Languages and Software Language Engineering

Lecture 3: Relevant definitions and Metamodelling with Eclipse
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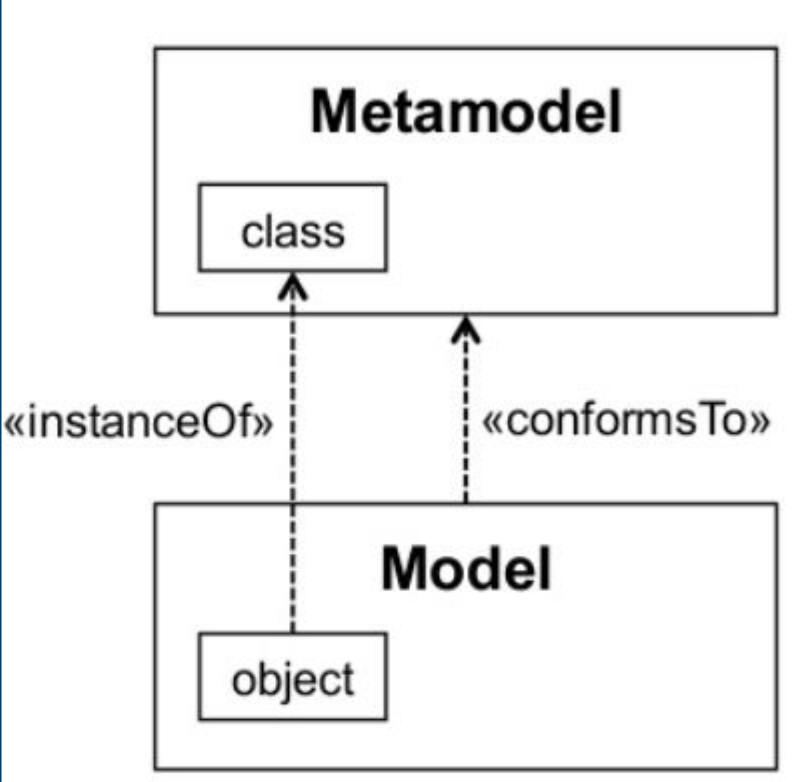
2022/2023

InstanceOf vs. ConformsTo

Conformance is between models
Instantiation is between model elements



Model Conformance

A model is valid in a given language if...

A model conforms to a given metamodel if each model element is an instance of a metamodel element. Then a model is valid with respect to the language represented by the metamodel.

Meta-language

A model is valid in a given language if...

Is a language dedicated to language modelling, i.e., for defining metamodels

MDE's meta-languages

MDE approaches leverages the object-oriented paradigm and most of the meta-languages are derivatives of UML's class diagram (we can also find ER like diagrams), often extended with related languages such as Object Constraint Language (OCL)

Modelling workbenches

A language workbench provides a set of tools and meta-languages supporting the development and evolution of a language and its associated tooling, including design, implementation, deployment, evolution, reuse, and maintenance.

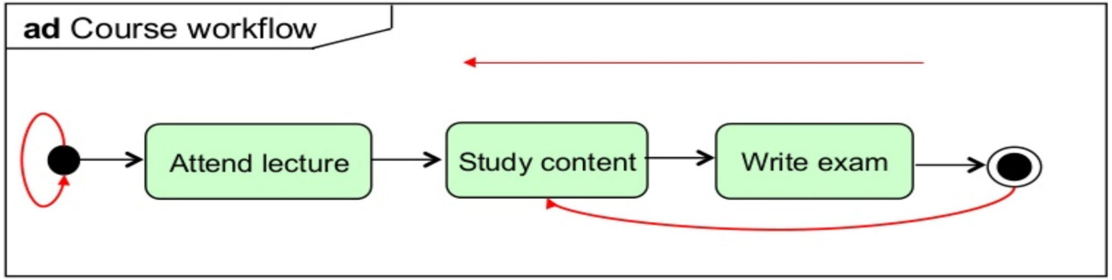
The term was coined in 2005 by Martin Fowler. Examples of workbenches are: JetBrains MPS, Metacase's MetaEdit, EMF, AtomPM, Microsoft Visualization and Modelling SDK

Meta Circularity

Use of a metamodel to model its own shape.All concepts available in a language can be modelled using the language itself.

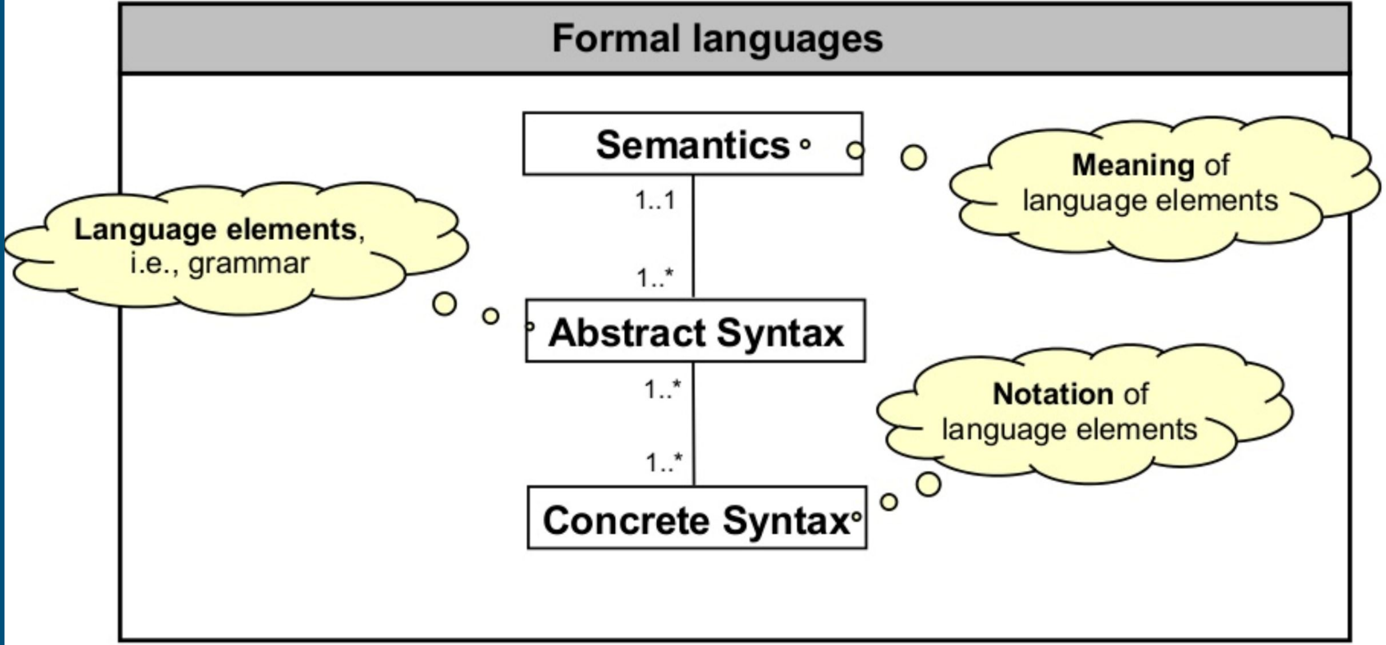
Example EBNF can model any kind of textual language, including itself, not being a threat to EBNF's usability or precision

- **Motivating example**: a simple UML Activity diagram
  - *Activity, Transition, InitialNode, FinalNode*



- **Question**: Is this UML Activity diagram **valid**?
- **Answer**: Check the **UML metamodel**!

- Languages have **divergent goals** and **fields of application, but** still have a **common** definition framework



- **Main components**
  - **Abstract syntax**: Language concepts and how these concepts can be combined (~ grammar)
    - It **does neither define** the **notation nor** the **meaning** of the concepts
  - **Concrete syntax: Notation** to illustrate the language concepts intuitively
    - **Textual**, **graphical** or a mixture of both
  - **Semantics**: **Meaning** of the language concepts
    - How language concepts are actually **interpreted**

- **Additional components**
  - **Extension** of the language by new language concepts
    - Domain or technology specific extensions, e.g., see UML Profiles
  - **Mapping** to other languages, domains
    - Examples: UML2Java, UML2SetTheory, PetriNet2BPEL, …
    - May act as translational semantic definition

- **Formal languages** have a **long tradition** in computer science
- **First attempts**: Transition from machine code instructions to high-level programming languages (Algol60)

- **Major successes**
  - Programming languages such as Java, C++, C#, …
  - Declarative languages such as XML Schema, DTD, RDF, OWL, …

- **Excursus**
  - **How** are **programming languages** and **XML-based languages** defined?
  - **What** can thereof be **learned** for defining modeling languages?

Programming languages

Overview

- John Backus and Peter Naur invented **formal languages** for the **definition of languages** called **meta-languages**
- Examples for meta-languages: BNF, EBNF, …
- Are used since 1960 for the **definition** of the **syntax** of **programming languages**
  - Remark: **abstract** and the **concrete** syntax are both defined
- EBNF Example

option · sequence · non-terminal

```
Java        := [PackageDec]  {ImportDec}  ClassDec;
PackageDec   := "package"  QualifiedIdentifier;
ImportDec   := "import"  QualifiedIdenfifier;
ClassDec   := Modifier  "class"  Identifier  ["extends" Identifier]
               ["implements" IdentifierList]  ClassBody;
```

production rule · terminal

Programming languages

Example: MiniJava

- Grammar

```
Java := [PackageDec] {ImportDec} ClassDec;
PackageDec := "package" QualifiedIdentifier;
ImportDec := "import" QualifiedIdenfifier;
ClassDec := Modifier "class" Identifier ["extends" Identifier]
            ["implements" IdentifierList] ClassBody;
Modifier := "public" | "private" | "protected";
Identifier := {"a"-"z" | "A"-"Z" | "0"-"9"}
```

- Program

```
package mdse.book.example;
import java.util.*;
public class Student extends Person { … }
```

- Validation: *does the program conform to the grammar*?
  - Compiler: javac, gcc, …
  - Interpreter: Ruby, Python, …

- Four-layer architecture

EBNF := {rules}; *rules* := Terminal | Non-Terminal |...	**Definition of EBNF in EBNF – EBNF grammar (reflexive)**	**M3-Layer**
Java := [PackageDec] {ImportDec} ClassDec; *PackageDec* := “**package**“ QualifiedIdentifier; ...	**Definition of Java in EBNF – Java grammar**	**M2-Layer**

`package mdse.book.example;`
`public class Student`
`extends Person { … }`
	Program – Sentence conform to the grammar	**M1-Layer**

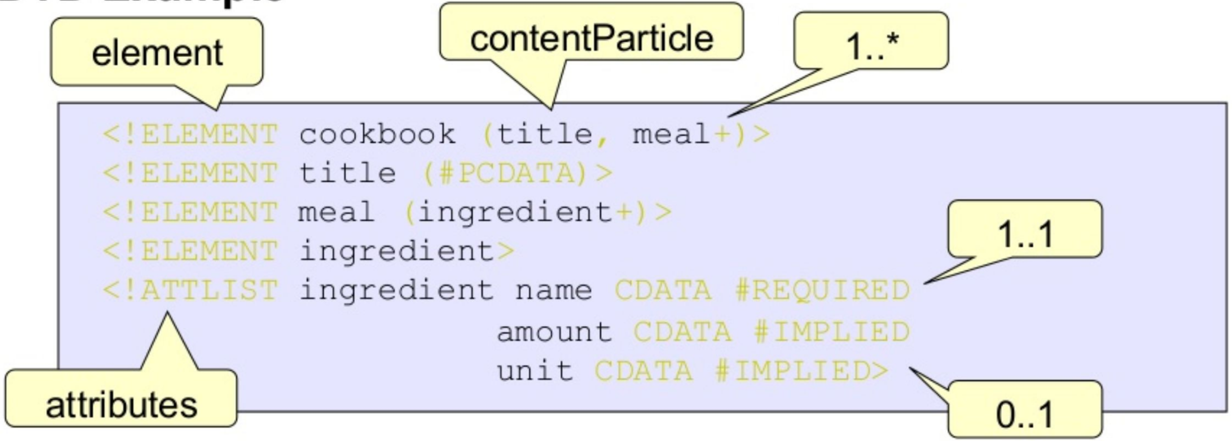
	**Execution of the program**	**M0-Layer**

XML-based languages

Overview

- XML files require specific structures to allow for a standardized and automated processing
- Examples for XML meta languages
  - DTD, XML-Schema, Schematron
- **Characteristics** of XML files
  - Well-formed (character level) vs. valid (grammar level)

- **DTD Example**



XML-based languages

Example: Cookbook DTD

- DTD

```
<!ELEMENT cookbook (title, meal+)>
<!ELEMENT title (#PCDATA)>
<!ELEMENT meal (ingredient+)>
<!ELEMENT ingredient>
<!ATTLIST ingredient name CDATA #REQUIRED
                     amount CDATA #IMPLIED
                     unit CDATA #IMPLIED>
```

- XML

```
<cookbook>
     <title>How to cook!</title>
     <meal name= „Spaghetti“ >
        <ingredient name = „Tomato“, amount=„300“ unit=„gramm“>
        <ingredient name = „Meat“, amount=„200“ unit=„gramm“> …
      </meal>
</cookbook>
```

- Validation
  - XML Parser: Xerces, …

XML-based languages

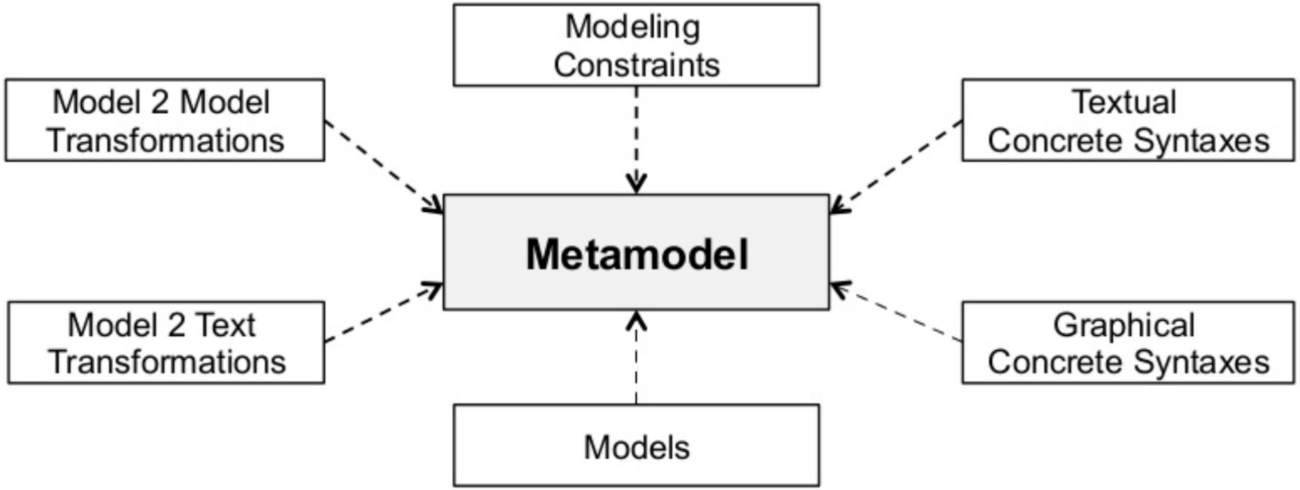
Meta-architecture layers

- Five-layer architecture (was revised with XML-Schema)

EBNF := {rules}; *rules* := Terminal | Non-Terminal |...	**Definition of EBNF in EBNF**	**M4-Layer**
ELEMENT := „<!ELEMENT " Identifier „>" ATTLIST; ATTLIST := „<!ATTLIST " Identifier …	**Definition of DTD in EBNF**	**M3-Layer**
`<!ELEMENT javaProg (packageDec*, importDec*, classDec)>` `<!ELEMENT packageDec (#PCDATA)>`	**Definition of Java in DTD – Grammar**	**M2-Layer**
<javaProg> <packageDec>**mdse.book.example**</packageDec> <classDec name=„**Student**" extends=„**Person**"/> </javaProg>	**XML – conform to the DTD**	**M1-Layer**
Concrete entities (e.g.: Student "Bill Gates")		**M0-Layer**

Abstract Syntax Metamodelling approach

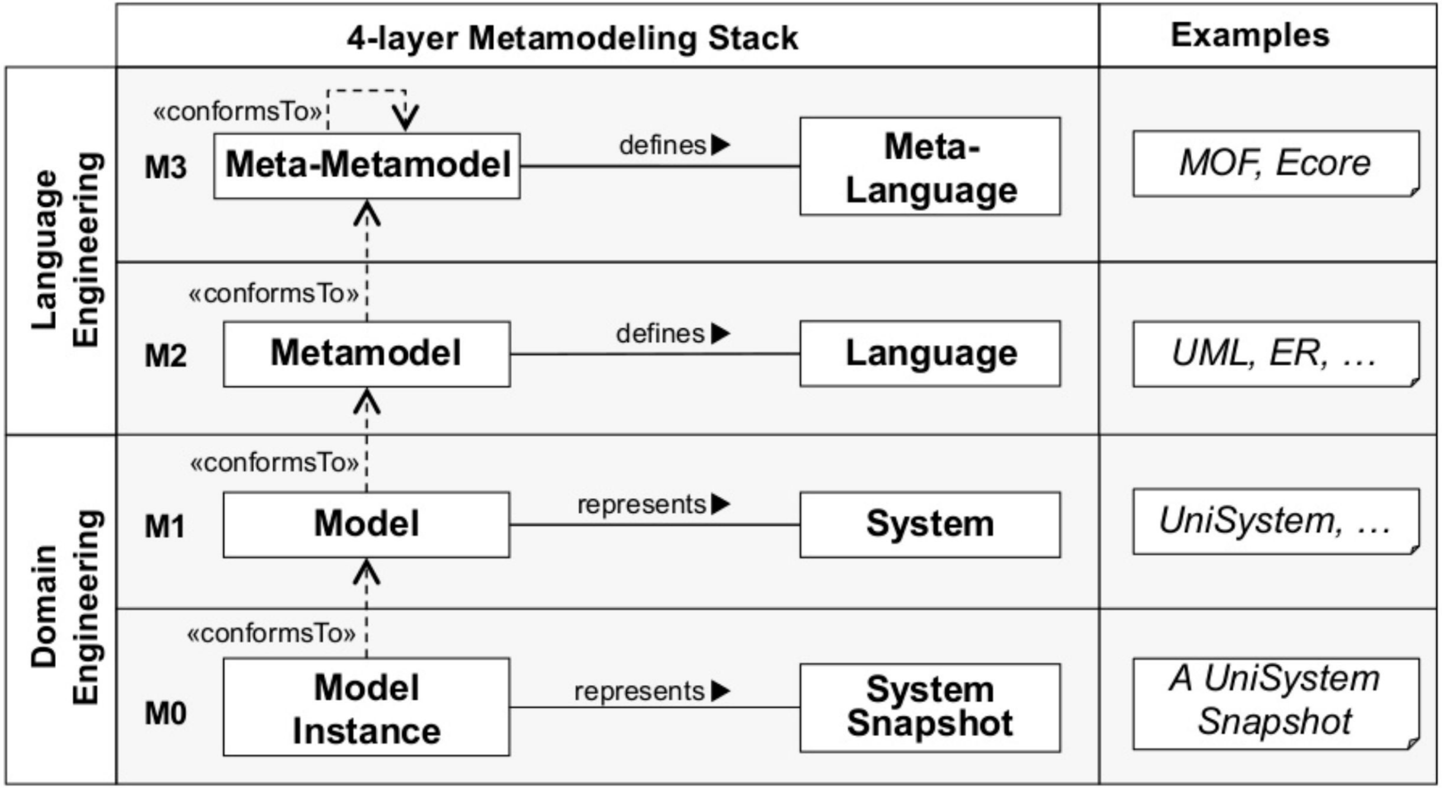
- **Metamodel-centric language design:**
  All language aspects base on the abstract syntax of the language defined by its metamodel



- **Advantages** of metamodels
  - Precise, accessible, and evolvable language definition

- **Generalization** on a higher level of abstraction by means of the **meta-metamodel**
  - Language concepts for the definition of metamodels
  - MOF, with Ecore as its implementation, is considered as a universally accepted meta-metamodel

- **Metamodel-agnostic** tool support
  - Common exchange format, model repositories, model editors, model validation and transformation frameworks, etc.

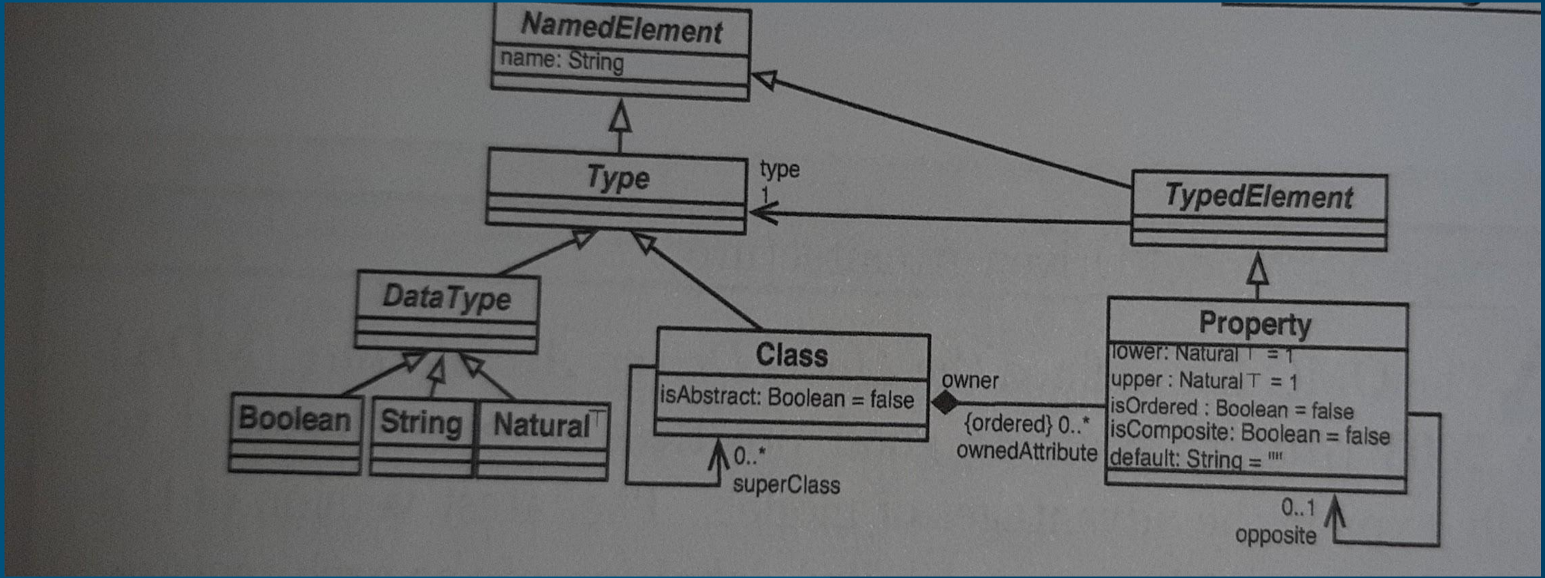

4-layer Metamodeling Stack
Examples
Language Engineering
Domain Engineering
M3
«conformsTo»
Meta-Metamodel
defines
Meta-Language
MOF, Ecore
M2
«conformsTo»
Metamodel
defines
Language
UML, ER, …
M1
«conformsTo»
Model
represents
System
UniSystem, …
M0
«conformsTo»
Model Instance
represents
System Snapshot
A UniSystem Snapshot

Meta-Object Facility (MOF)

Modelling formalism standardized by OMG to specify concepts and relationships between these concepts for a particular domain. MOF can be used for Domain Modelling and to describe the abstract syntax of a corresponding DSML

Meta-Object Facility (MOF)

Allows specifying concepts of a given domain in a package.
Package contains Classes, Properties, and relationships
Property can be an attribute or a reference to other class
Attribute is typed by enumeration or primitive type such as Boolean, String, integer, Real or Unlimited Natural



MOF - Meta Object Facility

Introduction 1/3

- **OMG standard** for the **definition of metamodels**
- MOF is an Object-Oriented modeling language
  - **Objects** are described by **classes**
  - **Intrinsic properties** of objects are defined as **attributes**
  - **Extrinsic properties** (links) between objects are defined as **associations**
  - **Packages** group classes
- MOF itself is defined by MOF (reflexive) and divided into
  - **eMOF** (essential MOF)
    - Simple language for the definition of metamodels
    - Target audience: **metamodelers**
  - **cMOF** (complete MOF)
    - Extends eMOF
    - Supports management of meta-data via enhanced services (e.g. reflection)
    - Target audience: **tool manufacturers**

MOF - Meta Object Facility

Introduction 2/3

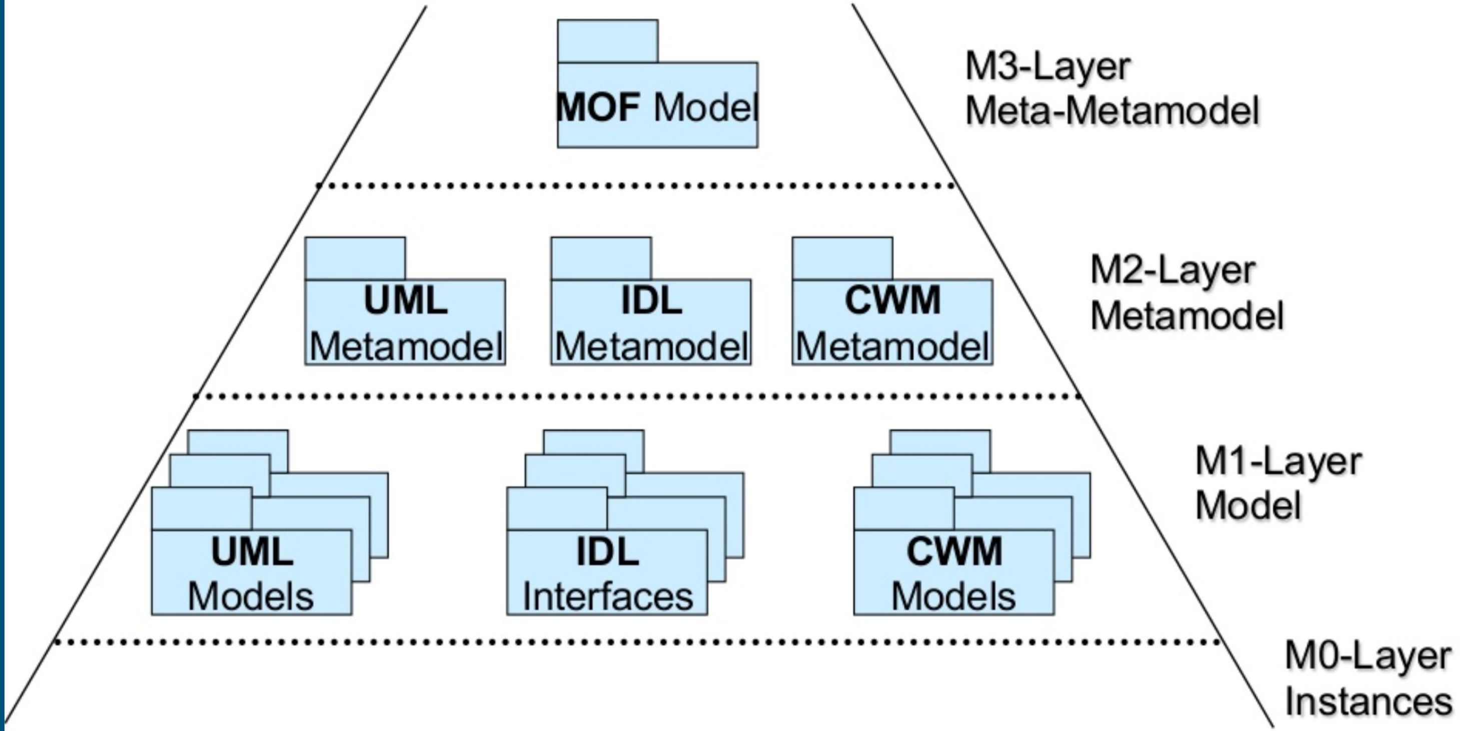
- Offers **modeling infrastructure** not only for MDA, but for MDE in general
  - MDA dictates MOF as meta-metamodel
  - UML, CWM and further OMG standards are conform to MOF

- **Mapping rules** for various **technical platforms** defined for MOF
  - XML: XML Metadata Interchange (XMI)
  - Java: Java Metadata Interfaces (JMI)
  - CORBA: Interface Definition Language (IDL)

MOF - Meta Object Facility

Introduction 3/3

- OMG language definition stack



Why an additional language for M3

… isn‘t UML enough?

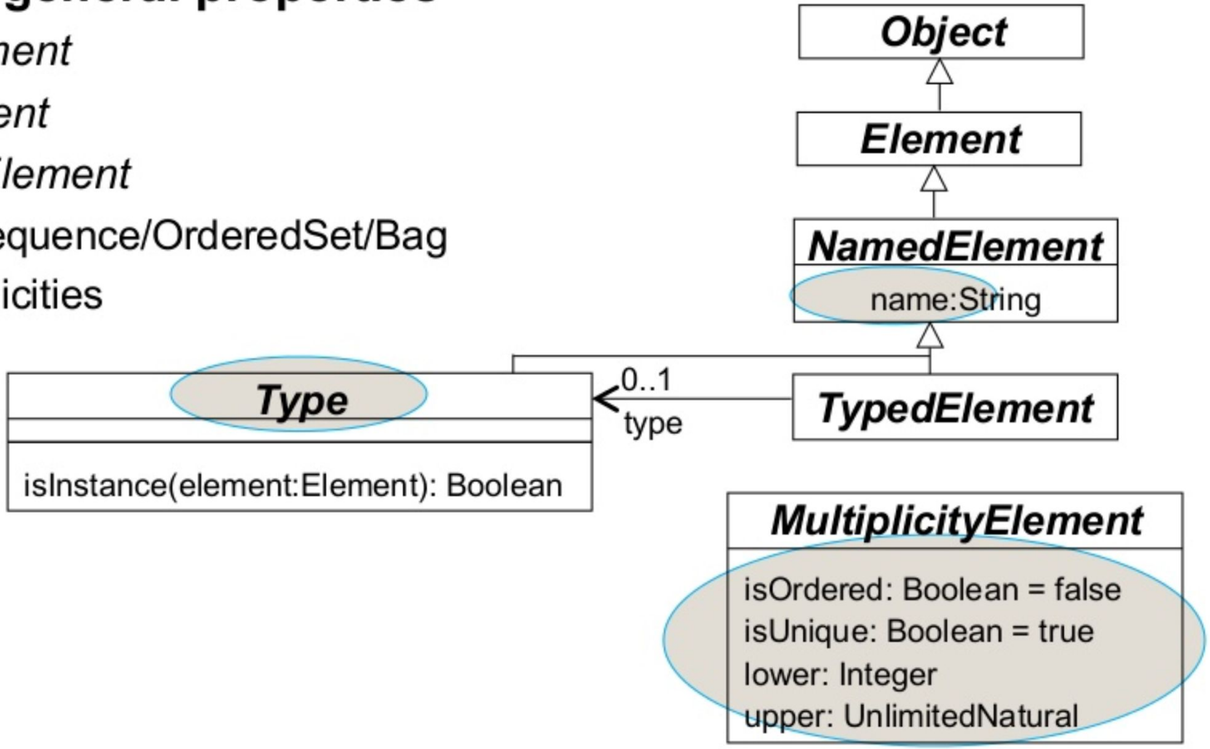
- **MOF** only a **subset** of **UML**
  - MOF is **similar** to the UML class diagram, but much more limited
  - No n-ary associations, no association classes, …
  - No overlapping inheritance, interfaces, dependencies, …
- Main differences result from the **field of application**
  - UML
    - Domain: **object-oriented modeling**
    - Comprehensive modeling language for various software systems
    - **Structural** and **behavioral modeling**
    - **Conceptual** and **implementation modeling**
  - MOF
    - Domain: **metamodeling**
    - Simple **conceptual structural modeling language**
- **Conclusion**
  - MOF is a highly **specialized DSML** for metamodeling
  - **Core** of UML and MOF (almost) **identical**

MOF – Meta Object Facility

Language architecture of MOF 2.0

- **Abstract classes** of eMOF
- Definition of **general properties**
  - *NamedElement*
  - *TypedElement*
  - *MultiplicityElement*
    - Set/Sequence/OrderedSet/Bag
    - Multiplicities

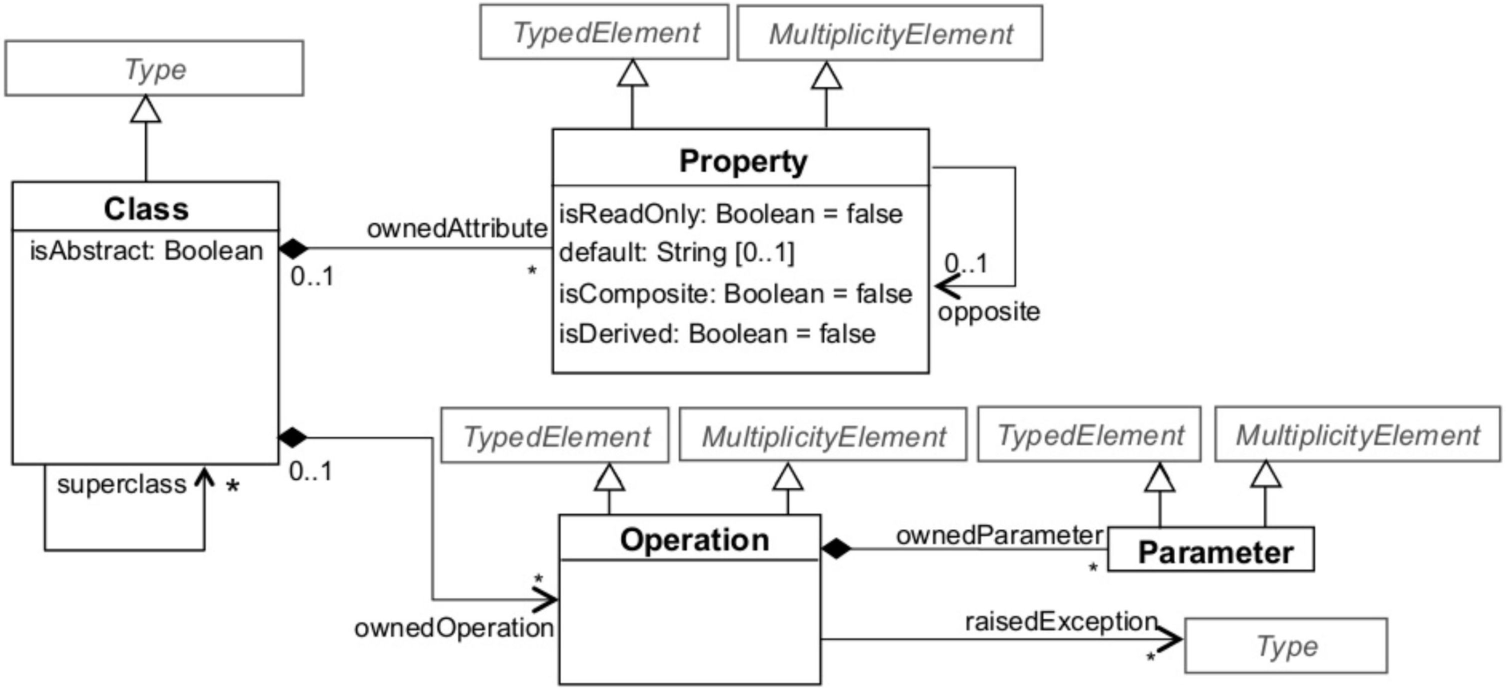
Taxonomy of abstract classes



MOF – Meta Object Facility

Language architecture of MOF 2.0

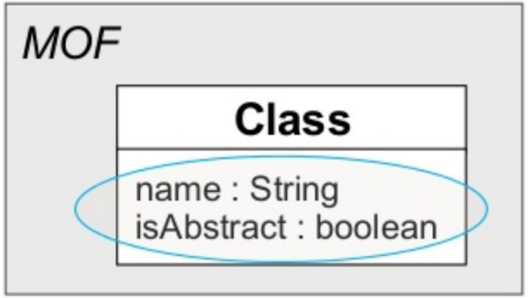
- **Core** of eMOF
  - Based on object-orientation
  - Classes, properties, operations, and parameters

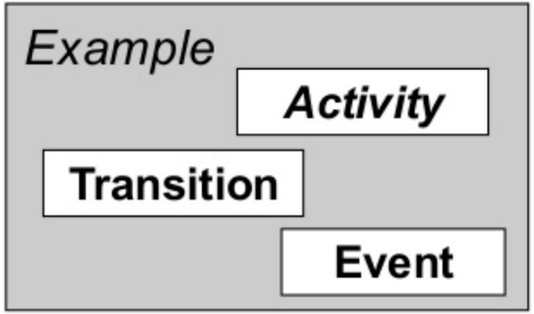


MOF – Meta Object Facility

Classes

- A class specifies ***structure*** and ***behavior*** of a **set of objects**
  - **Intentional** definition
  - An unlimited number of instances (objects) of a class may be created
- A class has an **unique name** in its namespace
- Abstract classes cannot be instantiated!
  - **Only useful in inheritance hierarchies**
  - Used for **»highlighting«** of **common features** of a set of subclasses
- Concrete classes can be instantiated!





MOF – Meta Object Facility

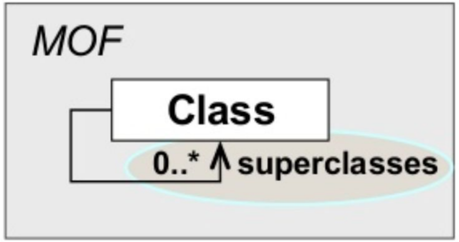
Generalization

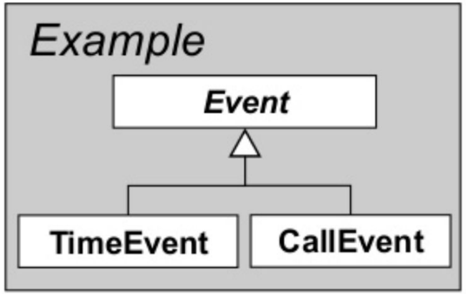
- **Generalization**: relationship between
  - a **specialized class** (*subclass)* and
  - a **general class** (*superclass*)

- Subclasses **inherit** properties of their superclasses and may add further properties

- Discriminator: „virtual“ attribute used for the **classification**

- **Disjoint** (non-overlapping) generalization
- **Multiple inheritance**

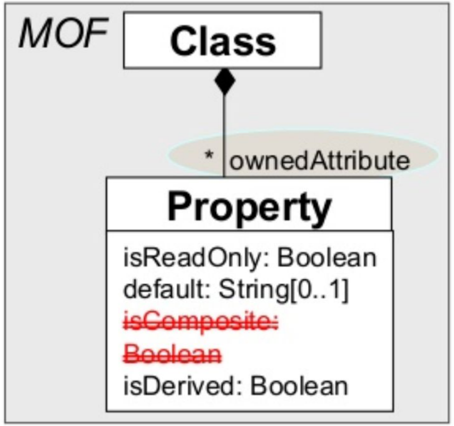


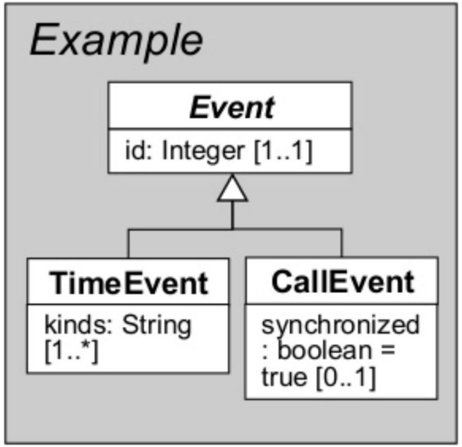


MOF – Meta Object Facility

Attributes

- **Attributes** describe *inherent* characteristics of *classes*
- Consist of a **name** and a **type** (obligatory)
- **Multiplicity**: how many values can be stored in an attribute slot (obligatory)
  - Interval: **upper** and **lower limit** are natural numbers
  - * asterisk - also possible for upper limit (Semantics: *unlimited number*)
  - 0..x means optional: null values are allowed
- **Optional**
  - **Default** value
  - **Derived** (calculated) attributes
  - **Changeable**: isReadOnly = false
  - isComposite is always true for attributes





MOF – Meta Object Facility

Associations

- An **association** describes the common structure of a set of relationships between objects

- MOF only allows ***unary*** and ***binary*** associations, i.e., defined between **two** classes

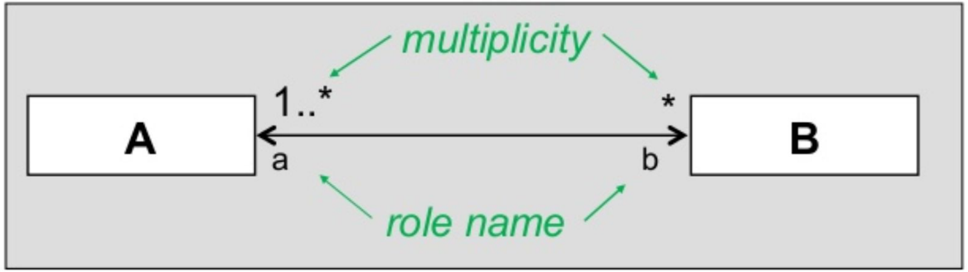
- **Binary associations** consist of **two roles** whereas each role has
  - **Role name**
  - **Multiplicity** limits **the number of** partner objects of an object

- **Composition**
  - „part-whole" relationship (also "part-of" relationship)
  - One part can be **at most** part of **one composed object** at one time
  - Asymmetric and transitive
  - Impact on multiplicity: 1 or 0..1

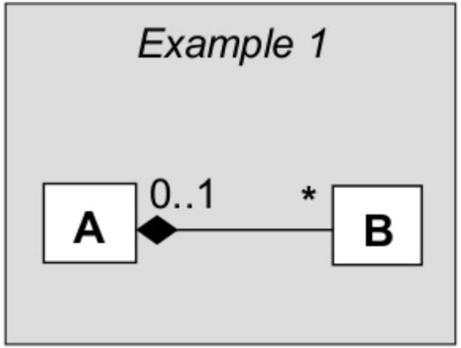
MOF – Meta Object Facility

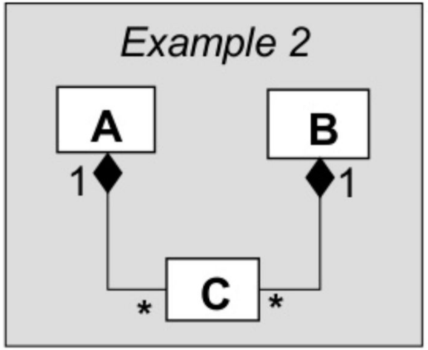
Associations - Examples

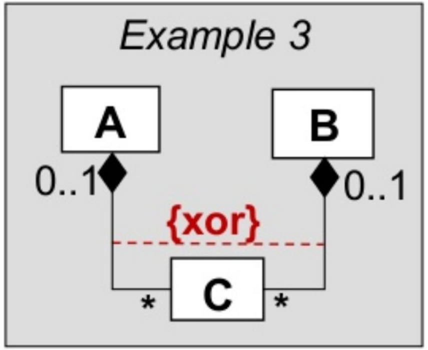
- **Association**



- **Composition**







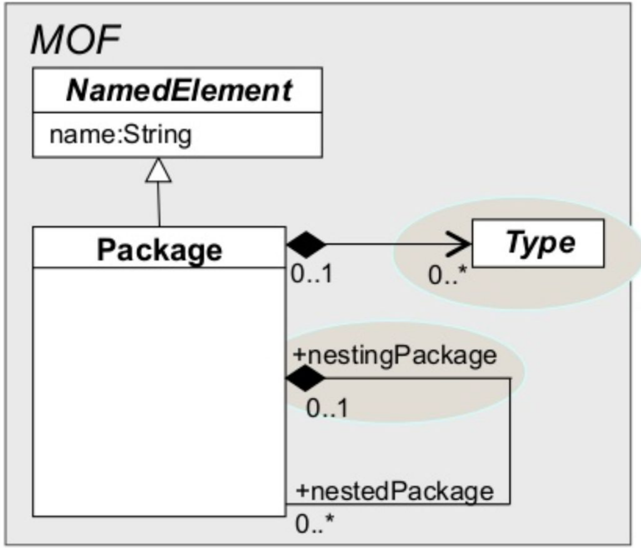
Example 2	
Syntax	✓
Semantics	×

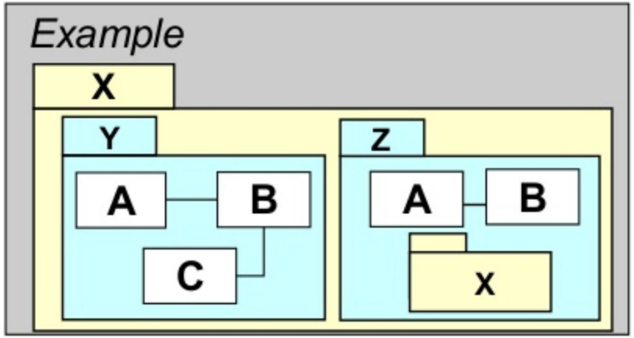
Example 3	
Syntax	✓
Semantics	✓

MOF – Meta Object Facility

Packages

- Packages serve as a **grouping mechanism**
  - Grouping of related types, i.e., classes, enumerations, and primitive types.
- Partitioning criteria
  - Functional or information cohesion
- Packages form **own namespace**
  - Usage of identical names in different parts of a metamodel
- Packages may be **nested**
  - *Hierarchical grouping*
- Model elements are contained in **one** package

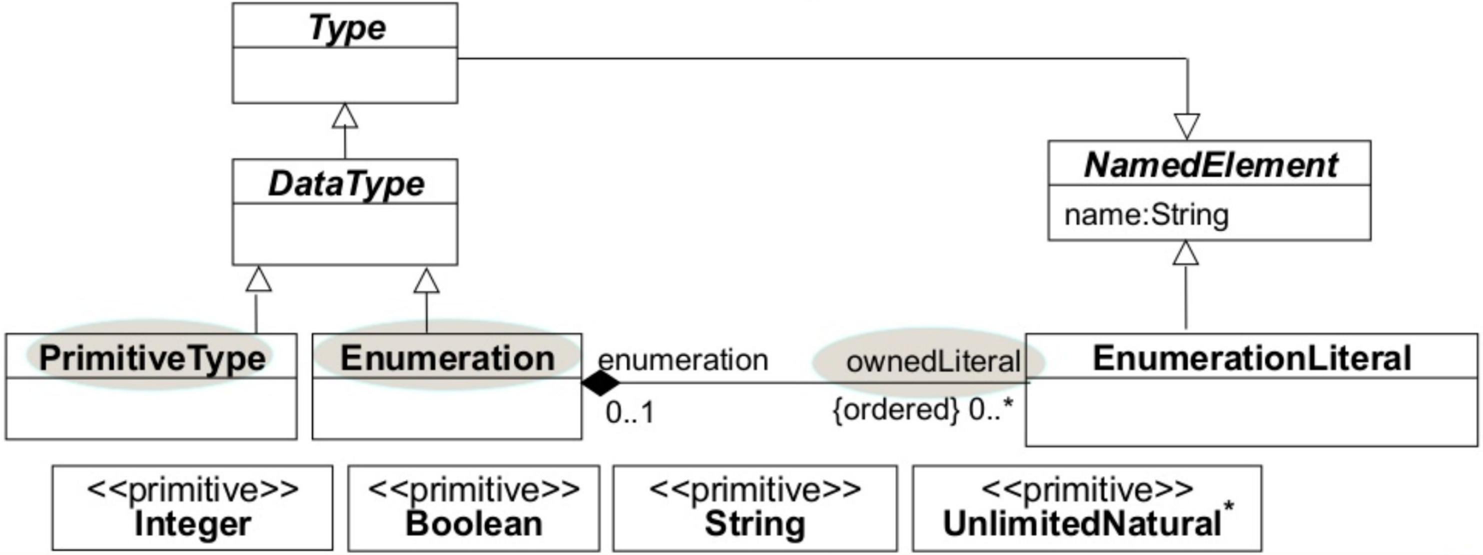




MOF – Meta Object Facility

Types 1/2

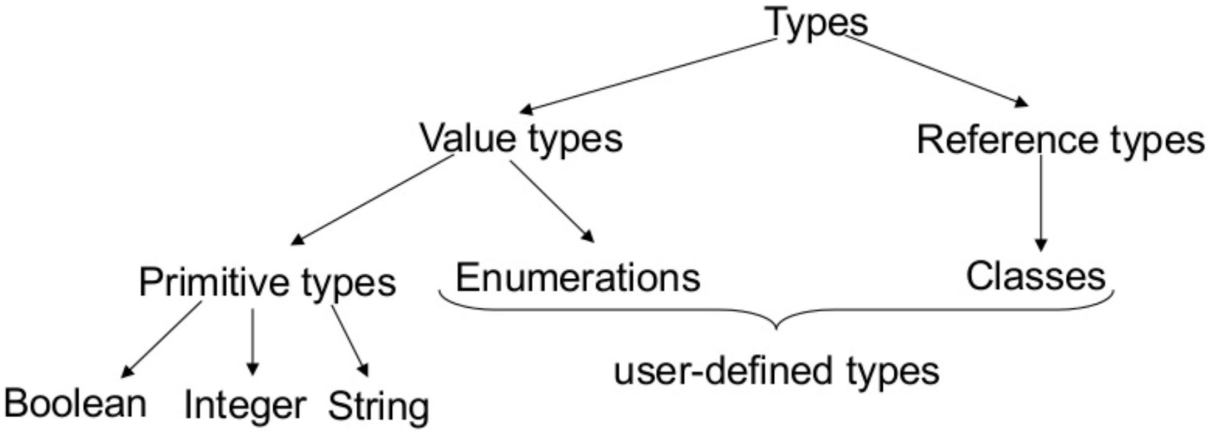
- **Primitive data types**: Predefined types for integers, character strings and Boolean values
- **Enumerations**: Enumeration types consisting of named constants
  - Allowed values are defined in the course of the declaration
    - Example: `enum Color {red, blue, green}`
  - Enumeration types can be used as data types for attributes



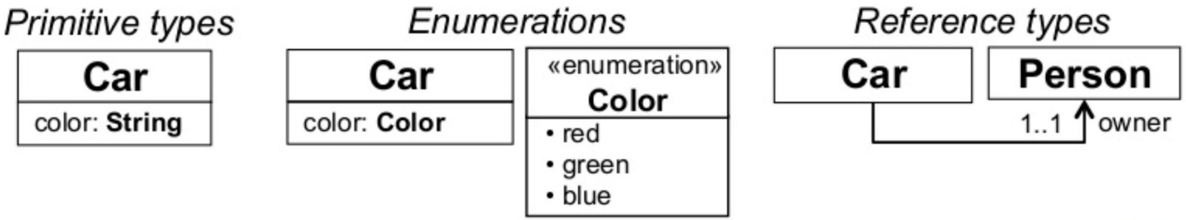
MOF – Meta Object Facility

Types 2/2

- Differentiation between ***value types*** and ***reference types***
  - Value types: contain a direct value (e.g., 123 or ‘x‘)
  - Reference types: contain a reference to an object

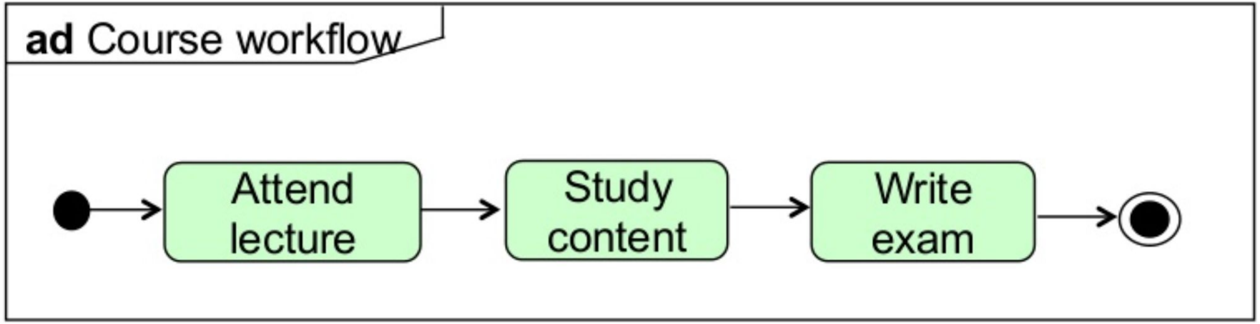


- **Examples**



Example 1/9

- **Activity diagram example**
  - Concepts: *Activity, Transition, InitialNode, FinalNode*
  - Domain: Sequential linear processes



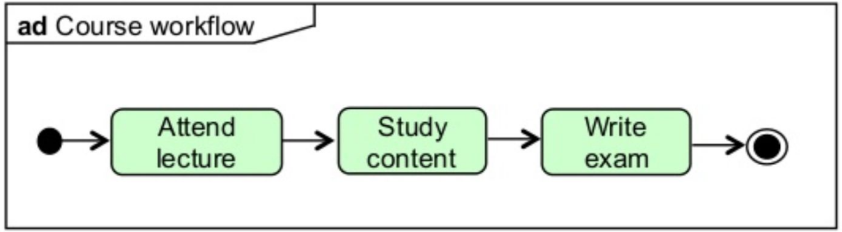
- Question: How does a possible metamodel to this language look like?

- Answer: apply metamodel development process!

Example 2/9

Identification of the modeling concepts

Example model = Reference Model



Notation table

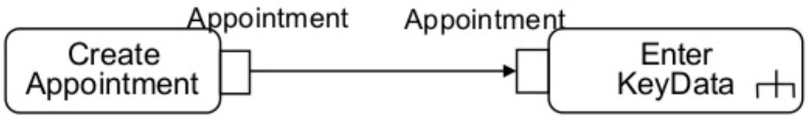
Syntax	***Concept***
ad name	ActivityDiagram
◉	FinalNode
●	InitialNode
name	Activity
→	Transition

- Several languages have **no formalized definition** of their **concrete syntax**

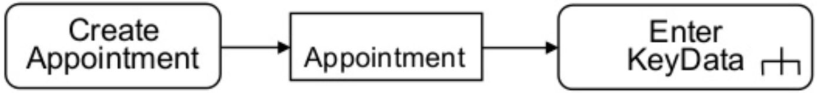
- Concrete syntax **improves** the **readability** of models
  - Abstract syntax not intended for humans!
- **One** abstract syntax may have **multiple** concrete ones
  - Including textual and/or graphical
  - Mixing textual and graphical notations still a challenge!

- **Example** – Notation alternatives for the creation of an appointment

Notation alternative 1:



Notation alternative 2:



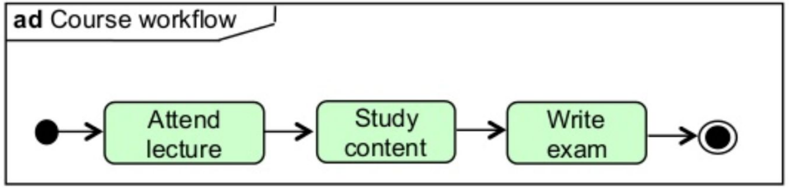
Notation alternative 3:

```
Appointment a;
a = new Appointment;
EnterKeyData (a);
```

Example 3/9

Determining the properties of the modeling concepts

Example model

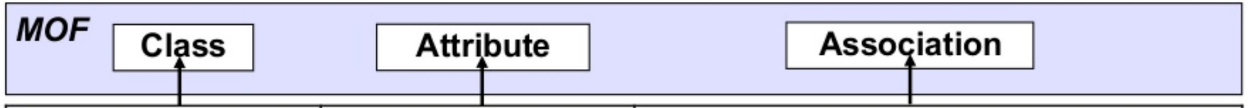


Modeling concept table

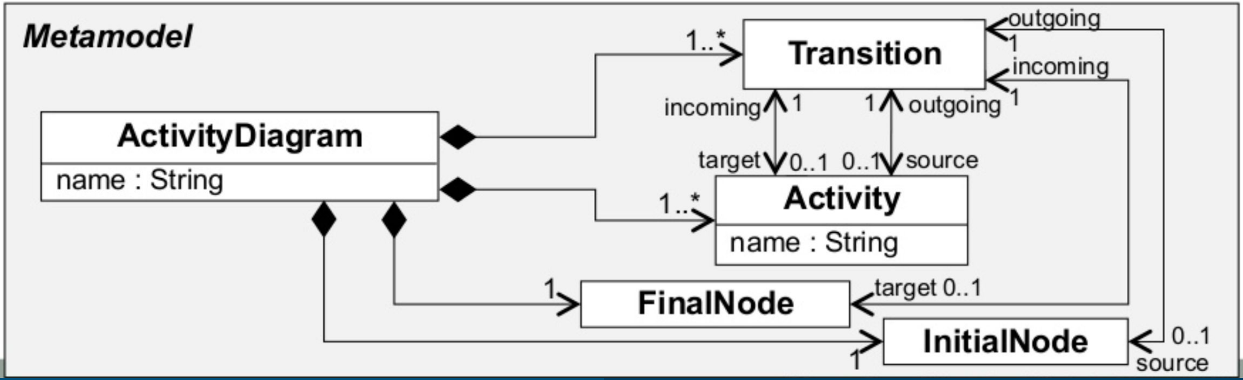
Concept	***Intrinsic properties***	***Extrinsic properties***
ActivityDiagram	Name	1 *InitialNode* 1 *FinalNode* Unlimited number of *Activities* and *Transitions*
FinalNode	-	Incoming *Transitions*
InitialNode	-	Outgoing *Transitions*
Activity	Name	Incoming and outgoing *Transitions*
Transition	-	Source node and target node Nodes: *InitialNode*, *FinalNode*, *Activity*

Example 4/9

Object-oriented design of the language

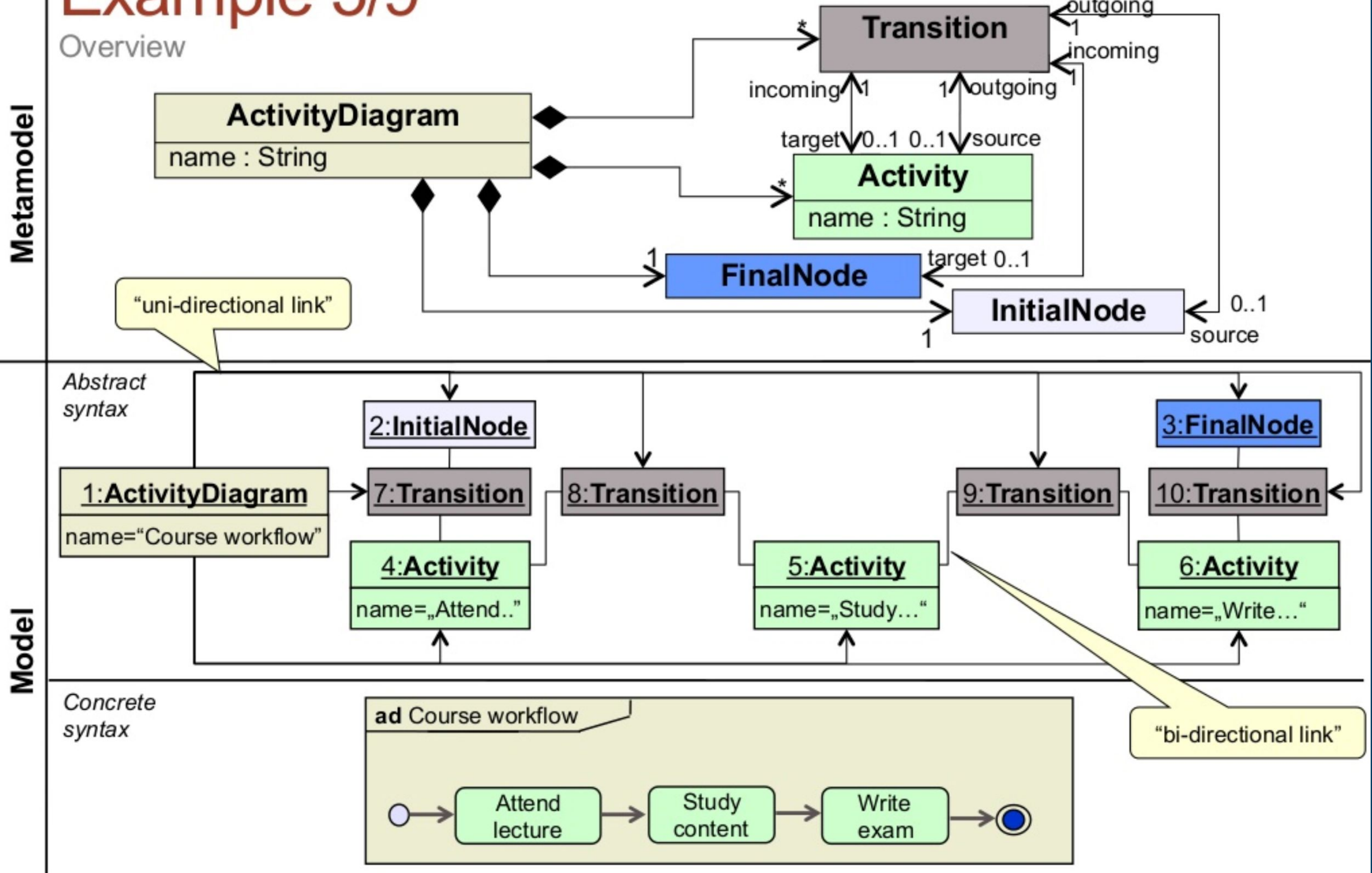


Concept	*Intrinsic properties*	*Extrinsic properties*
ActivityDiagram	Name	1 *InitialNode* 1 *FinalNode* Unlimited number of Activities and Transitions
FinalNode	-	Incoming *Transition*
InitialNode	-	Outgoing *Transition*
Activity	Name	Incoming and outgoing *Transition*
Transition	-	Source node and target node Nodes: *InitialNode*, *FinalNode*, *Activity*



Example 5/9

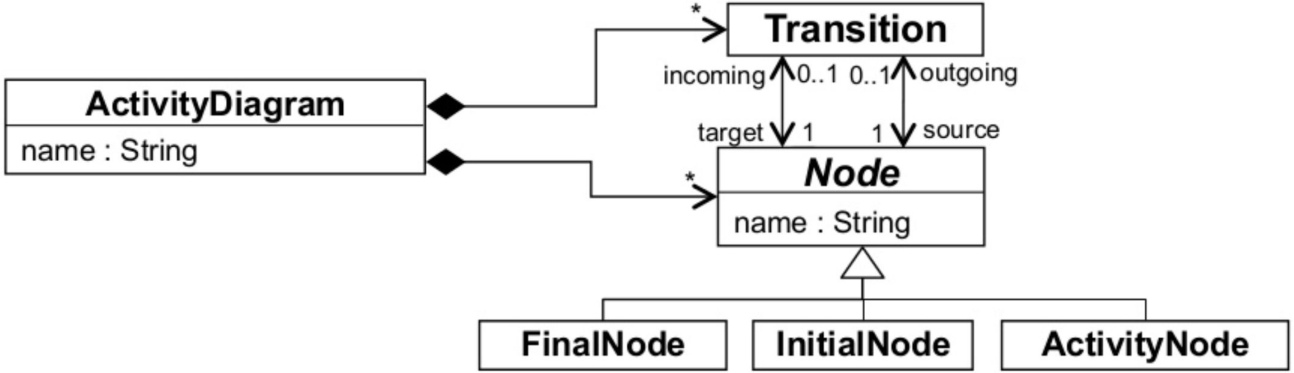
Overview



Example 6/9

Applying refactorings to metamodels

Metamodel



OCL Constraints

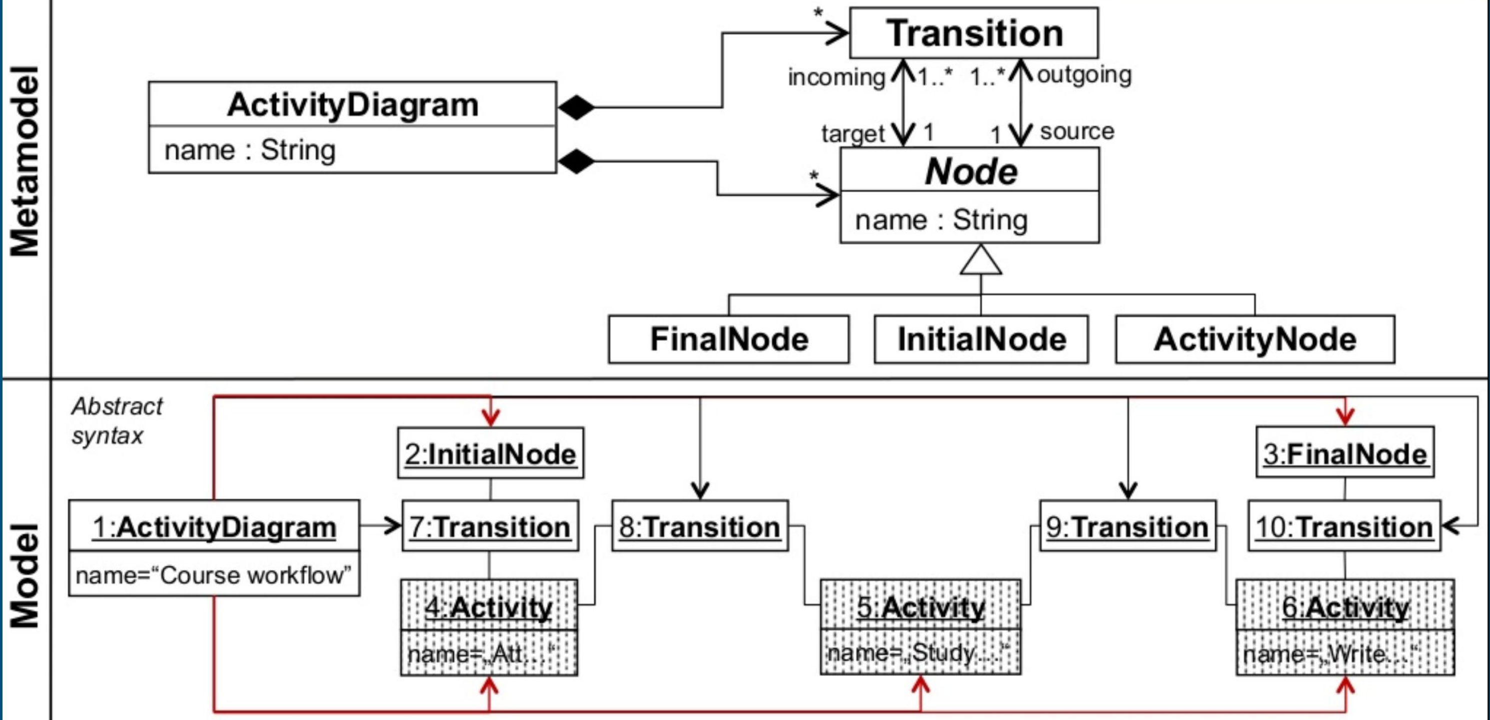
```
context ActivityDiagram
inv: self.nodes -> exists(n|n.isTypeOf(FinalNode))
inv: self.nodes -> exists(n|n.isTypeOf(InitialNode))

context FinalNode
inv: self.outgoing.oclIsUndefined()

context InitialNode
inv: self.incoming.oclIsUndefined()

context ActivityDiagram
inv: self.name <> '' and self.name <> OclUndefined …
```

Example 7/9

Impact on existing models

Changes:

- **Deletion** of class Activity
- **Addition** of class ActivityNode
- **Deletion** of redundant references



Validation errors:

- Class Activity is unknown,
- Reference finalNode, initialNode, activity are unknown

Example 8/9

How to keep metamodels evolvable when models already exist

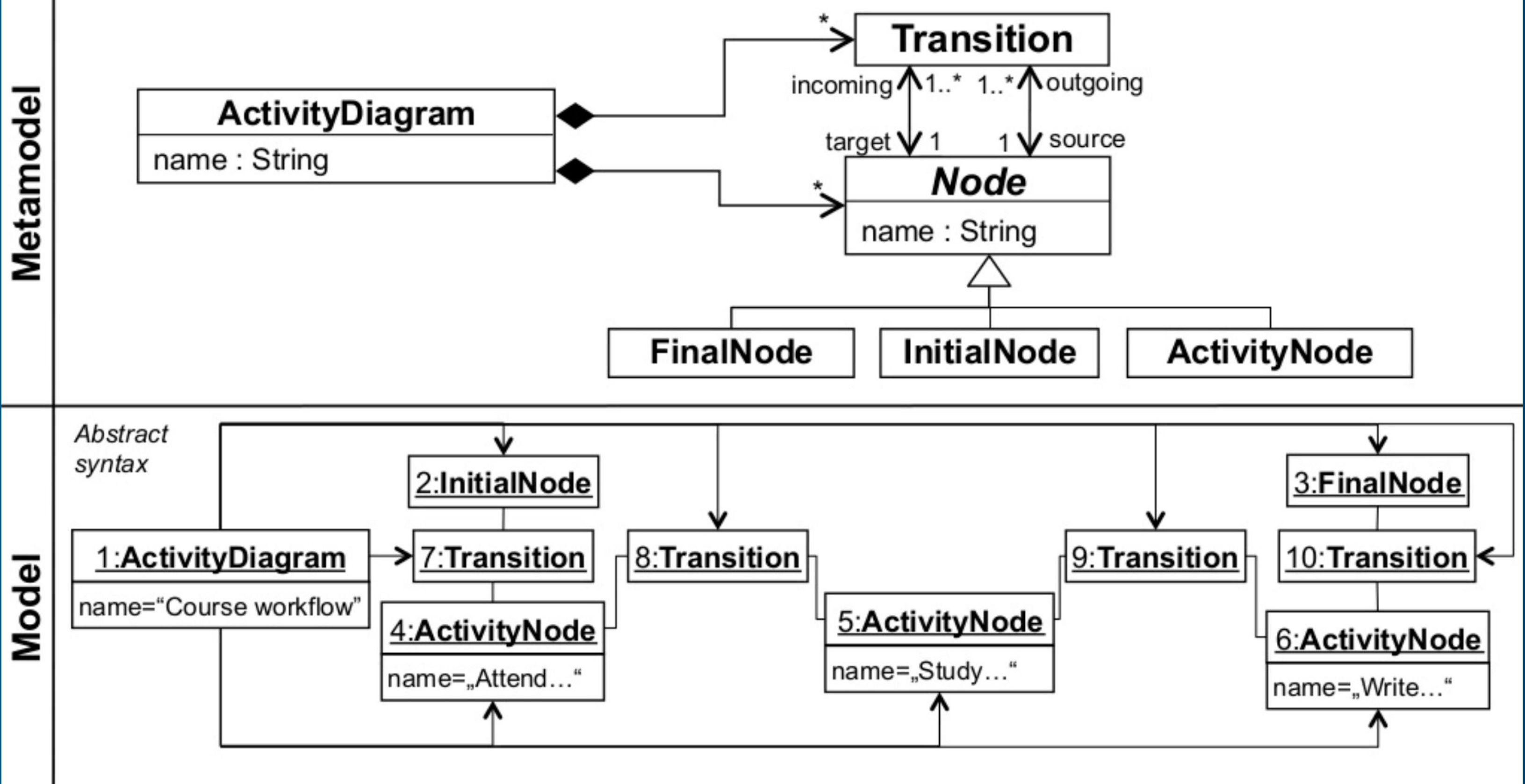
- **Model/metamodel co-evolution problem**
  - Metamodel is changed
  - Existing models eventually become invalid

- **Changes** may **break** conformance relationships
  - Deletions and renamings of metamodel elements

- **Solution**: **Co-evolution rules** for models **coupled** to metamodel **changes**
  - Example 1: Cast all *Activity* elements to *ActivityNode* elements
  - Example 2: Cast all *initialNode*, *finalNode*, and *activity* links to *node* links

Example 9/9

Adapted model for new metamodel version



Eclipse Modelling Framework (EMF)

EMF is a Modelling framework in the Eclipse workbench.Has tools such as reflective editors, XML serialization of models, uniform way to access models from Java

ECORE

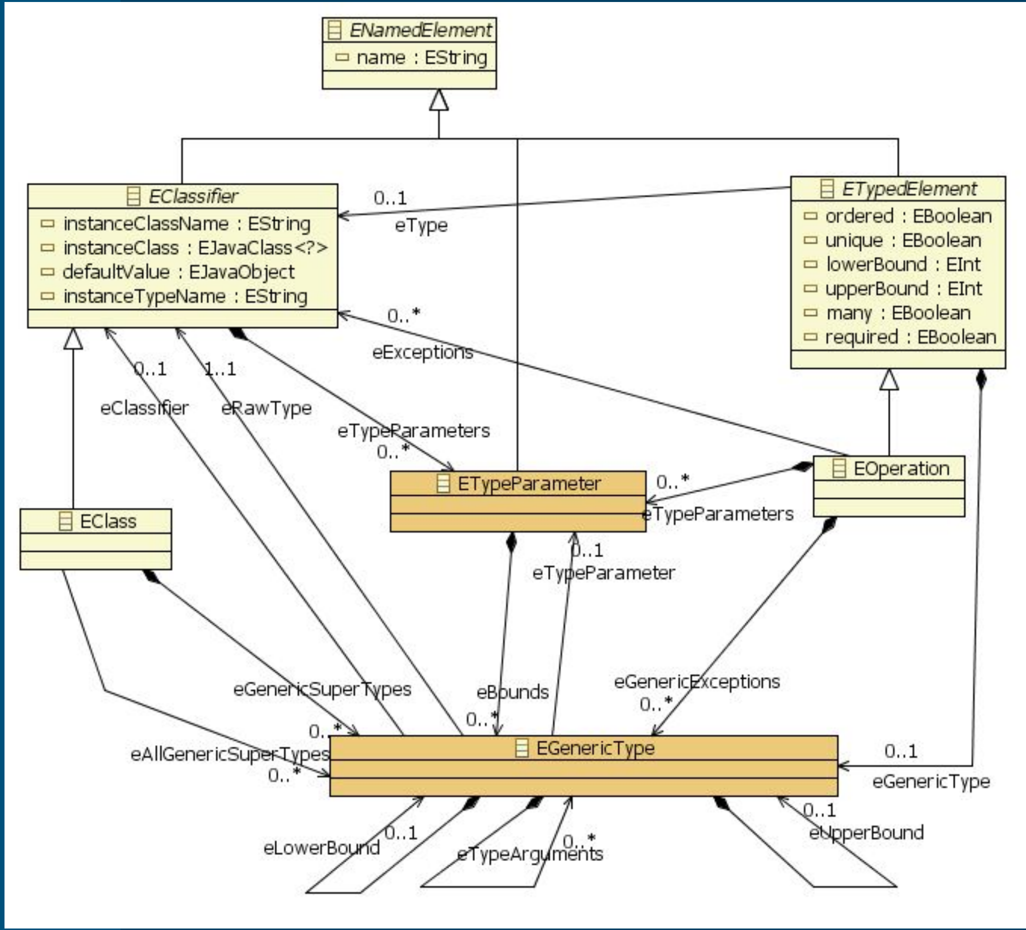
EMF meta-language (implementation of MOF)

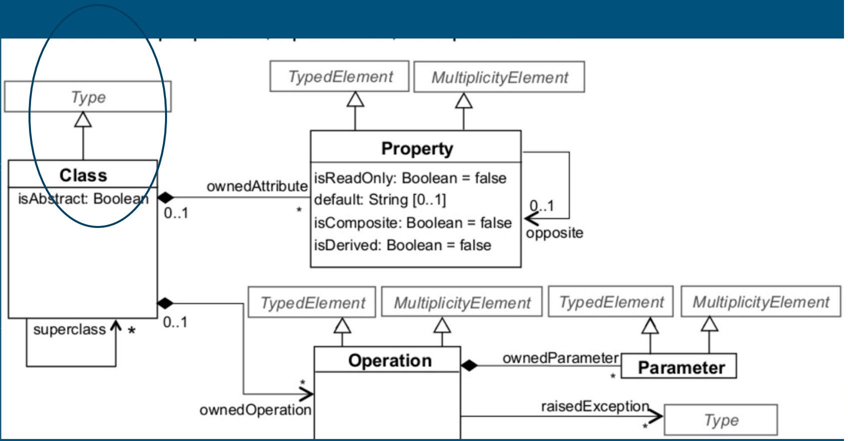
Some remarks:

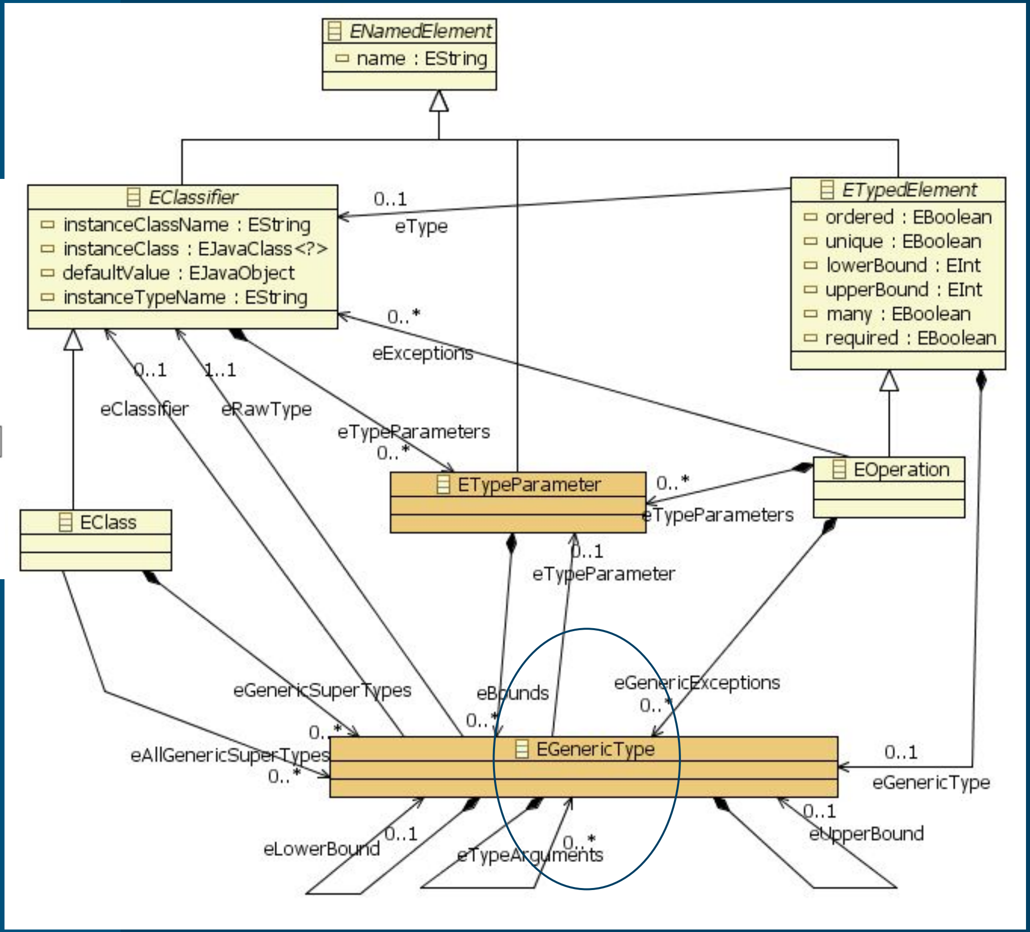
To avoid confusion in eclipse (for instance with the underlying Java elements) Ecore has prefixed all concepts with an **E**.

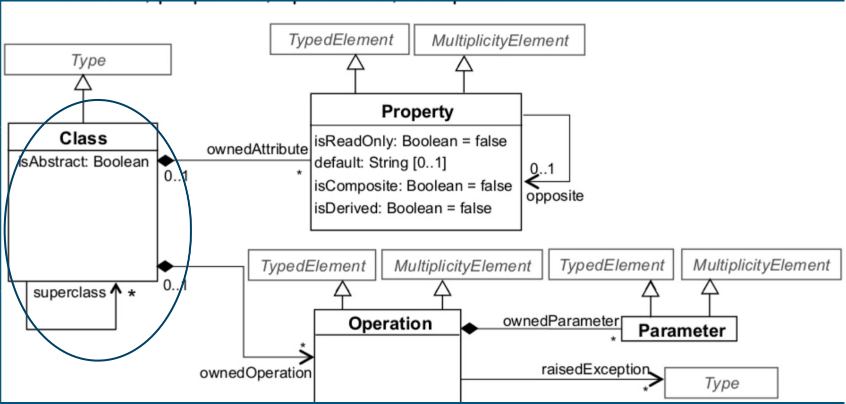
EMF is not tied with Eclipse as any java application with the EMF runtime jars in its classpath can use the project to manipulate models

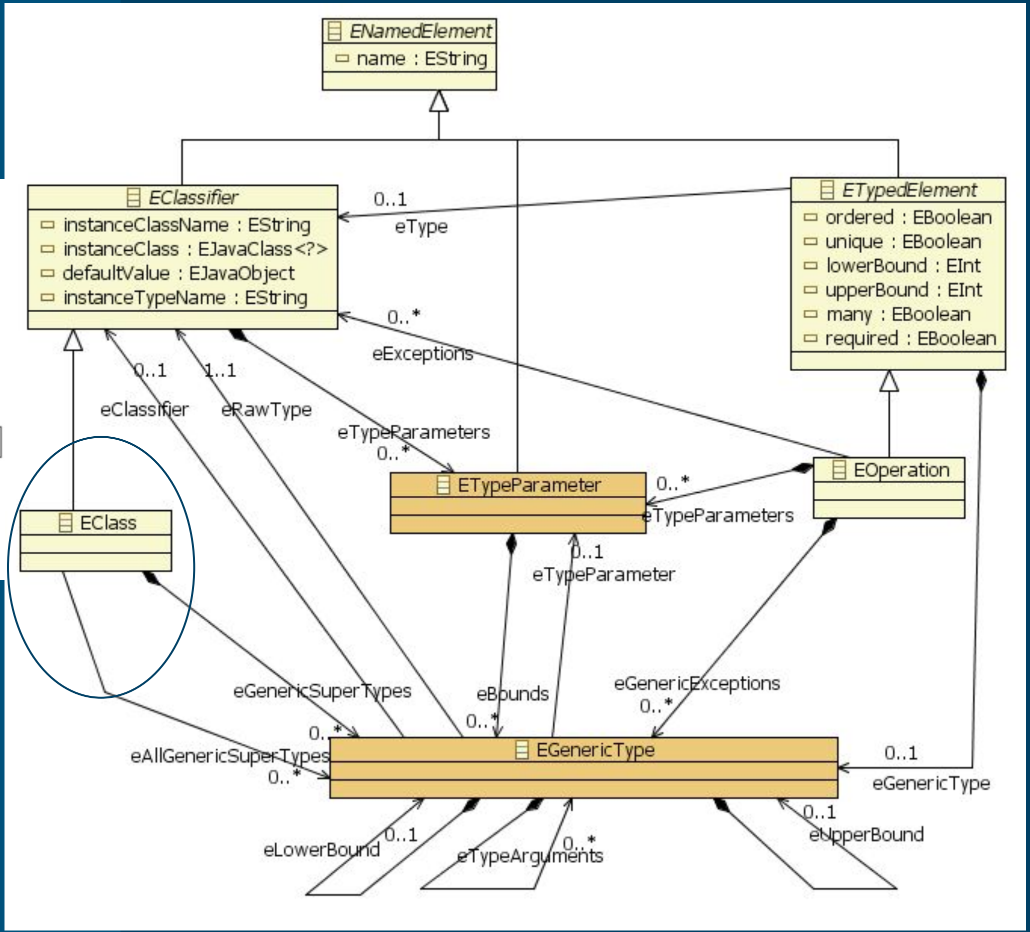
Generic Ecore Metamodel

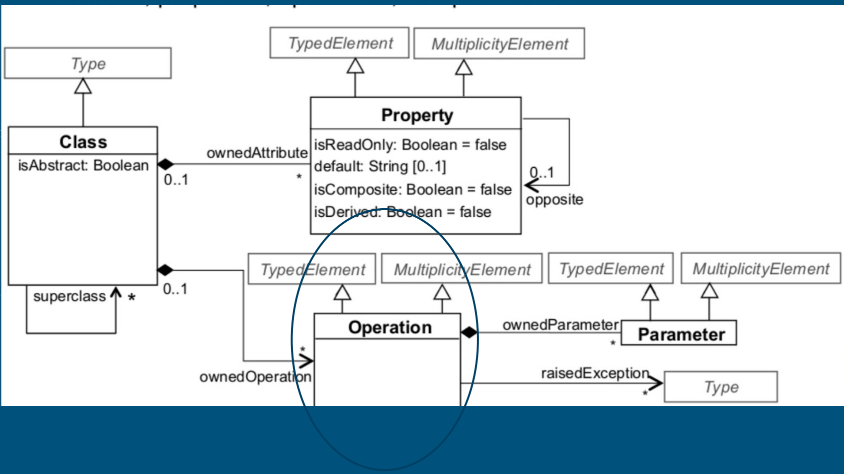



Type
TypedElement
MultiplicityElement
Class
isAbstract: Boolean
Property
isReadOnly: Boolean = false
default: String [0..1]
isComposite: Boolean = false
isDerived: Boolean = false
ownedAttribute
opposite
superclass
Operation
ownedParameter
Parameter
ownedOperation
raisedException


ENamedElement
name : EString
EClassifier
instanceClassName : EString
instanceClass : EJavaClass<?>
defaultValue : EJavaObject
instanceTypeName : EString
ETypedElement
ordered : EBoolean
unique : EBoolean
lowerBound : EInt
upperBound : EInt
many : EBoolean
required : EBoolean
0..1
eType
0..*
eExceptions
0..1
eClassifier
1..1
eRawType
eTypeParameters
0..*
EClass
ETypeParameter
EOperation
0..*
eTypeParameters
0..1
eTypeParameter
eGenericSuperTypes
0..*
eBounds
0..*
eGenericExceptions
0..*
EGenericType
eAllGenericSuperTypes
0..*
0..1
eGenericType
eLowerBound
0..1
eTypeArguments
0..*
0..1
eUpperBound


Type
TypedElement
MultiplicityElement
Class
isAbstract: Boolean
Property
isReadOnly: Boolean = false
default: String [0..1]
isComposite: Boolean = false
isDerived: Boolean = false
ownedAttribute
0..1
*
0..1
opposite
superclass
*
0..1
TypedElement
MultiplicityElement
TypedElement
MultiplicityElement
Operation
ownedParameter
Parameter
*
*
ownedOperation
raisedException
*
Type


ENamedElement
name : EString
EClassifier
instanceClassName : EString
instanceClass : EJavaClass<?>
defaultValue : EJavaObject
instanceTypeName : EString
0..1
eType
ETypedElement
ordered : EBoolean
unique : EBoolean
lowerBound : EInt
upperBound : EInt
many : EBoolean
required : EBoolean
0..*
eExceptions
0..1
1..1
eClassifier
eRawType
eTypeParameters
0..*
ETypeParameter
0..*
eTypeParameters
EOperation
EClass
0..1
eTypeParameter
eGenericSuperTypes
eBounds
eGenericExceptions
0..*
0..*
0..*
eAllGenericSuperTypes
0..*
EGenericType
0..1
eGenericType
eLowerBound
0..1
eTypeArguments
0..*
0..1
eUpperBound


Type
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MultiplicityElement
Property
Class
isAbstract: Boolean
ownedAttribute
0..1
*
isReadOnly: Boolean = false
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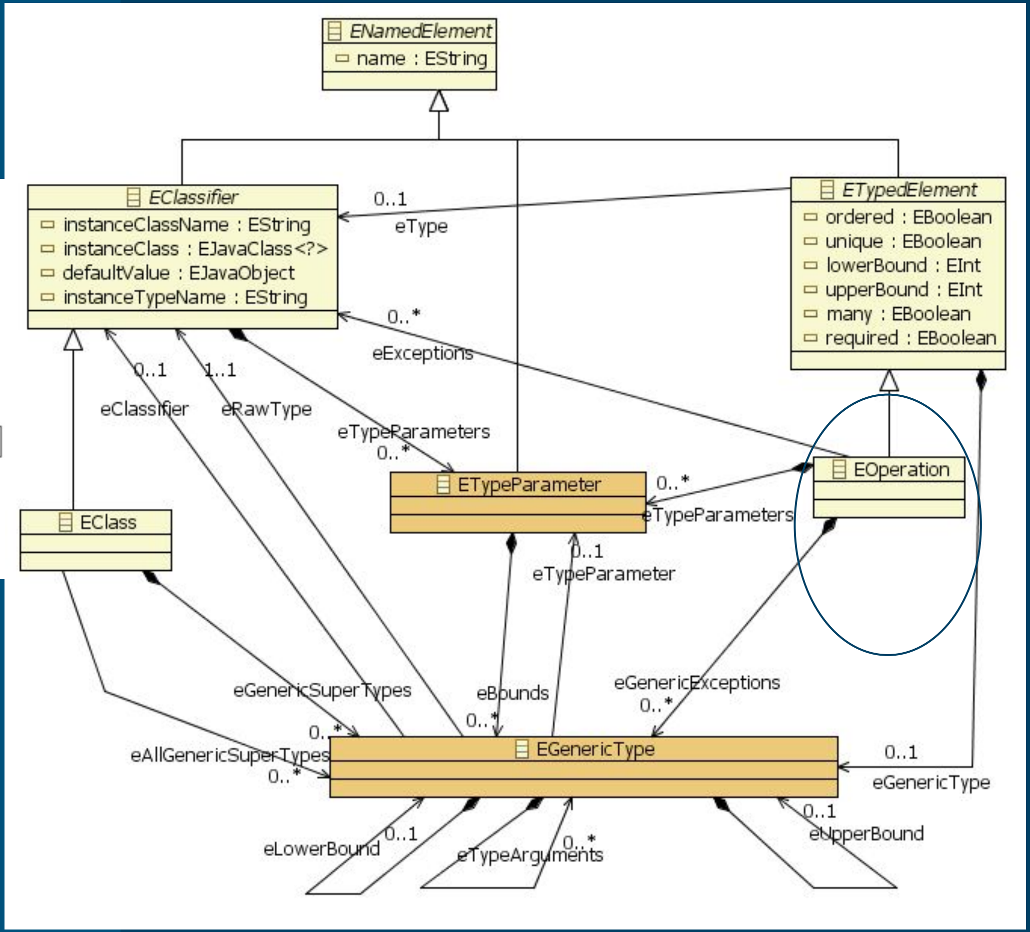
isComposite: Boolean = false
isDerived: Boolean = false
0..1
opposite
superclass
*
0..1
TypedElement
MultiplicityElement
TypedElement
MultiplicityElement
Operation
ownedParameter
*
Parameter
*
ownedOperation
raisedException
*
Type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EClassifier
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instanceClass : EJavaClass<?>
defaultValue : EJavaObject
instanceTypeName : EString
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eType
ETypedElement
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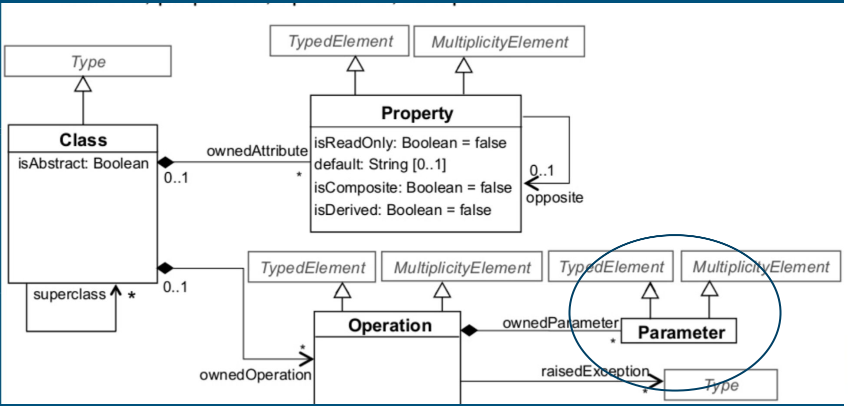
unique : EBoolean
lowerBound : EInt
upperBound : EInt
many : EBoolean
required : EBoolean
0..*
eExceptions
0..1
1..1
eClassifier
eRawType
eTypeParameters
0..*
EOperation
ETypeParameter
0..*
eTypeParameters
EClass
0..1
eTypeParameter
eGenericSuperTypes
eBounds
eGenericExceptions
0..*
0..*
0..*
eAllGenericSuperTypes
0..*
EGenericType
0..1
eGenericType
0..1
eLowerBound
0..1
eTypeArguments
0..*
eUpperBound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Operation
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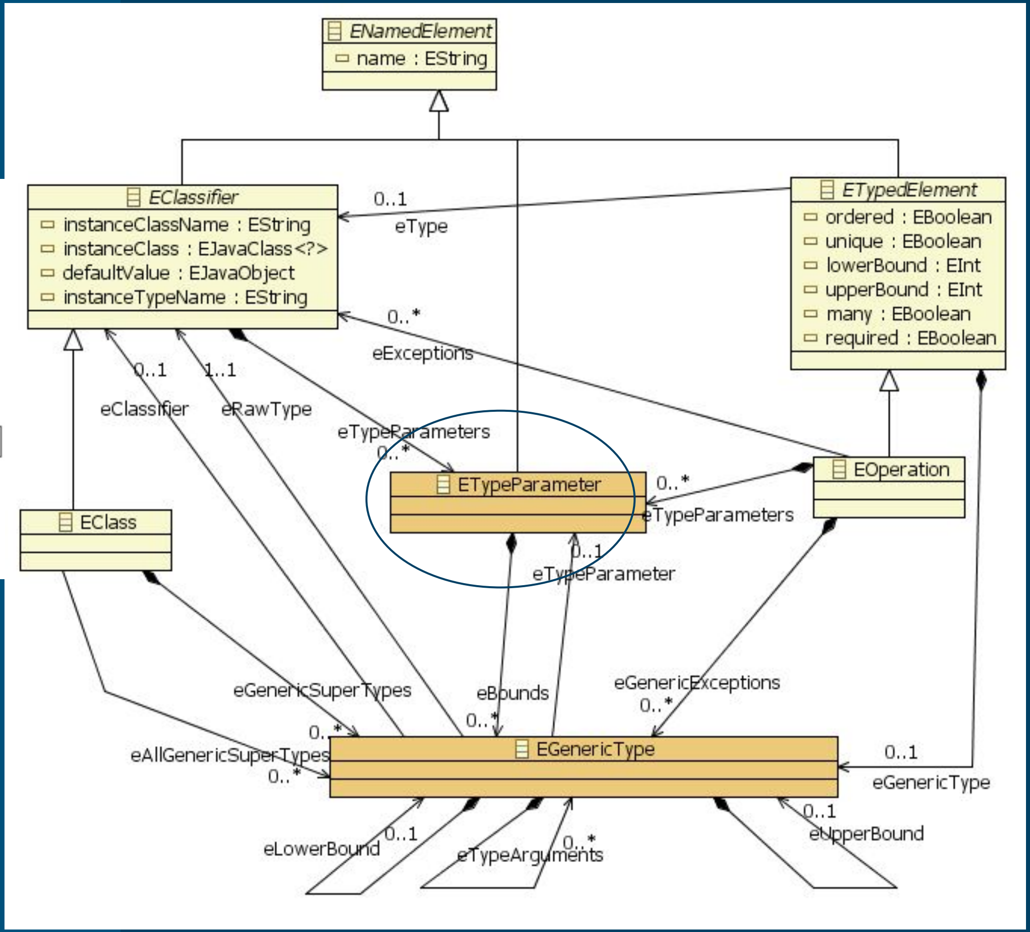
Parameter
ownedParameter
raisedException
0..1
*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defaultValue : EJavaObject
instanceTypeName : EString
ETypedElement
ordered : EBoolean
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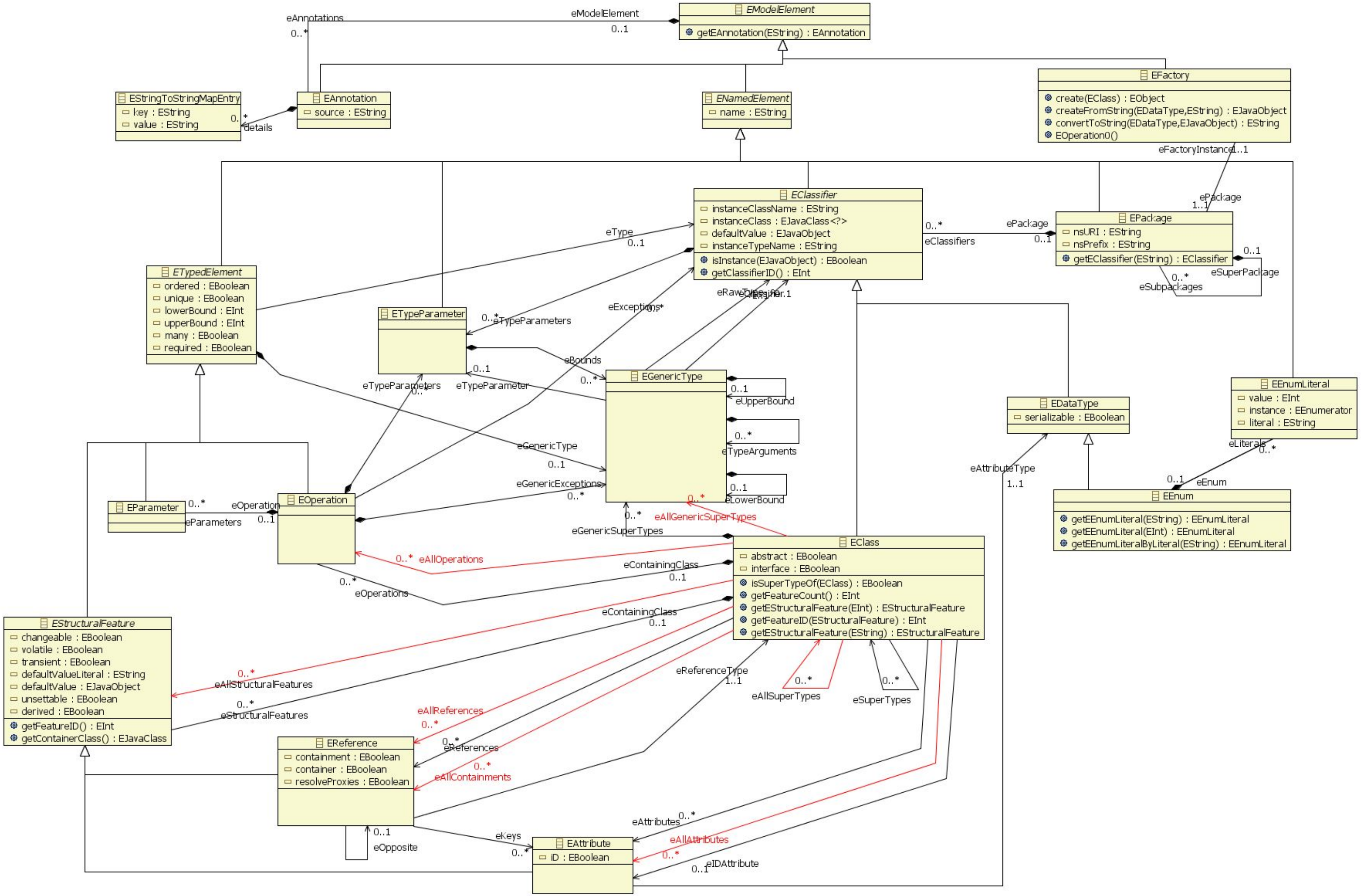
upperBound : EInt
many : EBoolean
required : EBoolean
eType
eExceptions
eClassifier
eRawType
eTypeParameters
EClass
ETypeParameter
EOperation
eTypeParameter
eGenericSuperTypes
eBounds
eGenericExceptions
eAllGenericSuperTypes
EGenericType
eGenericType
eLowerBound
eTypeArguments
eUpperBound
0..1
0..*
1..1



EModelElement
getEAnnotation(EString) : EAnnotation
eAnnotations
0..*
eModelElement
0..1
EStringToStringMapEntry
key : EString
value : EString
0..*
details
EAnnotation
source : EString
ENamedElement
name : EString
EFactory
create(EClass) : EObject
createFromString(EDataType,EString) : EJavaObject
convertToString(EDataType,EJavaObject) : EString
EOperation0()
eFactoryInstance
1..1
ePackage
1..1
EClassifier
instanceClassName : EString
instanceClass : EJavaClass<?>
defaultValue : EJavaObject
instanceTypeName : EString
isInstance(EJavaObject) : EBoolean
getClassifierID() : EInt
0..*
eClassifiers
ePackage
0..1
EPackage
nsURI : EString
nsPrefix : EString
getEClassifier(EString) : EClassifier
0..1
eSuperPackage
0..*
eSubpackages
eType
0..1
ETypedElement
ordered : EBoolean
unique : EBoolean
lowerBound : EInt
upperBound : EInt
many : EBoolean
required : EBoolean
ETypeParameter
0..*
eTypeParameters
eExceptions
0..*
eRawType
eClassifier
0..1
eBounds
0..*
EGenericType
0..1
eUpperBound
0..*
eTypeArguments
0..1
eLowerBound
0..1
eTypeParameters
eTypeParameter
eGenericType
0..1
eGenericExceptions
0..*
EDataType
serializable : EBoolean
EEnumLiteral
value : EInt
instance : EEnumerator
literal : EString
eLiterals
0..*
eAttributeType
1..1
0..1
eEnum
EEnum
getEEnumLiteral(EString) : EEnumLiteral
getEEnumLiteral(EInt) : EEnumLiteral
getEEnumLiteralByLiteral(EString) : EEnumLiteral
EParameter
0..*
eOperation
0..1
eParameters
EOperation
0..*
eAllGenericSuperTypes
0..*
eGenericSuperTypes
EClass
abstract : EBoolean
interface : EBoolean
isSuperTypeOf(EClass) : EBoolean
getFeatureCount() : EInt
getEStructuralFeature(EInt) : EStructuralFeature
getFeatureID(EStructuralFeature) : EInt
getEStructuralFeature(EString) : EStructuralFeature
0..* eAllOperations
eContainingClass
0..1
0..*
eOperations
eContainingClass
0..1
EStructuralFeature
changeable : EBoolean
volatile : EBoolean
transient : EBoolean
defaultValueLiteral : EString
defaultValue : EJavaObject
unsettable : EBoolean
derived : EBoolean
getFeatureID() : EInt
getContainerClass() : EJavaClass
0..*
eAllStructuralFeatures
0..*
eStructuralFeatures
eReferenceType
1..1
0..*
eAllSuperTypes
0..*
eSuperTypes
eAllReferences
0..*
0..*
eReferences
0..*
eAllContainments
EReference
containment : EBoolean
container : EBoolean
resolveProxies : EBoolean
0..1
eOpposite
eKeys
0..*
EAttribute
iD : EBoolean
eAttributes
0..*
eAllAttributes
0..*
0..1
eIDAttribute

Eclipse

- Eclipse Modeling Framework
- Full support for metamodeling and language design
- Fully MD (vs. programming-based tools)
- Used in this course!

EMF

EMF at Eclipse.org

- Foundation for the Eclipse Modeling Project
  - EMF project incorporates core and additional mature components: Query, Transaction, Validation
  - EMF Technology project incubates complementary components: CDO, Teneo, Compare, Search, Temporality, Ecore Tools…
  - Other projects build on EMF: Graphical Modeling Framework (GMF), Model Development Tools (MDT), Model to Model Transformation (M2M), Model to Text Transformation (M2T)…
- Other uses: Web Tools Platform (WTP), Data Tools Platform (DTP), Business Intelligence and Reporting Tools (BIRT), SOA Tools Platform (STP)…
- Large open source user community

EMF

- EMF models can be defined in (at least) three ways:
  1. Java Interfaces
  2. UML Class Diagram
  3. XML Schema
- Choose the one matching your perspective or skills and EMF can create the others, as well as the implementation code

EMF

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  1. Java Interfaces
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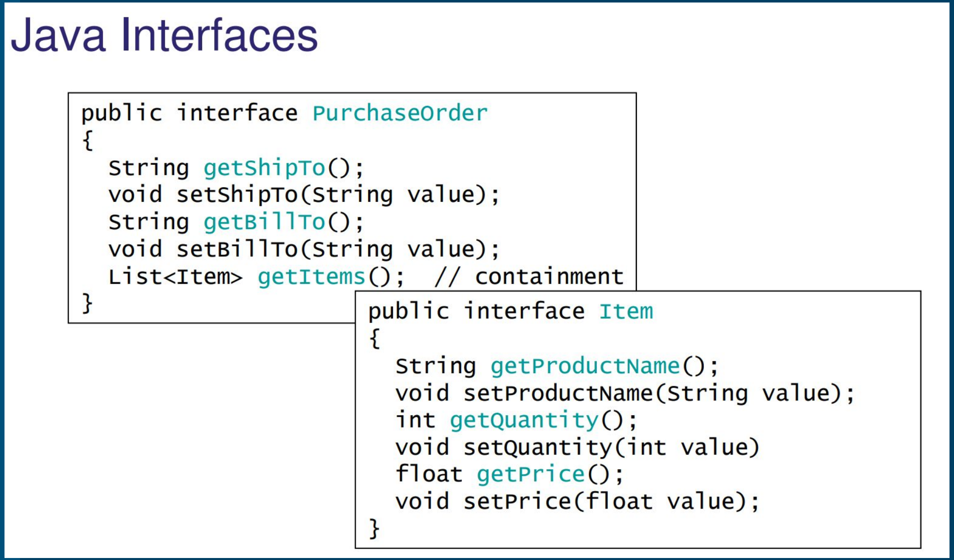
- Choose the one matching your perspective or skills and EMF can create the others, as well as the implementation code

EMF

Three Ecore Model Perspectives: Java API



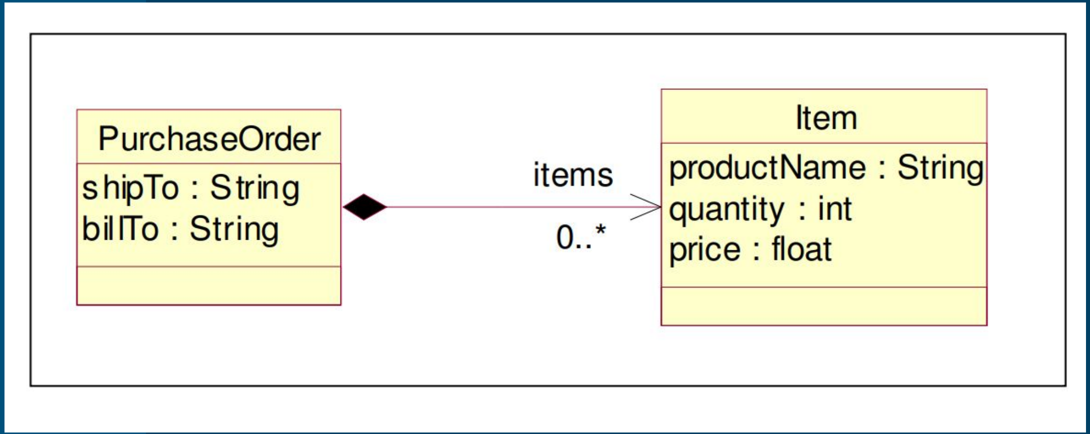
Java Interfaces

```java
public interface PurchaseOrder
{
  String getShipTo();
  void setShipTo(String value);
  String getBillTo();
  void setBillTo(String value);
  List<Item> getItems();  // containment
}
```

```java
public interface Item
{
  String getProductName();
  void setProductName(String value);
  int getQuantity();
  void setQuantity(int value)
  float getPrice();
  void setPrice(float value);
}
```

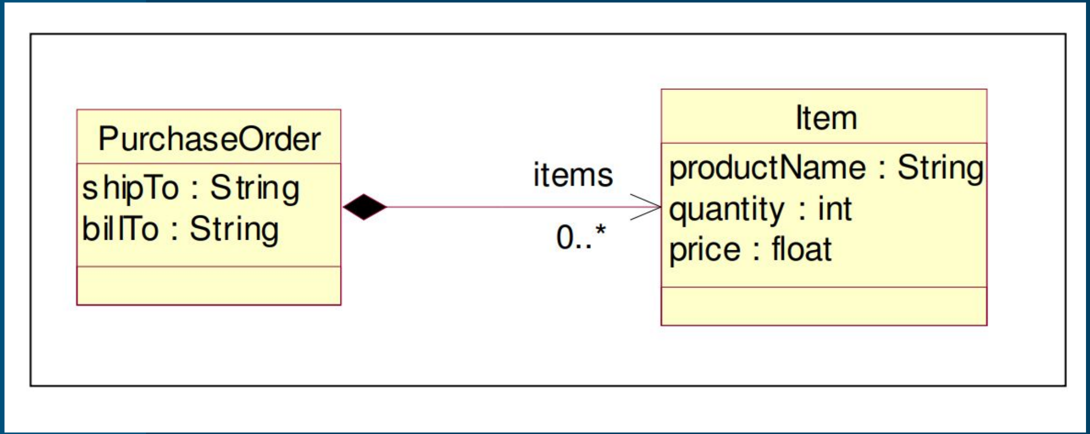
EMF

Three Ecore Model Perspectives: Diagram



EMF

Three Ecore Model Perspectives: Diagram

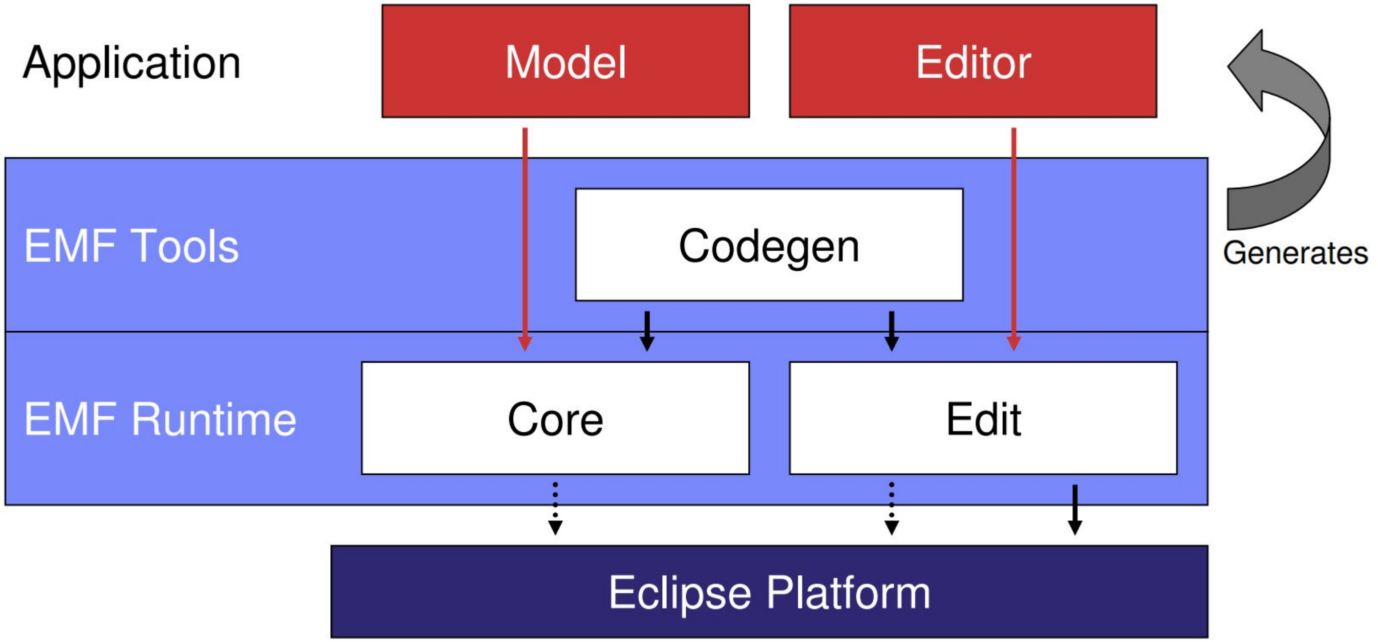


EMF

Three Ecore Model Perspectives: XML

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            targetNamespace="http://www.example.com/SimplePO"
            xmlns:po="http://www.example.com/SimplePO">
  <xsd:complexType name="PurchaseOrder">
    <xsd:sequence>
      <xsd:element name="shipTo" type="xsd:string"/>
      <xsd:element name="billTo" type="xsd:string"/>
      <xsd:element name="items"  type="po:Item"
                   minOccurs="0" maxOccurs="unbounded"/>
    </xsd:sequence>
  </xsd:complexType>
  <xsd:complexType name="Item">
    <xsd:sequence>
      <xsd:element name="productName" type="xsd:string"/>
      <xsd:element name="quantity" type="xsd:int"/>
      <xsd:element name="price" type="xsd:float"/>
    </xsd:sequence>
  </xsd:complexType>
</xsd:schema>
```

EMF Architecture



EMF Components

- Core Runtime
  - Notification framework
  - Ecore metamodel
  - Persistence (XML/XMI), validation, change model
- EMF.Edit
  - Support for model-based editors and viewers
  - Default reflective editor
- Codegen
  - Code generator for application models and editors
  - Extensible model importer/exporter framework

Ecore

- Persistent format is XMI (.ecore file)

```
<eClassifiers xsi:type="ecore:EClass"
  name="PurchaseOrder">
 <eStructuralFeatures xsi:type="ecore:EReference"
   name="items" eType="#//Item"
   upperBound="-1" containment="true"/>
 <eStructuralFeatures xsi:type="ecore:EAttribute"
   name="shipTo"
   eType="ecore:EDataType http:...Ecore#//EString"/>
 ...
</eClassifiers>
```

- Alternate format is Essential MOF XMI (.emof file)

Thank you!

Contact: vma@fct.unl.pt