Testing Distributed Component Based Systems Using UML/OCL

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Integrating Diagrammatic and Formal Specification Techniques
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Motivation

• **Diagrammatic Methods** raise interest:
  – Complex software systems increase the need for specification.
  – UML is the standard modeling language in industry.

• **Middleware Architectures** raise interest:
  – Distribution is the key–technology in the Internet.
  – Middleware offers possibilities to link new and legacy systems.
  – Well known middleware standards are CORBA and J2EE/EJB.

➤ *We explain the use of Diagrammatic Methods for modeling, specifying, and runtime testing of middleware architectures.*
Roadmap

1. Introduction

2. Specification of EJBs and Testing

3. Design Patterns for EJBs

4. Practical Experience

5. Future Work
We have chosen the J2EE/EJB Architecture from Sun Microsystems:

- J2EE is an extension of the Java language.
- Provides a wealth of additional services needed for distribution.
- Builds on existing tool support.
Distributed Systems Using J2EE: An EJB

- The “interface” of the EJB is used by the client and the server.

- An EJB is mainly described by three parts:
  - **Home–Interface H**: describing the life–cycle management
  - **Remote–Interface R**: describing the functional behavior
  - **Bean–Implementation I**: implements H and R

- Special life–cycle management (creation, passivation, deletion).
An example EJB Specification

Abstract View

«HomeInterface»
Account

+ ejbPostCreate()

life-cycle management

«RemoteInterface»
AccountRemote

+ getBalance():Real
+ makeDeposit(amount:Real):Boolean

Concrete View

«BeanImplementation»
AccountEJB

+ balance:Real
+ getBalance():Real
+ makeDeposit(amount:Real):Boolean
+ ejbPostCreate()
An example EJB Specification

**Abstract View**

- **context** `Account::ejbPostCreate()`
- **pre**: true
- **post**: `getBalance() = 0`

**Concrete View**

- `AccountEJB`
  - `+ balance:Real`
  - `+ getBalance():Real`
  - `+ makeDeposit(amount:Real):Boolean`
  - `+ ejbPostCreate()`

**Life-cycle management**

- `+ ejbPostCreate()`

**RemoteInterface**

- `AccountRemote`
  - `+ getBalance():Real`
  - `+ makeDeposit(amount:Real):Boolean`
An example EJB Specification

Abstract View

context Account::ejbPostCreate()
pre: true
post: getBalance() = 0

Account

«HomeInterface»

life-cycle management
+ ejbPostCreate()

context AccountRemote
inv: getBalance() > 0

context AccountRemote::makeDeposit(amount:Real):Boolean
pre: amount >= 0
post: self.getBalance() = self.pre.getBalance() + amount

AccountRemote

«RemoteInterface»

+ getBalance():Real
+ makeDeposit(amount:Real):Boolean

Concrete View

«BeanImplementation»

AccountEJB

+ balance:Real
+ getBalance():Real
+ makeDeposit(amount:Real):Boolean
+ ejbPostCreate()
An example EJB Specification

Abstract View

- **context** Account::ejbPostCreate()
  - **pre:** true
  - **post:** getBalance() = 0

- **context** AccountRemote
  - **inv:** getBalance() > 0

- **context** AccountRemote::makeDeposit(amount:Real):Boolean
  - **pre:** amount >= 0
  - **post:** self.getBalance() = self@pre.getBalance() + amount

Concrete View

- **context** AccountEJB
  - **inv:** balance > 5

- **context** AccountRemote
  - **inv:** getBalance() > 0

- **context** AccountRemote::makeDeposit(amount:Real):Boolean
  - **pre:** amount >= 0
  - **post:** self.getBalance() = self@pre.getBalance() + amount

Specification of Enterprise Java Beans

J2EE does not provide a concept of a “formal specification” of an EJB.

We fill this gap by adopting OCL. This means:

- **Syntactically:**
  
  **Abstract View:** The union of the signatures of \( H \) and \( R \) extended by further accessor methods for the (public) variables of \( I \), and annotated by OCL formulae.

  **Concrete View:** The bean implementation \( I \) annotated by OCL formulae.

- **Semantically:**
  
  What is the operational semantics of OCL formulae written on the different views?
Operational Semantics of the Specification Refinement

**Abstract View**

```plaintext
context
AccountRemote::makeDeposit(amount:Real):Boolean
```

**pre:**

```plaintext
amount > 0
```

**makeDeposit(amount:Real):Boolean**

```plaintext
context
AccountRemote::makeDeposit(amount:Real):Boolean
```

**post:**

```plaintext
self.getBalance() = self@pre.getBalance() + amount
```

**Concrete View**

```plaintext
context
AccountEJB::makeDeposit(amount:Real):Boolean
```

**pre:**

```plaintext
amount >= 0
```

**makeDeposit(amount:Real):Boolean**

```plaintext
{ . . . }
```

```plaintext
context
AccountEJB::makeDeposit(amount:Real):Boolean
```

**post:**

```plaintext
self.getBalance() = self@pre.getBalance() + amount
```
Operational Semantics of the Specification Refinement

**Abstract View**

- **context**
  - AccountRemote::makeDeposit(amount:Real):Boolean

- **pre**
  - amount > 0

- **makeDeposit(amount:Real):Boolean**

- **post**
  - AccountRemote::makeDeposit(amount:Real):Boolean
  - self.getBalance() = self@pre.getBalance() + amount

**Concrete View**

- **context**
  - AccountEJB::makeDeposit(amount:Real):Boolean

- **pre**
  - amount >= 0

- **makeDeposit(amount:Real):Boolean**

- **post**
  - AccountEJB::makeDeposit(amount:Real):Boolean
  - self.getBalance() = self@pre.getBalance() + amount
Operational Semantics of the Specification Refinement

**Abstract View**

- **context**
  - AccountRemote::makeDeposit(amount:Real):Boolean
- **pre:**
  - amount > 0
- makeDeposit(amount:Real):Boolean

**Concrete View**

- **context**
  - AccountEJB::makeDeposit(amount:Real):Boolean
- **pre:**
  - amount >= 0
- makeDeposit(amount:Real):Boolean
  
- **context**
  - AccountRemote::makeDeposit(amount:Real):Boolean
  
- **post:**
  - self.getBalance() = self@pre.getBalance() + amount

- **context**
  - AccountEJB::makeDeposit(amount:Real):Boolean
  
- **post:**
  - self.getBalance() = self@pre.getBalance() + amount
Operational Semantics of the Specification Refinement

The Concrete View is a refinement of the Abstract View.
Operational Semantics of the Specification
Black Box Testing

- Based on the specification of the Abstract View:
  - Testing the “external view”.
  - Suited for system implementor using pre–configured components.

- Based on the specification of the Concrete View:
  - Testing the “internal view”.
  - Suited for component developers.

➤ Runtime OCL constraint checking provides an a posteriori debugging method.
EJB Design Pattern

- Reduces complexity of specification for test data generation.

- We introduce the concept “ExpandedBean” where an EJB can consist of several home or remote interfaces.

- We provide three patterns:
  - **CompactBean** for standard development: Models an EJB with one remote interface, one home interface and one implementation.
  - **ExpandedBeanHome** for technological optimization: Extends the CompactBean by allowing several home interfaces.
  - **ExpandedBeanRemote** for modeling different kinds of accesses: Extends the CompactBean by allowing several remote interfaces.
The Compact Bean Pattern

context Account
inv: balance > 0
post: balance = balance@pre + amount
context Account::makeDeposit(amount:Real):Boolean
pre: amount >= 0
post: balance = balance@pre + amount

CASE tool representation

technology mapping

abstract view

concrete view

Constraint Checking and Practical Experience

- We integrated a OCL type checker into a CASE Tool for EJB support.
- We integrated a constraint checking code generator into a CASE Tool for EJB support.

- Type checking is based on the tools developed at the University Dresden.
- Runtime checking is done via “method–wise” wrapping code.
- Internal method invocations are checked.
Further Work

- Specification of transactions.
- Systematic generation of test–data based on the OCL specification.
- Formal analysis of the relation between Abstract View and Concrete View.

➤ We will develop a declarative semantics of OCL, which is done through an embedding of OCL into an theorem prover.
Appendix
**UML**

- several diagram types
- diagrammatic method
- metamodeling approach
- OMG standard
- widely accepted (in industry)

```
context Account::makeDeposit(amount:Real):Boolean
pre:  amount >= 0
post: balance = balance@pre + amount
```

**OCL**

- textual extension
- based on logic and set theory
- designed for annotation of UML diagrams
- class–diagrams:
  - preconditions
  - postconditions
  - invariants
- part of the UML
- no declarative semantics
The J2EE Application Model

first tier

presentation layer

client implementation
e.g. applets
or www-browser

second tier

business logic layer

server business logic implementation
e.g. EJBs
EJB container
EJB
EJB

third tier

enterprise information system layer

server data management
e.g. database systems

client

server

Modeling EJBs using UML/OCL with ArcStyler
The ExpandedBeanHome Pattern

Note:

context: makeWithdrawal(amount:Real)
pre: (amount > 0) and (amount <= 200.0)
post: sel.getBalance()=self@pre.getBalance()-amount

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The Expanded Bean Remote Pattern

- **BankAccountEJB**
  - balance: Real
  - setBalance(amount: Real)
  - getBalance(): Real
  - makeWithdrawal(amount: Real)
  - makeDeposit(amount: Real)

- **BankAccountHome**
  - Finder- and Factory – methods

- **BankAccountCustomer**
  - getBalance(): Real
  - makeWithdrawal(amount: Real)
  - makeDeposit(amount: Real)

- **BankAccountClerk**
  - getBalance(): Real
  - makeWithdrawal(amount: Real)
  - makeDeposit(amount: Real)

**Note:**
- **context:** makeWithdrawal(amount: Real)
- **pre:** (amount > 0) and (amount <= 200.0)
- **post:** self.getBalance() = self@pre.getBalance() - amount

**Note:**
- **context:** makeWithdrawal(amount: Real)
- **pre:** amount > 0
- **post:** balance = balance@pre - amount