Defining quality aspects for conceptual models

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Abstract

The notion of quality for information system models and other conceptual models is not well understood, and in most literature only lists of useful properties have been provided. However, the recent framework of Lindland et al. has tried to take a more systematic approach, defining the notions of syntactic, semantic, and pragmatic quality of models, and distinguishing between quality goals and the means to achieve them. Here, this framework is extended by discussing the six semiotic layers of communication identified by FRISCO. Definitions are provided for physical, syntactic, semantic, pragmatic, and social quality, respectively, and to the extent possible, metrics are provided for the defined quality goals. In addition the related areas of language and knowledge quality are discussed briefly.

Keywords

Quality, information system models, semiotics

1 INTRODUCTION

Within the information system field it is generally accepted that the quality of the information system is highly dependent on decisions made early in the development. The construction of *conceptual models* is often an important part of this early development. Although the importance of model quality is widely acknowledged, little work has been put into defining concepts and criteria for explaining factors affecting model quality. In several frameworks (Davis, 1990), (Kung, 1983), (Roman, 1985), and (Yeh et al., 1984) a set of useful properties for a good model is proposed.

However, the concepts varies among the frameworks and many of their definitions are vague, complicated, and in some cases lacking (Lindland et al., 1994).

A more recent framework proposed by Lindland et al. defines quality *goals* for conceptual models and *means* to achieve the goals. The goals and means are categorized into three main types: *syntactic, semantic* and *pragmatic*.

FRISCO (FRISCO, 1995; Lindgren ed., 1990) suggest that communication and related issues can be discussed according to six semiotic layers: *physical, empirical, syntactical, semantic, pragmatic* and *social*. Since one of the main roles of a conceptual model is to enhance communication, the quality of the model will be influenced by its communication properties. Thus, it is interesting to discuss model quality using the six semiotic layers. Lindland's framework has in its current version already used three of the layers.

Based on this observation, this article will review and compare the interpretations of the concepts given in Lindland's framework and the six semiotic layers. An extension of the framework will be proposed in order to cover more of the six layers.

The article is structured as follows: Section 2 reviews and compares Lindland's framework and the semiotic levels whereas Section 3 introduces an extended framework before quality goals and means to achieve these goals on the different levels are presented. Section 4 offers some concluding remarks.

2 REVIEW AND COMPARISON

We will in this section review the existing framework of Lindland et al. and compare the way of thinking with the differentiation in semiotic levels done in FRISCO.

2.1 Lindland/Sindre/Sølvberg's framework

The main structure of the framework by Lindland et al. is illustrated in Figure 1. The basic idea is to evaluate the quality of models along three dimensions — syntax, semantics, and pragmatics — by comparing sets of statements. These sets are:

- $\mathcal{M}$, the model, i.e., the set of all the statements explicitly or implicitly made in the model. The explicit model, $\mathcal{M}_E$ consist of the statements explicitly made, whereas the implicit model, $\mathcal{M}_I$, consisting of the statements not made but implied by the explicit ones.
- $\mathcal{L}$, the language, i.e., the set of all statements which are possible to make according to the vocabulary and grammar of the modeling language used.
- $\mathcal{D}$, the domain, i.e., the set of all statements which would be correct and relevant about the problem at hand.
- $\mathcal{I}$, the audience interpretation, i.e., the set of all statements which the audience (i.e., various stakeholders of the modeling process) think that the model consists of.

The primary sources for model quality are defined using the relationships between the model and the three other sets:

- *syntactic quality* is the degree of correspondence between model and language, i.e., the set of syntactic errors is $\mathcal{M} \setminus \mathcal{L}$.

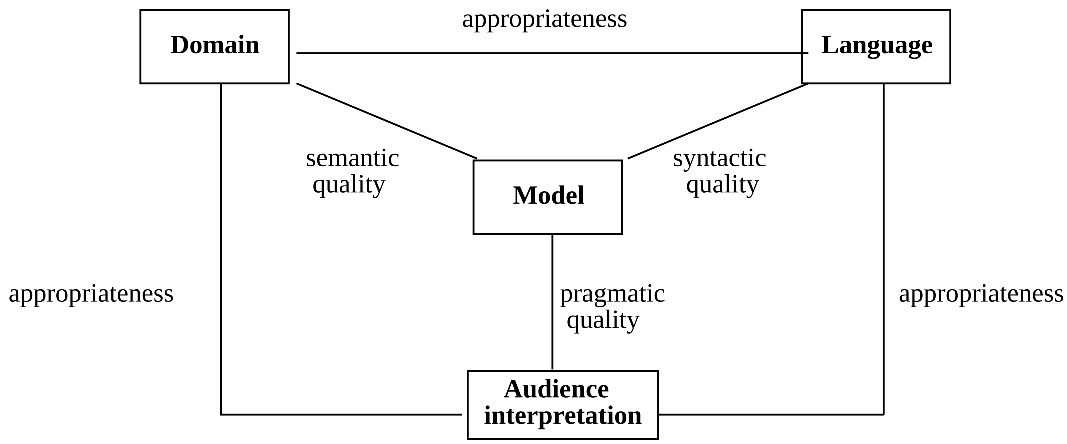

Figure 1: The framework by Lindland et al. (From (Lindland et al., 1994)).

- *semantic quality* is the degree of correspondence between model and domain. If $\mathcal{M} \setminus \mathcal{D} \neq \emptyset$ the model contains invalid statements; if $\mathcal{D} \setminus \mathcal{M} \neq \emptyset$ the model is incomplete. Since total validity and completeness are generally impossible, the notions of *feasible validity* and *feasible completeness* were introduced. Feasible validity is reached when the benefits of removing invalid statement from $\mathcal{M}$ are less than the drawbacks of the effort, whereas feasible completeness is reached when the benefits of adding new statements to $\mathcal{M}$ is less than the drawbacks of the effort.
- *pragmatic quality* is the degree of correspondence between model and audience interpretation (i.e., the degree to which the model has been understood). If $\mathcal{I} \neq \mathcal{M}$, the comprehension of the model is somehow erroneous. Usually, it is neither necessary nor possible that all stakeholders understand the entire conceptual model - instead each member of the audience should understand the part of the model which is relevant to him or her. *Feasible comprehension* was defined along the same lines as feasibility for validity and completeness.

In addition to these primary quality concerns, it is pointed out that correspondence between domain and language, between domain and audience interpretation, and between language and audience interpretation may affect the model quality indirectly. These relationships are all denoted *appropriateness* as shown in Figure 1.

It was also argued that previously proposed quality goals are subsumed by the four goals of syntactic correctness, validity, completeness, and comprehension, and a distinction is made between goals and means to reach these goals. For more details on this framework, the reader should consult (Lindland et al., 1994).

2.2 The semiotic layers in FRISCO

The FRISCO report (Lindgren ed., 1990) identifies that the means of communication and related areas can be examined in a semiotic framework. The below semiotic layers for communication are distinguished, forming a so-called semiotic ladder. Together with the description is listed a number of of illustrative terms, which are examples of concepts often treated at the levels in question.

- *Physical:* This layer concentrate on the physical appearance, the media, and amount of contact available. Examples of concepts treated are signals, traces, hardware, component density, and speed.
- *Empirical:* This layer concentrate on aspects such as the entropy, variety, and equivocation encountered. Examples of concepts treated are pattern, variety, noise, entropy, channel capacity, codes, efficiency, and redundancy.
- *Syntactic:* This layer looks on the language, the structure and logic used. Concepts such as formal structure, language, logic, data, records, files, and software are often discussed.
- *Semantic:* The meanings and validity of what is expressed is covered on this layer, discussing concepts such as meanings, propositions, validity, truth, and signification.
- *Pragmatic:* The pragmatic layer concentrate on the intentions and signification behind the expressed statements including concepts such as intentions, communication, conversation, and negotiation.
- *Social:* Finally this layer discuss the interests, beliefs, and commitments shared as a result of the communicative process, covering concepts such as beliefs, expectations, commitments, contracts, laws, and culture.

These layers can be divided into two groups in order to reveal the technical vs. the social aspect. Physics plus empirics plus syntactics comprise an area where technical and formal methods are adequate. However, semantics plus pragmatics plus the social sphere cannot be explored using those methods unmodified.

A problem when discussing an area is that people, when using multi-layer related terms frequently fail to mention the layer they are focusing on, which may result in severe misunderstanding.

2.3 Overall comparison

We see that the framework suggested by Lindland et.al. to some extend take the insight from semiotics into account by differentiating between syntactic, semantic, and pragmatic quality. Even if the terms are used somewhat differently, the overall levels can be said to coincide. On the other hand, neither the lower physical and empirical level or the social level can be said to be discussed and covered in the existing framework. For instance is not the social aspects of agreement currently handled in a satisfactory way. Even if people understand the requirements, this does not mean that they will agree to them. When discussing agreement, the concept of domain as currently defined is also insufficient, since it represents some ideal knowledge about a particular problem, a knowledge not obtainable by those that are to agree. We will in this article look upon how to include these levels in the framework for discussing the quality of conceptual models.

3 EXTENDING THE FRAMEWORK

After the introduction of the extended overall framework, the quality concepts for each of the semiotic layers is given in subsections 3.2–3.8, respectively.

3.1 Overall framework

Conceptual modeling can be looked upon as a process of social construction (Berger and Luckmann, 1966; Gjersvik, 1993). The mechanisms of social construction in an organization when constructing conceptual models can briefly be described as follows: An organization will consist of individual social actors that see the world in a way specific to them. The *local reality* is the way the individual perceives the world that s/he acts in. The term 'individual knowledge' as used below restricted to the explicit local reality of an individual actor. When the social actors of an organization act, they *externalise* their local reality. The most important ways the social actors of an organization externalise their internal realities, are to speak and to construct languages, artifacts and institution. What they do is to construct *organizational reality*: To make something that other actors have to relate to in their work. This organizational reality may consist of different things, for instance conceptual models and computerized information systems. Finally, *internalization* is the process of making sense out of the actions, institutions, artifacts etc. in the organization, and making this organizational reality part of the individual local reality.

Based on the discussion above we are now ready to define the extensions of the framework to Lindland et al. The main concepts and their relationships are shown in Figure 2. Most of the sets of statements defined below will potentially change during the development and maintenance of an computerized information system. A statement is defined as a sentence representing one property of a certain phenomenon. What constitutes a statement in a given language must be defined for each language used for modeling to be able to actually count statements.

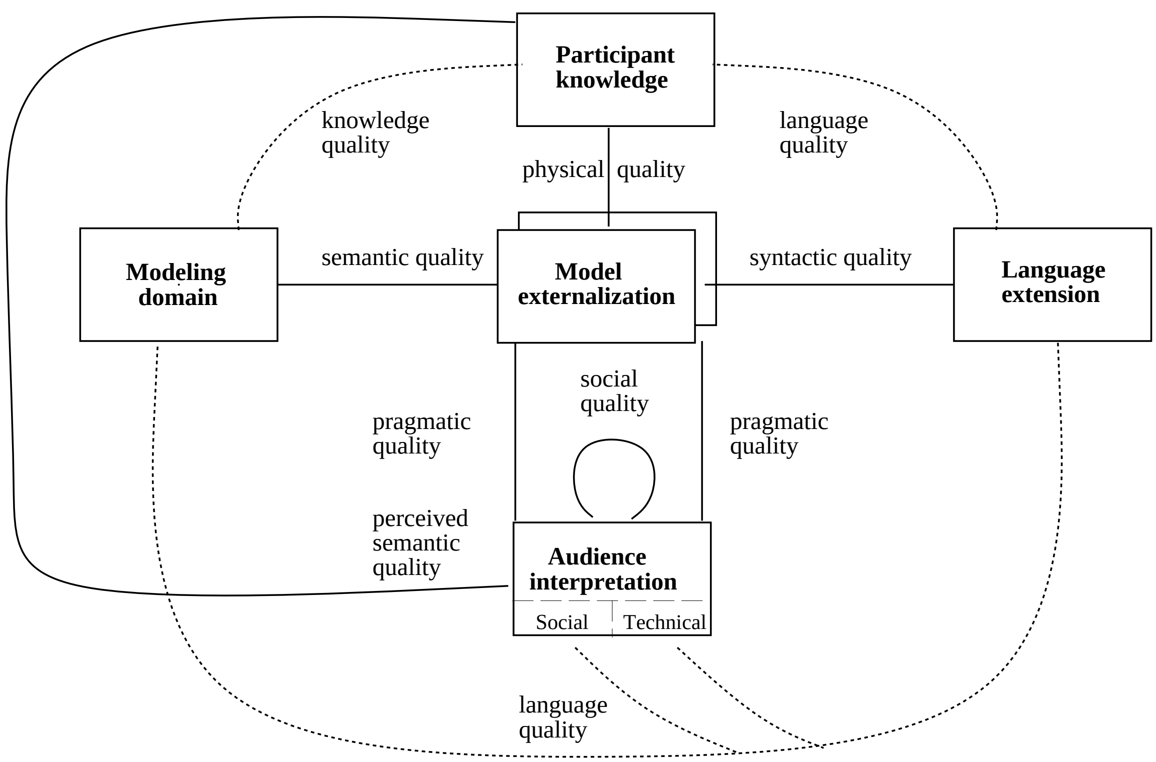

Figure 2: Extended framework.

- $\mathcal{A}$, the audience, i.e., the union of the set of individual actors A_1,...,A_k the set of organizational social actors A_{k+1},...,A_n and the set of technical actors A_{n+1},...,A_m who needs to relate to the model. The individual social actors being members of the audience is called the *participants* of the modeling process.
  A technical actor is typically a computer program e.g. a CASE-tool, which must 'understand' part of the specification to automatically manipulate it to for instance perform execution based on the conceptual model.
- $\mathcal{L}$, the language, or more precisely the language extension, i.e., the set of all statements that are possible to make according to the vocabulary and syntax of the modeling languages used. Several languages can be in use at the same time, corresponding to the sets $\mathcal{L}_1$,...,$\mathcal{L}_j$. Such sub-languages are related to the complete language by limitations on the vocabulary or on the set of grammar rules in the syntax or both.
  The statements in the language model for a formal or semi-formal language L_i are denoted $\mathcal{M}(L_i)$.
  $\mathcal{L}$ can be divided into three subsets, $\mathcal{L}_I$, $\mathcal{L}_S$, and $\mathcal{L}_F$ for the informal, semi-formal and formal parts of the language, respectively. A language with formal syntax is termed semi-formal, whereas a language which also has formal semantics, is termed formal (Pohl, 1994).
- $\mathcal{M}$, the externalized model, i.e. the set of all statements explicitly or implicitly made in the model. For each individual social actor, the part of the model which is considered relevant for the actor can be seen as a projection of the total model, hence $\mathcal{M}$ can be divided into projections $\mathcal{M}^1, ..., \mathcal{M}^k$ corresponding to the involved participants $A_1, ..., A_k$. Generally, these projections will not be disjoint. A model written in language L_i is written $\mathcal{M}_{L_i}$.
- $\mathcal{D}$, the domain, i.e. the set of all statements which would be correct and relevant about the situation at hand. '$\mathcal{D}$' denotes the 'ideal' knowledge and is used as a conceptual fixpoint to enhance terminology discussions. In developing computerized information systems, one can recognize several interrelated domains, e.g. the existing information system as it is perceived, the requirements to a new information system, and the requirements to a new computerized information system.
- $\mathcal{K}$, the relevant explicit knowledge of the audience, i.e., the union of the set of statements, $\mathcal{K}_1$,...,$\mathcal{K}_k$, one for each participant. $\mathcal{K}_i$ is all possible statements that would be correct and relevant for addressing the problem at hand according to the explicit knowledge of the participant A_i. $\mathcal{K}_i \subset \mathcal{K}^i$, the explicit internal reality of the social actor A_i. $\mathcal{M}_i$ is an externalization of $\mathcal{K}_i$ and is a model made on the basis of the knowledge of the individual or organizational actor. Even if the internal reality of each individual will always differ to a certain degree, the explicit internal reality concerning a constrained area might be equal, especially within certain groups of participants (Gjersvik, 1993; Orlikowski and Gash, 1994), thus it can be meaningful to also speak about the explicit knowledge of an organizational actor.
  $\mathcal{M}_i \setminus \mathcal{M}^i = \emptyset$, whereas the opposite might not be true, i.e. more of the total externalized model than the part which is an externalization of parts of an actors internal reality is potentially relevant for this actor.
- $\mathcal{I}$, the audience interpretation, i.e., the set of all statements which the audience think that an externalized model consists of. Just like the externalized model itself, its interpretation is projected into $\mathcal{I}_1, ..., \mathcal{I}_n$ denoting the statements in the externalized model that are understood by each social actor. In addition is the model also projected into $\mathcal{I}_{n+1}, ..., \mathcal{I}_m$

denoting the statements in the conceptual model as they are 'understood' by each technical actor in the audience.

The primary goal for semantic quality is a correspondence between the model and the domain, but this correspondence can neither be established nor checked directly: to build the model, one has to go through the audience's understanding of the domain, and to check the model one has to compare this with the audience's interpretation of the model. Hence, what we do observe at quality control is not the actual semantic quality of the model, but a perceived semantic quality based on comparison of the two imperfect interpretations.

3.2 Physical quality

The basic quality features on the physical level is externalizability, that the knowledge of some social actor has been externalized by the use of a conceptual modeling language, and internalizability, that the externalized model is persistent and available enabling participants to make sense of it. Sense-making and internalization is looked into in particular after the discussion of pragmatic and social quality below.

Externalizability can be defined as:

$$externalizability = 1 - \frac{\#(\mathcal{K} \backslash \mathcal{M})}{\#(\mathcal{K})}. \qquad (1)$$

The major mean for achieving this is the domain and participant knowledge appropriateness of the modeling language used, as will be discussed briefly under language quality.

Internalizability on the physical level has two primary means, persistency and availability:

- **persistency:** One measure for the upper bound of persistency of a model is

  $$persistency = 1 - \frac{\sum_{s \in \mathcal{M}_E} p(s)}{\#\mathcal{M}_E}. \qquad (2)$$

  where *p(s)* is the probability that the statement *s* will be lost.
- **availability:** This is dependent on its externalization and since the model is usually of interest to several actors, availability also depends on distributability, especially if members of the audience are geographically dispersed. One measure for the availability of a model is

  $$availability = \frac{\sum_{i=1}^{k} \sum_{s \in \mathcal{M}^i} E(t_{avail}(s) - t_{make}(s))}{k * \#\mathcal{M}_i}. \qquad (3)$$

  where $t_{make}(s)$ is the time when a statement is externalized in the model, and $t_{avail}(s)$ is the time when the statement is available to the social actor A_i, i.e., the measure is the average over involved participants of expected delays from a statement is made till it is available.

Main activities in connection with physical quality are typical based on traditional database-functionality.

3.3 Empirical quality

Communication about models mostly require human participation. The comprehension of models has been dealt with in (Lindland et al., 1994) in connection with pragmatic quality. Hence, it can be questioned whether the notion of 'empirical quality' really has any mission here. Since the measure for persistency will also take care of the problem that parts of the model will be lost in transmission etc., we cannot at the moment see the need for providing any measure of empirical quality for models. This issue will be further elaborated on in Sections 3.7 and 4.

3.4 Syntactic quality

Syntactic quality is the correspondence between the model $\mathcal{M}$ and the language extension $\mathcal{L}$ of the language in which the model is written. There is only one syntactic goal, **syntactical correctness**, meaning that all statements in the model are according to the syntax of the language, i.e.

$$\mathcal{M} \setminus \mathcal{L} = \emptyset. \tag{4}$$

The degree of syntactic quality can be measured as one minus the rate of syntactically erroneous statements, i.e.

$$syntactic\,quality = 1 - \frac{\#(\mathcal{M}_E \setminus \mathcal{L})}{\#\mathcal{M}_E}. \tag{5}$$

Typical means to ensure syntactic quality is *formal syntax* of the modeling language used, i.e., that the language is parseable by a technical actor, and the modeling activity to perform this is termed syntax checking.

3.5 Semantic quality

Semantic quality is the correspondence between the model and the domain (Lindland et al., 1994), where the domain is considered the ideal knowledge about the situation to be modeled. Our framework contains two semantic goals; **validity** and **completeness**.

- **Validity** means that all statements made by the model are correct and relevant to the problem, i.e. $\mathcal{M} \setminus \mathcal{D} = \emptyset$.
  A possible definition for the degree of validity is

  $$validity = 1 - \frac{\#(\mathcal{M}_E \setminus \mathcal{D})}{\#\mathcal{M}_E}. \tag{6}$$

  however, it can be questioned how useful such a metric might be, since it can never be measured due to the intractability of the domain.
- **Completeness** means that the model contains all the statements which would be correct and relevant about the problem domain, i.e. $\mathcal{D} \setminus \mathcal{M} = \emptyset$.
  A measure for the degree of completeness could be provided along the same lines as above, but would only be interesting in limited domains.

For anything but extremely simple problems, total validity and completeness cannot be achieved. Hence, for our semantic goals to be realistic, they have to be somewhat relaxed, by introducing the concept of *feasibility*. Attempts at reaching a state of total validity and completeness will lead to unlimited spending of time and money for the modeling activity. The time to terminate a modeling activity is thus not when the model is perfect, but when it has reached a state where further modeling is less beneficial than applying the model in its current state. With respect to this, a relaxed kind of validity and completeness can be defined.

- **Feasible validity:** $\mathcal{M} \setminus \mathcal{D} = \mathcal{R} \neq \emptyset$, but there is no statement $r \in \mathcal{R}$ such that the benefit added to the conceptual model by removing *r* from $\mathcal{R}$ exceeds the drawback eliminating the invalidity *r*.
- **Feasible completeness:** $\mathcal{D} \setminus \mathcal{M} = \mathcal{S} \neq \emptyset$ but there is no statement $s \in \mathcal{S}$ such that the benefit added to the conceptual model by including *s* exceeds the drawback of adding the statement *s*.

Feasibility thus introduces a trade-off between the *benefits* and *drawbacks* for achieving a given model quality. These benefits and drawbacks are themselves part of the $\mathcal{D}$ since they form an integral part of the problem to be solved. We have used the term 'drawback' here instead of the more usual 'cost' to indicate that the discussion is not necessarily restricted to purely economical issues — it should also allow for factors such as the personal pleasure of the end-users of the system, social risks, and ethics.

Relaxing validity and completeness with the demand for feasibility, the framework conforms to the observation that there is *no one right solution* to a wicked problem (Rittel, 1972) as well as to social constructivity. The choice of solution will depend, and correctly so, on who is doing the modeling.

Activities for establishing higher semantic quality, are statement insertion and deletion, in addition to consistency checking, as discussed in (Lindland et al., 1994).

3.6 Perceived semantic quality

Perceived semantic quality is the correspondence between the actor interpretation of a model and his or hers current knowledge of the domain. Similarly to semantic quality, we define two goals, perceived validity and perceived completeness

- *Perceived validity* of the model projection: $\mathcal{I}_i \setminus \mathcal{K}_i = \emptyset$.
- *Perceived completeness* of the model projection: $\mathcal{K}_i \setminus \mathcal{I}_i = \emptyset$.

Metrics for the degree of perceived validity and completeness can be defined by means of cardinalities the same ways as syntactic quality.

$$perceived\, validity = 1 - \frac{\#(\mathcal{I}_i \setminus \mathcal{K}_i)}{\#(\mathcal{I}_i)}. \quad (7)$$

,i.e. the number of invalid statements interpreted, divided by the total number of statements interpreted by the actor A_i.

$$perceived\, completeness = 1 - \frac{\#(\mathcal{K}_i \setminus \mathcal{I}_i)}{\#\mathcal{K}_i}. \quad (8)$$

, i.e. the number of relevant knowledge statements known but not seen in the model, divided by the total number of relevant knowledge statements known by the actor A_i. Also on this measures, discussion of feasibility is useful.

The means for achieving a high perceived validity and completeness is similar to the ones for normal validity and completeness, with the addition of participant training.

3.7 Pragmatic quality

Pragmatic quality is the correspondence between the model and the audience's interpretation of it, here denoted by the set $\mathcal{I}$, the statements that the audience think that the model consists of. The framework only contains one pragmatic goal, namely **comprehension**. Not even the most brilliant solution to a problem would be of any use if nobody was able to understand it. Moreover, it is not only important that the model has been understood, but also *who* has understood it.

Individual comprehension is defined as the goal that the participant A_i understands the part of the model relevant to that actor, i.e. $\mathcal{I}_i = \mathcal{M}^i$.

For total comprehension, one must have $(\forall i, i \in [1 \dots k])(\mathcal{I}_i = \mathcal{M}^i)$ i.e., that every participant understands the part of $\mathcal{M}$ relevant for him/her.

The corresponding error class is *incomprehension*, meaning that the above formula does not hold. For a large model, it is unrealistic to assume that each member of the audience will be able to comprehend all the statements which are relevant to them. Thus, comprehension as defined above is an ideal goal, just like validity and completeness. Again it may be useful to introduce the notion of feasibility:

- **Feasible comprehension** means that although the model may not have been correctly understood by all audience members, i.e.

  $$(\exists i)(\mathcal{I}_i \setminus \mathcal{M}^i) \cup (\mathcal{M}^i \setminus \mathcal{I}_i) = \mathcal{R}_i \neq \emptyset. \tag{9}$$

  there is no statement $s \in \mathcal{R}_i$ such that the benefit of rooting out the misunderstanding corresponding to *s* exceeds the drawback of taking that effort.

That a model is 'comprehended' by the technical actors means that $(\forall i, i \in [n+1...m])\mathcal{I}_i = \mathcal{M}^i$, thus all statements that are relevant to the technical actor to be able to perform code generation, simulation, etc. is comprehended by this actor. In this sense, formality can be looked upon as being a pragmatic goal, formal syntax and formal semantics are means for achieving pragmatic quality. This illustrates that pragmatic quality is dependent on the different actors. This also applies to social actors. Whereas some individuals from the outset are used to formal languages, and a formal specification in fact will be best for them also for comprehension, other individuals will find a mix of formal and informal statements to be more comprehensive.

Some of the means to achieve pragmatic quality has earlier been identified, namely executability, expressive economy and structuredness. The corresponding modeling activities are inspection, visualization, animation, simulation, filtering, explanation, and translation as described in (Lindland et al., 1994). Another example of a pragmatic mean is aesthetics for diagram layout and the possible tool support for this. An extensive list of graph aesthetics is presented in (Tamassia et al., 1988). Some might feel that such aesthetics should rather have been listed as goals for empirical quality. However, the aesthetics are related to the participants' possibility to comprehend, and are thus most conveniently presented as pragmatic means in our framework.

3.8 Social quality

The goal we have defined for social quality is *agreement*. Four kinds of agreement is identified, according to binary distinctions along two orthogonal dimensions:

- agreement in knowledge vs. agreement in model interpretation.
- relative agreement vs. absolute agreement

Relative agreement means that the various projections are consistent — hence, there may be many statements in the projection of one actor that are not present in that of another, as long as they do not contradict each other. Absolute agreement, on the other hand, means that all projections are the same.

Agreement in model interpretation will usually be a more limited demand than agreement in knowledge, since the former one means that the actors agree about what (they think) is stated in the model, whereas there may still be lots of things they disagree about which is not stated in the model so far, even if it might be regarded as relevant for one of the actors.

Hence, we can define

- Relative agreement in interpretation: all I_i are consistent.
- Absolute agreement in interpretation: all I_i are equal.
- Relative agreement in knowledge: all K_i are consistent.
- Absolute agreement in knowledge: all K_i are equal.

The equation below specify a metric for relative agreement in interpretation(RAI).

$$RAI = 1 - \frac{\#(\{s \mid (\exists i, j) s \in \mathcal{I}_i \wedge \neg s \in \mathcal{I}_j\})}{\#(\mathcal{M}_E)}. \tag{10}$$

Since different actors are supposed to have their expertise in different fields, relative agreement is a more useful concept than absolute agreement. On the other hand, the different actors must have the *possibility* to agree on something, i.e. the parts of the model which are relevant to them should overlap.

It is not given that all individuals will come to agreement. Few decisions are made in society under consensus, and those that are are not necessarily good, due to e.g. group-think. To answer this we introduce the concept of *feasible agreement*:

Feasible agreement is achieved if feasible comprehension is achieved and inconsistencies between statements in the different interpretations of the model $\mathcal{I}_i$ are resolved by choosing one of the alternatives when the benefits of doing this is less than the drawbacks of working out an agreement.

The pragmatic goal of comprehension is looked upon as a social mean. This because agreement without comprehension is not very useful, at least not when having democratic ideals.

Some activities for achieving social quality are:

- Viewpoint analysis (Leite and Freeman, 1991): This includes techniques for comparing two or more externalized models and find the discrepancies.
- Conflict resolution: Specific techniques for this can be found in the area of computer supported cooperative work, see e.g (Conklin and Begeman, 1988; Hahn et al., 1990) where systems for supporting an argumentation process are presented.
- Model merging: Merging two potentially inconsistent models into one consistent one.

3.9 Internalization

Internalization of a model happens as a result of comprehension and agreement on statements not being part of the model made as an externalization of the persons existing internal reality.

Internalization can be expressed crudely as a mapping between the sets of statements being part of the explicit internal reality of a social actor.

$$INT : \mathcal{K}_i \rightarrow (\mathcal{K}_i \cup (\mathcal{N} \subset \mathcal{M}_j)) \setminus (\mathcal{O} \subset \mathcal{K}_i). \quad (11)$$

$i \neq j, \mathcal{O} \cap \mathcal{N} = \emptyset, \mathcal{K}_i \setminus \mathcal{N} = \mathcal{K}_i$

$\mathcal{N}$ and $\mathcal{O}$ above is sets of statements. $\mathcal{O}$ might be empty giving a monotonous growth of $\mathcal{K}_i$. If $\mathcal{O}$ is not empty there is a non-monotonous growth of $\mathcal{K}_i$.

3.10 Knowledge quality

From a pure standpoint of social construction, it is difficult to talk about the quality of explicit knowledge. On the other hand, within certain areas, for instance mathematics, what is regarded as 'true' is comparatively stable, and it is inter-subjectively agreed that certain people have more valid knowledge of an area than others. The 'quality' of the participant knowledge can thus be expressed by the relationships between the audience knowledge and the domain. The 'perfect' situation would be if the total audience knew everything about the domain at a given time i.e. $\mathcal{D} \setminus \mathcal{K} = \emptyset$, and that they had no incorrect superstitions about the domain, i.e., $\mathcal{K} \setminus \mathcal{D} = \emptyset$.

This is usually unrealistic. To get a *good enough* knowledge about the domain, careful *participant selection* based on *stakeholder identification* is necessary (if you have a problem and can choose the participants), or alternatively, careful *problem selection* (if the participants are given, but not the problem to be solved). In the case that both participants and problem are more or less given, and not fitting too well, some development in terms of training of the participants may be necessary. Just as for the other aspects of quality, it will be possible to talk about *feasible knowledge quality*, meaning that the knowledge of the audience could still be improved, but the benefit of improving it through additional education or the hiring of additional experts or including additional stakeholders will be less than the drawbacks of mistakes made due to imperfect knowledge.

3.11 Language quality

Goal for language quality appears as means for model quality in the overall framework. We have regrouped factors from earlier discussions on language quality e.g. (Seltveit, 1994; Sindre, 1990) according to the framework for model quality as follows:

- Domain appropriateness: This can be describes as follows $\mathcal{D} \setminus \mathcal{L} = \emptyset$. i.e. there are no statements in the domain that can not be expressed in the language used.
- Participant knowledge appropriateness: This can be expressed by:

  $$(\forall i \in [1...k])\forall j \mathcal{M}^i_{L_j}(\mathcal{M}(L_j) \setminus \mathcal{K}^i = \emptyset). \quad (12)$$

  i.e. all the statements in the meta-model of the languages used by the different participants are part of the explicit knowledge of this participant.

Similar to model interpretation, one can define language interpretation, thus the set of possible statements that can be made in the language that are understood by the audience member . Ideally $\mathcal{L} \setminus \mathcal{I} = \emptyset$. i.e. all the possible statements of the language is understood by the participants in the modeling effort using the language.

- Technical actor interpretation enhancement: For the technical actor, it is especially important that the language lend itself to automatic reasoning. This requires formality (i.e. both formal syntax and semantics are useful), but formality is not necessarily enough, since the reasoning must also be fairly efficient to be of practical use. This is covered by executability discussed under pragmatic quality.

  Looking back at the discussion on pragmatic quality, formality can most usefully be defined as follows:

$$necessary\ formality = \frac{\#(\bigcup_{i=n+1}^{m} \mathcal{M}^i \cap \mathcal{L}_F)}{\#(\bigcup_{i=n+1}^{m} \mathcal{M}^i)}. \tag{13}$$

One can further distinguish between the conceptual basis of a language and its external representation. Different criteria in the different categories will often be contradictory, i.e. one would expect to find certain deficiencies for most conceptual modeling languages based on goals for language quality. On the other hand, this can be addressed by how the language is used within a methodology, as discussed in the overview of model quality.

4 CONCLUSIONS

Table 1 shows an overview of the goals and means as identified on the different semiotic levels used. Within the means again, one can come up with goals for these e.g. that explanation generation meets the standard of textuality, and identify means for how to achieve this.

The main objective of the paper has been to push our understanding of quality aspects in conceptual modeling one step further and to define viable concepts in this context. In order to reach the objective we have reviewed and compared two recent frameworks for discussing quality of conceptual model: the framework in (Lindland et al., 1994) and the six semiotic layers for communication used by FRISCO (FRISCO, 1995; Lindgren ed., 1990). The comparison has shown that Lindland's framework is included in the six semiotic layers. One major purpose of the paper has been to investigate whether it is possible to extend the framework so that all six layers are covered. Our findings so far is that the physical level can be used to discuss the possibility for externalization and internalization of a conceptual model. The empirical level did not transform naturally to quality goals for models, aesthetics rather being looked upon as a means for achieving comprehension. On the other hand, the social level has inspired us to look deeper into the social process of building a specification. Thus, social construction theory forms the philosophical basis for our extended framework.

In contrast to the previous version of the framework, we are now able to discuss the quality of model where different social actors are developing their projected submodels based on their own knowledge. Furthermore, the process of merging different viewpoints is discussed under social quality. Here, agreement among the actors is the major goal.

Although the framework contributes to our understanding of quality issues with respect to conceptual modeling, the contribution so far lies on a rather high level of abstraction. There are

Table 1 Framework for model quality

Quality type	*Goal*	*Mean*	
		Model property	*Activity*
Physical quality	Externalizability	Domain appropriateness Participant knowledge appropriateness	
	Internalizability	Persistence Availability	DB-activities
Syntactic quality	Syntactic correctness	Formal syntax	Error prevention Error detection Error correction
Semantic quality	Feasible validity	Formal semantics	Consistency checking Driving questions
	Feasible completeness	Modifiability	Statement insertion Statement deletion
Perceived sem.quality	Feasible perceived validity Feasible perceived completeness		Participant training
Pragmatic quality	Feasible comprehension	Expressive economy Aesthetics	Inspection Visualization Filtering Diagram layout Paraphrasing Explanation Participant training
		Executability	Execution Animation Simulation
Social quality	Feasible agreement	Inconsistency handling	Viewpoint analysis Conflict resolution Model merging
Knowledge quality	Feasible knowledge completeness Feasible knowledge validity		Stakeholder ident. Participant selection Problem selection Participant training

several interesting paths for further work by which the framework can be refined to become more directly useful for practitioners. Among others, the following areas need further exploration:

- *development of product metrics:* In the current framework quality goals are mainly defined as the degree of correspondence between various sets. Future work should concentrate on developing quantitative metrics so that the quality of models can be more explicitly assessed.
- *development of process guidelines:* The framework gives an overview of decisions that will have to be made in an modeling effort. Further work should result in guidelines that practitioners may use directly in concrete projects for the modeling of e.g. requirement specifications.

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