

DAIMLERCHRYSLER

Using XSLT to derive schemata from UML

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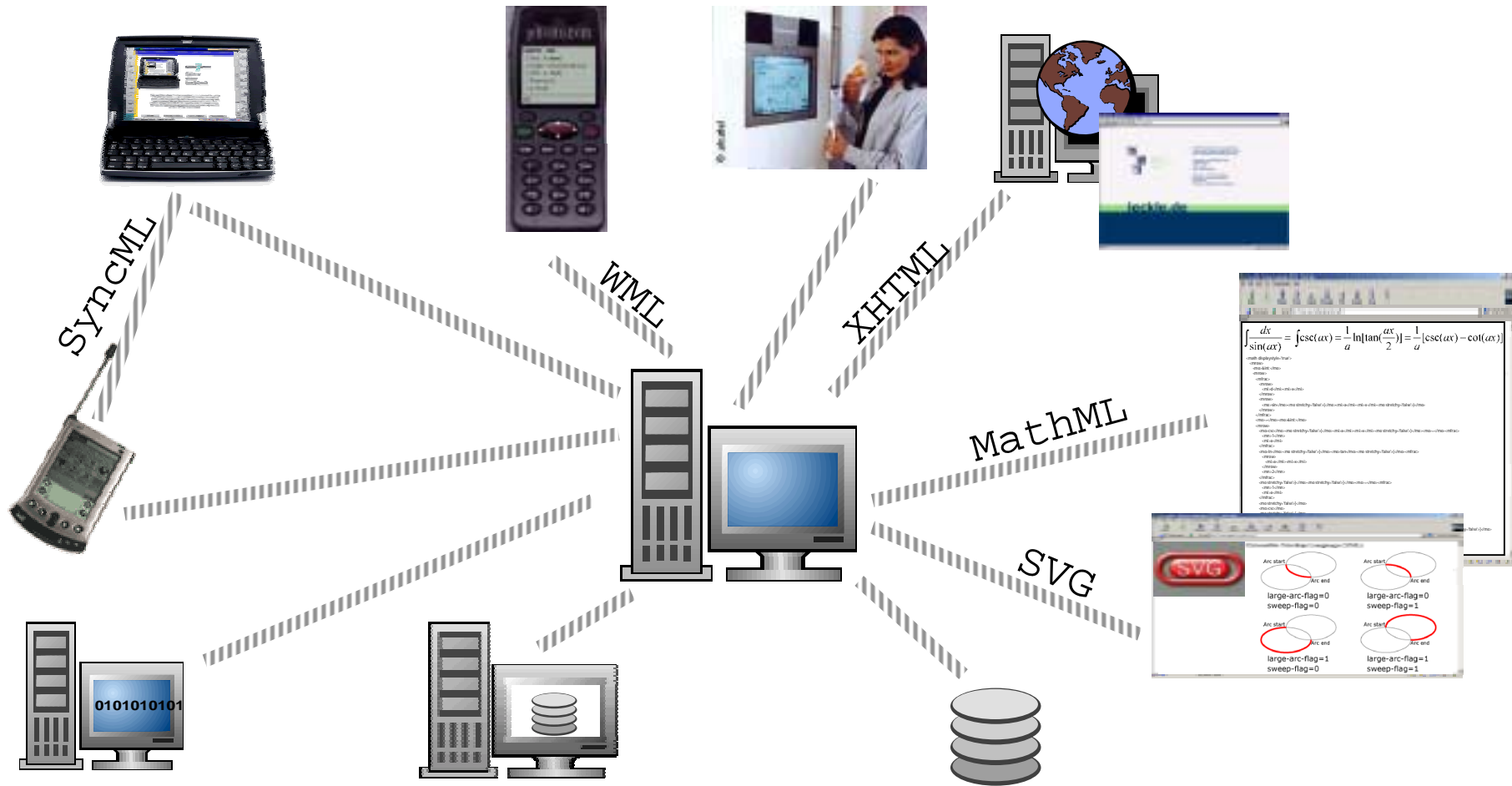
Overview

- Problem Statement
- The Big Picture:

Seamless Derivation of XML-Schemata from UML Models

- UML a short introduction
- OMG's XML Metadata Interchange (XMI)
- W3C's XML Schema
- A Schema Derivation Algorithm based on XMI and UML
- Implementing Schema Derivation using XSLT

XML everywhere

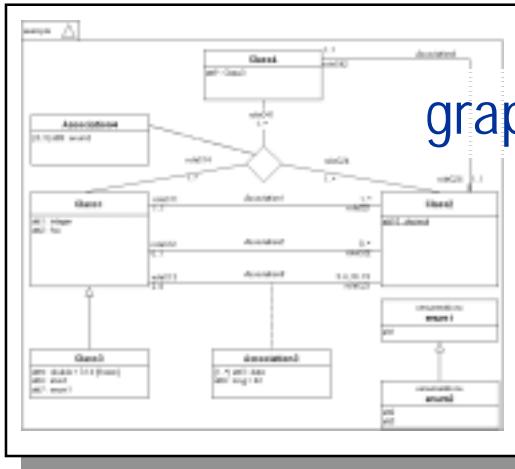


- Access to Data, Systems and Services is getting *XML-ized*
- XML will become the ASCII of the 21st century

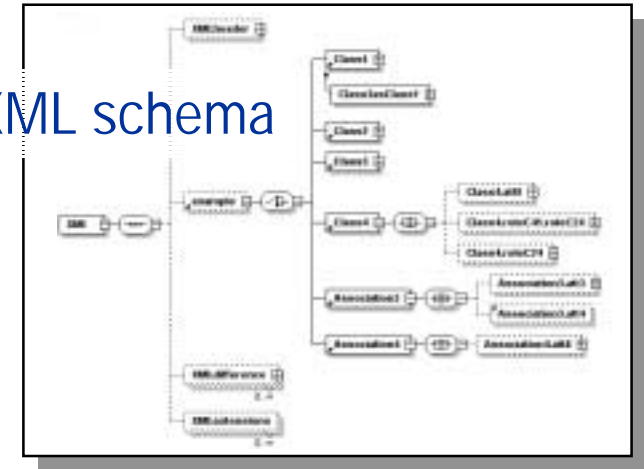
Problem Statement: Creation of XML Vocabularies

- **Flexibility**
Future proof (i.e. easy to adapt) languages
- **Speed**
Amount of XML-Languages needed for today's applications (e.g. B2B, ...)
- **Coherence**
Need to keep application's data structures and XML format in sync
- **Accuracy**
XML structures should reflect business structures and rules
- **Style**
Languages for similar applications domains should offer the same *look and feel*
- **Integration**
Current development processes do not take care of serialization formats
- **Reuse**
Of existing design meta-knowledge

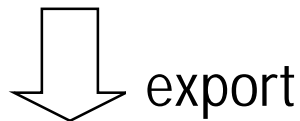
Seamless Derivation of XML-Schemata from UML Models



graphical UML model



graphical XML schema

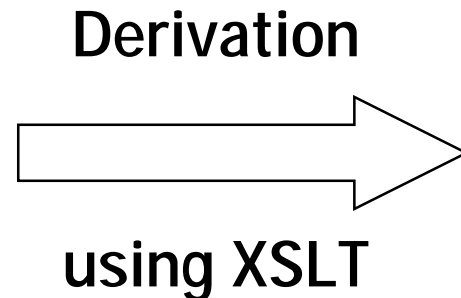


```
<?xml version="1.0" encoding="UTF-8"?>
<XMI xmi.version="1.0">
  <XMI.header>
    <XMI.documentation>
      <XMI.exporter>DaimlerChrysler Research and Technology FT3/EK</XMI.exporter>
      <XMI.exporterVersion>1.0</XMI.exporterVersion>
    </XMI.documentation>
    <XMI.metamodel xmi.name="UML" xmi.version="1.3"/>
  </XMI.header>
  <XMI.content>
    <Model_Management.Model xmi.id="Model:example">
      <Foundation.Core.ModelElement.name>example</Foundation.Core.ModelElement.name>
      <Foundation.Core.ModelElement.visibility xmi.value="public"/>
    </Model_Management.Model>
  </XMI.content>
</XMI>
```

XML representation

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
  xmlns:xlink="http://www.w3.org/1999/xlink">
  <xsd:annotation>
    <xsd:documentation>Created by DaimlerChrysler's
      XSD-Generator 2001-04-05T14:34:00+2:00</xsd:documentation>
  </xsd:annotation>
  <xsd:attributeGroup name="LinkAttribs">
    <xsd:attribute name="href" type="xsd:string"/>
    <xsd:attribute name="idref" type="xsd:IDREF"/>
    <xsd:attribute name="link" type="xsd:string"/>
    <xsd:attribute name="xlink:inline" type="xsd:boolean"/>
    <xsd:attribute name="xlink:actuate">
      <xsd:simpleType>
        ...
      </xsd:simpleType>
    </xsd:attribute>
  </xsd:attributeGroup>
</xsd:schema>
```

XML Schema (XSD)



OMG's Unified Modeling Language (UML)

- Object oriented modeling language for general purpose systems
- Includes most of precursor graphical modeling languages
- Various diagram types supporting different development phases
(e.g. *use case, class, sequence, activity, collaboration diagram, ...*)
- Defines no development process, i.e. precludes none
- Widely adopted by tool vendors
- An OMG industry standard

- Defines no textual representation
Subject to a separate RFP entitled *Stream-based Model Interchange Format*

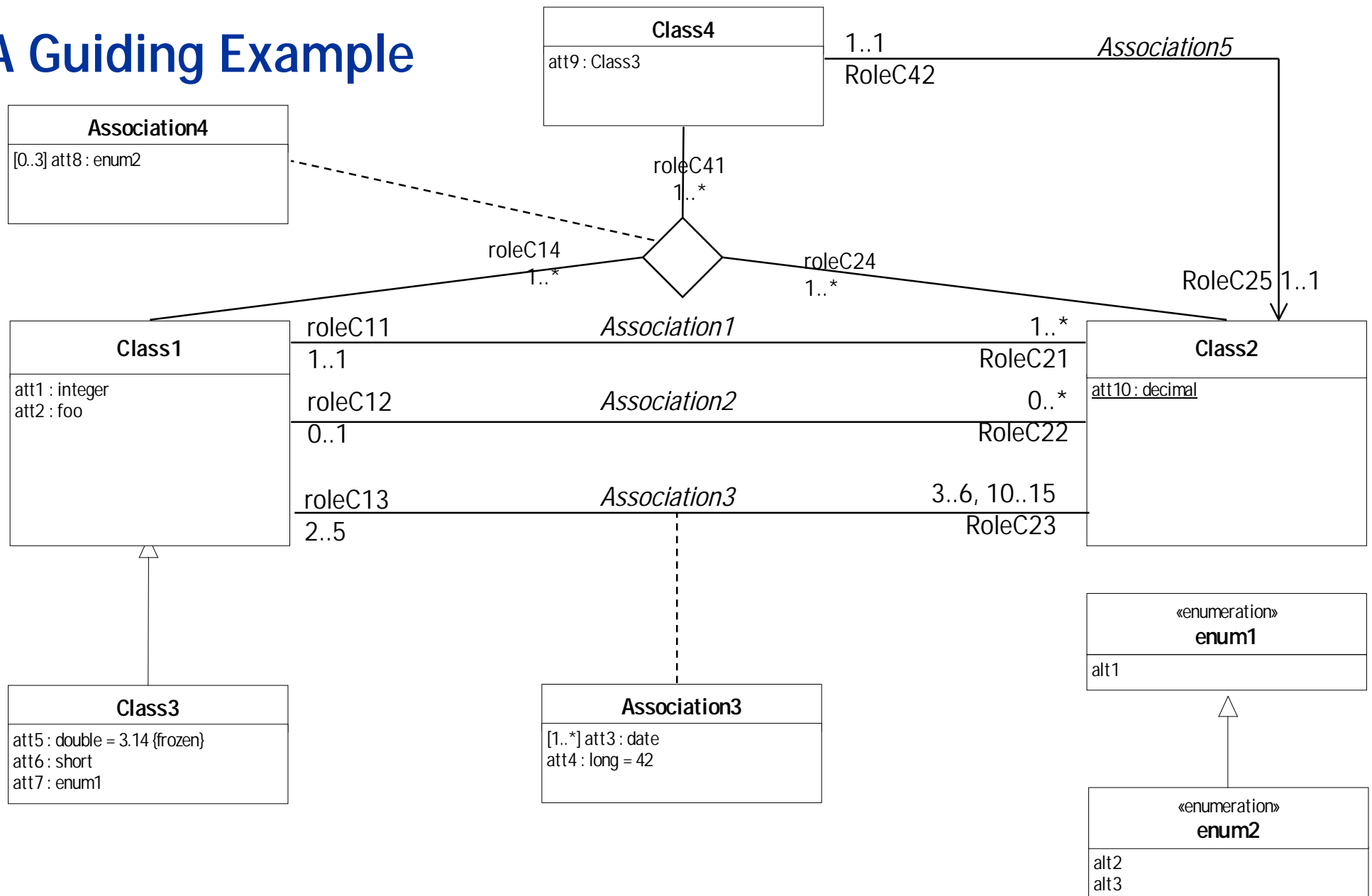
OMG's XML Metadata Interchange (XMI)

- **#1 goal:** Model Interchange a.k.a. Metadata Interchange among heterogeneous object oriented modeling tools
- **Purpose:** Encoding of MOF-based metamodels i.e. UML models and UML-based metamodels
- **Developed by:** Unisys, IBM, DSTC, Oracle, Platinum, Fujitsu, Softeam, Recerca Informatica, DaimlerChrysler
- **Supported by:** Genesis, Inline, Rational, Select, Sprint, Cayenne, Sybase, Xerox, Boeing, Ardent, MCI Systemhouse, Aviatis, ICONIX, Integrated Systems, Verilog, Nihon Unisys, NTT, Telefonica I+D, NCR, Universitat Politecnica de Catalunya

XMI Application Domains

- Model Interchange
- Metamodel Interchange
 - Interchange of Data Warehouse Models (e.g. OMG's CWM)
- Middleware related component information (e.g. CORBA components)
- Vertical Data integration (e.g. clinical information)
- Model Centric Development (not CASE-Tool centric)
 - Code generation (e.g. Java; also legacy systems)
 - Model assessments (e.g. metrics)
 - Assertion of modeling guidelines

A Guiding Example



XMI[UML] to Encode Graphical UML Models Using XML

```
<?xml version="1.0" encoding="UTF-8"?>
```

```
<XMI xmi.version="1.0">
```

```
<XMI.header>
```

```
<XMI.documentation>
```

```
<XMI.exporter>DaimlerChrysler Research and Technology FT3/EK</XMI.exporter>
```

```
<XMI.exporterVersion>1.0</XMI.exporterVersion>
```

```
</XMI.documentation>
```

```
<XMI.metamodel xmi.name="UML" xmi.version="1.3"/>
```

```
<XMI.header>
```

```
<XMI.content>
```

```
<Model_Management.Model xmi.id="Model:example">
```

```
<Foundation.Core.ModelElement.name>example</Foundation.Core.ModelElement.name>
```

```
<Foundation.Core.ModelElement.visibility xmi.value="public"/>
```

```
<Foundation.Core.ModelElement.isSpecification xmi.value="false"/>
```

```
<Foundation.Core.GeneralizableElement.isRoot xmi.value="false"/>
```

```
<Foundation.Core.GeneralizableElement.isLeaf xmi.value="false"/>
```

```
<Foundation.Core.GeneralizableElement.isAbstract xmi.value="false"/>
```

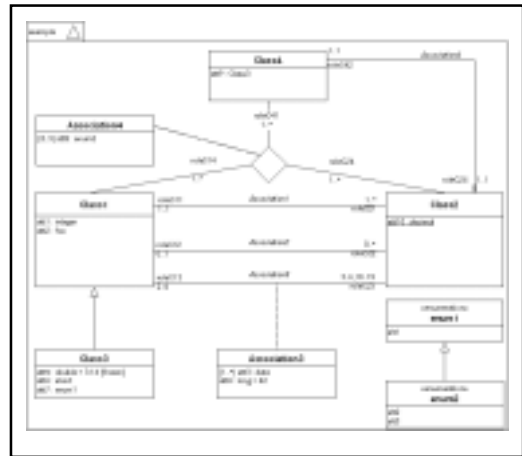
```
<Foundation.Core.Namespace.ownedElement>
```

```
<Foundation.Core.Class xmi.id = 'Class:Class1' >
```

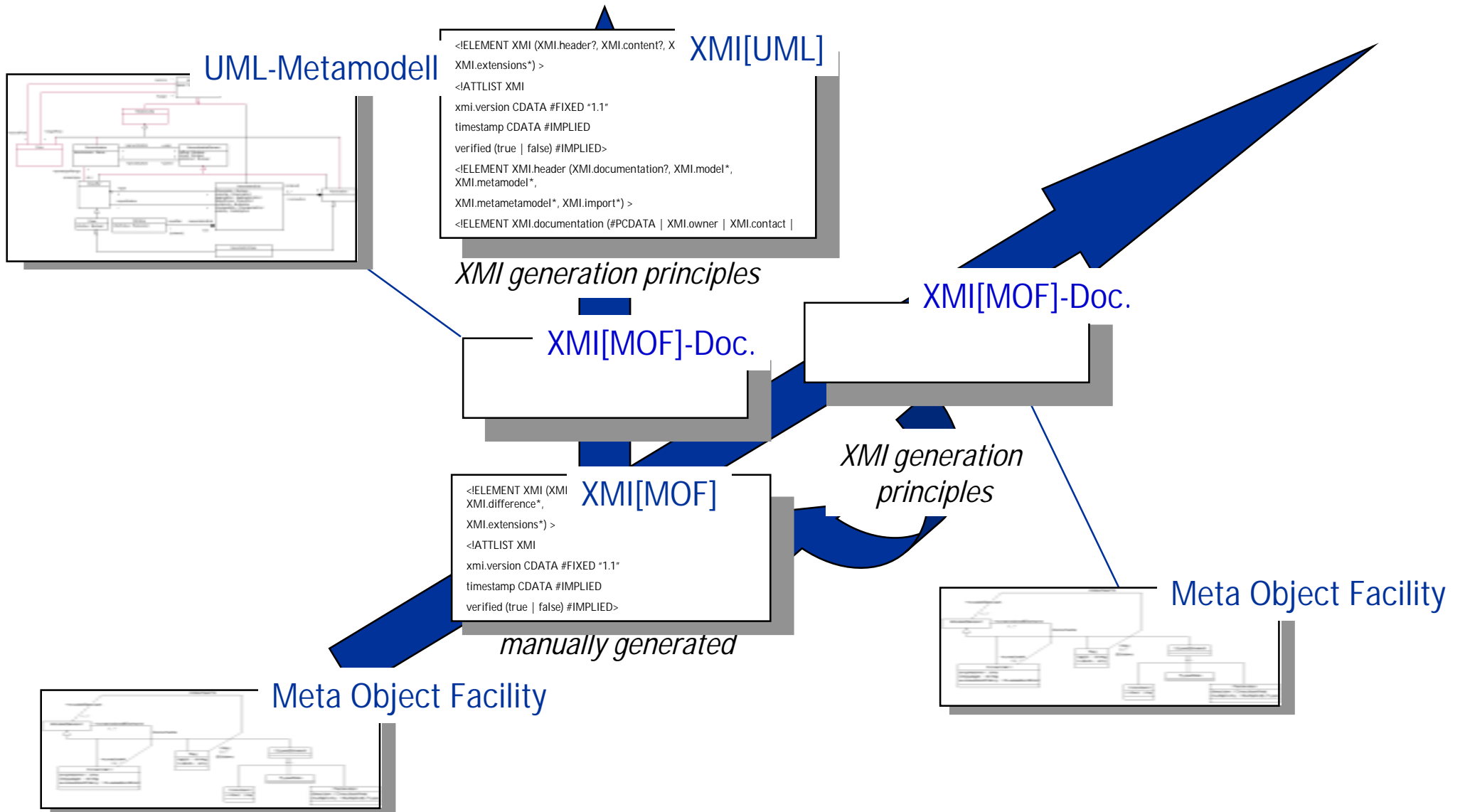
```
<Foundation.Core.ModelElement.name>Class1</Foundation.Core.ModelElement.name>
```

```
<Foundation.Core.ModelElement.visibility xmi.value = "public"/>
```

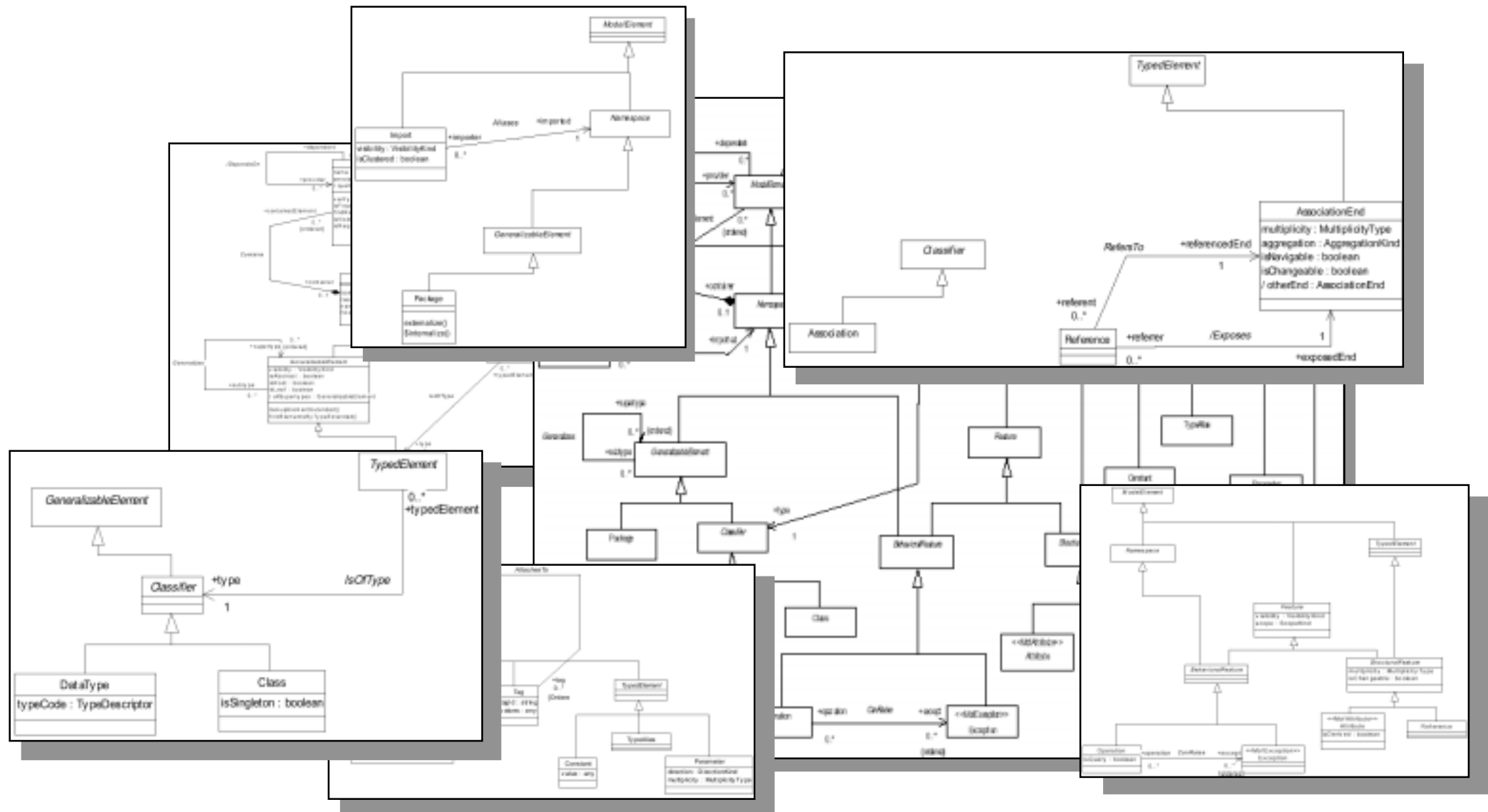
```
...
```



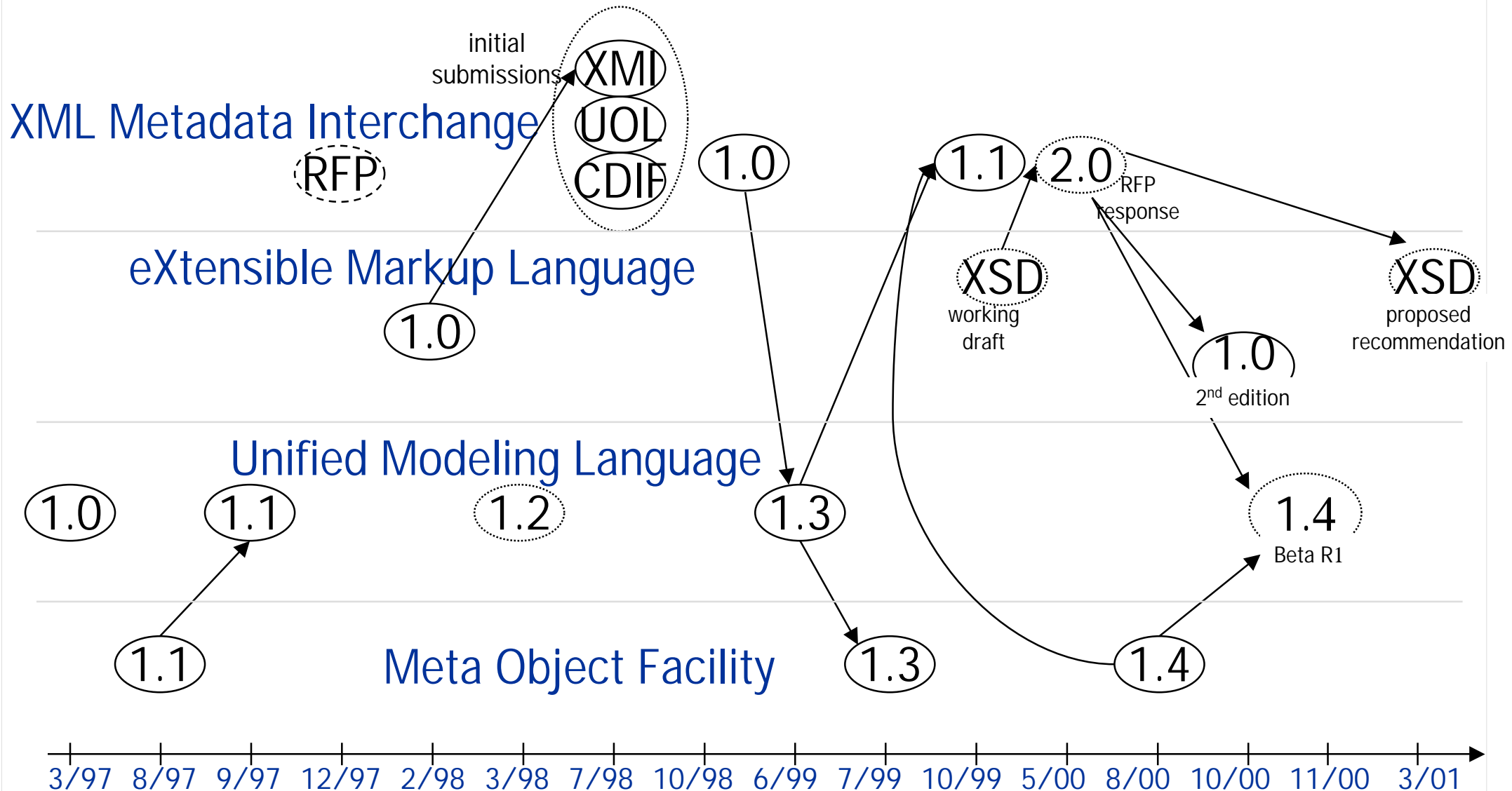
Generating the Standardized Document Type Definitions



MOF-Meta-Metamodell



XMI -- part of a world of interconnected standards



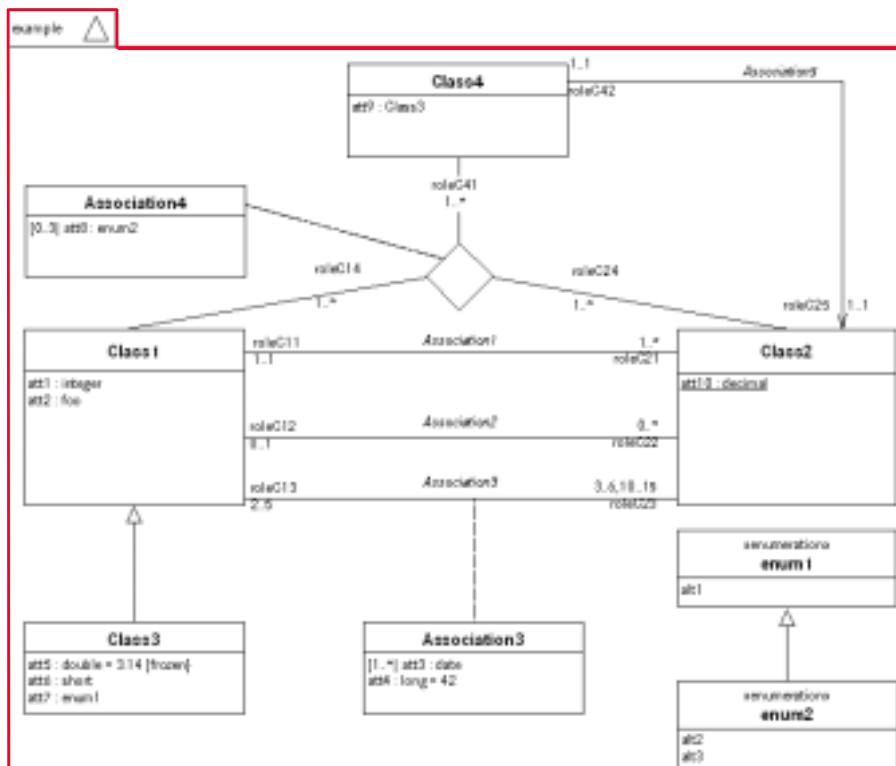
Structural Concepts of UML Relevant to Derivation Process

- Classes
 - Specialization relationships
 - Association classes
- Attributes
 - Constants
 - Default values
 - Multiplicity-aware (i.e. optional and multi valued attributes)
- Data types (primitive and complex)
 - pre-defined (by UML, MOF, and CORBA)
 - used-defined
- Associations
 - Navigability
 - Multiplicities

Derivation Patterns -- Model and Packages

Match pattern:

/XMI/XMI.content/Model_Management.Model/Foundation.Core.ModelElement.name



```

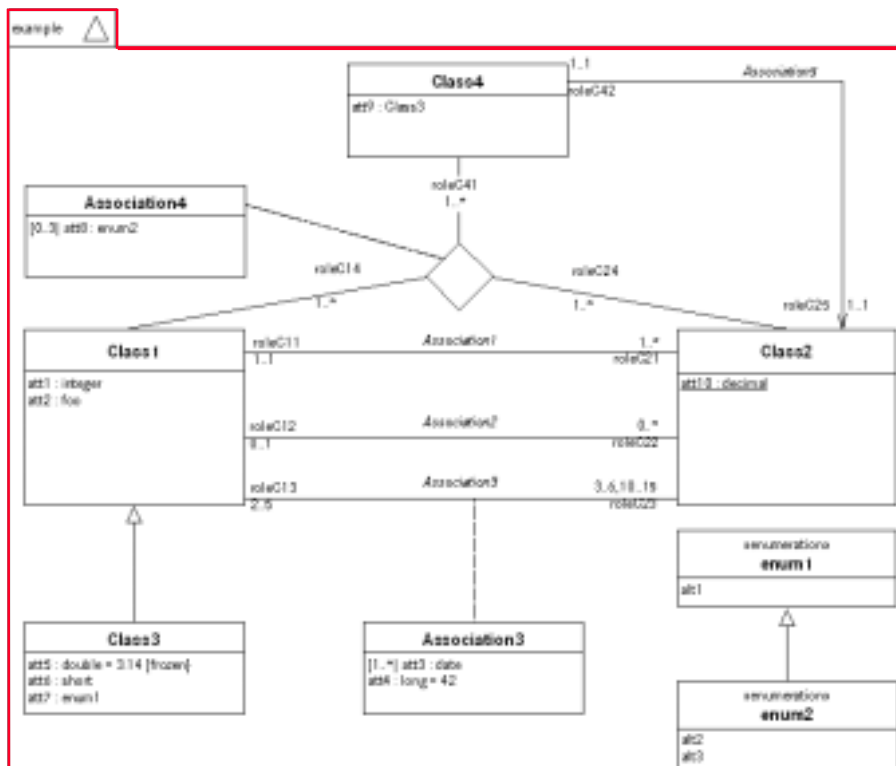
<xsd:complexType>
  <xsd:choice minOccurs="0"
    maxOccurs="unbounded">
    <xsd:element ref="Class1"/>
    <xsd:element ref="Class2"/>
    <xsd:element ref="Class3"/>
    <xsd:element ref="Class4"/>
    <xsd:element ref="Association3"/>
    <xsd:element ref="Association4"/>
  </xsd:choice>
</xsd:complexType>

```


Derivation Patterns -- Model and Packages

Match pattern:

/XMI/XMI.content/Model_Management.Model/Foundation.Core.ModelElement.name



```

<xsd:complexType>
  <xsd:choice minOccurs="0"
    maxOccurs="unbounded">
    <xsd:element ref="Class1"/>
    <xsd:element ref="Class2"/>
    <xsd:element ref="Class3"/>
    <xsd:element ref="Class4"/>
    <xsd:element ref="Association3"/>
    <xsd:element ref="Association4"/>
  </xsd:choice>
</xsd:complexType>
  
```

Derivation Patterns -- Classes

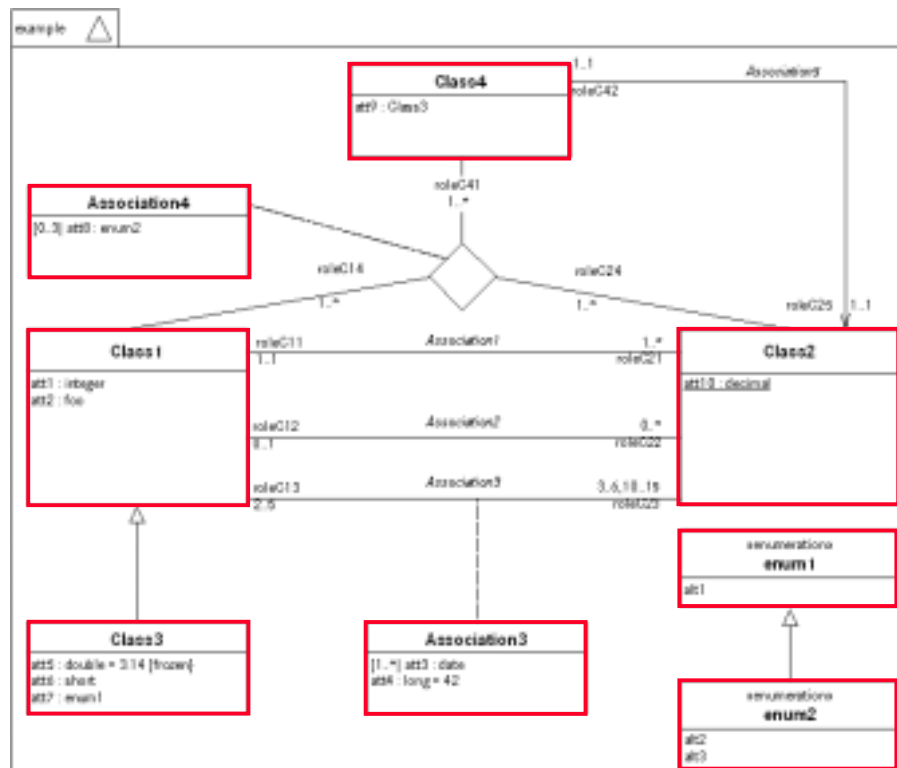
Purpose: Get all classes including association classes not stereotyped as *enumeration*.

Match pattern:

```
/XMI/XMI.content/Model_Management.Model/  
Foundation.Core.Namespace.ownedElement//Foundation.Core.Class  
[not(//Foundation.Extension_Mechanisms.Stereotype  
[Foundation.Core.ModelElement.name='enumeration']/  
@xmi.id=Foundation.Core.ModelElement.stereotype/  
Foundation.Extension_Mechanisms.Stereotype/@xmi.idref)]  
| /XMI/XMI.content/Model_Management.Model/  
Foundation.Core.Namespace.ownedElement//Foundation.Core.AssociationClass  
[not(//Foundation.Extension_Mechanisms.Stereotype  
[Foundation.Core.ModelElement.name='enumeration']/  
@xmi.id=Foundation.Core.ModelElement.stereotype/  
Foundation.Extension_Mechanisms.Stereotype/@xmi.idref)]
```

Derivation Patterns -- Classes

Purpose: Get all classes including association classes not stereotyped as *enumeration*.



```
<xsd:complexType name="Class1Type">
```

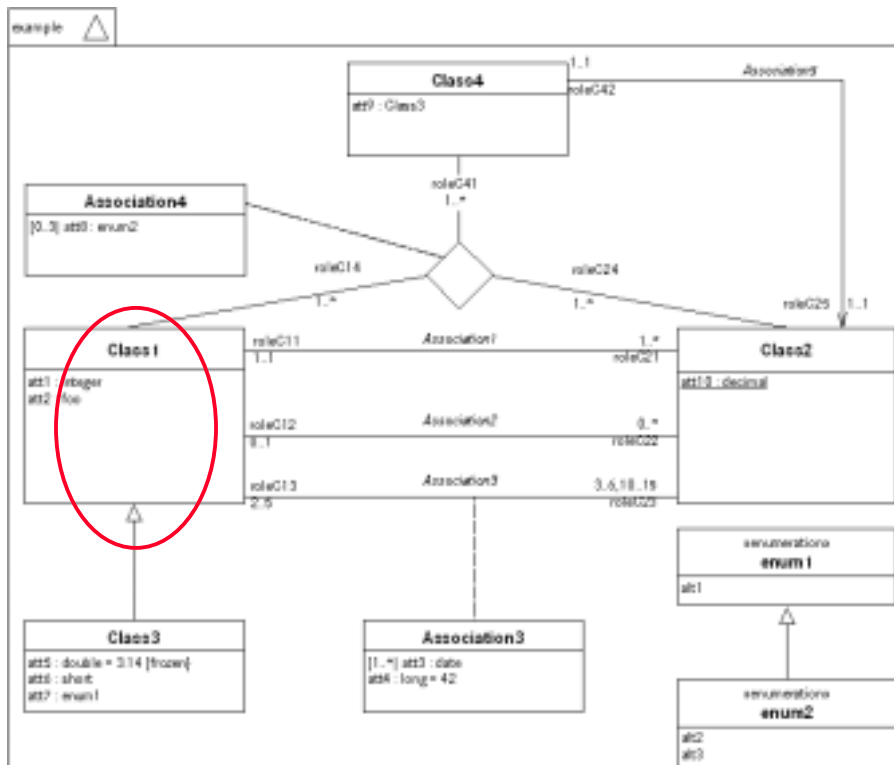
```
...
```

```
</xsd:complexType>
```

```
<xsd:element name="Class1"
  type="Class1Type"/>
```

Derivation Patterns -- Specialization of classes (Inheritance)

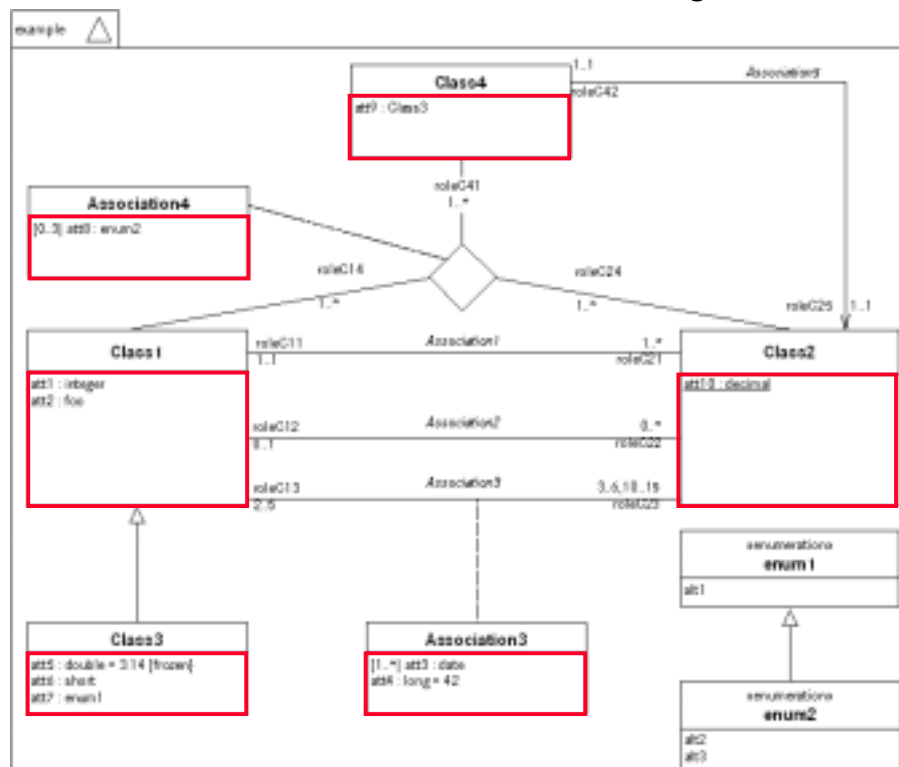
Purpose: Usage of XSD's *extension* mechanism for single inheritance
 Processing of multiple generalizations by hand ...
 Therefore, usage of *substitutionGroups*, implementation of copy-down semantics by hand



```
<xsd:complexType name="Class3Type">
  <xsd:complexContent>
    <xsd:extension base="Class1Type">
      ...
    </xsd:extension>
  </xsd:complexContent>
</xsd:complexType>
```

Derivation Patterns -- Attributes

Purpose: Derivation of XSD content models according to the semantics (e.g. data types) and meta semantics (e.g. UML structuring principles) formulated by the UML model



```
<xsd:element name="attribut'sNameType"
  type="matchingType"/>
```

```
<xsd:complexType name="Class1Type">
```

...

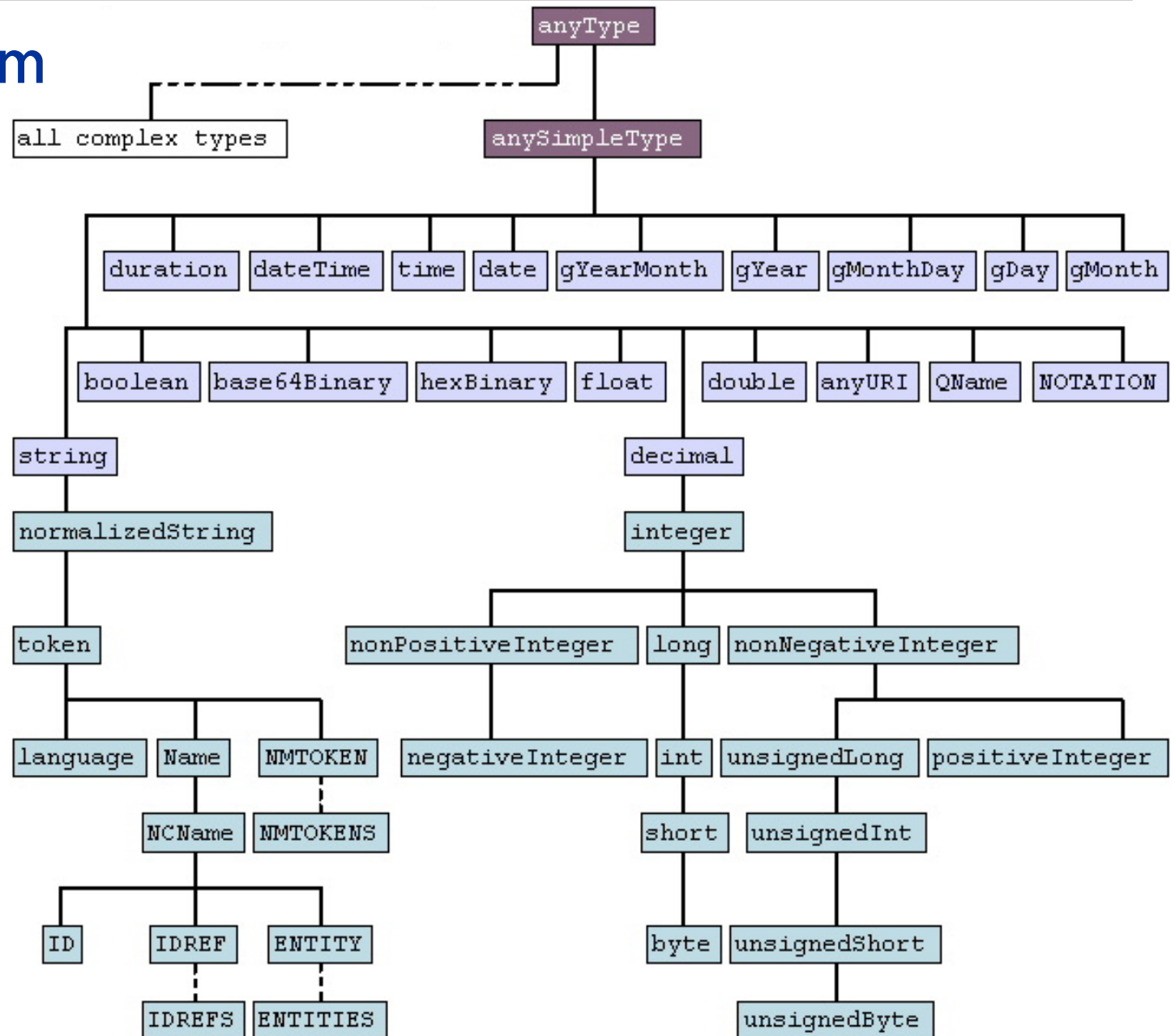
```
<xsd:element ref=" attribut'sNameType"/>
```

...

```
</xsd:complexType>
```

XSD's Type System

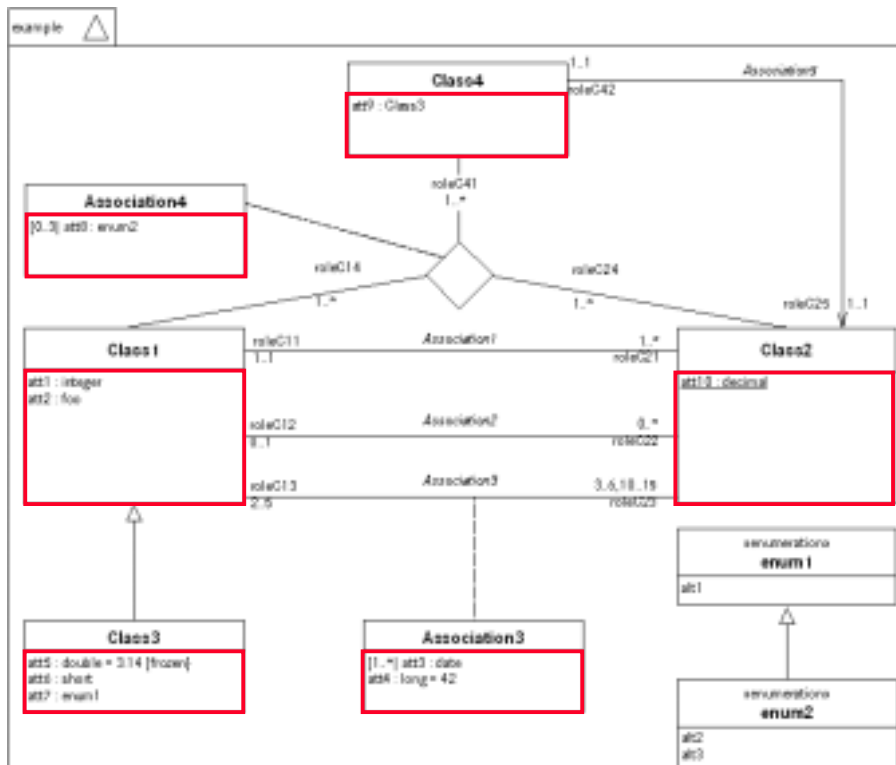
- ur type
- built-in primitive types
- built-in derived types
- derived by restriction
- - - - derived by list



Derivation Patterns -- Attributes

Purpose: Identify the *matchingType* ...

I. data types predefined by UML/MOF/CORBA



Integer → integer

String → string

Name → Name

Boolean → boolean

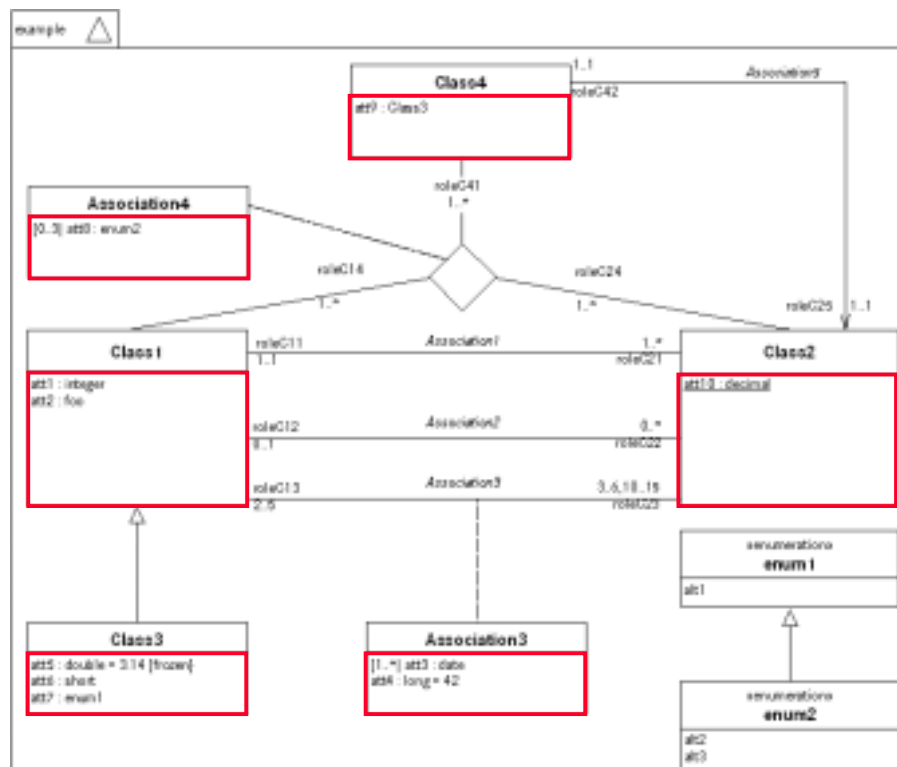
Time → ???

Uninterpreted → { base64Binary, hexBinary }

Derivation Patterns -- Attributes

Purpose: Identify the *matchingType* ...

I. data types predefined by UML/MOF/CORBA



Time → `<xsd:simpleType name="UDtime">`

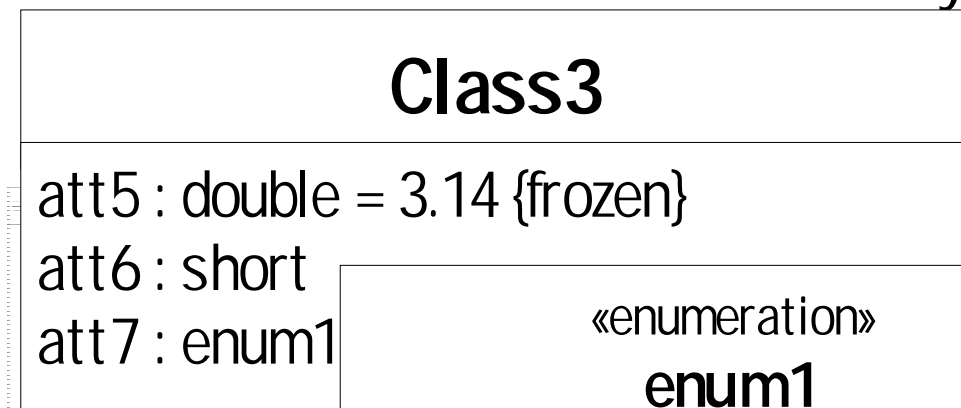
```

<xsd:union
  memberTypes="
    xsd:dateTime
    xsd:time
    xsd:date
    xsd:gMonth
    xsd:gYear"/>
</xsd:simpleType>

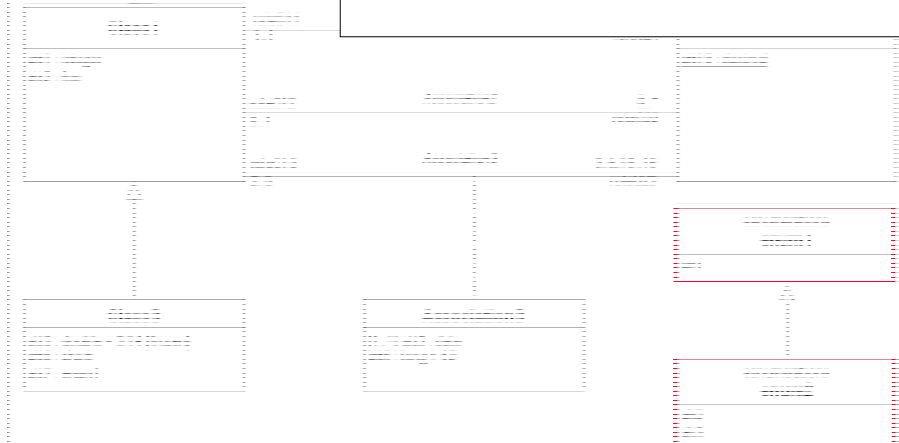
```


Derivation Patterns -- Attributes

Purpose: Identify the *matchingType* ...
 II. used defined data types (e.g. *enumeration types*)



alt1



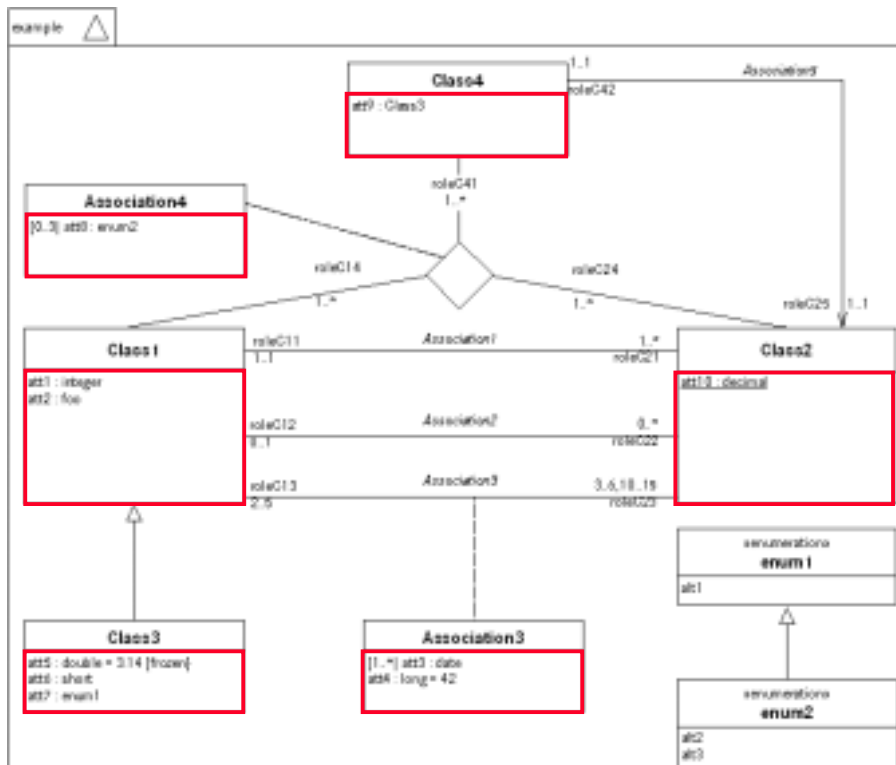
```
<xsd:simpleType name="enum1Type">
  <xsd:restriction base="xsd:string">
    <xsd:enumeration value="alt1"/>
  </xsd:restriction>
</xsd:simpleType>
```

```
<xsd:element name="att7Type"
  type="enum1Type"/>
```

Derivation Patterns -- Attributes

Purpose: Identify the *matchingType* ...

III. (direct) usage of XSD's pre-defined types

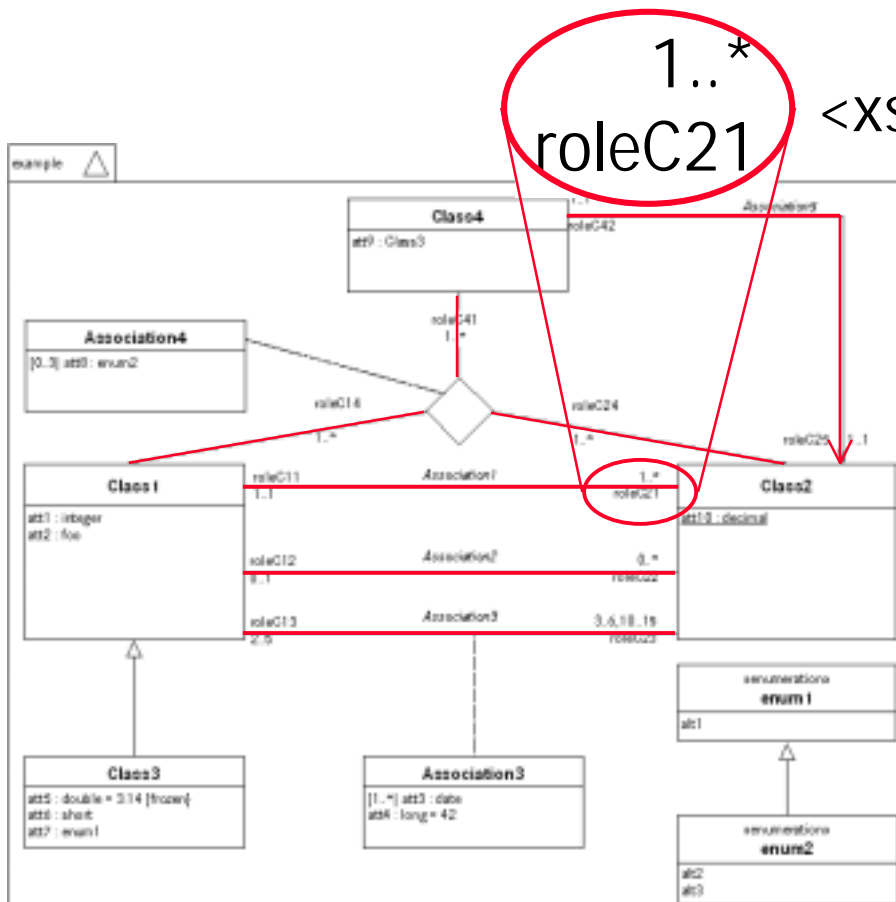


- normalizedString
- token
- language
- IDREFS
- ENTITIES
- NMTOKEN
- NMTOKENS
- Name
- NCName
- ID
- IDREF
- ENTITY
- gYearMonth
- gYear
- gMonthDay
- gDay
- gMonth
- hexBinary
- base64Binary
- anyURI
- QName
- NOTATION
- integer
- nonPositiveInteger
- negativeInteger
- long
- int
- short
- byte
- nonNegativeInteger
- unsignedLong
- unsignedInt
- unsignedShort
- unsignedByte
- positiveInteger
- string
- boolean
- decimal
- float
- double
- duration
- dateTime
- time
- date

Derivation Patterns -- Associations

Purpose: Transformation from the net to structure of trees

Basic Idea: Modification of all minimal multiplicities to zero



```

<xsd:element name="Class1" type="Class1Type">
  <xsd:complexType>
    <xsd:all>
      <!-- attributes -->
      <xsd:element name="Class2.role21"
        ref="Class2Type"
        minOccurs="0"
        maxOccurs="unbounded"/>
      ...
    </xsd:all>
  </xsd:element>
  
```

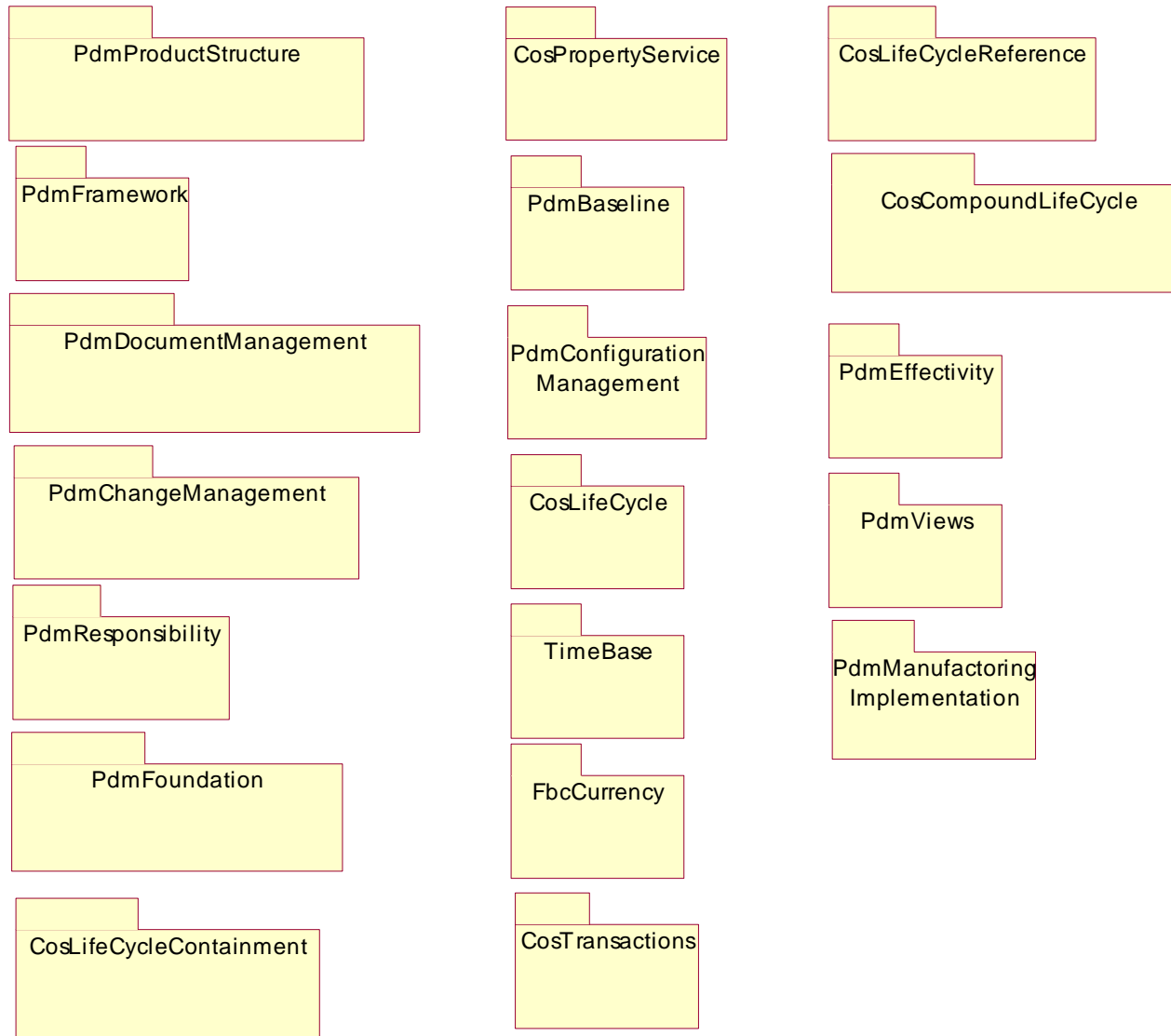
Derivation Patterns -- Handling Redundancy

Purpose: Coping with possibly multiple referenced elements

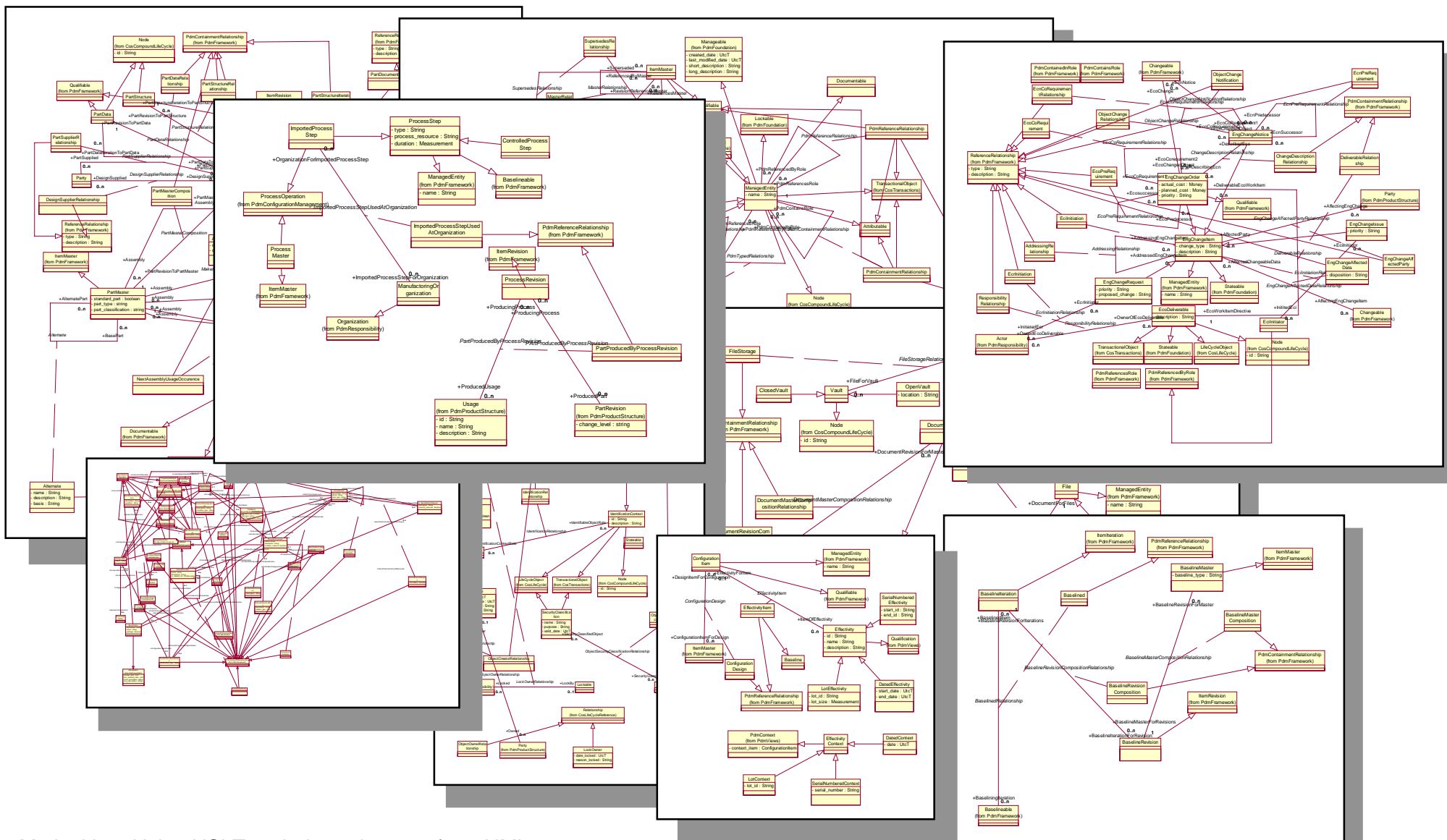
Basic Idea: Definition of unique identifier at class level,
separating defining occurrence from pure reference

```
<xsd:element name="Class1" type="Class1Type">
  <xsd:all>
    <xsd:element name="Class1.att1" type="xsd:integer"
      minOccurs="0"/>
    ...
  </xsd:all>
  <xsd:attribute name="xmi.id" type="ID"/>
  <xsd:attribute name="xmi.idref" type="IDREF"/>
  ...
</xsd:element>
```

OMG's PDM-Enablers



OMG's PDM-Enablers



Summary

- Derivation algorithm is stable and could be used widely
- Flexible, since new vocabularies could be easily re-generated
- Fast, since automatic derivation is deployed instead of a craftsmen's approach
- Coherent, built-in synchronization between data model and XML voc.
- Style, UML model (with it's modeling style) determines *style* of XML vocabulary. Meta-Structure is identical due to consistent derivation rules.
- If UML model reflects business structures and rules, derived XML schema also does
- Integrated, plug able into every object oriented development process
- Reuses existing data modeling knowledge (e.g. design patterns)
- Portable since XSLT implementation precludes neither programming language nor operating system