Towards a Multi-Faceted Framework for Semantics in Enterprise Modeling Languages

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Abstract: The semantic specification of Enterprise Modeling Languages (EMLs) is a challenging task that is primarily caused by the immanent subjectivity in the context of enterprise modeling. This covers the interpretation of respective meta model constructs due to their references to the reality. In contrast, EMLs may also contain formal semantics in regard of automating specific parts. Despite the generally accepted relevance of semantics for the application of EMLs, current research lacks in the provision of appropriate description means and largely omits semantic investigations. This paper therefore proposes a multi-faceted framework for the analysis and description of EML semantics in order to increase the awareness of relevant influences. The framework consists of an ontic and epistemological dimension in its core, as material semantics finally address such fundamental aspects. On this basis, several wrapping dimensions are outlined: Conceptualization dimension, pragmatic dimension, representation dimension and the final consensus dimension.

Keywords: Enterprise Modeling Languages, Semantics, Ontic Reality, Formal Semantics, Material Semantics, Semantics Specification, Meta Modeling

1 Context and Motivation

1.1 Enterprise Modeling Languages

Enterprises are multifarious, heterogeneous socio-technical information systems, whose components are interrelated within a complex nexus of interdependencies on various abstraction levels [Ve03, SL08, Fr14]. Enterprise Modeling (EM) aims to conceptualize, abstract and represent parts and aspects of enterprises by creating conceptual models in order to foster communication between involved stakeholders and enable an integration of static, procedural and functional dimensions [La09]. EM serves as capable and auspicious approach for managing present-day business complexity in the light of increasing interdependencies between and within information systems [Ve14]. EM may also provide specific means for operative support for different levels of automation [Ma13, BF14].

A plenty of Enterprise Modeling Languages (EMLs) evolved during the last decades. The range reaches from integrated approaches like ArchiMate [LPJ09] over Purpose-Specific Modeling Languages like BPMN [OM11] towards domain-specific approaches like the set of MEMO languages (e.g. RiskM [SHF11]). Especially rather generic languages like BPMN are often subject for language extension or simplification (cf. [BE14, Fe10]), since
the complexity of enterprise-related issues requires a permanent review of the communicative usefulness of existing EMLs [PVSH05], which leads to the addressed EML adaptations [BPS13] and language evolution [Pa06].

1.2 Relevance of Semantics and Struggles with Semantics

Language adaptations are inevitably related to semantic considerations in order to identify requirements of prospective users, which result from the expected utility of an EML [Fr13, dKMP14, DKM15, PVSH05]. Investigating the relevant semantics of an EML is further crucial for an adequate justification of EML adaptation need indicating respective syntactical necessities [BS14]. Consequently, the focus should merely lay on semantics and pragmatics of EMLs in order to facilitate adequate adaptations [BPS14].

Despite the high relevance of both aspects for EML application and dissemination (cf. [BSH99, p. 212], [BPS13, p. 440]), they are still under-investigated. Several authors explicitly criticize the imprecise semantic justification and specification of conceptual modeling languages (cf. [HR04, pp. 67-69], [HH05, p. 19]), EMLs (cf. [Si03, p. 108], [SAG13, pp. 690, 706], [HBO12, pp. 485]) and also EML extensions [BE14, p. 52]. These shortcomings hamper language comprehensibility [Gu07] and cause severe issues in terms of inter-subjective communication. For instance, mismatched understandings of meta model elements remain undetected [Ka12] or superficially similar meta concepts are erroneously treated as being the same [vdL15]. Weak semantic specifications of EMLs also hinder the establishment of common understandings of meta concepts [vdL15, pp. 3, 66, 104].

The reasons for these issues are manifold. For instance, some EMLs have a rather formal background (e.g. BPMN), which often implicates a naive-realistic understanding of semantics. It means that a particular meta model element is supposed to be interpreted in exactly one way. This is insufficient in semi-formal modeling languages like EMLs, as the semantics of those languages are mostly material [GBE05]. Recipients of EMLs are mostly human beings, which in turn causes the immanent issue of subjectivity in regard of understanding a (meta) model differently (cf. [Se84, p. 6], [PG05, p. 112], [vdL15, p. 5]). Technically spoken, the semantic mapping of a syntactical construct to a particular semantic domain construct differs and leads to the above mentioned issues [vdLvZ14, KK02]. This is even intensified by multi-disciplinarity in present-day industries, the sheer amount of participating systems and resulting collaborative modeling tasks [Ro08].

Although objectification and particular semantic harmonization within a group of EML users are stated as worthwhile objectives (cf. [Sc98, p. 25] and [Fr13, pp. 13-14]), current research lacks in the provision of techniques for describing EML semantics in an appropriate manner. Also methodic guidance for detecting and eliminating misunderstandings is missing and there is no special consideration of integrating material semantics and formal semantics, which seems to be a relevant issue in the field of process modeling, for instance (cf. [BF14, p. 3400], [OM11, p. 435]). Also respective semantic description approaches like UEML [An10] are not well disseminated or applied in many EMLs. Research on semantics in the context of EMLs can hence be assessed as rather immature, isolated and less integrated.
1.3 Research Scope and Objective of the Paper

It is therefore advisable to focus EML semantics on the meta model layer in general. Due to the fact that EML semantics are closely related to the issue of subjectivity, each investigation finally results in discussing the fundamental questions, what something is (ontic aspect) and how this thing is perceived and described by somebody (epistemological aspect). While several works from the beginning of the last decade partly address such aspects for the model layer [Sc99, Be04, BE06, Fr06], there is a lack of research regarding to further development in recent years and explicit consideration in the context of EML semantics on the meta model layer. Also the very few papers on EML semantics largely omit such issues [Op11, BPS14, vdL15].

We therefore aim to design a multi-faceted framework for EML semantics in this paper, which has an ontic and epistemological dimension in its core. This is done in order to cover the diversity of relevant (mostly subjective) sources for ambiguity and establish awareness for different types of things and possible consequences. Additionally, surrounding dimensions are introduced in order to emphasize factors, which influence and determine particular EML semantics. Consequently, the paper aims to initially integrate several aspects and serves as starting point and orientation framework for further research on specifying EML semantics. The framework should also support the alignment of research on different dimensions. The framework is designed based on an analysis of existing research in the context of EML semantics and their grouping within particular dimensions.

The remainder of this paper is as follows. Section 2 briefly introduces the SemFrame framework, presents the ontic core of the framework and discusses consequences for semantics. Section 3 then briefly outlines the remaining dimensions. Section 4 summarizes the contributions of the paper and explicates further research topics.

2 Ontic and Epistemic Dimension

Figure 1 presents the structure of the SemFrame framework, which aims to provide orientation for the analysis of different facets in the context of semantics of EMLs. Each dimension is briefly introduced below.

2.1 Preliminary Considerations

The consideration of meta model semantics bases on the work of Ullmann (1979), who proposes a triangle consisting of a thing (as part of an area of discourse), its conceptualization (by an individual) and a symbol (of a language) for its representation [Ul79]. Fig. 2a presents the adaptation of the linguistic triangle to the meta model layer in order to provide an orientation frame for the discussion below. A meta model element is understood as symbol, which aims to enable the explication of conceptualizations from a particular area of interest. It represents syntactical constructs. Further, a thing is rather understood as
class of things, as the meta model layer usually refers to already abstracted things. Hence we consider an implicit abstraction step of meta model readers, which have to infer from single entities to a class of those entities\(^2\). Thus, it represents the affected semantic domain constructs and the refers to relation represents the semantic mapping (cf. [KK02]). Finally, conceptualization explicitly refers to the stated classes of things and cover the individual understanding of meta model constructs. VAN DER LINDEN (2015) therefore proclaims the term personal semantics in order to stress different understandings of fundamental enterprise-related things [vdLvZ14].

2.2 Ontic and Epistemic Dimension

Each consideration of EML semantics should start with an awareness of the ontic type of things\(^3\), as the respective types may determine various conceptualizations of classes of things. Generally, the ontic positions of Realism, Idealism and the open-ontic position can be divided [Ca50, Be03].

**Ontic Realism:** Realism affirms the existence of an ontic reality that is generally perceptible [SBZ96]. Naturally, it seems to be plausible that physical and haptic things are perceived as real (e.g. the complex thing production machine) or that respective visual signs are perceived as real (e.g. optic or acoustic effects). Consequently, things that are somehow perceptible by sensory perception capabilities can be seen as real. In contrast, the ontic type of virtually constructed things from the field of EM like processes, programs or competences is debatable. On the one hand, it could be argued that such things are actually essential and hence real within the world of the group of enterprise modelers. On the other hand, it could be argued that the stated things only become real by final exposure

\(^2\) The term meta things is avoided, as we follow a language-based understanding of the term meta that indicates a specific role in terms of creating statements about other elements.

\(^3\) Thereby, ontic is understood in the sense of an observable and atomically describable entity; independent of any epistemic position (referring to [He96, AP03]).
of perceptible things. For instance, a process is physically exposed either by its physical outcome or respective state changes of participated things, which can be observed and quantified in some way. More precisely, a process itself can be rather seen as denotational wrapper around a specific set of connected perceptible explications.

With respect to the epistemic position, things in realism can be divided into objectively perceptible things (Epistemic Realism) and subjectively perceptible things (Epistemic Idealism [Be03]). As presented in Fig. 2b, the combination of the ontic and epistemic position determines the respective epistemological position, which in turn is relevant for applicable theories of truth (cf. [BE06]). In case of Positivism, semantics are understood as mappings from syntactical constructs to referred semantic domain constructs, which implies an invariant interpretation and possible automation [GFPVS02, PG05]. Possibly existing personal conceptualizations of individuals are hence less relevant ($C_n$). The unit of semantic analysis is therefore the relation $Sy-T$.

![Figure 2: a) Adapting the generic linguistic triangle [Ul79] to the meta model layer of EMLs. b) Ontic and epistemic positions in the shape of the adapted linguistic triangle.](image)

In contrast, subject-dependent Critical Rationalism [Re03] or Methodic Constructivism [Ka72] comply with subjective variance that is explicated by different conceptualizations of an ontic thing ($C_1, C_2$ and $C_n$). Those conceptualizations can be seen as personal semantics [vdL15]. It is therefore necessary to identify these differences and reduce them in order to establish shared semantics. Consequently, semantic analysis primarily considers the set of relations $C_n-T$. Conceptualizations differ according to granularity, level of detail and relations to other classes of things [vdLvZ14]. From a semantic point of view, it is desirable to identify and cluster similar conceptualizations for two reasons: Firstly, similar conceptualizations should be homogenized in order to shape shared semantics [vdLH12]. Secondly, notable differences between those groups of conceptualizations may indicate different views on one and the same thing (e.g. multi-perspectivity [Fr08]). The degree
of different conceptualizations is naturally influenced by the affected domain. A long existing domain (e.g. healthcare) may have a higher level of regulation and terminological standardization than a rather young domain (e.g. social media).

**Ontic Idealism:** Idealism negates the existence of objectively perceptible things in a world. Instead, things are completely constructed within the mind of individuals (e.g. [Be03]). This position mandatorily requires the epistemic position of Idealism and results in Radical Constructivism (e.g. [Fr07, p. 13]). An idealist position seems to be plausible for totally immaterial things, highly innovative things and possible worlds. Semantics mean here that each individual has its own conceptualization of something s/he has in mind, which is then referred to a meta model element. Due to the lack of objective things ($T_0$, $T_1$, $T_2$ and $T_n$), it is questionable to accomplish shared semantics, as the analysis of each relation $C_n$-$T_n$ actually remains contingent, since there is no rational opportunity to match them. Consensus-oriented approaches hence proclaim to focus the process of conceptualization by considering commonly applied methods (e.g. in Method Constructivism), but it is currently unclear how to adapt and conduct such approaches in the context of EML semantics. It is therefore hard to accept idealist things as reference points in EML semantics due to the questionable contribution to inter-subjective communication.

**Open-Ontic Position and Remarks:** Further, the open-ontic position is proposed in literature (e.g. [Be03]), which omits any ontic positioning. With respect to the above mentioned issue within Idealism, this position is also questionable, as it cannot provide a stable reference point for meta model constructs. Visually, the semantic reference point is vague and not precise. It became obvious that the ontic dimension is not trivial and even spans philosophical topics. As it is important to be aware the characteristics of things and their differing conceptualizations, we are facing a factual problem shift regarding to description (and consensus building) of those things; independent of any semantic discussion.

### 3 Further Dimensions of the SemFrame Framework

#### 3.1 Conceptualization Dimension

As mentioned above, conceptualization is understood as the individual understanding of the stated class of things. This conceptualization is a central point of analysis, as it depends on the personal understanding of a particular meta model and finally refers to some things s/he has in mind. The only exception is represented by a class of things that is perceived as real and objectively perceptible (Positivism). In each other constellation, the conceptualization is strongly subject-dependent and can cause variant interpretations of meta model constructs by interpreting them differently, for instance [vdL15].

#### 3.2 Pragmatic Dimension

The intended application context determines the expected capabilities of a modeling language [Th12, p. 5]. Also the situational modeling purpose plays an immanant role within
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categorization [BPS14, p. 436]. Some authors state that the real meaning of a language finally results from its factual usage [BPS14, p. 438], serving a particular utility [PVSH05]. The strong influence of pragmatics on semantics is hence obvious and requires the respective consideration by defining requirements profiles, for instance (referring to [DKM15]). Table 1 summarizes typical purposes in the context of EMLs.

Table 1: Purposes in the context of EML pragmatics.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>Documentation</td>
<td>EMLs are intended to work as base for documentation, inter-subjective communication and manual decision making. There is no kind of automation and this purpose usually covers material semantics and variant conceptualizations of addressed things of a domain. The semantics have therefore a descriptive character.</td>
</tr>
<tr>
<td>Documentation and Automation</td>
<td>As stated in Section 1.2, the combination of material and formal semantics may be required in process modeling. For instance, in case of manually interpretable process flows (e.g. clinical treatment processes) and vertical processes (e.g. resources flows), which can be integrated with respective application systems. This scenario could be referred as hybrid semantics.</td>
</tr>
<tr>
<td>Automation</td>
<td>This purpose reflects the complete automation of an EML, i.e. formal semantics. This could be either required within model-driven engineering approaches in order to configure application systems or as direct intervention into parts of reality. For instance, if the control unit of a production machine is completely configured. The semantics have therefore a prescriptive character.</td>
</tr>
<tr>
<td>Model Analysis</td>
<td>This purpose reflects any kind of analysis or assessment of created models. There is consequently no direct relation to the actual area of discourse, but rather some kind of self-reference. However, such implementation can be found in EML extensions [BE14, p. 45] and may require respective formal semantics for the analysis of models.</td>
</tr>
</tbody>
</table>

3.3 Representation Dimension

Conceptualizations and things (in case of Positivism) need to be explicated in any form. Ontologies are often proclaimed as means for semantic annotations [Hö07, Ka15]. Basically, even those rather minimalistic languages have certain syntax and semantics, which have to be taken into account. Further, also the semantics of the meta modeling language have to be considered, as it indirectly refers to artificial things of constructs (e.g. Generalizations). The respective meta language further shapes and also limits a particular expression space. This is covered by the framework element modeling language.

In addition, natural language emphasizes the importance of single words (sememe) as basic source of ambiguity, since people usually think in the semantics of their own natural language [So10]. While structural issues are covered by the above mentioned dimensions, natural language based ambiguity is also a crucial issue, since all the stated
problems finally lead to lexical topics like synonym and homonym conflicts [PLM15]. For instance, further research on other lexical types like hypernyms, hyponyms, meronyms, holonyms, antonyms and troponyms is needed (cf. [Hö07, p. 1628], [Th12, p. 8], [MLP14, p. 89]). Also controlled natural language techniques or rather formal approaches like SBVR [OM15] are promising.

3.4 Consensus Dimension

Despite divergence and ambiguity, it is important to find a particular consensus on semantics in the sense of an agreement of different personal conceptualizations in order to provide an applicable language within a language community. Although consensus theory of truth is usually applied in Constructivism and Critical Rationalism, we suggest to examine its consequent application, since EM usually covers at least some things that are not invariant interpretable.

4 Conclusion and Outlook

4.1 Contribution and Framework Application

This research paper outlines a framework for the multi-faceted analysis and description of EML semantics by focusing the primal aspect of analysis – the things, which are addressed by an EML. Therefore, different ontic positions are discussed in regard of their consequences for semantics. Additional dimensions were outlined in order to foster a deeper integration and consolidation between existing research approaches, which relate to EML semantics. Due to the complexity of the addressed topic, it would be presumptuous to proclaim a complete solution for specifying semantics. Instead, the paper aims to revitalize a fruitful discussion of EML semantics and their potential specification in order to increase to practical relevance of EMLs to a certain degree.

The proposed framework should be understood as an initial approach to tackle the manifold issue of EML semantics in an integrated manner, especially regarding to various sources of ambiguity. The framework aims to provide an orientation architecture for several approaches like research on personal semantics [vdL15], linguistic ambiguity [PLM15] and user-centric language design [PVSH05, Fr13, BS14, BPS14, DKM15]. To the best of our knowledge, this is the first effort that intends to bring together all those relevant issues.

The framework should further support EML language designers at specifying the semantics of an EML. For instance, it is significant to state what things are covered by particular meta concepts and what things are explicitly not covered. Language designers should also explicate their ontic and epistemological position in regard of the addressed domain. The description of specific pragmatic use cases may illustrate the intended type of semantics. Further, the provision of synonyms may enhance the understanding of language concepts and may avoid linguistic misunderstandings. Finally, the framework may act as orientation framework for research on single semantic aspects and their alignment with affected dimensions.
4.2 Further Research

It is obvious that research on semantics and pragmatics should be generally intensified. Adequately specified semantics seems to be a potential gate opener for larger dissemination of EMLs in general. This paper also reveals the strong need for cumulative, inter-disciplinary and cross-cutting research in order to move EM forward. This comprises a deeper analysis of fundamental research disciplines like philosophy, linguistics and cognition, since fundamental semantic issues are at some point decomposable to such basic questions.

Consequently, plenty of research questions should be investigated. For instance: How can we determine the ontic type of things? How can personal conceptualizations explicated and compared in a standard manner? Is it feasible to adapt consensus-oriented techniques from Methodic Constructivism for elaborating shared semantics? Despite the academical relevance of these issues, it is also necessary to consider potential trade-offs between over-engineering (e.g. by massive semantic annotations) and practicability.

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