Tool Support to Automate Transformations between CIM and PIM Levels

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Keywords: CIM, PIM, Model Transformations, SBVR, UML Diagrams, Eclipse Plug-in.

Abstract: The Model Driven Architecture is a specific variant of Model Driven Engineering that aims to separate different areas of concerns. This architecture is defined by three levels of abstraction, i.e. Computation Independent Model (CIM), Platform Independent Model (PIM) and Platform Specific Model (PSM) that defines the architecture of the generated code. The transition between these levels is realized throw Model Transformations which are the core of MDA. In this paper we will focus on the highest level of abstraction of MDA which is represented by Computation Independent Model and its transformation into the Platform Independent Model. Our approach is based primarily on OMG standards: UML diagrams (Unified Modeling Languages) and SBVR (Semantic Business Vocabulary and Business Rules). We represent the CIM level by an extension of Use Case Diagram to support Data Object elements, and SBVR standard, while after transformation the PIM level is modeled by Business Class Diagram and System Sequence Diagrams. The paper presents also the implementation of our approach which is an eclipse plug-in that allows to automatically transform models from CIM to PIM. We furthermore illustrate our approach with a case study of a car rental agency management application.

1 INTRODUCTION

To stay competitive, companies seek more and more to increase their productivity and their effectiveness. They are in permanent quest of reliable tools that will cover the most features. In this context, the OMG proposed their initiative called MDA (Model Drive Architecture), which has for objective the elaboration of sustainable models that are independent from technical details and executions platforms (JEE, PHP, .net), in order to develop more rapidly software system and generate automatically source code in the chosen platform . The MDA approach is a specific variant of Model Driven Engineering (MDE) which is an alternative approach of system information development. The concept behind this approach is to create source models in the highest level of abstraction and transform them to multiple levels until generating automatically source code. It aims to automate the process of software development which is done manually by specialists. The MDA is the most important variant of MDE, indeed it describes the architecture that ensures the main objective of MDE which is the separation of system requirements from their implementation in a specific platform.

The MDA approach is defined by several models and meta-models, that serve as the first step to model the application, and then to generate source code by successive model transformations. These models are classified into three levels of abstraction to reach the main objective of MDA which is the separation of concerns(Soley, 2000):

- CIM (Computation Independent Model): This level is used by Business Manager and Business Analysts that model the system requirements and describe the business activities to meet the business objectives.
- PIM (Platform Independent Model): This level describes the Business Logic of the system regardless of technical platform.
- PSM (Platform Specific Model): that adds to PIM the technological aspects of the target platform. It is called also the model of code.

The transition from one level to the next is realized through successive transformation rules. In this context, we limited our focus to the highest levels of abstraction: CIM and PIM levels. This paper presents

Essebaa, I. and Chantit, S.
Tool Support to Automate Transformations between CIM and PIM Levels.
DOI: 10.5220/0006388703670378
In *Proceedings of the 12th International Conference on Evaluation of Novel Approaches to Software Engineering (ENASE 2017)*, pages 367-378
ISBN: 978-989-758-250-9

our approach on how to model each level and defines transformation rules that allow the automatic generation of the PIM from the CIM. We also describe an eclipse plug-in conception that implement our approach.

This paper is organised as follow: In the second section we describe the context of our research. Section 3 presents the previous works made on this context, while section 4 presents our approach to transform the CIM to the PIM level. Then the following section (section 5) describes tools used to implement our approach. In section 6, we apply the approach on a case study to illustrate results of our transformations, and we finish by a conclusion and some future works.

2 OVERVIEW OF CONCEPTS

2.1 Model Driven Architecture

Model Driven Architecture (MDA) was published by the OMG (Object Management Group) in 2000. This standard is intended to provide a new way to design applications by separating the business logic of the company from any technical platform. Indeed, the business logic and technologies are in current changes. It is, therefore, obvious to separate the two to deal with the growing complexity of information systems and strong technological migration costs.

This separation allows the capitalization of software knowledge and the know-how of the company. At this level, the object and the component approaches did not keep their promises. It was becoming increasingly difficult to develop software based on these technologies. The use of additional processes, such as design patterns or aspect oriented programming, was necessary.

The standard MDA offers also the possibility to stop the stack of technologies that requires keeping special skills to bring together various systems. This is enabled through the passage from an interpretative approach to a transformational approach. In the interpretative approach, human has an active role in the construction of information systems while in the transformational approach, it has a simplified and reduced role thanks to the automated construction. (Miller and Mukerji, 2003)

2.2 Model Transformations

The transition from one level to another is realized by applying transformations to source elements, to generate target elements.

Model Transformation is the key of MDA approach, it aims to generate automatically the source code of the application from successive automatic transformations; CIM to PIM, PIM to PSM, then PSM to source code. Each transformation adds necessary information to generate source code, and ensures the traceability link between MDA models that guarantee the quality of software.

There are two types of model transformations; model to model transformation which is from CIM to PIM, and from PIM to PSM, the second type is model to text which is the generation of source code from PSM (PSM to Code). In this work we will focus on model to model transformation, specially between CIM and PIM.

The next section, we present different works and approaches proposed on this context.

3 RELATED WORKS

Model Transformations are considered as the main research area of the MDA approach Several works were realized in this context. However, most of them focused on the generation of the source code from PSM level which is the result of transformations from PIM level. In our research, we focused on transformations from CIM to PIM level on which few studies has been conducted. In this section we present our analysis of previous works in this context which is based on the different aspects defined by OMG for CIM and PIM levels and the logic between models.

N.Addamssiri and al. modeled in their approach (N.Addamssiri et al., 2014) CIM level by Business Process Modeling and Notation (BPMN) and then through horizontal transformations Use Case Diagram and SBVR are generated. The PIM level in this approach is represented by System Sequence Diagram which is the result of vertical transformations from CIM. We note that this approach covers all CIM aspects (Functional, Behavioral and static) while the structural aspect of PIM level was not covered as the System Sequence Diagram covers just PIM behavioral aspect. We also note that the CIM level was very detailed as recommended by OMG, while PIM level contains less details about the system. Indeed the BPMN diagram is more detailed than System Sequence Diagram.

In their paper (Kherraf et al., 2008), Kherraf and al. propose to model the CIM level by the UML Activity Diagram, which is detailed by requirements and transformed to System Components Diagram in PIM level. We note that this approach does not cover all aspects of both CIM and PIM levels. Indeed the Activity diagram covers only the behavioural aspect of CIM, while the Component Diagram covers the structural aspect of PIM.

Kriouile and al. (A.Kriouile, 2015) modelled the CIM level by two diagrams: Business Process Model Diagram and Use Case Diagram, while the PIM level is represented by Domain Class Diagram and Sequence Diagram which are generated using transformation rules between CIM and PIM levels. It is true that this method covers all the MDA aspects but we note that the defined rules to generate PIM level from CIM are not complete. For example there is no associations between classes. We have to note also that CIM level is more detailed than PIM level by the use of BPM Diagram in CIM level.

In their method (Kardo and Drozdov, 2010), Kardo and al. modelled the CIM level using Data Flow Diagram (DFD) while the PIM level was modelled using four UML diagrams: Use Case Diagram, Activity Diagram, Sequence Diagram and the domain models. This method does not cover all aspects of the CIM level as the behavioural aspect was neglected.

Wu and al. Method (Wu et al., 2007) describes how to get PIM level from CIM one, and the transformation of PIM into PSM. In this method CIM is represented by Use Case Diagram, Activity Diagram and robustness diagram, while the PIM one was represented by Sequence Diagram and Class diagram. Even if this method covers all aspects of MDA levels, the defined rules are not complete as they do not allow to generate all diagrams elements in PIM level.

In our first work we chose to model the CIM level by Use Case Diagram and Activity Diagram, and through transformation rules we generate PIM level which is represented by Business Class Diagram and System Sequence Diagram. While testing this approach, we deduce that we can not generate all diagrams elements in PIM level such as associations and their cardinality. To resolve this problem, in our second work, we used the OMG standard SBVR to express relations between elements, which is transformed into OCL constraints. Thus CIM level was represented by the Use Case Diagram, Activity Diagram, SBVR standard and OCL constraints and the mapping in this approach was realized through QVT rules which mean that transformations were not automated. We note that the use of Activity Diagram in CIM level gives more details in this level as recommended by the OMG. In the current paper we will present an amelioration of previous methods to automate transformations and to optimize the use of multiple diagrams.(Essebaa and Chantit, 2017) (Essebaa and Chantit, 2016)

In their paper, Bouseta and al.(B. BOUSETTA, 2013) describes a method to construct CIM level and transform it (semi-) automatically to PIM level. In this approach, CIM level is modeled by BPMN diagram to cover both static and behavioral aspects, and Usecase diagram to cover functional aspect. These diagrams are used to generate the PIM level which is represented by Domain Class Diagram (DCD) that define the structural aspect and System Sequence Diagram that cover the Dynamic aspect. This approach covers all CIM and PIM levels aspects previously cited but does not allow the automatic generation of PIM level from CIM. We also note that using BPMN in CIM level gives more detailed information of the system than System Sequence Diagram used in PIM level, that do not meet the standards of abstraction required by the OMG. In addition, using BPMN and Usecase diagram in the same level leads to a redundancy of information.

Furthermore, there exist several studies where authors propose just to model CIM level without defining transformation rules to get PIM level.(Sharifi and Mohsenzadeh, 2012)

The analysis that we did on previous works allows us to deduce that transformation rules proposed are not completely defined and not automatic. Based on this analysis, we conclude that previous methods may be classified into two categories: researchers that did not cover all the various aspects of CIM and PIM levels (Kardo and Drozdov, 2010),(Kherraf et al., 2008) and researchers that cover the different aspects of CIM and PIM but did not define complete transformation rules(B. BOUSETTA, 2013),(Wu et al., 2007), (A.Kriouile, 2015),(N.Addamssiri et al., 2014).

In the second part of this section, we will present previous works made on the context of transformation of SBVR to UML.

In their paper (Afreen et al., 2011), H. Afreen and al. proposed an approach to extract manually the Object-Oriented information from SBVR then to generate Class model. The paper proposes a conception of an eclipse plug-in called SBVR2UML that may generate Class model but it does not contain any description on how the link is made between these elements. We also note that this approach does not automate transformation between SBVR and UML Class Model, indeed the Oriented-Object information are generated manually. Moreover the paper defines just a conception of an eclipse plug-in called SBVR2UML. We note also that this approach does not define how to generate other diagrams such as Sequence Diagram or Activity Diagram.

A.Raj and al. present in their paper (Raj et al., 2008) an approach to transform SBVR into several UML diagrams: Class Diagram and Activity Diagram. We note that this approach describes for each generation the algorithm to follow in order to get UML Diagrams, but this generation is still limited as it does not for example define how to get parameters of Class operation. Furthermore, in order to generate Activity Diagram, the approach takes in account just if then conditions but does not explain how it will be transformed and how the diagram is generated. In this paper, authors consider the SBVR standard in the CIM level of MDA, while generated UML diagrams (Class Diagram, Activity Diagram and Sequence Diagram) represent the PIM level. We also note that the Activity Diagram contains the same information as the Sequence Diagram modeled differently and their use in the same level does not add more information.

It exists another type of approaches that focuses on modeling CIM level and its transformation to PIM level, these approaches are basically based on Topological Functionning Modeling "is a model developed by Janis Osis at Riga Technical University (RTU, former Riga Polytechnic Institute) in 1969" (J.Osis, 1969), these approaches have a Mathematical background which proved the formalism aspect used in higher level of abstraction of the MDA (Solomencevs, 2016) (Ovchinnikova and Nazaruka, 2016).

4 PROPOSED APPROACH

In this section we present our proposed approach to automate transformations between CIM and PIM levels, our approach consists on:

- Modeling system's requirements by an extended use case diagram in CIM level.
- Describing Business Vocabulary and Business Rules of the system using SBVR standard in CIM level
- Applying transformation rules implemented in an eclipse plug-in to generate automatically Business Class Diagram and System Sequence Diagrams that represent PIM level.

Figure 1 below describes this approach:

4.1 CIM Level in Our Approach

The CIM level is the most abstract level in MDA approach. This level is considered as the most important because it models system requirements, and from this model we can generate all the other levels of MDA; other models are affected if any changes is made in CIM level.

To well represent and cover all the system requirements in CIM level the OMG recommends, the CIM

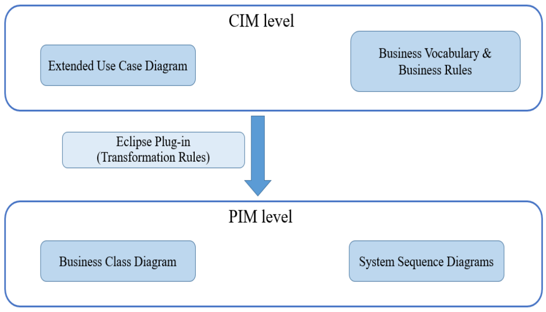


Figure 1: Overview of our proposed approach.

level should cover three aspects as defined by Kriouile and al in their paper (A.Kriuouile, 2013); Functional, Behavioral and Static, but does not present any consensus or recommendation about how the CIM level should be represented or even how many models or which of them we have to use.

In order to respect OMG recommendations and to cover all the aspect of CIM level, we propose to represent it by an extended Use Case Diagram and OMG standard SBVR.

In this paper we present an improved version of our previous proposed approaches, that express constraints using only Business Rules of SBVR standard, We minimize horizontal transformations in CIM level to get OCL constraints from SBVR we eliminate the Activity Diagram and propose to define the behavioral aspect of the system using Business rules, we optimized our approach in order to respect the abstraction required for the CIM level and also make our tool more simple to use.

4.1.1 UML use case Diagram

OMG (Object Management Group) defines a Use Case as: the specification of a set of actions performed by a system, which yields an observable result that is, typically, of value for one or more actors or other stakeholders of the system". (OMG, 2011)

The choice of using UML Use Case Diagram is due to its simplicity to express system requirements and the link between actors in the system and functionalities, Use Case Diagram is such a bridge that covers the gap between the simple user of the system and the software designer, indeed it gives a general view of the system.

A simplified version of the metamodel of the Business Use Case Diagram is represented in the figure 2:

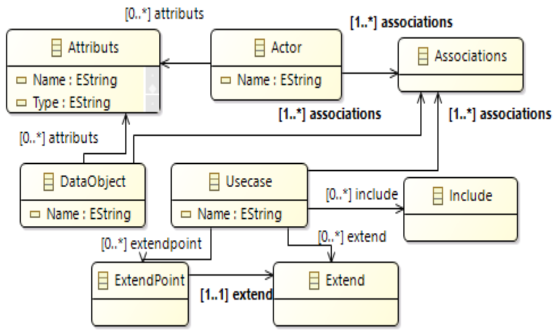


Figure 2: Main fragments of Use Case Diagram Meta-model.

4.1.2 Semantic Business Vocabulary and Business Rules

The OMG standard Business Vocabulary and Business Rules (SBVR), is a specification that was accepted by the OMG in 2005. The basic idea behind SBVR is to express the requirements in a structured language. It allows the business analyst or a business person to express system requirements using structured English instead of using its own language.(SBV, 2008) Using SBVR to express business requirements affect a semantic to business rules and business vocabulary.

SBVR is used in our approach at the CIM level to complete UML Use Case Diagram and gives more details about the system, such as Business Management Rules that describes the interaction between system elements.

A meta-model diagram of main fragments of SBVR is presented in the figure 3:

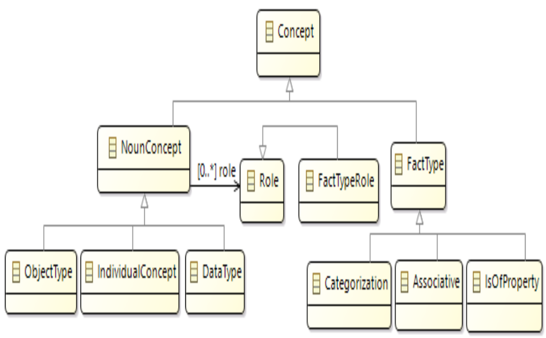


Figure 3: Main fragments of Sematic Business Vocabulary and Business rules Meta-model.

4.2 PIM Level in Our Approach

Platform Independent Model; PIM level, called also the model analysis and design describes the "What" of the system independently of any technical information about the execution platform. It defines the business logic of the system regardless of their technical details.

The PIM level must be generated automatically, through many transformation rules, from CIM level.

As many aspects are defined for CIM level, the PIM level has aspects that must be covered to well model the PIM level: Structural and Dynamic aspects (A.Kriuouile, 2013).

In our approach, we represent the structural aspect by the Business Class Diagram, while the dynamic aspect is modeled by System Sequence Diagrams.

4.2.1 "Business" Class Diagram

In UML, the class diagram is used to present the domain model. It provides an overview of the target system by describing objects and classes that exists in the business environments and describes the relationships between them.

We use Class Diagram in PIM level in order to cover the structural aspect of this level, in our approach we use a "Business" Class Diagram which is an optimised Class Diagram that describes less information than the standard Class Diagram, the use of "Business" Class Diagram in this level respects the abstraction required by the MDA approach.

The Business Class Diagram in our approach generated automatically from the CIM level by applying several transformations applied on Use Case Diagram and SBVR standard.

Figure 4 shows main fragments of UML Business Class Diagram meta-model:

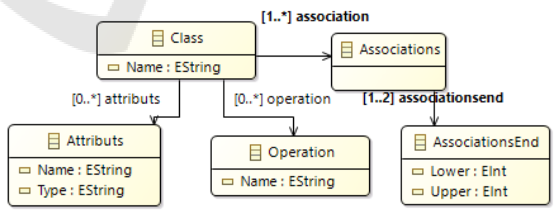


Figure 4: Main fragments of Business Class Diagram Meta-model.

4.2.2 System Sequence Diagram

The Sequence diagram is an interaction diagram that shows how objects operate with one another and in what order. It shows object interactions arranged in time sequence and depicts objects and classes involved in the scenario with the messages sequence exchanged between objects needed to carry out the functionality of the scenario.

Sequence diagrams are typically associated with use case in the Logical View of the system under development.

In our approach, we propose to use System Sequence Diagram to represent the dynamic aspect of PIM level and to respect the platform independence criteria of PIM level.

This diagram will be generated using automatic transformations from Use Case Diagram and SBVR standard that model the CIM level.

Figure 5 represents the meta-model of sequence diagram.

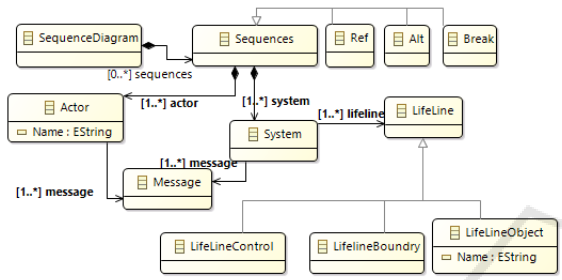


Figure 5: Main fragments of System Sequence Diagram Meta-model.

4.3 Transformation Rules

In this section, we will define different transformation rules that allow the automatic generation of PIM level from CIM level. The transformation process proposed takes as input source models, applies transformation rules, and generate target models. This process is conform to MOF (Model Object Facility) (MOF, 2009)which is an OMG standard that allow describing metamodels and their manipulation. The figure 6 illustrates the process of model transformation. A model transformation is like a function that takes as input parameters a set of models and returns in output another set of models. Those models, input and output, are structured by meta-models that specify the model transformation executed on models. There are two types of transformations:

- M2M: Model to Model transformation which is defined at the highest levels of MDA approach and aims to transform models to another models that contain more information.
- M2T: Model to Text transformation which is dedicated to the code generation. It is executed to the PSM level to generate source code.

In this paper, we will focus on the first type of transformations, Model to Model (M2M), that we divided in two main sets of transformations:

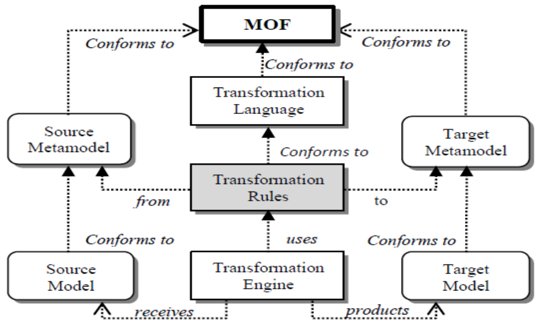


Figure 6: Relationship between the model transformation and meta-models.

- UCD&SBVR2BCD (Use Case Diagram and SBVR to Business Class Diagram): Transformations that allow the generation of Business Class Diagram from Use Case Diagram and SBVR.
- UCD&SBVR2SSD (Use Case Diagram and SBVR to System Sequence Diagram): Transformations that allow the generation of System Sequence Diagram from Use Case Diagram and SBVR. Next sections will present in details each of these sets of transformations.

4.3.1 UCD&SBVR2BCD Transformations

UCD&SBVR2BCD is a vertical transformation that aims to generate a Business Class Diagram from both a Use Case Diagram and the OMG standard SBVR. The table 1 describes these transformations:

Table 1: Transformation rules to get Business Class Diagram from UCD and SBVR.

N	Rules	Source Model	Target Model
1	Actor2Class	Actor	Class
2	DataObject2Class	DataObject	Class
3	isOfPropertyFactType2Attribute	isOfPropertyFactType	Attribute
4	associativeFactType2Association	AssociativeFactType	Association
5	structuralBusinessRule2Cardinality	StructuralBusinessRule	Cardinality
6	operativeBusinessRule2Operation	OperativeBusinessRule	Operation

Transformation rules defined in the table above can be described as follow:

- Transformations from Use Case Diagram:
  1. Actor2Class: The Actor element in Use Case Diagram is turned into a Class element in Business Class Diagram.
  2. DataObject2Class: The DataObject element in Use Case Diagram is turned into a Class element in Business Class Diagram.
- Transformations from Semantic Business Vocabulary and Business Rules:
  3. isOfPropertyFactType2Attribute:"is_property_of" fact type element is transformed to an Attribute

of a Class, this element is expressed by "is_property_of" or by "has", as described in the following figure 7.

```
customer
    Definition:  person who rents cars from agency
id_customer
    General_concept:  number
name_customer
    General_concept: text

customer has id_customer
    Synonymous_form:  id_customer is_property_of customer
customer has name_customer
    Synonymous_form: name_customer is_property_of customer
```

Figure 7: is_property_of fact type example.

4. associativeFactType2Association : the association fact type, which is expressed by verb, is turned into an association with the same verb between classes, the figure 8 describes an example of associative fact type.

```
customer owns account
    Synonymous_form: account is_owned_by customer

admin owns account
    Synonymous_form: account is_owned_by admin

admin manages account
    Synonymous_form: account is_managed_by admin
```

Figure 8: Associative fact type example.

5. structuralBusinessRule2AssociationsEnd: structural business rules formulated by a necessity or a possibility are turned into Cardinality as shown in figure 9 below:

```
It is necessary that customer owns at most 1 account.
It is necessary that admin owns at most 1 account.
It is necessary that account is_owned_by exactly one admin.
It is necessary that account is_owned_by exactly one customer.
It is necessary that manager manages at least 1 rental.
It is possible that customer books car.
```

Figure 9: Cardinality example.

6. operativeBusinessRule2Operation: operative business rules formulated by an obligation or a permission are turned into operations of the class.The name of the operation is the verb of the fact type on which the business rule is based, while parameters are generated from the two concept types linked by the verb used in the fact type, we mention that concept types in our approach are linked to Actor and DataObject elements in Usecase Diagram, as described in figure 10:

```
It is permitted that customer requests car_catalog.
It is obligatory that customer  receives car_catalog if customer requests car_catalog.
It is permitted that manager manages at least 1 rental.
It is permitted that admin manages account.
```

Figure 10: Class operation example.

4.3.2 UCD&SBVR2SSD Transformations

UCD&SBVR2SSD is a vertical transformation that aims to generate System Sequence Diagram from both Use Case Diagram and OMG standard SBVR. The table 2 describes these transformations:

Table 2: Transformation rules to get System Sequence Diagram from UCD and SBVR.

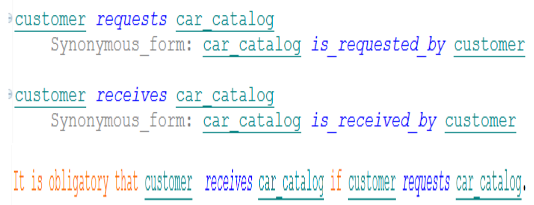
N	Rules	Source Model	Target Model
1	UseCaseDiagram2SystemLifeLine	Actor	SystemLifeLine
2	Actor2ActorLifeLine	Actor	ActorLifeLine
3	DataObject2DataObjectLifeline	DataObject	DataObjectLifeline
4	UseCase2Message	UseCase	Message
5	Extend2OptFragment	Extend	OptFragment
6	Include2RefFragment	Include	RefFragment
7	GeneralizationUseCase2AltFragment	GeneralizationUseCase	AltFragment

Transformation rules defined in the table above, allow to generate all elements of System Sequence Diagram from Use Case Diagram while links between them are extracted from SBVR standard:

1. UseCaseDiagram2SystemLifeLine: The Use Case Diagram is turned into a SystemLifeLine in the System Sequence Diagram generated.
2. Actor2ActorLifeline: The Actor element in Use Case Diagram is turned into an ActorLifeLine element in the System Sequence Diagram generated.
3. DataObject2DataObjectLifeline: The DataObject element in Use Case Diagram is turned into a DataObject Lifeline element in the System Sequence Diagram generated.
4. UseCase2Message: A UseCase element is transformed to message between elements of System Sequence Diagram. There are several types of messages, but at this stage of our approach, we need just two types; created message and reply message . The difference between them is deduced from SBVR.
5. Extend2AltFragment : An extend association between Use Case elements is transformed into an optional fragment (Opt) in the SSD generated.
6. Include2RefFragment: An include association between Use Case elements is transformed into a reference fragment (Ref to other sequence diagram) in the SSD generated.
7. GeneralizationUseCase2AltFragment: the generalization association between Use Case elements

is turned into an alternative fragment (Alt) in the SSD generated.

The synchronization between messages can be extracted from Business vocabulary and Business rules, indeed we can easily express this with conditions and different Business rules defined by SBVR and based on associative fact type in Business vocabulary; when an actor sends request to the system, the system answers according to the request previously received, the figure 11 describes ans example of interaction between an actor and the system.


customer requests car_catalog
Synonymous_form: car_catalog is_requested_by customer

customer receives car_catalog
Synonymous_form: car_catalog is_received_by customer

It is obligatory that customer receives car catalog if customer requests car catalog.

Figure 11: Example of actions synchronization using Business rules.

In the figure above we describe an example on how actions will be synchronized in sequence diagram. For example, the customer receives catalog after sending the request. In our approach we aim to generate for each Use Case element a System Sequence Diagram. For every Use Case element we define automatically elements in links with it: Actors, DataObjects, and other Use Case elements through different types of associations (extend, include, generalization) which define the interaction between different fragments of System Sequence Diagrams. Moreover we separate two types of Use Case elements: Use Case elements that define functionalities allowed for an actor, this type is linked through an association with Actor, and transformed into Sequence Diagram (System Sequence Diagram). The second type contains Use Case elements that describe how the first type of Use Case elements is realized. It defines sequence diagram that is linked to the first one according to the type of association that linked them (Include, Extend, Generalization) in Use Case Diagram as we mention before.

Usecase elements that are transformed to messages ensure the interaction between Sequence Diagram elements. There are several types of messages, but according to our approach we use the following:

- ”Synchronous Message” which is a simple message between lifeline elements.
- ”Message Create”: this type of message creates a new lifeline in the diagram, in our approach it is used to generate a DataObject which is linked with a simple association with a Usecase element.
- ”Reply Message”: this kind of message are generated to reply to previous message, it is generated from business rule that contains an if condition and is based on Associative FactType.

5 IMPLEMENTATION OF OUR APPROACH

To implement our approach we need tools that allow to create input elements (UML diagrams and SBVR). After analyzing and testing existing tools, we found that those which allow to create diagram doesnt offer an SBVR editor. The unique tool that support SBVR is an eclipse plug-in called Vetis which was implemented for an old version of Eclipse to support SBVR standard. Other components of input elements can be realized through different designer eclipse plug-in. In our case, we choose Papyrus because it supports all UML diagrams elements. According to this, we choose to implement our solution as an eclipse plug-in to benefit from the existing tools and also to facilitate the use of our implemented solution by designers and developers.

5.1 Papyrus Modeling Tool

Papyrus is an Open Source UML tool based on Eclipse. It was developed by the Laboratory of Model Driven Engineering and Embedded Systems and can be used as a standalone tool or as an Eclipse Plug-in. Papyrus is designed to be easily extensible because it is based on UML profile.(Papyrus, 2010)

In our approach we used Papyrus as an Eclipse plug-in that we extend to support DataObject elements in Use case Diagram. As papyrus is based on EMF (Eclipse Modeling Framework) tool that allows creating UML diagrams, we start by extending the EMF plug-in to define DataObject element and its specifications to be used by Use Case Diagram, and then we configure Papyrus in order to add DataObject element in Use Case Diagram, so that it can be accessible from the palette menu.

5.2 Vetis Plug-in

Vetis tool was implemented to support transformations from SBVR to UML&OCL. It was based on Eclipse platform 3.4.1 and it supports UML 2.0, and SBVR 1.0 and ATL, in our approach we use Vetis plug-in to recognise SBVR elements and their structure.(Nemuraite et al., 2010)

Using Vetis plug-in in our approach was to benefit from the editor of SBVR standard.

5.3 Our Eclipse Plug-in

Plug-in is a software component used in computing that adds a specific functionalities and features to an existing computer program. The plug-in we have developed, defines transformations rules based on QVT (Query View transformation). These rules are automatically executed from a Java program.

The plug-in takes as input a Papyrus Project that contains one or more UML Use Case Diagrams modeled using Papyrus tool and Business Vocabulary and Business Rules expressed using SBVR standard. The Transforms feature added in the menu, allow the execution of transformations defined automatically. As result of transformations an out folder is created in the Papyrus Project that contains the output generated diagrams: Business Class Diagram and System Sequence Diagrams.

The figure 12 below shows the transforms menu and the architecture of Papyrus project.

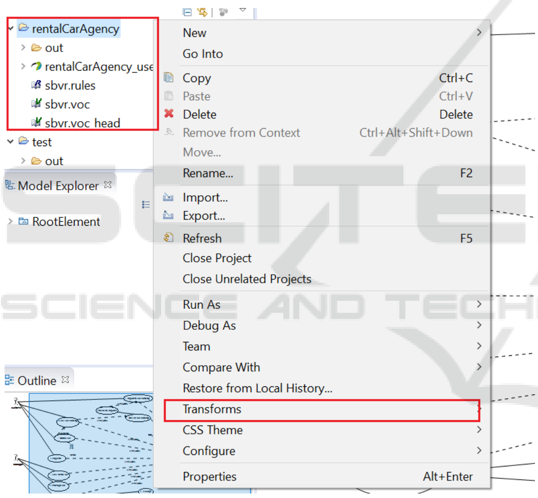


Figure 12: Papyrus project architecture and ”Transforms” menu.

6 CASE STUDY

In order to illustrate our approach and the transformation rules defined, this section shows how to apply the approach on a RentalCarAgency application. The example is described as follow: The application to realize must guarantee the following services:

- Visualization of available cars.
- Customers subscription.
- Booking of cars.
- Visualization of reservations.
- Management of reservations (accept/decline).
- Management of cars.
- Management of customer accounts.
- Management of accounts Managers.

The application have three users profiles that have different privileges :

- customer: Person who can view the cars available in the agency, rates and promotions and may subscribe. Once registered, the visitor becomes a client of the Agency. A client must authenticate in the system to search for available cars and book a car by indicating the reservation date and time.
- Manager: A Manager must also authenticate to view all cars, add, edit or remove cars and view the bookings made by customers waiting for validation to decide to accept or refuse them.
- Administrator: Once authenticated into the system, the administrator has the privilege of modifying and deleting a customer account, as well as the management of managers account (add, change or delete).

We can define some management rules as below:

- A customer can rent several cars.
- A car can be rented by or several customers.
- A manager can manage 1 or more cars.
- A car is managed by 1 or more managers.
- An administrator can manage 1 or several customer accounts.
- An administrator can manage 1 or more account managers.

After analyzing the application requirements, the user have to model those requirements in CIM level of MDA by an Extended Use Case Diagram, we present our conception of the Use Case Diagram of the application in the figure 13

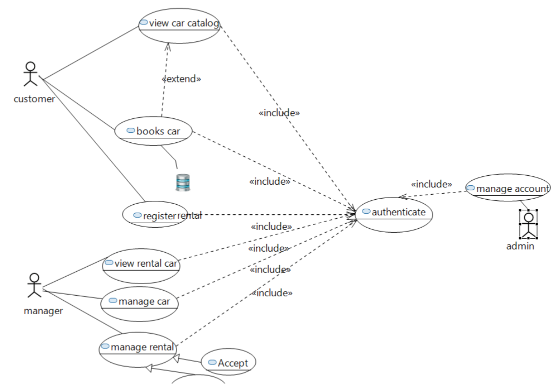


Figure 13: Papyrus project architecture and ”Transforms” menu.

In the same level of MDA; CIM designer must describes all requirements vocabulary and their corresponding transformation rules, we present in following figures 14 and 15.

```
customer
    Definition:  person who rents cars from agency
id_customer
    General_concept:  number
name_customer
    General_concept: text

customer has id_customer
    Synonymous_form:  id_customer is_property_of customer
customer has name_customer
    Synonymous_form: name_customer is_property_of customer

admin
    Definition: the administrator of the application
id_admin
    General_concept: number
name_admin
    General_concept: text

admin has id_admin
    Synonymous_form:  id_admin is_property_of admin
admin has name_admin
    Synonymous_form: name_admin is_property_of admin

manager
    Definition: person who manage rentals, cars and account
id_manager
    General_concept: number
name_manager
    General_concept: text
account
login
    General_concept: text
password
    General_concept: text
account has login
    Synonymous_form: login is_property_of account

account has password
    Synonymous_form: password is_proprty_of account

customer owns account
    Synonymous_form: account is_owned_by customer

customer manages account
    Synonymous_form: account is_managed_by customer

admin owns account
    Synonymous_form: account is_owned_by admin

admin manages account
    Synonymous_form: account is_managed_by admin

manager owns account
    Synonymous_form: account is_owned_by manager

customer requests car_catalog
    Synonymous_form: car_catalog is_requested_by customer
customer views car_catalog
    Synonymous_form: car_catalog is_viewed_by customer
customer receives car_catalog
    Synonymous_form: car_catalog is_received_by customer
```

Figure 14: Business Vocabulary of RentalCarAgency.

It is permitted that customer books at least 1 car.
It is permitted that customer requests car catalog.
It is obligatory that customer receives car catalog if customer requests car catalog.
It is possible that customer owns at most 1 account.
It is possible that admin owns at most 1 account.
It is permitted that admin manages account.
It is possible that manager owns at most 1 account.
It is necessary that manager manages rental.
It is permitted that rental contains at least 1 car.
It is permitted that manager manages rental.
It is possible that test makes account.

Figure 15: Business rules of RentalCarAgency.

The PIM level of MDA is generated automatically, this level is represented by two diagram: Class Diagram (Business Class Diagram) that represents the Structured aspect of the PIM and the several Sequence Diagrams (System Sequence Diagrams) for each UseCase element to cover the dynamic aspect of MDA.

Structured Business Rules are defined by two specific terms; Possible and Necessary, in our approach each business rule, defined as a possibility or a necessity based on a specific associative fact type, allows to generate association ends for the association generated from the associative fact type.

Executing transformation rules, we generate Business Class Diagram of the system, the figure 16 represents the result automatically generated from previous diagrams.

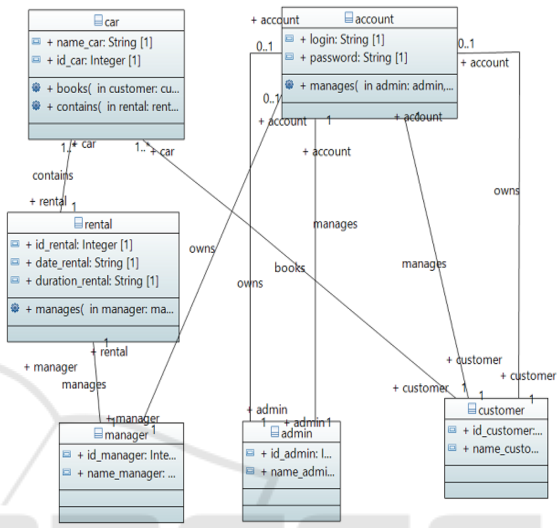


Figure 16: Generated Business Class Diagram of RentalCarAgency.

Comparing the generated Class Diagram presented in the figure 16 and the table 4 we conclude that our tool generate all the elements of class diagram (Classes, attributes,operation, association, ...).

The same execution generates also different System Sequence Diagrams for each UseCase element, as we explained before we separate two types of Usecase element, in the following we will detail some UseCase element from RentalCarAgency example, we choose ”view car catalog” to detail different concepts; extend with ”‘book car”’ and include with ”Authenticate”, we will also generate ”Authenticate” sequence diagram to clarify the interaction between actor and system, and finally we chose ”manage rental” to represent in order to show the integration of generalization association in the diagram.

Executing transformation rules, we generate different Sequence Diagram of the system, figure 17, 18, 19 represent the result automatically generated from previous diagrams of ”Authenticate”, ”View car catalog” and ”Manage rental”.

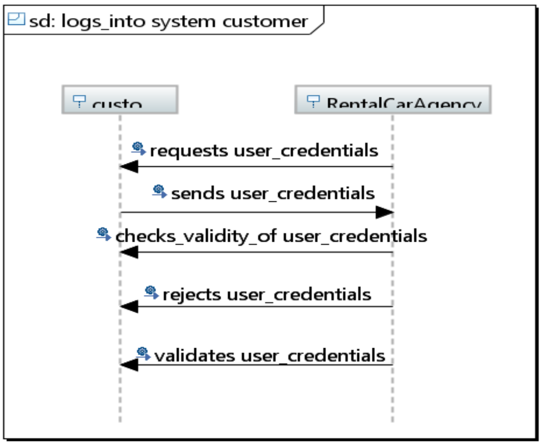


Figure 17: Generated ”Authenticate” Sequence Diagram of RentalCarAgency.

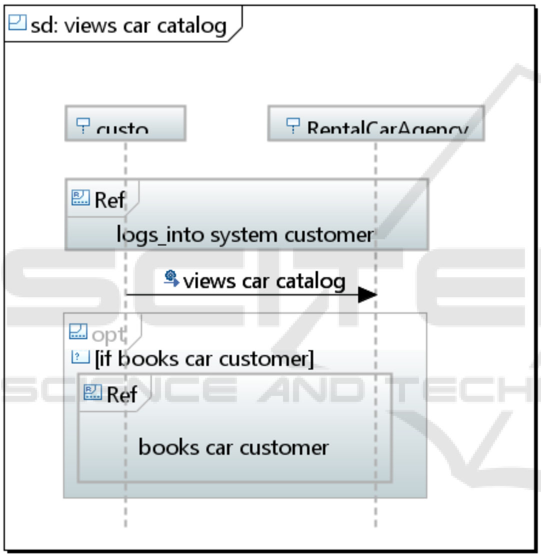


Figure 18: Generated ”View Catalog” Sequence Diagram of RentalCarAgency.

7 ANALYSIS AND DISCUSSION

To evaluate our approach we devote this section to make a comparison between results of existing approach and ours, the comparison is made according two areas; Model transformation of CIM to PIM and transformation of SBVR to UML diagrams.

For the first area; CIM to PIM transformations, the comparison is made according to proposed transformation rules, automation of transformations and their traceability. The second area, the comparison is made according to transformations rules and their automation.

We present in the Table 5 below a summary of

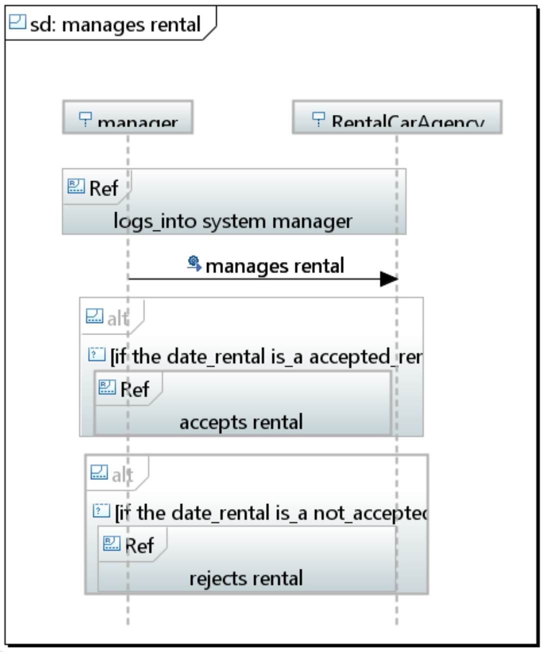


Figure 19: Generated ”Manage Rental” Sequence Diagram of RentalCarAgency.

the analysis done on our approach and the existing methods ,previously presented in related works section of this paper. For each work, we study if it covers or not all CIM level aspects (Functional, Static and Dynamic), all PIM level aspects(Structured and Dynamic), and for the transformations between CIM and PIM levels, if rules are provided (P for partially, Y for Yes and N for No) but also their automation and traceability. As shown in Table 5, even if (Kriouile and al.) and (Wu and al.) approaches cover all CIM and PIM aspects, they partially define transformations from CIM to PIM and do not provide automation neither traceability. Our approach is the unique one that besides covering CIM and PIM aspects, provide transformation rules between CIM and PIM, automate them and allow their traceability.

Table 3: Analyse and discussion of different approach of CIM to PIM transformations.

Methods	CIM level			PIM level		CIM to PIM transformations		
	Functional	Static	Dynamic	Structured	Dynamic	Rules	Automation	traceability
Addamssiri and al.	Y	Y	Y	N	Y	P	N	P
Kherraf and al.	N	N	Y	Y	N	P	N	N
Kriouile and al.	Y	Y	Y	Y	Y	P	N	N
Kardo and al.	N	N	N	Y	Y	N	N	N
Wu and al.	Y	Y	Y	Y	Y	P	N	N
Raj and al.	Y	N	Y	Y	Y	P	N	N
Bousetta and al.	Y	Y	Y	Y	Y	P	P	P
Essebaa and al. (Current Approach)	Y	Y	Y	Y	Y	Y	Y	Y

In the next Table 6, we summarize the analysis done on our approach and previously existed one that transform SBVR to UML diagrams. We study if proposed methods ensure transformation rules to generate UML form SBVR and if these rules are implemented automatically.

Table 4: Analyse and discussion of different approach of SBVR to UML transformations.

Methods	SBVR to UML transformations	
	Rules	Automation
Arfeen and al.	P	N
Raj and al.	P	N
Nemuraite and al.	P	N
Essebaa and al. (current approach)	Y	Y

As we show in the Table 6 all presented approach even if they partially define transformation rules but they didn't ensure their automation. Our approach provides transformation rules to generate two UML diagrams; Class Diagram and Sequence Diagram, and implements these rules in an eclipse plug-in to ensure their automation

8 CONCLUSION

The primary objective of this paper is to propose an approach that covers all the OMG aspects of the highest levels of abstraction in the MDA approach, CIM and PIM, and automate transformations between them. Indeed in our approach we model the CIM level by a Use Case Diagram and OMG standard SBVR. Those models cover all the aspects of CIM: functional, static and dynamic. The PIM level in our approach is generated automatically from CIM and it is represented by Class Diagram to cover the CIM structured aspect and different Sequence Diagrams to cover the dynamic aspect.

In this paper, we also present transformation rules that were implemented in an Eclipse plug-in in order to ensure the automatic generation of the PIM level from the CIM level. The proposed tool is based on Papyrus eclipse plug-in that allows the design of different UML diagrams, and Vetis plug-in that offers an SBVR editor which recognize all SBVR elements.

The present paper proposes an optimized and extended approach of our previous works and we aim in our future works to cover other MDA levels Transformations: From PIM to PSM and then from PSM to code in order to develop a tool that automate all these transformations. We also plan to apply our approach on more projects in order to evaluate the developed tool.

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