

Model Transformation in Web Engineering and Automated Model Driven Development

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Abstract—When dealing with the complexity of IT systems during their development as well as maintenance processes, modeling plays a very important role. The complexity and diversity of these applications emerges the need of flexibility and combining operations with existing models to create other new, more complex models. As more complex models are used, the importance of transformations between models grows. Model transformations allow the definition and implementation of operations on models and also provide a chain that can enable the automated development of a system from its corresponding models. In this context, approaches to model transformation techniques promise to bring productivity and efficiency to the whole process. This paper outlines practices from current model transformation approaches. We explain our focused research in the Web domain and introduce a novel two-way meta-model definition methodology that is best fitted to support transformation and other related operations. We introduce the approach of using hybrid transformation with ATLAS Transformation Language (ATL) to support automation of model driven development illustrating it with a use-case example. To achieve automation development we outline a formal approach to testing model transformation with automated test data generation.

Index Terms—ATL, Meta-model, Model Driven Development, Model Transformation, Web Engineering.

I. INTRODUCTION

A model is a simplified representation of an aspect of the world for a specific purpose. Nowadays, in many complex systems, a lot of aspects need to be considered from architectural to dynamic behaviors, functionalities and user interfaces. The design process can be described as the weaving of all these aspects into a detailed design model. Model-driven methods aim at automating this weaving process. Model-driven engineering (MDE) is a software development methodology, which focuses on creating models, or abstractions of something that describes the elements of a system. It is meant to increase productivity by maximizing compatibility between systems, simplifying the process of design and promoting communication between individuals and teams working on the system [3]. Models are good for several purposes as they generalize operations applied into them. A “wisely” built model can be better reused than a piece of code that is suited for a particular program. A model can be refined and reused much easier than having to do refactoring from scratch. Moreover the level of abstraction is an important factor affecting the scale

of applicability of these techniques. In such terms we speak about of models of a model, meta-models. The scale by which this logic is applied directly affects using of transformation methods and their optimization.

Model Driven Architecture (MDA) aims to separate application structure PIM (Platform Independent Model) from its functionality, PSM (Platform specific Model). The mapping between these models is realized by model transformation. The problem of model transformation based on Meta-Object Facility (MOF) can, then, be stated in the following way: “Given a source model ‘*m1*’ described by a meta-model ‘*MM1*’ we define an automatic process making it possible to obtain a model ‘*m2*’ conforming to a meta-model ‘*MM2*’; ‘*MM1*’ and ‘*MM2*’ being MOF compliant” [2]. Model transformations require specialized support in order to realize their full potential. Nowadays, there are still open issues in their foundations, semantics, structuring mechanisms that demand further research and study. Model transformations also require methodological support to integrate into existing software development practices.

In the first part of this paper we outline the classification of current model transformation approaches and give several reviews on the application of these methods. Further we introduce a methodology of applying a two-way meta-modeling approach in web engineering, which is the area of software engineering that we focus on and how it can make use of model transformation in principle. We then introduce the approach of using ATL to develop model transformation. Finally we present the approach to testing of model transformations and discuss important issues that need to be solved to achieve a good and applicable technique for testing model transformations.

II. CLASSIFICATION OF CURRENT MODEL TRANSFORMATION APPROACHES

To help making a decision of choosing the appropriate model transformation approach that is best suited for the requirements of a project, we need to have a comprehensive overview of transformation classification. This classification not only helps people in the domain of interest but also helps vendors and tool builders in identifying the advantages and weaknesses of their tools compared to others, researchers can also identify the limitation of a technology and improve current methodologies and formalisms. Based on the study of current model transformation technologies, the following sections depict the classification and overview on the previous work and methods in model transformation.

A. Graph transformation

Generally, (meta-) models are represented in UML formalism. As a result, the models can be viewed as graphs. It is therefore natural to consider the use of graph grammars to express model transformation [5]. Graph transformation approaches are very well built theoretically. Graph transformations are usually based on matching and replacement strategy. They are based on syntactic graph rules that consist of finding a Left Hand Side graph and replacing it by a Right Hand Side graph. This approach has the power of a clear operational idea, which enhances rule specification. The complexity of this approach stems from its non-determinism in scheduling and application strategy, which requires careful consideration of termination of the transformation process and the sequence of rule application [2]. Early work involving graph transformation and models largely centered on their use in defining the semantics of different modeling diagram types, such as the continuing work of Gogolla M., Ziemann P., Kuske S. [5]. More recent work by Kuster J.M., Heckel R., Engels G. [6] has defined a more general model transformation approach using graph transformation as the underlying mechanism, allowing them to draw upon some of the properties of graph transformations in a model transformation context. Heckel R., Kuster J.M., Taentzer G., [7] have continued this work, reasoning about confluence with typed attributed graphs. [8] Braun P. and Marschall F. [8] have proposed model transformation approaches which are essentially based upon simplified views of graph transformations, as is Agrawal A., Karsai G., Shi F.'s more mature GReAT system [9]. Although graph transformations have several interesting properties when applying to model transformations, it is still not used widely in practical situation due to the complexity and lack of structuring mechanisms. Solutions based on the graph transformation paradigm therefore have relatively little real-world usage [10].

B. API approach

This type of transformation is based firstly on Meta Object Facility specification. MOF is used in many modeling tools to create model repositories. After that Application Programming Interfaces (API) are generated for each supported meta-model. These interfaces are used to describe the model transformation process by means of programs written in an imperative language: Java, C++, etc. This approach provides the user with a set of interfaces used to describe the transformation process as a series of instructions that allow the generation of a target model from a corresponding source model. The use of APIs to describe a transformation process is a powerful solution because programming languages generally have good performance at runtime. Basically, the user must perform the entire procedure: he is in charge of the organization and description of all stages, explicitly in terms of imperative statements [2].

C. XSLT approach

Along with XML technology, XML Metadata Interchange (XMI) enables the exchange of meta-models as a standard. There is a need for bridging between XML processing and other form of data and a language for that purpose is in

demand. XSL stands for EXtensible Stylesheet Language and XSLT stands for XSL Transformations. As models are described in XML format, it appears that EXtensible Stylesheet Language Transformation (XSLT) is a convenient solution for model transformation. XSLT is an appropriate standard for XML document transformation, but suffers from limitations in realizing model transformation. Moreover, XSLT data types are limited; this restricts the scope of information that must be computed during the transformation process. In a DTD, the syntax and the semantics of an XML documents are fixed, and transformation rules therefore have to deal with both [2]. The main weakness of XSLT lies in the fact that it was adequate for the simple transformations but has serious shortcomings for more advanced transformations. Recently, a formal proof was constructed that XSLT is Turing complete. However it took several years before that was proven and in practical usages the limits in XSLT make it harder to conveniently apply this approach. A final issue, which makes expressing model transformations in XSLT less than ideal, is that XML documents are represented as a tree structure; models are, in the general case, naturally describable as graphs. Although graphs can be represented by trees with link references between nodes, the difference in representation can lead to an unnatural representation of many types of model transformations [10].

D. Declarative approach

In declarative approach, the relationship between concepts in the source and the target meta-model is defined by patterns. The transformation is defined by a set of rules. A rule lays forth a pattern of source model concepts, which is then transformed into a set of elements in the target model. The sequence of the various stages of the transformation process is controlled by the user, thanks to operators that allow the carrying out of explicit transformation rules invocation. The implementation is realized by an inference engine [2]. However, one of the disadvantages of this approach is the significant amount of work burden the developer with specifying all the constraints supporting the transformation.

E. Imperative approach

As similar to imperative programming, imperative approach works in the paradigm that describes the transformation in terms of statements that change the program states. Imperative approach defines a sequence of commands to perform. An example of this approach is Transformation Rule Language (TRL). This language is in essence a standard rule-based imperative language specialized for UML-esque model transformations. This comes in several forms:

- 1) Some of the information recorded in the new first class elements is used for additional purposes such as to create tracing information.
- 2) Extra syntax is provided for accessing the stereotype of a UML model element.

Rules consist of a raw signature (works as the declaration of the types of the source and target model elements) and an imperative body. In TRL, the syntax and semantics of actions are similar to that of the Object Constraint Language (OCL). Moreover, there are additional control structures and side

effects that add up to the syntax of TRL that makes it adequate for building model transformations. The benefit of such an approach is its relative familiarity to users, and the knowledge that largely imperative solutions traditionally lead to efficient implementations [10]. However language such as TRL on the other hand is only capable of expressing unidirectional stateless transformations, due to the imperative nature of rule actions.

F. Hybrid approach

In a declarative approach, a transformation is defined by a set of relations between the concepts of the source and target models, as described in their meta-models. The implementation is realized by an inference engine, which allows the application of the transformation to generate the target model. In an imperative approach, a transformation is described by a set of algorithms as functions or procedures that explicitly describe the sequence of transformation applications. Hybrid approaches combine the declarative and imperative approaches. The declarative approach is generally used in the definition and selection of the transformations which can be applied, while the imperative approach is well adapted to describing the transformation strategy by a control flow of execution rules, and hence to executing the transformation [2]. In hybrid languages, transformation rules mix the syntax and the semantics of the concepts they handle. ATLAS Transformation Language (ATL) as an example implements imperative bodies inside declarative shell to specify transformation. Hybrid approaches potentially have the advantages since they combine both values of declarative and imperative ones. The next section illustrates how ATL can be used to construct transformations.

III. A TWO-WAY META-MODELING APPROACH IN WEB ENGINEERING

On the practical side of the problem we already think of areas, where model transformation techniques can have a great impact. While the usage of World Wide Web has rapidly grown in the last decade, new technological scenarios throughout many waves of innovation and new revolutionary concepts have emerged. Especially with new trends in the Web 2.0 [11], thoughts of the community now aiming at a Web 3.0, social media strongly shifting the meaning of Web technologies and WebOS [12] becoming a strong candidate for modern devices, it is important to focus in this area and to keep up with practices that are probably far ahead in classical software but may bring new challenges for the Web engineering domain.

Methodologies and tools already implemented in the Web domain usually adopt common concepts and backgrounds [13]. In their perspective, the model to be defined is a *view* from the MDA terminology. These *views* belong usually to the conceptual, navigation or presentation models, sometimes named differently by methodology-specific notions. But logically, most of the limitations that arise apply to all of them affecting their presentation and attraction in practice. These limitations are based on platform and architectural specifications of such methods. The mentioned techniques are tightly tied to the technologies bounded with the given platform. Moreover, all methodologies from the

Web family deal with a particular set of common entities related to that kind of the Web application. This means, that they are specialized and strong for a certain set of aspects, but simultaneously weak for other, more generic purposes. Another issue worth mentioning is that most of these proposals, address the integration and interoperability issue somewhere during the implementation phase, therefore making it again specific to execution constraints and not properly aligned to the model level. Through all these limitations, transformation techniques and the modeling paradigm are quite imperfect and sometimes restricted. In practice, using domain specific concepts is preferred, therefore leading to segmentation and fragmentation which is common in the area of Web engineering today.

Our proposal to avoid these problems consists in considering building a meta-model that allows definition by refinement of its concepts from different, distinct gatherings and bases of knowledge. This is the main purpose of using meta-modeling in the first place. The meta-model itself is an abstract concept "behind the scene" as it is an artifact that needs to be translated into graphically or other work-ready entities. The important thing is that the required flexibility needs to be addressed at the high level before becoming too specific. As a result of practical and hands-on oriented manner of dealing with Web modeling in practice, we suggest a philosophy of spanning the software design phase through a two-way meta-model definition by refinement path, firstly bottom-up to gather level-specific fragments at different levels and then the classical top-down model creation and transformation. This idea is novel in the sense that it implies building partial and distinct meta-model fragments that are to be put together later in a whole, complete meta-model. This approach avoids getting stuck with the platform-specific issues, because instead of dealing with them at a high level, and therefore already becoming platform-dependent, a repository of concept blocks is used and components of the final meta-model are chosen from it. Platform-dependent knowledge is only embodied during the top-down phase.

Transformation and code generation play a crucial role in this process. Firstly, following this approach, several options appear that enable building of the adequate meta-model. For example, relevant concepts are put together into one single generic meta-model, which is to be weaved later into a final model. Another possibility is building of multiple diverse versions of the meta-model representing the same system, in order to provide artifacts for various operations, such as union, comparison and transformation. Other options can also be thought of, once solid background is laid and standard technologies are used for its realization.

On this front we have analyzed and reviewed several works that present comparisons of different UML-based MDA tools, including ready-to-use code generators, for Model-Driven Development (MDD) of Web services [14]. The aim of such efforts is to use UML, in its most standard form for Web services modeling - transform the UML models into WSDL files and generate Java code from the Web Services Description Language (WSDL). We tend to use open source or free of charge tools as much as possible. These tools together would have to provide the ability to

model Web services for WSDL, to generate WSDL and XML Schema Document (XSD) files from the model, to generate Java code from the WSDL.

IV. USING ATL FOR MODEL TRANSFORMATION

A. Hybrid approach transformation using ATL

In this section we demonstrate the hybrid approach by using ATL. For working with ATL as a transformation language, ATL Integrated Environment was used. This environment provides a number of standard development tools that aims to ease development of ATL transformations. An ATL transformation is composed of rules that define how source model elements are matched and navigated to create and initialize the elements of the target models. To understand the concepts, the architecture of model transformation could be depicted in the following figure:

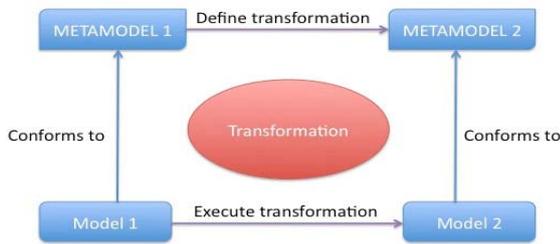


Figure 1. Architecture of model transformation

To start building ATL transformation, we use a simple use-case of meta-model transformation from a source meta-model M1 to target meta-model M2. The graphical presentation of M1 and M2 are depicted in fig. 2.

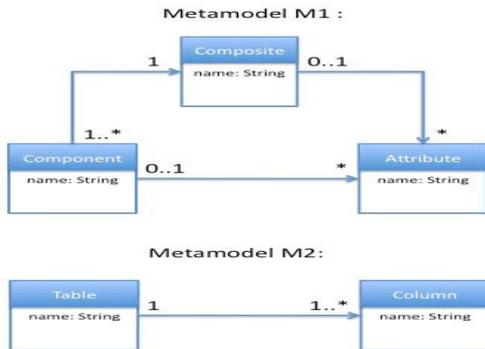


Figure 2. Meta-models M1 and M2

Our goal is to construct the transformation from an instance I1 of meta-model M1 to instance I2 of meta-model M2 given that I1 conforms to meta-model M1 and I2 must conform to meta-model M2. Before defining the transformation itself, we need to define the source and the target meta-model M1 and M2. We use KM3 or Kernel Meta Meta Model, a neutral language that is convenient to describe meta-models and to define Domain Specific Languages for this purpose. KM3 is available under the Eclipse platform and could be easily used with ATL. The next step is to build the transformation using ATL, the transformation is defined as a module:

```
module M1toM2;
```

```
create OUT: M2 from IN: M1;
```

Inside the module, we describe the transformation process. Conceptually, the transformation process could be simplified as follows:

- 1) For each instance of class Composite in the IN model, create an instance in the OUT model.
- 2) For each instance of class Attribute we create an instance of Column in the OUT model.
- 3) Name of column in the OUT model is defined as the attribute name.

The transformation is built as the set of rules and helpers. A helper is an auxiliary function that computes a result needed in a rule. A rule for transforming the name attribute from the source model to the target model for our transformation is defined in ATL as:

```
rule Attribute2Column {
  from s : M1!Attribute
  to t : M2!Column (
    name <- s.name
  )
}
```

Similar process is applied to create all the rules needed for the transformation. Once the ATL transformation is created, the result of its execution will create the OUT model. ATL combines both declarative approach and imperative approach such that the declarative part is generally used in the definition and selection of the transformations which can be applied, while the imperative approach is well adapted to describing the transformation strategy by a control flow of execution rules, and hence to executing the transformation.

B. Testing of model transformation

As an important factor for automation in the development cycle, development of model transformations should be conducted according to standard software engineering principles. Hence, transformations need to be validated by some testing methods or else developed within the software development lifecycle.

However, currently in the domain, there is still lack of adequate techniques to support model transformation testing: testing techniques for code do not immediately carry across to the model transformation context, due to the complexity of the data under consideration [13]. To build test cases for model transformation, we need to have model instances that conform to a given meta-model. These models have to satisfy the precondition of the transformation's specification and additional constraints employed to target particular aspects of the implementation's capability.

The proposed approach aims to build a process that automatically generates a set of test models that satisfy the constraints. There are several strategies that can be used to build these models. Depending on each case, we should choose the values for the properties in a particular range; decide when objects go together in one model or when a new model should be generated. There might not be one strategy that is the best in every case. The approach in general can be described in the following way:

- 1) Decompose the source meta-model into more simple

classes.

- 2) Create model parts base on simple classes decomposed in the previous step.
- 3) Generate complete test model from parts and meta-model specification.

One drawback of completely automatic generation of test model is the complication for testers in reading and comprehending the model. To reduce the difficulty when interpret the obtained models by a human tester, more interactive phase should be introduced. This helps the tester to better understand the input model and provide more precise data that is closer to the test requirements. To obtain a good and practical model transformation testing technique, we need to have a clear and well-defined specification that can verify the quality of testing data. An effective algorithm to build test models from the input meta-model also plays an important part in enhancing the quality of test.

C. Constraints in model definition and transformation

There are certain constraints to the ideas that we present and must be strictly followed. The rationale behind this is that this approach must not be 'just another approach' in Web modeling and transformation paradigms. Analyzing the reasons and based on previous works [13] the following conclusions are drawn:

- 1) Meta-model specification sets must be based on standard OMG's technologies and on extensions that conserve those standards, or that are also defined by those standards.
- 2) These specifications must enable a certain level of formal analysis of some kind, with respect to syntax, semantics, validation and other similar concepts.
- 3) The intention that can be captured by these sets of specifications does not need to be precise, but it must be processable. This means that both, the final meta-model and its fragments can be as complementary as they need to be, but they must conform to the rules of the OMG's technologies under which they are defined.
- 4) The processing operations with the meta-model and its artifacts cannot be binary value functions, in the sense that they must not be limited to in-scope technologies and platforms to work, but they can allow other manual, semi-, or fully-automated post-processing.
- 5) All the phases of processing and post-processing must be modular. They should provide interfaces of control and internal operations of the artifacts they work with.

These constraints are the basic foundation of success for this approach. Further development of this work will be based strongly on these rules and follow them strictly, in order to maintain a clear line of progress towards the wanted target and meet all the initial requirements.

V. FUTURE WORKS

Currently we are applying these methodologies in several case studies aiming at validation and evaluation of several parameters of these methodologies. Our future work will address model transformations using hybrid approach and applying it for building web applications. The results will be published in upcoming academic events. In terms of research

we are building a framework underlying the fields of Web modeling, transformation and model driven development. Concepts are also shared with other areas such as Business Process Modeling within our faculty.

VI. CONCLUSIONS

In this paper, we discussed techniques of various types of transformation from the modeling paradigm. We outlined the overview of current model transformation approaches and outlined some common weaknesses and advantages. In imperative model transformation approach, such as TRL, new elements in the target model are explicitly created this weakens the ability to propagate changes. From the authors' perfective, declarative solutions assure no duplicates are created in such a situation. This method works well for both initial transformations and for subsequent updates. Hybrid approaches combine the declarative and imperative approaches promise to bring a lot of advantages. To demonstrate this, we introduced the usage of ATL as a hybrid transformation approach to implement model transformation. We focus application of our research in the area of Web engineering where we feel that there is a great opportunity for improvement. A methodology introducing a two-way meta-model definition by refinement and applying transformation and other related operations was described together with some practical insights in this area. Key concepts are analyzed in order to provide constraints to these methodologies. The reason is to be conforming to the OMG guidelines and best practices in the area, therefore aiming for support in both academic and business domains. For supporting automated model driven development, we also discussed an approach to testing of model transformation and identified important challenges to make model transformations dependable. From practical viewpoint, presenting more interactive phase to automatic generation of test model could bring more benefits and increase effectiveness by making model more readable and easily adaptable in the future. It is far too early to decisively conclude which of many different approaches, if any, is the most promising. Therefore one of the main challenges for the community is simply to continue exploring different approaches to model transformations. The authors' future work and research will focus on building model transformation with hybrid and declarative approach. This will also include the research on approaches to testing and validation of model transformation.

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