Extending the UML for Multidimensional Modeling

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- UML Extension for MD Modeling
- MD Modeling in Rational Rose
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Introduction

• Multidimensional (MD) modeling → Data warehouses, MD databases, OLAP applications
• Many years of historical information
• Different approaches for the conceptual design:
  – Golfarelli et al
  – Husemann et al
  – Sapia et al
  – Tryfona et al
  – …

Own graphical notations

Learn a new notation

Extending the UML for Multidimensional Modeling

Introduction

• UML → Standard OO modeling language for software systems
• Minimize the efforts in learning new notations
• Extensible language → Stereotypes, tagged values, and constraints → Profile
• Allows the user to introduce new elements for specific domains (web applications, business modeling, etc.)
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Introduction

• Some proposals to extend the UML for DB design…
  – Persistence Modeling (Ambler)
  – Data Modeling (Rational Software)
  – UML Profile for DB Design (Naiburg et al)
  – Object-Relational DB Design Methodology (Marcos et al)
• …but not for MD modeling

Extending the UML for Multidimensional Modeling

Introduction

• UML profile for MD modeling based on our previously proposed approach
  – Main MD properties:
    • many-to-many
    • degenerate dimensions
    • multiple and alternative path classification hierarchies
  – OCL: well-formedness rules of the new defined elements → Avoids an arbitrary use of our extension
• Rational Rose
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• **OO Multidimensional Modeling**
  • UML Extension for MD Modeling
  • MD Modeling in Rational Rose
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**OO Multidimensional Modeling**

• Our MD modeling approach represents both the structural and dynamic parts of MD modeling using the UML
• MD modeling structural properties are specified by means of a UML class diagram
• Facts and dimensions are considered by *fact classes* and *dimension classes*
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OO Multidimensional Modeling

• Fact classes are specified as composite classes in shared aggregation relationships of n dimension classes.

Additivity rule

• All measures in the fact class are considered additive.
• Non-additive measures ⇒ Additivity rules defined as constraints.
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OO Multidimensional Modeling

\{inventory is (AVG, MIN, MAX) along Time\}

\{total = qty * price\}

Derived measures are defined by means of *derivation rules*

- Identifying attributes \{OID\} → Represent degenerate dimensions

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OO Multidimensional Modeling

\{SID: cod_time\}

\{D: day_of_week\}

\{Year\} → \{Month\} → \{Week\} → \{Day\}

- An association of classes specifies the relationships between two levels of a *classification hierarchy*
- Every classification hierarchy level is specified by a class called *base class*
• The classes in a classification hierarchy must define a Directed Acyclic Graph (DAG) rooted in the dimension class \((\text{dag})\).

• Every classification hierarchy level must have an identifying attribute \((\text{OID})\) and a descriptor attribute \((D)\).

• The multiplicity 1 and 1..* addresses the concepts of strictness and non-strictness.

• The \{completeness\} constraint addresses the completeness of a classification hierarchy.
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**OO Multidimensional Modeling**

- The categorization of dimensions is considered by means of generalization-specialization relationships

```
<table>
<thead>
<tr>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>{OID}: cod_prod</td>
</tr>
<tr>
<td>{D}: description</td>
</tr>
</tbody>
</table>

Food

Drink

Meat

Fish

...```

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UML Extension for MD Modeling

- UML Extensibility Mechanism
  - Extension mechanisms: stereotypes, tagged values, and constraints
- UML can be adapted to fit a specific method, organization, or user

UML Extension for MD Modeling

- **Stereotype**: a new model element that specializes a UML element (Class, Attribute, Package, Association, etc.)
- **Tagged value**: a new property of a model element
- **Constraint**: refines the semantics of a model element — Informal or formal (Object Constraint Language)
UML Extension for MD Modeling

- Extension summary:
  - 8 stereotypes:
    - Class: Fact, Dimension, and Base
    - Attribute: FactAttribute, DimensionAttribute, OID, and Descriptor
    - Association: Completeness
  - 2 tagged values:
    - isTime and derivationRule
  - 23 constraints
UML Extension for MD Modeling

• Facts and dimensions → Fact, Dimension, and Base
• Fact attributes → OID and FactAttribute
• Dimension attributes → OID, Descriptor, and DimensionAttribute
• Derived measures: derivationRule tagged value
• Classification hierarchies → Association between Dimension and Base
• Completeness → Completeness stereotype

UML Extension for MD Modeling

• Name: Fact
• Base class: Class
• Description: Classes of this stereotype represent facts in a MD model
• Icon:

- Tagged values: None
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UML Extension for MD Modeling

• Constraints:
  – All attributes of a Fact must be OID or FactAttribute:
    self.feature->select(oclIsKindOf(Attribute))->forAll(oclIsTypeOf(OID) or oclIsTypeOf(FactAttribute))
  – All associations of a Fact must be aggregations:
    self.association->forAll(aggregation = #aggregate)
  – A Fact can only be associated to Dimension classes:
    self.allOppositeAssociationEnds->forall(participant.oclIsTypeOf(Dimension))

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UML Extension for MD Modeling

• Name: Dimension
• Base class: Class
• Description: Classes of this stereotype represent dimensions in a MD model
• Icon:

  \[ \text{\texttt{\text{
\begin{center}
\includegraphics[width=0.2\textwidth]{dimension_icon.png}
\end{center}\
}}}} \]

• Tagged values: None
Extending the UML for Multidimensional Modeling

UML Extension for MD Modeling

• Constraints:
  – All attributes of a Dimension must be OID, Descriptor, or FactAttribute:
    
    ```
    self.feature->select(oclIsKindOf(Attribute))->forAll(oclIsTypeOf(OID) or oclIsTypeOf(Descriptor) or oclIsTypeOf(FactAttribute))
    ```
  – All associations of a Dimension with a Fact must be aggregations at the opposite end:
    ```
    self.association.associationEnd->forAll(associationEnd.participant.oclIdTypeOf(Fact) implies associationEnd.aggregation = #aggregate)
    ```

• Constraints:
  – All associations of a Dimension with a Fact must not be aggregations at its end:
    ```
    self.association.associationEnd->forAll(associationEnd.participant.oclIdTypeOf(Fact) implies aggregation <> #aggregate)
    ```
  – A Dimension cannot be associated to another Dimension:
    ```
    self.allOppositeAssociationEnds->forAll(not participant.oclIsTypeOf(Dimension))
    ```
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UML Extension for MD Modeling

• Name: **Base**
• Base class: **Class**
• Description: **Classes of this stereotype represent dimension hierarchy levels in a MD model**
• Icon:

```
B
```

• Tagged values: **None**

Extending the UML for Multidimensional Modeling

UML Extension for MD Modeling

• **Constraints:**
  - All attributes of a Base must be OID, Descriptor, or DimensionAttribute:
    ```
    self.feature->select(oclIsKindOf(Attribute))->forall(oclIsTypeOf(OID) or oclIsTypeOf(Descriptor) or oclIsTypeOf(DimensionAttribute))
    ```
  - A Base must have an OID attribute and a Descriptor attribute:
    ```
    self.feature->select(oclIsKindOf(Attribute))->exist(oclIsTypeOf(OID)) and self.feature->select(oclIsKindOf(Attribute))->exist(oclIsTypeOf(Descriptor))
    ```
Extending the UML for Multidimensional Modeling

UML Extension for MD Modeling

• Constraints:
  – A Base can only be associated with another Base or another Dimension:
    self.allOppositeAssociationEnds ->
    forAll(participant.oclIsTypeOf(Base) or participant.oclIsTypeOf(Dimension))
  – A Base can only be child in one generalization:
    self.generalization -> size <= 1

• Constraints:
  – A Base cannot simultaneously belong to a generalization/specialization hierarchy and an association hierarchy:
    (self.generalization -> size > 0 or self.specialization -> size > 0)
    implies (self.association -> size = 0)
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MD Modeling in Rational Rose

• Rational Rose is one of the most well-known visual modeling tools
• RR is extensible by means of add-ins through the Rose Extensibility Interface:
  – Main menu items
  – Stereotypes
  – Properties (tagged values)
  – Data types
  – Event handling
  – Scripts
  – …
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MD Modeling in Rational Rose

- Our add-in customizes:
  - Stereotypes → Stereotype configuration file
  - Properties → Property configuration file
  - Constraints → Menu item → Menu configuration file
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Conclusions and Future Work

- UML extension for MD modeling: allows us to represent structural MD properties at the conceptual level
- OCL to specify the constraints, avoiding an arbitrary use of the extension
- Main advantage: UML avoids developers learning a new graphical notation

Future work:
- Dynamic part
- Automatic generation of database schema into object-oriented and object-relational databases
- Methodology