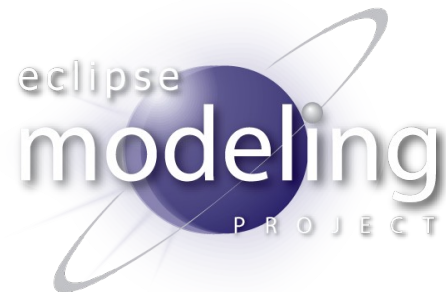



OOPSLA'06 Tutorial T38

Introduction to the Eclipse Modeling Framework

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IBM Rational Software
Toronto, Canada
EMF Project

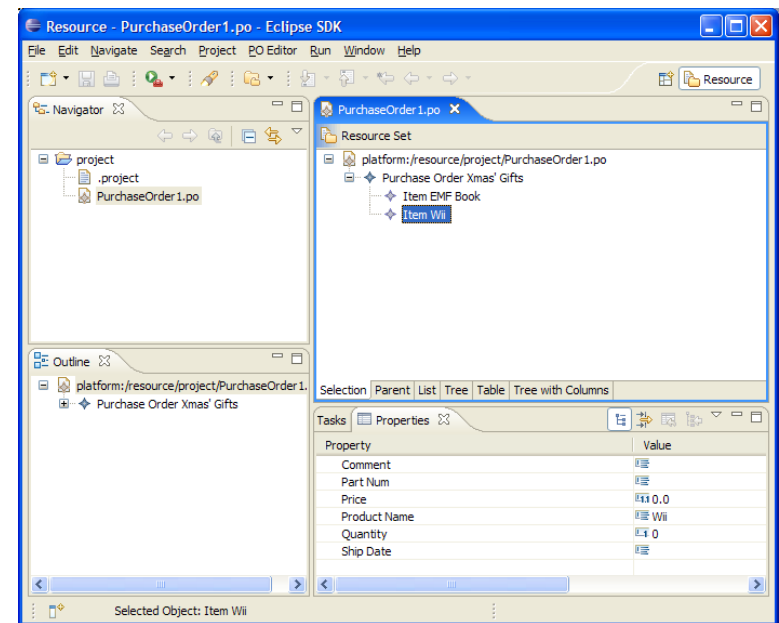
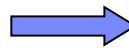
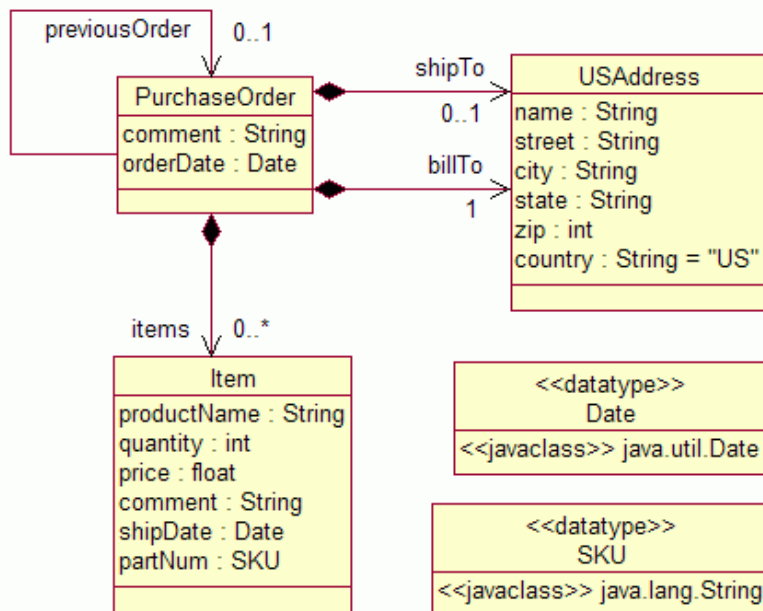


Agenda


- **Demo**
 - Introduction
 - EMF in a Nutshell
 - EMF Components
 - The Ecore Metamodel
 - Exercise 1: Code Generation, Regeneration and Merge
 - Exercise 2: EMF Runtime
- 
- Exercise 3: Recording Changes
 - Exercise 4: Validation
 - Exercise 5: Reflection, Dynamic EMF and XML Processor
- What's New in EMF 2.2
 - Summary

Demo

- Using EMF to quickly generate a working graphical editor to create and manipulate instances of a UML model



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What is EMF?

- A modeling & data integration framework
- Exploits the facilities offered in Eclipse to...
 - Generate code without losing user customizations (merge)
 - Automate important tasks (such as registering the runtime information)
 - Improve extensibility
 - Provide a UI layer
- What is an EMF “model”?
 - Specification of your application’s data
 - Object attributes
 - Relationships (associations) between objects
 - Operations available on each object
 - Simple constraints (eg. cardinality) on objects and relationships
 - Essentially it represents the class diagram of the application

What does EMF Provide?

- From a model specification, EMF can generate efficient, correct, and easily customizable implementation code
- Out of the box, EMF provides support for
 - Java™ interfaces
 - UML
 - XML Schema
- EMF converts your models to Ecore (EMF metamodel)
- Tooling support within the Eclipse framework (UI, headless mode, Ant and standalone), including support for generating Eclipse-based and RCP editors
- Reflective API and dynamic model definition
- Persistence API with out of box support for XML/XMI (de)serialization of instances of a model
- And much more....

Why EMF?

- EMF is middle ground in the modeling vs. programming worlds
 - Focus is on class diagram subset of UML modeling (object model)
 - Transforms models into Java code
 - Provides the infrastructure to use models effectively in your application
- Very low cost of entry
 - EMF is free and open source
 - Full scale graphical modeling tool not required
 - Reuses your knowledge of UML, XML Schema, or Java
- It's real, proven technology (since 2002)

EMF History

- First version was released in June, 2002
- Originally based on MOF (Meta Object Facility)
 - From OMG (Object Management Group)
 - Abstract language and framework for specifying, constructing, and managing technology neutral metamodels
- EMF evolved based on experience supporting a large set of tools
 - Efficient Java implementation of a practical subset of the MOF API
- 2003: EMOF defined (Essential MOF)
 - Part of OMG's MOF 2 specification; UML2 based
 - EMF is approximately the same functionality
 - Significant contributor to the spec; adapting to it

Who is Using EMF Today?

- Eclipse projects
 - UML2
 - Graphical Modeling Framework (GMF)
 - EMF Technologies (EMFT): OCL, Validation, Query, Transaction, EODM, and Database Persistence
 - Visual Editor (VE)
 - Data Tools Platform (DTP)
 - Web Tools Platform (WTP)
 - Test and Performance Tools Platform (TPTP)
 - Business Intelligence and Reporting Tools (BIRT)
... to name but a few
- Commercial offerings
 - IBM, Borland, Oracle, Omondo, Versata, MetaMatrix, Bosch, Ensemble, ...
- Applied sciences
 - Darmstadt University of Technology, Mayo Clinic College of Medicine, European Space Agency, ...
- Large open source community
 - Over 770,000 download requests from January to July 2006
 - In first month of its release, over 100,000 download requests for EMF 2.2.0!

EMF at IBM

- Pervasive usage across product lines
 - IBM® Rational® Software Architect
 - IBM Rational Application Developer for WebSphere Software
 - IBM WebSphere® Integration Developer
 - IBM WebSphere Application Server
 - IBM Lotus® Workplace
- Emerging technology projects: alphaWorks
 - Emfatic Language for EMF Development
(<http://www.alphaworks.ibm.com/tech/emfatic>)
 - Model Transformation Framework
(<http://www.alphaworks.ibm.com/tech/mtf>)
 - XML Forms Generator (<http://www.alphaworks.ibm.com/tech/xfg>)

What Have People Said About EMF?

- EMF represents the **core subset** that's left when the non-essentials are eliminated. It represents a **rock solid foundation** upon which the more ambitious extensions of UML and MDA can be built.
 - Vlad Varnica, OMONDO Business Development Director, 2002
- EMF **provides the glue between the modeling and programming worlds**, offering an infrastructure to use models effectively in code by integrating UML, XML and Java. EMF thus fits well into [the] Model-Driven Development approach, and is **critically important for Model-Driven Architecture**, which underpins service-oriented architectures [SOA].
 - Jason Bloomberg, Senior analyst for XML & Web services, ZapThink, 2003
- EMF is capable of **creating sophisticated editors** from abstract business models. ... EMF creates feature complete implementations including persistence, **business model implementation**, editing framework and editors. ... At InferData, we have been using EMF [to] create **persistence implementation** for various in-house products, ... **standalone products** for the Eclipse platform, [and] quick prototypes to validate complex business models. Business models remain technology independent; code generation is performed for all that can be code generated and kept separate from the manually developed code.
 - Petter Graff, SYS-CON Media, 2004
- EMF was chosen because it (a) provides a **lightweight, pragmatic approach to modeling** with very **low entry cost** and is thus suitable for rapid prototyping, (b) unifies key technologies such as Java and XML, and (c) integrates well into Eclipse.
 - Bruch, Bockisch, Schäfer, Mezini, Darmstadt Univ. of Technology, Germany, 2005
- [As] a consultant with fiduciary responsibility to my customers, [...] given the **enormous traction** that Eclipse has gathered, we have to view the EMF metadata management framework as the **de facto standard**.
 - David Frankel, as seen in Business Process Trends, March 2005

Creating the Ecore Model

- Representing the modeled domain in Ecore is the first step in using EMF
- Ecore can be created
 - Directly using the EMF editors
 - Through a graphical UI provided by external contributions
 - By converting a model specification for which a Model Importer is available
- Model Importers available in EMF
 - Java Interfaces
 - UML models expressed in Rational Rose® files
 - XML Schema
- Choose the one matching your perspective or skills

Model Importers Available in EMF

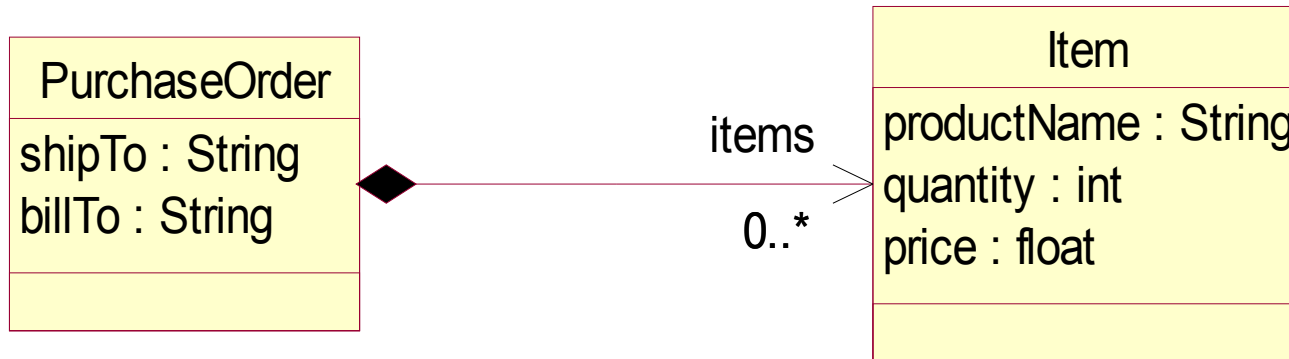
- Java Interfaces

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

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

Model Importers Available in EMF

- UML Class Diagram



Model Importers Available in EMF

■ XML Schema

```
<?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>
```


Unifying Java, XML and UML Technologies

- The Model Importers available in EMF were carefully chosen to integrate today's most important technologies
- All three forms provide the same information
 - Different visualization/representation
 - The application's "model" of the structure
- From a model definition, EMF can generate
 - Java implementation code, including UI
 - XML Schemas
 - Eclipse projects and plug-in

Typical EMF Usage Scenario

- Create an Ecore model that represents the domain you are working on
 - Import UML (e.g. Rose .mdl file)
 - Import XML Schema
 - Import annotated Java interfaces
 - Create Ecore model directly using EMF's Ecore editor or a graphical editor
- Generate Java code for model
- Prime the model with instance data using generated EMF model editor
- Iteratively refine model (and regenerate code) and develop Java application
 - You will use the EMF generated code to implement the use cases of your application
- Optionally, use EMF.Edit to build customized user interface

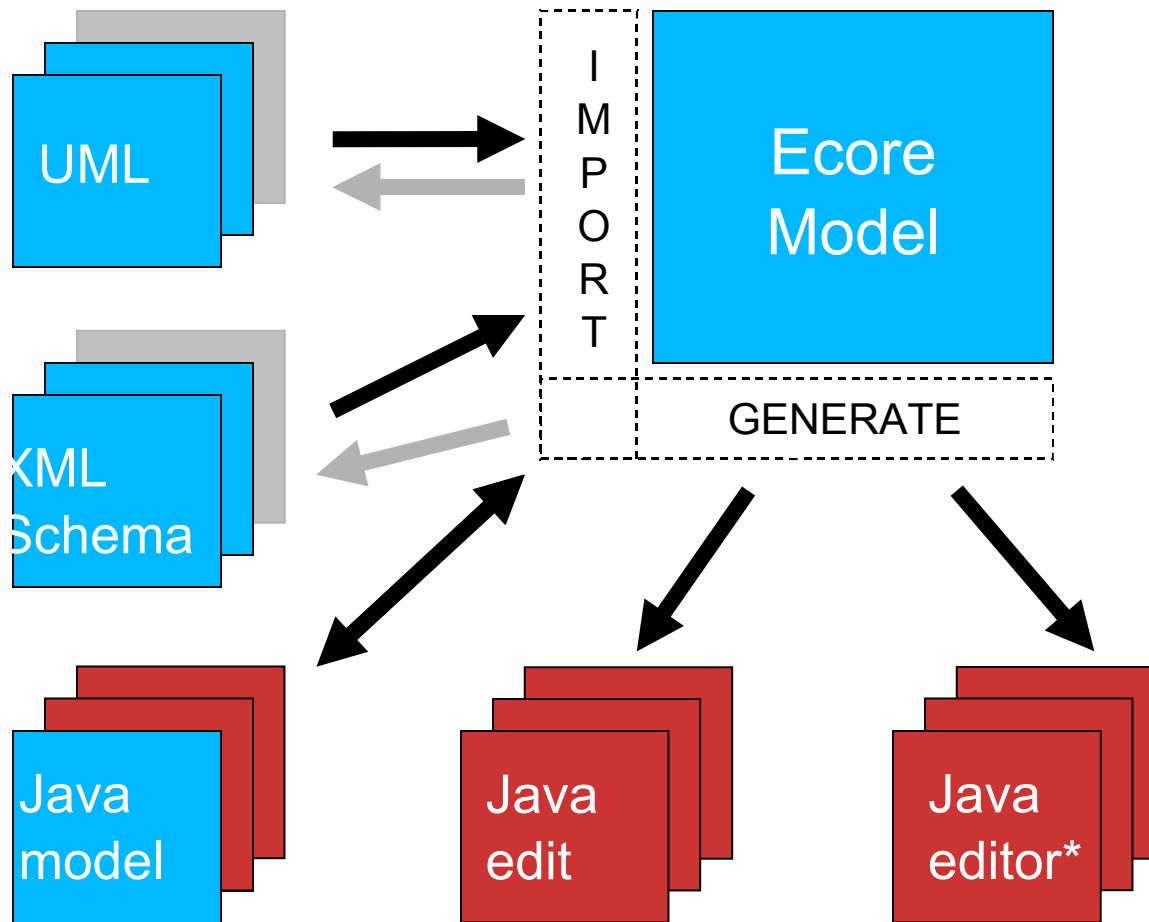
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EMF Components

- EMF Core
 - Ecore metamodel
 - Model change notification & validation
 - Persistence and serialization
 - Reflection API
 - Runtime support for generated models
- EMF Edit
 - Helps integrate models with a rich user interface
 - Used to build editors and viewers for your model
 - Includes default reflective model editor
- EMF Codegen
 - Code generator for core and edit based components
 - Extensible model importer framework

EMF Tools: Model Import and Generation



Generator Features:

- Customizable JSP-like templates (JET)
- JDT-integrated, command-line, or Ant
- Fully supports regeneration and merge

* Eclipse IDE-integrated or RCP-based

EMF Model Importers

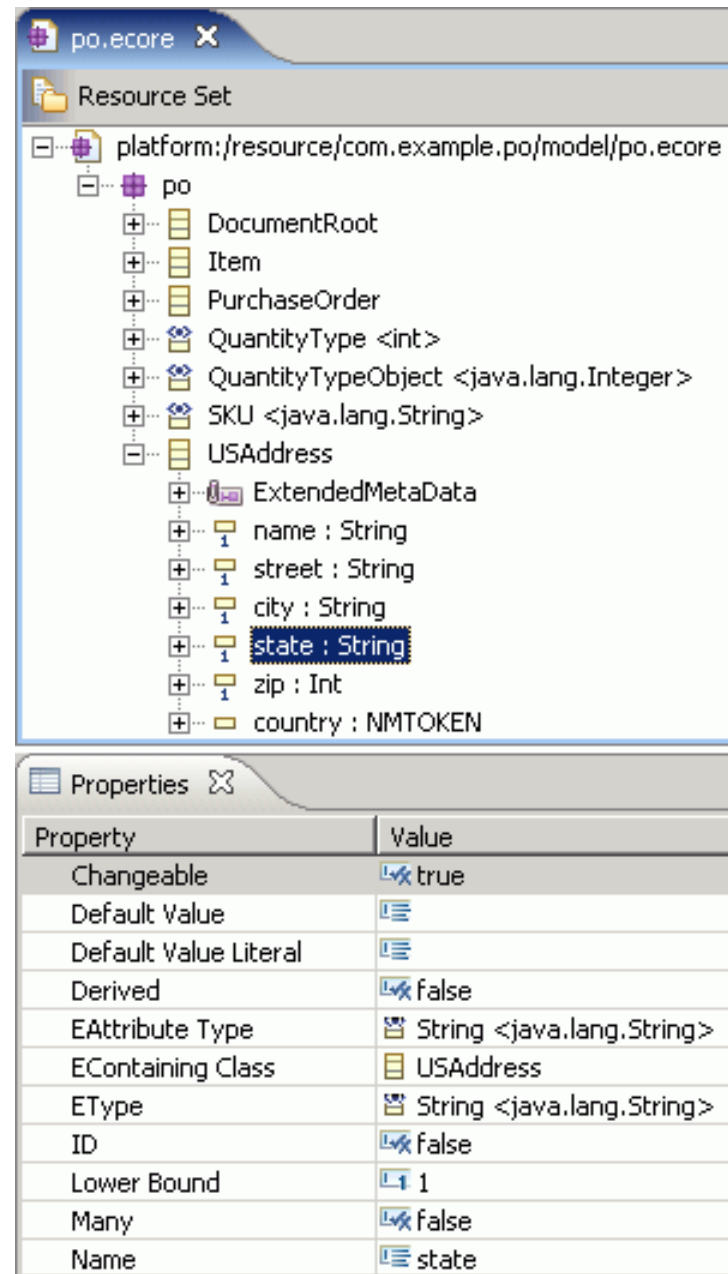
- UML
 - Rational Rose .mdl file
 - Eclipse UML2 project provides importer for .uml2
- Annotated Java
 - Java interfaces representing modeled classes
 - Javadoc annotations using @model tags to express model properties not captured by method declarations
 - Lowest cost approach
- XML Schema
 - Describes the data of the modeled domain
 - Provides richer description of the data, which EMF exploits
- Ecore model (*.ecore file)
 - Just creates the generator model (discussed later)
 - Also handles EMOF (*.emof)

Ecore Model Creation

- An Ecore model is created within an Eclipse project via a wizard
- Input: one of the model specifications from the previous slide
- Output:
 - `modelname.ecore`
 - Ecore model file in XMI format
 - Canonical form of the model
 - `modelname.genmodel`
 - A “generator model” for specifying generator options
 - Decorates `.ecore` file
 - EMF code generator is an EMF `.genmodel` editor
 - Automatically kept in synch with `.ecore` file

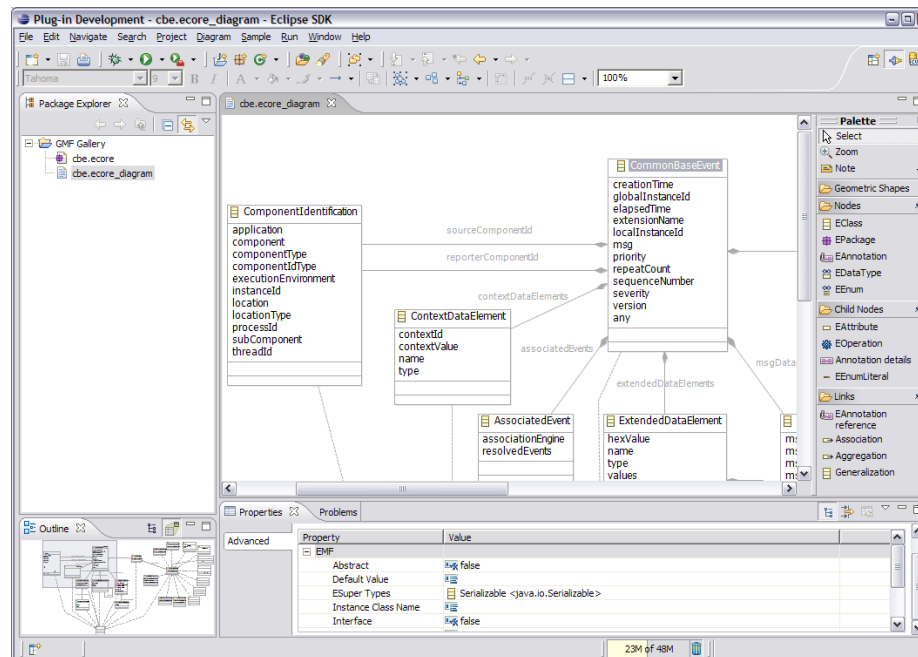
Ecore Model Editor

- A generated (and customized) EMF editor for the Ecore model
- Create, delete, etc. model elements (EClass, EAttribute, EReference, etc.) using pop-up actions in the editor's tree
- Set names, etc. in the Properties view



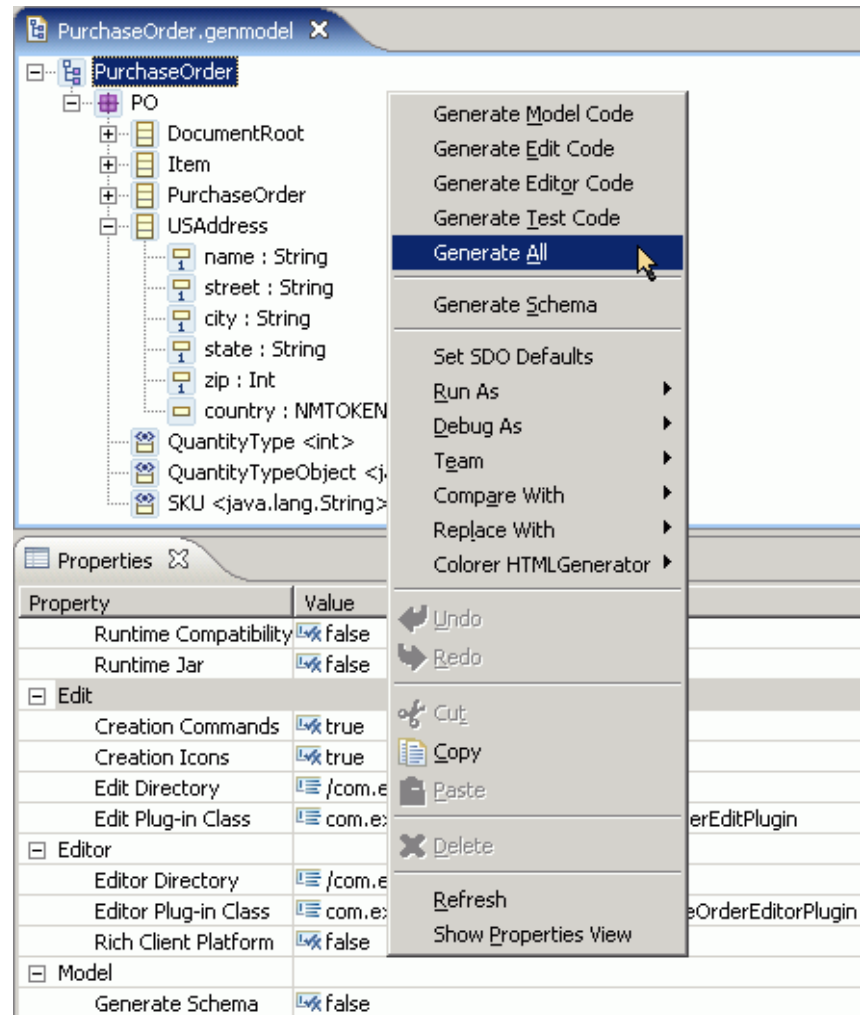
Ecore Model Editor

- A graphical editor is a better approach
 - GMF Ecore Diagram Example (<http://www.eclipse.org/gmf/>)
 - Omondo EclipseUML (<http://www.omondo.com/>)




EMF Generator

- Similar layout to Ecore model editor
- Automatically keeps in synch with .ecore changes
- Generate code with pop-up menu actions
 - Generate Model Code
 - Generate Edit Code
 - Generate Editor Code
 - Generate Test Code
 - Generate All
- Code generation options in Properties view
- Generator > Reload to reload .genmodel and .ecore files from original model form

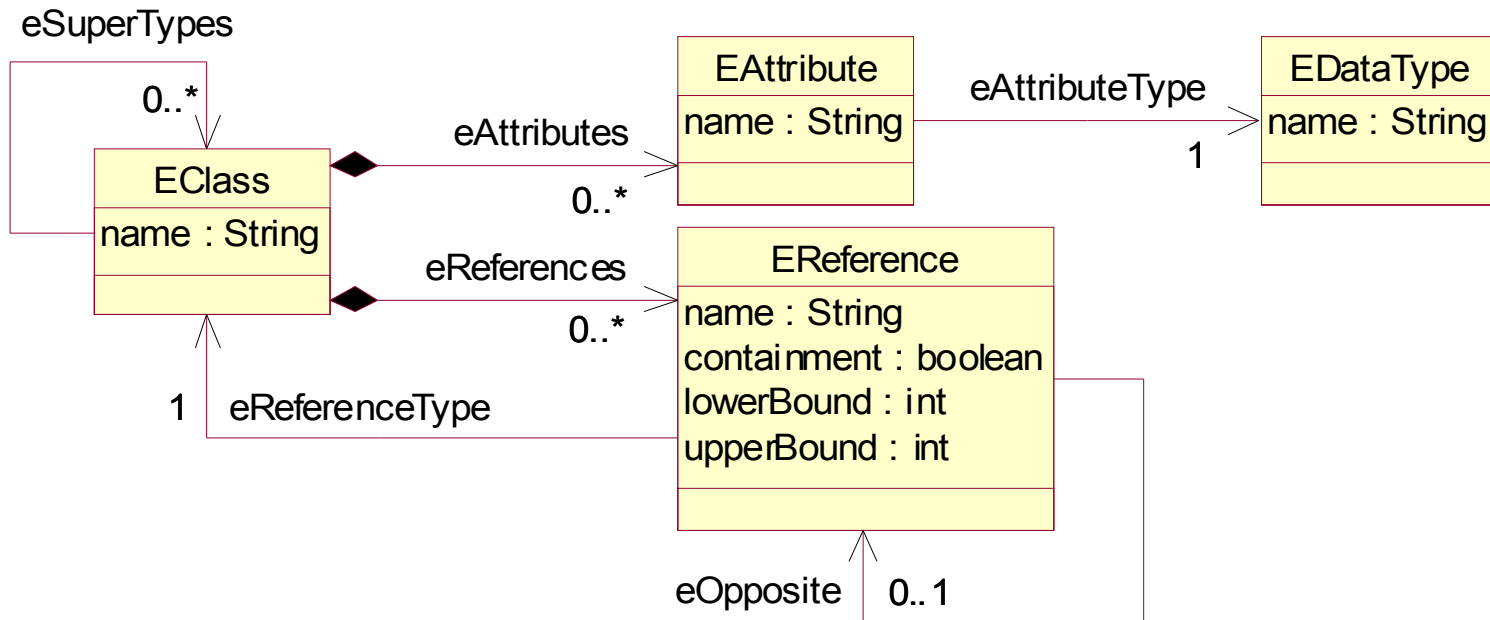


Agenda

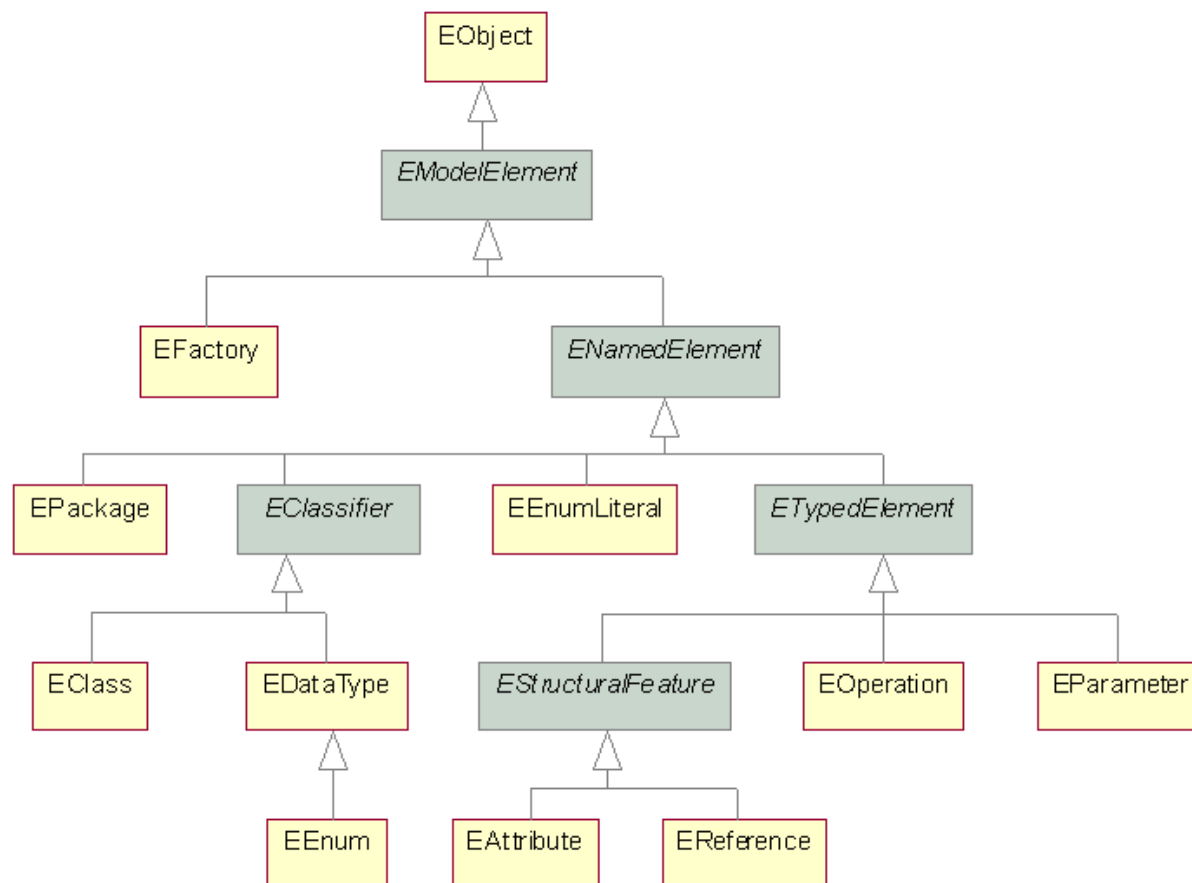
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The Ecore (Meta) Model

- Ecore is EMF's model of a model
 - Also called a “metamodel”
 - Persistent representation is XML

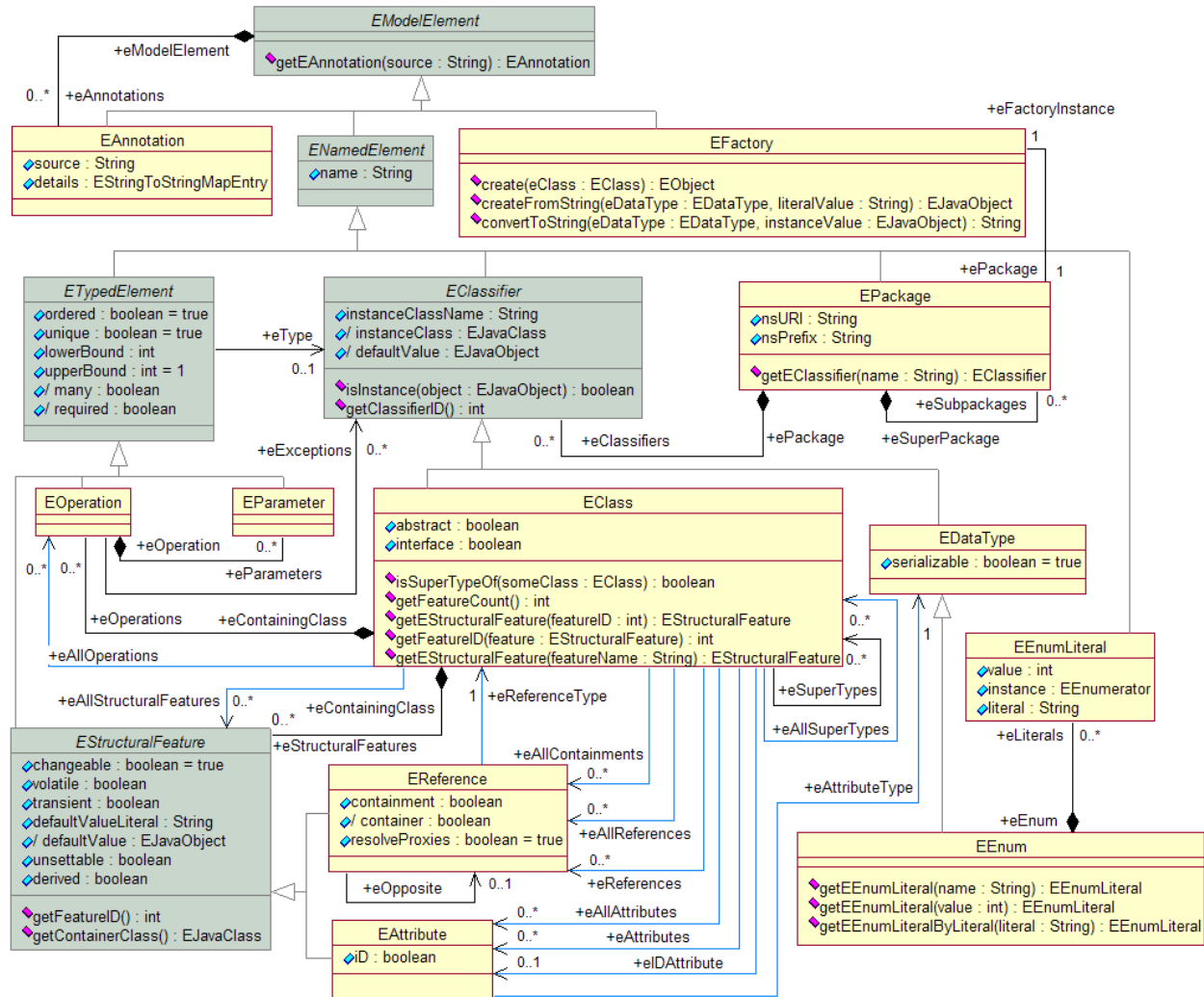


The Ecore Metamodel



- EObject is the root of every model object – equivalent to `java.lang.Object`

The Ecore Metamodel

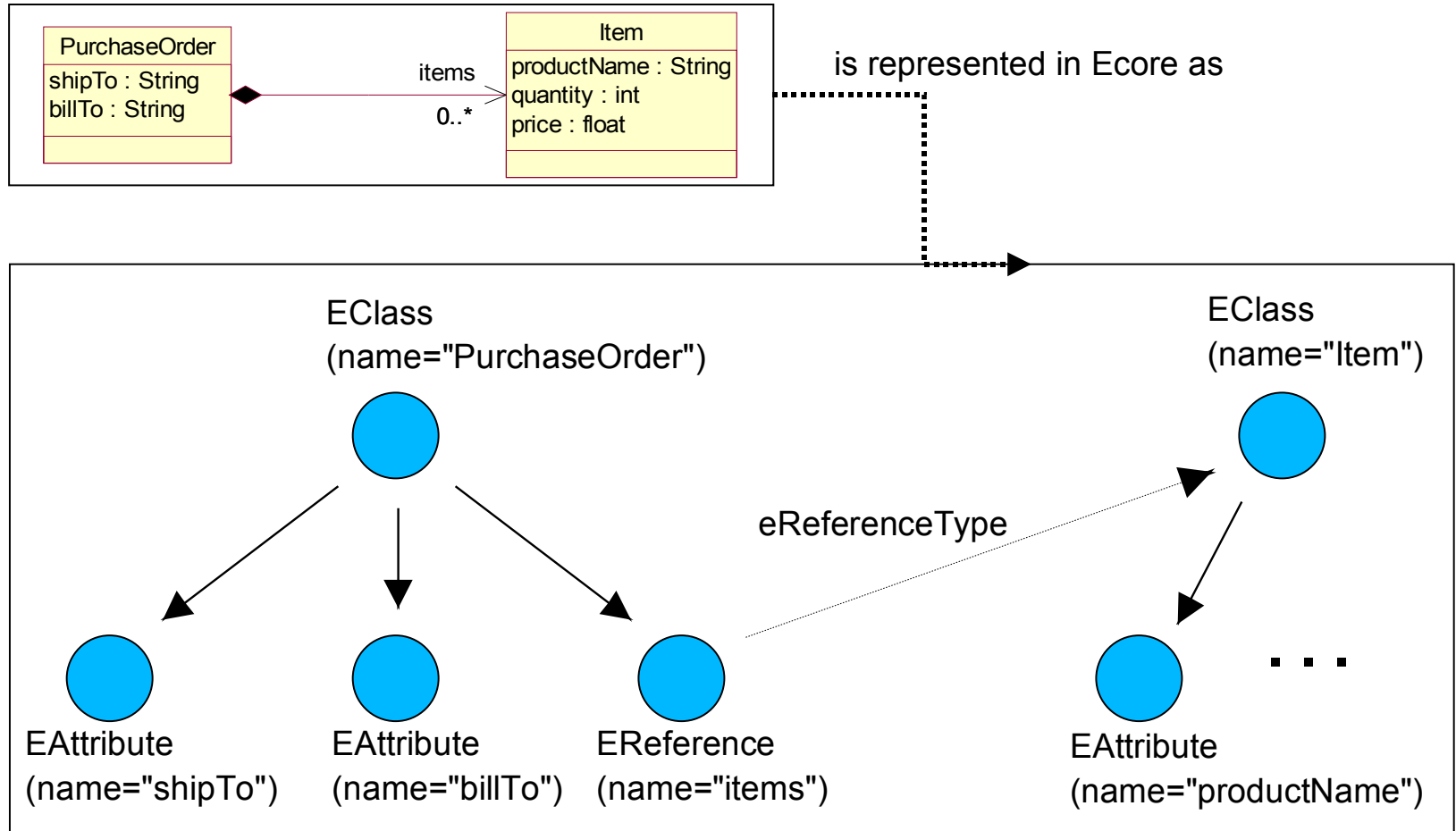


Partial List of Ecore Data Types

Ecore Data Type	Java Primitive Type or Class
EBoolean	boolean
EChar	char
EFloat	float
EString	java.lang.String
EByteArray	byte[]
EBooleanObject	java.lang.Boolean
EFloatObject	java.lang.Float
EJavaObject	java.lang.Object

- Ecore data types are serializable and custom data types are supported

Ecore Model for Purchase Orders



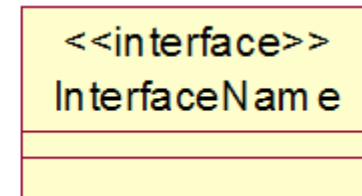
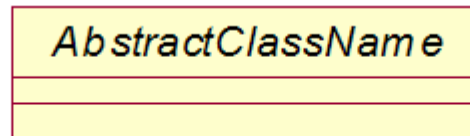
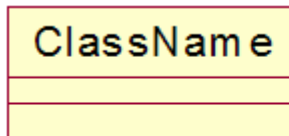
Purchase Order Ecore XMI

```
<eClassifiers xsi:type="ecore:EClass"
  name="PurchaseOrder">
  <eReferences name="items" eType="#//Item"
    upperBound="-1" containment="true"/>
  <eAttributes name="shipTo"
    eType="ecore:EDatatype http:...Ecore#//EString"/>
  <eAttributes name="billTo"
    eType="ecore:EDatatype http:...Ecore#//EString"/>
</eClassifiers>
```

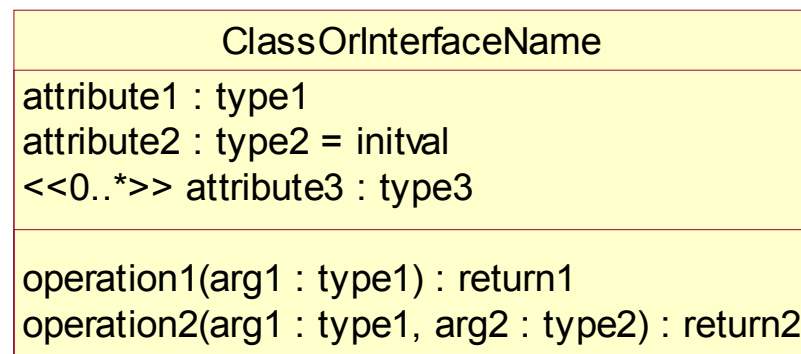
- Alternate serialization format is EMOF (Essential MOF) XMI
 - Part of OMG Meta Object Facility (MOF) 2.0 standard (<http://www.omg.org/docs/ptc/04-10-15.pdf>)

UML Constructs Available in Ecore

- Classes, Abstract Classes, and Interfaces

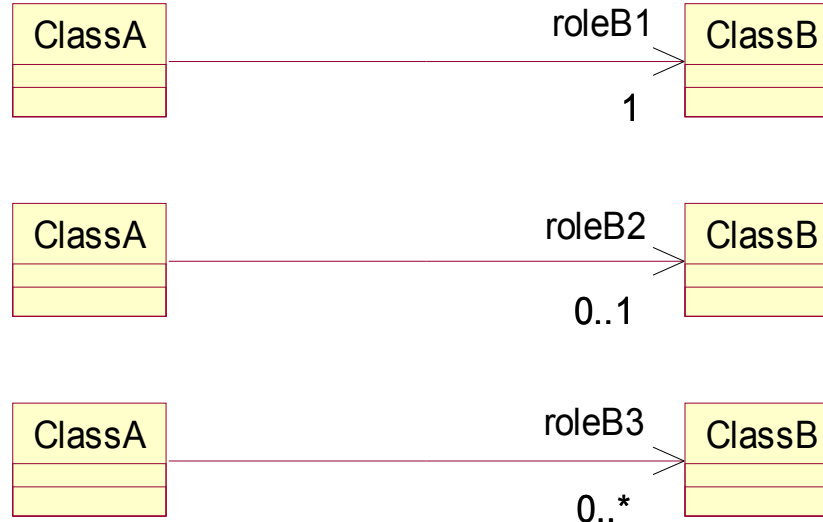


- Attributes and Operations



UML Constructs Available in Ecore

- References (Associations)
 - One-way



UML Constructs Available in Ecore

- References (Associations)
 - Bidirectional

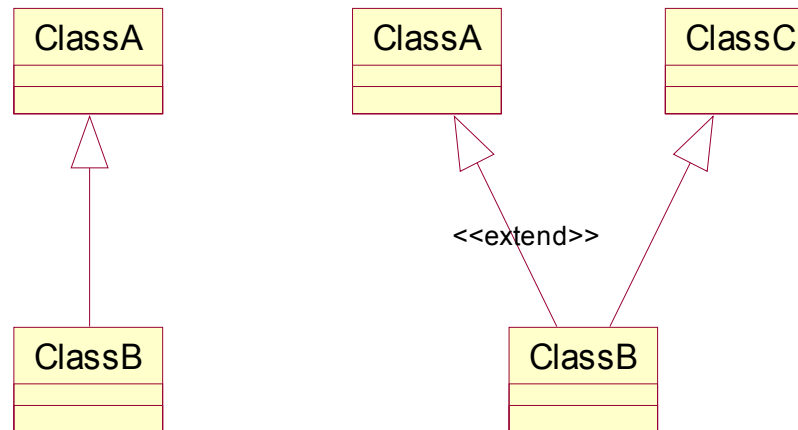


- Containment

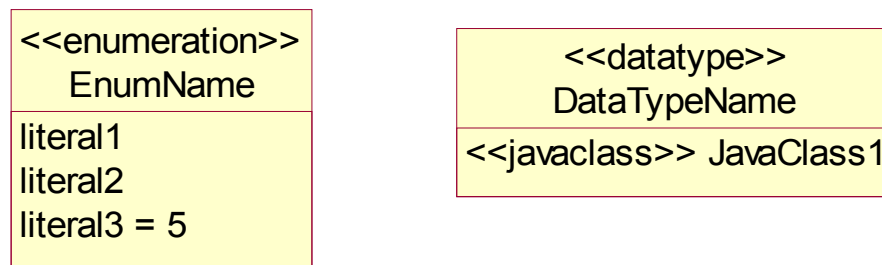


UML Constructs Available in Ecore


■ Class Inheritance



■ Enumerations and Data Types



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Code Generation

- EMF framework is lightweight
 - Generated code is clean, simple, efficient
- EMF can generate
 - Model implementation
 - UI-independent edit support
 - Editor and views for Eclipse IDE-integrated or RCP application
 - JUnit test skeletons
 - Manifests, plug-in classes, properties, icons, etc.

Generated Model Code

- Interface and implementation for each modeled class
 - Includes get/set accessors for attributes and references

```
public interface PurchaseOrder extends EObject
{
    String getShipTo();
    void setShipTo(String value);
    String getBillTo();
    void setBillTo(String value);
    EList.getItems();
}
```

- Usage example

```
order.getItems().add(item);
```

Generated Model Code

- Factory to create instances of model objects

```
POFactory factory = POFactory.eINSTANCE;  
PurchaseOrder order = factory.createPurchaseOrder();
```

- Package class provides access to metadata

```
POPackage poPackage = POPackage.eINSTANCE;  
EClass itemClass = poPackage.getItem();  
  
EAttribute priceAttr = poPackage.getItem_Price();  
//or itemClass.getEStructuralFeature(POPackage.ITEM__PRICE)
```

- Also generated: switch utility, adapter factory base, validator, custom resource, XML processor

Generated Edit/Editor Code

- Viewing/editing code divided into two parts
 - UI-independent code
 - Item providers (adapters)
 - Item provider adapter factory
 - UI-dependent code
 - Model creation wizard
 - Editor
 - Action bar contributor
 - Advisor (RCP)
- By default each part is placed in a separate Eclipse plug-in

Summary of Generated Artifacts

- Model
 - Interfaces and classes
 - Type-safe enumerations
 - Package (metadata)
 - Factory
 - Switch utility
 - Adapter factory base
 - Validator
 - Custom resource
 - XML Processor
- Editor
 - Model Wizard
 - Editor
 - Action bar contributor
 - Advisor (RCP)
- Tests
 - Test cases
 - Test suite
 - Stand-alone example
- Manifests, plug-in classes, properties, icons...
- Edit (UI independent)
 - Item providers
 - Item provider adapter factory

Regeneration and Merge

- Hand-written code can be added to generated code and preserved during regeneration
 - This merge capability has an Eclipse dependency, so is not available standalone
- All generated classes, interfaces, methods and fields include @generated marker in their Javadoc
- To replace generated code:
 - Remove @generated marker
 - Or include additional text, e.g.
@generated NOT
- Methods without @generated marker are left alone during regeneration

Regeneration and Merge

- Extend (vs. replace) generated method through redirection
 - Append “Gen” suffix to the generated method's name

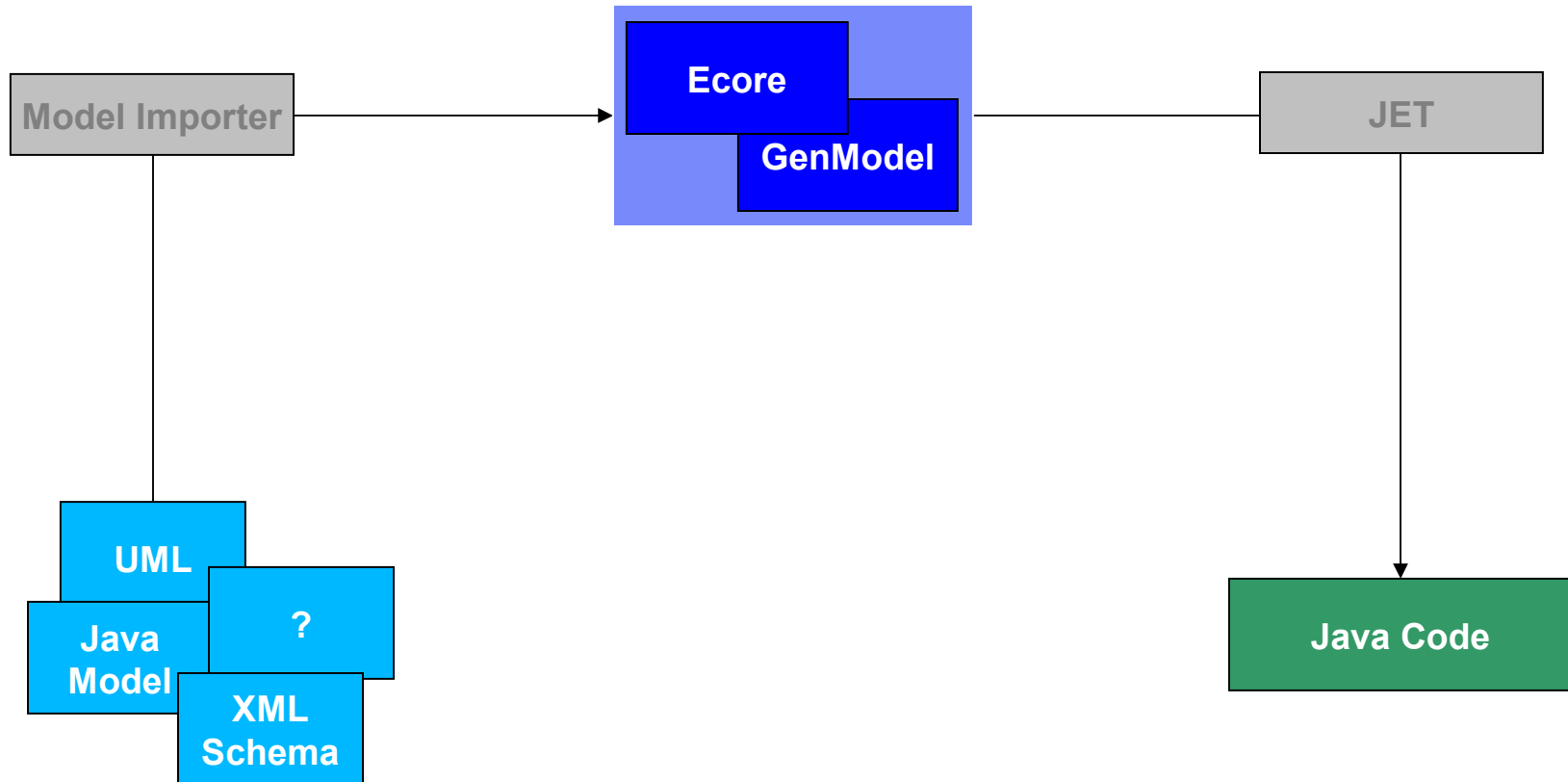
```
/**
 * <!-- begin-user-doc -->
 * <!-- end-user-doc -->
 * @generated
 */
public String getName()
{
    return name;
}
```



```
/**
 * <!-- begin-user-doc -->
 * <!-- end-user-doc -->
 * @generated
 */
public String getNameGen()
{
    return name;
}

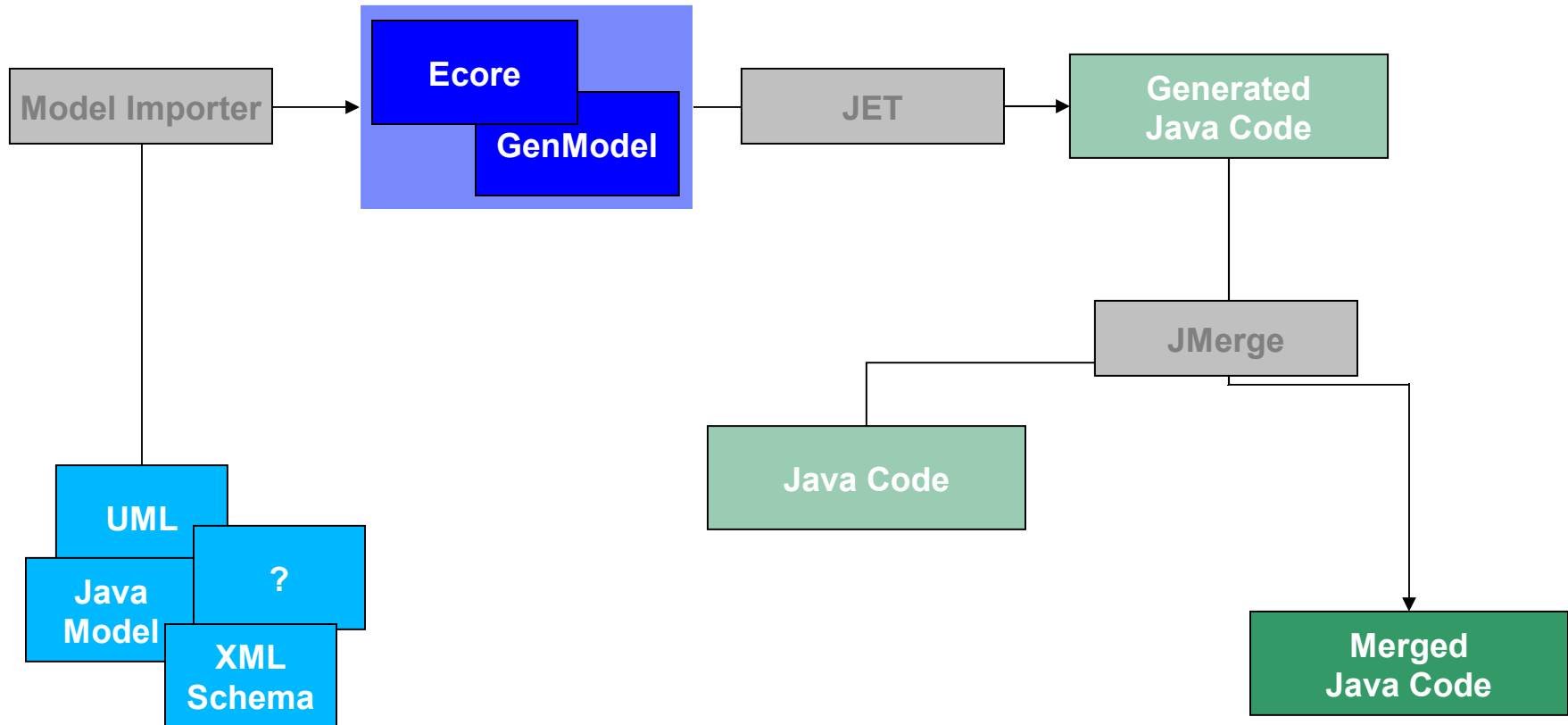
public String getName()
{
    return format(getNameGen());
}
```

Summarizing the Code Generation Process



Simplified version

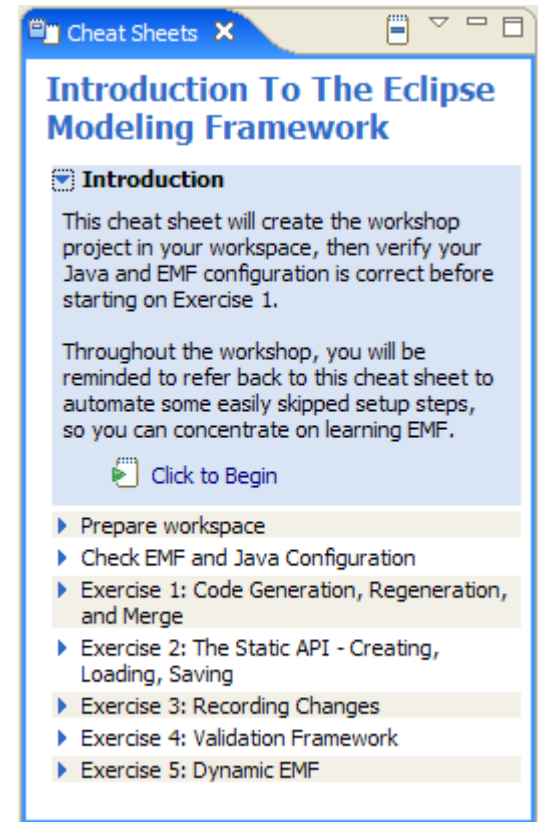
Summarizing the Code Generation Process



Full version

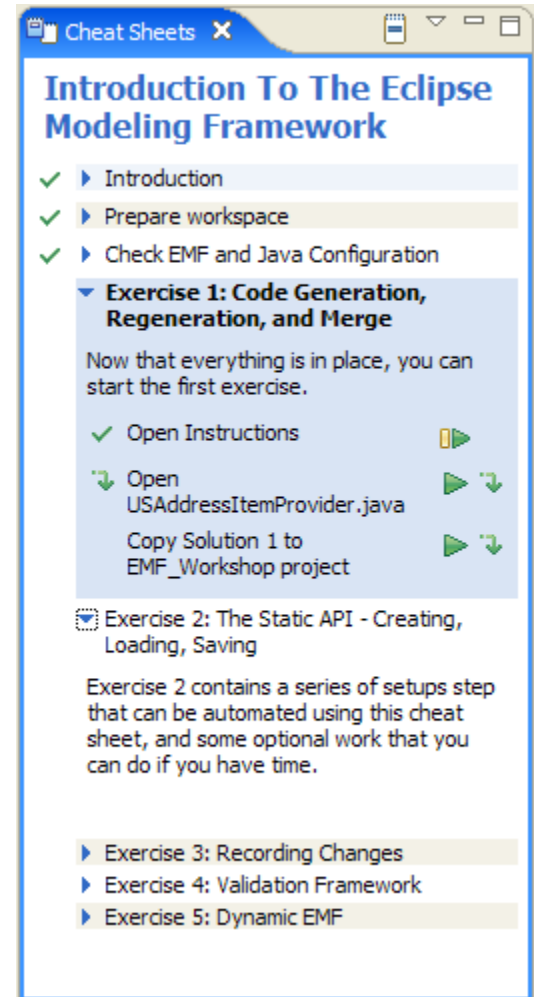
About the Exercises

- The instructions for the exercises are laid out as HTML files
- You can use the tutorial's cheat sheet to perform some of the steps in the exercises
- If you are running out of time...
 - All code you have to write can be copied from a .jpage file located in the “EMF_Workshop” project
 - You can add the complete solutions using the cheat sheet



Eclipse Cheat Sheets

- Were introduced in Eclipse to guide the user through a series of steps
- The steps have to be performed in the order they are presented
- A step can implement some of the manual tasks the user would need to perform
 - Open wizards, create files, manage projects
- Available via the “Help -> Cheat Sheets” menu




Exercise 1:

Code Generation, Regeneration and Merge

- First step: open the “Introduction to The Eclipse Modeling Framework” cheat sheet from the “Help > Cheat Sheets” menu

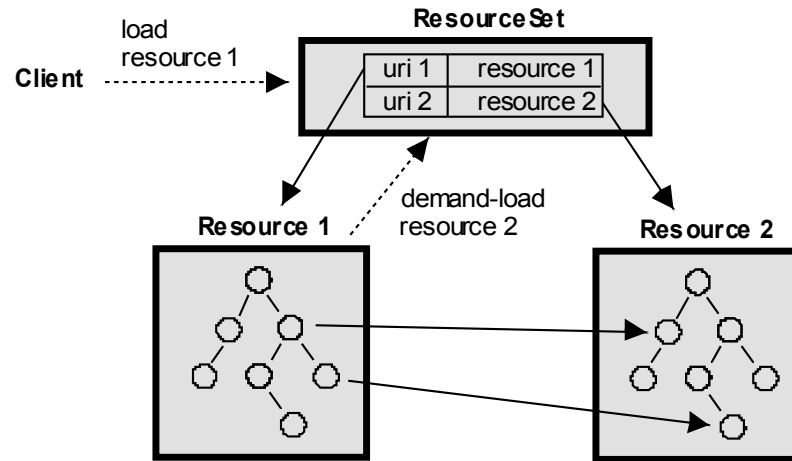
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EMF Runtime

- Persistence and serialization of model data
 - Proxy resolution and demand load
- Automatic notification of model changes
- Bi-directional reference handshaking
- Dynamic object access through a reflective API
- Runtime environments
 - Eclipse
 - Full IDE
 - RCP
 - Standalone Java

Persistence and Serialization



- Serialized data is referred to as a resource
- Data can be spread out among a number of resources in a resource set
- One resource is loaded at a time, even if it has references to objects in other resources in the resource set
 - Proxies exist for objects in other resources
 - Lazy or demand loading of other resources as needed
 - A resource can be unloaded

Resource Set

- Context for multiple resources that may have references among them
- Usually just an instance of `ResourceSetImpl`, or a customized subclass
- Provides factory method for creating new resources in the set:

```
ResourceSet rs = new ResourceSetImpl();  
URI uri = URI.createFileURI("C:/data/po.xml");  
Resource resource = rs.createResource(uri);
```

- Also provides access to the registries, URI converter, and default load options for the set

Resource Factory Registry

- Returns a resource factory for a given type of resource
 - Based on the URI scheme or filename extension
 - Determines the type of resource, hence format for save/load

```
Resource.Factory.Registry reg = rs.getResourceFactoryRegistry();  
reg.getExtensionToFactoryMap().put("xml", new  
XMLResourceFactoryImpl());
```

- For models created from XML Schema, the generated custom resource factory implementation should be registered to ensure schema-conformant serialization
 - When running as a plug-in under Eclipse, EMF provides an extension point for registering resource factories
 - Generated plugin.xml registers generated resource factory against a package specific extension (e.g. "po")
- Global registry: Resource.Factory.Registry.INSTANCE
 - Consulted if no registered resource factory found locally

Package Registry

- Returns the package identified by a given namespace URI
 - Used during loading to access the factory for creating instances

```
EPackage.Registry registry = rs.getPackageRegistry();  
registry.put(POPackage.eNS_URI, POPackage.eINSTANCE);
```

- Global registry: EPackage.Registry.INSTANCE
 - Consulted if no registered package found locally
- Running in Eclipse, EMF provides an extension point for globally registering generated packages
- Even standalone, a package automatically registers itself when accessed:

```
POPackage poPackage = POPackage.eINSTANCE;
```

Resource

- Container for objects that are to be persisted together
 - Convert to and from persistent form via `save()` and `load()`
 - Access contents of resource via `getContents()`

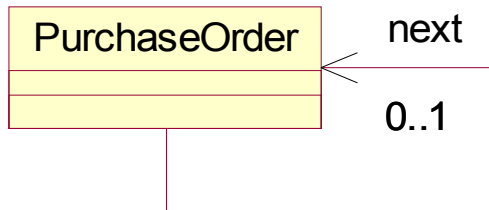
```
URI uri = URI.createFileURI("C:/data/po.xml");  
Resource resource = rs.createResource(uri);  
resource.getContents().add(p1);  
resource.save(null);
```

- EMF provides XMLResource implementation

```
<PurchaseOrder>  
  <shipTo>John Doe</shipTo>  
  <next>p2.xml#p2</next>  
</PurchaseOrder>
```

- Other, customized XML resource implementations, provided, too (e.g. XMI, Ecore, EMOF)

Proxy Resolution and Demand Load



p1.xml

```

<PurchaseOrder>
  <shipTo>John Doe</shipTo>
  <next>p2.xml#p2</next>
</PurchaseOrder>
  
```

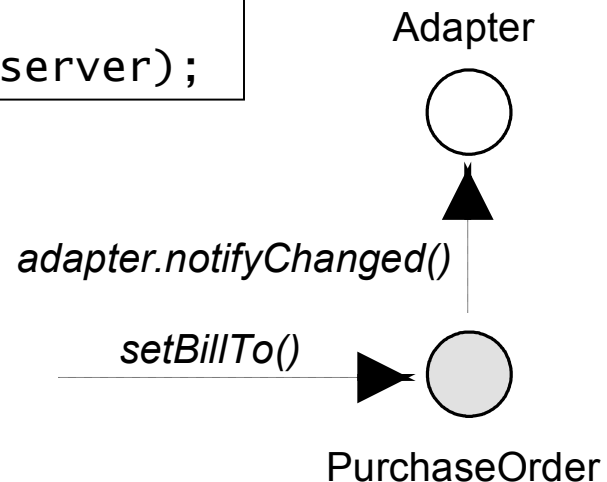


```
PurchaseOrder p2 = p1.getNext();
```

Model Change Notification

- Every EMF object is also a Notifier
 - Send notification whenever an attribute or reference is changed
 - EMF objects can be “observed” in order to update views and dependent objects

```
Adapter poobserver = ...  
purchaseOrder.eAdapters().add(poobserver);
```



Model Change Notification

- Observers or listeners in EMF are called adapters
 - An adapter can also extend class behavior without subclassing
 - For this reason they are typically added using an AdapterFactory

```
PurchaseOrder purchaseOrder = ...
AdapterFactory somePOAdapterFactory = ...
Object poExtensionType = ...

if (somePOAdapterFactory.isFactoryForType(poExtensionType))
{
    Adapter poAdapter = somePOAdapterFactory.adapt(purchaseOrder,
                                                    poExtensionType);
    ...
}
```

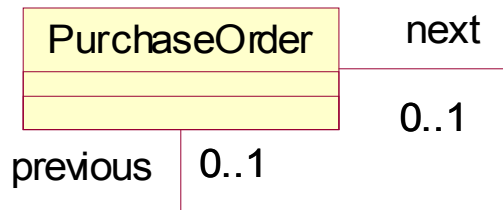
Model Change Notification

- Efficient notification in “set” methods
 - Checks for listeners before creating and sending notification

```
public String getShipTo()
{
    return shipTo;
}

public void setShipTo(String newShipTo)
{
    String oldShipTo = shipTo;
    shipTo = newShipTo;
    if (eNotificationRequired())
        eNotify(new ENotificationImpl(this, ... ));
}
```

Bidirectional Reference Handshaking



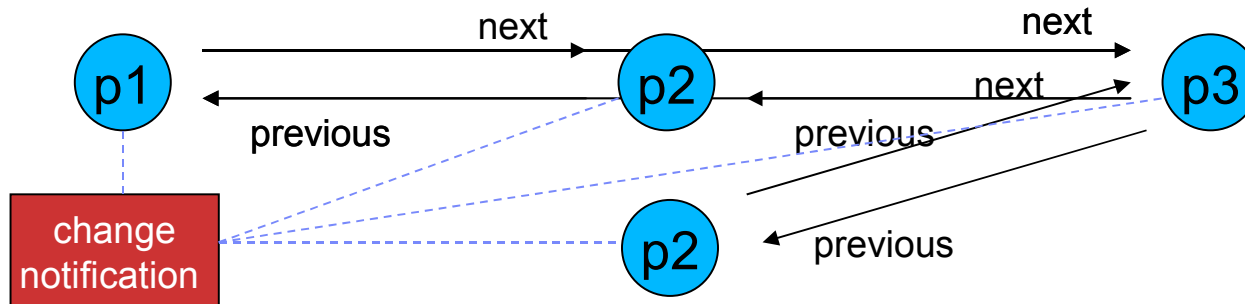
Invariant imposed by the bidirectional reference:

`po.getNext().getPrevious() == po`

```

public interface PurchaseOrder
{
    PurchaseOrder getNext();
    void setNext(PurchaseOrder value);
    PurchaseOrder getPrevious();
    void setPrevious(PurchaseOrder value);
}
    
```

Bidirectional Reference Handshaking



```
p1.setNext(p3);
```

Reflection

- All EMF classes implement interface EObject
- Provides an efficient API for manipulating objects reflectively
 - Used by the framework (e.g., serialization/deserialization, copy utility, generic editing commands, etc.)
 - Also key to integrating tools and applications built using EMF

```
public interface EObject
{
    EClass eClass();
    Object eGet(EStructuralFeature sf);
    void eSet(EStructuralFeature sf, Object val);
    ...
}
```

Reflection Example

- Setting an attribute using generated API:

```
PurchaseOrder po = ...  
po.setBillTo("123 Elm St.");
```

- Using reflective API:

```
EObject po = ...  
EClass poClass = po.eClass();  
po.eSet(poClass.getEStructuralFeature("billTo"),  
        "123 Elm St.");
```


Reflective Performance

- Efficient generated switch-based implementation of reflective methods

```
public Object eGet(int featureID, ...)
{
    switch (featureID)
    {
        case POPackage.PURCHASE_ORDER__SHIP_TO:
            return getShipTo();
        case POPackage.PURCHASE_ORDER__BILL_TO:
            return getBillTo();
        ...
    }
}
```

Reflection Benefits

- Reflection allows generic access to any EMF model
 - Similar to Java's introspection capability
 - Every EObject (that is, every EMF object) implements the reflection API
- An integrator need only know your model!
- A generic EMF model editor uses the reflection API
 - Can be used to edit any EMF model

Dynamic EMF

- Ecore models can be defined dynamically in memory
 - No generated code required
 - Dynamic implementation of reflective EObject API provides same runtime behavior as generated code
 - Also supports dynamic subclasses of generated classes
- All EMF model instances, whether generated or dynamic, are treated the same by the framework
- A dynamic Ecore model can be defined by
 - Instantiating model elements with the Ecore API
 - Loading from a .ecore file

Dynamic EMF Example

- Model definition using the Ecore API

```
EPackage poPackage = EcoreFactory.eINSTANCE.createEPackage();
poPackage.setName("po");
poPackage.setNsURI("http://www.example.com/PurchaseOrder");


EClass poClass = EcoreFactory.eINSTANCE.createEClass();
poClass.setName("PurchaseOrder");
poPackage.getEClassifiers().add(poClass);

EAttribute billTo = EcoreFactory.eINSTANCE.createEAttribute();
billTo.setName("billTo");
billTo.setEType(EcorePackage.eINSTANCE.getEString());
poClass.getEStructuralFeatures().add(billTo);
...

EObject po = EcoreUtil.create(poClass);
po.eSet(billTo, "123 Elm St.");
```

Exercise 2: EMF Runtime and Static Model APIs

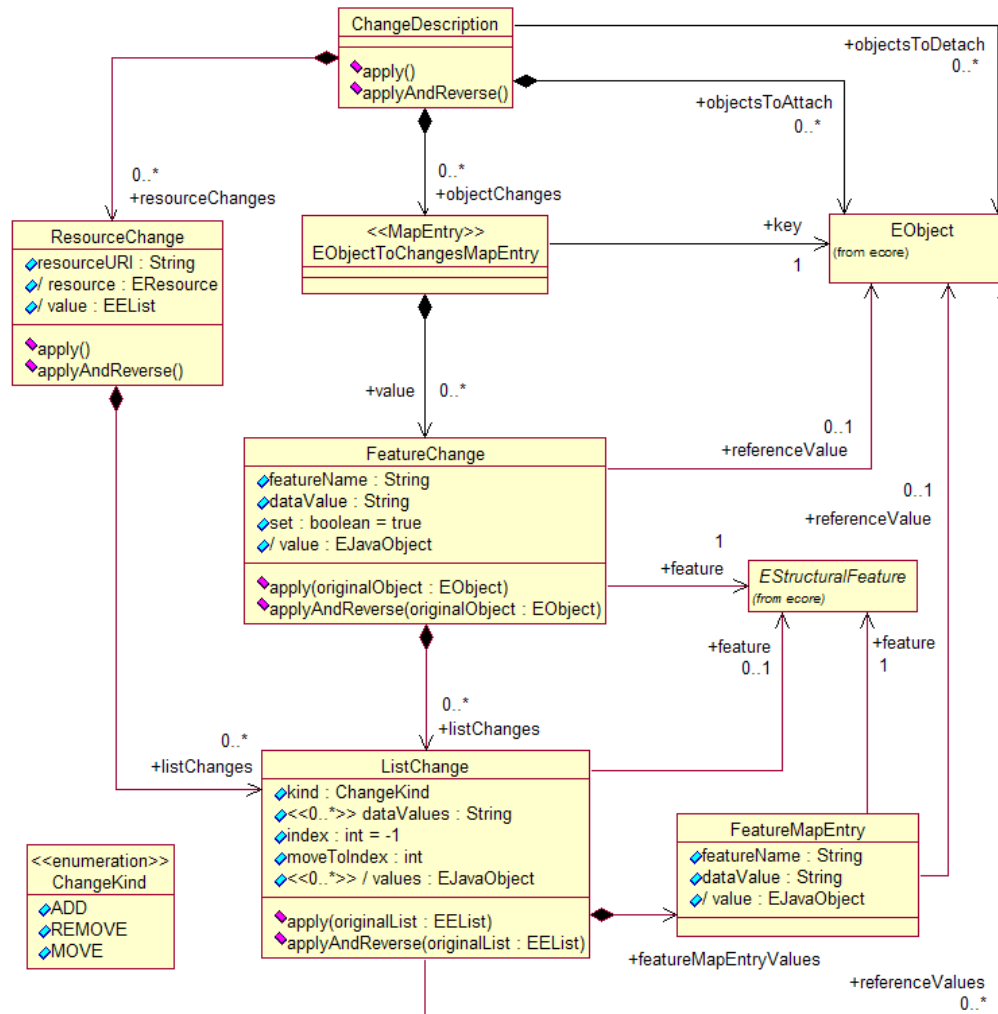
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- ***Exercise 3: Recording Changes***
- Exercise 4: Validation
- Exercise 5: Reflection, Dynamic EMF and XML Processor
- What's New in EMF 2.2
- Summary

Recording Changes

- EMF provides facilities for recording the changes made to instances of an Ecore model
- Change Model
 - An EMF model for representing changes to objects
 - Directly references affected objects
 - Includes “apply changes” capability
- Change Recorder
 - EMF adapter
 - Monitors objects to produce a change description (an instance of the change model)

Change Model



Change Recorder

- Can be attached to EObjects, Resources, and ResourceSets
 - Monitors changes to the objects and their contents trees
- Produces a description of the changes needed to return to the original state (a reverse delta)

```
PurchaseOrder order = ...  
order.setBillTo("123 Elm St.");  
  
ChangeRecorder recorder = new ChangeRecorder();  
recorder.beginRecording(Collections.singleton(order));  
order.setBillTo("456 Cherry St.");  
ChangeDescription change = recorder.endRecording();
```

- Result: a change description with one change, setting billTo to "123 Elm St."

Applying Changes

- Given a change description, the change can be applied:
 - `ChangeDescription.apply()`
 - consumes the changes, leaving the description empty
 - `ChangeDescription.applyAndReverse()`
 - reverses the changes, leaving a description of the changes originally made (the forward delta)
- The model is always left in an appropriate state for applying the resulting change description


Example: Transaction Capability

- If any part of the transaction fails, undo the changes

```
ChangeRecorder changeRecorder =  
    new ChangeRecorder(resourceSet);  
  
try  
{  
    // modifications within resource set  
}  
catch (Exception e)  
{  
    changeRecorder.endRecording().apply();  
}
```

Exercise 3: Recording Changes

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Validation Framework

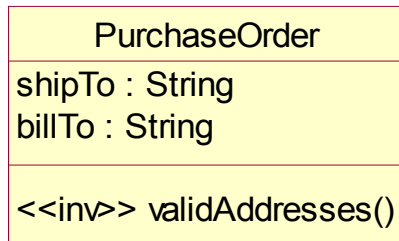
- Model objects validated by external EValidator

```
public interface Evalidator
{
    boolean validate(EObject eObject,
                    DiagnosticChain diagnostics, Map Context);
    boolean validate(EClass eClass, EObject eObject,
                    DiagnosticChain, diagnostics, Map context);
    boolean validate(EDatatype eDataType, Object value,
                    DiagnosticChain diagnostics, Map context);
    ...
}
```

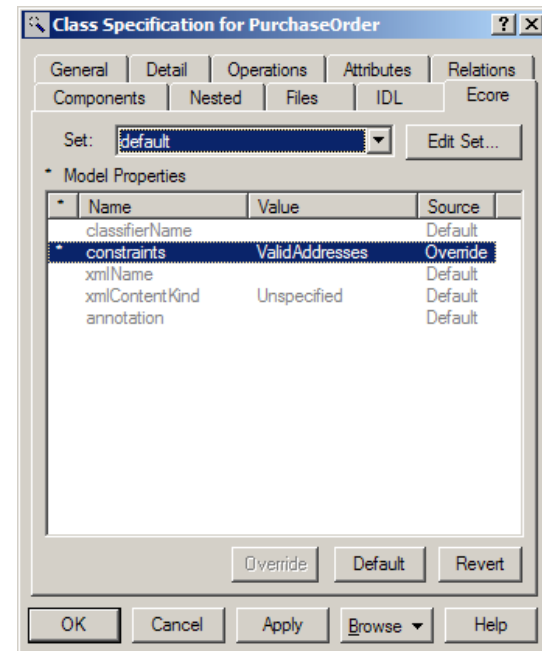
- Detailed results accumulated as Diagnostics
 - Essentially a non-Eclipse equivalent to IStatus
 - Records severity, source plug-in ID, status code, message, other arbitrary data, and nested children

Invariants and Constraints

- Invariant
 - Defined directly on the class, as an operation with <<inv>> stereotype
 - Stronger statement about validity than a constraint



- Constraint
 - Externally defined for the class via a method on the validator



Generated EValidator Implementations

- Generated for each package that defines invariants or constraints
- Dispatches validation to type-specific methods
- For classes, a validate method is called for each invariant and constraint
 - Method body must be hand coded for invariants and named constraints

Schema-Based Constraints

- In XML Schema, named constraints are defined via annotations:

```
<xsd:annotation>  
  <xsd:appinfo source="http://www.eclipse.org/emf/2002/Ecore"  
    ecore:key="constraints">VolumeDiscount</xsd:appinfo>  
</xsd:annotation>
```

- Also, constraints can be defined as facets on simple types, and no additional coding is required
 - Constraint method implementation generated

```
<xsd:simpleType name="SKU">  
  <xsd:restriction base="xsd:string">  
    <xsd:pattern value="\d{3}-[A-Z]{2}"/>  
  </xsd:restriction>  
</xsd:simpleType>
```

Framework EValidator Implementations

- EObjectValidator validates basic EObject constraints:
 - Multiplicities are respected
 - Proxies resolve
 - All referenced objects are contained in a resource
 - Data type values are valid
- Used as base of generated validators and directly for packages without additional constraints defined

Framework EValidator Implementations

- Diagnostician walks a containment tree of model objects, dispatching to package-specific validators
 - Diagnostician.validate() is the usual entry point
 - Obtains validators from its EValidator.Registry


```
Diagnostician validator = Diagnostician.INSTANCE;
Diagnostic diagnostic = validator.validate(order);

if (diagnostic.getSeverity() == Diagnostic.ERROR)
{
    // handle error
}

for (Iterator i = diagnostic.getChildren().iterator(); i.hasNext();)
{
    Diagnostic child = (Diagnostic)i.next();
    // handle child diagnostic
}
```

Exercise 4: Validation

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if time permits
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 - Exercise 4: Validation
 - ***Exercise 5: Reflection, Dynamic EMF and XML Processor***
- What's New in EMF 2.2
 - Summary


XML Processor

- Simplified API for loading and saving XML
 - Handles resource set, registries, etc. under the covers
- Can automatically create a dynamic Ecore representation of a schema
 - Load/save instance documents without generating code
 - Manipulate the objects using reflective EObject API

```
URI schemaURI = ...  
String instanceFileName = ...  
  
XMLProcessor processor = new XMLProcessor(schemaURI);  
Resource resource = processor.load(instanceFileName);  
  
EObject documentRoot = (EObject)resource.getContents().get(0);
```

Exercise 5: Reflection, Dynamic EMF and XML Processor

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Important Changes in EMF 2.2

- Content adapter for managing reverse of 1-way references
- Cross-resource containment
- XMI 2.1 support
- Model exporter
- Improve XML Schema generation
- Improve code generation error reporting and handling

- Performance optimizations
- For more, see:
 - <http://www.eclipse.org/emf/docs.php#plandocs>
 - <http://www.eclipse.org/emf/news/>

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Summary

- EMF is low-cost modeling for the Java mainstream
- Boosts productivity and facilitates integration
- Mixes modeling with programming to maximize the effectiveness of both

Summary

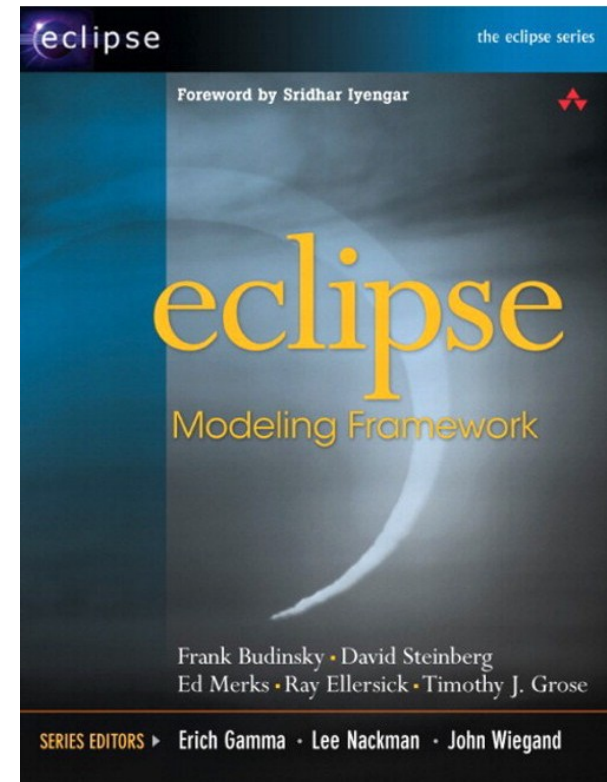
- EMF provides...
 - A metamodel (Ecore) with which your domain model can be specified
 - Your model can be created from UML, XML Schema or annotated Java interfaces
 - Generated Java code
 - Efficient and straightforward
 - Code customization preserved
 - Persistence and Serialization
 - Resource-based serialization
 - Proxy resolution and demand loading
 - Default resource implementation is XMI (XML metadata interchange), but can be overridden

Summary

- EMF provides...
 - Model change notification is built in
 - Just add adapters (observers) where needed
 - Reflection and dynamic EMF
 - Full introspection capability
 - Simple change recording and roll-back
 - Extensible validation framework
 - Standalone runtime support
 - A UI-independent layer for viewing and editing modeled data (EMF.Edit)

Resources

- **This presentation and related workshop materials**
 - <http://www.eclipse.org/emf/docs/presentations/OOPSLA/>
-
- EMF documentation in Eclipse Help
 - Overviews, tutorials, API reference (javadoc)
 - EMF Project Web Site
 - <http://www.eclipse.org/emf/>
 - Overviews, tutorials, newsgroup, Bugzilla
 - Eclipse Modeling Framework by Frank Budinsky et al.
 - Addison-Wesley; 1st edition (August 13, 2003)
 - ISBN: 0131425420.



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