OOPSLA'06 Tutorial T38
Introduction to the Eclipse Modeling Framework

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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

*if time permits*
Using EMF to quickly generate a working graphical editor to create and manipulate instances of a UML model.
Agenda

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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)
  - 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

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

```java
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

```
PurchaseOrder
shipTo : String
billTo : String

Item
productName : String
quantity : int
price : float

0..* items
```
Model Importers Available in EMF

- **XML Schema**

```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>
```
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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  - The Ecore Metamodel
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- Summary

if time permits
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 sync 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
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The Ecore (Meta) Model

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

```
EClass
  name : String
  0..*

EAttribute
  name : String
  eAttributeType
  0..*

EReference
  name : String
  containment : boolean
  lowerBound : int
  upperBound : int
  eOpposite
  0..1

EDataType
  name : String
  eAttributeType
  1
```

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

<table>
<thead>
<tr>
<th>Ecore Data Type</th>
<th>Java Primitive Type or Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBoolean</td>
<td>boolean</td>
</tr>
<tr>
<td>EChar</td>
<td>char</td>
</tr>
<tr>
<td>EFloat</td>
<td>float</td>
</tr>
<tr>
<td>EString</td>
<td>java.lang.String</td>
</tr>
<tr>
<td>EByteArray</td>
<td>byte[ ]</td>
</tr>
<tr>
<td>EBooleanObject</td>
<td>java.lang.Boolean</td>
</tr>
<tr>
<td>EFloatObject</td>
<td>java.lang.Float</td>
</tr>
<tr>
<td>EJavaObject</td>
<td>java.lang.Object</td>
</tr>
</tbody>
</table>

- Ecore data types are serializable and custom data types are supported
Ecore Model for Purchase Orders

EClass (name="PurchaseOrder")

- EAttribute (name="shipTo")
- EAttribute (name="billTo")
- EReference (name="items")

EClass (name="Item")

- EAttribute (name="productName")
- EAttribute (name="quantity")
- EAttribute (name="price")

is represented in Ecore as

eReferenceType

...
Purchase Order Ecore XMI

- 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)

```xml
<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>
```
UML Constructs Available in Ecore

- Classes, Abstract Classes, and Interfaces
  - ClassOrInterfaceName
  - AbstractClassName
  - <<interface>> InterfaceName

- Attributes and Operations
  - ClassOrInterfaceName
  - attribute1 : type1
  - attribute2 : type2 = initval
  - <<0..*>> attribute3 : type3
  - operation1(arg1 : type1) : return1
  - operation2(arg1 : type1, arg2 : type2) : return2
UML Constructs Available in Ecore

- References (Associations)
  - One-way

```
ClassA               roleB1
                     1
                      
ClassB

ClassA               roleB2
                      0..1
                      
ClassB

ClassA               roleB3
                      0..*
                      
ClassB
```
**UML Constructs Available in Ecore**

- **References (Associations)**
  - **Bidirectional**
    
    ![Diagram](image)

- **Containment**
  
  ![Diagram](image)
UML Constructs Available in Ecore

- **Class Inheritance**

  ![Class Inheritance Diagram]

- **Enumerations and Data Types**

  ![Enumerations and Data Types Diagram]
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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

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

- Usage example

```java
order.getItems().add(item);
```
Generated Model Code

- Factory to create instances of model objects

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

- Package class provides access to metadata

```java
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

- **Edit (UI independent)**
  - Item providers
  - Item provider adapter factory

- **Editor**
  - Model Wizard
  - Editor
  - Action bar contributor
  - Advisor (RCP)

- **Tests**
  - Test cases
  - Test suite
  - Stand-alone example

- **Manifests, plug-in classes, properties, icons...**
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

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

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

```java
/**
 * <!-- begin-user-doc -->
 * <!-- end-user-doc -->
 */
public String getName()
{
    return name;
}
```
Summarizing the Code Generation Process

Model Importer → Ecore → GenModel → JET

- UML
- Java Model
- XML Schema
- ?

Java Code

Simplified version
Summarizing the Code Generation Process

Model Importer → Ecore → GenModel → JET → Generated Java Code

- UML
- Java Model
- XML Schema

Java Code

Merged Java Code

Full version
Eclipse Workspace Setup

- Download Eclipse 3.2.1, EMF 2.2.1, tutorial materials
  - http://www.eclipse.org/emf/docs/presentations/OOPSLA/
- Extract all zips into the same target folder. You will be prompted to override license files. This is normal.
- Download and install JDK or JRE (recommend 5.0)
- Launch Eclipse
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

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:

```java
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

```java
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

```java
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:

```java
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()

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

- EMF provides XMLResource implementation

```xml
<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

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

XML Example:
```
<purchaseOrder>
  <shipTo>John Doe</shipTo>
  <next>p2.xml#p2</next>
</purchaseOrder>
```
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

```java
Adapter poObserver = ...;
purchaseOrder.eAdapters().add(poObserver);
```

```java
adapter.notifyChanged()
purchaseOrder.setBillTo()
```

Diagram:
- Adapter
- PurchaseOrder
- `setBillTo()` action
- `notifyChanged()` function
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

```java
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

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

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

### PurchaseOrder Interface

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

Invariant imposed by the bidirectional reference:
```
po.getNext().getPrevious() == po
```
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

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

- Setting an attribute using generated API:

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

- Using reflective API:

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

- Efficient generated switch-based implementation of reflective methods

```java
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

```java
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
Agenda

- Demo
- Introduction
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- Exercise 1: Code Generation, Regeneration and Merge
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  if time permits

- 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)

```java
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

```java
ChangeRecorder changeRecorder = new ChangeRecorder(resourceSet);

try {
    // modifications within resource set
} catch (Exception e) {
    changeRecorder.endRecording().apply();
}
```
Exercise 3: Recording Changes
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- **Exercise 4: Validation**
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- What’s New in EMF 2.2
- Summary
Validation Framework

- Model objects validated by external EValidator

```java
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

```
PurchaseOrder
shipTo : String
billTo : String

<<inv>> validAddresses()
```
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:

  ```xml
  <xsd:annotation>
      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

  ```xml
  <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

```java
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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- What’s New in EMF 2.2
- Summary

if time permits
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

```java
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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- What’s New in EMF 2.2
- Summary
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
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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)
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