Language Independent Enterprise Model Mapping and Integration

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Abstract: Large organizations use established enterprise architecture frameworks like TOGAF or NAF to master the increasing complexity of their systems and processes. Especially for efficient cooperation the usage of different modelling approaches in different departments or due to company fusions is problematic. Furthermore, the different level of detail as well as different views and focuses makes the adaption or mapping of such models to challenging task. Considering this situation, the Phd objective is the complete and consistent transformation of enterprise architecture models from one specification to another on a generic methodology. This includes the technical verification and validation based on syntax, semantic and ontology. It ultimately forms the basis for objective comparability of operational capabilities and their systematic further development. This enables a sustainable, systematic adaptation of system development processes to constantly evolving operational capability driven requirements.

1 INTRODUCTION

The increasing digitalization and thus growing complexity of IT landscapes becomes a challenge for more and more enterprises. Organizations are required to present the information systems underlying their business in a transparent manner, at least within the company. Furthermore, the management have to align the IT systems continuously with the strategic orientation of the company in terms of business IT alignment. This ensures that companies can react quickly to new technology and market-driven demands on the business model or IT-support. The establishment of Enterprise Architecture Management (EAM) has emerged as a mandatory discipline for companies to overcome this challenge. The multitude of existing frameworks and methods facilitates the development and ongoing further development of an enterprise architecture model according to the corporate philosophy and the individual focal points.

The diversity of over 50 frameworks (Matthes, 2011) becomes a problem when considering the architecture of a company as a whole. The need for a holistic view exists, for example, in the collaboration or fusion of two companies, but also internally in the consideration of supply chains or integrated enterprises (Al Hadidi and Baghdadi, 2019). This is where different languages and model structures meet when architectural models are combined or information is exchanged on the basis of these, which are not necessarily directly compatible. Figure 1 shows the interface at which enterprise architecture based communication (EAC) becomes necessary for the scenarios mentioned above.

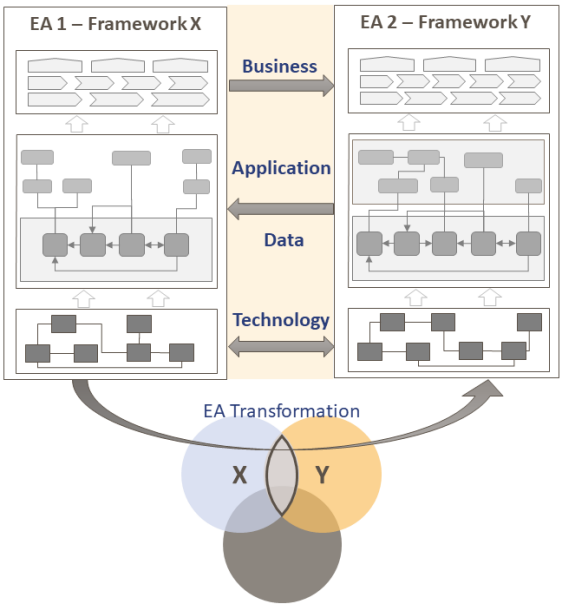

Figure 1: Semantic overlap as a basis for ea-based communication.

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So far, there are no standardized procedures for this. Frameworks such as the Nato Architecture Frame-work (NAF) and The Open Group Architecture Framework (TOGAF), due to their general applicability and the multitude of possible connecting points, do not provide any concrete statements as to how architecture building blocks are defined and how their interfaces must look in order to be interchangeable or integrable.

In this paper we present a holistic approach for the realization of model transformations for enterprise architectures. The degree of semantic overlap between two frameworks determines the potential amount of transferable information and forms the basis for a rule-based model transformation. Our approach is framework independent and supports both the transformation based on semantically aligned enterprise ontologies as well as user-defined input and output formats.

The remainder of this paper is structured as follows. Section 2 describes in detail the research problem. In the next section we present the requirements and research questions of the PhD approach. In Section 4 current approaches are briefly discusses accompanied by related work categorized in three areas related to the main topic. Afterwards, the scientific approach and method is presented. The main part in Section 6 elaborate the expected concept and solutions in detail. Thereafter, Section 7 shows the current stage of research. Finally, we summarize our PhD proposal and give a short outlook.

2 RESEARCH PROBLEM

Problems arise due to the variety of variants and individualization of frameworks in cross-company collaboration or communication on the basis of the architecture models. However, EAC is increasingly necessary, especially in cooperation with IT service providers, in order to implement transparent and flexible IT support in the company.

Differently structured metamodels usually do not allow a 1:1 transfer of the contents into the target architecture. Furthermore, the elements are also assigned different meanings depending on the company, which can lead to misinterpretations. For example, an IT service provider may give the term service a far more technical meaning with a focus on applications, ports, and transmission protocols, while another company takes a far more differentiated look at IT and business process-related services. Terminological coordination and level-appropriate mapping are decisive factors for successful integration. Figure 2 shows an example of the discrepancy between the two architectural models EA1 and EA2 with regard to the use of the term service. It can be resolved by a third, differentiated understanding of service in EA3.

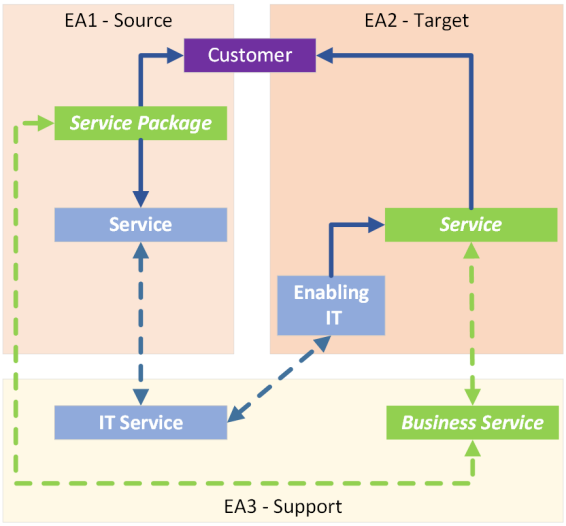

Figure 2: Bridging the semantic gap between two architectures by using a third service understanding.

In this context, there is no standardized method to develop a common understanding of architecture, independent of the framework, and to translate and integrate relevant business models on the basis of this understanding.

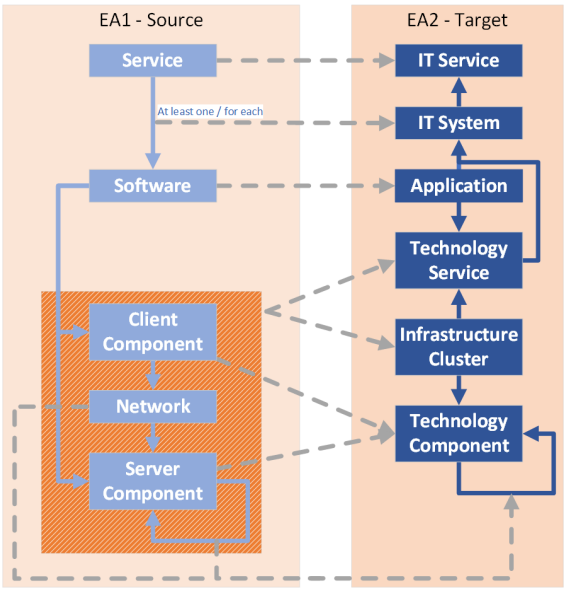

Figure 3: Example scenario for transformation problems.

Figure 3 shows the complexity of enterprise architecture mappings in a simplified context. Within the EA2, there is a cluster element that provides all the

required hardware in the form of a *technology service* for *applications*. The creation of this upper structure can only be achieved by considering all connected individual components that are used by the software within EA1. Furthermore, there is no direct relationship between a *service* and an *application* on the target side. The number of *IT systems* to be created in between depends on the technical realization of the *service* and the mapping definition. This means that either one logical *IT system* is created per *service*, which contains all *applications*, or a physical distinction is made on the basis of the hardware used.

From this example it becomes clear that before the technical realization of a model transformation the semantic alignment of the architecture understandings must take place. The difficulty arises from the different degrees of formalization of the enterprise models, ranging from simple tables and documents via models according to a description language up to strictly formal ontologies.

As a result of the semantic alignment, the following conflict areas can be identified in the subsequent transformation of enterprise models:

- Meaning: Architectural elements of the same name have different connotations
- Aggregation: Context based consolidation of content from different elements, attributes and relations
- Splitting: Creation of several target contents on the basis of a single element; separation of owned attributes of elements as independent ones with association to them
- Case dependencies: In dependence of the situation and the context, different solutions are possible.
- Context relation: Definition of conditions, which apply together or optionally, that the contents are transformed.
- Generalization: Mapping of several source contents to the same target element, with the possibility to differentiate them during further consideration.
- Directed associations: Enterprise architecture specification often have associations, which may force directions.

In addition to this major challenge, there are other related problems to consider. These include the semantic enrichment of enterprise architectures and their alignment, as well as the integration of transformed content into an existing target model. Thereby the visualization of the produced result is also of interest.

3 OUTLINE OF OBJECTIVES

The transformation process for enterprise architecture models faces many challenges when it comes to complete mapping. Especially the creation of a common business and IT comprehension is important to interpret transferred information correctly.

The requirements for a scientific and practical usable system are the following:

- Pairwise enterprise architecture model transformation of two different architecture frameworks. The transformation design and engine have to be independent of a specific framework to be usable for future EA approaches.
- Each model follows a specification, which provides the description by elements and relations. These can contain further information like attributes or tagged values, which have to be preserved.
- Creation of a target model without modification or additional enrichment of the input.
- Definition of unidirectional mapping rules that can be chained for overall transformations.
- Overarching concatenation of mapping rules, to create target models via intermediate models in complex situations or if no direct mapping rule exists.

The solution addresses the heterogeneity of frameworks and description languages within the enterprise architecture domain by providing a neutral platform. This serves to create a common understanding of architecture and to exchange and integrate enterprise models.

In this context, the following research questions are expected to be answered:

- How have enterprise architectures to be described in order to be able to communicate and collaborate with other enterprises on the basis of the models in the sense of a federated enterprise?
- What is a methodology and approach to contribute to the creation of a common conceptual understanding between enterprises and to transform the content, independent of language or metamodel?
- How can the transformed content be integrated and verified into a target enterprise model as well as visualized?

Beside this, we will analyze the limitation of model transformations. Furthermore, a concept of a simple formal description of the transformation will be developed. The definition of an interface that supports the enterprise comprehension of the current

main 50 EA frameworks can only transport a small subset of the semantics of the models. It is fragile with regard to its validity in view of the growing number of frameworks and in-house developments or agile enterprise description models. Thus, we focus on an integrative approach, which can be defined between two models, but which can be extended at will in order to successively contribute to a federated understanding of enterprise models.

4 STATE OF THE ART

At the beginning, we start our research with a systematic method for related work. Afterwards, it is combined with the method of centric circles to identify highly important publications. Current approaches for our problem can be divided in three categories *Enterprise model Transformation*, *Enterprise ontologies*, and *Ontology alignment*.

4.1 Enterprise Model Transformation

With regard to the technical realization of the mapping of Enterprise Architecture Frameworks we consider solutions from the field of model transformation. Numerous tools exist for model-to-model transformation. A current survey of Kahani et al. (2018) classified 60 of them according to several criteria. Most of them implement the OMG standard QVT (OMG, 2016) or similar, using OCL (OMG, 2014) or other expression languages to define transformation rules. Our approach addresses domain experts in enterprise architecture modeling who do not necessarily have experience in programming, metamodeling, or model transformation. Therefore, we follow the definition of Acreţoaie et al. (2018) of "end-model-users", who need a solution that is as intuitive and easy to learn as possible. Their Visual Model Transformation Language (VTML) is the only language known to us that pursues such an approach. However, it only allows endogenous transformations, which means that source and target models conform to the same metamodel (Westfechtel, 2018). This conflicts with our mandatory requirement for a model transformation between heterogeneous frameworks.

4.2 Enterprise Ontologies

Ontologies described in machine-readable form like OWL (World Wide Web Consortium, 2012) are a suitable starting point for the semantic alignment of enterprise models. Hinkelmann et al. (2016) describes the advantages of describing enterprise architectures as ontologies in terms of enterprise analysis and decision making. Beside this, there are different methods for developing ontologies (Forbes et al., 2018) and various projects regarding the design of enterprise ontologies (Fedotova et al., 2018). We consider methods that deal with the semantic enrichment of existing enterprise models, respectively their metamodels, with regard to the improvement of the compatibility to other frameworks. Al Hadidi and Baghdadi (2019) developed a domain ontology for Extended and Virtual Enterprises to improve knowledge sharing within such collaborations. The adaptation requires that the existing business models are already described as ontologies. Furthermore, only a small subset of possible architectural elements is provided under the concept *framework*, into which the models must be classified. This abstraction is not sufficient for us as preparation for a semantic alignment of different frameworks.

4.3 Ontology Alignment

The semantic coordination of heterogeneous enterprise architecture frameworks is a prerequisite for transformation at model level. One aspect of our research is the derivation of transformation rules by aligning the frameworks on the basis of their representation as ontologies. This excludes a merging of both ontologies, since the result must contain the relational connections between both ontologies. Various general matching techniques are discussed by Ramar and Gurunathan (2016) and Hu et al. (2017). Furthermore, there are more than 90 tool-based approaches for (semi-)automatic matching, of which only a few are still available and applicable (Ganzha et al., 2016). Chen et al. (2019) examined tools with a focus on visualization of the alignments, which appear to be most suitable for a practical application in the context of EA mapping. Nevertheless, the research approaches only fulfill a subset of the corresponding relationships between two frameworks that are relevant for us. According to the definition of Ochieng and Kyanda (2018), ontology matching tools serve to identify equivalent and disjunctive concepts, as well as subsumption. For example, we still need statements about aggregation and case-based equivalence depending on existing instances. However, the semantic integration approaches can only support the enterprise architecture transformation and may be partially used as a technical realization.

To the best of our knowledge, there is no holistic approach that meets all the identified requirements on a language independent enterprise model transformation.

5 METHODOLOGY

The goal is the development of a coordination and transformation platform under consideration of the following emphases:

- Semantic enrichment of enterprise models and their metamodels for representation as ontologies
- Mapping of formalized metamodels to create a common conceptual understanding (EA Alignment)
- Transformation of the models based on the alignment and integration into the target model

The concept of the PhD approach will be built on this basis, under consideration of existing approaches.

In order to achieve an applicable solution, we start with a requirements analysis regarding the challenges of EA-based communication. To present a generic approach, it is necessary to examine a wide range of existing frameworks, metamodels and description languages in more detail. The results of the analysis provide statements about the required degree of formalization and structure of the model contents, challenges regarding semantic diversity and requirements for the transformation language to solve recurring problems.

Existing transformation languages are taken into consideration for the technical realization of the mapping, considering the simple applicability and fulfillment of the requirements. For the implementation we evaluate different programming paradigms and languages regarding their suitability for the problem. To describe the transformation rules using graphical syntax, the adaptability of the solution within existing modeling environments is intended.

The evaluation of the results is carried out on real and fictitious case studies. These include the expressiveness of the language, the degree of adaptability for different frameworks and the manageability of the solution. As there is no comparable approach as a whole to date, the results are partially reflected in the individual approaches described.

6 EXPECTED OUTCOME

The Phd thesis should provide a complete and generic framework for the transformation of enterprise architecture models. Figure 4 shows the structure of the overall solution, which considers the following aspects:

Semantic Lifting. A methodology for the ontological description of enterprise architectures will be developed to support the semantic comparison of heterogeneous metamodels. We focus on the application of a reference ontology that makes architectural concepts more comparable. This includes the consideration of definitions, aggregation structures and the embedding into the overall architecture.

Enterprise Ontology Alignment. We examine approaches that are suitable for semantic alignment in preparation for model transformation. Enterprise architecture frameworks have a varying degree of coverage with regard to their semantics. In addition to obvious similarities that allow a bidirectional mapping, more complex derivations of the context often arise, for example if the target metamodel represents a specialization of the source metamodel. The feasibility of deriving such constellations through ontology matching will be part of our work in order to ensure the highest possible degree of information transfer.

Enterprise Model Transformation. The objective of the research is to develop a lightweight approach to model transformation that meets the requirements of enterprise architecture models. The designed language allows incremental and from scratch target model generation for endogenous and exogenous transformations. The input and output format of the models to be translated is independent of the transformation logic. The API allows any content interpreter to be adapted for model processing. In the same way, the description form of the mapping rules can be extended by an interface. In addition to the formal syntactic description, we present a graphical syntax and an interpreter based on a specific ontology matching result. The research result includes an API implementation for the interpretation of ontologies and an exemplary custom realization of an XML interpretation logic.

Our approach allows transformation rules to be chained across multiple frameworks. This has the advantage that model transformations are also possible if no direct mapping is defined. Furthermore, a stepwise transformation can be advantageous if the semantic overlaps of the frameworks differ in such a way that more information can be transferred via an intermediate model than with direct mapping.

The Phd thesis includes a detailed description of the stepwise methodology. The entire process is aligned with a generic software framework, which is independent of a specific enterprise architecture or modelling specification. Furthermore, the theoretical limitations will be outlined. Beside this, the chained model transformation is analyzed in detail.

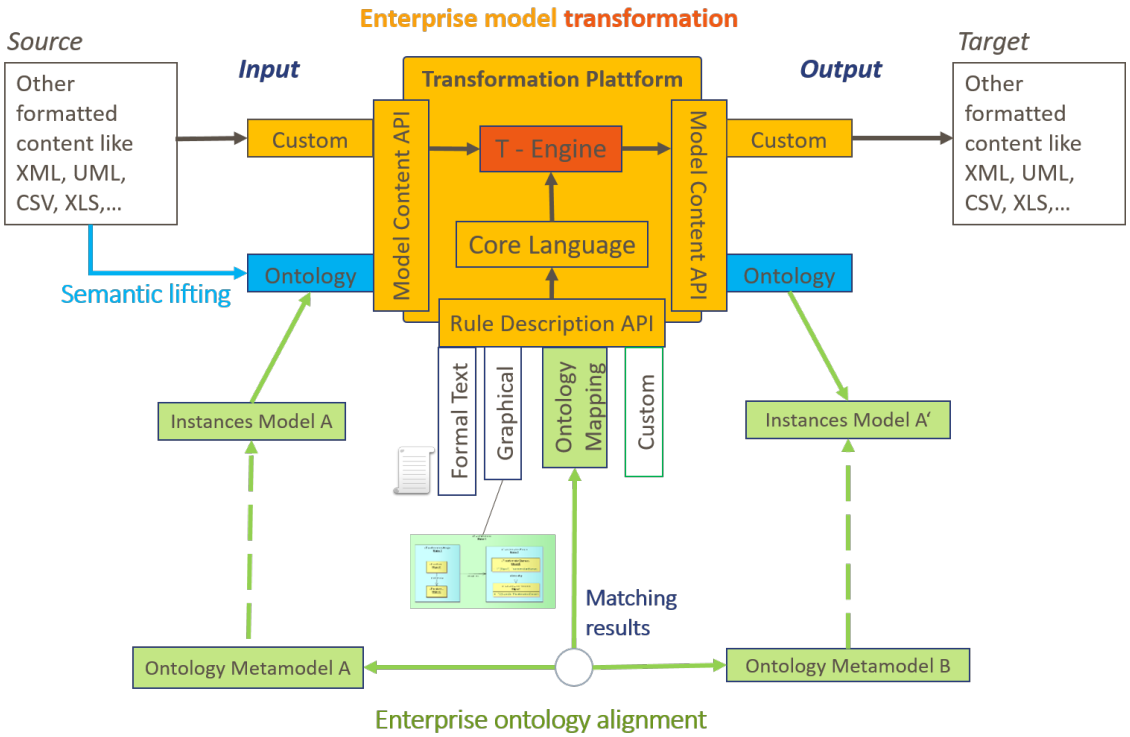

Figure 4: Overall Approach for Enterprise Model Transformation.

7 STAGE OF THE RESEARCH

A literature analysis was carried out to identify existing approaches from the research areas mentioned above and to adapt them for a holistic solution to EA-based communication. For the transformation of the enterprise models different languages and tools were examined for their applicability and the necessity for a more practicable solution for this domain was explained. An initial evaluation was carried out using an example from industry between different frameworks and a prototypical implementation of the concept. Based on this, we have developed a transformation language and a corresponding graphical syntax that is suitable for the formulation of production rules in the context of EAF mapping. We aim at further model transformations with other frameworks to investigate more complex examples and to evaluate the expressiveness of the language. In this context, one aspect will be the concatenation of more than two EA concepts to generate target models.

The next step is to improve and partially automate the previously manual semantic coordination of the frameworks by ontological observation. We do this by building on existing approaches for semantic enrichment of business models and alignment of ontologies and extending them according to the described requirements. Furthermore, the integration into an existing target model as well as an incremental change of the contents must be examined more closely and the solution evaluated in the overall context on the basis of further use cases.

8 CONCLUSION AND NEXT STEPS

In this PhD proposal, we present the need for an enterprise model mapping and transformation engine. The challenges are explained in detail as well as the integration of the generated model in a specific head structure is requested. Furthermore, the requirement of a language independent design is pointed out. The current state of the art shows that there are no systems which offer an holistic solution for the problem. Beside this, existing approaches are too complex in use. Our introduced approach of the usage of ontologies show many advantages in relation for a complete transformation. The semantics in the model are preserved.

In the next steps, we will design and implement the transformation engine in all details. This include

a language to describe the mapping between two enterprises in two steps with a general and a specific rule set. Current tests for evaluation with the industry already show a high potential and added value for system modelers.

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REFERENCES

Acreţoaie, V., Störrle, H., and Strüber, D. (2018). Vmtl: a language for end-user model transformation. *Software & Systems Modeling*, 17(4):1139–1167.

Al Hadidi, F. and Baghdadi, Y. (2019). Ontology for enterprise interactions: Extended and virtual enterprises. In Räder, A., editor, *Poesie des Alltäglichen*, volume 12 of *Film, Fernsehen, Medienkultur*, pages 365–379. Springer Fachmedien Wiesbaden GmbH and Springer VS, Wiesbaden.

Chen, J., Xue, X., Huang, L., and Ren, A. (2019). An overview on visualization of ontology alignment and ontology entity. In Krömer, P., Zhang, H., Liang, Y., and Pan, J.-S., editors, *Proceedings of the Fifth Euro-China Conference on Intelligent Data Analysis and Applications*, volume 891 of *Advances in Intelligent Systems and Computing*, pages 369–380. Springer, [S.l.].

Fedotova, A. V., Tabakov, V. V., Ovsyannikov, M. V., and Bruening, J. (2018). Ontological modeling for industrial enterprise engineering. In Abraham, A., Kovalev, S., Tarassov, V., Snasel, V., and Sukhanov, A., editors, *Proceedings of the Third International Scientific Conference "Intelligent Information Technologies for Industry" (IITI'18)*, volume 874 of *Advances in Intelligent Systems and Computing*, pages 182–189. Springer International Publishing and Springer, Cham.

Forbes, D. E., Wongthongtham, P., Terblanche, C., and Pakdeetrakulwong, U. (2018). Ontology engineering. In Forbes, D. E., Wongthongtham, P., Terblanche, C., and Pakdeetrakulwong, U., editors, *Ontology Engineering Applications in Healthcare and Workforce Management Systems*, Studies in Systems, Decision and Control, pages 27–40. Springer International Publishing and Imprint: Springer, Cham.

Ganzha, M., Paprzycki, M., Pawłowski, W., Szmeja, P., Wasielewska, K., and Fortino, G. (2016). Tools for ontology matching—practical considerations from interiot perspective. In Li, W., editor, *Internet and distributed computing systems*, volume 9864 of *LNCS sublibrary: SL 3 - Information systems and applications, incl. Internet/Web, and HCI*, pages 296–307. Springer, [Switzerland].

Hinkelmann, K., Gerber, A., Karagiannis, D., Thoenssen, B., van der Merwe, A., and Woitsch, R. (2016). A new paradigm for the continuous alignment of business and it: Combining enterprise architecture modelling and enterprise ontology. *Computers in Industry*, 79:77–86.

Hu, X., Feng, Z., Chen, S., Huang, K., Li, J., and Zhou, M. (2017). Accurate identification of ontology alignments at different granularity levels. *IEEE Access*, 5:105–120.

Kahani, N., Bagherzadeh, M., Cordy, J. R., Dingel, J., and Varró, D. (2018). Survey and classification of model transformation tools. *Software & Systems Modeling*, 45(3):621.

Matthes, D. (2011). Am markt verfügbare enterprise architecture frameworks. In Matthes, D., editor, *Enterprise Architecture Frameworks Kompendium*, Xpert.press, pages 37–57. Springer Berlin Heidelberg, Berlin, Heidelberg.

Ochieng, P. and Kyanda, S. (2018). Large-scale ontology matching. *ACM Computing Surveys*, 51(4):1–35.

OMG (2014). Object Constraint Language v 2.4.

OMG (2016). Meta Object Facility (MOF) 2.0 Query/View/Transformation specification v 1.3.

Ramar, K. and Gurunathan, G. (2016). Technical review on ontology mapping techniques.

Westfechtel, B. (2018). Case-based exploration of bidirectional transformations in qvt relations. *Software & Systems Modeling*, 17(3):989–1029.

World Wide Web Consortium (2012). OWL 2 Web Ontology Language.