TWO APPROACHES IN SYSTEM MODELING AND THEIR ILLUSTRATIONS WITH MDA AND RM-ODP

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Abstract: We explain two approaches to the design of system modeling frameworks and perform their comparative analysis. The analysis familiarizes the reader with strengths and weaknesses of the approaches, and thus helps to grasp the preferences for their practical applications. The first of the approaches is illustrated with the example of Model Driven Architecture (MDA), and the second – with the example of Reference Model of Open Distributed Processing (RM-ODP).

1 INTRODUCTION

Constantly growing number of new system architectures and meta-data standards increases the difficulty of interoperability problems. Fortunately, the fundamental principles that are used by different system modeling frameworks are not so numerous. Understanding of ontological foundations for existing system modeling standards allows for the classification of the standards, and thus, provides system architects and ordinary modelers with the Ariadne's thread that helps to pass successfully through the labyrinth of heterogeneous system models.

Our experience shows that in many cases the aforementioned understanding of the standards' foundations remains unreachable for the ordinary modelers. Many system modeling practitioners have difficulties with mastering the relatively abstract meta-modeling principles of existing standards. This often leads to the inadequate choices of modeling frameworks, - that is to the situations where a chosen modeling framework is not designed to deal with the targeted modeling problems.

In fact, to resolve this problem there is no need to try explaining the abstract principles to all the modelers. Such kind of explanation would probably require significant efforts, and, in addition, it is not really necessary. Indeed, in most of the cases in a system modeling project there is no need to analyze the fundamental meta-modeling principles, instead there is a need to apply those principles within an appropriate context. Returning to the Ariadne's thread metaphor we may say that for an explorer of labyrinths it is not necessary to know why the thread is there and how it finds a way through a labyrinth, but it is very important to possess the thread and to know to what kind of labyrinths the thread is applicable. In the same way, for a modeler to construct an adequate model it is not necessary to know why the meta-modeling principles are there and how they assure their efficiency for modeling, but it is essential to have the principles ready to be applied and to know in which context they are applicable.

And thus it is the responsibility of systems analysts, ontological engineers and designers of system modeling standards to design consistent meta-modeling principles, to justify their efficiency for practical applications and to explain the context in which a concrete set of principles could be appropriate for an application.

This paper contributes to the definition of application contexts for two approaches existing in general system modeling. These are the approaches to design of system modeling frameworks. Through the paper the reader will become acquainted with a technical explanation of the approaches and with their comparative analysis. The analysis familiarizes the reader with strengths and weaknesses of the approaches, and thus helps to grasp the preferences for the practical applications of their subsequent system modeling frameworks.

To illustrate each of the two approaches with an example we chose two concrete system modeling frameworks that are relatively popular both in research and in practical applications of the modern system modeling community. The first of the approaches is illustrated with the example of Model Driven Architecture (MDA), and the second – with the example of Reference Model of Open Distributed Processing (RM-ODP).

Model Driven Architecture (MDA) ((DSouza 2001), (Soley 2000)) proposed by the Object Management Group (OMG) is a recently emerging vision on system modeling that targets integration of different successful industrial solutions for the system architecture.

Reference Model of Open Distributed Processing (RM-ODP) (ISO/ITU 1996) is an ISO and ITU standard presenting general framework for modeling of distributed systems.

The scope of applications of MDA and RM-ODP and their goals are similar. Particularly, MDA deals with "*full lifecycle integration and interoperability of enterprise systems comprised of software, hardware, humans, and business practices*" (DSouza 2001); and RM-ODP considers lifecycle of distributed systems from enterprise, information, computational, engineering and technology viewpoints. Both MDA and RM-ODP present ontologies for system modeling (for details see (Bezivin 1998) and (Wegmann 2001) correspondingly). However from the ontological engineering point of view, these frameworks employ two fundamentally different approaches for their respective organizations.

2 FOUR-LEVEL ONTOLOGICAL APPROACH AND ITS APPLICATION WITH MDA

As it is explained in (Bezivin 2001), the MDA ontology uses an approach of four conceptual levels. This four-level approach is presented on Figure 1. The lowest level (4L-M0) presents different subjects for modeling; each of them called as a universe of discourse. Next level (4L-M1) contains different models of each of the universes of discourse. These models belong to diverse independent domains of interest with regard to the universe of discourse that they represent. It is possible that the same kind of interest is applicable to different universes of discourse, thus models of different universes of discourse may belong to the same domain of interest. The next level (4L-M2) presents domain-specific meta-models: one meta-model for each of the domains of interest relevant for the 4L-M1 models. For a given domain of interest, its corresponding meta-model defines relations between different conceptual categories that exist in the domain models, as well as the meaning of each modeling concept. And finally, 4L-M3 level presents a meta-meta-model. The meta-meta-model should be designed to allow for definition of all the existing in the scope of modeling interest meta-models and for their unification under a common framework. Thus a meta-meta-model is domain-independent and it contains the meta-characteristics for all the domain-specific meta-models.

An application of the four-level approach is presented with MDA. In the case of MDA a 4L-M1 model is used to describe an arbitrary universe of discourse. This model belongs to a particular "*platform-specific*" domain of interest in relation to the universe of discourse. The model should use a conceptual framework that is described in its corresponding "*platform-specific model*" (PSM) (OMG 2001). PSMs are the meta-models from 4L-M2. For example, CORBA, Java/EJB, .NET and other conceptual frameworks present possible PSMs within MDA. Then, in correspondence with the 4L-M3 meta-meta-model, MDA introduces a "*platform-independent model*" (PIM) (OMG 2001) as the

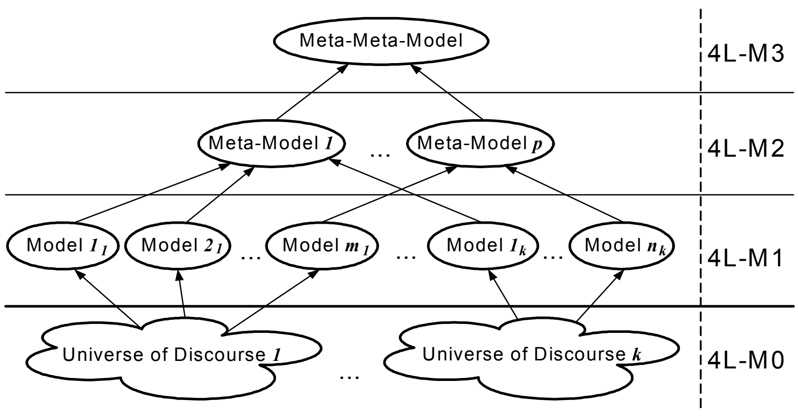

Figure 1: Four-level ontological approach (indexes k, m, n and p are natural numbers).

framework to integrate all the defined PSMs. The Meta-Object Facility (MOF) (OMG 2002) is an example of PIM supported by Object Management Group within MDA. To summarize the MDA case of the four-level ontological approach application, let us quote (OMG 2001): "*A complete MDA application consists of a definitive PIM, plus one or more PSMs and complete implementations, one on each platform that the application developer decides to support.*"

3 THREE-LEVEL ONTOLOGICAL APPROACH AND ITS APPLICATION WITH RM-ODP

Another ontological approach is based on three conceptual levels; it is applicable to the RM-ODP ontology that was introduced by the standard (ISO/ITU 1996) and explained in the standard related work (Naumenko 2001). The three-level approach is presented on Figure 2. The lowest level (3L-M0) presents different subjects for modeling; each of them called as a universe of discourse. Next level (3L-M1) contains models: one per each of the universes of discourse that are interesting for modeling. The models have a uniform structure; that is, all of them use the same modeling framework that is defined in a meta-model presented on the level 3L-M2. The meta-model defines relations between different conceptual categories existing in the 3L-M1 models as well as the meaning of each modeling concept used in the 3L-M1 models.

On the 3L-M1 level the models are disintegrated into their diverse domain-specific viewpoints. Since all the 3L-M1 models have a uniform structure, the structure of viewpoints is also the same for all of the models. That is, if a specific viewpoint can be defined as relevant for one of the 3L-M1 models, then it will be automatically relevant for all the other 3L-M1 models, because all the 3L-M1 models use the same modeling framework defined in their common 3L-M2 meta-model.

The scope of the 3L-M1 viewpoints is limited by the scope of the 3L-M1 models. The scope for a particular viewpoint from 3L-M1 is less general then the scope of a 3L-M1 model, since it is related only to a specific domain within the model. But at the same time concepts within the scope of a viewpoint are more precise than their ancestors from models, since in a specific domain it is relevant to define the corresponding specific features that are not applicable in the general context of the original models. Thus the context of a 3L-M1 viewpoint is less broad but more profound than the context of the originating model of the viewpoint. We can call the 3L-M1 models as domain-independent in relation to the domain-specific 3L-M1 viewpoints for those models.

Let's demonstrate an application of the three-level approach on example of RM-ODP. In this case a 3L-M1 model represents an arbitrary universe of discourse, and should be constructed by means of the RM-ODP basic modelling and specification concepts presented in "RM-ODP part 2: Foundations" (ISO/ITU 1996) that is a part of the RM-ODP meta-model. The RM-ODP meta-model, that is an example of 3L-M2 meta-model, contains definitions of concepts and conceptual categories from part 2 of the standard, including the definitions for: RM-ODP 2-5 ("*categorization of concepts*"),

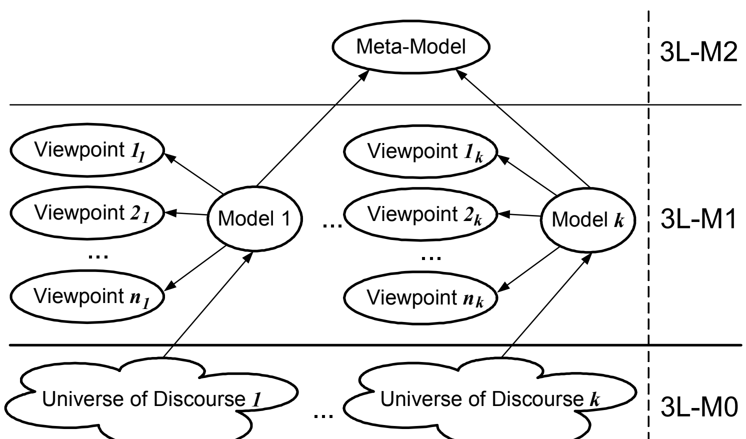

Figure 2: Three-level ontological approach (indexes k and n are natural numbers).

RM-ODP 2-6 (“*basic interpretation concepts*”), RM-ODP 2-8 (“*basic modelling concepts*”) and RM-ODP 2-9 (“*specification concepts*”). The formalized version of the RM-ODP meta-model can be found in (Naumenko 2001). The 3L-M1 viewpoints in the case of RM-ODP defined in “RM-ODP part 3: Architecture” (ISO/ITU 1996). There are five viewpoints introduced by the standard: enterprise, information, computational, engineering and technology, each of them defining its corresponding domain of interest in relation to the RM-ODP models.

4 COMPARATIVE ANALYSIS

Now, as we have introduced two ontological approaches and illustrated them on examples, we can make their comparative analysis. But before starting with the comparison we need to introduce two of the important properties of meta-modeling.

First of all, a meta-model is self-sufficient; that is, it is capable to explain all the terms and relations that are used for its own definition. Then, a meta-model is always defined for a specific domain of modeling interest, and all the domains that have no intersection with the domain of interest will be beyond the scope of the meta-model applications. So-called “domain-independent” meta-models introduce a conceptual framework that is general enough to be instantiated in any specific domain of modeling interest. But of course, the definition of a domain-independent meta-model requires a definition of the scope for all the domains considered as interesting for modeling. Thus, the domain-independent meta-model is not applicable for the irrelevant domains, which ensures its completeness with regard to its application scope.

Now we can look at the difference in the structural organization of the presented ontological approaches. Both of them have a structure of diverse modeling perspectives: the models from 4L-M1 and the viewpoints from 3L-M1. Their principal difference here is the subjects of modeling for the 3L-M1 viewpoints and for the 4L-M1 models. The models from 4L-M1 are the diverse views on the universes of discourse from 4L-M0. While 3L-M1 viewpoints do not refer to the universes of discourse from 3L-M0; instead they are the views on the 3L-M1 models that, in their turn, are the uniform representations of their universes of discourse. Each of the two choices has an advantage in comparison with the other.

In the three-level approach, a 3L-M1 model is already the result of a universe of discourse modeling. Thus, within a modeling project there will be an authority that is responsible for the content of the 3L-M1 model. This ensures determinism in the model that is, in its turn, the subject of modeling for the diverse viewpoints. Hence the 3L-M1 model determinism makes possible to establish formal correspondences across the viewpoints.

In the four-level approach the models from 4L-M1 are the direct representations of the universes of discourse from 4L-M0. A universe of discourse is just a subject for modeling; in general it is not a result of a prior modeling and thus cannot be controlled by a modeler. Hence there cannot be an authority that is responsible for the universe of discourse content, which makes it never possible to formally assert that different 4L-M1 models do model the same universe of discourse. And this is quite often the case of practical applications for the four-level ontological approach: we find often in practice the situation when the 4L-M1 models are assumed to model the same universe of discourse. Unfortunately, as we explained, in this situation there is no authority that is responsible to give the same subject as modeling input for the different models.

Thus we showed that a formal consistency across multiple 4L-M1 models is unreachable, while it is reachable across multiple 3L-M1 viewpoints due to the determinism of 3L-M1 models. Of course, this advantage of the three-level ontological approach doesn’t come for free. Flexibility is the price that this approach has to pay for the mentioned determinism.

Namely, in the three-level case 3L-M1 viewpoints always depend on the 3L-M1 models. Thus in a particular ontology the 3L-M1 viewpoints have to be concretely defined for the corresponding ontology-specific 3L-M1 models. And since the scope of any 3L-M1 model is limited, the 3L-M1 viewpoints will correspondingly have pre-defined limits. Hence it is impossible to consider any viewpoint that would go beyond these pre-defined limits. As we showed, the RM-ODP example demonstrates this with the definitions of five viewpoints within the scope of RM-ODP models. These five viewpoints are the specializations of the generic RM-ODP models; and none of these viewpoints (as well as none of the other viewpoints that could be defined within the RM-ODP framework) can go beyond the scope limits defined by the RM-ODP meta-model for the generic RM-ODP models. As we explained, the RM-ODP viewpoints can go as deep as it will be necessary in their specificity, but cannot go broader than the RM-ODP models in their scope (coverage).

The four-level approach doesn’t have this limitation. Here a 4L-M1 model may have an arbitrary scope that will be determined by its corresponding 4L-M2 meta-model. However, the 4L-M2 meta-model should be integrated within the 4L-M3 meta-meta-model. So, if the arbitrary scope from the 4L-M2 meta-model did not exist in the 4L-M3 meta-meta-model, then the meta-meta-model should be extended. Therefore, if a meta-meta-model of the four-level framework is extendable, then the scope limits for a 4L-M1 model are not pre-defined.

Thus, the four-level approach is more flexible then the three-level approach. As we can conclude from the two previous paragraphs the gain in flexibility of the four-level approach is in fact possible because here we can define additional 4L-M2 meta-models and then extend the 4L-M3 meta-meta-model. While with the three-level approach it is not possible to define additional 3L-M1 models or viewpoints, because their scopes are pre-defined in the 3L-M2 meta-model, and any domain that is out of the pre-defined scope considered to be beyond the modeling interest.

The explained flexibility even supports the potential possibility of the three-level approach integration within the frame of the four-level approach. Indeed, a 3L-M1 model could be considered as one of the 4L-M1 models, and the 3L-M2 meta-model as one of the 4L-M2 meta-models. However this integration would not be reasonable in general case, because overall objectives of both approaches are the same. And both approaches succeed to achieve the objectives with the similar degrees of success. Particularly the 3L-M2 meta-model and the 4L-M3 meta-meta-model have similar degrees of generalities of their scopes, as well as diverse 3L-M1 viewpoints and diverse 4L-M1 models have similar levels of specificities. Thus, in general case it is not reasonable to consider one of the approaches as a subordinate part of another.

5 CONCLUSION

We presented two ontological approaches and illustrated their applications on the examples of two ontologies that exist in modern system modeling: MDA and RM-ODP. Also we presented a comparative analysis of the approaches that allows for comprehension of their particularities and hence helps to understand the concrete application contexts of different system modeling frameworks and to select an appropriate framework for a concrete practical situation.

We explained that in the general case a modeling framework employing the 3-level ontological approach (like RM-ODP) should not be integrated as a subordinate part into a modeling framework employing the 4-level approach (like MDA).

In addition our analysis demonstrated that in system modeling a concreteness of viewpoints definitions allows for a gain in consistency of the represented system architecture but at the same time brings a lack of the architecture flexibility.

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