L3 Mention Informatique
Parcours Informatique et MIAGE

Génie Logiciel Avancé

UML/MOAL II

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Plan of the Chapter

- Semantics of MOAL Constraints
  - Class Invariants
  - Pre- and Post-Conditions
- Other applications of MOAL:
  - ... in sequence diagrams
  - ... in state machines

Recall:

- MOAL is logics used to make UML diagrams more precise
- it comprises
  - typed sets, lists, and some base types
  - classes and objects from UML class diagrams
  - subtyping and casts
  - a semantics for path navigation and associations.

Recall: Object Attributes

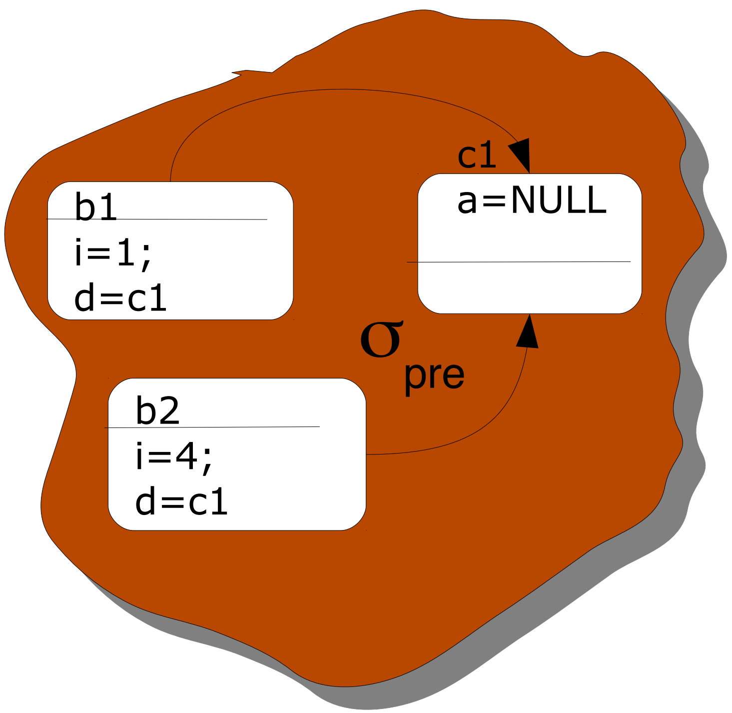
- Objects represent structured, typed memory in a state σ. They have attributes.

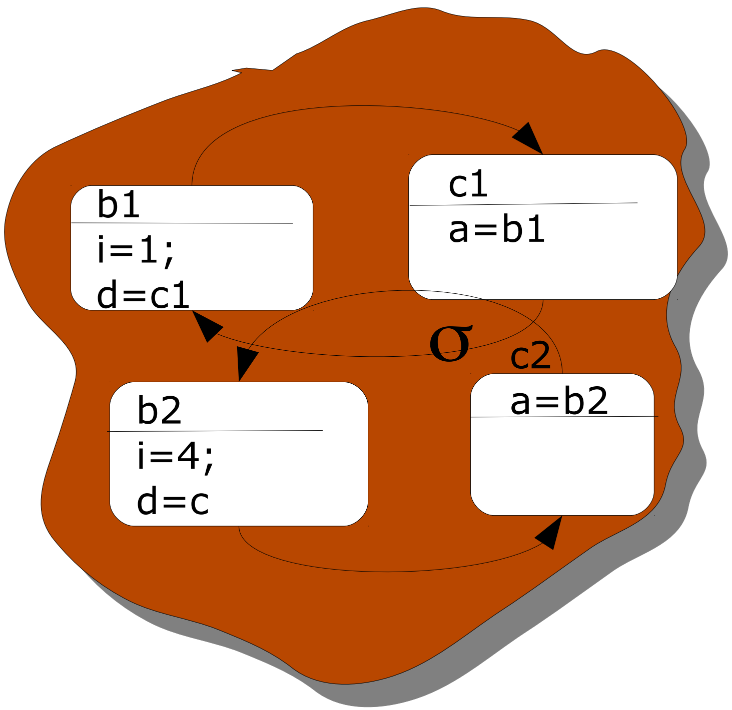
  They can have class types.

- Reminder: In class diagrams, this situation is represented traditionally by Associations (equivalent)

Syntax and Semantics of Object Attributes

- Example:
  attributes of class type in states σ' and σ.





Recall Object Attributes

- Object assessor functions are „dereferentiations of pointers in a state"
- Accessor functions of class type are strict wrt. NULL.
  - `NULL.d = NULL`
    `NULL.a = NULL`
  - Recall that navigation expressions depend on their underlying state:

    $\texttt{b1.d}(\sigma_{pre})\texttt{.a}(\sigma_{pre})\texttt{.d}(\sigma_{pre})\texttt{.a}(\sigma_{pre}) = \text{NULL}$

    $\texttt{b1.d}(\sigma)\texttt{.a}(\sigma)\texttt{.d}(\sigma)\texttt{.a}(\sigma) = \text{b1}$!!!

(cf. Object Diagram pp 28)

Recall Object Attributes

- Object assessor functions are „dereferentiations of pointers in a state“
- Accessor functions of class type are strict wrt. NULL.
  - `NULL.d = NULL`
    `NULL.a = NULL`
  - The σ convention allows to write :

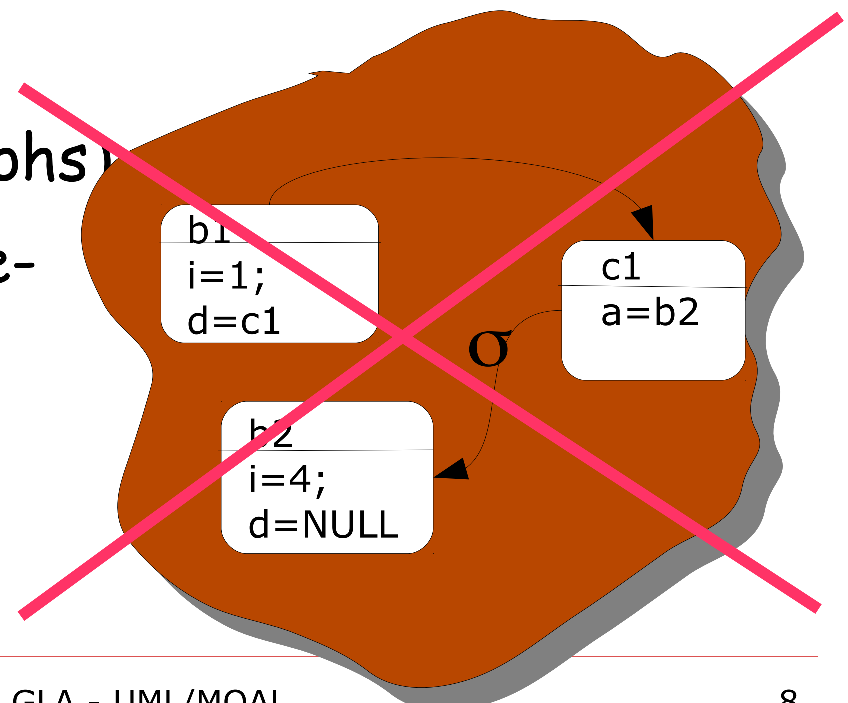
    old(`b1.d.a.d.a`) = NULL
    `b1.d.a.d.a` = b1 !!!

(cf. Object Diagram pp 28)

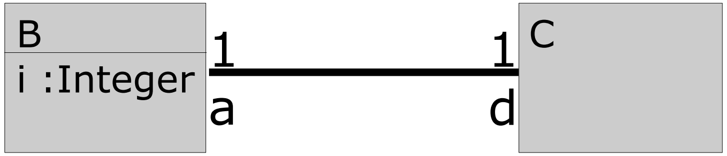
Recall Object Attributes

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

  Thus, states (object-graphs) of this form do not represent an association:



Recall Object Attributes



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

> - definition $ass_{B.d.a} \equiv \forall x \in B.\ x.d.a = x$
> - definition $ass_{C.a.d} \equiv \forall x \in C.\ x.a.d = x$

Recall Object Attributes

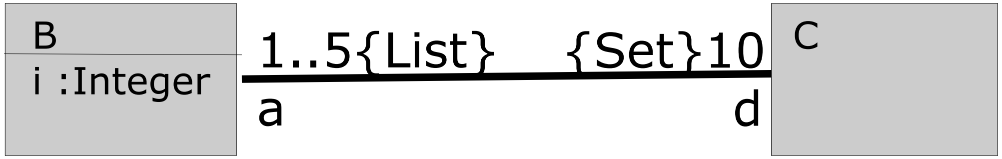
- Attibutes can be List or Sets of class types:

- Reminder: In class diagrams, this situation is represented traditionally by Associations (equivalent)

- In analysis-level Class Diagrams, the type information is still ommitted; due to overloading of $\forall x \in X.\ P(x)$ etc. this will not hamper us to specify …

Recall Object Attributes

- Cardinalities in Associations can be translated canonically into MOCL invariants:



- $\text{definition } card_{B.d} \equiv \forall x \in B.\ |x.d| = 10$

- $\text{definition } card_{C.a} \equiv \forall x \in C.\ 1 \leq |x.a| \leq 5$

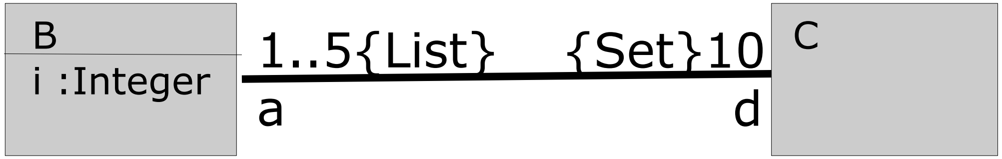
Strictness of Collection Attributes

- Accessor functions are defined as follows for the case of NULL:

  - NULL.d = {} -- mapping to the neutral element
  - NULL.a = [] -- mapping to the neural element.

Syntax and Semantics of Object Attributes

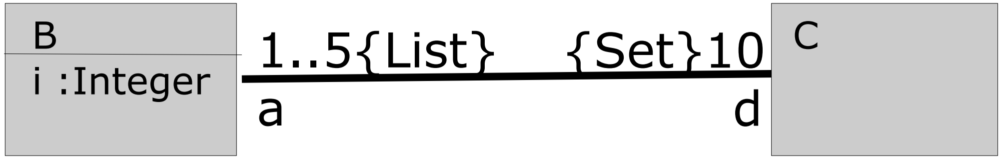
- Cardinalities in Associations can be translated canonically into MOCL invariants:



- definition $card_{B.d} \equiv \forall x \in B.\ |x.d| = 10$
- definition $card_{C.a} \equiv \forall x \in C.\ 1 \leq |x.a| \leq 5$

Integrity of Collection Object Attributes

- The corresponding association integrity constraints for the *-*-case are:



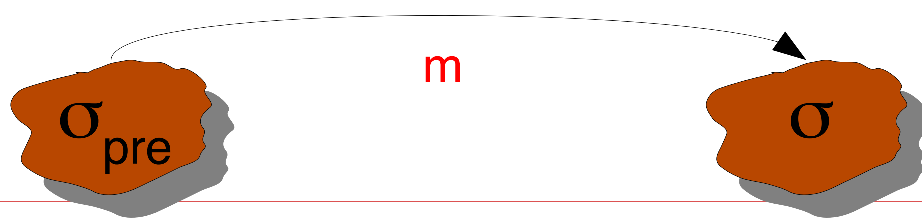
- $\texttt{definition ass}_{B.d.a} \equiv \forall x \in B.\ x \in x.d.a$
- $\texttt{definition ass}_{C.a.d} \equiv \forall x \in C.\ x \in x.a.d$

Operations in UML and MOAL

- Many UML diagrams talk over a sequence of states (not just individual global states)
- This appears for the first time in so-called contracts for (Class-model) methods:

B
i : Integer
m(k:Integer) : Integer

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



Pré et post-conditions (piqué de Delphine !)

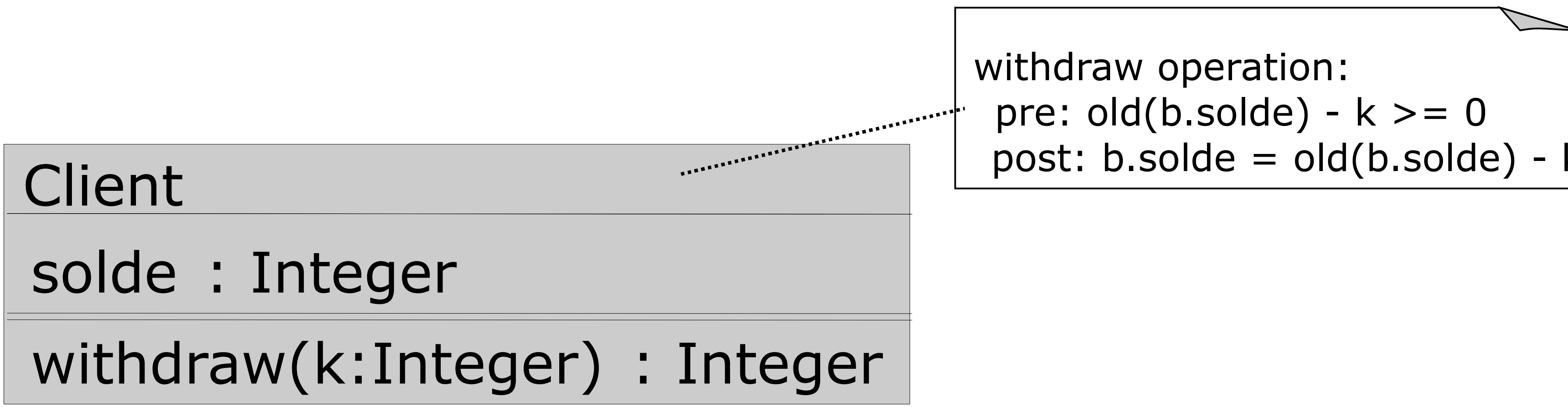
Principe de la conception par contrats : contrat entre l'opération appelée et son appelant

- 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

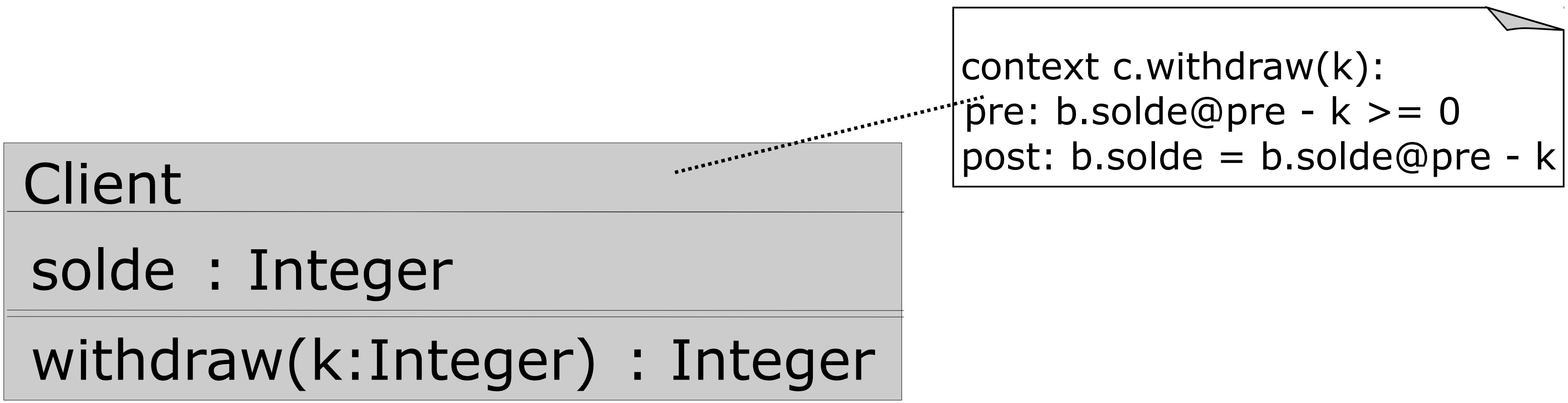
Operations in UML and MOAL

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



Operations in UML and MOAL

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



Operations in UML and MOAL Contracts

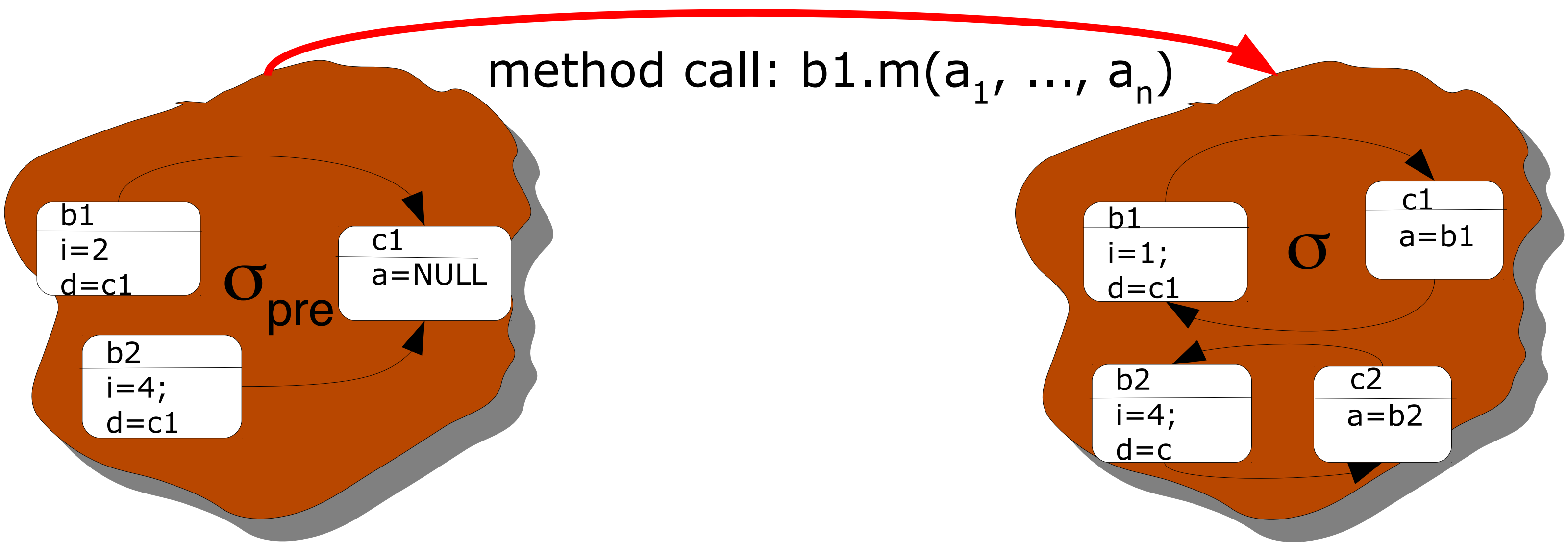
- This appears for the first time in so-called contracts for (Class-model) methods:

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.

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).



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)

Syntax and Semantics of MOAL Contracts

- Consequence:
  - 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)

Syntax and Semantics of MOAL Contracts

- Consequence:
  - The semantics of a method call:

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

is thus:

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

  - Note that moreover all global class invarants have to be added for both pre-state σ_{pre} and post-state σ !

    For a succesful transition, the following must hold:

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

Syntax and Semantics of MOAL Contracts

- 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
∧ result = ok

- definition $\mathtt{inv}_{\mathtt{Client}}(\sigma) \equiv$
  $\forall c \in \mathtt{Client}(\sigma).\ 0 \leq c.\mathtt{solde}(\sigma)$
- definition $\mathtt{pre}_{\mathtt{withdraw}}(c, k)(\sigma) \equiv$
  $c \in \mathtt{Client}(\sigma) \wedge 0 \leq k \wedge 0 \leq c.\mathtt{solde}(\sigma)-k$
- definition $\mathtt{post}_{\mathtt{withdraw}}(c, k, result)(\sigma_{pre},\sigma) \equiv$
  $c \in \mathtt{Client}(\sigma_{pre}) \wedge result = ok$
  $\wedge\ c.\mathtt{solde}(\sigma) = c.\mathtt{solde}(\sigma_{pre})-k$

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.

Syntax and Semantics of MOAL Contracts

- Example (revised):

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
∧ result = ok

- definition $inv_{Client} \equiv \forall c \in Client.\ 0 \leq c.solde$
- definition $pre_{withdraw}(c, k) \equiv$
  $c \in Client \wedge 0 \leq k \wedge 0 \leq c.solde - k$
- definition $post_{withdraw}(c, k, result) \equiv$
  $c \in old(Client) \wedge result = ok$
  $c.solde = old(c.solde) - k \wedge$

MOAL convention!

Syntax and Semantics of MOAL Contracts

- Alternative Example:

Client

solde : Integer

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

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

operation c.withdraw(k) :
  pre: true
  post:
    if k >= 0 ∧ old(c.solde) - k>=0
    then c.solde = old(c.solde) - k
              ∧ result = ok
    else result = nok

What are the differences between these contracts?

Semantics of MOAL Contracts

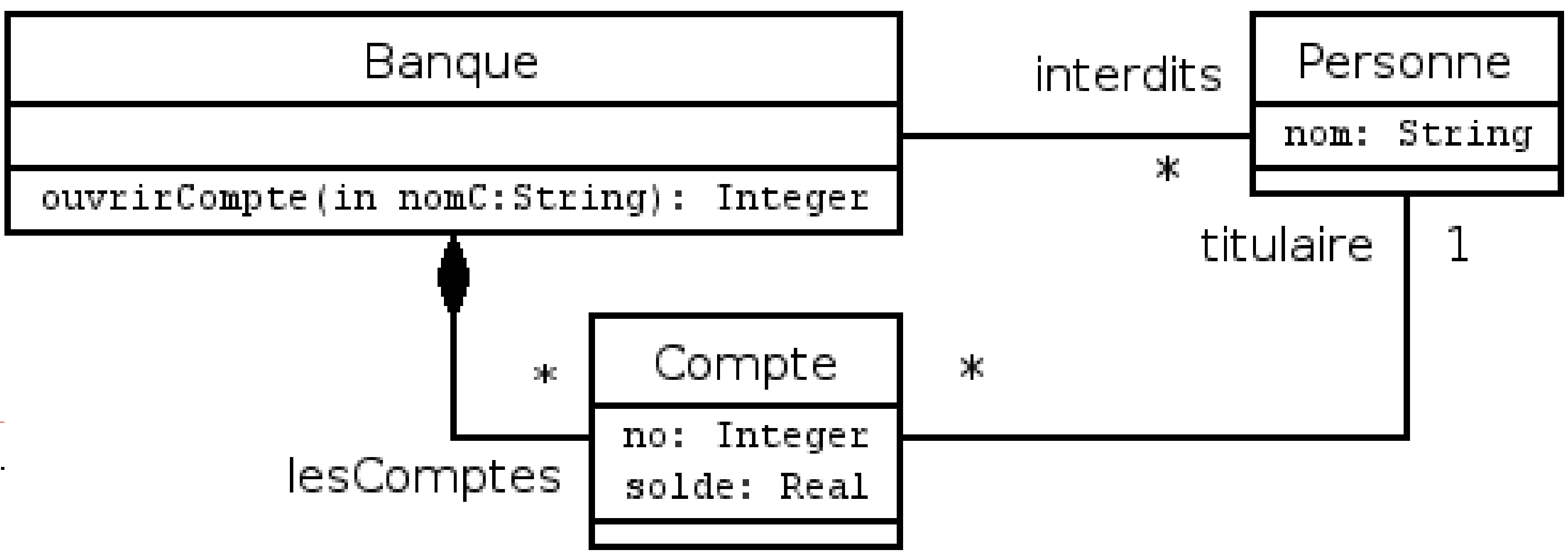
- Two predicates are helpful when defining contracts. They exceptionally refer to both (σ_{pre},σ)
  - isNew (p) (σ_{pre},σ) is true only if object p of class C does not exist in σ_{pre} but exists in σ
  - modifiesOnly(S)(σ_{pre},σ) is only true iff
    - all objects in σ_{pre} are except those in S identical in σ
    - all objects exist either in σ are or are contained in S

With this predicate, one can express : „and nothing else changes". It is also called «framing condition»

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.



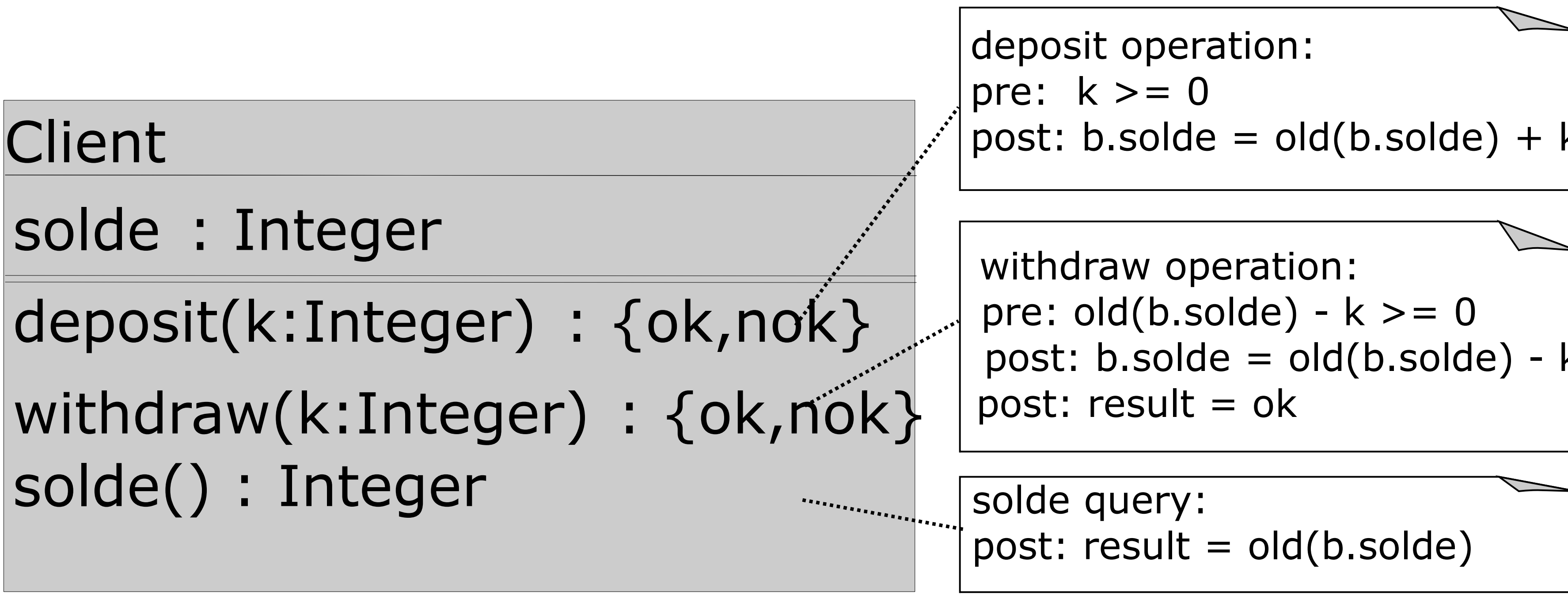
A Revision of the Example: Bank (2)

```
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})
```

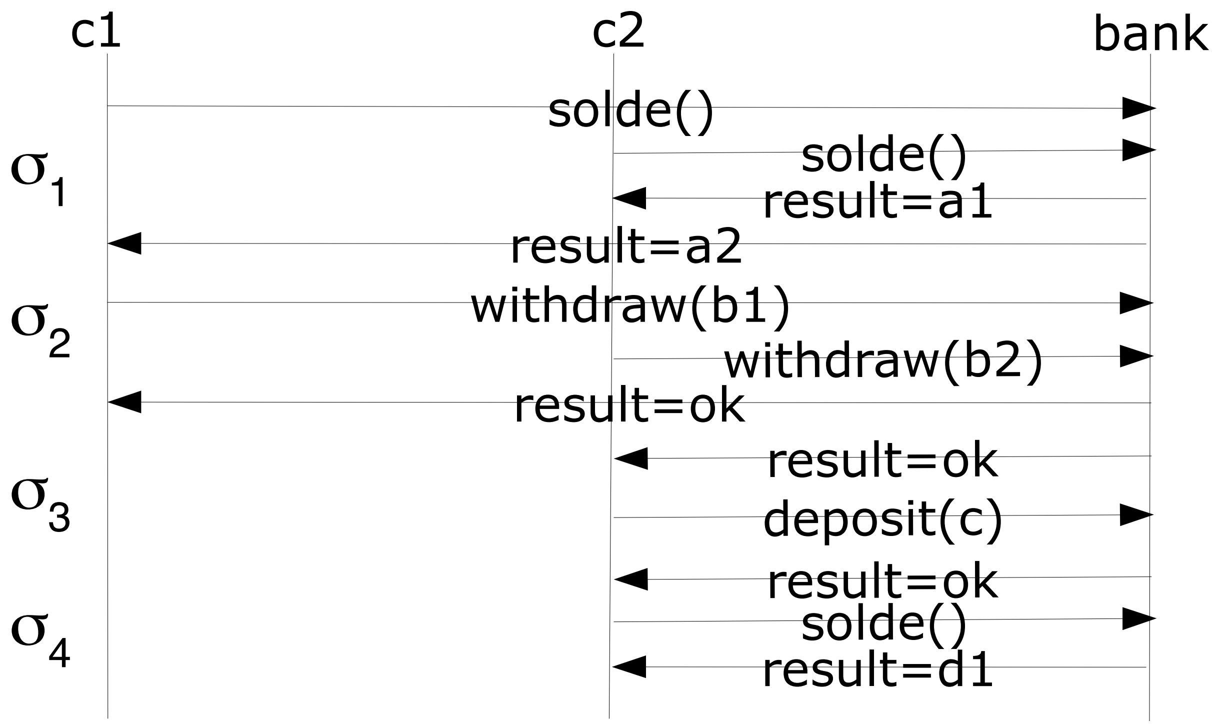
Operations in UML and MOAL

- Example:



Operations in UML and MOAL

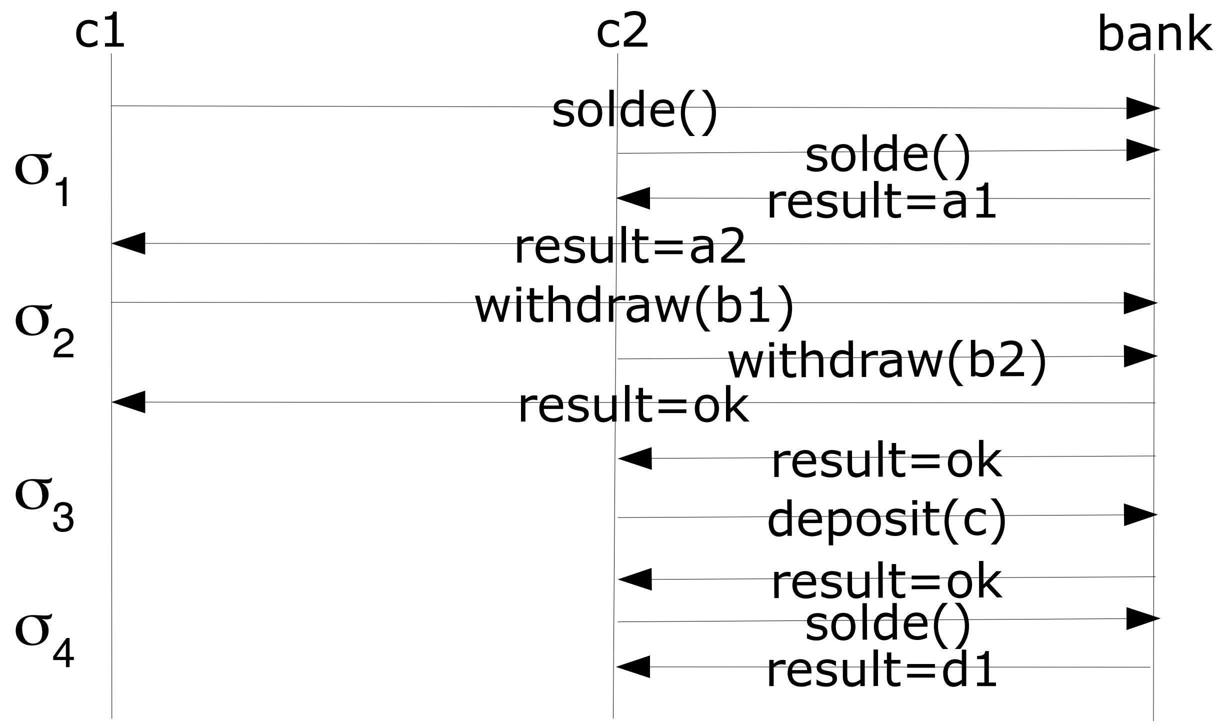
- Abstract Concurrent Test Scenario:



assert $c1.solde(\sigma_4)=a2-b1 \wedge b1 \geq 0 \wedge a2 \geq b1$

Operations in UML and MOAL

- Abstract Concurrent Test Scenario:



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

Summary

- MOAL makes the UML to a real, formal specification language
- 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.