A Step Towards Context Insensitive Quality Control for Ontology Building Methodologies*

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Abstract. A methodology provides description of process and guidance for producing ontology that facilitates management of the enterprise engineering products. Method support in terms of detailed guidelines is important to ensure the quality of ontologies. Then, it is also important to be able to evaluate the quality of such method guidelines.

This paper proposes an analytical framework for such evaluations, achieved by combining Uschold's unified methodology for ontology building with a semiotic framework for understanding quality in conceptual modelling. These two frameworks are shown to map well onto each other, and indicates a potential in applying the semiotic framework not merely in evaluation and choice of methodology for ontology building, but also in embodying quality throughout the process of ontology building.

1 Introduction

Enterprise Engineering (EE) is considered an important means towards business perfection. It includes enterprise and business process modelling and results with enterprise information architecture design. All these parts should be integral. EE also contributes to better alignment between business and application. Specifically, it enables efficient change management and continuous co-evolution of both enterprise and information systems.

However, the EE process still remains a labour intensive work, because the analysis and design phases rely heavily on human interpretation. In practice, the biggest communication gap can be observed between system designers and end-users. System designers use a computer terminology at the syntactic level that the users often are unfamiliar with. Similarly, the terminology used by the latter group may be difficult for the former to understand. This conflict is apparent when trying to integrate different levels of abstraction – pragmatic, semantic and syntactic. Transition from one level to another is not trivial.

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Furthermore, the end product of EE is not a homogeneous specification, but rather a collection of loosely correlated fragments with various perspectives focusing on different aspects. The problem becomes evident when the process is geographically or logically distributed. As a result of outsourcing, the interactions often involve not only consumer and supplier, but also sub-contractors with various roles.

The conversion from personal into public knowledge is accompanied by denotations of concepts using signs of some language [24]. The statements of such languages need to enable the receiver understand them as intended by the sender. The knowledge originator and the knowledge consumer rarely communicate directly. Therefore, when knowledge is communicated to others, interpretations become independent of the knowledge originator. In this context, knowledge modelling in the form of ontology is a core issue in the enabling interoperability and facilitating communication between artefacts. The use of ontology to organize information has advantage against the use of plain syntactic techniques [7, 9, 12]. It allows an information description in a more flexible way. It also defines semantics using concepts and provides computer readable instructions for software components. An ontology can be seen as an explicit representation of a shared conceptualization [6] that is formal [25], and will thus encode the semantic knowledge enabling the sophisticated services.

The paper assumes that the co-ordination of the EE process and consolidation of different views is possible by the medium of common reference layer [21]. An ontology is chosen as intermediate layer. It is the meta-data about information (e.g., different views, modelling languages) and interpretation facility that enable more intelligent information-based enterprise specification development and management. Thus the quality of interoperability highly depends on the quality of used ontology.

Methodology is an important means to make ontology building possible for a wider range of developers, e.g., not only a few expert researchers in the field but also companies wanting to develop semantic Web applications for internal or external use. The quality of the underlying ontology will depend on factors such as 1) the appropriateness of the language used to represent the ontology, and 2) the quality of the chosen methodology for the ontology building by means of that language.

This paper proposes a combination of the semiotic quality framework [15] and the unified approach for ontology building [26]. The idea is to apply quality principles developed in information systems and requirements engineering to ontology engineering. The hypothesis is that the goals of a semiotic quality framework are necessary yet not sufficient attributes for the evaluation and for the development of methodological support for high quality ontology building. The paper suggests application of the quality framework as a cornerstone for quality control in ontology building process by assigning quality criteria to each step of the unified approach for ontology building.

The structure of the paper is as follows. In section 2, existing ontology building methodologies are surveyed. In section 3, existing quantitative and qualitative approaches to evaluate the ontology building processes and guidelines are discussed. In section 4, the goals and means of the semiotic quality framework are situated for the ontology building process. In section 5, the quality criteria of the semiotic quality framework are combined with the unified ontology building methodology. Finally, section 6 presents the conclusions and directions for future work.

2 Ontology Building Methodologies

There exist a number of ontology building approaches. According to the organizational knowledge approach [9], an ontology building process consists of four iterative steps: understanding the environment, performing inductive qualitative and quantitative studies, derivation of concepts, and evaluation of the product. In the crossed life cycle approach [5], the ontology building is described as consisting of seven steps: requirements specification, knowledge acquisition, conceptualization, formalization, implementation, integration, and evaluation. In the quality management Web services approach [7, 11], the ontology building is considered as three-step process consisting of definition of ontology's requirements in the form of questions that ontology have to answer, definition of the terminology for the ontology, and ontology specification.

There exist several methodologies which guide the process of semantic Web-based ontology building for varying generality and granularity. However, the methodologies do not provide the ontology creation details, but, primarily, support ontology knowledge elicitation and management. [4] proposes an evolving prototype methodology with six states in ontology life-cycle. [25] proposes a general ontology building framework, which includes quality criteria for formalisation. [23] proposes an application-driven ontology development process which emphasizing the organisational value, integration, and the cyclic nature of the development process.

To increase the scale of practical applications for the semantic Web technologies, the developers need to be provided with method guidelines for the ontology creation. However, only a limited selection of guidelines is found for the semantic Web-based ontology specification languages. For example, [13] presents a tutorial for making ontologies using OWL by means of the open source editor Protégé. [3] presents a user guide for making ontologies in the DAML+OIL, again in Protégé. [18] presents guidelines for making ontologies, called "Ontology Development 101". This method is independent of any specific representation language.

The unified approach [26] attempts to provide a comprehensive methodology in order to facilitate a situated guidance for ontology building. The main ontology building guidelines include a) identifying the steps and techniques that are of general applicability; b) identifying the circumstances in which the non-general techniques apply; and c) attempting to put all together in a coherent framework. The process of ontology building consists of the following basic steps of: (i) identification of purpose for which ontology will be used; (ii) selection level of formality for ontology; (iii) identification of scope, where ontology will be used; (iv) creation of definitions and axioms; and finally, (v) evaluation of the created ontology. Figure 1 illustrates the steps.

The strengths of this approach are the generic applicability and the support for reusability. However, as the unified approach is application centred just like all the above methodologies, it fails in connecting to referents in reality. Generally, criteria to evaluate ontology and ontology building process fall under specific environment characteristics, and the evaluation is performed together with the ontology life cycle [5, 11]. Therefore, evaluation of the final product and iteration of the formal definitions and axiom creation when quality is not assured, are the main drawbacks of this approach.

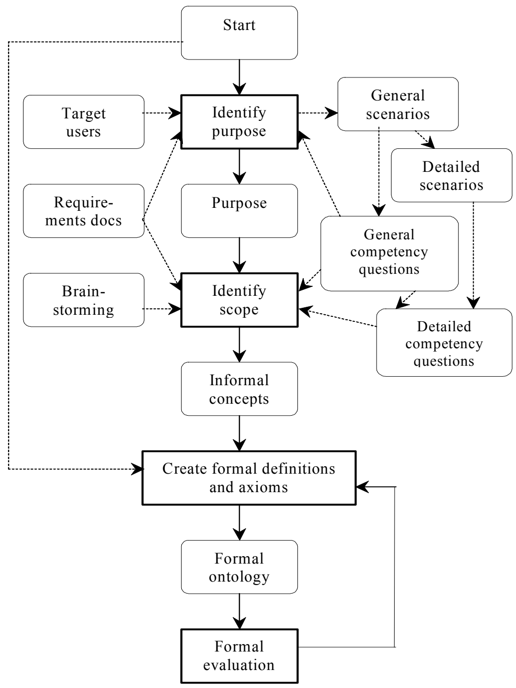

Fig. 1. Unified ontology building methodology approach, adopted from [26]

3 Evaluation Methods for Ontology Building Methodologies

The intersection between ontology building (methods and guidelines) and evaluating of conceptual modelling approaches (i.e., representation languages, method guidelines, and tools) is so far fairly limited. A comprehensive evaluation of the semantic Web enabling representation languages is done in [22]. The study analyzes RDF(S), OIL, SHOE or DAML+OIL and traditional ontology languages such as CycL, LOOM and Telos. The paper also evaluates tools for ontology building, such as Ontolingua, Protégé 2000, OntoEdit, and OilEd. Similarly, [2] evaluates various ontology languages and method guidelines in industrial settings. These works concentrate on evaluating the product and the physical environment for ontology development, rather than methodological support for the building process.

There are a number of frameworks suggested for evaluating conceptual modelling approaches. For instance, the Bunge-Wand-Weber ontology [27] has been used on several occasions as a basis for evaluating modelling techniques, e.g. NIAM [28] and UML [19], as well as ontology languages and tools [2]. The semiotic quality framework [16] for the evaluation of conceptual models had later been extended for evaluation of modelling approaches and used to evaluate UML and RUP [14]. [10] provides a theory of logic, semantic, and situated criteria for conceptual models specifying information requirements, where information demand is dependent of production and relevance of the model.

One of the main steps in ontology and EE is requirements engineering (RE) that assists in discovering the most representative application features. In [20] a framework for evaluation of RE process is analyzed. The framework deals with the representation, agreement and specification dimensions of RE and corresponds to semantic, syntactic and pragmatic quality aspects. In [1] a four worlds model of information modelling and acquisition is analyzed. The worlds provide usage, information system, development, and application aspects as the model context.

The semiotic quality framework [15] for conceptual modelling (figure 2) is anchored in linguistic and semiotic concepts, based on a constructive world view. It describes goals to express quality and means to reach these goals. *Physical quality* deals with two basic goals: externalization, i.e. the explicit knowledge $\boldsymbol{K}_M$ of some person has been externalized in the model ***M*** by the use of a modelling language ***L***; and internalizability, i.e. the externalized model ***M*** is persistent and available, enabling the other persons involved to make sense of it. *Empirical quality* deals with error frequencies when a model ***M*** is read or written by different users, as well as coding and ergonomic of computer-human interaction for modelling tools. *Syntactic quality* is the correspondence between the model ***M*** and the language ***L*** extension of the language in which the model is written. *Semantic quality* is the correspondence between the model ***M*** and the domain ***D***. The framework has two semantic goals: validity and completeness. *Pragmatic quality* is the correspondence between the model ***M*** and social and technical audience's interpretation (***I*** and ***T***) of it. *Perceived semantic quality* is the correspondence between the participants, interpretation ***I*** of a model and their current explicit knowledge $\boldsymbol{K_s}$. *Social quality* has the goal of agreement among participant interpretations ***I***. *Organisational quality* has to fulfil the goals ***G*** of modelling (organizational validity) and address them through the model ***M*** (organizational completeness).

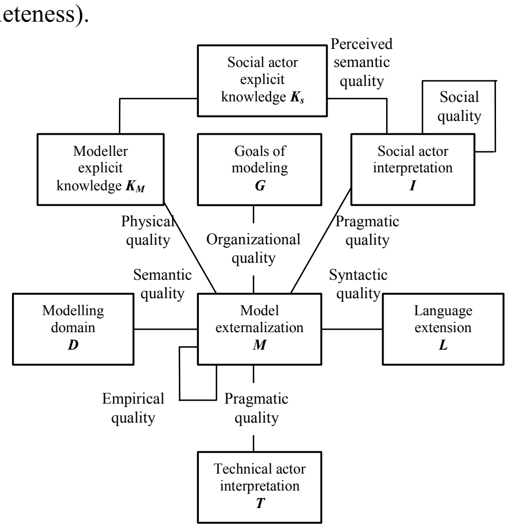

Fig. 2. Semiotic quality framework, adopted from [15]

The semiotic framework has previously been adapted to evaluate the RE facilities [17], ontology languages, tools [22], and guidelines [8]. However, the semiotic framework does not directly apply to existing ontology building methodologies. The level of maturity and the lack of user participation in a typical ontology building process cause the framework to fail in connecting to organisational and social goals.

4 Semiotic Quality Criteria in the Ontology Building Process

The way to build ontology depends on the particular circumstances under which ontology is desired [26]. The initial premises - like *level of formality*, *scope* and *purpose* – should be identified, first. The evaluation of each of these factors (figure 3) could lead to better ontology building.

The **purpose** for ontology building is generally identified in the organizations, when the workers externalize their knowledge and in the form of organizational knowledge. In general the purpose could be *communication*, *interoperability* or *system engineering*. Different purposes require different focus on the quality measures. Physical quality suggests facilities, which has database management functionality for knowledge externalization. Participants' knowledge and domain appropriateness lead to the meta-model adaptation facilities. Semantic validity and completeness require consistency checking, reusing and testing. For both communication and system engineering purposes, it is vital to have social agreement about the ontology, because it involves the participants, who should have the same understanding about the issue. When the purpose is system interoperability, agreement is not a social act, but the technical aspect, since the different systems should 'know' how to use information.

Formality addresses the degree by which a vocabulary is created and meaning is specified. It ranges from *highly informal* to *structured formal*, *semi formal* and *rigorously formal*. Syntactic quality defines the level of language correctness and suggests the means for error preventions, detection and correction. Empirical quality suggests means for readability. Pragmatic quality defines formality comprehension. To deal with comprehension, means for operational semantics (inspection, visualization, and filtering) and executability (animation and simulation) could be used. Highly informal or structured informal ontologies allow involvement of a higher number of participants. The physical externalization deals with participant knowledge appropriateness. If ontology is semiformal or formal, the physical internalizability help to understand the structure and internal concept relationships.

Scope characterizes the nature of the subject matter that ontology is describing. For *domain ontology* scope is defined as particular domain (for example medicine, geology, or finance). Physical internalizability suggests knowledge storing facilities. *Problem solving ontology* is a targeted instrument to find the solution to the problem. Physical quality goal suggests means for participant knowledge (as problem and solution space) externalization. Perceived semantic validity and completeness, semantic validity and organizational completeness in both cases ensure that the knowledge is right and complete in the environment and according to participant knowledge. The scope of ontology building is dealing with *knowledge representation languages*. Syntactic quality suggests means for ensuring syntactic correctness.

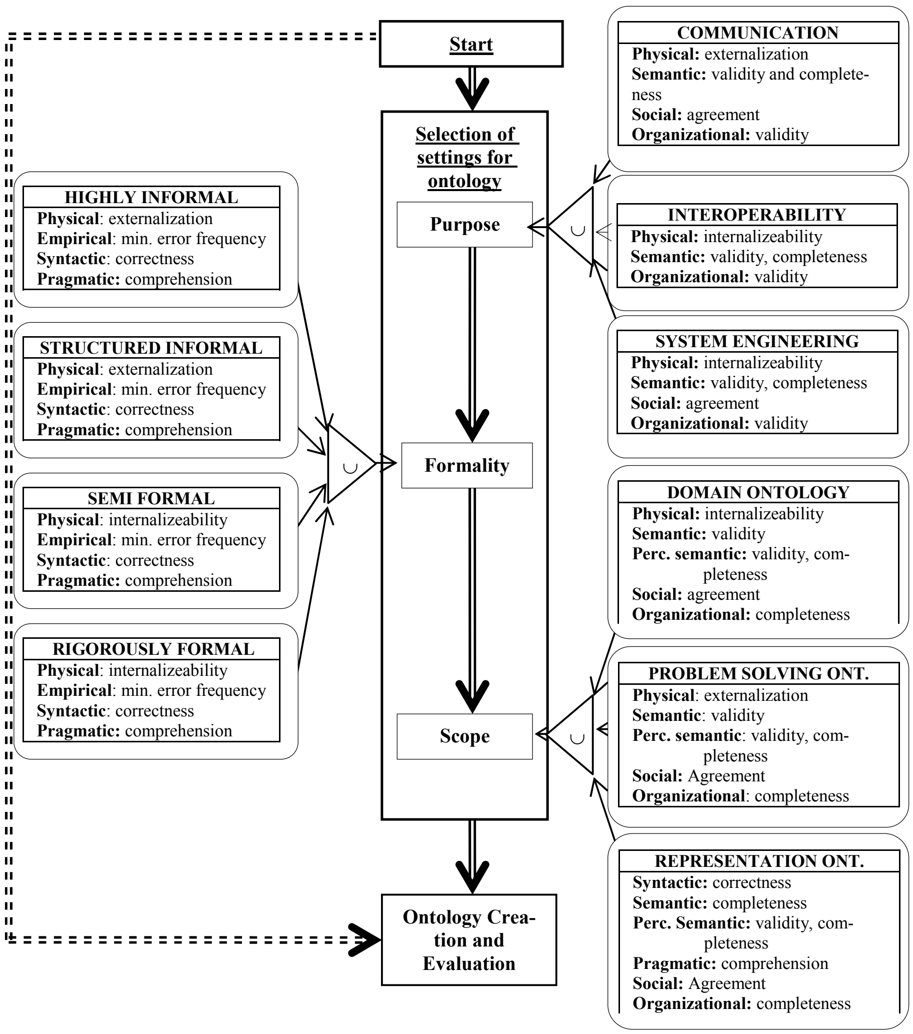

Fig. 3. The semiotic quality framework goals situated for ontology building methodology. ∪ in the triangle indicate, that at least one on the items should be selected for ontology settings.

Here, the output of the above described ontology settings phase is the agreed purpose, formality level and scope. In the following section the synergy effects of combining the unified ontology building approach with the semiotic quality framework are analysed. The results of bridging the shortcomings of both approaches are discussed using the notion of supplementary relationships and correspondences.

5 Suggestion for a Combined Evaluation Framework

The applicability of the goals and means of the extended semiotic quality framework [15] is discussed here with respect to the qualitative characteristics of the unified process [26] for ontology building. The objective is to investigate how can the semiotic quality framework be used in embodying quality, reusability and maintainability in the ontology as a final product, rather, than merely how it is applicable in evaluation, choice and development of methodology. In (Table 1) the ontology building steps have been incorporated with the situational aspects of syntactic, semantic and pragmatic quality dimensions, which are extended with technical and social quality aspects.

Physical quality has the externalisation and internalizeability goals. In order to determine knowledge about the purpose, level of formality, scope of the ontology the requirements elicitation techniques are applied. The externalized knowledge is summarised into comprehensive data dictionaries, which serve as intermediate artefacts for the phases of continuous ontology building. The knowledge about the ontology building should be available and persistent to organisational audience in order to ensure the internalizability goal. Here, the tool support for maintaining repository functionality is helpful to achieve internalizability goal.

Empirical quality is meant to obtain minimal error frequency and it deals with model aesthetics, ergonomics and the way of representation for externalised artefacts. If the model has poor empirical quality, it is difficult for ontology building stakeholders (including social and technical actors) to exchange knowledge for the purpose of either communication, or interoperability or system engineering.

Syntactic quality is obtained through the syntactic correctness goal. The means to achieve this goal are error prevention, error detection, and error correction. Syntactic quality characterises the ontology building scope in terms of granularity and precision. The level of formality describes the audience interpretation of the ontology.

Semantic quality describes the correspondence between a model and the modelling domain. The scope of ontology building is discovered in the organisational environment. The primary outputs of the scoping phase are complete and valid sets of concepts and terms for the proposed ontology. The means include knowledge elicitation techniques, e.g. motivating scenarios, driving competency questions, brainstorming, and reuse of knowledge from previous analysis. Moreover, the means for formal validity and completeness checking benefit in reaching the validity and completeness during the ontology building.

Perceived semantic quality is the correspondence between an actor interpretation of a model and current knowledge. Social actors differ in their education and work experience. Actor training helps to reach the perceived validity and perceived completeness goals. Training is needed during all the ontology building cycle. For example, training in purpose identification helps to externalize more complete and valid knowledge, and training in scope identification helps to elicit more valid and complete lists of concepts for the ontology construction.

Pragmatic quality is the correspondence between the model and audience interpretation of it. Comprehension goal is achieved through model inspections, transformations, visualization, filtering, and prototyping. Operational semantics and executability help to understand the model for social and technical actor.

Table 1. Relationships between unified approach for ontology building and semiotic quality framework. In the cells, '+' - supplementary relationship; '●' - correspondence relationship between the semiotic quality framework and the unified approach for ontology building.

Unified approach for ontology building \ Semiotic quality framework		Physical		Empirical	Sytactic	Semantic		Perceived semantic		Pragmatic	Social	Organisational	
		Externalization	Internalizability	Min.error frequency	Correctness	Validity	Completeness	Perceived validity	Perceived completeness	Comprehension	Agreement	Org. completeness	Org. validity
Purpose	Communication	+		+		+	+				+		+
	Inter-operability		+	+		+	+						+
	System engineering		+	+		+	+				+		+
	– Re-Usability		+										
	– Knowledge acquisition		+								+		
	– Reliability												+
	– Specification	+											+
Formality	Highly informal	+		+	+					+			
	Structured informal	+		+	+					+			
	Semi formal			+	+					+			
	Rigorously formal			+	+	+	+			+			
Subject Matter	Domain ontology	+	+			+		+	+		+	+	
	Problem solving ontology	+				+		+	+		+	+	
	Representation ontology				+		+	+	+	+	+	+	
Ontology creation		+	+	+	+	+	+	+	+	+	+	+	+
Ontology Evaluation	Generic criteria												
	– Clarity			●	●			●	●				
	– Consistency					●	●						
	– Reusability	●	●							●			
	Specific criteria										●	●	●

Social quality deals with actor interpretation and has the goal of agreement. Six agreement types are identified for the ontology building: relative and absolute agreement in ontology interpretation, relative and absolute agreement in knowledge about ontology purpose, scope and level of formality; relative and absolute agreement about the ontology itself. In order to achieve agreement goal, activities related to model viewpoint integration and conflict resolution are performed.

Organisational quality is the correspondence between the model and modelling goals. The goals for ontology building are defined during initial stages, when purpose, formality and scope of the ontology are elicited. To fulfil the organisational quality means to prioritize goals of ontology building (satisfy the organisational validity) and address them through the ontology (satisfy organisational completeness). The goal of the ontology building is to combine the work groups in their situated actions. All the potential audience is regarded to be equally valid. In order to avoid model monopoly the community should be feasibly comprised into the process of ontology building.

Two groups of evaluation criteria – generic and specific – are considered in the unified ontology building approach. The generic criteria are clarity, consistency and reusability of ontology. Clarity corresponds to the empirical, syntactic and perceived semantic qualities in the semiotic quality framework. Reusability clarifies the pragmatic and physical qualities, whereas consistency corresponds to the semantic quality. The project specific criteria are defined in a physical environment for a particular ontology. Such specific criteria include manual ontology checking against the identified purpose, user requirements document, informal competency questions and similar techniques. They correspond to social and organisational qualities.

Finally, it is observed that the semiotic quality framework embodies both the generic and the specific criteria. It also provides means to control the quality during the ontology building process, rather than in the creation step only. Thus, given the above distribution and allocation of quality criteria and goals quality is throughout the process of ontology building embodied in the product.

6 Concluding remarks

The usage of an ontology building methodology is decisive for ontology-based interoperability in heterogeneous enterprise engineering environment. A methodology provides process and guidance for producing ontology that facilitates management of the EE products. A control of systematic approach for ontology building is needed in order to increase the quality, reusability and maintainability of the final product. High quality specification is required to obtain semantic interoperability both in the ontology building and among the humans and the artefacts utilizing the specifications.

The working hypothesis of the research is that in combination with an ontology construction method, the semiotic framework [15] is applicable not merely in evaluation and choice of methodology but in embodying quality, reusability and maintainability in the ontology as a final product. Application of the ontology building for a Web-based knowledge management is based on trying out languages and tools and analytically evaluating ontology construction guidelines. However, it was argued that the framework does not directly apply to evaluation of existing ontology building methodologies. [26] proposes the unified approach for ontology building based on overview of ontology building methodologies.

The technical contribution of this paper lies in consolidating the semiotic quality framework [15] with the unified ontology building approach [26], where a preliminary evaluation framework for ontology building has been constructed. The work presented here is a first step towards a generic and context insensitive quality framework for evaluation, choice, improvement and development of methodology for ontology building. In each step of ontology building the situational aspects have been incorporated with syntactic, semantic and pragmatic quality dimensions.

It is shown that the ontology evaluation step of the unified approach covers all of the quality criteria of the semiotic quality framework. However, the unified methodology concerns only the evaluation of the final product. Whereas, in this approach the quality criteria and goals are distributed and allocated to each step. Furthermore, the analysis of the supplementary relationships demonstrates that the consolidated framework is suitable to guide towards high quality methodology for ontology building.

Ontology creation concerns modelling activities and has many features of conceptual modelling. Quality control during the ontology creation is case sensitive and depends on a chosen ontology language. Integration of language specific quality constraints is a next step for improving applicability of the approach presented in this paper. Furthermore, guidelines for situational applicability should be added, for instance, through connecting criteria to generic and specific requirements. We acknowledge the necessity to prepare, not only a general framework, but also to facilitate definition of possible situational combinations. Then, decisions in one step will guide and filter out the options for the next step, e.g. when prioritizing re-usability and interoperability, the rigorously formal ontology should be the only one way to go in order to achieve high quality product.

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