From Models to Code with the Eclipse Modeling Framework

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EMF and XSD Projects

Agenda

- ***Introduction to Modeling and EMF***
- EMF Components
- The Ecore Metamodel
- Model Definition
- Code Generation, Regeneration and Merge
- EMF Runtime Framework
- EMF.Edit Framework
- Summary and Q&A

What is Modeling?

Model Driven Architecture (MDA)™

- A software development architecture proposed by the OMG (Object Management Group)
- Application is specified in a high-level platform independent model (PIM)
  - abstracts away underlying platform technology
- Transformation technologies are used to convert PIM to platform specific model (PSM), implementation code, etc.
- Includes several open modeling standards
  - UML (Unified Modeling Language)
  - MOF (Meta-Object Facility)
  - XMI (XML Metadata Interchange)
  - CWM (Common Warehouse Model)

What is Modeling?

Why don't we care about MDA?

1. It's mostly vaporware
2. "Real programmers" know that implementing complex systems by simply transforming a picture, is a "pipe dream"
   - not to mention the fact that it could put us "real programmers" out of business!
3. Smart people know that all the expressive power of the Java programming language can't be available in the model
   - if it was, it wouldn't be any simpler (higher level)
   - it would just be another "programming language"

What is Modeling?

Why should we care about MDA?

1. It's not totally vaporware
2. "Real programmers" know that generating some of the code that we write over and over, must be possible
   - it will simply pave the way for even more complex systems on top of it … programmers like us will never be out of business!
3. Smart people (that have been around long enough) recognize many of the same arguments that were used to oppose high-level languages vs. assembly language

EMF Model Definition

What is an EMF “model”?

- Specification of an application’s data
  - Object attributes
  - Relationships (associations) between objects
  - Operations available on each object
  - Simple constraints (e.g., multiplicity) on objects and relationships
- Essentially the Class Diagram subset of UML

EMF Model Definition (cont)

Model Sources

- 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 generate the others as well as the implementation code

EMF Model Definition (cont)

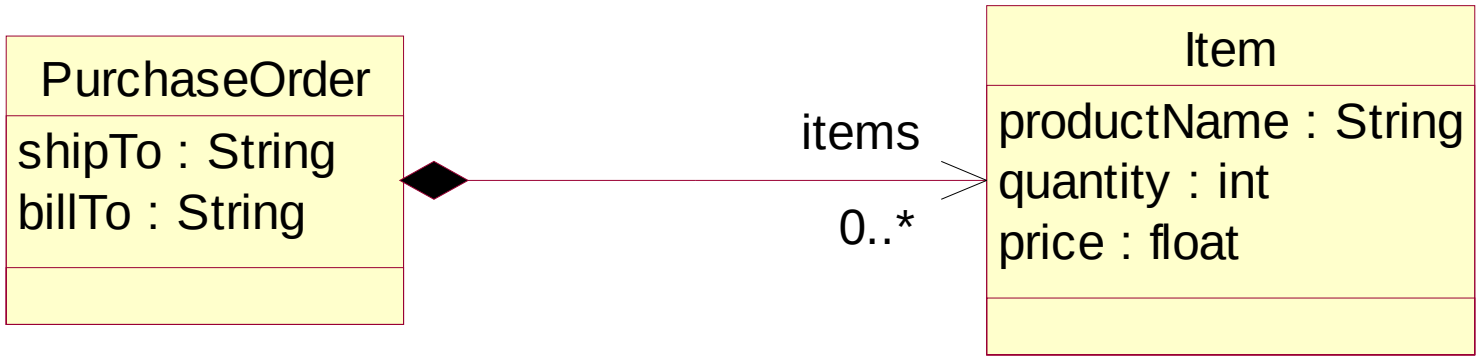
1. Java Interfaces

```
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);
}
```


EMF Model Definition (cont)

2. UML Class Diagram



EMF Model Definition (cont)

3. XML Schema

```
<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>
```


EMF Model Definition (cont)

Unifying Java™, XML, and UML 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-ins

What does EMF Provide?

- Meta model
  - A general model of models from which any model can be defined
  - Models classes, attributes, relationships, data types, etc.
  - Referred to as **Ecore**
  - Ecore is just another EMF model
    - EMF is used to implement EMF!
- Tooling support within the Eclipse framework (or command line)
- Runtime environment
  - Reflective and dynamic model invocation
  - XML/XMI default model serialization

Why should I care?

- EMF is middle ground in the modeling vs. programming world
  - Focus is on class diagram subset of UML modeling (object model)
  - Transforms models into efficient, correct, and easily customizable Java code
  - Provides the infrastructure to use models effectively in your code
- Very low cost of entry
  - Full scale graphical modeling tool not required
  - EMF is free
  - Small subset of UML

EMF History

- Originally based on MOF (Meta Object Facility)
  - From OMG (Object Management Group)
  - Abstract language and framework for specifying, constructing, and managing technology neutral meta-models
- EMF evolved based on experience supporting a large set of tools
  - Efficient Java implementation of a practical subset of the MOF API
- Foundation for model-based IBM WebSphere Studio/Rational development tools
  - Example: J2EE model in Rational Application Developer
- 2003: EMOF defined (Essential MOF)
  - Part of MOF 2 specification; UML2 based; recently approved by OMG
  - EMF is approximately the same functionality
    - Significant contributor to the spec
- 2004: Service Data Objects (SDO) reference implementation
  - IBM and BEA Joint Specification (Nov 2003)
  - Currently being standardized through the Java Community Process
    - JSR 235

Who is using EMF today?

- IBM WebSphere/Rational product family
- Other Eclipse projects (XSD, UML2, VE, Hyades, WTP)
- ISV's (TogetherSoft, Ensemble, Versata, Omondo, and more)
- SDO reference implementation
- Large open source community
  - O(1K) downloads/day
  - and growing …

A Typical EMF Usage Scenario

1. Create EMF model
   - Import UML (e.g. Rational Rose .mdl file)
   - Import XML Schema
   - Import annotated Java interfaces
   - Create Ecore model directly using EMF Ecore editor or Omondo's (free) EclipseUML graphical editor
2. Generate Java code for model
3. Iteratively develop Java application
4. Refine model; regenerate Java code
5. Prime the model with instance data using generated EMF model editor
6. Use EMF.Edit to build customized user interface

- Let's demo

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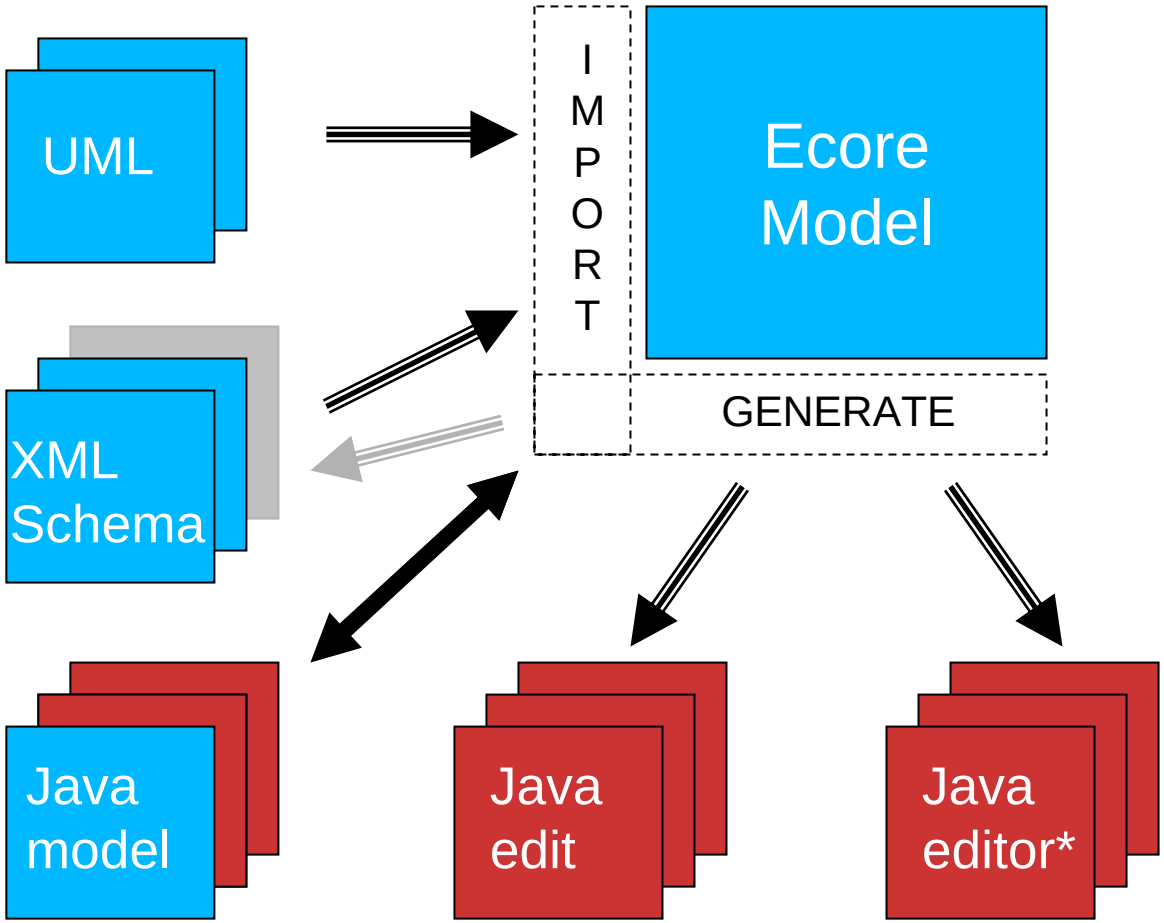
EMF Components

- **EMF Core**
  - Ecore meta model
  - Model change notification
  - Persistence and serialization
  - Reflection API
  - Runtime support for generated models
  - Change model and recorder
  - Validation framework
- **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
  - Model importers from Rose, XML, or Java interfaces

EMF Tooling

Model Import and Generation



Generator features:

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

* requires Eclipse to run

Model Import

- Import from
  - UML
    - Rational Rose `.mdl` file directly supported
    - Other UML editors possible
  - Annotated Java
    - Consists of Java interfaces for each class model
    - Annotations using `@model` tags added to interface to express model definition not possible with code
    - Lowest cost approach
  - XML Schema
    - May produce more complicated EMF model than from Java or UML
  - Ecore model (`*.ecore` file)
    - Just creates the generator model (discussed later)

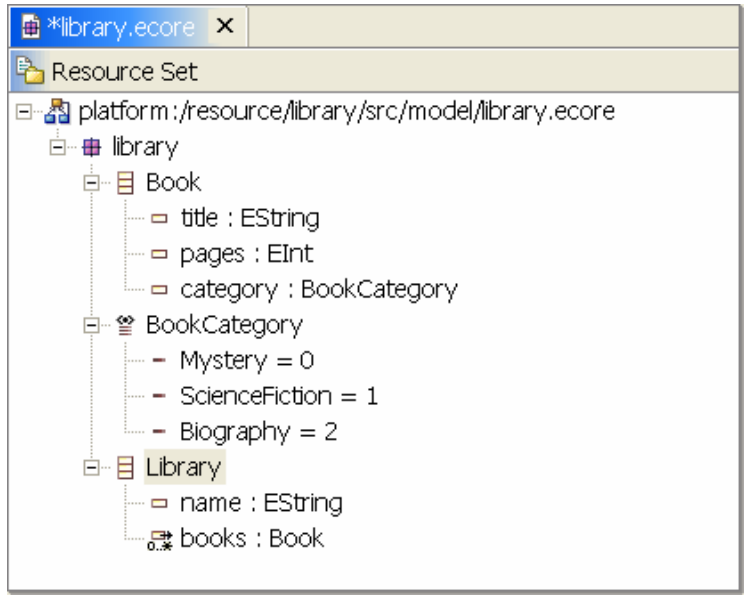
Model Creation

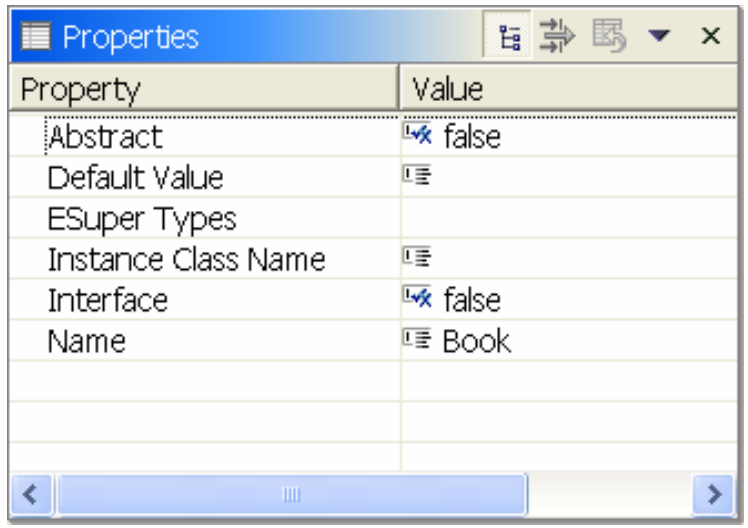
- Ecore model created within an Eclipse project via wizard using a sources described in previous slide

- Output is:
  - *modelname*`.ecore` file
    - Ecore model file in XMI format
    - Canonical form of the model
  - *modelname*`.genmodel` file
    - A “generator model” for specifying generator options
    - Decorates `.ecore` file
    - EMF code generator is an EMF `.genmodel` editor
    - `.genmodel` and `.ecore` files automatically kept in sync

Ecore Model Editor

- A generated (and customized) EMF editor for the Ecore model
- Models can be edited using tree view in conjunction with property view
  - New components (EClass, EAttribute, EReference, etc.) created using popup actions in tree view
  - Set names, etc., in property view
- Note: a graphical editor (e.g., Omondo) is better approach





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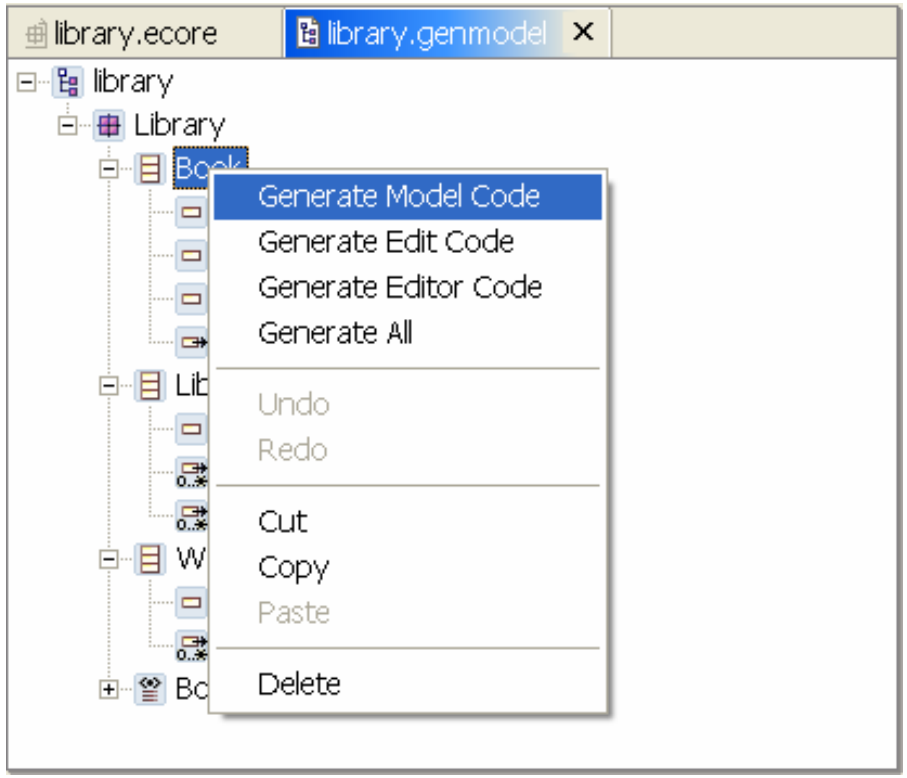
Generator Model Editor

- Looks nearly the same as the Ecore model editor
- Kept in sync with changes to `.ecore` file
- Context menu actions generate code
  1. The **Generate Model Code** action produces Java code to implement the model
  2. The **Generate Edit Code** action produces adapter code to support viewers
  3. The **Generate Editor Code** action produces a full function Eclipse editor
  4. The **Generate All** action produces all three
- Generation options expressed in Properties view
- Command line API and Ant tasks also available



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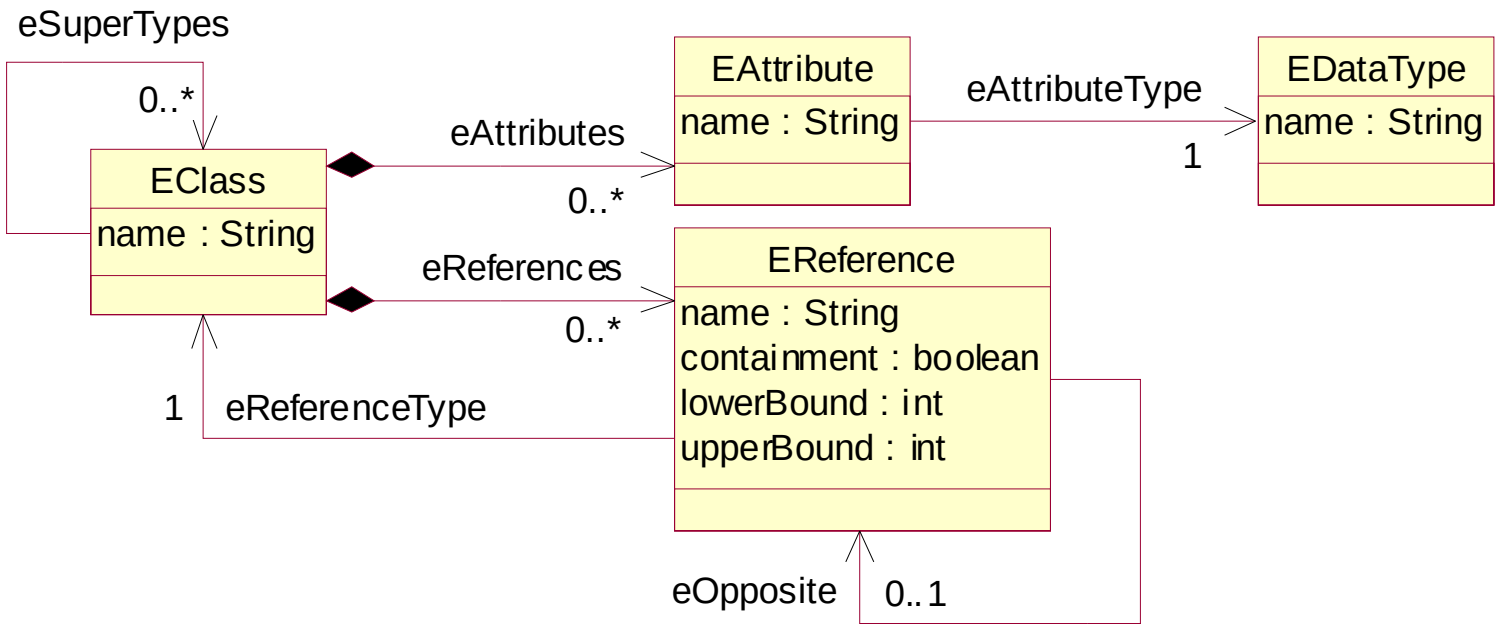
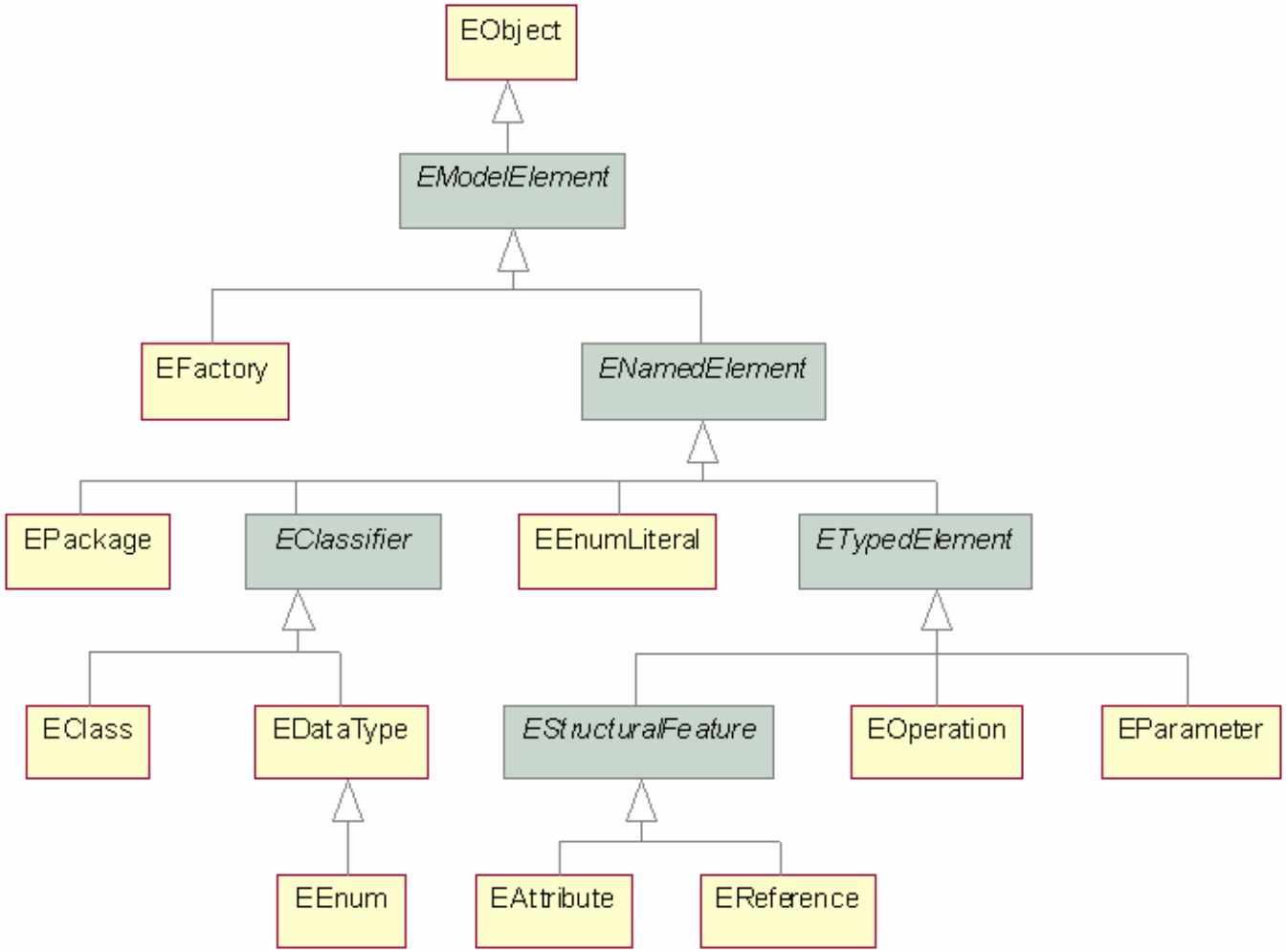
The Ecore (Meta) Model

- Ecore is EMF's model of a model (metamodel)
  - Persistent representation is XMI



Ecore Meta Model



EObject is the root of every model object. Equivalent to java.lang.Object

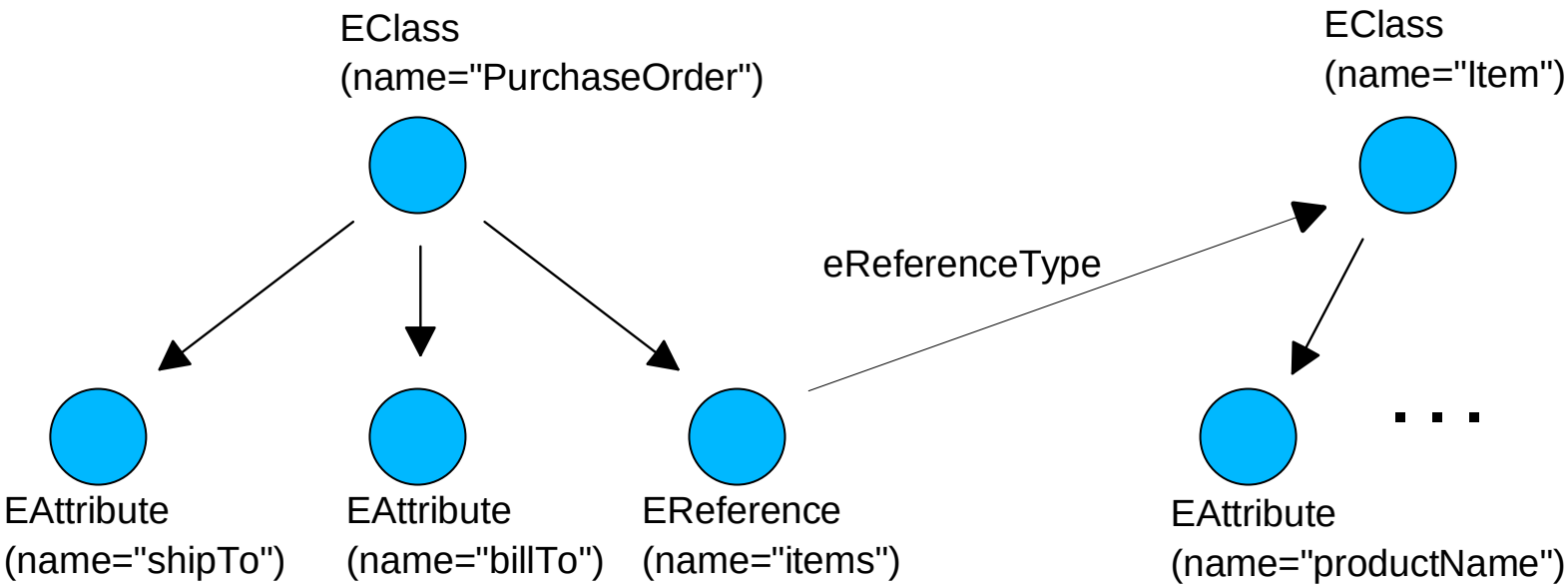
Partial List of Ecore Data Types

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 datatypes are serializable

Support for custom datatypes

PurchaseOrder Ecore Model



PurchaseOrder 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
  - Part of OMG MOF 2 Standard

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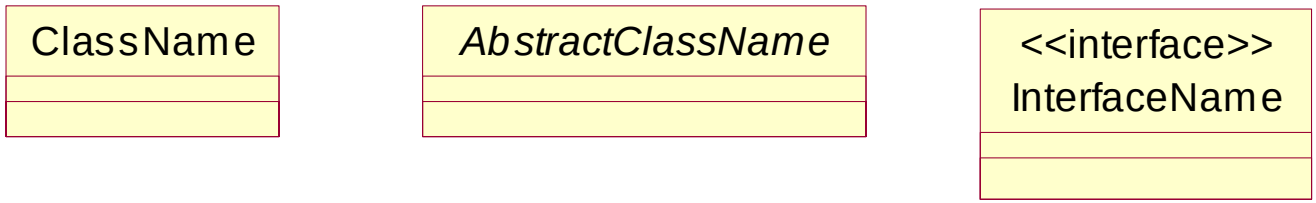
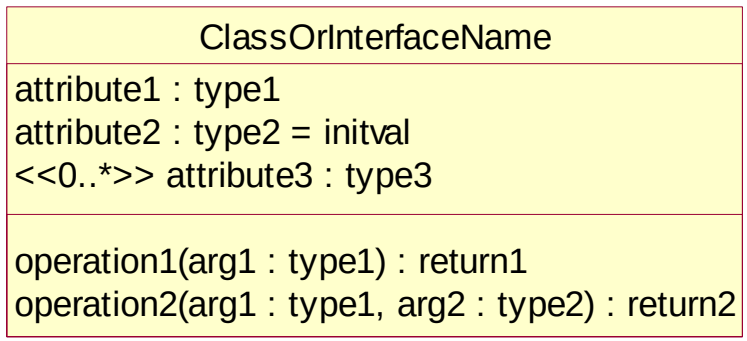
The EMF Subset of UML



Classes*, Abstract classes, and Interfaces



Attributes and operations

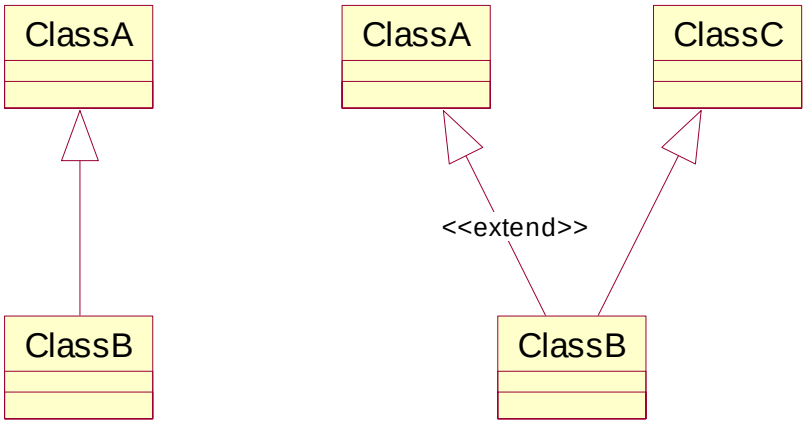
* An EMF class corresponds to both an interface and a corresponding implementation class in Java

The EMF Subset of UML (cont)

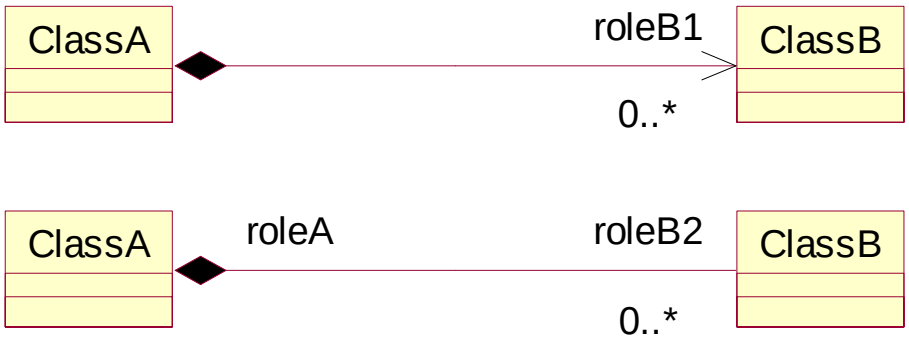
One-way Associations

Bi-directional Associations

The EMF Subset of UML (cont)

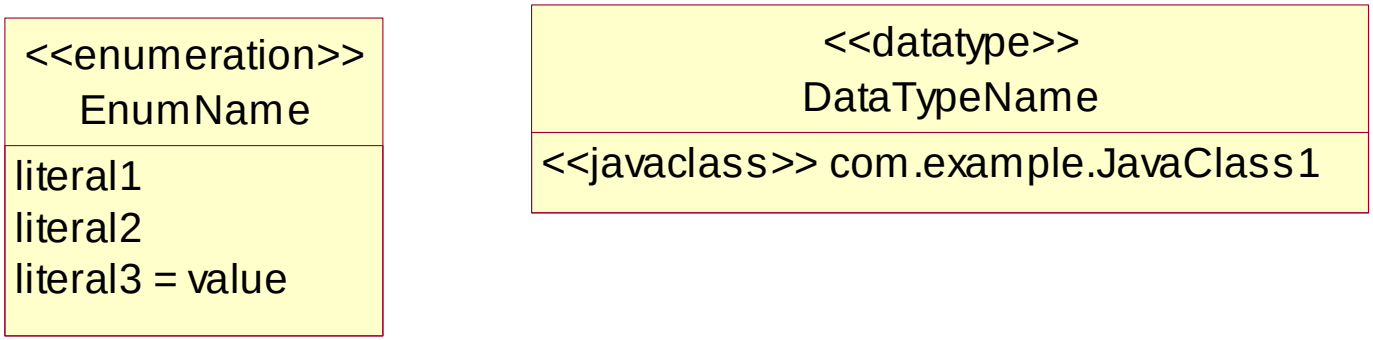


Class Inheritance



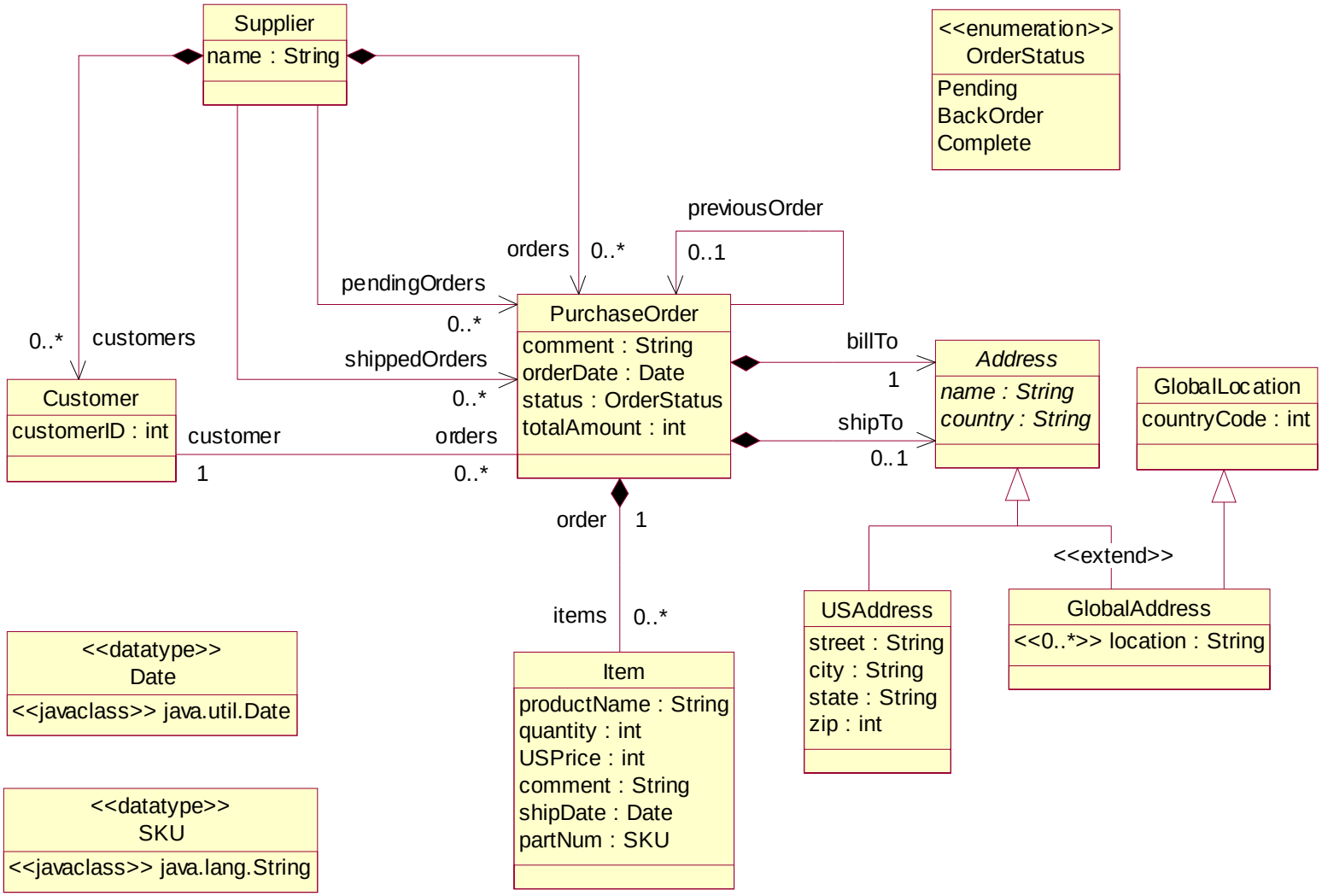
Containment Associations

The EMF Subset of UML (cont)



Enumerations and Datatypes

An Example Model



Java Annotations

- Imbedded as Java comments before classes and methods
- **`@model`** tag specifies model metadata not contained in Java interface code
- Form

  `@model [`*`property`* `= "`*`value`*`" | `*`property`* `= "`*`value`*`"] …`

- Example: Containment relationship between Library and Book classes

```
public interface Library extends EObject {
  /**
   * @model type="Book" containment="true"
   * @generated
   */
  EList getBooks()
```


 |

Sampling of @model Annotations

Ecore Object	Properties
EClass	abstract, interface
EAttribute	defaultValue, unique, many, dataType, changeable, required, upperBound, lowerBound, unsettable …
EReference	opposite, containment, unique, many, changeable, required lowerBound, upperBound, unsettable, …
EOperation	parameters, dataType
EDataType	instanceClass, serializable

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Generated Java Code

- EMF framework is lightweight
  - Generated code is clean, simple, efficient
- Model Generator produces
  - Interface class for every modeled object
    - Includes get/set methods for all object attributes
  - Implementation class for every interface
    - Support for model change notification
  - A factory class to create instances of our model objects
  - A package class that provides access to model's metadata

Generated Java Code

- View support code is divided into two parts:
  - UI-independent code (placed in an edit plug-in)
    - Item providers (adapters)
  - UI-dependent code (placed by default in a separate editor plug-in)
    - Model editor
    - Model creation wizard

Regeneration and Merge

- Hand-written code can be added to generated code and preserved during regeneration
- All generated classes, interfaces, methods include `@generated` marker
- Override generated code by removing `@generate` marker
  - or include additional text like `@generated NOT`
- Methods without `@generated` marker are left alone during regeneration
- If duplicate methods names exist your code takes precedence
  - generated code is discarded

Regeneration and Merge

- Extend (vs. replace) generated method through redirection
- To override the `getQuantity` generated method:
  - Add suffix `Gen` to generated method

    `getQuantity()` becomes `getQuantityGen()`
  - During regen, the …`Gen()` method will be regenerated
  - Create your own `getQuantity()` method and call `getQuantityGen()`

Regeneration and Merge

- Other merge behavior is as expected
  - Extend a generated interface
  - Add interfaces to a generated class
- Support for regeneration from updated Rose model, XML Schema or @model annotations

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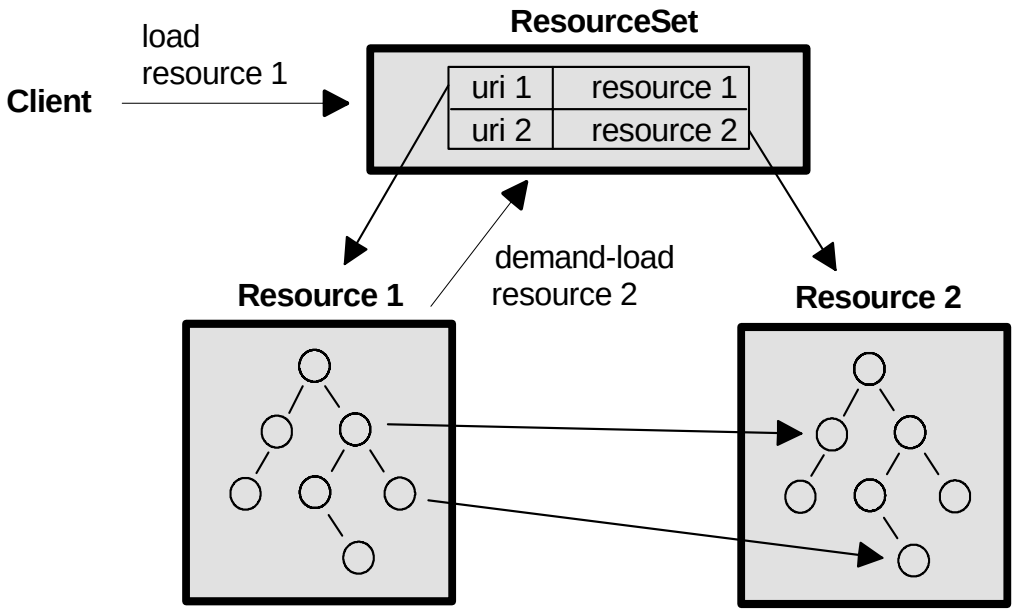
EMF Runtime Framework

- 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 reflection API
- Runtime environments
  - Eclipse
  - Standalone Java

Persistence and Serialization



- Serialized data is referred to as a **Resource**
  - –Data can be spread out among a number of resources becoming a **Resource Set**
- When a model is loaded only the required resources of the resource set are loaded
  - –Proxies exist for other resources in the set
  - –Lazy or demand-loading of other resources as needed
  - –A resource can be unloaded

Persistence and Serialization

- Save model objects using EMF Resources
  - Generic XML Resource implementation
  - Other Resource implementations possible

```
poResource = ...createResource(..."p1.xml"...);
poResource.getContents().add(p1);
poResource.save(...);
```

p1.xml:

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

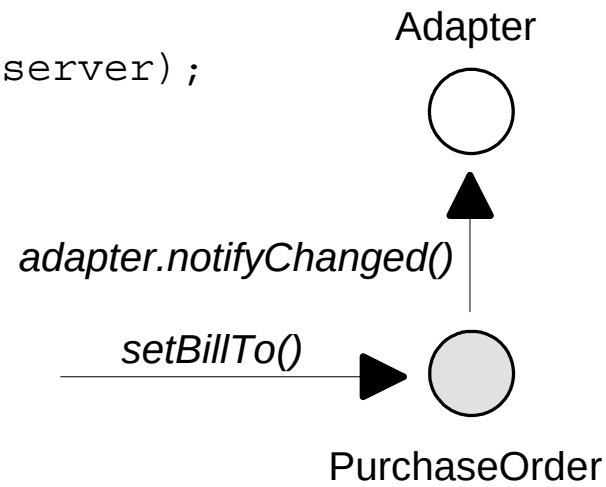

Proxy Resolution and Demand Load


```
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 = ...
aPurchaseOrder.eAdapters().add(poObserver);
```



Model Change Notification

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

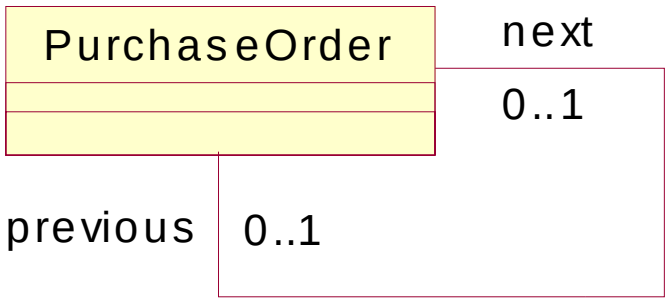
```
PurchaseOrder aPurchaseOrder = ...
AdapterFactory somePOAdapterFactory = ...
Object poExtensionType = ...
if (somePOAdapterFactory.isFactoryForType(poExtensiontype) {
  Adapter poAdapter =
     somePOAdapterFactory.adapt(aPurchasOrder,
                                poExtensionType);
  ...
}
```


Model Change Notification

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

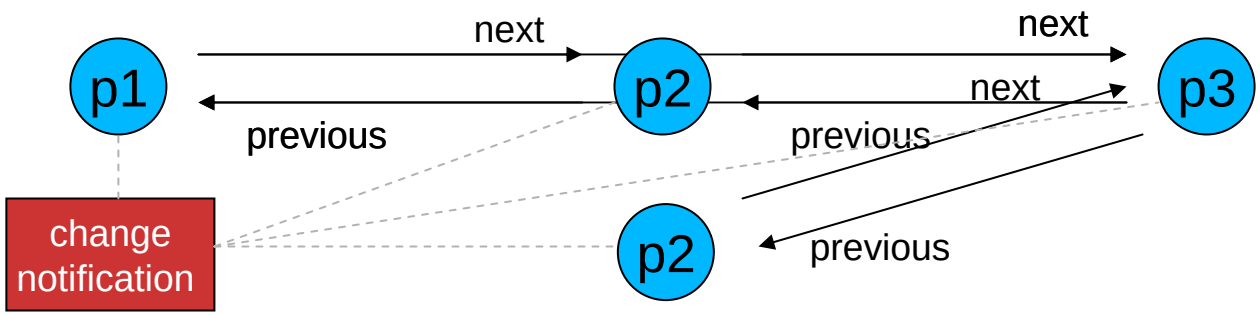
```
public String getShipTo() {
  return shipTo;
}

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


Bidirectional Reference Handshaking




```
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., generic serializer, copy utility, generic editing commands, etc.)
  - Also key to integrating tools and applications built using EMF

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


Reflection

- Efficient generated switch implementation of reflective methods

```
public Object eGet(EStructuralFeature eFeature) {
  switch (eDerivedStructuralFeatureID(eFeature))
  {
    case POPackage.PURCHASE_ORDER__SHIP_TO:
      return getShipTo();
    case POPackage.PURCHASE_ORDER__BILL_TO:
      return getBillTo();
    ...
  }
}
```


Reflection Example

- Adding a book in a Library model using generated API

```
Book book = LibraryFactory.eINSTANCE.createBook();
book.setTitle("King Lear");
book.setLibrary(branch);
```

- Adding a book to the model using reflection

```
Book bookR = (Book)LibraryFactory.eINSTANCE.create(
  LibraryPackage.eINSTANCE.getBook());
bookR.eSet(LibraryPackage.eINSTANCE.getBook_Title(),
  "King Lear");
bookR.eSet(LibraryPackage.eINSTANCE.getBook_Library(),
  branch);
```

Reflection and Dynamic EMF

- Given an Ecore model, EMF also supports dynamic manipulation of instances
  - 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

Reflection and Dynamic EMF

- Reflection allows generic access to any EMF model
  - Similar to Java's introspection capability
  - Every EObject (which 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 Demo

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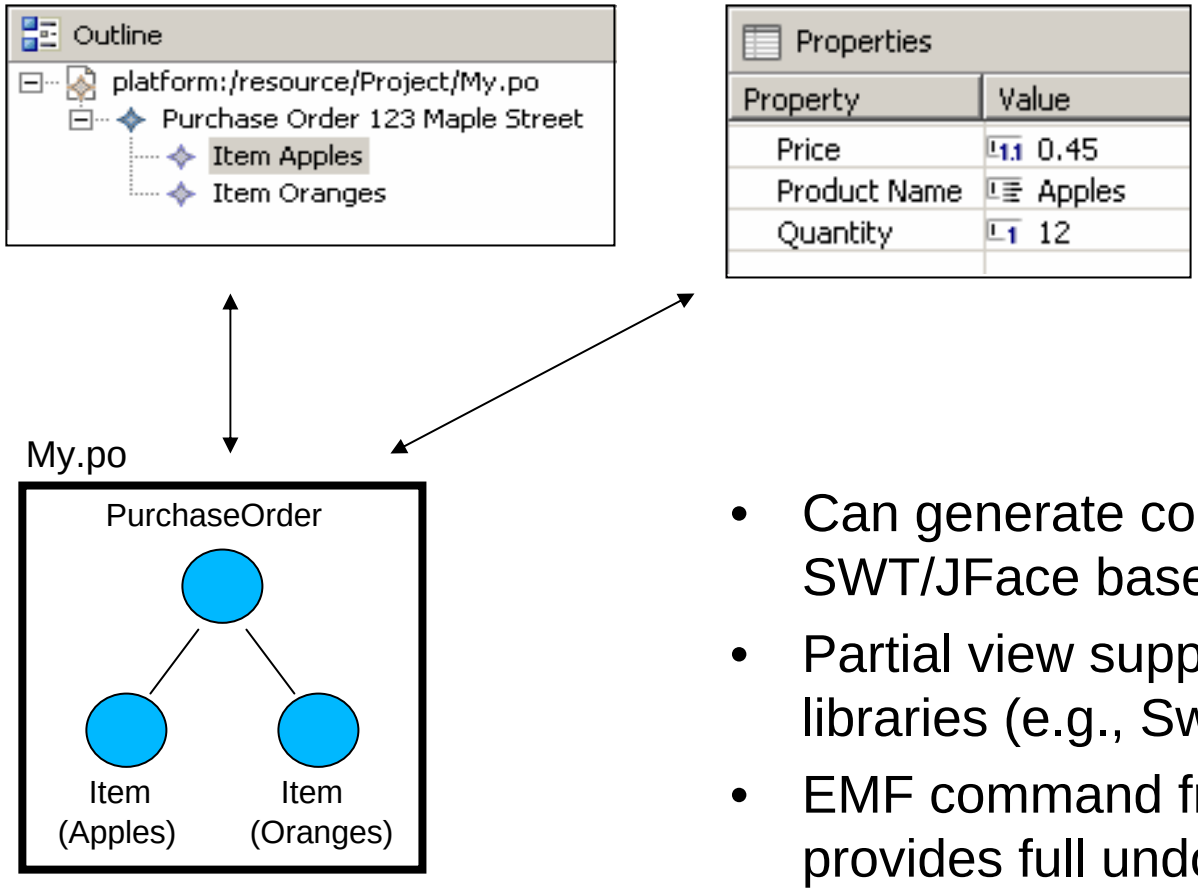
The EMF.Edit Framework

- The EMF.Edit framework extends the base EMF model framework with generic reusable classes to support:
  - Model viewers
  - Command-based model modifications
  - Building editors for EMF models
- It provides:
  - Adapters that link an EMF Model to the requirements of Eclipse editors, views and property sheets
  - A command framework, including a set of generic command for building editors
  - A generator that produces a fully functional structured editor, integrated into Eclipse or as an RCP application

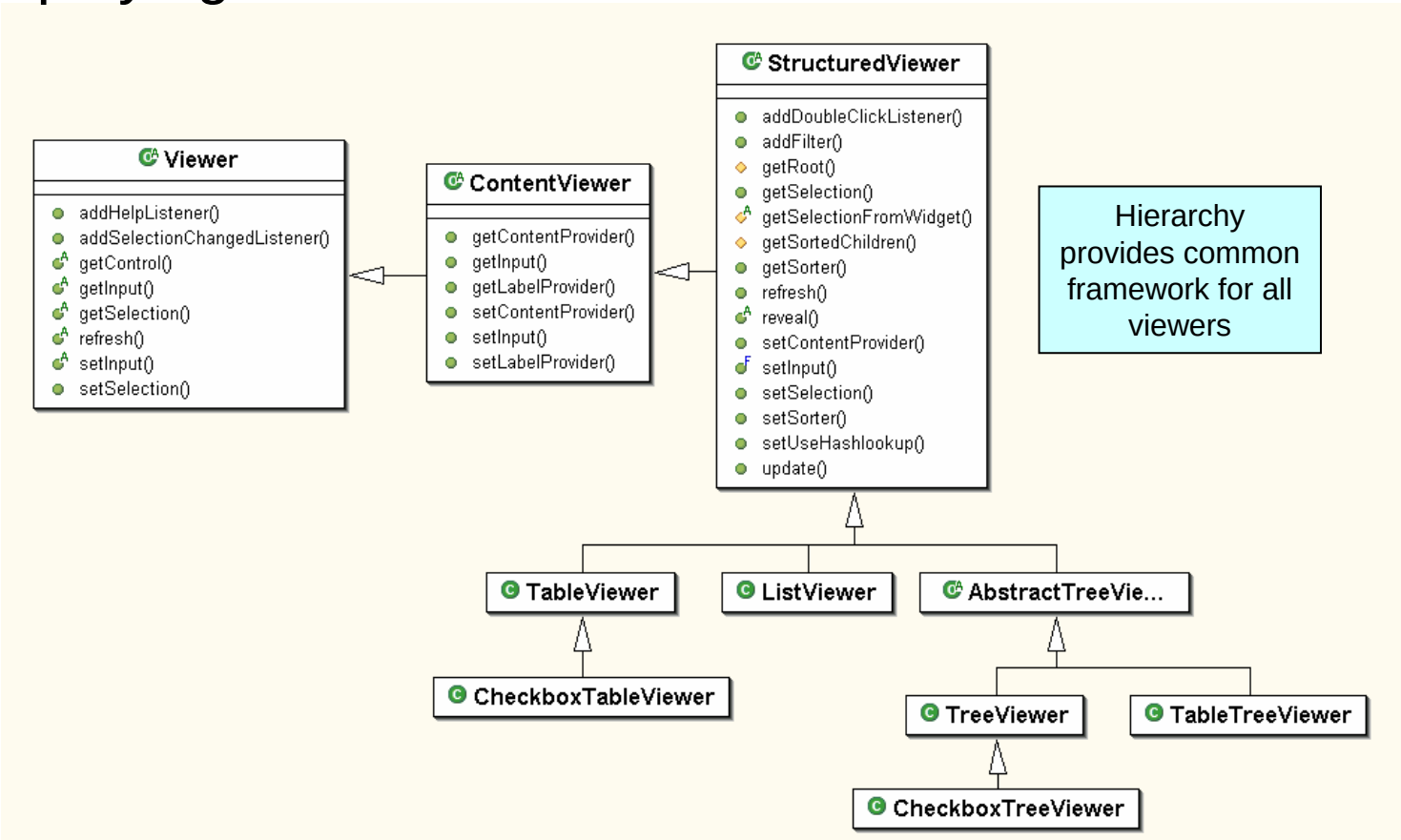
EMF.Edit Model Viewers and Editors



- Can generate complete Eclipse SWT/JFace based editors
- Partial view support for other UI libraries (e.g., Swing)
- EMF command framework provides full undo/redo support

Standard Eclipse Viewers – JFace

- The Eclipse UI framework includes viewer classes for displaying structure models.

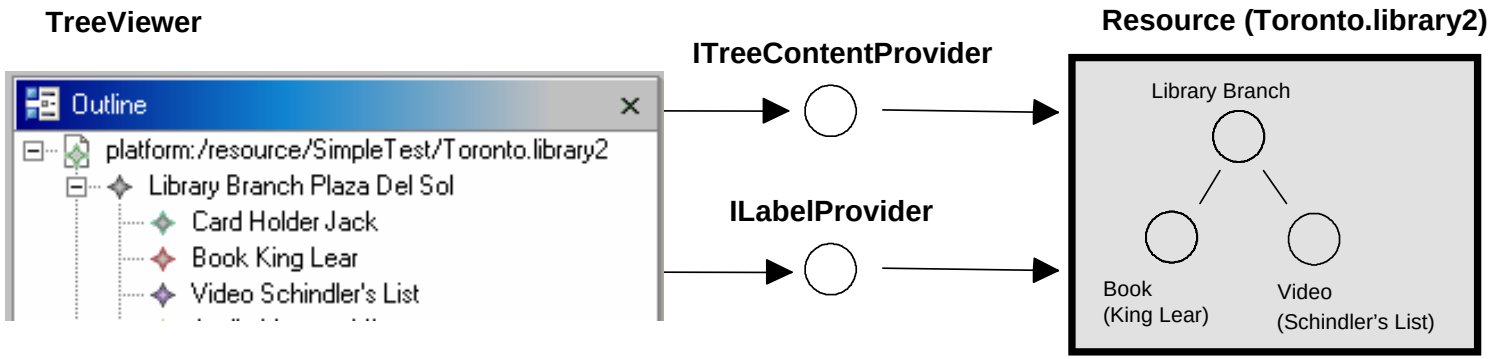


JFace Viewers

- JFace viewers work with any kind of object
- Viewers access the model objects through an adapter object called a content provider
- Viewers are adapters that add model-based content to certain kinds of SWT widgets (list, tree, table)
- Content viewers interact with a content provider and label provider to obtain viewer structure and visual content

Content and Label Providers

- Mapping between an Eclipse view and a model
  1. **ContentProvider:** Maps the input object to the set of objects and associated structure
  2. **LabelProvider:** Provides a text label and icon for each displayed object



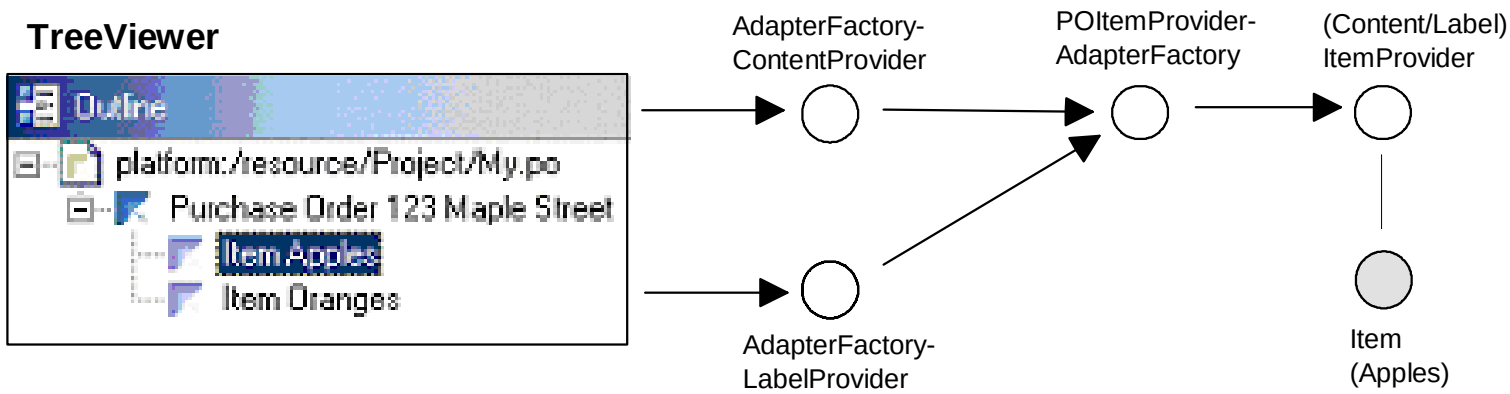
EMF.Edit ItemProviders

- EMF.Edit introduces Item Providers which mesh nicely with JFace content and label providers
- ItemProviders are the key to EMF edit with the following functions:
  1. Implement content and label provider functions
  2. Provide property descriptors
  3. Forward EMF model change notifications to viewers
- Provide functions on behalf of an editable model object (item)
- Reflective Item Provider

EMF.Edit ItemProviders

- EMF.Edit's *AdapterFactoryContentProvider* implements all generic JFace content provider interfaces
- EMF.Edit's *AdapterFactoryLabelProvider* works similarly for label providers
- Both Delegate to corresponding ItemProvider interfaces
  for example, *ITreeItemProviders* know how to navigate the model objects (items) for a TreeViewer

```
public interface ITreeItemProvider
{
   public Collection getChildren(Object object);
   public Object getParent(Object object);
                  ……..
}
```



Editing Commands

- So far, we've looked at how to view an EMF model, what about editing?
- Editing means undoable modification
- Editing command support:
  - Interact with EMF objects
  - Automatic undo and redo
  - Commands work on any EMF model
  - Handle simple or complex operations

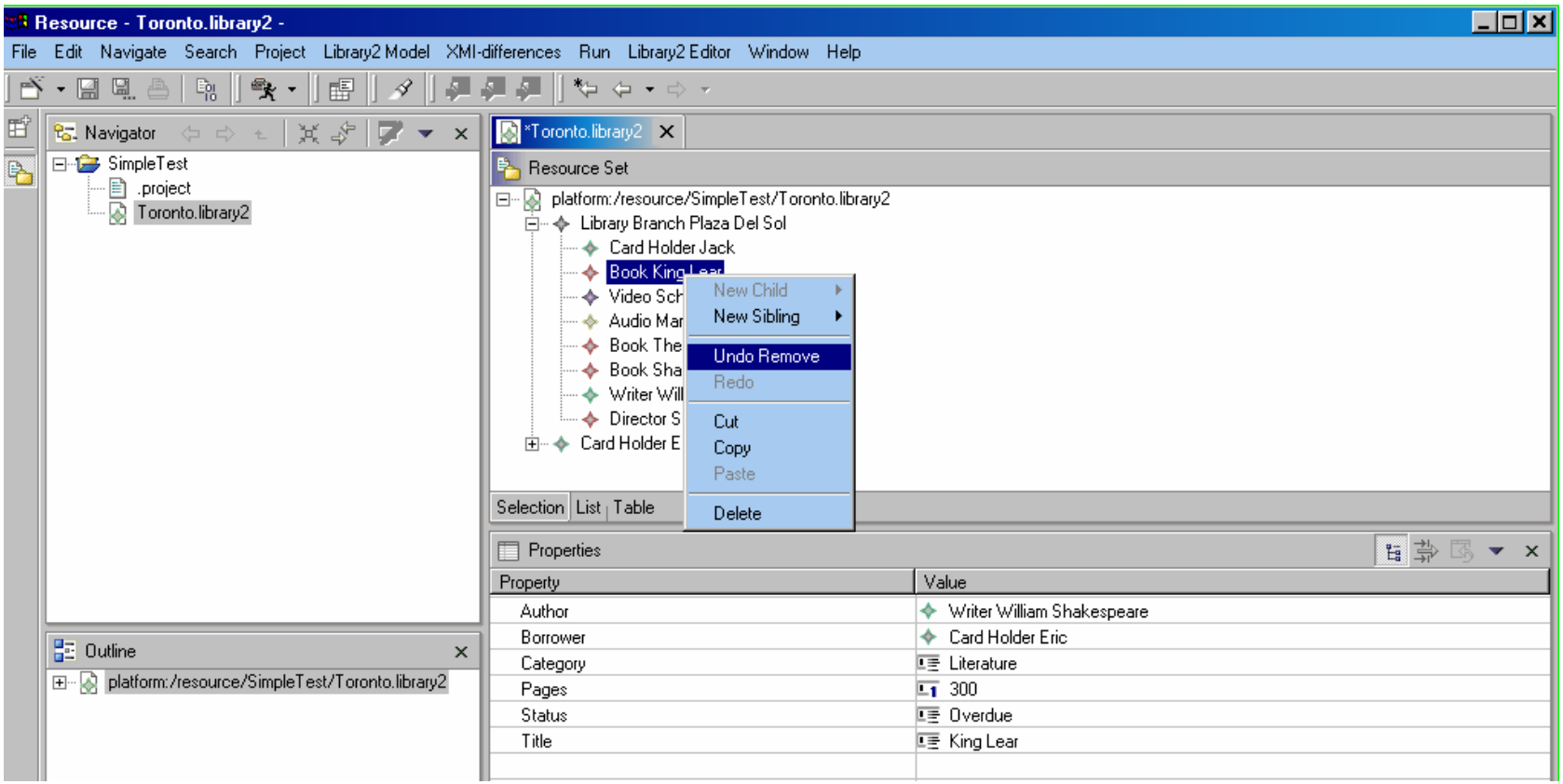
EMF.Edit Commands

The Basic EMF.Edit Commands are:

1. SetCommand
2. AddCommand
3. RemoveCommand
4. MoveCommand
5. ReplaceCommand
6. CopyCommand
7. DragAndDropCommand
   - uses CopyCommand, RemoveCommand, and AddCommand

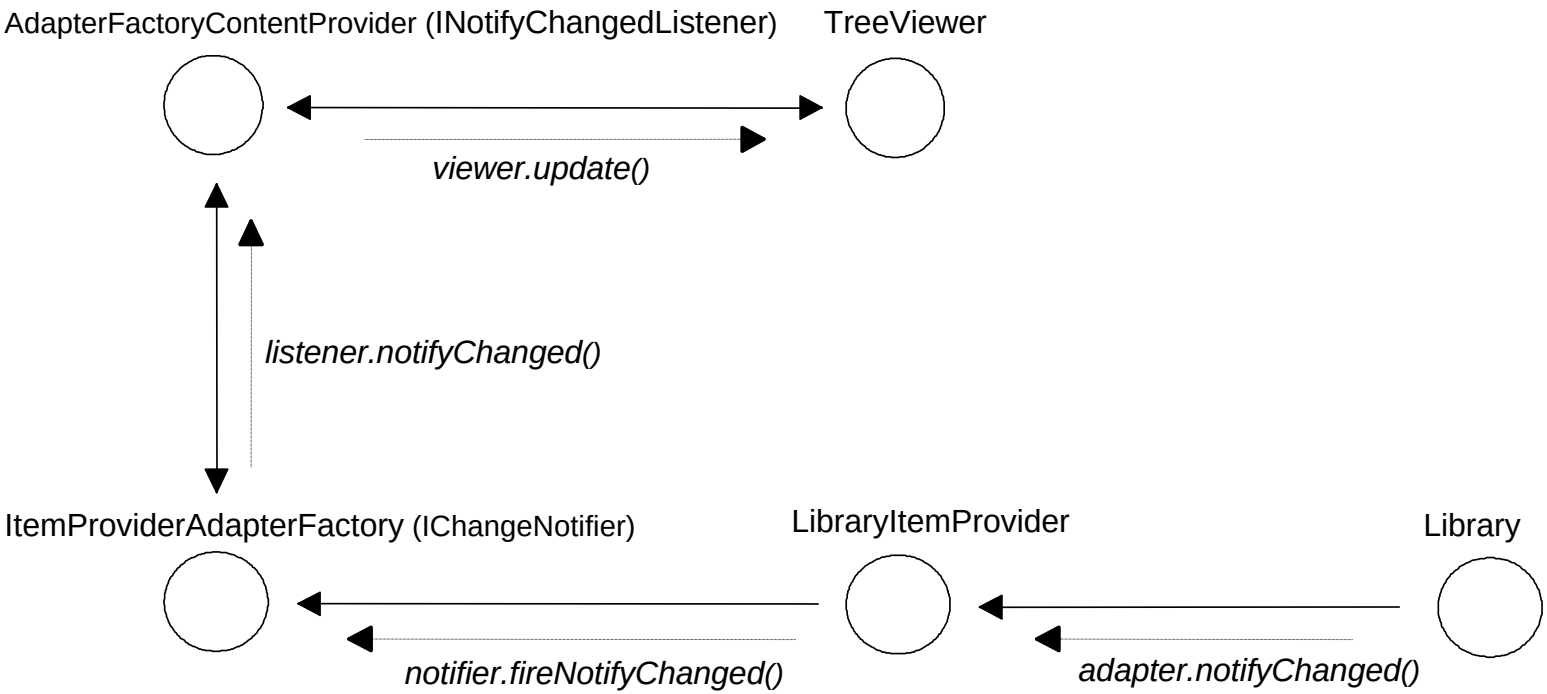
Command-based Editor Actions

- EMF.Edit also provides editor actions for the generic commands



EMF.Edit Viewer Refresh

- How to refresh a viewer after a command changes something in a model?



EMF.Edit EditingDomain

- EMF.Edit framework uses an Editing Domain to manage an editor's command-based modification of a model
- The Editing Domain provides a context for executing commands
- An Editing Domain interface is used to provide editing access to an EMF model
- The Editing Domain provide three main functions:

1. Creating commands
2. Managing the command undo stack
3. Providing convenient access to the set of EMF resources being edited

Command Creation

- EditingDomains delegate command creation to ItemProviders
  - Makes it easy to override any command for specific types of objects
- To customize a command:
  - Override the required c*reateCommand()* method from the framework item provider base class, *ItemProviderAdapter*

```
protected Command createSetCommand(
    EditingDomain domain,
    EObject owner,
    EStructuralFeature feature,
    Object value,
    int index)
{
  if (feature == LibraryPackage.eINSTANCE.getMedia_Status())
    return new SetMediaStatusCommand(domain, owner, feature, value, index);
  return super.createSetCommand(domain, owner, feature, value, index);
}
```


Agenda

- Introduction to Modeling and EMF
- EMF Components
- The Ecore Metamodel
- Model Definition
- Code Generation, Regeneration and Merge
- EMF Runtime Framework
- EMF.Edit Framework
- ***Summary and Q&A***

Summary

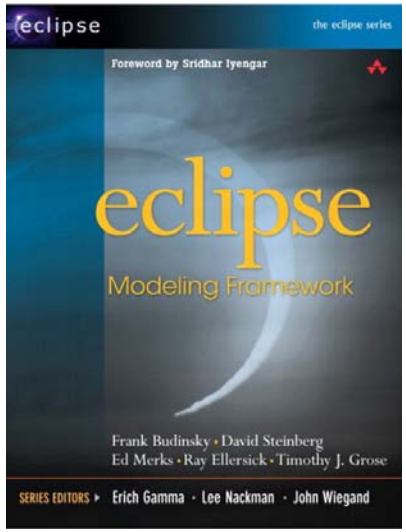
- EMF is low-cost modeling for the Java mainstream
- Leverages the intrinsic model in an application
  - No high-level modeling tool required
- Boosts productivity and facilitates integration
- Mixes modeling with programming to maximize the effectiveness of both

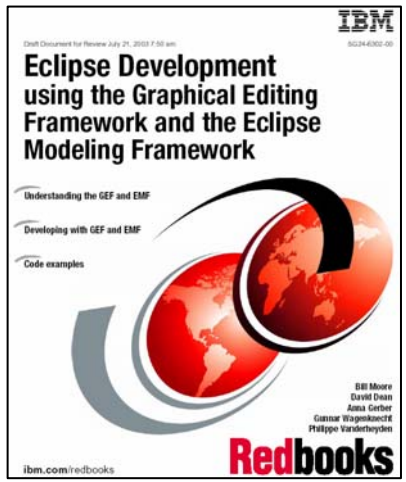
Summary (cont)

- EMF provides the following:
  - A model (Ecore) with which your models can be built
    - Model created from Rose, XML Schema, or annotated Java interfaces
  - Generated Java code
    - Efficient and straight forward
    - Code customization preserved
  - Persistence and Serialization
    - Default is XMI (XML metadata interchange) but can be overridden
    - Serialized to resources and resource sets
  - Model change notification is built in
    - Just add observers (listeners) where needed
  - Reflection and Dynamic EMF
    - Full introspection capability

For More Information

- Eclipse EMF Help
  - overviews, tutorials, API reference
- EMF Project Web Site
  - http://www.eclipse.org/emf/
  - documentation, FAQ, newsgroup, Bugzilla, EMF Corner
- *Eclipse Modeling Framework* by Frank Budinsky et al.
  - Addison-Wesley; 1st edition (August 13, 2003)
  - ISBN: 0131425420.
- IBM Redbook
  - publication number: SG24-6302-00





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