Model Refactoring in Eclipse by LTK, EWL, and EMF Refactor: A Case Study

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Abstract. Since model-driven development (MDD) has evolved to a promising trend in software development, models become the primary artifacts of the software development process. To ensure high model quality, using appropriate quality assurance techniques like model refactoring is an essential task. So far, tool support for model refactoring is limited, particularly for models using the Eclipse Modeling Framework (EMF). In this paper we present the results of a small case study that examines three solutions for a sample EMF model refactoring, namely the Language Toolkit (LTK), the Epsilon Wizard Language (EWL) and EMF Refactor, a new Eclipse plug-in for EMF model refactoring.

1 Introduction

Model-driven development (MDD) has become a promising trend in software development. Here, models are in the focus of work and represent the primary artifacts in the software development process. Considering code generation, software quality depends directly on the quality of input models. Furthermore, the Unified Modeling Language (UML) evolved to a quasi-standard to be used to develop high quality models.

To obtain high quality models, the existing model quality has to be determined regarding selective quality aspects of interest. During model evolution, an ongoing revision of the model quality is required. An obvious approach for quality assurance of UML2 models is to lift software assurance techniques to the level of models where possible. Here, well-known techniques like software metrics, code smells, and code refactorings [10] have been taken into account.

A variety of tools for quality assurance of code exist, in particular for the refactoring of Java code. For model refactoring, however, tool support is limited so far. Since the Eclipse Modeling Framework (EMF) [1] has become a key reference in the field of MDD, it is obvious to adapt tools supporting quality assurance techniques for EMF models.

In this paper, we present three approaches for specifying and applying EMF model refactorings. We specify a sample UML2 model refactoring by means of the Language Toolkit (LTK) [6] and the Epsilon Wizard Language (EWL) [4], two existing solutions to handle refactorings in Eclipse. Furthermore, the case study investigates a new EMF model refactoring tool, called EMF Refactor [2] which relies on EMF Tiger [3], a model transformation tool based on graph transformation concepts. The approaches are analyzed with respect to seven defined evaluation criteria. As a result, the different ways of specifying and executing a selected model refactoring are discussed and the benefits as well as drawbacks of each approach are pointed out. EMF Tiger is not in the focus of this study. In [15], however, EMF Tiger and a number of other graph transformation-based tools were compared with each other using a compact practical model transformation case study.

This paper is organized as follows: In Section 2, the evaluation criteria for the case study and the selected model refactoring *Change Attribute to Association End* are presented. Section 3 briefly explains how the selected refactoring is specified using the investigated approaches. Their benefits and drawbacks are discussed in Section 4. In Section 5, we summarize our contributions and discuss future work.

2 Case Study Description and Evaluation Criteria

This section introduces the sample UML2 model refactoring *Change Attribute to Association End* and specifies the evaluation criteria for the case study.

2.1 Sample Refactoring

Since UML2 class diagrams are very closely related to source code, many existing code refactorings can be directly adopted to UML2 class diagrams. However, there are few model refactorings which are specific to the model level and therefore cannot be adopted from code refactorings. The sample refactoring used in this case study is one of the latter category which changes an attribute to an association end.

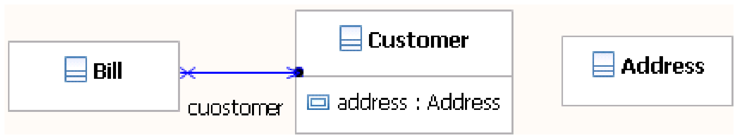


Fig. 1. Sample Class Diagram before Refactoring (excerpt)

Fig. 1 shows an excerpt of a class diagram. At a first glance, one might suppose that class *Address* is isolated from all other model elements. But if we take a closer look to the model, we identify attribute *address* in class *Customer* which is of type *Address*.

For a better understanding of class structures, it would be worthwhile to represent this relationship more explicitly. This can be achieved by applying model refactoring *Change Attribute to Association End*. After refactoring application, attribute *address* of class *Customer* will be depicted as an association end (see specification of UML2.1 [5]).

2.2 Evaluation Criteria

Each approach is investigated considering the following evaluation criteria. For each criterion questions are defined which are evaluated during the specification and execution of sample refactoring solutions.

Refactoring Specification

- **Complexity** - How complex is the effort to specify the refactoring? Are there ways to reduce this effort? Here, LoC and the number of specified rules have to be considered.
- **Correctness** - Is it possible to specify a refactoring which application results in an inconsistent model? Are there any precautions to avoid it?
- **Testability** - Which effort is needed to test the specified refactoring in detail? Are there ways to automate these tests?
- **Modularity** - Can the specified refactoring be combined with other refactorings? (This is an important aspect when defining more complex refactorings by reusing existing ones.)

Refactoring Application

- **Interaction** - How convenient is the application of a refactoring? Are there any facilities to simplify user inputs? Here, differences considering UI features have to be evaluated from a (subjective) user's point of view.
- **Features** - Does the refactoring provide a preview in order to be able to cancel or commit the refactoring? Does it provide undo and redo functionality?
- **Malfunction** - What happens if the appropriate refactoring cannot be executed in a given situation? Are there reasonable error messages?

3 Case Study Execution

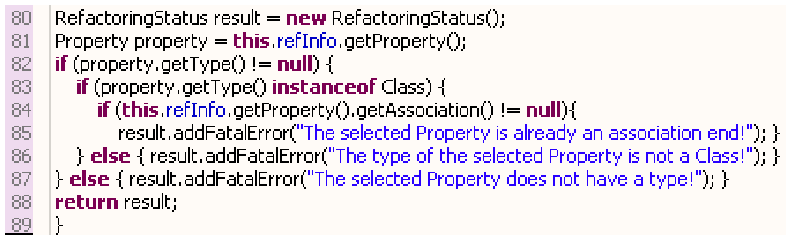
The sample model refactoring was implemented using LTK, EWL and EMF Refactor. Due to space limitations, the implementations are presented in a very compact form. The entire specifications (source code, rules, etc.) can be found on the EMF Refactor web site [2].

3.1 Refactoring Implementation using LTK

The Language Toolkit (LTK) [6] is a language neutral API to specify and execute refactorings in an Eclipse-based IDE. So it is possible to handle EMF model refactorings by LTK. The API can be found in the `org.eclipse.ltk.core.refactoring` and `org.eclipse.ltk.ui.refactoring` plug-ins. The API classes of LTK incorporate an exact, predefined procedure for refactorings in Eclipse.

For specifying the sample model refactoring, 7 classes have to be implemented. During implementation it became obvious that only 4 classes are refactoring specific (`RefactoringInfo`, `RefactoringInputWizardPage`, `RefactoringAction`, and `RefactoringProcessor`). Classes `EMFChange` and `Refactoring` are generic for EMF model refactorings. Class `RefactoringWizard` is refactoring specific only, since it initializes `RefactoringInputWizardPage`. The refactoring specific classes are:

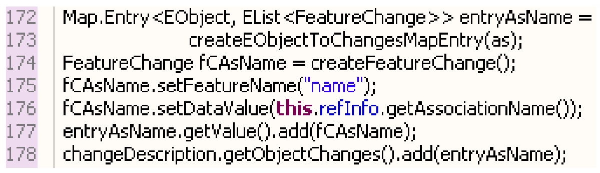
- `RefactoringInfo` - This class manages all required informations like the selected `Property` object, the name of the new association and the name of the association's *ownedEnd* property.
- `RefactoringInputWizardPage` - This class is responsible for displaying and handling the required user input (name of the new association and name of the association's *ownedEnd* property).



```
RefactoringStatus result = new RefactoringStatus();
Property property = this.refInfo.getProperty();
if (property.getType() != null) {
    if (property.getType() instanceof Class) {
        if (this.refInfo.getProperty().getAssociation() != null){
            result.addFatalError("The selected Property is already an association end!"); }
    } else { result.addFatalError("The type of the selected Property is not a Class!"); }
} else { result.addFatalError("The selected Property does not have a type!"); }
return result;
}
```

Fig. 2. LTK: method body *RefactoringProcessor.checkInitialConditions()*

- `RefactoringAction` - This class is responsible for refactoring initiation. It sets the selected `Property` and initializes instances of `RefactoringWizard`, `RefactoringProcessor`, `Refactoring`, and `RefactoringInfo`. The refactoring is initiated by invoking method `RefactoringWizardOpenOperation`[3] `::run()`. The extension point `org.eclipse.ui.popupMenus` is served by this class.



```
Map.Entry<EObject, EList<FeatureChange>> entryAsName =
            createEObjectToChangesMapEntry(as);
FeatureChange fCAsName = createFeatureChange();
fCAsName.setFeatureName("name");
fCAsName.setDataValue(this.refInfo.getAssociationName());
entryAsName.getValue().add(fCAsName);
changeDescription.getObjectChanges().add(entryAsName);
```

Fig. 3. LTK: method *createChange()* (excerpt)

- `RefactoringProcessor` - This is the main class for executing the sample refactoring. Method `checkInitialConditions()` checks whether the type of the selected `Property` is an instance of `Class` and whether it is not already part of an `Association` (see Fig. 2). The most important method of class `RefactoringProcessor` is `createChange()`. This method creates an instance of `EMFChange` by generating a `ChangeDescription`[4] that describes

[3] `org.eclipse.ltk.ui.refactoring.RefactoringWizardOpenOperation`
[4] `org.eclipse.emf.ecore.change.ChangeDescription`

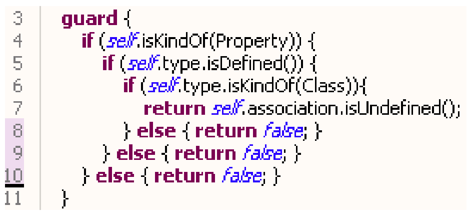
all required model changes and is also used for undo and redo functionality. Fig. 3 shows an excerpt of method `createChange()`. Here, feature *name* of the newly created `Association` is set to the appropriate String managed by the `RefactoringInfo` object.

3.2 Refactoring Implementation using EWL

The Epsilon Wizard Language (EWL) is an integral part of Epsilon [13], a platform for building consistent and interoperable task-specific languages for model management tasks. For this purpose, Epsilon consolidates common facilities in a base language, the Epsilon Object Language (EOL) [11], that new task-specific languages can reuse.

EWL is a tool-supported language for specifying and executing automated model refactorings which the authors of EWL call *update transformations in the small* [12]. These model refactorings are applied on model elements that have been explicitly selected by the user. Epsilon provides an Eclipse-based interpreter that can execute programs written in EWL.

In EWL, the sample refactoring has been implemented as follows: First, the type of the selected model element has to be checked to be a `Property` of type `Class`. Furthermore, this property does not already have to be part of an `Association`. These preconditions are checked in the `guard` section of the EWL program. Variable *self* refers to the model object which is used to invoke the refactoring and is a `Property` in this example. If the guard conditions fail, the refactoring will not be performed. Fig. 4 shows the `guard` section of the EWL solution.

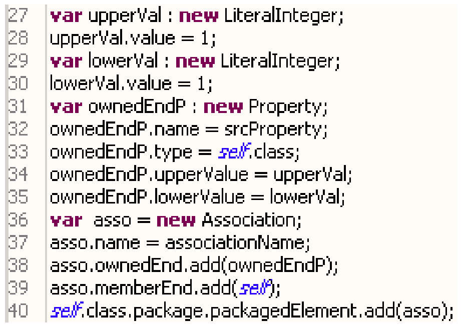


```
guard {
  if (self.isKindOf(Property)) {
    if (self.type.isDefined()) {
      if (self.type.isKindOf(Class)){
        return self.association.isUndefined();
      } else { return false; }
    } else { return false; }
  } else { return false; }
}
```

Fig. 4. EWL: guard section

The next step is to specify the label that will be provided to the user in the context menu of the selected model element. This is done in the `title` section of the EWL program.

The final and most important part of the EWL solution is the `do` section that specifies the effects of the refactoring when applied to a compatible selection of model elements (see Fig. 5). Regarding the sample refactoring we have to organize the required user input first, in particular the name of the new association and the name of the association's *ownedEnd* property.



```
var upperVal : new LiteralInteger;
upperVal.value = 1;
var lowerVal : new LiteralInteger;
lowerVal.value = 1;
var ownedEndP : new Property;
ownedEndP.name = srcProperty;
ownedEndP.type = self.class;
ownedEndP.upperValue = upperVal;
ownedEndP.lowerValue = lowerVal;
var  asso = new Association;
asso.name = associationName;
asso.ownedEnd.add(ownedEndP);
asso.memberEnd.add(self);
self.class.package.packagedElement.add(asso);
```

Fig. 5. EWL: do section (excerpt)

After obtaining the user input all necessary new objects are created and the appropriate features are set. These are in particular:

– A new `Property` with features `name`, `type`, `upperValue`, and `lowerValue` (that are set to `1` each).
– A new `Association` with features `name`, `ownedEnd`, and `memberEnd`.

Again, global variable *self* is used to get the appropriate features of the selected `Property`. Finally, the new association has to be added to the including package.

3.3 Refactoring Implementation using EMF Refactor

A new approach to specify and execute EMF model refactorings is EMF Refactor [2]. The development of new refactorings in EMF Refactor is based on EMF Tiger [3] [8], an Eclipse plug-in that performs in-place EMF model transformations [7] [14]. The model transformation concepts of EMF Tiger are based on algebraic graph transformation concepts. It provides a graphical editor for the design of transformation rules and a Java code generator which has been extended by EMF Refactor.

Model refactorings are designed by ordered sets of rules. Each rule describes an if-then statement on model changes. If the pattern specified in the left-hand side (LHS) exists, it is transformed into another pattern defined in the right-hand side (RHS). Here, several input parameters can be used to specify the LHS pattern in more detail. Additionally, several negative application conditions (NACs) can be specified which represent patterns that prevent the rule from being applied. Mappings between objects in LHS and RHS and/or between objects in LHS and NACs are used to express preservation, deletion, and creation of objects. A LHS object being mapped to a RHS object is preserved, while an object without mapping to a RHS object is deleted from the model including all its possible children. A RHS object without an original LHS object is newly created and attached to the model.

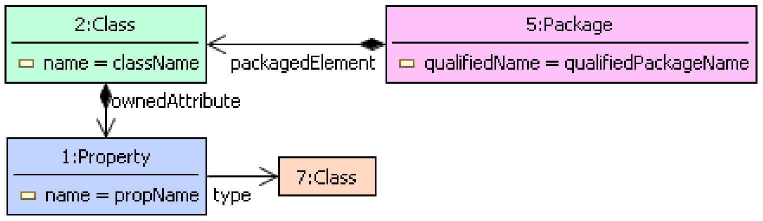


Fig. 6. EMF Refactor: LHS

To specify the sample refactoring in EMF Refactor we have to define one rule. The LHS of this rule is shown in Fig. 6. This pattern represents the abstract syntax which has to be found when starting the refactoring from within the context menu of a `Property` named *propName* whose type is a `Class`. To ensure that the selected `Property` is not already part of an `Association` an appropriate NAC is defined, that is similar to the LHS but with an additional `Association` instance that references the selected `Property` as *memberEnd* (not shown here).

Fig. 7 shows the RHS of the sample refactoring rule. It contains a new `Association` object with a new opposite association end (`Property`). This end

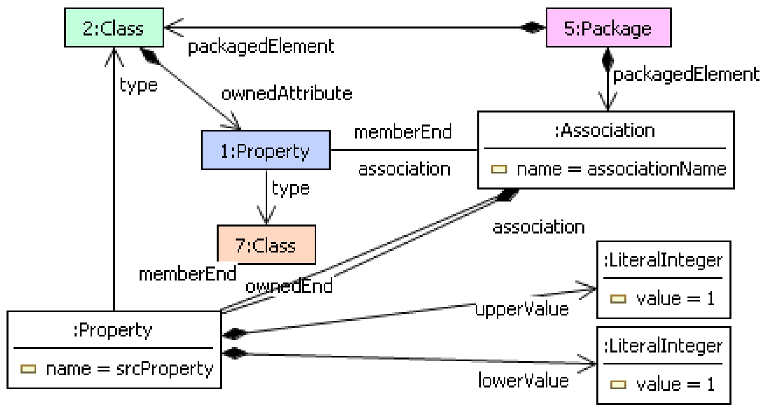


Fig. 7. EMF Refactor: RHS

is equipped with multiplicity 1 as lower and upper bound. The newly created objects are named by additional input variables *associationName* and *srcProperty*.

The rule specification ensures that the specified transformation rule is consistent. This means that the application of an appropriate EMF model transformation always leads to EMF models consistent with typing and containment constraints. To do so, you have to check whether the rules perform restricted changes of containments only. Consistent EMF model transformations behave like algebraic graph transformations. Hence, the rich theory of algebraic graph transformation can be applied to show functional behavior and correctness [9]. The sample refactoring rule is consistent, since all new object nodes (`Association`, `Property`, and two `LiteralIntegers`) are connected immediately to their according container (see Fig. 7).

After rule definition the corresponding refactoring code is generated, including a wizard for parameter specification. Here, default values for the parameters *associationName* and *srcProperty* are set.

4 Case Study Results and Evaluation

This section presents the results of the case study. First, all three solutions are compared along the criteria introduced in Section 2 and finally they are interpreted.

Complexity - All approaches require a comprehensive understanding of the UML2 meta model [5]. In *LTK*, 7 Java classes including 711 LoC were implemented. 416 LoC can be generated and 195 are refactoring specific, in particular methods `checkInitialConditions()` and `createChange()` of class `RefactoringProcessor`. Here, the most challenging task is to exactly implement the corresponding `ChangeDescription` object because of its general and complex API. In *EWL*, one single file with 47 LoC was implemented. Automatically generating generic parts would not lead to a significant reduction. Finally, in *EMF Refactor* the whole refactoring code was generated from one rule only, containing 32 objects (`EClasses` and texttttEReferences). Individual parameter settings for code generation are supported by a convenient wizard.

Correctness - In *LTK*, an incorrectly specified `ChangeDescription` object would lead to an inconsistent model after executing the refactoring. There are no known precautions available to avoid this. Since all model changes in *EWL* are directly implemented, there is also no special support to specify refactorings which yield consistent models only. *EMF Refactor* instead uses EMF Tiger that provides consistency checks regarding containment and multiplicity issues, incorporated in its visual editor. Hence, it is almost impossible to specify transformations, especially refactorings leading to inconsistent models.

Testability - A specified refactoring has to be tested by applying it to various models that represent possible situations. Since every refactoring in *LTK* is a single Eclipse plug-in, it is very time-consuming to start a new Eclipse instance after each code change. This task could be significantly facilitated by generating test code or using PDEUnit which is a test framework for Eclipse plug-ins. Since *EWL* is an interpreted language, testing is not that time-consuming, but a straightforward task. However, there is no known way to automate these tests. For *EMF Refactor* the same comments as for *LTK* hold. Here, a first approach for generating tests using JUnit is available.

Modularity - Since all model changes in *LTK* are directly implemented in Java, it seems to be possible to combine several existing refactorings to more complex ones by passing required parameters and adapting conditions, using class `Change Description`. Here, it is necessary to develop an advanced approach to support this features. In *EWL*, there is no known way to combine refactorings so far, except for copying and adapting code of existing ones. For *EMF Refactor* the same comments as for *LTK* hold. A first approach to combine so-called *basic refactorings* to more complex ones is under development.

Interaction - All approaches provide the selection of refactorings by the context menu of a `Property` element in the standard EMF instance editor. *EWL* additionally supports UML2Tools which can be supported by the others as well if a further extension point is served. The refactoring wizard page of *LTK* provides one input line for each required parameter. Each parameter has a specified default value. Using *EWL*, the context menu has an entry named specifically according to the name of the selected `Property`. All parameters are entered in separate dialogs including specified default values. For *EMF Refactor* the same comments as for *LTK* hold.

Features - After parameter editing in *LTK*, the wizard provides an optional preview of the model changes made by the refactoring. The preview is provided by EMF Compare. Undo/Redo functionality is also supported. In *EWL*, there is no preview available, but Undo/Redo functionality is supported. After parameter editing in *EMF Refactor* the wizard always shows a preview of potential model changes when executing the refactoring. Again, this is provided by EMF Compare. Undo/Redo functionality is not supported.

Malfunction - If a certain precondition in *LTK* fails, a message box including a reasonable error message is shown as specified in method `checkInitial`

`Conditions()` of class `RefactoringProcessor`. *EWL* provides the refactoring only, if all preconditions specified in the `guard` section hold. After parameter input in *EMF Refactor*, the user is informed when the refactoring can not be executed because of violated conditions. This is merely done by the generic message *The refactoring changed nothing at all.* For the considered example, each solution requires non-empty parameters, i.e. names for the new model elements `Association` and `Property`.

Goal	**LTK**	**EWL**	**EMF Refactor**
Complexity	o	+	+
Correctness	-	-	+
Testability	o	o	o
Modularity	o	-	o
Interaction	+	+	+
Features	+	o	o
Malfunction	+	+	o

Table 1. Results of the Case Study

Table 1 summarizes the results of the case study. Each approach has been evaluated and marked as follows:

– The approach meets the evaluation criterion: +
– The approach does not meet the evaluation criterion but is still moderate: **o**
– The approach does not meet the evaluation criterion at all: **-**

Each approach has its individual strengths and weaknesses. *LTK* provides permanent positive results when executing the model refactoring. This is not astonishing, because *LTK* was developed to unify refactoring processes in Eclipse. However, *EMF Refactor* seems to be more suitable for specifying EMF model refactorings. This is because of its graphical nature of defining model transformations and its underlying graph transformation concepts. Last but not least, *EWL* shows advantages in both categories, refactoring specification and application. However, in both categories there is another approach each that seems to be more suitable than *EWL*.

5 Summary and Future Work

In this paper, we present the results of a small case study that examines three options for EMF model refactoring, namely the Language Toolkit (LTK), the Epsilon Wizard Language (EWL) and EMF Refactor, a new approach in the field of EMF model refactoring. The study demonstrates that each approach has its individual strengths and weaknesses. *LTK* is the leading approach during model refactoring application, whereas *EMF Refactor* seems to be the most promising one in specifying EMF model refactorings.

It is recommended to consider the results of this case study in future work on model refactoring tools, and to extend it by specifying further refactorings. Several extensions concerning *Testability* and *Modularity* are under development, especially for *EMF Refactor*. Moreover, undo/redo functionality and the allocation of reasonable error messages have to be considered for *EMF Refactor*. As a conclusion of the presented case study, it looks worthwhile to check whether *LTK* can be combined with an EMF-related refactoring tool in a way that merges the benefits of both approaches. At least, a combination of *LTK* with *EMF Refactor* seems to be a promising way to go.

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