(σ') = b1 !!!

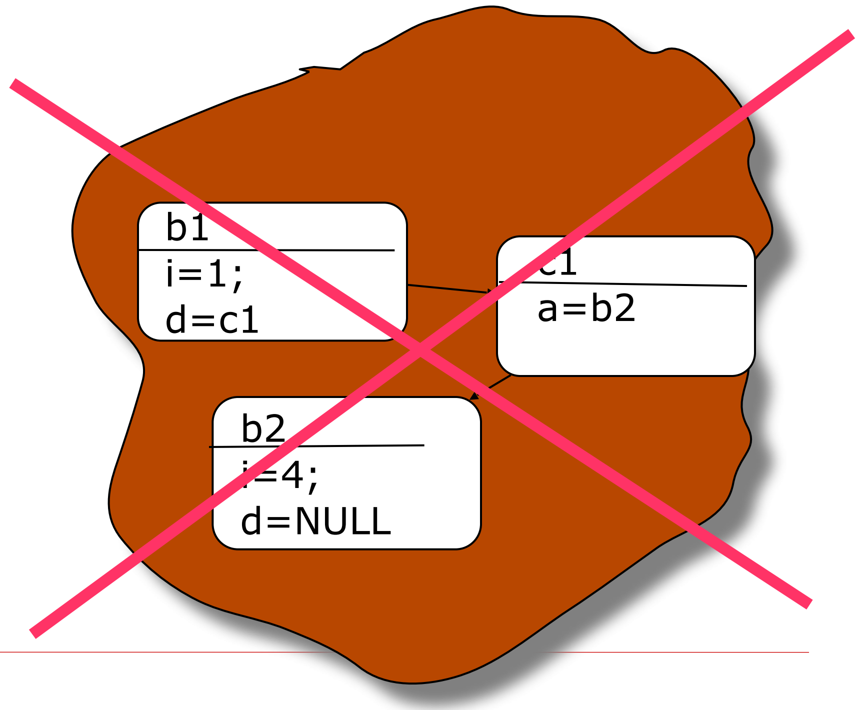
(cf. Object Diagram pp 27)

Syntax and Semantics of Object Attributes



- Note that associations are meant to be « relations » in the mathematical sense.

Thus, states (object-graphs) of this form do not repre-sent the 1:1 association:



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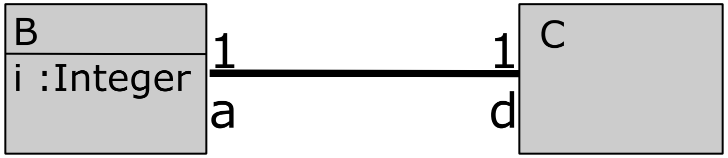

- This is reflected by 2 « association integrity constraints ».
  For the 1-1-case, they are:

> ➢ definition $ass_{B.d.a} \equiv \forall x \in B.\ x.d.a = x$
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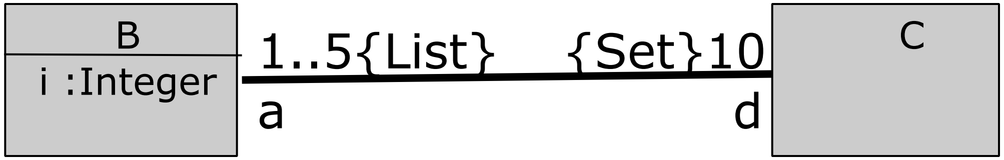
- In analysis-level Class Diagrams, the type information is still omitted; due to overloading of ∀x∈X. P(x) etc. this will not hamper us to specify ...

Syntax and Semantics of Object Attributes



Syntax and Semantics of Object Attributes

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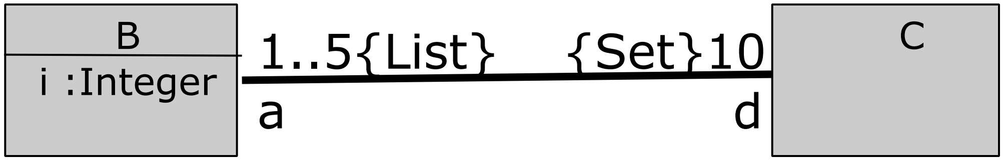

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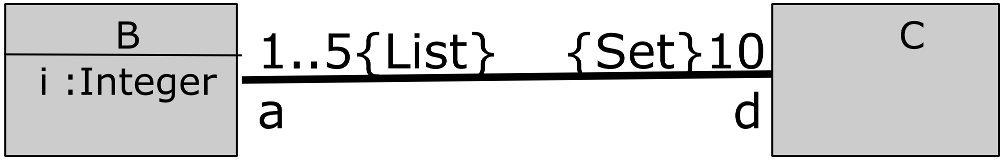

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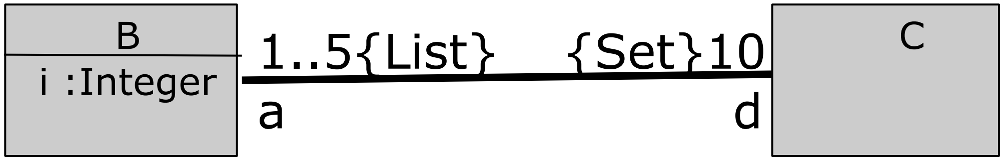

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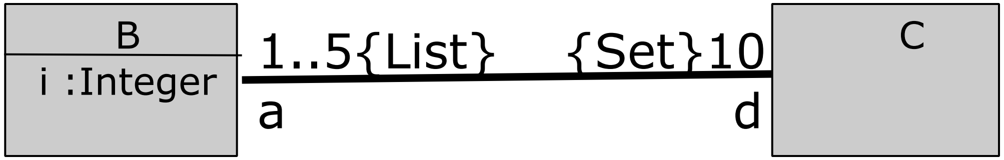

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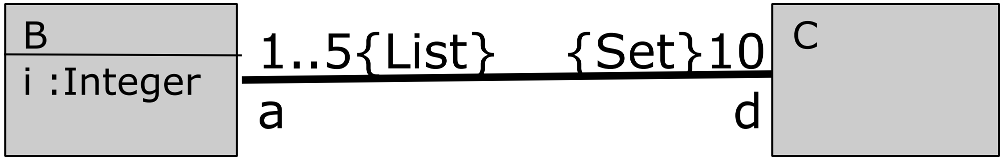

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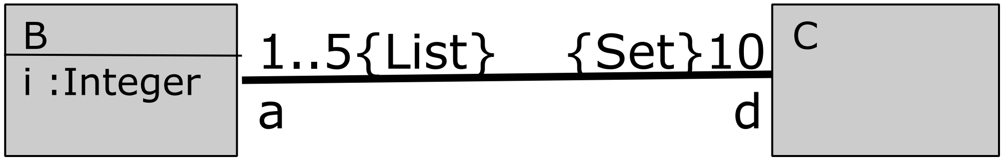

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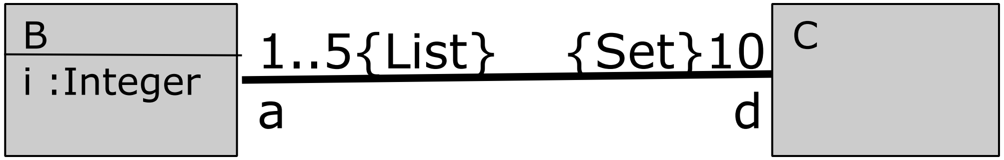

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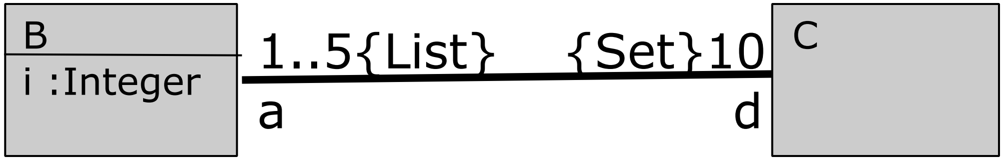

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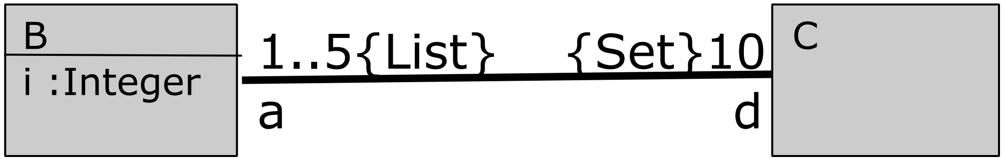

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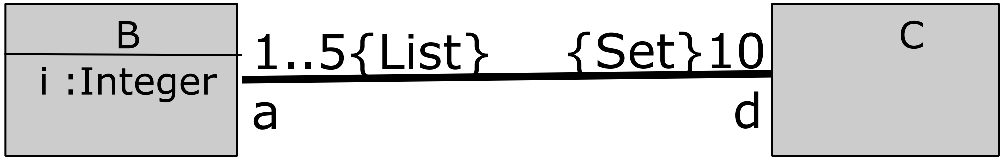

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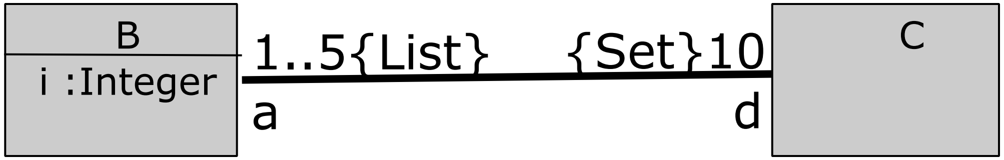

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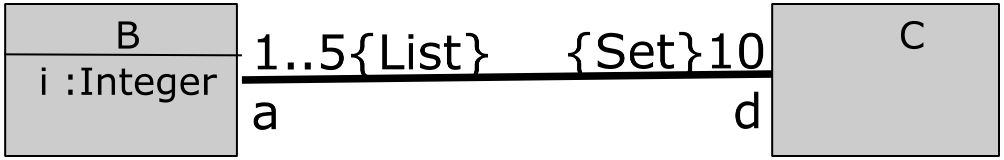

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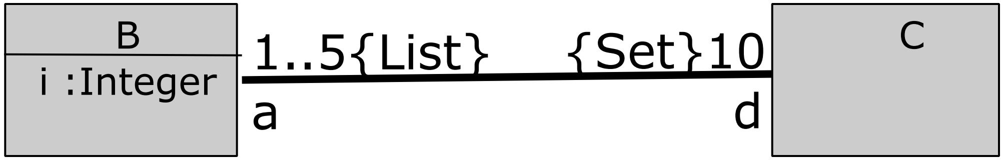

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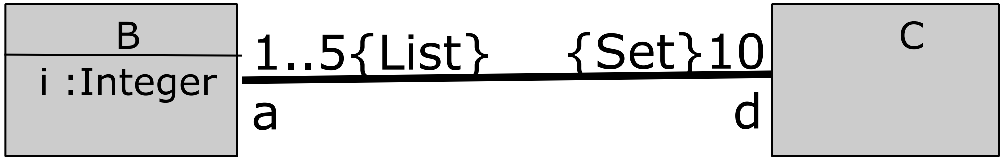

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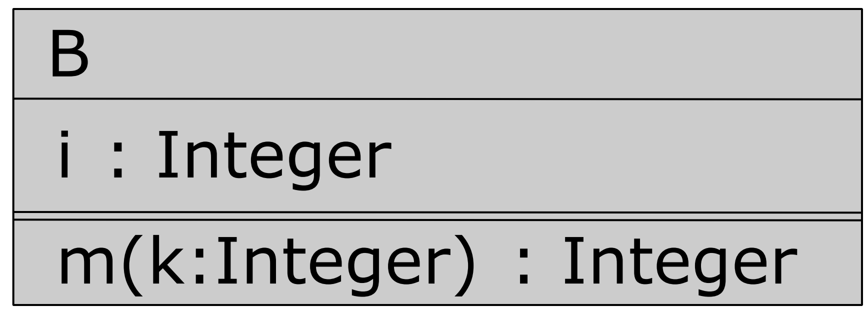

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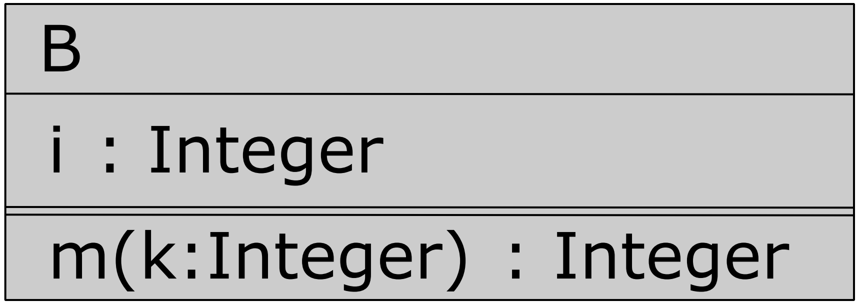

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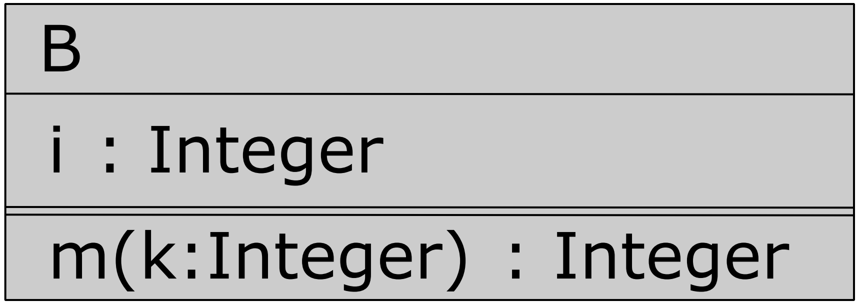

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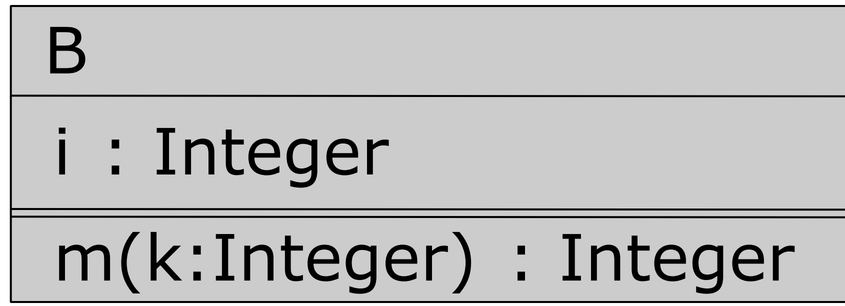

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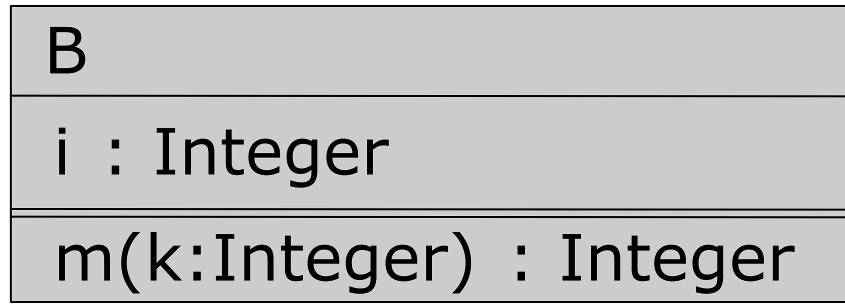

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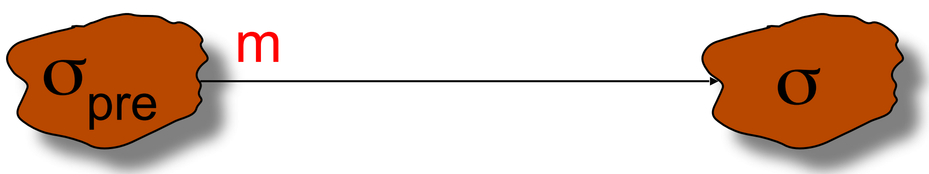

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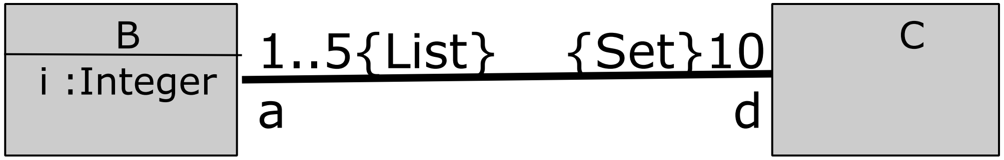

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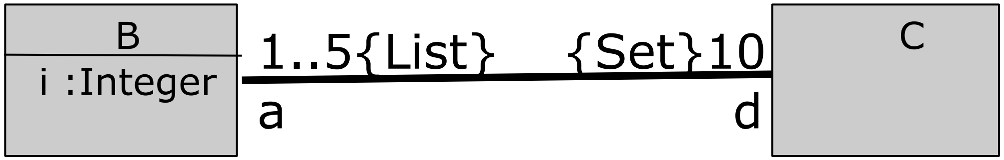

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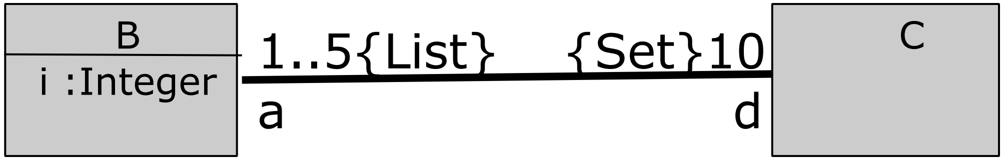

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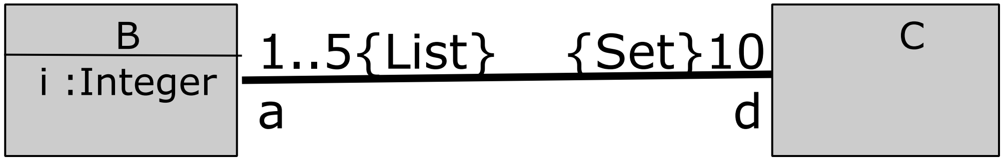

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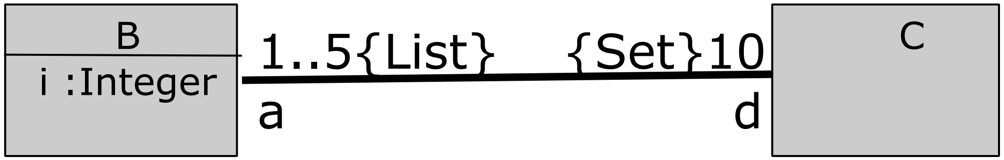

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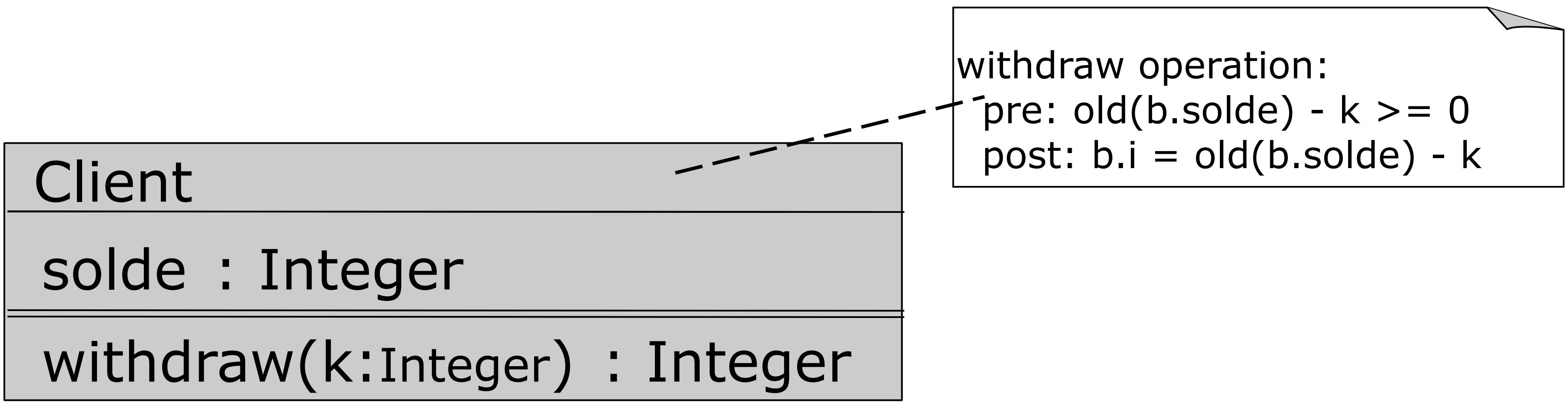

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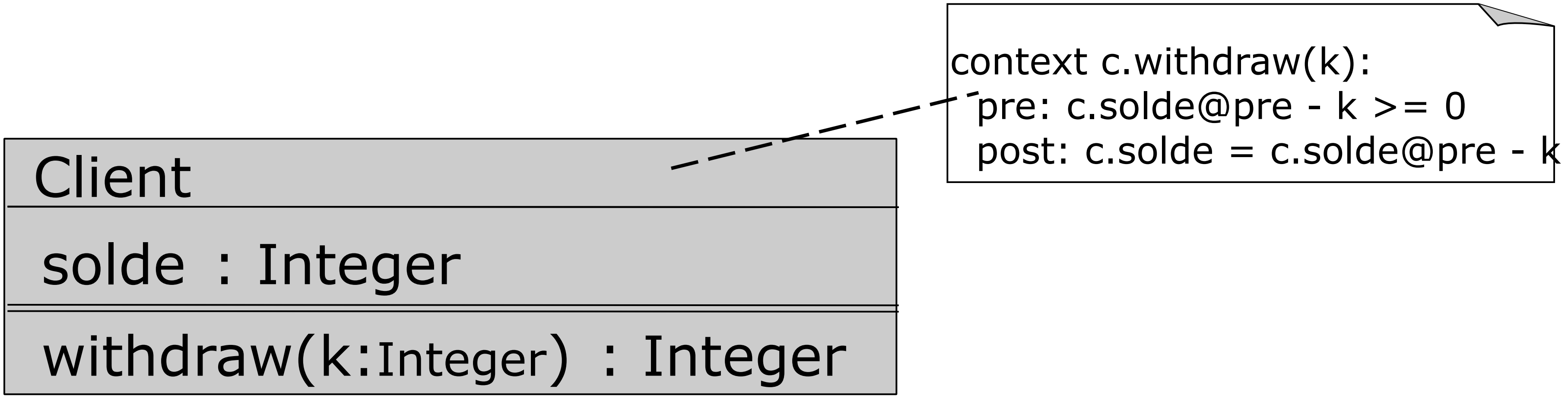
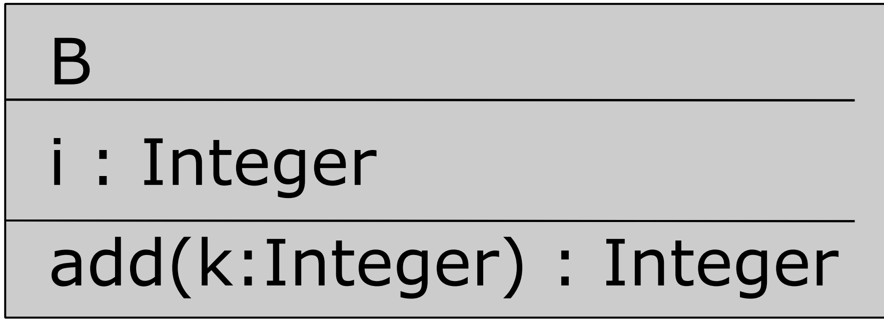
- ... or like this (OCL-ish):



Operations in UML and MOAL Contracts

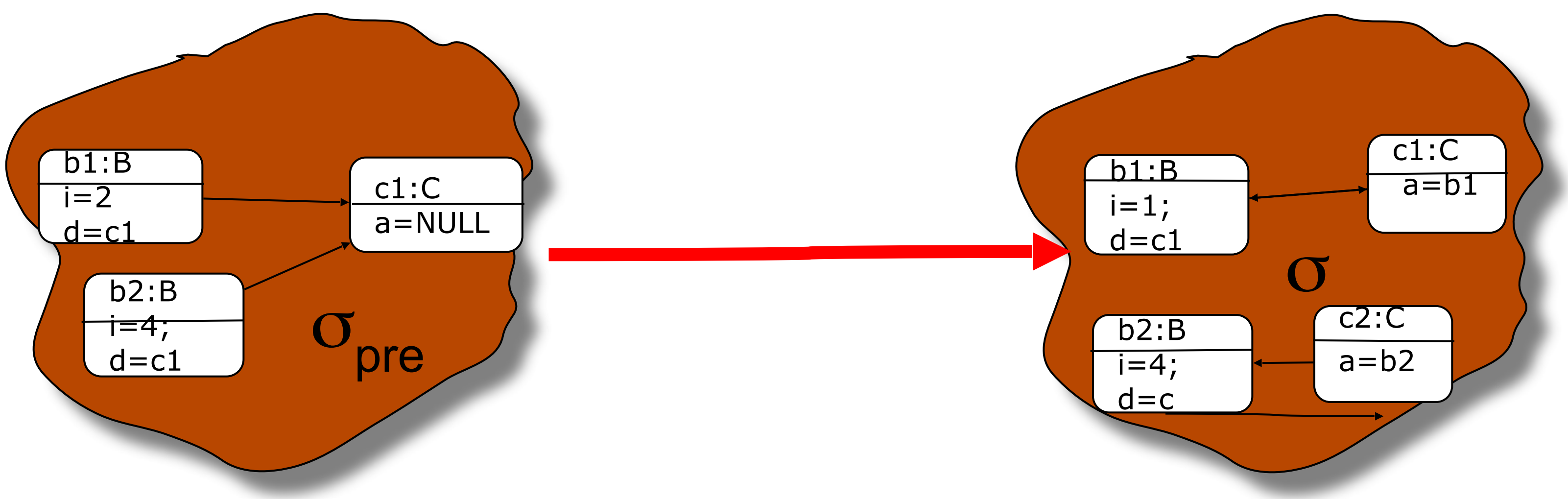
- This appears for the first time in so-called contracts for (Class-model) methods:



- 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.

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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    - raise an exception
      (recommended in Java Programmer Guides
      for public methods to increase robustness)

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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.
  - any transition is permitted that satisfies the post-condition (provided that the pre-condition is true)

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

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$$pre_m(b1,a_1, ..., a_n)\ (\sigma_{pre})$$

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    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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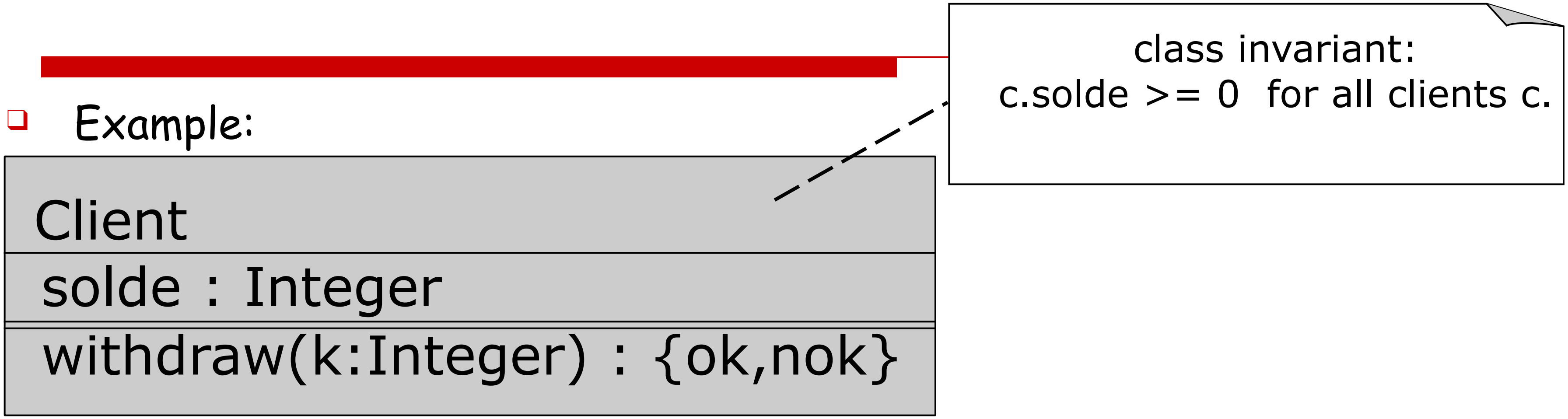

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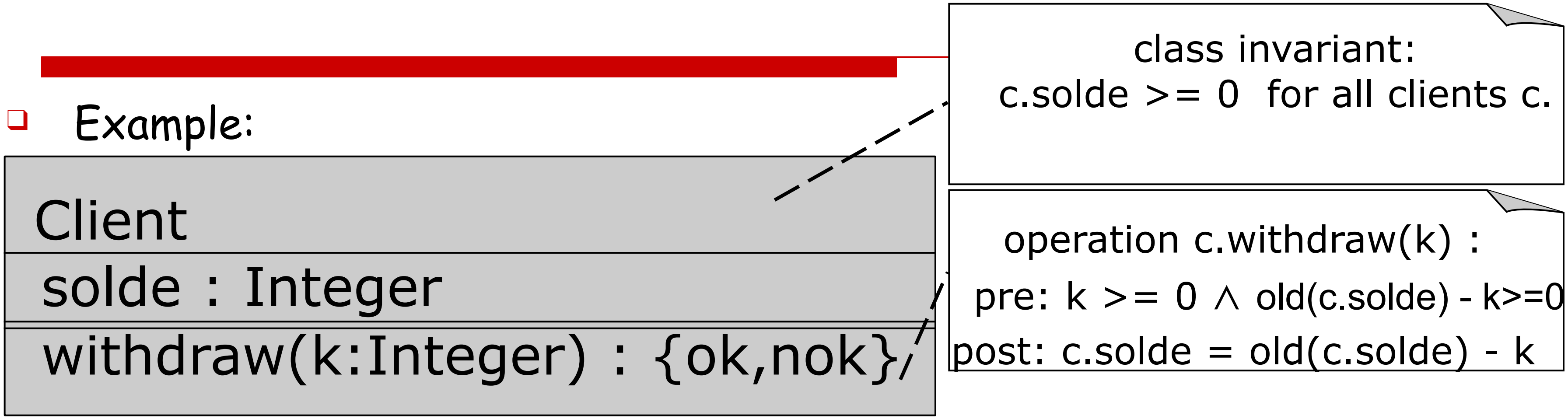

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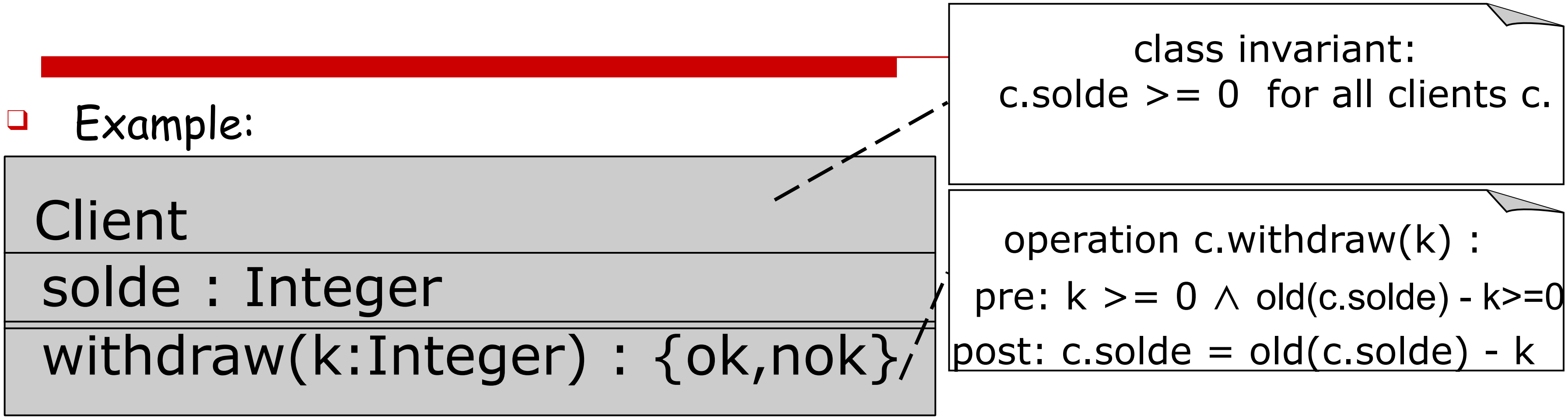

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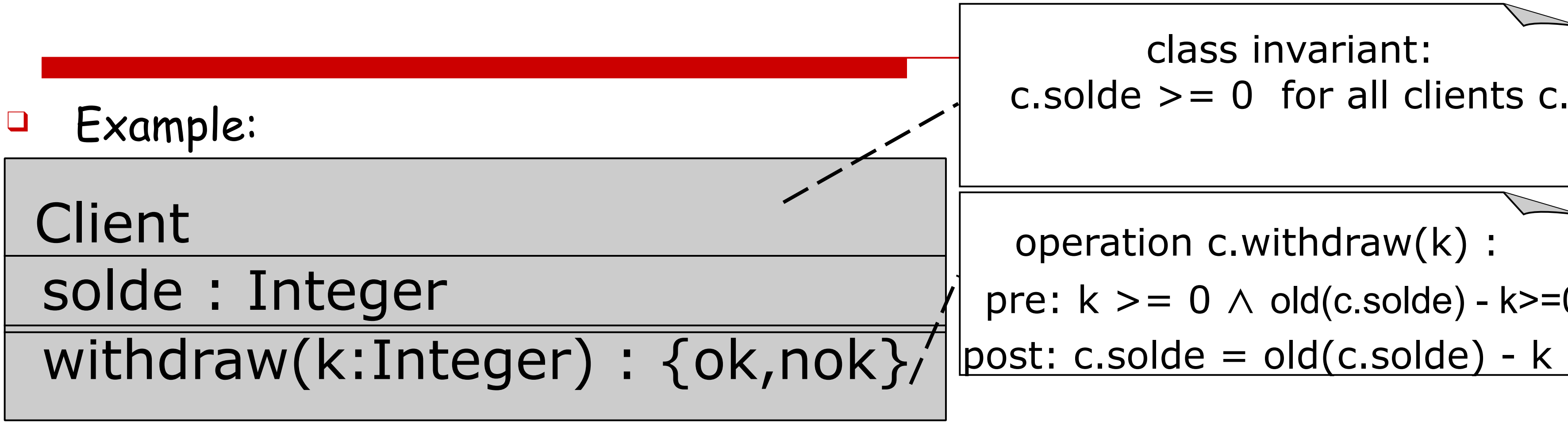

- definition $inv_{Client}(\sigma) \equiv$
  $\forall c \in Client(\sigma).\ 0 \leq c.solde(\sigma)$

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solde : Integer
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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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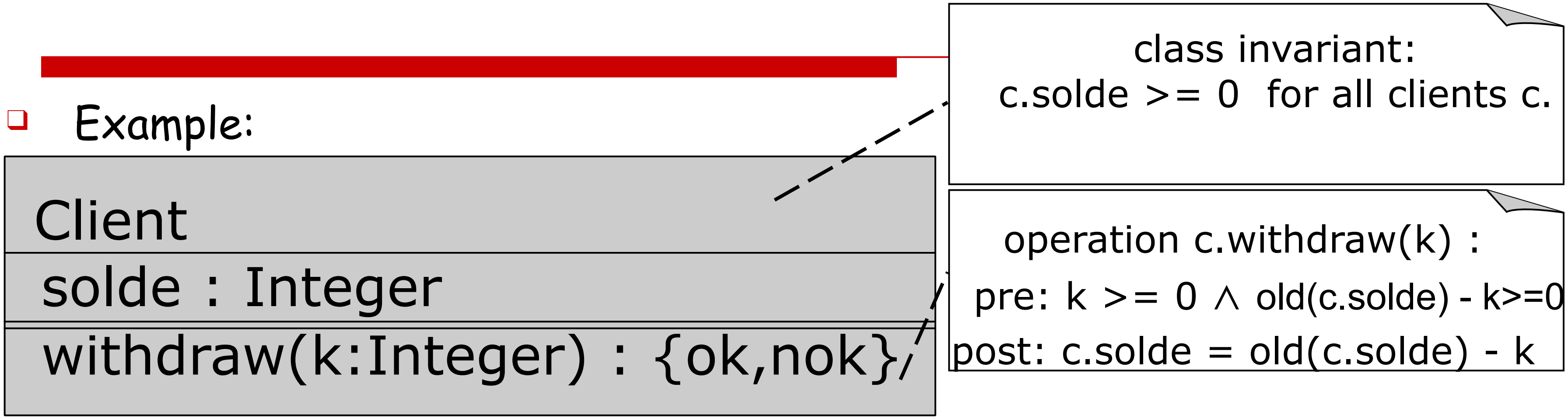

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etc.

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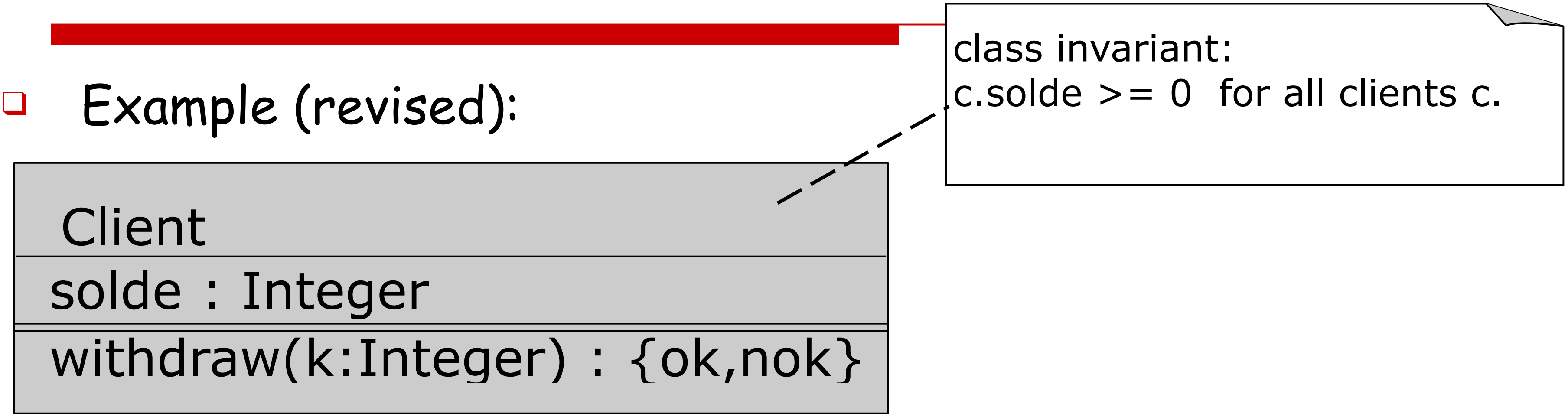

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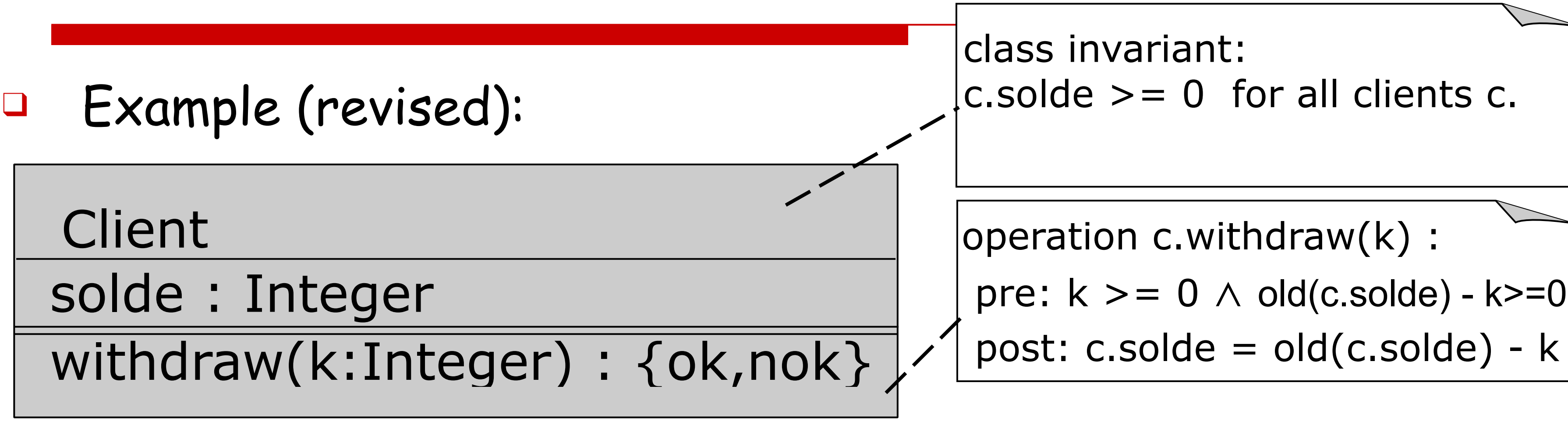

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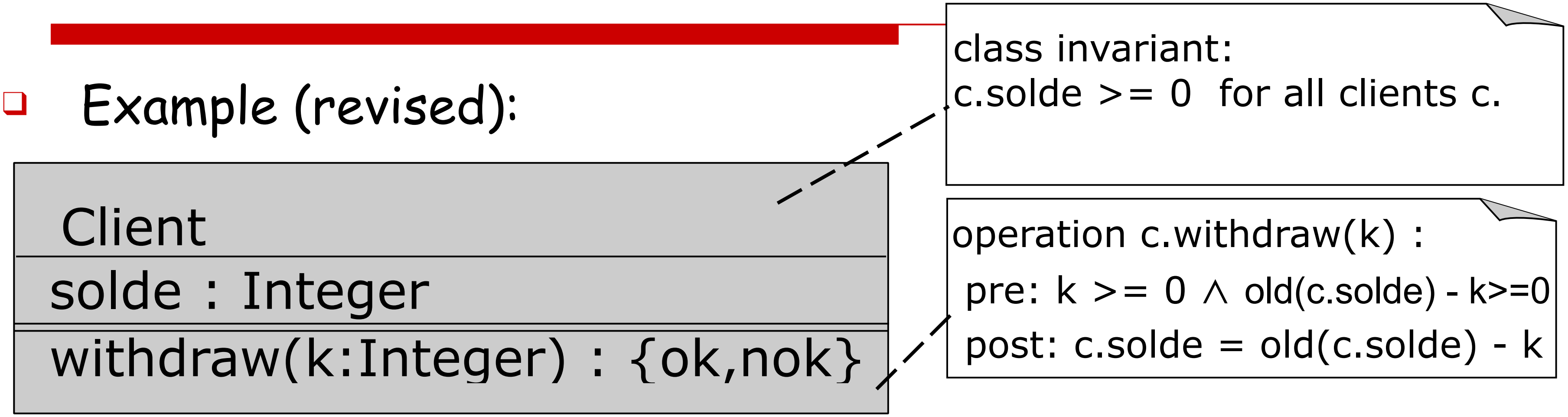

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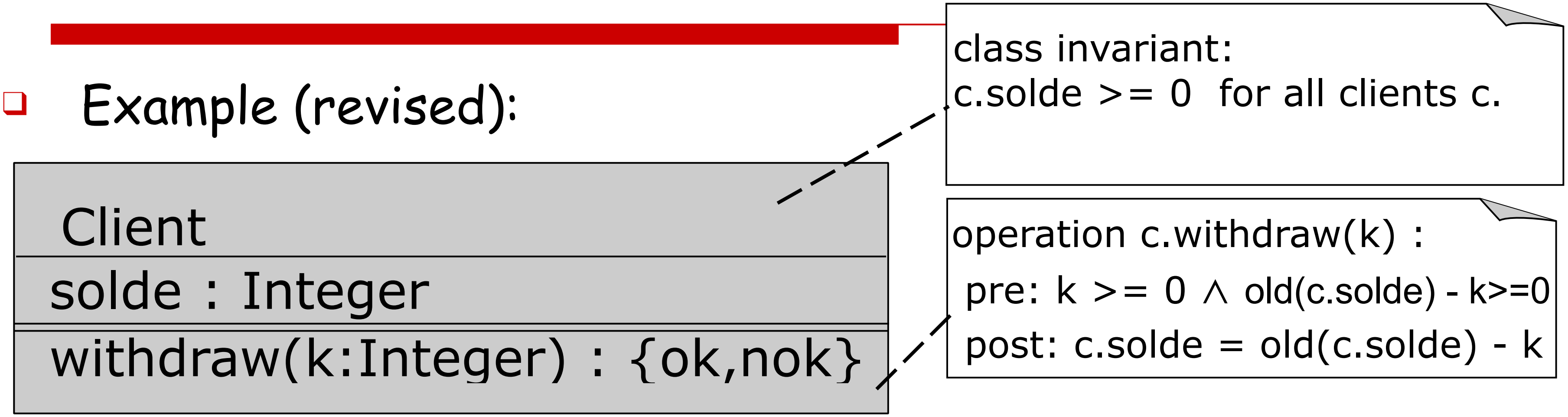

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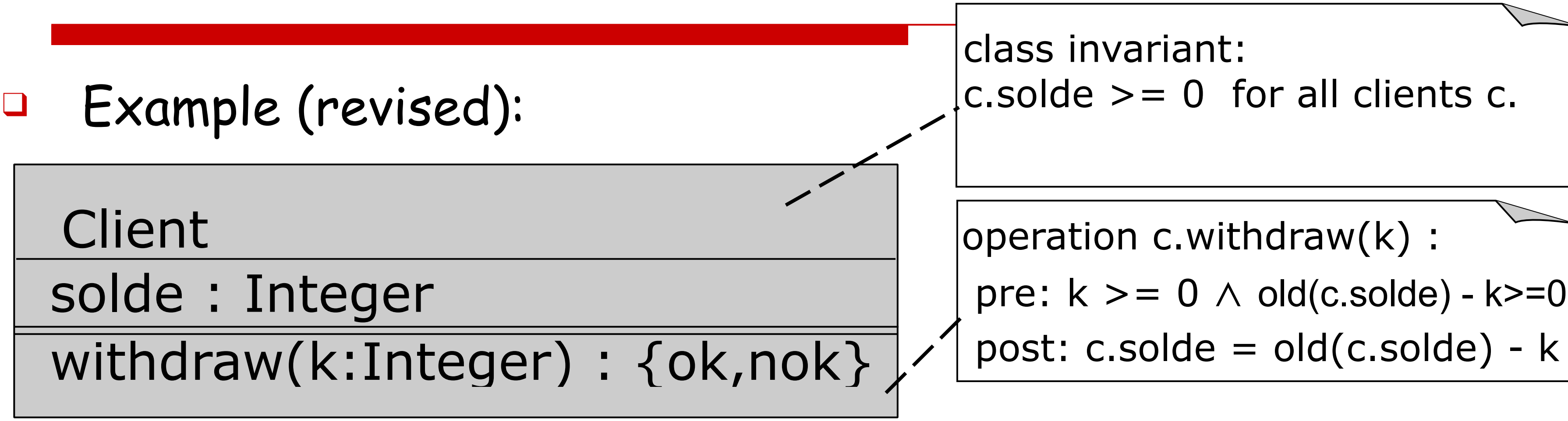

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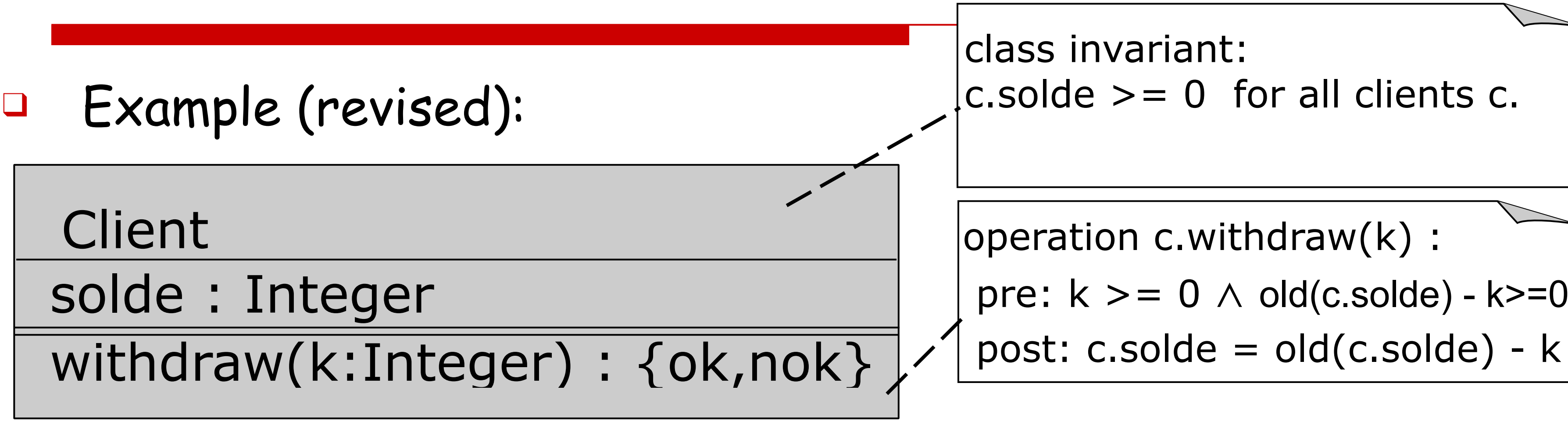

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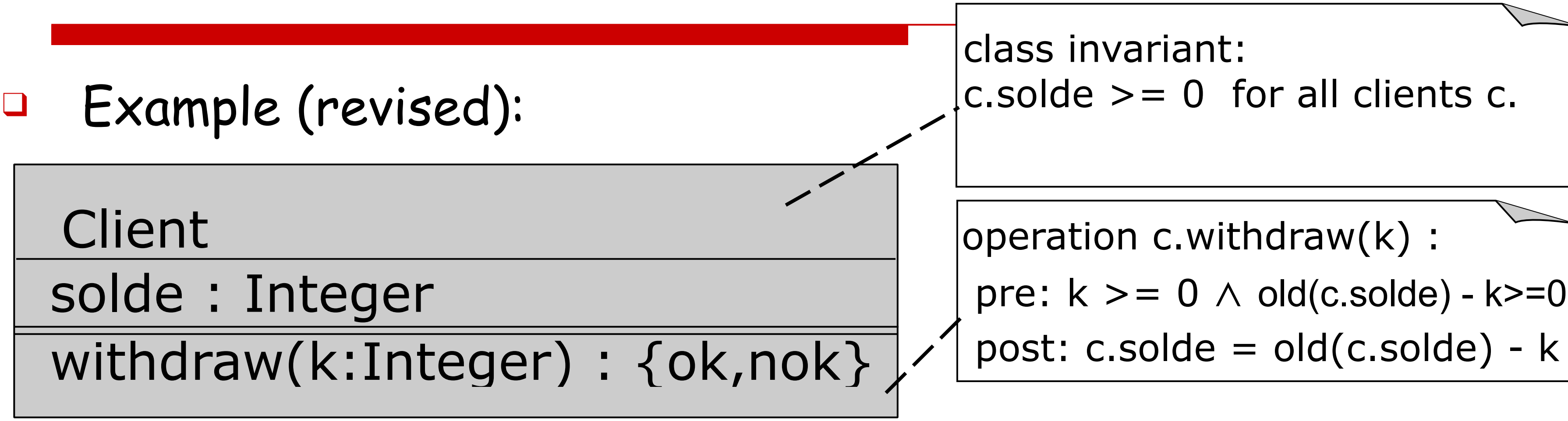

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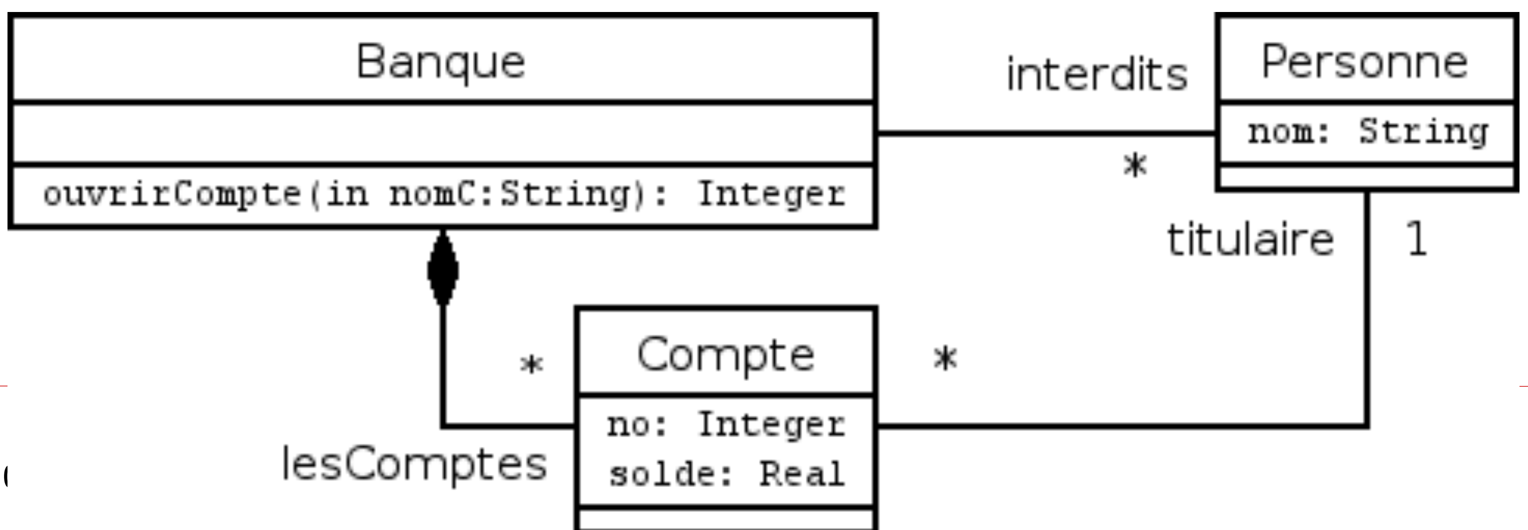

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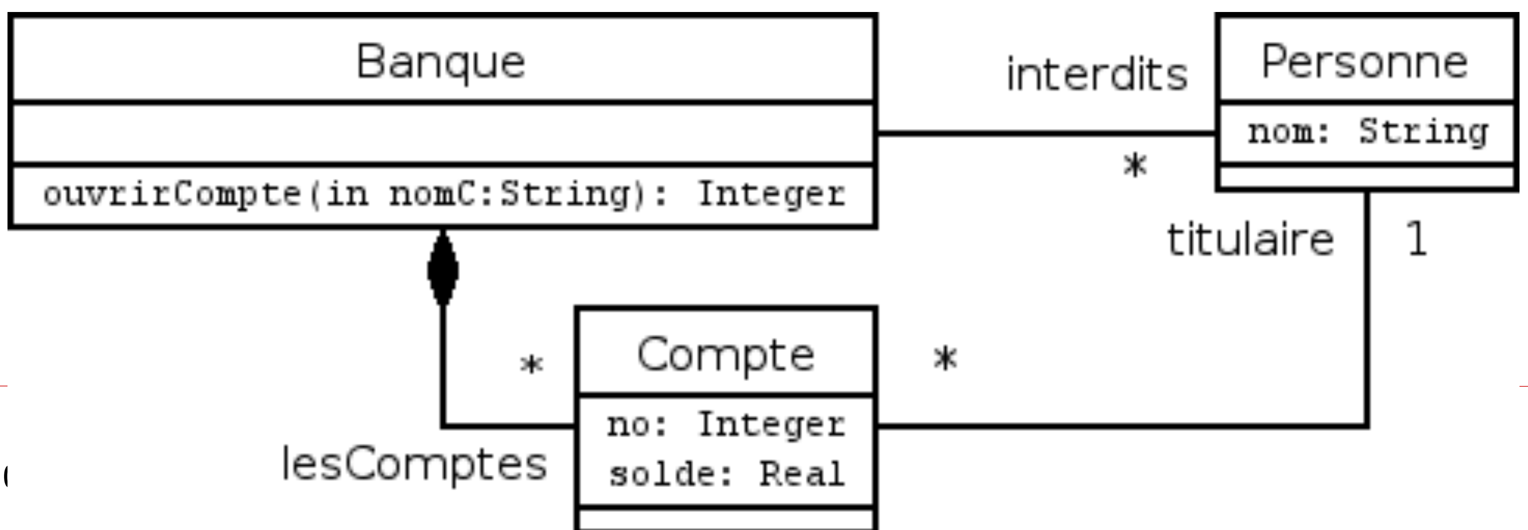

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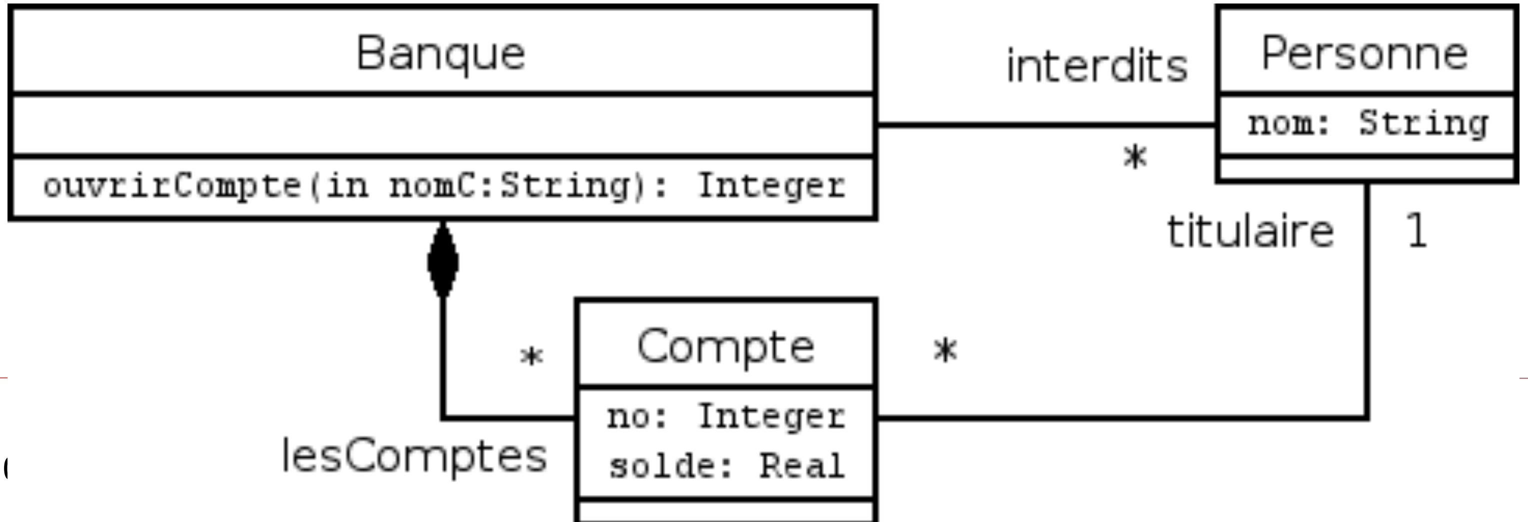
- no more overdraft than 200 EUR



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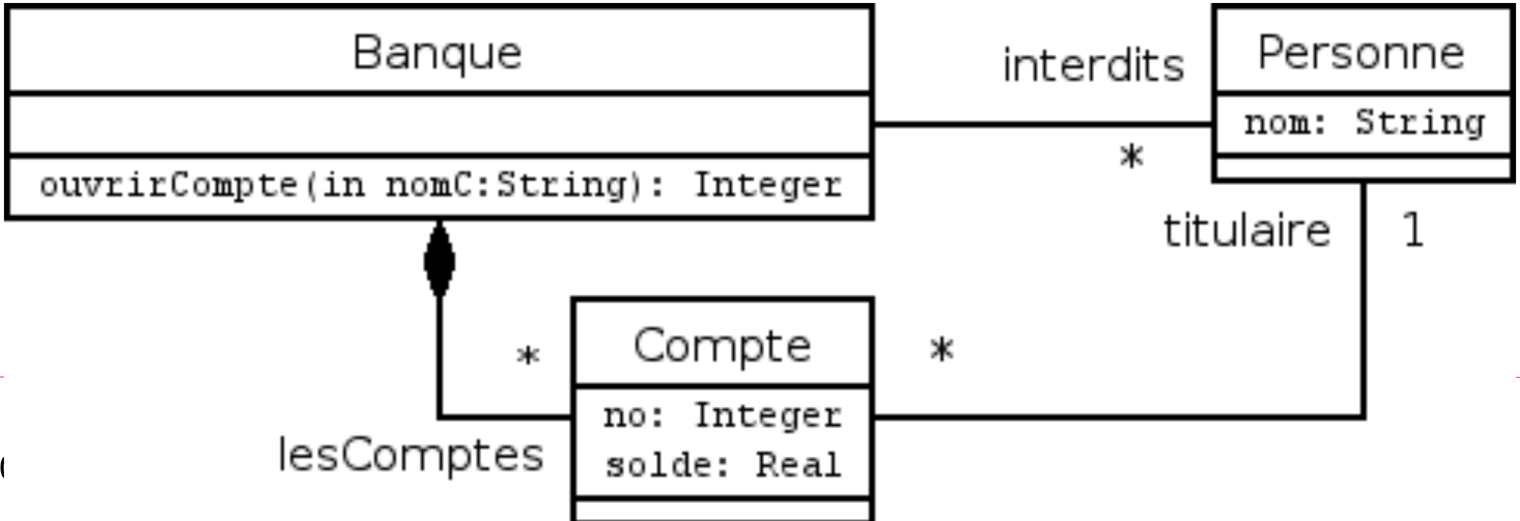

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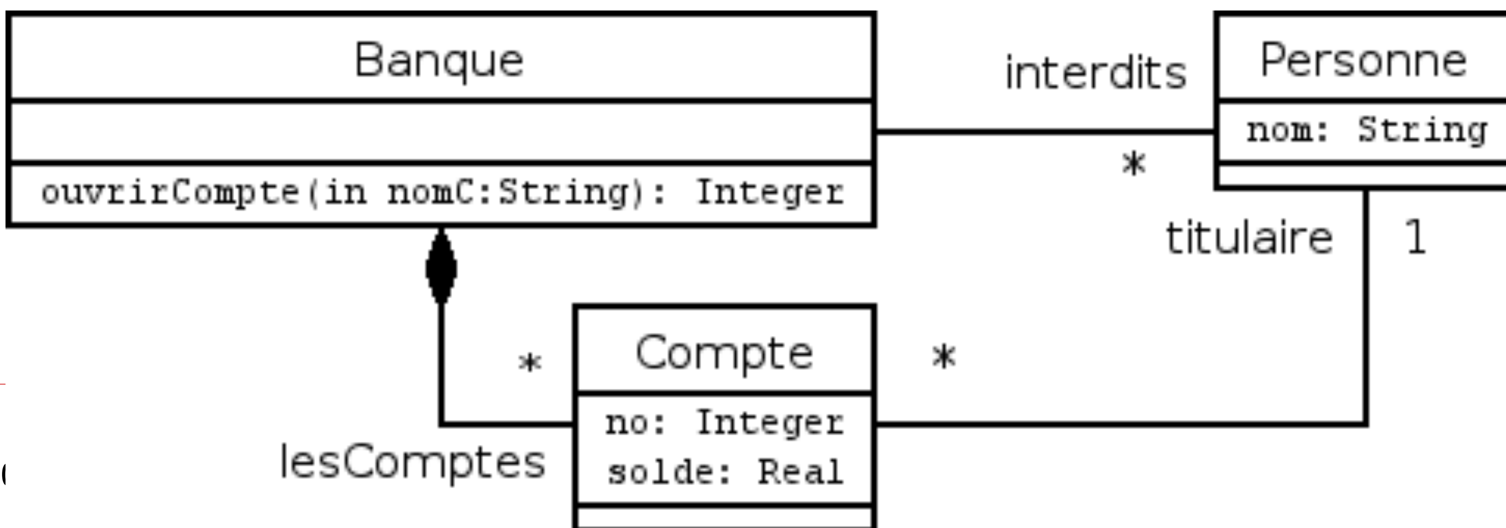
- there is a present of 15 euros in the initial account
- account numbers must be distinct.



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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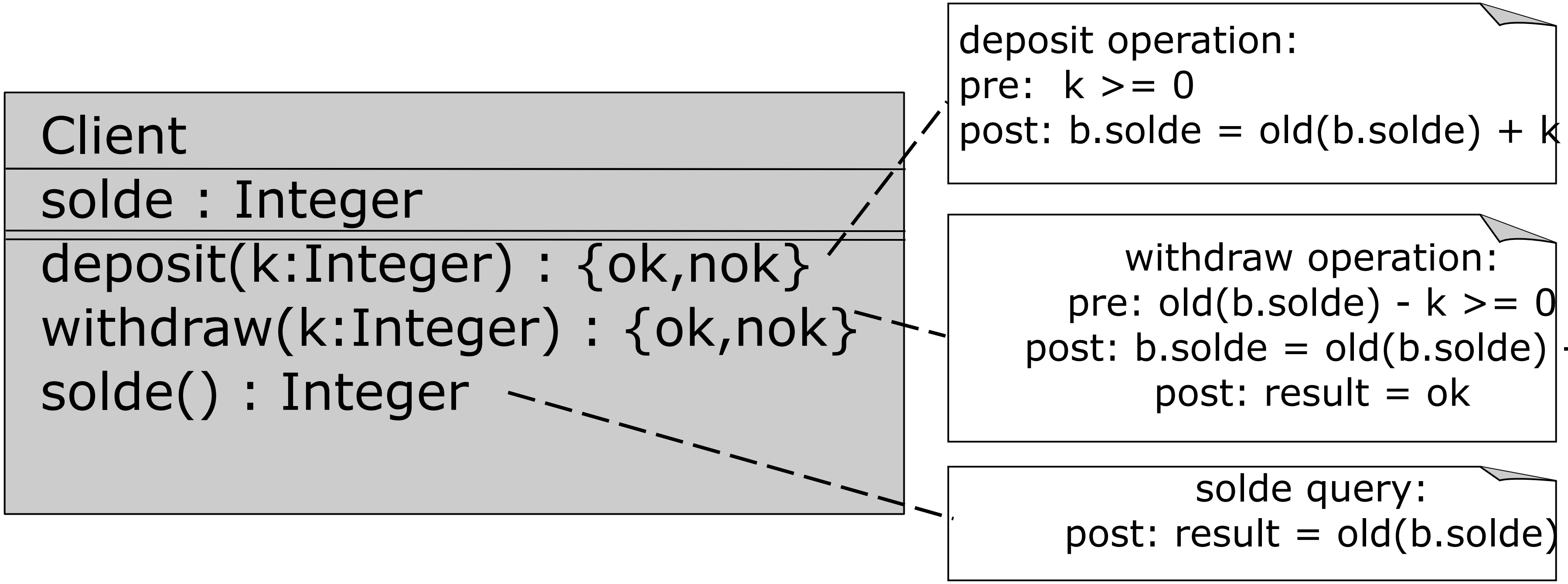
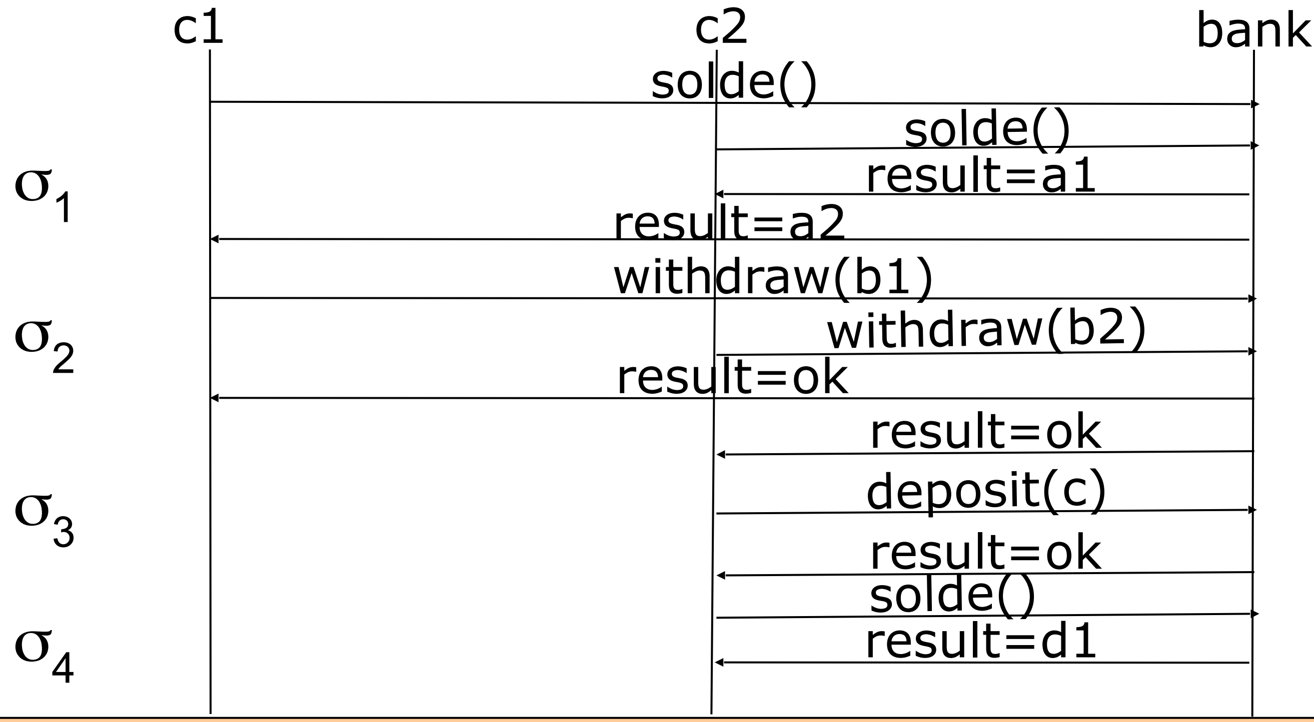


Operations in UML and MOAL

- Abstract Concurrent Test Scenario:



assert c1.solde(σ_4)=a2-b1 $\wedge$ b1 ≥ 0 $\wedge$ a2 ≥ b1

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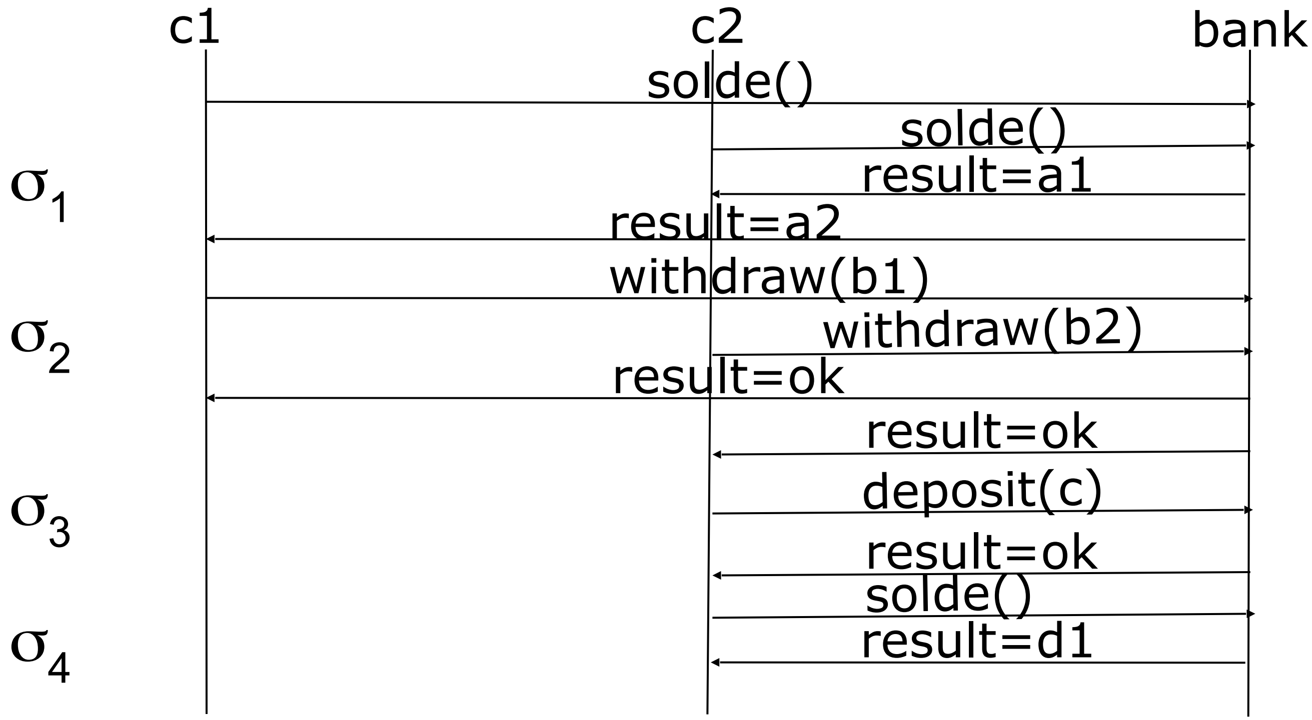

Any instance of b1 and a1 is a test ! This is a „Test Schema" !
Note: b1 can be chosen dynamically during the test !

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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.