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BRIDGING A SEMANTIC GAP BETWEEEN PIM AND PSM OF TRANSFORMATION LEVELS OF AN MDA APPROACH

***Abstract**: Currently, there is no unified software development tool that could combine the semantics models of PIM and PSM models based on abstract metamodeling in the UML language with transformation operations between them. This in turn would solve the problem of mismatch between the PIM and PSM. It is known that each methodology is based on pragmatics that describes its semantics. The purpose of this paper is to try to eliminate the discrepancy between the semantic design models of PIM, which is represented as a Class diagram, and PSM, which is a State diagram, by constructing abstract metamodels and developing transformation rules between the two models. Besides, in research paper described the transformation artifact which derived from the mapping table. The paper presents scientific and research examples of the MDA approach in new concepts, the value of object theory applicable to MDA, as well as semantic aspects of design and implementation, giving pragmatic importance and building a conceptual solution based on it to obtain specific results without losing semantics.*

***Key words**: MDA, transformation, UML Statechart diagram, UML Class diagram, metamodel, metamodeling.*
***Language**: English*
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***Scopus ASCC**: 1704.*

Introduction

The research value of the presented approach in the paper consists in avoiding the semantic gap between the high-level design models. A semantic gap is a discrepancy in the logical connection of elements of one model in another, transformed based on the first.

Semantics is based on pragmatics, which in turn is a notation of the model and transformation between MDA levels. In the MDA approach, the definition of pragmatics can be given as the creation of relations between abstract and objective models based on semantics.

The MDA approach is so far the only methodology that can be used to study and solve the problem of the semantic gap in software product design. MDA was invented by OMG in 2001 and includes the standards Unified Modeling Language (UML), Meta-Object Object (MOF), XML Metadata Exchange (XMI), Enterprise Distributed Object Computing (EDOC), Software Process Metamodel (SPEM), and Common Warehouse Metamodel (CWM).

1.Model Driven Architecture

Model-driven is an approach to software development, where models are the primary sources of documentation, analysis, design, construction, deployment, and maintenance of a system.

Model-driven engineering is a software development methodology that focuses on creating and exploiting domain models, which are conceptual models of all the topics related to a specific problem.

Model Driven Architecture (or MDA) is a software development approach that focuses on creating software systems based on models. MDA's overall idea is to turn non-executable models into executable code. In this approach, the software engineering process is based on a series of models that describe the various aspects of the system's behavior, structure, and functionality. The MDA approach promotes standardization and automation, enabling developers to create high-quality software systems that are easier to maintain and modify over time. In the MDA approach, it was tacitly accepted to apply UML in the design of abstract models. An important aspect of UML is abstraction. Abstraction plays the role of a complete software implementation that provides automatic transformation execution based on transformation rules obtained from mapping between PIM-level Class UML diagram and PSM-level Statechart UML diagram metamodels. The use of this language in designing models of the MDA approach is due to the attitude to the object-oriented paradigm. The UML Class diagram has elements such as attributes and objects in its conceptual model and is therefore easy to use. Object-oriented concepts were introduced much earlier than the creation of the UML methodology. UML-based models help you understand entities in the real world and how they interact with each other.

2. Viewpoints and metamodeling

A viewpoint is an abstraction technique for focusing on a particular set of concerns within a system while suppressing all irrelevant detail. A viewpoint can be represented via one or more models.

MDA default viewpoints on a system:

The Computation Independent, Platform Independent, and Platform Specific. Figure 1 illustrates the models of MDA and the transformations between them.

The Computation Independent Model (or CIM) is a notation or high-level specifications of a system without consideration for its structure or processing. Nothing about the software systems. Describes a business system.

The Platform Independent Model (or PIM) is oriented on the operational capabilities of a system outside the context of a Specific Platform by presenting only models of a complete specification that then could be abstracted out of that platform. PIM could be transformed into one or various PSMs. It is a unique model for transformation by developing machine-readable high-level mapping functions.

The Platform Specific Model (or PSM) is based on a platform-independent viewpoint with detailed elements relating to the use of a specific platform. PSM specifies the systems in terms of the implementation solutions which normally would include all necessary constructs used in the implementation technology.

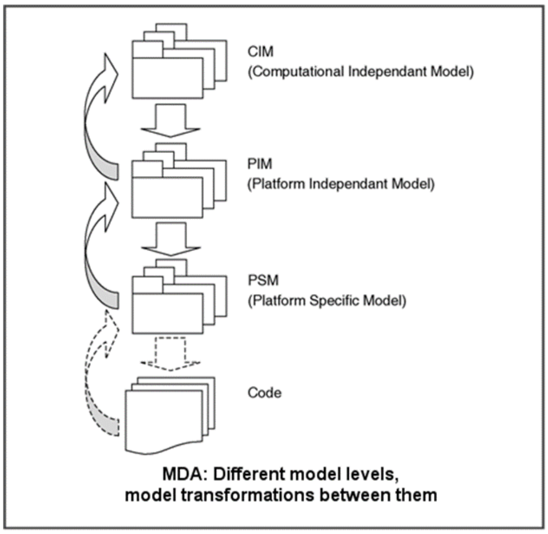

Figure 1. Models of MDA and transformations between them

Bridging the PIM and PSM models of MDA lies in transformation rules which represents how one element of PIM is mapped to another element in the PSM. Transformation rules may provide for elimination of some elements or extension of existing models by adding new elements.

Mapping rules usually performed in table interpretation. Figure 2 is an representation of written above.

Figure 2.Conceptual view of transformation between models

3.Metamodelling

Metamodelling is the basic notion that defines using a model to describe another model as an instance. The Figure below illustrates the abstractions levels of metamodelling.

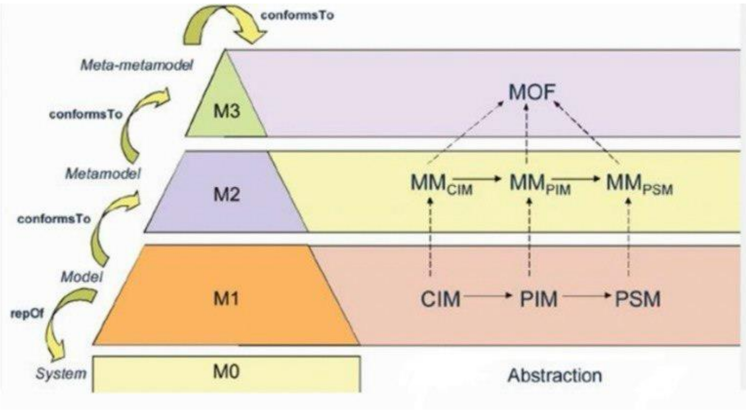

Figure 3. Abstraction models of metamodelling

M3. *Metametamodel*: One unique meta-meta-model, the Meta-Object Facility (MOF).

It is some kind of "top level ontology". MOF provides the standard modeling and interchange constructs that are used in MDA. UML is defined in terms of MOF constructs. MOF represents a common foundation for model/metamodel interoperability. The idea of MDA is to abstract and detail. Abstraction is a better way of controlling, managing, creating, and adapting to different requirements. The idea of abstraction is that a person minimally participates in the completion of the code. Abstracting helps in writing more effective transformational rules. The rules of transformation can be complicated, and this is understandable. Since it is necessary to get the code at a low level of abstraction. If the transformational rules are simple, then the person will then have to finish everything himself. The granularity is determined by the fact that the computer itself automatically performs code generation so that a person does not have to finish the code to the end. This is the importance of abstraction and detail.

M2. *Metamodel* is also a model and must be written in a well-defined language (metametamodel). It defines structure, semantics and constraints for a family of models. The M2 layer uses a UML abstract implementation of the model. since there is an unspoken agreement on the use of UML for writing M2 models. The MDA approach is subject to an object-oriented paradigm.

M1. *Model*: is an abstract representation of a part of the function, structure and/or behavior of a system. It is expressed in a well-defined language (syntax and semantics) which is suitable for automated interpretation. Each of the models is defined in the language of its unique metamodel. Example, a UML model should be defined using the constructs defined within the UML specification.

4.UML

A Unified Modeling Language (or UML) is a language for specifying, constructing, visualizing, and documenting the software system and its components. UML is a graphical language with a set of rules and semantics. The rules and semantics of a model are expressed in a form known as object constraint language.

Figure 4 illustrates the structural concept of a unified modeling language. UML is divided into two types: static and behavioral. Static diagrams include the following: Composite structure diagram, Deployment Diagram, Package diagram, Profile diagram, Object Diagram, and Component Diagram.

The behavioral analysis includes the Activity Diagram, Use Case, Statechart Diagram, Interaction Diagram, and sub diagrams.

UML diagrams are divided into static and dynamic ones. Static diagrams consist of entities that are permanently located in the system, as well as relationships between these entities. This type of diagram includes diagrams of objects, Classes, deployments, and components.

Dynamic diagrams describe the processes that occur in the system. This type of diagram includes diagrams of scenarios, activities, states, and interactions.

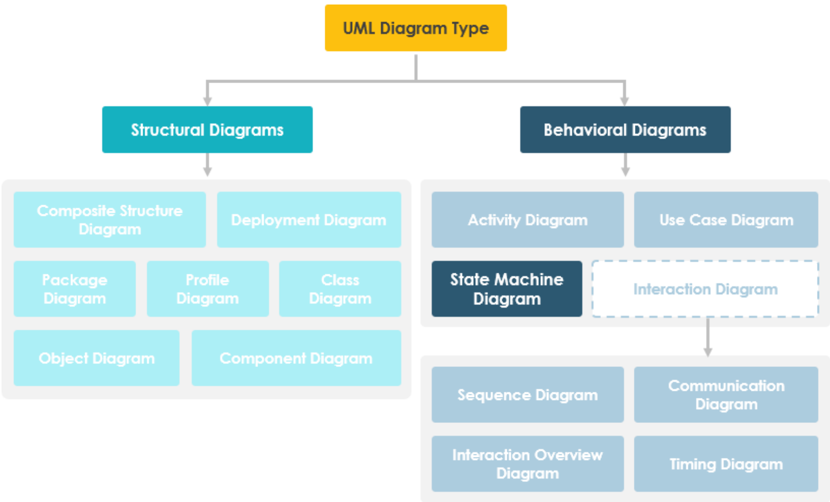

Figure 4. Conceptual view of UML

A model is an abstract of UML semantics, which is a visual representation.

4.1 Class and Statechart diagrams

In software engineering, a UML Class diagram is a type of static structure diagram that describes the structure of a system by showing the system's Classes, its attributes, and the relationships among objects. Figure 5 shows a metamodel of a UML Class diagram that illustrates the notation and semantics of elements.

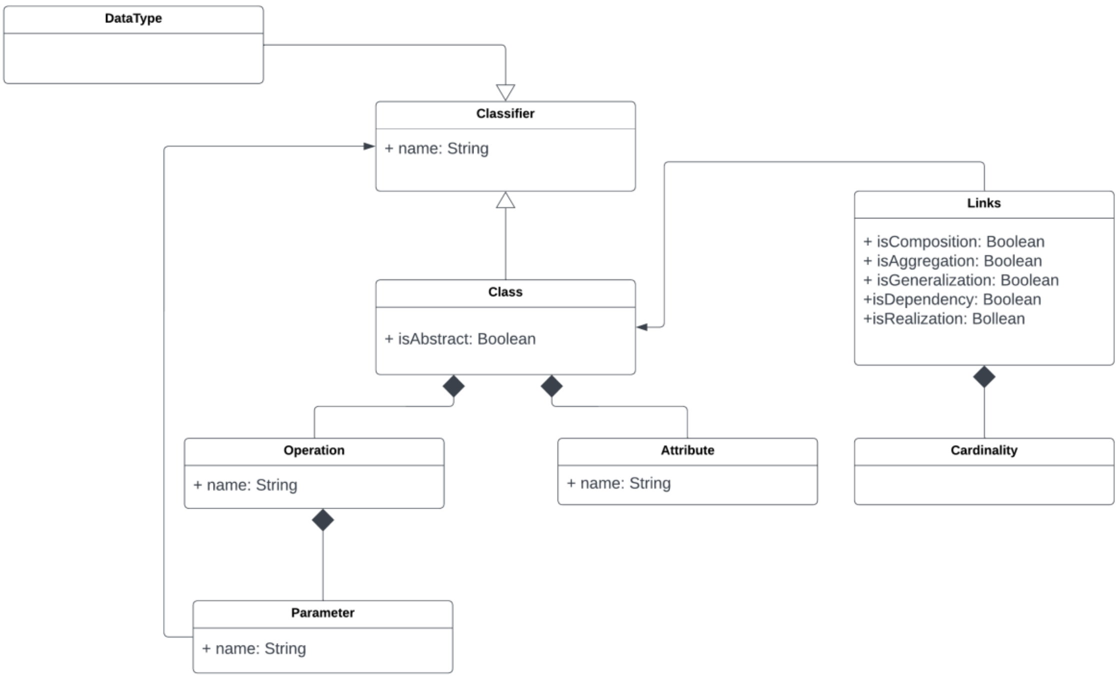

Figure 5. Metamodel of Class diagram

UML Statechart diagram is a visual construct that enables the definition of the event- and time-driven behavior of various objects (agents). Statechart diagrams are quite helpful in simulation modeling. Statechart diagrams consist of states and transitions and are dynamically structured. Figure 6 describes the UML state diagram metamodel. meta-model was taken as a basis, but it had been refined. Was added *a Participant entity* for meta-model, it was necessary to provide for the connection of the Class diagram and the Statechart diagram. This helps to eliminate to some extent the problems of the semantic gap between the PIM and PSM levels of the MDA approach.

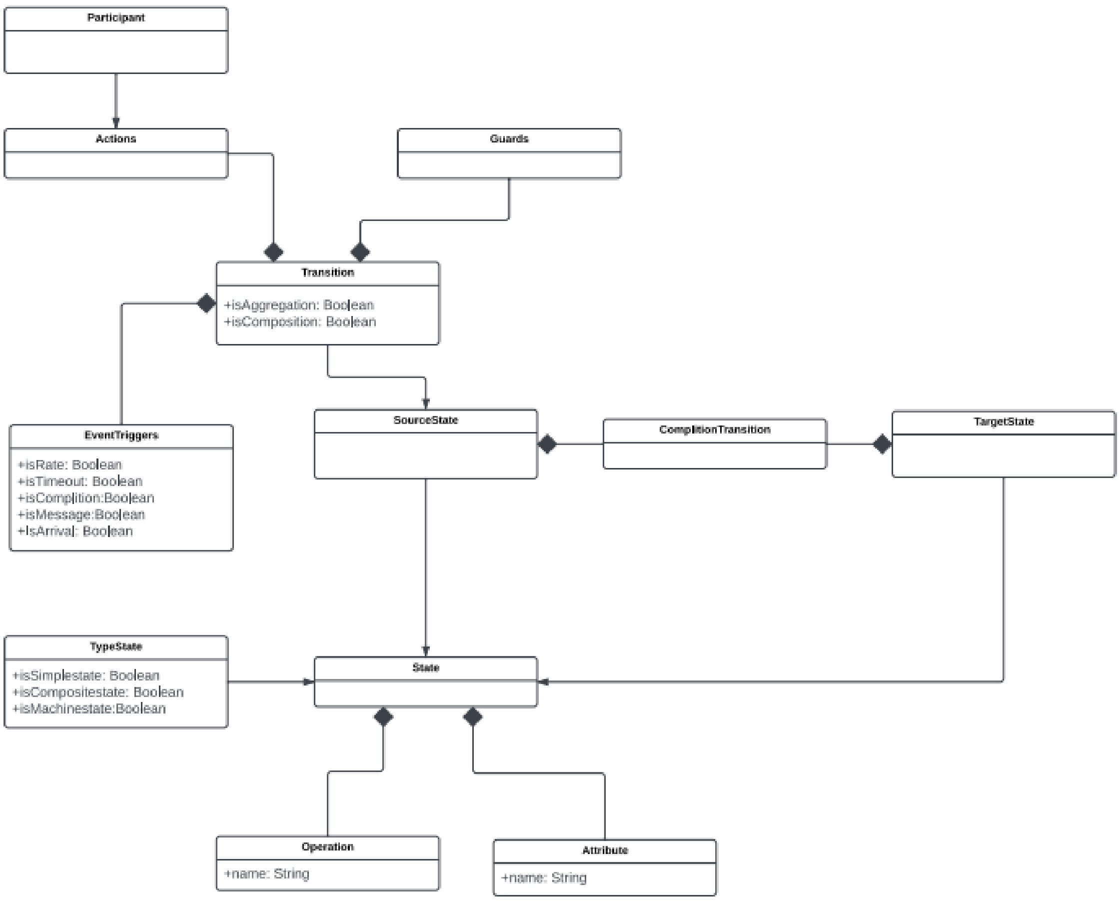

Figure 6. Metamodel of Statechart diagram

5.Object oriented theory

A collection of object-oriented theories is a set of rules. Object theory diagrams (hereinafter referred to as OTD diagrams) can be Classified either as axioms or as rules, where the OTD axiom is simply an object diagram and OCL, and a rule is defined as a collection of previous OTD object diagrams, subsequent object diagrams, and side conditions of the Object Constraint Language. From the above conditions of object-oriented theory, a pragmatic language should describe the rules that apply to UML models. In this case, the pragmatic language was conventionally designated as a transformation tool.

Pragmatic significance in the design of a software product is reflected at the levels of transformation where it is necessary to preserve the semantics, which are determined by the logic of models. In the research work, the object-oriented programming language KErmeta was chosen. Abstract Transformation program written in the Kermeta language Kermeta will perform the role of pragmatics, which will be written on the basis of transformation rules. Transformation rules are derived based on the mapping.

6.Kermeta

An object-oriented programming language that is based on a metamodel conforming to the EMOF standard. The goal of the model approach in Kermeta is to bring an additional level of abstraction on top of the "object" level, and thus see a given system as a set of concepts that form an explicitly consistent whole of the model. In Kermeta ince, EMOF concepts are used for model specification. It has a specific syntax that is well-suited for writing models and metamodels. It also uses two paradigms: object and model. The object orientation of this language consists of multiple inheritance and late binding.Mapping. Pragmatics of mapping

The semantics of domain specification should not change on transformation levels. Pragmatics of mapping. Semantic pragmatics is a comparison of two models by separating the essential part from the non-essential. Semantic pragmatics is embedded in matching, which means it is embedded in mapping, which in case embedded in transformations of levels of MDA. The role of pragmatics in the transformation between the stages of PSM to code will be performed by a translator program or tool that performs the transformation of one program written in one language into another. The translator refers not only to computer concepts but is also applicable to transformations in visual design and not only. The purpose of the translator is to transform visual interpretation into machine code understandable to the processor. Mapping is not an easy part of MDA. The semantics of domain specification should not change on transformation levels. Pragmatics of mapping. In sequential of all written above may conclude following definition which contained in the notion of matching according to software development:

Semantic pragmatics is a comparison of two models by separating the essential from the non-essential. For instance, semantic pragmatics between model programming language and the model of PSM level, which in case the transformed model of previous levels of MDA, reveals in cutting off elements do not correspond to the syntax of programming language and domain-driven design specifications.

Semantic pragmatics is embedded in matching, which means it is embedded in mapping, which in case embedded in transformations of levels of MDA.

7. Transformation rules of PIM to PSM

The mapping table illustrates matching of elements of metamodels of Class diagram and Statechart diagram

Table 1. Mapping table of elements of Class and Statechart metamodels

Class diagram elements	Statechart diagram elements
Classifier	Statemachine
Links	Transitions
Attribute	State
Operation	TriggerTransition
Class	Participant

When depicting StateMachine redefinition in a Class diagram, the default rectangle notation for Classifier can be used, with the keyword «state machine» inside the name compartment above or before the name of the StateMachine. The association between a StateMachine and its context Classifier or Behavioral Features does not have a special graphical representation. Associations between Classes in Statechart diagram interpretation are the transitions between the states. States are the attributes that define the states. Operation is triggered. As written in a section to the Statechart metamodel added the entity participant which will do the role of defining particular entities of Class diagrams for bridging the semantic gap in the transformation of diagrams.

For the correct writing of the instruction, a mapping table is used, where the elements of one diagram correspond to the elements of another. Transformation rules help define transformation methods and write instructions for transforming a model from one diagram to another. All transformation instructions must be based on the pragmatics of the meta-model, which defines the semantics, which are inferred from the mapping table. Based on the table, the following type of transformation, illustrated in picture 7, of a class diagram element into a variance state in the aggregate of state diagram elements is obtained.

The illustration below demonstrates the conceptual view of the transformation of the object of the Class diagram of the PIM level of MDA to a Statechart element of the PSM level of MDA, where the Attribute of the Class diagram translates into State entities of Statechart diagram, and methods into Triggered Transitions which awoke new states.

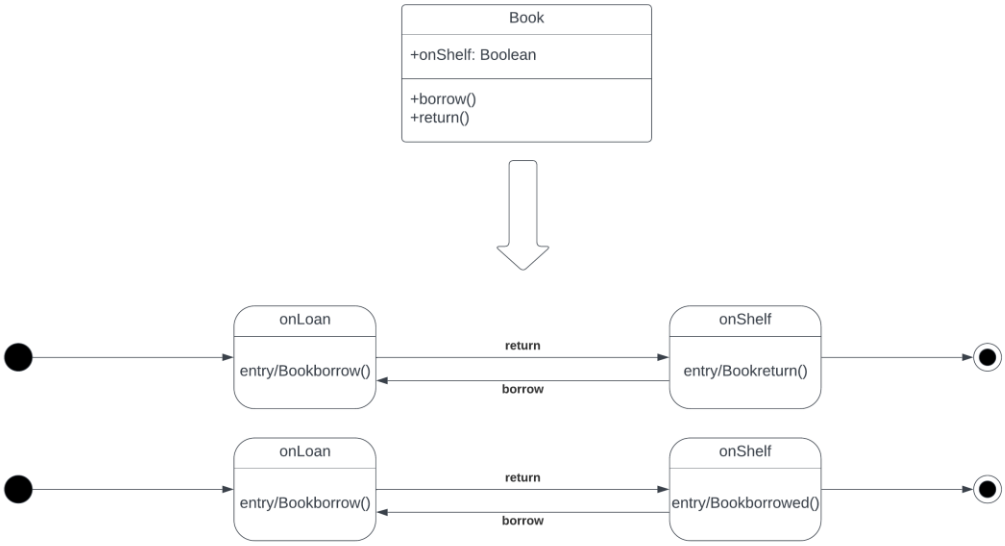

Figure 7. Transformation of UML Class diagram object into UML Statechart diagram states

Transformation rules of PIM and PSM:

For every **Class** in the UML Class diagram, there is **a Participant** in the Statechart diagram.

For every **Class Attribute** in the UML Class diagram, there is **a State** in the Statechart diagram.

For every **Class Method** in the UML Class diagram, there is **a TriggerTransition** in the Statechart diagram.

For every **Link** in the UML Class diagram, there is **a Transition** in the Statechart diagram.

Currently, these transformational rules are being implemented in the Kermeta language.

Literature review

MDA reviewed in papers [1][2][3][4]. In articles considered MDA methodology in detailed position from statement to levels transformation description.

In the paper of Peter D. Mosses el at. [5] a semantics of programming language is determined as conceptual meaning of a program. It means that semantics provides abstract version of how the application will work in real. The form and structure of semantics of any program are determined by their syntax. So, the syntax has the defining role in collecting a semantics of implementing application.

In [6], considered the solution of bridging translating problems between pseudo-code and code with using NLTK library functions. NLP is a developing sphere of information technology. Nowadays, most applications based on trained "AI", the abbreviation AI in parenthesis, because it is not complete version of human brain, it works similar and with human written algorithms. It is not existing by itself. NLP use machine learning methods and related to data science, because from the namespace, it processes the text. Data is textual and symbolic information. NLP use in automatic word detection, words translator. Tokenization and summarization are the main parts of NLP. In paper, the primary objective in research was to translate the pseudo-code to code automatically. The method to solve was using seq2seq technique. The prevented technique solves the 26% blank pseudo-code problem of SPoC dataset.

In [7], authors present an approach to automatically transform textual business rules to an SBVR model, Semantics of Business Vocabulary and Business Rule is a standard of OMG. The approach sate on NLP and SBRV model, which include semantic notations of each rule. The semantics contained as XMI file.

In paper [8], presented approach of automatic generation of code using smart contract code examples from Solidity PSM. then the generated smart contract code compile on the Ethereum blockchain JavaScript virtual machine, compare with original contract code in terms of Solidity code metrics, similarity scores and execution costs. Authors elaborate on how the Solidity PSM is used for Solidity smart contract code generation by employing model-to-text transformations.

In [9], proposed transformation from PIM to PSM as a process. Authors extend it as separating mapping specification and transformation definition. The proposed process involves a metamodel based on MOF and Ecore, a UML metamodel, a mapping and transformation language model, and a transformation engine.

The mapping model specifies a relationship between the source and target metamodel, which is an UML.

A transformation model generates from a mapping model. The transformation program implements on the base of the transformation model.

Transformation accomplishes according to the transformation engine, which executes the transformation program. Then the transformation engine on output produces the target model.

Three categories of mapping given in the article based on the concept of similar structure and semantics between the elements of metamodels. There are: one – to – one, one – to – many, many – to – one.

A one - to - one mapping is defined by one element from a target metamodel that equal to similar structure and semantics of one element from a source metamodel. A one – to – many mapping is defined by non-empty and non-unitary set of elements from a target metamodel with similar semantics to one element from a source metamodel. The last mapping is opposite definition of the one – to – many mapping.

Article [10] describe tool and approach of automatic generation code from UML Class diagram in software development, consequently. Authors in their article describe the Eclipse modeling tool in concrete and Java code generation from UML diagram file. In [11] given approach of automatically generating Java code. Authors created GenCode named tool as solution for mobile application development. GenCode is open access and generate Java code from UML only. The algorithm of GenCode tool is as follows: First, the diagram is fixed and sorted into the "structure" and "sequence" packages. The structure package contains a Class diagram, and sequence contains a sequence diagram. After that, the "models' generator" package will generate code for Android generator and CSharpgenerator for the selected one. First, the structural code is generated, then the behavioral code.

In article [13], the authors research focuses on identification of significance of Class diagram in software development. And formulated the Class diagram description.

Conclusion

The approach of automatic generation PSM from PIM and further transformation to the code representation with adhering abstraction without virtue the semantics is not much researched and not dynamically developed. Currently, there is no concept for such reasons. The important part of metamodeling is a mapping between transformation models of MDA levels. Because mapping defines the pragmatics to determine the need for a particular tool as a programming language or changes in metamodels to map elements. In this case, the metamodel of the Statechart diagram of the PSM level has changed, added the Participant entity to the Statechart UML diagram metamodel to avoid the gap between varying elements of Class diagrams, and then based on it derive the transformation rules. Pragmatics in the transformation notion of the MDA approach is the required tool for transformation. The Kermeta is an object-oriented language based on an object-oriented paradigm as a UML Class diagram. The usage of Kermeta will bridge the semantic gap between PIM and PSM of MDA. The paper concludes with reviews related to the topic papers of the research of other authors.

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