A UML-Based Testing Approach

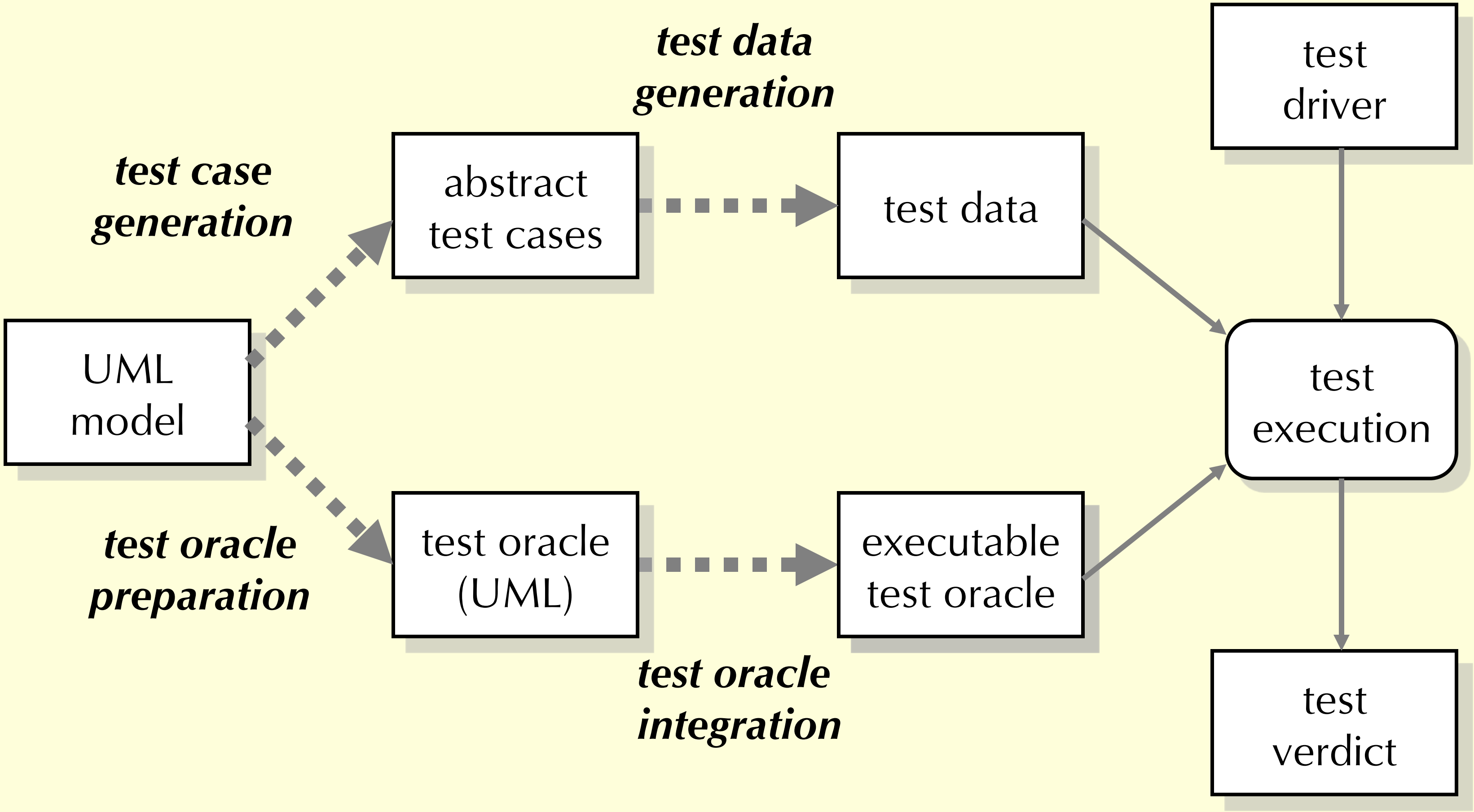
Using Sequence Diagrams, Statecharts, and OCL Constraints

Dehla Sokenou

TU Berlin

Softwaretechnik

Overview of the Test System



Agenda

- motivation
- UML-based testing
  - test case generation
  - test oracle
- aspects used for testing
- summary and outlook

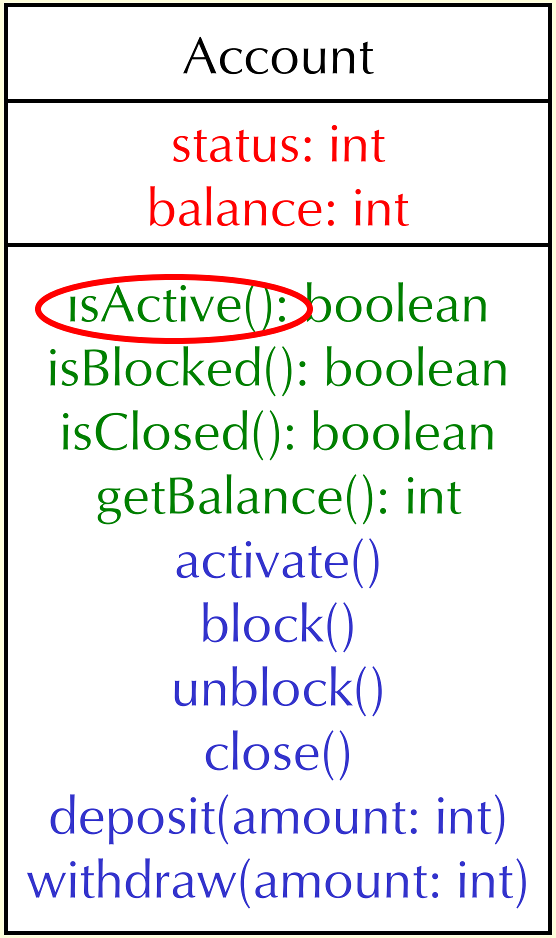
Motivation (1)

- open issue: testing object-oriented systems
  - problems: lack of specification, test code integration
- UML widely used for modeling and specifying object oriented systems
  - artifacts created in the analysis and design phases provide a good foundation for model-based testing
  - different views are modeled by using different diagram types
- ➢ our idea: *combining* several diagram types for testing
  - test case selection based on UML diagrams
  - main information from sequence diagrams
  - additional information from state diagrams (UML statecharts) and OCL constraints

Motivation (2)

- test code integration often expensive
  - test code needs privileged access to the SUT
  - version control
- ➢ our idea: using dynamic aspects for testing
  - code is integrated in non-invasive manner
  - aspects have privileged access to the adapted system

Example: Bank Account

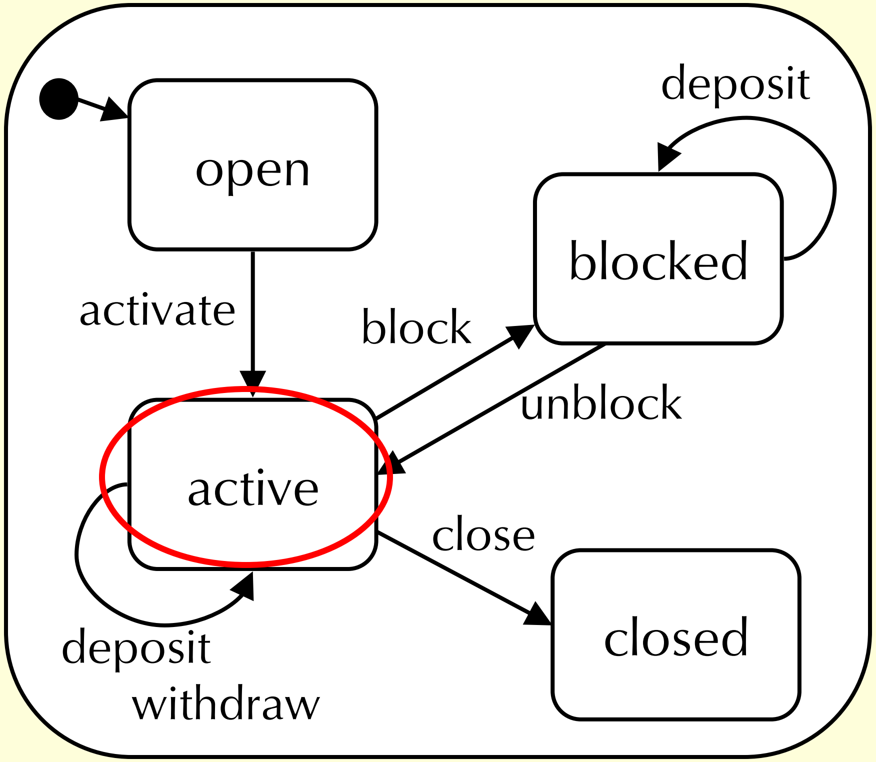


Account

status: int
balance: int

isActive(): boolean
isBlocked(): boolean
isClosed(): boolean
getBalance(): int
activate()
block()
unblock()
close()
deposit(amount: int)
withdraw(amount: int)

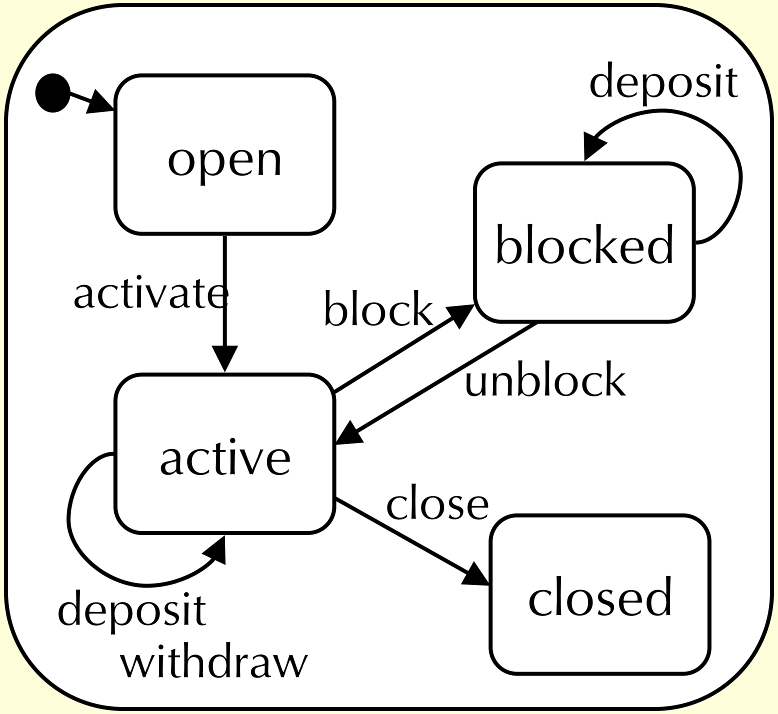
protocol state machine



open
activate
active
deposit
withdraw
block
unblock
blocked
deposit
close
closed

Protocol State Machines

- life cycle of objects
- call events
- no associated actions
- implicit preconditions
- observer methods

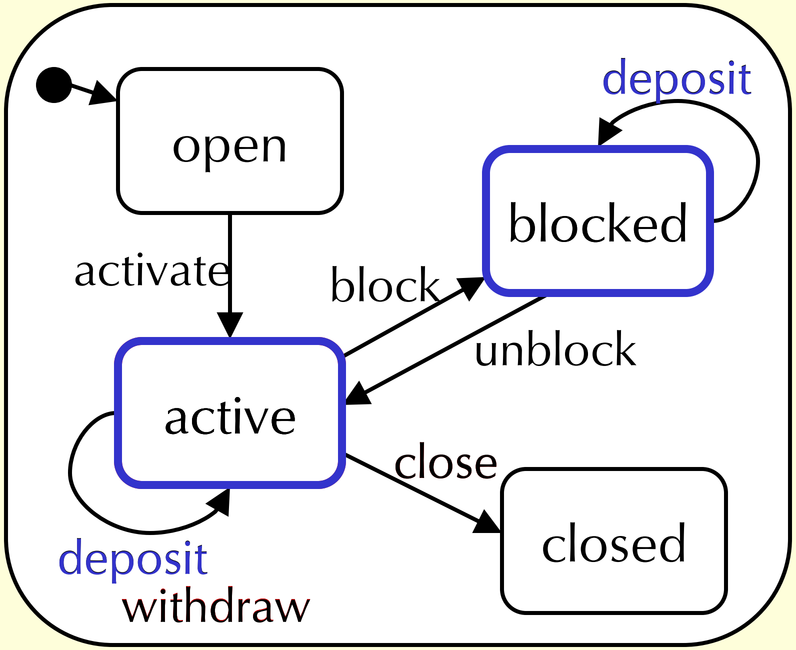


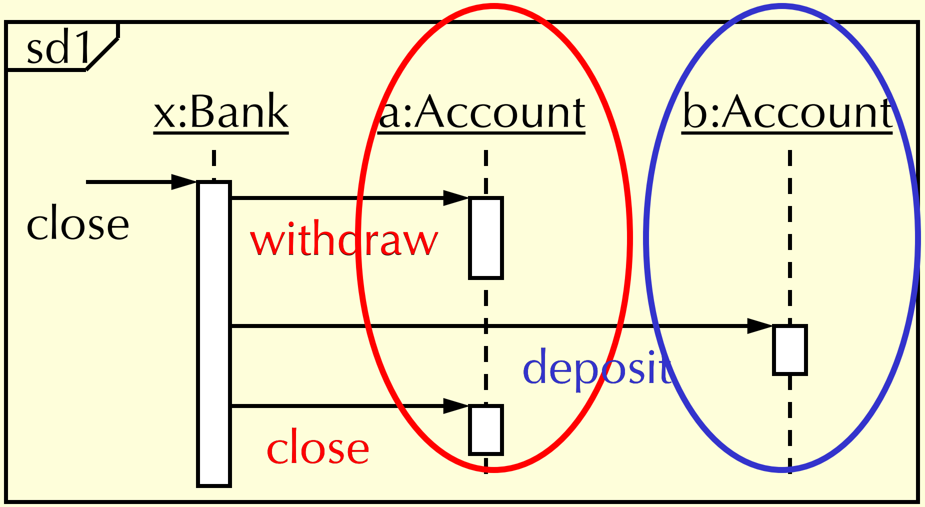
Test Case Generation

⇒ based on sequence diagrams and UML statecharts

- sequence diagrams
  - typical message sequences
  - communication between objects
- statecharts (*protocol state machines*)
  - life cycle of objects
- each sequence diagram = 1 test case
- additional information from statecharts
  - initialization of test sequences
  - (test oracle)

Test Case Generation: Example





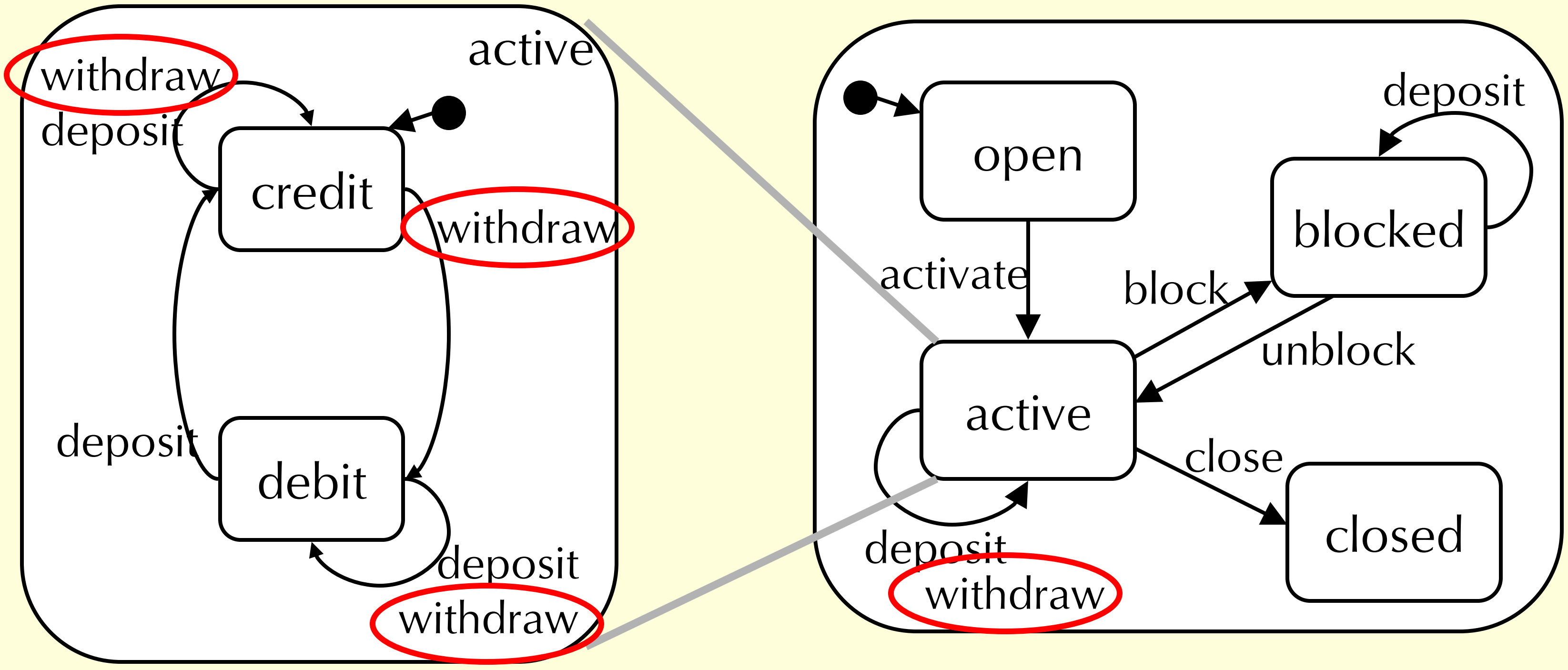
TF 1) x{new}; a{new}; a.activate; b{new}; b.activate; x.close

TF 2) x{new}; a{new}; a.activate; b{new}; b.activate; b.block; x.close

Test Oracle

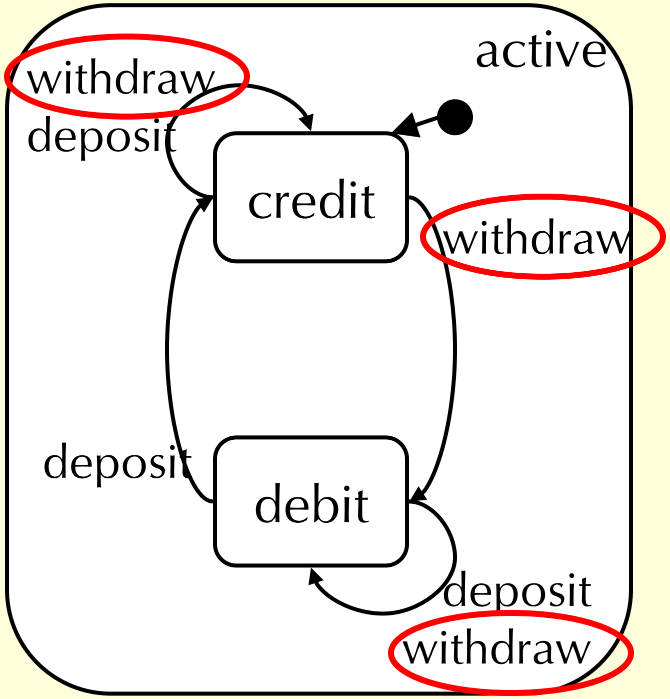
- statecharts
  - implicit pre and post conditions
  - valid states and transitions
- OCL constraints
  - explicit pre and post conditions
- 2 variants of combination
  1. integration of OCL pre and post conditions into statecharts
  2. derivation of pre and post conditions from statecharts and combination with explicit OCL constraints

Test Oracle: Example (1)



Test Oracle: Example (2)

- protocol state machine



- OCL: pre and post condition

context

Account::withdraw(amount:int)

pre: *true*

post: *self.balance =*

self.balance@pre - amount

Test Oracle: Example (3)

- statechart: pre and post condition

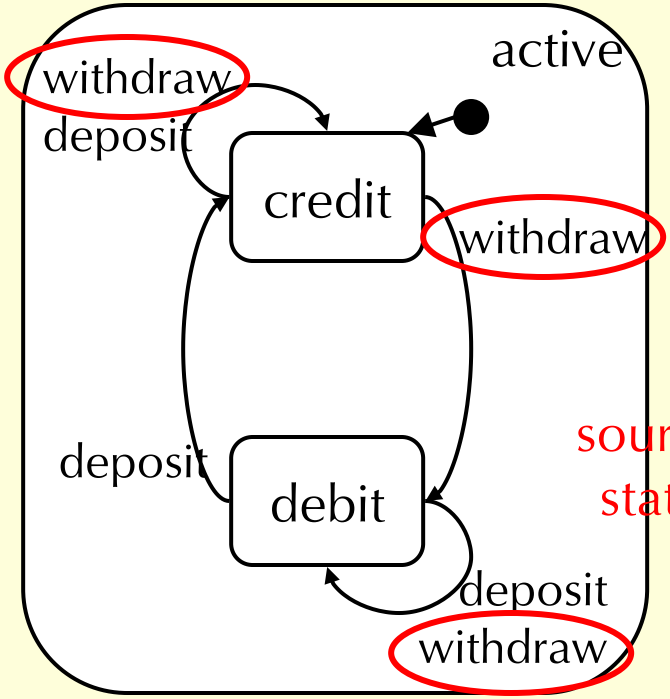
```
context
    Account::withdraw(amount:int)
  pre:   self.isActive and
   (self.balance >=0 or self.balance <0)
  post: ((self.balance@pre >= 0
          implies self.balance >= 0 or
                    self.balance < 0)
                and
        (self.balance@pre < 0
         implies self.balance < 0))
       and self.isActive
```

- OCL: pre and post condition

```
context
    Account::withdraw(amount:int)
  pre:   true
  post: self.balance =
        self.balance@pre - amount
```

Test Oracle: Example (4)

- statechart: derivation of pre and post condition



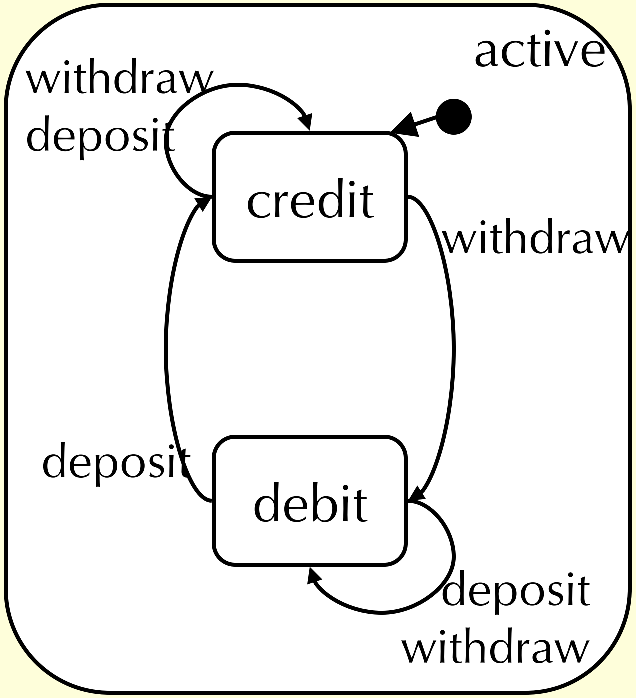
```
context Account::withdraw(amount:int)

pre:  self.isActive and
      (self.balance >=0 or self.balance <0)

post: ((self.balance@pre >= 0
         implies self.balance >= 0 or
                 self.balance < 0)
                 and
      (self.balance@pre < 0
         implies self.balance < 0))
      and self.isActive
```

state invariants of source states

source states

target states

Test Oracle: Example (5)



- resultant pre and post condition

***context** Account::withdraw(amount:int)*

***pre:** true and self.isActive and ...*

***post:** ((self.balance =*
self.balance@pre - amount)
and

OCL

(self.balance@pre >= 0
implies self.balance >= 0 or
self.balance < 0) and
(self.balance@pre < 0
implies self.balance < 0)))
and self.isActive

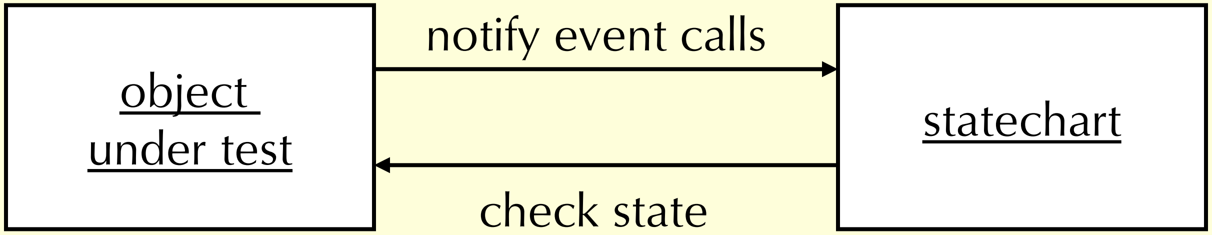
statechart

Test Code Integration (1)

- integration of test oracles into the SUT
  - aspect-oriented language: Object Teams
  - generation of executable statecharts
  - compilation of OCL constraints
- advantages
  - source and byte code of SUT not changed
  - aspects as roles with own state
  - tight coupling between aspect and role object
    - observer pattern already implemented (method calls are forwarded to aspect)
    - privileged access to the SUT

Test Code Integration (2)

- executable statechart with Object Teams
  - statechart as role of object under test
  - one team for each statechart level
  - dynamic aspect activation for statechart hierarchy implementation



- more teams for OCL constraints and logging

Test Code Integration: Example

```
team class Account_OCL {
 class Account_Role playedBy Account {
   Account obj_$AT_$PRE;
   abstract boolean isActive(); isActive -> isActive; /* CallOutBinding */
      •••                    // also for clone and other query methods
   pre_withdraw <- before withdraw;               /* CallInBinding */
   post_withdraw <- after withdraw;
   void pre_withdraw(int amount) {               /* Implementation */
      obj_$AT_$PRE = clone();
      if (!pre) { // test failed } }
   void post_withdraw(int amount) {  •••  }
} }
```

Summary

- combination of different diagram types
  - test case generation from sequences and statecharts
  - test oracle derivation from statecharts and OCL constraints
- information collected from different views
- independent test oracle
  - easy extension by using other diagram types
- aspect-oriented integration of test oracle
  - non-invasive integration
  - privileged access

Outlook

- integration of additional UML diagram types
  - class diagram
  - activity diagram
  - additional OCL constraints (beside pre, post conditions, invariants)
- derivation of test data from UML models
- use of efficient techniques
  - e.g. DresdenOCL
- industrial case study