Model Adequacy

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Abstract: Models, modeling languages, modeling frameworks and their background have dominated research on information systems engineering for last four decades. Models are mainly used as mediators between the application world and the implementation or system world. Modelling is still conducted as the work of an artisan and workmanship. While a general notion of the model and of the conceptual model has already been developed, the modelling process is not investigated so well.

Modelling has to be based on principles and a general theory of modelling activities. One of the lacunas is still a proper understanding of adequacy of models, adequacy of modelling and deployment methods, and a theory of adequacy. We will concentrate on the first issue.

Keywords: model notion; model adequacy; analogy; focus/truncation/abstraction; purposeful; well-formed model; mode dependability

1 Models, Modelling Activities, Systematic Modelling

Models are principle and central *instruments* in mathematics, data analysis, modern computer engineering (CE), in teaching any kind of computer technology, and also modern computer science (CS). They are built, applied, revised and manufactured in many CE&CS sub-disciplines in a large variety of application cases with different purposes and context for different communities of practice. CE&CS expressively use the conception of model for daily work. Modelling is one of their four central paradigms beside structures (in the small and large), evolution or transformation (in the small and large), and collaboration (based on communication, cooperation, and coordination). It is now well understood that models are something different from theories. They are often intuitive, visualisable, and ideally capture the essence of an understanding within some community of practice and some context. At the same time, they are limited in scope, context and the applicability. Models have been considered to be somewhere in the middle between the perception and understanding of the state of affairs (world, situations, data etc.) and theories (concepts and conceptions, statements, beliefs, etc.) since they may describe certain aspects of a situation and may represent parts of a theory. Models should thus be considered to be the third dimension of science [2, 50, 52][2]. Other disciplines (see for instance [50]) have developed a different

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[2] The title of the book [4] has inspired this observation.

understanding of the notion of model, of the function of models in scientific research and of the purpose of the model. Models are often considered to be artifacts where also virtual models are considered beside real one. Models might also be mental models and thought concepts. Models are used as instruments in *utilisation scenarios*. They function in these scenarios.

2 The Notion of the Model

There is however a general notion of a model and of a conception of the model:

A **model** *is a well-formed, adequate, and dependable instrument that represents origins.* (see [8, 45, 47])

Its criteria of well-formedness, adequacy, and dependability must be commonly accepted by its community of practice within some context and correspond to the functions that a model fulfills in utilisation scenarios.

The model should be well-formed according to some well-formedness criterion. As an instrument or more specifically an artifact a model comes with its *background*, e.g. paradigms, assumptions, postulates, language, thought community, etc. The background its often given only in an implicit form. The background is often implicit and hidden.

A well-formed instrument is *adequate* for a collection of origins if it is *analogous* to the origins to be represented according to some analogy criterion, it is more *focused* (e.g. simpler, truncated, more abstract or reduced) than the origins being modelled, and it sufficiently satisfies its *purpose*.

Well-formedness enables an instrument to be *justified* by an empirical corroboration according to its objectives, by rational coherence and conformity explicitly stated through conformity formulas or statements, by falsifiability or validation, and by stability and plasticity within a collection of origins.

The instrument is *sufficient* by its *quality* characterisation for internal quality, external quality and quality in use or through quality characteristics (see [40]) such as correctness, generality, usefulness, comprehensibility, parsimony, robustness, novelty etc. Sufficiency is typically combined with some assurance evaluation (tolerance, modality, confidence, and restrictions).

A well-formed instrument is called *dependable* if it is sufficient and is justified for some of the justification properties and some of the sufficiency characteristics.

3 Adequacy as a Generalisation of Mapping, Truncation, and Pragmatic Properties

Following H. Stachowiak (see, for instance, [33, 34]), a model is often defined in a phenomenalistic way based on three properties:

(1) *Mapping* property: the model has an origin and can be based on a mapping from the origin to the instrument.

(2) *Truncation* (*reduction*) property: the model lacks some of the ascriptions made to the origin.

(3) *Pragmatic* property: the model use is only justified for particular model users, the tools of investigation, and the period of time.

We observe however that these properties do not qualify a representation as a model. The mapping and truncation properties are far too strict and need further investigation. A model must not be a mapping from some origin. Homomorphism is a nice property but far too strict in most applications. We might use representations that are not images of mappings such as a Turing machine, a system architecture, or development strategies. Furthermore, we might use representations that are not reducts of origins such as (conceptual) information system models for the variety of viewpoints users of databases might have. Truncation (or abstraction) considers a model to be an Aristotelian one by abstraction by disregarding the irrelevant. The relevance criterion is based on the purpose (or goal or function) of a model. So, truncation is far too fuzzy. Models are developed by a community of practice for utilisation by a community of practice and in a context. The utilisation depends on the intentions of users and their context. So, we observe that the utilisation of models determines (a) the kind of model, (b) the governing purposes or goals of utilisation of the model, (c) the properties of a model, (d) the amplification a model provides with extensions, (e) the idealisation by scoping the model to the ideal state of affairs, (f) the divergence by deliberately diverging from reality in order to simplify salient properties of interest, and (g) the added value of a model. The seven additional statements are combined in the *mission* a model has. The mission clarifies how the model functions well within its intended scenarios of usage according to its capacity and potential. The mission must be coherent with the context, the determination or specific basis of conduct or utilisation of the model, and must be acceptable for the users or – more concrete – the community of practice. Therefore, the mission clarifies the functions (and anti-functions or forbidden ones), purposes and goals of the utilisation, the potential and the capacity of the model.

4 An Agenda: Towards Adequacy of Modelling Methods

The theory of modelling is still struggling with a number of research challenges (see [40]): Adjustable selection of principles depending on modelling goals; model suites with explicit model association; development of a language culture; models 2.0; explicit treatment of model value; coexistence of theory, languages, and tools; adequate representation variants of models; compiler development for models; model families and variants. These challenges are the background behind the consternation that has been summarised at Modellierung 208 by W. Hesse (see also [11, 12]): ... but they do not know what they do ...; Babylonian language confusion and muddle; “it’s not a bug, it’s a feature” and other statements for de-facto-standards and lobbyists; why I should cope with what was the state of art yesterday; each day a new wheel, new buzzwords without any sense, and a new trend; without consideration of the value of the model; competition is a feature, inhomogeneity; Laokoon forever; dreams about a sound mathematical foundation; take but don’t think - take it only without critics; academia in the ivory tower without executable models; where is the Ariadne thread through.

This consternation and the challenges can be summarised by a research agenda, e.g. with the following problems:

- *Can be develop a simple notion of adequateness that still covers the approaches we are used in our subdiscipline?*
- *Do we need this broad coverage for models? Or is there any specific treatment of dependability for subdisciplines or specific deployment scenarios?*
- *Which modelling methods are purposeful within which setting?*
- *Which model deployment methods are properly supporting the function of a model within a utilisation scenario?*
- *How does the given notion of model match with other understandings and approaches to modelling in computer science and engineering?*
- *What is the background of modelling, especially the basis that can be changed depending on the function that a model plays in some utilisation scenario?*
- *Language matters, enables, restricts and biases (see [54]). What is the role of languages in modelling?*
- *Which modelling context results in which modelling approach?*
- *What is the difference between the modelling process that is performed in daily practice and systematic and well-founded modelling?*
- *Are we really modelling reality or are we only modelling our perception and our agreement about reality?*
- *What is the influence of the modeller’s community and schools of thought?*

5 The Storyline for this Keynote

In this keynote we discuss mainly the first element of the research agenda: adequateness of models, modelling methods, and modelling as a systematic activity. So far, the adequateness notion is far too fuzzy and too wide. The keynote is based on a large body of knowledge developed on models, modelling activities, and systematic modelling[3] The basis of our understanding of adequacy and dependability is the case study in the Kiel compendium of models, modelling activities and systematic modelling (see [50]). This MMM approach to modelling has been investigated for models in agriculture, archaeology, arts, biology, chemistry, computer science, economics, electrotechnics, environmental sciences, farming, geosciences, historical sciences, languages, mathematics, medicine, ocean sciences, pedagogical science, philosophy, physics, political sciences, sociology, and sports.

The introduction is based on a discussion of adequacy for two modelling methods widely used in our area. The specific utility of models follow the line given in [19, 20]. We are going to introduce a general and formal notion of adequacy. Since adequacy cannot be separated from dependability we have also to investigate it for the two modelling methods. Finally, the keynote ends with a collection of open problems on adequacy of modelling methods.

References

[1] C. Batini, S. Ceri, and S. Navathe. *Conceptual database design (an entity-relationship approach)*. Benjamin/Cummings, Redwood City, 1992.

[2] M. Bichler, U. Frank, D. Avison, J. Malaurent, P. Fettke, D. Hovorka, J. Krämer, D. Schnurr, B. Müller, L. Suhl, and B Thalheim. Theories in business and information systems engineering. *Business & Information Systems Engineering*, pages 1–29, 2016.

[3] M. Bjekovic, H. A. Proper, and J.-S. Sottet. Embracing pragmatics. In *Proc. ER 2014*, volume 8824 of *Lecture Notes in Computer Science*, pages 431–444. Springer, 2014.

[4] S. Chadarevian and N. Hopwood, editors. *Models - The third dimension of science*. Stanford University Press, Stanford, California, 2004.

[5] P.P. Chen, J. Akoka, H. Kangassalo, and B. Thalheim, editors. *Conceptual Modeling, Current Issues and Future Directions, Selected Papers from the Symposium on Conceptual Modeling 1997*, volume 1565 of *Lecture Notes in Computer Science*. Springer, 1999.

[6] A. Dahanayake and B. Thalheim. W*h: The conceptual model for services. In *Correct Software in Web Applications and Web Services*, Texts & Monographs in Symbolic Computation, pages 145–176, Wien, 2015. Springer.

[3] For details and classical database design books we refer to [5, 17, 21, 22, 26, 1, 31, 37, 38].
For details on language theory we refer to [3, 18, 27, 28, 7, 36, **?**, 43, 56].
For details of design science research we refer to [13, 15, 30, 55].
Formalisation also includes approaches to a general theory of modelling such as [9, 10, 16, 23, 24, 25, 29, 32, 35, 57].
For details of our work we refer to [2, 49, 6, 8, 14, 39, 41, 42, 43, 44, 45, 46, 48, 51, 52, 53].

[7] F. de Saussure. *Cours de Linguistique Générale*. Payot, 1995.

[8] D. Embley and B. Thalheim, editors. *The Handbook of Conceptual Modeling: Its Usage and Its Challenges*. Springer, 2011.

[9] U. Frank and S. Strecker. Open Reference Models - Community-driven collaboration to promote development and dissemination of reference models. *Enterprise Modelling and Information Systems Architectures*, 2(2):32–41, 2007.

[10] I.A. Halloun. *Modeling Theory in Science Education*. Springer, Berlin, 2006.

[11] W. Hesse. Modelle - Janusköpfe der Software-Entwicklung - oder: Mit Janus von der A- zur S-Klasse. In *Modellierung 2006*, volume 82 of *LNI*, pages 99–113. GI, 2006.

[12] W. Hesse and H. C. Mayr. Modellierung in der Softwaretechnik: eine Bestandsaufnahme. *Informatik Spektrum*, 31(5):377–393, 2008.

[13] A. Hevner, S. March, J. Park, and S. Ram. Design science in information systems research. *MIS Quaterly*, 28(1):75–105, 2004.

[14] H. Jaakkola, J. Henno, T. Welzer-Družovec, J. Mäkelä, and B. Thalheim. Why information systems modelling is so difficult. In *SQAMIA'2016*, pages 29–39, Budapest, 2016. CEUR Workshop Proceedings.

[15] P. Johannesson and E. Perjons. *An introduction to design science*. Springer, Cham, 2014.

[16] R. Kaschek. *Konzeptionelle Modellierung*. PhD thesis, University Klagenfurt, 2003. Habilitationsschrift.

[17] M. Klettke and B. Thalheim. Evolution and migration of information systems. In *The Handbook of Conceptual Modeling: Its Usage and Its Challenges*, chapter 12, pages 381–420. Springer, Berlin, 2011.

[18] B. Kralemann and C. Lattmann. Models as icons: modeling models in the semiotic framework of peirce's theory of signs. *Synthese*, 190(16):3397–3420, 2013.

[19] F. Kramer and B. Thalheim. Holistic conceptual and logical database structure modelling with adoxx. In D. Karagiannis, H.C. Mayr, and J. Mylopoulos, editors, *Domain-specific conceptual model*, pages 269–290, Cham, 2016. Springer.

[20] Y. Kropp and B. Thalheim. Data mining design and systematic modelling. In *Proc. DAMDID/R-CDL'17*, pages 349–356, Moscov, 2017. FRC CSC RAS.

[21] P. Lockemann and J. W. Schmidt. *Datenbankhandbuch*. Springer, 1987.

[22] P.C. Lockemann and H.C. Mayr. *Rechnergestützte Informationssysteme*. Springer, 1978.

[23] P. Loos, P. Fettke, B. E. Weißenberger, S. Zelewski, A. Heinzl, U. Frank, and J. Iivari. Welche Rolle spielen eigentlich stilisierte Fakten in der Grundlagenforschung der Wirtschaftsinformatik? *Wirtschaftsinformatik*, 53(2):109–121, 2011.

[24] B. Mahr. On judgements and propositions. *ECEASST*, 26, 2010.

[25] B. Mahr. Modelle und ihre Befragbarkeit - Grundlagen einer allgemeinen Modelltheorie. *Erwägen-Wissen-Ethik (EWE)*, Vol. 26, Issue 3:329–342, 2015.

[26] H. Mannila and K.-J. Räihä. *The design of relational databases*. Addison-Wesley, Wokingham, England, 1992.

[27] S. Overbeek, U. Frank, and C. Köhling. A language for multi-perspective goal modelling: Challenges, requirements and solutions. *Computer Standards & Interfaces*, 38:1–16, 2015.

[28] C.S. Peirce. What is a sign? In Peirce Edition Project, editor, *The essential Peirce: selected philosophical writings*, volume 2, pages 4 – 10. Indiana University Press, Bloomington, Indiana, 1998.

[29] A. Rutherford. *Mathematical Modelling Techniques*. Dover publications, 1995.

[30] H.A. Simon. *The science of the artificial*. MIT Press, Cambridge, 1996.

[31] G. Simsion. *Data modeling essentials - Analysis, design and innovation*. Van Nonstrand Reinhold, New York, 1994.

[32] B.Ja. Sovetov and S.A. Jakovlev. *Systems Modelling*. Vysschaja Schkola, 2005. In Russian.

[33] H. Stachowiak. *Allgemeine Modelltheorie*. Springer, 1973.

[34] H. Stachowiak. Modell. In Helmut Seiffert and Gerard Radnitzky, editors, *Handlexikon zur Wissenschaftstheorie*, pages 219–222. Deutscher Taschenbuch Verlag GmbH & Co. KG, München, 1992.

[35] W. Steinmüller. *Informationstechnologie und Gesellschaft: Einführung in die Angewandte Informatik*. Wissenschaftliche Buchgesellschaft, Darmstadt, 1993.

[36] V. Storey and B. Thalheim. Conceptual modeling: Enhancement through semiotics. In *Proc. ER'17*, LNCS, 10650, page forthcoming, Cham, 2017. Springer.

[37] T. J. Teorey. *Database modeling and design: The entity-relationship approach*. Morgan Kaufmann, San Mateo, 1989.

[38] B. Thalheim. *Entity-relationship modeling – Foundations of database technology*. Springer, Berlin, 2000.

[39] B. Thalheim. *The Conceptual Framework to Multi-Layered Database Modelling based on Model Suites*, volume 206 of *Frontiers in Artificial Intelligence and Applications*, pages 116–134. IOS Press, 2010.

[40] B. Thalheim. Towards a theory of conceptual modelling. *Journal of Universal Computer Science*, 16(20):3102–3137, 2010. http://www.jucs.org/jucs_16_20/towards_a_theory_of.

[41] B. Thalheim. The art of conceptual modelling. In *Information Modelling and Knowledge Bases XXII*, volume 237 of *Frontiers in Artificial Intelligence and Applications*, pages 149–168. IOS Press, 2012.

[42] B. Thalheim. The science and art of conceptual modelling. In A. Hameurlain et al., editor, *TLDKS VI*, LNCS 7600, pages 76–105. Springer, Heidelberg, 2012.

[43] B. Thalheim. Syntax, semantics and pragmatics of conceptual modelling. In *NLDB*, volume 7337 of *Lecture Notes in Computer Science*, pages 1–12. Springer, 2012.

[44] B. Thalheim. The conception of the model. In *BIS*, volume 157 of *Lecture Notes in Business Information Processing*, pages 113–124. Springer, 2013.

[45] B. Thalheim. The conceptual model ≡ an adequate and dependable artifact enhanced by concepts. In *Information Modelling and Knowledge Bases*, volume XXV of *Frontiers in Artificial Intelligence and Applications, 260*, pages 241–254. IOS Press, 2014.

[46] B. Thalheim. Das Modell des Modelles. *Erwägen-Wissen-Ethik*, EWE-Heft, Heft 3, 2015, 26. Jg.:407–409, 2015.

[47] B. Thalheim. Conceptual modeling foundations: The notion of a model in conceptual modeling. In *Encyclopedia of Database Systems*. 2017.

[48] B. Thalheim. General and specific model notions. In *Proc. ADBIS'17*, LNCS 10509, pages 13–27, Cham, 2017. Springer.

[49] B. Thalheim and A. Dahanayake. Comprehending a service by informative models. In *Conceptual Modeling of Services*, LNCS 10130, pages 87–108, Berlin, 2016. Springer.

[50] B. Thalheim and I. Nissen, editors. *Wissenschaft und Kunst der Modellierung: Modelle, Modellieren, Modellierung*. De Gruyter, Boston, 2015.

[51] B. Thalheim and M. Tropmann-Frick. The conception of the conceptual database model. In *ER 2015*, LNCS 9381, pages 603–611, Berlin, 2015. Springer.

[52] B. Thalheim and M. Tropmann-Frick. Models and their capability. In C. Beierle, G. Brewka, and M. Thimm, editors, *Computational Models of Rationality*, volume 29 of *College Publications Series*, pages 34–56. College Publications, 2016.

[53] B. Thalheim and M. Tropmann-Frick. Wherefore models are used and accepted? The model functions as a quality instrument in utilisation scenarios. In I. Comyn-Wattiau, C. du Mouza, and N. Prat, editors, *Ingénierie Management des Systèmes d'Information*, pages 131–143. Cépaduès, 2016.

[54] B.L. Whorf. *Lost generation theories of mind, language, and religion*. Popular Culture Association, University Microfilms International, Ann Arbor, Mich., 1980.

[55] R. Wieringa. *Design science methodology for information systems and software engineering*. Springer, Heidelberg, 2014.

[56] Z. Zarwin, M. Bjekovic, J.-M. Favre, J.-S.. Sottet, and H. A. Proper. Natural modelling. *Journal of Object Technology*, 13(3):4: 1–36, 2014.

[57] S. Zelewski. Kann Wissenschaftstheorie behilflich für die Publikationspraxis sein? In F. Lehner and S. Zelewski, editors, *Wissenschaftstheoretische Fundierung und wissenschaftliche Orientierung der Wirtschaftsinformatik*, pages 71–120. GTO, 2007.