

Quality in Conceptual Modeling – New Research Directions

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Abstract. Quality is currently one of the main research topics in conceptual modeling. In this paper nine new research contributions are organized using a classification framework that is based on the well-known framework for conceptual modeling quality of Lindland, Sindre, and Sølvberg. The aim of this work is to identify new directions in conceptual modeling quality research.

1 Introduction

Quality has been identified as one of the main topics in current conceptual modeling research [6]. In this paper we classify nine new research contributions, accepted for the first International Workshop on Conceptual Modeling Quality¹, using the framework of conceptual modeling quality that was proposed by Lindland, Sindre, and Sølvberg [4] in the mid-nineties. Although since its proposal, the Lindland et al. framework has been repeatedly extended and several alternative frameworks have been developed, its role as inaugural work in this field of research is undisputed. The comprehensive nature of the framework allows us to link, compare and differentiate the workshop contributions in order to identify related work and current areas of interest and to sketch a (necessarily incomplete) state-of-the-art in conceptual modeling quality.

We hope that this paper will help to better evaluate the different contributions in order to assess their scope and value. We also hope that this exercise will help to

¹ The first International Workshop on Conceptual Modeling Quality (IWCMQ'02) was held in conjunction with the 21st International Conference on Conceptual Modeling (ER'02) in Tampere, Finland, on October 11, 2002.

discern uncovered areas, remaining research questions, and future opportunities for research in conceptual modeling quality.

The rest of this paper is structured as follows. In section 2 the basic ideas underlying the Lindland et al. framework and some of its extensions are presented. We further discuss how the framework can be used to classify and structure the nine workshop papers. The actual classification and comparison of the workshop contributions is presented in section 3. Finally, in section 4 we summarize our work by distilling the new research directions in conceptual modeling quality as observed in the workshop contributions.

2 A Classification Framework

High quality conceptual models are critical to the success of system development efforts. Despite this importance, quantitative methods for evaluating conceptual model quality are virtually nonexistent. Even definitions of quality (when they are given) are vague and complicated, and there is no underlying structure that helps the user to understand how the properties relate to one another. Lindland, Sindre, and Sølvsberg [4] addressed this problem with a systematic examination of the nature of quality in conceptual models.

The original framework consisted of three types of model quality: syntactic, semantic, and pragmatic quality. Syntactic quality describes how well the model follows the rules of the modeling language. Semantic quality describes how well the model captures the domain of interest within the context of the user. Pragmatic quality captures how well a conceptual model is understood by its audience. Within each of these types of quality are two main quality concepts: completeness and validity. A model is complete if it contains all of the elements of the domain. It is valid if it does not contain any elements that are not in the domain.

This framework was extended by Nelson, Monarchi, and Nelson [5] to include two types of quality that cover the earliest stages of modeling and one type that gives an overall assessment of model quality. Perceptual quality measures how well the actors within the domain of interest understand that domain. Descriptive quality measures the ability of the modeler to elicit a description of that domain. Finally, inferential quality measures how well the conceptual model as understood by the audience matches the original domain.

These six types of quality form the first dimension for classifying conceptual model quality research. Another useful dimension is the object of the study. Quality research can focus on any (or all) of three modeling objects. The first object is the conceptual model itself, the product of the modeling activity. The second object is the process of creating the model. In general, the quality of the modeling process is directly proportional to the quality of the model produced by the process. If the modeling process is of high quality, then the conceptual model that is produced should also be of high quality. The third object is the modeling facility. The modeling facility includes all of the tools, techniques, and controls that are used to direct the modeling process.

The final conceptual model quality research classification dimension is the research goal. There are five research goals in the classification framework: understanding, measuring, evaluating, assuring, and improving conceptual model quality. Research into understanding quality seeks to define the various dimensions, or measures, of quality. It develops the scales that can be used to determine quality. Measuring quality examines how to apply those dimensions against conceptual models. Research that evaluates quality explores the correlation between the quality measurements and real-world experiences with the model. For example, how various measurements correlate with model understanding, model maintenance, and so on. Quality assurance research examines how to ensure that the process that produces the conceptual model actually does produce a quality model. Finally, the research into improving quality examines how to make conceptual model quality better.

The three classification dimensions that form the framework are summarized in the table below. In the next section, we will use the classification framework to organize the research contributions in the workshop.

Table 1. Quality research classification dimensions

Type of Quality	Object of Study	Research Goal
perceptual quality	product	understanding quality
descriptive quality	modeling process	measuring/assessing quality
syntactic quality	modeling facility	evaluating quality
semantic quality		assuring quality
pragmatic quality		improving quality
inferential quality		

3 Classification of New Research Contributions

In this section we classify the nine papers along the dimensions proposed in the previous section. The section is structured according to an initial grouping that is roughly based on the type of conceptual model considered. The same structure has been used for the workshop agenda. We end this section by summarizing our classification efforts.

3.1 Requirements and Entity Relationship Models

Two of the papers propose techniques to improve the quality of conceptual data models developed using Entity Relationship (ER) modeling. In his paper, Bowers presents and demonstrates an algorithm to detect redundant relationships in ER models. The presence of such relationships may cause automatically generated relational schemas to be un-normalized. In terms of the Lindland et al. framework, this work contributes towards developing a modeling activity (i.e. using an algorithm, implemented in a CASE tool, to detect and subsequently remove redundant relationships) to ascertain the presence of a quality-carrying property (i.e. the absence

of redundant relationships) with the goal of improving quality. The type of quality considered is pragmatic quality, in the sense of making the conceptual model easier to use by the techniques that generate relational schemas from ER diagrams. It should be noted that in the Lindland et al. framework, users of conceptual models include technical actors, like for instance CASE tools, which need to 'understand' the model.

In another paper related to ER modeling, Danoch, Shoval, and Balaban present a method, called HERD, to create hierarchical ER diagrams starting from a 'flat' diagram. In their paper, Danoch et al. describe the design and results of an experiment to compare the user comprehension of hierarchical and flat ER diagrams. Like Bowers, the authors propose a means (i.e. the HERD method) to assure a quality-carrying model property (i.e. being hierarchically structured) to improve pragmatic quality. The experiment aims at evaluating the effectiveness of this method.

The paper of Matulevicius and Strasunskas is different from the other workshop contributions in the sense that it does not focus on the quality of a conceptual model as a product, but on the quality of modeling facilities. Their proposal concerns a new quality framework to evaluate the validation and verification capabilities of requirements engineering (RE) tools. The authors show that their evaluation framework covers all quality dimensions in the semiotic framework for conceptual modeling quality by Krogstie, Lindland, and Sindre [3]². They further test the framework on a set of commercial RE tools and compare the results of their evaluation with an independent survey of RE tools.

3.2 Class Models and Architectures

The quality of UML class diagrams is the topic of two workshop papers. But apart from the object of study these papers take different positions in our classification framework.

Letelier and Sanchez present a graphical animation environment that is used to animate the behaviour of an object system that is specified in a UML class diagram. They propose animation as a means to help assuring the 'right' product functionality. Through animation differences between stakeholder requirements and the conceptual model can be detected. The type of quality concerned is therefore semantic quality. As a proof of concept the authors apply their animation tool on a simple banking example.

Instead of quality assurance, the goal of the work of Genero, Olivas, Piattini, and Romero is quality prediction. They propose a set of metrics to measure the structural complexity (i.e. a quality-carrying property) of UML class diagrams and conduct a controlled experiment to show a relationship with the maintainability (i.e. a pragmatic quality issue) of the diagrams. By means of a machine learning technique called Fuzzy Prototypical Knowledge Discovery, the authors were able to build a

² This framework is another extension of the Lindland et al. framework. It adds two lower-level, technical quality aspects (i.e. physical quality and empirical quality) and one higher-level, social quality aspect (i.e. social quality) to the syntactic, semantic, and pragmatic quality types.

maintainability prediction model based on structural complexity metrics. This work addresses the need for 'quantization' of conceptual modeling quality, as suggested by Lindland et al. [4]. The metrics-based prediction model can be considered as an indirect measurement instrument for UML class diagram maintainability.

The paper of Avgeriou, Retalis, and Skordalakis is different from the other contributions as the object of study is a high-level systems design artifact, rather than a conceptual model. This paper describes the use of a new architectural quality evaluation framework, similar to the quality frameworks for conceptual modeling, to evaluate a proposed software architecture for learning management systems. By applying their framework the authors show that pragmatic quality attributes are built into the architecture.

3.3 Web and Interactive Models

Two of the workshop papers propose instruments to measure and evaluate the quality of conceptual representations of web artifacts. Comai, Matera, and Maurino present a new quality model for conceptual schemas that are specified using the WebML modeling language. This quality model is related to the Lindland et al. framework in the sense that it incorporates different types of quality, including syntactic quality (e.g. syntactic correctness), semantic quality (e.g. semantic correctness) and pragmatic quality (e.g. usability attributes). As a quality model (instead of a purely conceptual framework) the proposal of Comai et al. also addresses the need to decompose quality goals into measurable attributes, as suggested by Lindland et al. in [4]. The authors further present and demonstrate an XSL-based framework, called WebML Quality Analyzer, as a tool to automatically measure and evaluate the quality attributes of WebML conceptual schemas.

Abrahao, Olsina, and Pastor describe the WebFP_QEM methodology for evaluating the quality of operative web sites and applications. This methodology considers both quality aspects related to nonfunctional requirements (i.e. pragmatic quality) and functional requirements (i.e. semantic quality). In their paper, the authors specifically discuss the interplay between conceptual modeling (using the OOWS modeling approach) and measurement (using new structural complexity metrics for object models, agents, navigational maps and navigational context). They demonstrate their ideas using a simple example of adaptive maintenance of an e-commerce web application. The empirical validation of the metrics, as in the previously mentioned paper of Genero et al., is listed as a topic for further work.

In the final paper we discuss here, Krogstie and Jorgensen propose a further extension of the conceptual modeling quality framework of Krogstie et al. [3]. Their new framework is specifically intended to better understand the quality of interactive models, which are a special type of active models.

3.4 Summary

Table 2 summarizes our classification efforts. Each paper is identified by its first author.

Table 2. Classification of new contributions to conceptual modeling quality research

Paper	Type of Quality	Object of Study	Research Goal
Bowers	pragmatic	product	improving
Danoch	pragmatic	product	improving
Matulevicius	syntactic semantic pragmatic other	modeling facility	evaluating
Letelier	semantic	product	assuring
Genero	pragmatic	product	measuring
Avgeriou	pragmatic	product	evaluating
Comai	syntactic semantic pragmatic	product	measuring, evaluating
Abrahao	semantic pragmatic	product	measuring, evaluating
Krogstie	syntactic semantic pragmatic other	product	understanding

4 Conclusions

The diverse nature of the conceptual representations that are the object of study in the papers accepted for IWCMQ'02 demonstrates the bridge function fulfilled by conceptual modeling. As an early stage activity, conceptual modeling plays a crucial role in software, database, and web development. Therefore the success of systems development strongly depends upon the quality of the conceptual models that are produced. The massive response to the workshop's call for papers³ is another evidence of the huge importance of quality in conceptual modeling products, processes, and facilities. It also shows that quality issues are nowadays high on the agenda of conceptual modeling researchers.

Although the workshop papers cover diverse application domains and focus on many different types of conceptual models, our classification shows that the main emphasis of current research efforts is product quality. In spite of the need for quality-related process guidelines and quality assurance of modeling processes in general (already recognized in the frameworks of Krogstie et al. [3] and Nelson et al. [5]), it seems that current research has largely disregarded quality aspects of conceptual modeling processes and facilities. Given that quality processes result in quality products, we identify this topic as a major opportunity for future research in conceptual modeling quality.

³ The nine accepted papers represent less than half of the submitted papers.

Regarding the types of quality considered in the papers, the main focus is on pragmatic quality and, to a lesser extent semantic quality. The concern for pragmatic quality issues is not unrelated to the current interest in the quality of software development artifacts. Syntactic quality issues seem to be well understood and supported by automated tools. The other quality types, added by the Nelson et al. framework, are not addressed, perhaps because they do not lend themselves easily to objective measurement [5].

In section 2, the goals of conceptual modeling quality research were organized into a hierarchical structure. According to our classification, workshop papers are found at each level. Some papers focus on understanding quality by elaborating a conceptual framework or multi-level quality model for specific types of model (or modeling facilities). A subset of these papers go further by using the framework or model as a practical quality assessment and evaluation instrument. Other papers aim at developing objective and automatically computable measurement instruments (i.e. metrics) for quality attributes of conceptual models. In domains where quality seems to be reasonably well understood (e.g. static conceptual models like Entity Relationship diagrams and class diagrams), research aims at techniques to assure and improve model quality. In other domains, like web development, the quality of the conceptual models is a relatively new research topic that needs to be further elaborated.

As another idea for future research we like to stress that, to our knowledge, little work has been done towards measuring, evaluating and assuring the quality of conceptual representations of behavior, activities, processes, etc.. The need for more research on the quality of functional and dynamic models has also been pointed at in the recent software engineering literature (see e.g. [1]).

We end this paper by drawing the attention upon the research method employed in the papers that we discussed. Although some papers include a well-designed experiment or a representative case study, in most papers new research ideas are only illustrated by means of some proof of concept. We believe that to grow into a mature research discipline more scientific validation is needed. Again we refer to recent developments in software engineering research, where there is a remarkable increase in empirical validation efforts of existing or new theories, methods, techniques, and tools. We believe that research in conceptual modeling quality can benefit from the experiences and guidelines of empirical software engineering research (see e.g. [2], [7]). Clearly more quality models and metrics are needed, but also a thorough validation of these models and metrics in a real (or realistic) environment.

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