Semantic-based Modeling for Information Systems using the SeMFIS Platform

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Abstract: In this paper an outline of semantic-based modeling and the approach of SeMFIS is given. At its core, semantic-based modeling characterizes the annotation of semi-formal conceptual models with concepts from formal semantic schemata such as ontologies. Semantic-based modeling is used for the design and analysis of information systems where it supports the extension of the semantic representation and analysis scope of existing modeling methods. The approach has been previously used for applications in semantic business process management, for benchmarking, semantic-based simulation and several others. With the ADOxx-based SeMFIS platform, which constitutes a flexible engineering platform for realizing semantic annotations of conceptual models, a technical implementation is provided. The SeMFIS platform is offered for free via the Open Models Initiative Laboratory.

Keywords: Conceptual Modeling, Semantic Annotation, Ontology, SeMFIS

1 Introduction

In the area of information systems, modeling methods are today a standard approach for representing and analyzing knowledge and data, for designing and implementing systems, and for interacting with systems at run-time [FJ16, Ka08, BBF09]. For these purposes it can be reverted to a large number of existing modeling methods. Or, if no adequate method is available, new methods can be realized that address domain-specific requirements. Although the implementation of new modeling methods has been considerably simplified with the availability of powerful meta modeling platforms such as ADOxx, Eclipse or MetaEdit, creating new methods from scratch still involves a lot of effort. In addition, once a modeling method has been successfully established in an organization, the wide usage of a method hampers its modification. For example, when thousands of models have been created using a particular modeling language – as it is today the case in large organizations [Ro06] – changes in the modeling language can require considerable adaptation efforts and may lead to unexpected side effects, e.g. regarding the interoperability with runtime systems. Furthermore, regulations may restrict modifications of a modeling method, e.g. as enforced by the Swiss modeling conventions for public administration[2].

Nevertheless, the representation and analysis scope of modeling methods often needs to be adapted for meeting emerging requirements. This can either result from changes in the

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[2] See the Guideline eCH-0158: `http://www.ech.ch/vechweb/page?p=dossier&documentNumber=eCH-0158&documentVersion=1.1`

business environment, e.g. due to new legal requirements [Fi07], or also from changes in the technological environment, e.g. with upcoming new technologies such as the internet-of-things [Hu14]. It thus seems desirable to decouple changes in a modeling method from the model instances. In traditional approaches such changes can however not be easily accomplished as the modeling language is strictly tied to its corresponding model instances.

The approach of semantic-based modeling offers a concept for resolving this coupling. In the remainder of this paper we will therefore briefly introduce the concept of semantic-based modeling and its realization in the SeMFIS approach and technical platform in section 2. For illustrating the practical usage of SeMFIS previous applications will be outlined in section 3. The paper will be concluded with an outlook on future developments of the approach in section 4.

2 Semantic-Based Modeling with SeMFIS

For illustrating in detail the approach of semantic-based modeling, the traditional way of extending the scope of a modeling language needs to be described at first. The fundamental relationships of the effects of changing a modeling language are depicted in figure 1.

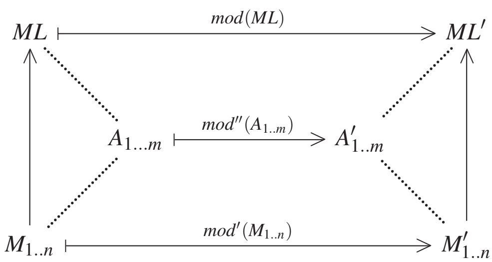

Figure 1: Effects Resulting from Changes in a Modeling Language

We start with the assumption that a number of models $M_{1..n}$ corresponds to a modeling language *ML*. For brevity we do not make the detailed relationships between modeling languages and models explicit but refer the interested reader to formal specifications e.g. in [FRK12, HR00]. In addition, a number of algorithms $A_{1..m}$ exist that refer to the modeling language *ML* and the models $M_{1..n}$. The exact nature of these references is intentionally left open as algorithms may have very distinct ways of interacting with the specifications given by the modeling language and the content of models. They encompass for example analysis algorithms for querying model content, process simulation algorithms targeting the behavior of process-like structures or also code generation algorithms.

In case that the modeling language is generally applicable to a problem domain but does not meet some specific requirements for representing information, a modification $mod(ML)$ is applied which results in a new variant of the modeling language ML'. The modification may include the addition, deletion or modification of elements, attributes and relations of the modeling language. Upon these changes, also the models have to be adapted as expressed by the transition $mod'(M_{1..n})$. Depending on the changes of the modeling language, this may lead to extensions, reductions or modifications of the content of models.

In any case, the resulting models $M'_{1..n}$ have to correspond again to the new variant of the modeling language ML'. At the same time the algorithms need to be adapted. This is expressed by the transition $mod''(A'_{1..m})$. Again, the new variants of the algorithms $A'_{1..m}$ have to refer to ML' and the corresponding models $M'_{1..n}$. From these relationships it follows that changes in the modeling language potentially trigger a large number of changes both in the existing models as well as in the algorithms. It thus needs to be checked at least for each of the n models and each of the m algorithms whether they need to be modified.

2.1 Concept of Semantic-Based Modeling

As an alternative solution, the concept of semantic-based modeling can be applied which uses ontologies for representing new information [FB09]. The combination of conceptual models and ontologies has been discussed in several contexts. The most prominent ones are the area of *semantic business process management* where ontologies have been used primarily to permit the processing of natural language information contained in models and thus support the analysis and execution of processes [TF07, Ho07, He05]. Another direction is found in the context of *semantic lifting* where models are translated into ontologies to enable interoperability [Ka06].

The approach of *semantic-based modeling* presents a third direction. It originated from the goal of meeting three challenges: a. the ex-post representation of new requirements in conceptual models without changing the original modeling language, b. to make knowledge explicit that is implicitly covered in models, and c. to process this explicit, ex-post represented knowledge using algorithms. Semantic-based modeling can be compared to a special variant of what is called *model weaving*, i.e. the linkage between different types of models [De05, DDFV07]. In contrast to model weaving semantic-based modeling however does not aim for the transformation between the linked models but uses the linked models as meta-data for representing additional requirements.

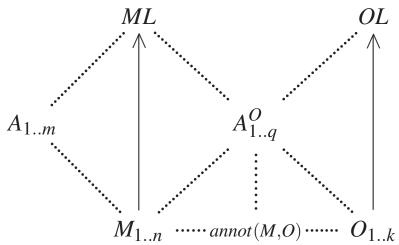

Figure 2: Concept of Semantic-Based Modeling for Representing Information via Annotations

The core idea of the approach is depicted in figure 2. On the left-hand side again the modeling language, models, and algorithms are shown. For adding new representation and analysis concepts to the existing models, semantic-based modeling does not modify the existing modeling language *ML*. Rather, a second representation pillar is added in the form of an ontology language *OL* and corresponding ontologies $O_{1..k}$. Ontologies are thereby used in their generic sense as formal, i.e. computational, forms of shareable terminologies [Ne91]. They can thus be used for making additional knowledge aspects explicit that can be understood by algorithms and humans alike.

The ontologies are then linked to the conceptual models via annotations $annot(M,O)$. Annotations are a form of meta-data in the sense of a markup that adds additional information to existing data. In the context of semantic-based modeling, annotations add information from ontologies to conceptual models. Therefore, they do not require a modification of the original modeling language but rather act as an additional layer of information on top of existing model content. Based on the annotations, the ontology language, and the ontology instances new algorithms $A^{O}_{1..q}$ can be designed that process the information in models in new ways. At the same time the existing algorithms $A_{1..m}$ are not affected.

2.2 Conceptual Realization in SeMFIS

The approach of SeMFIS (Semantic-based Modeling Framework for Information Systems) is based on the concept of semantic-based modeling. A particular feature of SeMFIS is the provision of a separate semantic annotation model type – see the meta model in figure 3. Through this model type, the annotation of conceptual models with ontology concepts can be established without modifications in the conceptual modeling language [Fi11a]. This is achieved via *model reference* and *connector reference* objects that are linked to *ontology references*. The linkage between model and ontology references can also be semantically specified via *annotator* objects.

On the ontology side, the SeMFIS approach currently provides three ontology languages in the form of model types: the *term model type* for representing controlled vocabularies, the *frames ontology model type* for representing ontologies in the OKBC frames format as implemented in Protégé, and the *OWL ontology model type* for representing ontologies in OWL format.

2.3 Technical Implementation: The SeMFIS Platform

The SeMFIS approach has been technically implemented and is provided free of charge via the Open Models Initiative [Fi16, Fi12b][3]. The SeMFIS platform is based on the ADOxx metamodeling platform [FK13]. ADOxx is an industry-scale platform that offers generic mechanisms for automatically generating model editors from meta model specifications as well as a wide range of additional components and functionalities for interacting with models.

[3] See the SeMFIS website on OMiLAB: http://www.semfis-platform.org or http://www.omilab.org/web/semfis

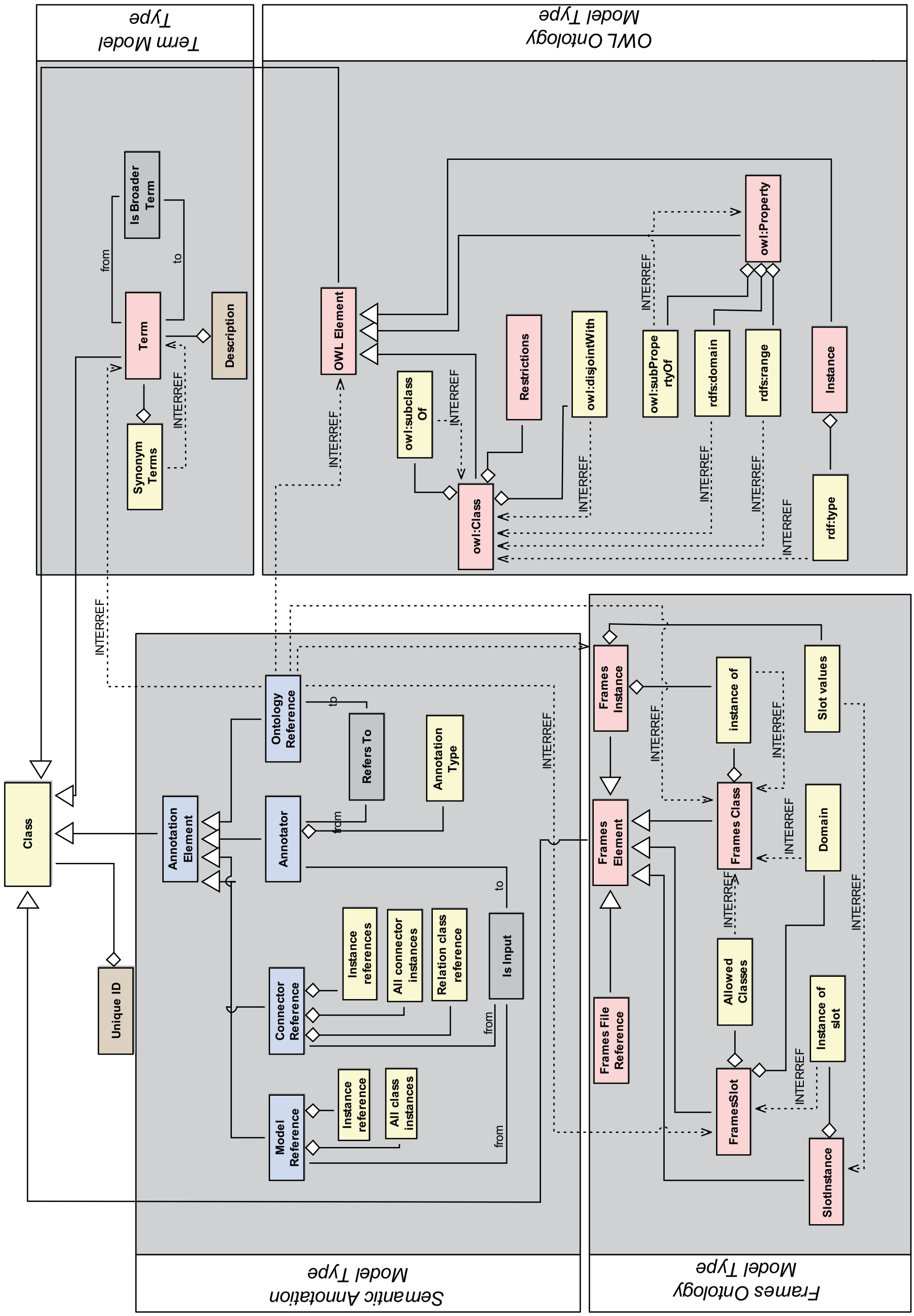

Figure 3: SeMFIS Metamodel [Fi16]

Besides the SeMFIS model types for ontologies and semantic annotations, the implementation also includes ADOxx components for accessing the platform via a SOAP-based web service interface, for processing the models via the ADOscript scripting language, as well as the AQL query component for querying model content in a proprietary query language. In addition, XML import and export interfaces are contained for exchanging model content.

3 Applications of SeMFIS

The approach of SeMFIS has been applied in the past to several scenarios. Some of the most prominent ones include the following. In [Fi12a] it has been described how business process models can be annotated with concepts from a risk ontology. In this way risks in business processes could be represented and subsequently analyzed using rules and simulation algorithms. In [Fi11b] the approach has been used to support the benchmarking of business processes by providing a common reference in the form of ontologies. In [FSK13] parts of the SeMFIS approach together with the web service interface have been used to embed the tool in a service-oriented architecture. This permitted to realize an interface to the Protégé ontology management platform.

Further scenarios that were based on the approach or re-used parts of it included the obfuscation of model information [Fi12c], the use in e-business scenarios [Fi09], for user-specific visualizations of models [FR11] or in the context of social network-based semantic annotations [Fi14].

4 Conclusion and Future Work

In this paper the concept of semantic-based modeling and the SeMFIS approach have been briefly described. For further information on SeMFIS it is referred to the SeMFIS website and the most recent publication on the platform [Fi16]. Future work on SeMFIS will include the further development of the concept and the technical implementation, as well as the application to further scenarios. As next steps it is planned to provide an API to ease the implementation of new algorithms on the SeMFIS platform. In addition, an existing plugin for the Stanford Protégé that permits to export ontologies in the SeMFIS XML format will be further enhanced and extended. Regarding future application scenarios it will be investigated how the approach can be used to represent requirements in the context of internet-of-things applications and social media management.

References

[BBF09] Blair, G.; Bencomo, N.; France, R.B.: Models@run.time. IEEE Computer, 42(10):22–27, 2009. DOI: 10.1109/MC.2009.326.

[DDFV07] Didonet Del Fabro, M.; Valduriez, P.: Semi-automatic model integration using matching transformations and weaving models. In: SAC '07 Proceedings of the 2007 ACM symposium on Applied computing. ACM, 2007.

[De05] Del Fabro, M. D.; Bezivin, J.; Jouault, F.; Valduriez, P.: Applying Generic Model Management to Data Mapping. In: BDA 2005. 2005.

[FB09] Fill, H.-G.; Burzynski, P.: Integrating Ontology Models and Conceptual Models using a Meta Modeling Approach. In: 11th International Protégé Conference. 2009.

[Fi07] Fill, H.-G.; Gericke, A.; Karagiannis, D.; Winter, R.: Modellierung für Integrated Enterprise Balancing. Wirtschaftsinformatik, 06/2007:419–429, 2007.

[Fi09] Fill, H.-G.: Design of Semantic Information Systems using a Model-based Approach. In: AAAI Spring Symposium. AAAI, 2009.

[Fi11a] Fill, H.-G.: On the Conceptualization of a Modeling Language for Semantic Model Annotations. In (Salinesi, C.; Pastor, O., eds): Advanced Information Systems Engineering Workshops, CAiSE 2011, volume LNBIP Vol. 83. Springer, London, UK, pp. 134–148, 2011.

[Fi11b] Fill, H.-G.: Using Semantically Annotated Models for Supporting Business Process Benchmarking. In (Grabis, J.; Kirikova, M., eds): 10th International Conference on Perspectives in Business Informatics Research. LNBIP 90. Springer, pp. 29–43, 2011.

[Fi12a] Fill, H.-G.: An Approach for Analyzing the Effects of Risks on Business Processes Using Semantic Annotations. In: European Conference on Information Systems 2012. AIS, 2012.

[Fi12b] Fill, H.-G.: SeMFIS: A Tool for Managing Semantic Conceptual Models. In (Kern, H.; Tolvanen, J.-P.; Bottoni, P., eds): Workshop on Graphical Modeling Language Development. 2012.

[Fi12c] Fill, H.-G.: Using Obfuscating Transformations for Supporting the Sharing and Analysis of Conceptual Models. In (Robra-Bissantz, S.; Mattfeld, D., eds): MKWI 2012. GITO Verlag, 2012.

[Fi14] Fill, H.-G.: On the Social Network based Semantic Annotation of Conceptual Models. In (Buchmann, R.A.; Kifor, C.V.; Yu, J., eds): 7th International Conference on Knowledge Science, Engineering and Management. Springer, pp. 138–149, 2014.

[Fi16] Fill, H.-G.: SeMFIS: A Flexible Engineering Platform for Semantic Annotations of Conceptual Models. accepted for Semantic Web (SWJ), 2016.

[FJ16] Fill, H.-G.; Johannsen, F.: A Knowledge Perspective on Big Data by Joining Enterprise Modeling and Data Analyses. In: Proceedings of the 49th Hawaii International Conference on System Sciences. IEEE, pp. 4052–4061, 2016. DOI: 10.1109/HICSS.2016.503.

[FK13] Fill, H.-G.; Karagiannis, D.: On the Conceptualisation of Modelling Methods Using the ADOxx Meta Modelling Platform. Enterprise Modelling and Information Systems Architectures, 8(1):4–25, 2013.

[FR11] Fill, H.-G.; Reischl, I.: Stepwise Semantic Enrichment in Health-related Public Management by Using Semantic Information Models. In (Smolnik, S.; Teuteberg, F.; Thomas, O., eds): Semantic Technologies for Business and Information Systems Engineering: Concepts and Applications. volume 195–212. IGI Press, 2011.

[FRK12] Fill, H.-G.; Redmond, T.; Karagiannis, D.: FDMM: A Formalism for Describing ADOxx Meta Models and Models. In (Maciaszek, L.; Cuzzocrea, A.; Cordeiro, J., eds): Proceedings of ICEIS 2012, Wroclaw, Poland, volume 3. pp. 133–144, 2012.

[FSK13] Fill, H.-G.; Schremser, D.; Karagiannis, D.: A Generic Approach for the Semantic Annotation of Conceptual Models using a Service-oriented Architecture. International Journal of Knowledge Management, 9(1):76–88, 2013.

[He05] Hepp, M.; Leymann, F.; Domingue, J.; Wahler, A.; Fensel, D.: Semantic business process management: A vision towards using semantic web services for business process management. In: IEEE International Conference on e-Business Engineering, 2005. ICEBE 2005. pp. 535–540, 2005.

[Ho07] Hoefferer, P.: Achieving Business Process Model Interoperability Using Metamodels and Ontologies. In (Oesterle, H.; Schelp, J.; Winter, R., eds): 15th European Conference on Information Systems (ECIS2007). University of St. Gallen, pp. 1620–1631, 2007.

[HR00] Harel, D.; Rumpe, B.: Modeling Languages: Syntax, Semantics and All That Stuff - Part I: The Basic Stuff. Technical Report MCS00-16, The Weizmann Institute of Science, August 22, 2000 2000.

[Hu14] Hui, G.: How the Internet of Things Changes Business Models. Harvard Business Review, July 29, 2014.

[Ka06] Kappel, G.; Kapsammer, E.; Kargl, H.; Kramler, G.; Reiter, T.; Retschitzegger, W.; Schwinger, W.; Wimmer, M.: On Models and Ontologies - A Layered Approach for Model-based Tool Integration. In (Mayr, H.C.; Breu, R., eds): Modellierung 2006. volume GI-Edition-Lecture Notes in Informatics (LNI), P-82, pp. 11–27, 2006.

[Ka08] Kaschek, R. H.: On the evolution of conceptual modeling. In (Delcambre, L.; Kaschek, R.H.; Mayr, H.C., eds): Dagstuhl Seminar Proceedings. volume 08181. Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, Germany, 2008.

[Ne91] Neches, R.; Fikes, R.; Finin, T.; Gruber, T.; Patil, R.; Senator, T.; Swartout, W.R.: Enabling Technology for Knowledge Sharing. AI Magazine, 12(3):36–56, 1991.

[Ro06] Rosemann, M.: Potential pitfalls of process modeling: part B. Business Process Management Journal, 12(3):377–384, 2006.

[TF07] Thomas, O.; Fellmann, M.: Semantic Business Process Management: Ontology-based Process Modeling Using Event-Driven Process Chains. IBIS, 2(1):29–44, 2007.