

Towards Foundations of Conceptual Modelling

ER Online Summer Seminars EROSS

21.10.2020

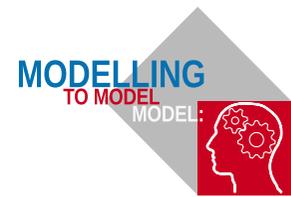
Prof. Dr. Bernhard Thalheim

Former Information Systems Engineering Group

Computer Science Institute

Kiel University, Germany





Towards Foundations of Conceptual Modelling

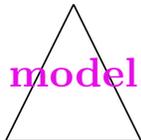
Conceptual modelling is one of main tools during database and information system development. It is also a general universal instrument in computer science despite the tradition not to name it “conceptual model”. We are still developing foundations and theories of conceptual models, modelling as activities, and modelling despite its wide deployment. We use so far more than threescore notions of conceptual model in the database area. Conceptual modelling has at least a 4.000 years old history and a surprising long success story list in almost all spheres of human activities. Therefore, we should ask ourselves whether we have to develop a common notion of conceptual model, a foundation of modelling and especially conceptual modelling, and a mathematical toolbox for modelling activities. This talk is going to explore one approach that answers these research challenges and allows tackling the main issues.

We base the explanation on the entity-relationship modelling language as one of the potential language underpinnings. E.g., the ER schema is an essential component of a conceptual database or information system’s model.

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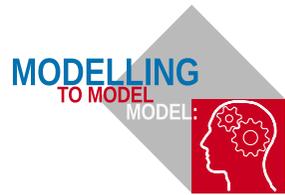
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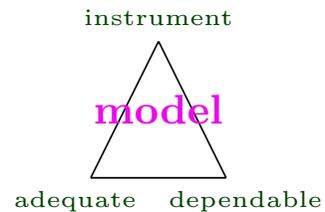
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The Background of this Talk

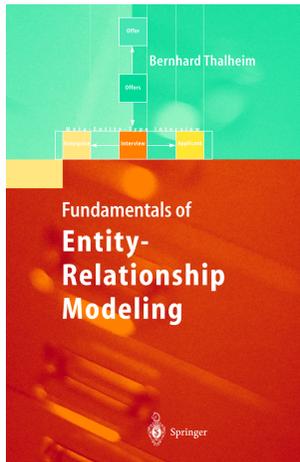


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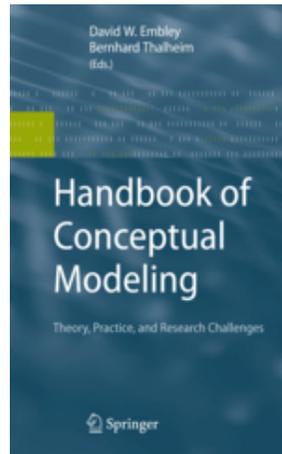
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ER - main guide



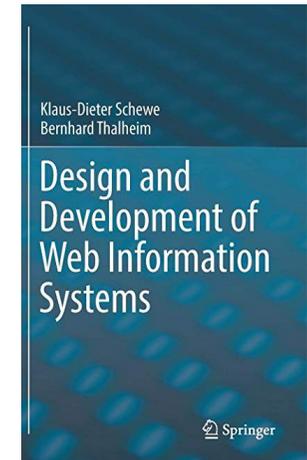
Handbook



Modelling



Website modelling



==== videos =====

<https://video.informatik.uni-kiel.de/pub/is/vorlesungen2020/>

==== vk.com <https://vk.com/id349869409>

==== youtube Channel "Bernhard Thalheim"

e.g. from `model4programming` via `modelling2program` towards `models_as_programs`
<http://bernhard-thalheim.de/ModellingToProgram/>

See also three collection of papers at Research Gate:

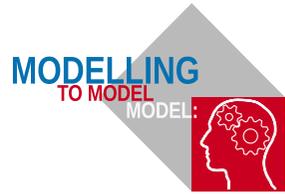
https://www.researchgate.net/publication/338685564_Models_To_Model_and_Modelling_-_Towards_a_Theory_of_Models_especially_Conceptual_Models_and_Modelling_-_Third_Collection_of_Recent_Papers_2018-2019

https://www.researchgate.net/publication/320688612_Models_To_Model_and_Modelling_-_Towards_a_Theory_of_Models_especially_Conceptual_Models_and_Modelling_Second_Collection_of_Recent_Papers_2015-2017

https://www.researchgate.net/publication/276205166_Wissenschaft_und_Kunst_der_Modellierung_Science_and_Art_of_Modelling_-_Kieler_Zugang_zur_Definition_Nutzung_und_Zukunft

also at: <https://www.academia.edu/>

What is a Model (in a nutshell)



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A **MODEL** is a well-formed **instrument** that is for origins \mathcal{D} adequate for origins, i.e. analogous, focused (or reduced), and purposeful.

dependable: (or workmanlike, professional), i.e. justified (corroborated, rational coherent and conform, falsifiable, stable and plastic) and sufficient (of firm quality and evaluated).

Background of an instrument used as a model:

- (a) grounding (basement, paradigms, postulates, restrictions, theories, culture, foundations, conventions, commonsense);
- (b) basis (concepts, foundations, language as carrier, assumptions, thought community, practice);

Directives

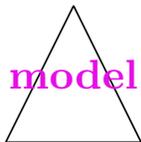
- (A) functions (purposes, goals) a model has in a utilisation scenario ;
- (B) origins to be represented by the model;
- (C) context (application domain or discipline, school of thought, time, space, granularity, scope);
- (D) community of practice (interest, portfolio, profile, roles, specific plays, rights, obligations, current practice).

Functional models are models for which methods exists for utilisation in dependence on the end/purpose/function such that is properly functions in scenarios for which the model is going to be used.

Effective models are functional models that thoroughly function in the application scenario ('usage games').

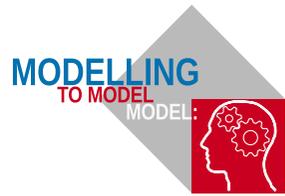
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Towards Foundations: What is Left?



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What is a model? What NOT? Can we use the definition for this separation? Can we describe what is not a model based on adequacy and dependability criteria? 😊😐😄✓

What is a function of a model in a scenario? Which scenarios we should consider? Are there scenario stereotypes? Have scenarios some kind of maturity? Do models have several functions in scenarios? 🎵🎵🎵📺

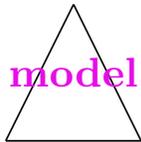
Can we delineate, demarcate, and stereotype scenarios? Can we derive their corresponding model functions? Can we use maturity for model quality characteristics? 📐🔗📞⚙️

How to describe functioning of models? Is there any general description? Should be the function an element of the informative model of a model? *∅♣Ω

How to use the function description for model usage? Can we enhance the cargo of a model? Is there a good proof of concept? 🔄⚡🔄✦

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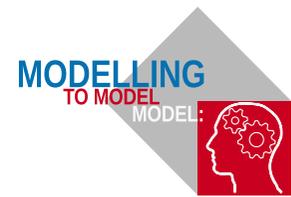
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**We know so far many notions of
conceptual model.**

**Which one to the best, most effective,
most appropriate, simplest, ...?**

Or shall we live with this variety?

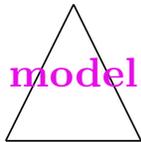
What is Conceptual Modelling????



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O. Pastor (ER 2016, keynote): most models are conceptual!!!

Talk: *“A simplification of a system built with an intended goal in mind. An abstraction of a system to reason about it (either a physical system or a real or language-based system).*

A description of specification of a system and its environment for some purpose. One main conclusion that we can reach is that the distinction between ‘model’ and ‘conceptual model’ is not always as precise as it should be.”

A. Olive (2007): *“... we use the name of conceptual modeling for the activity that elicits and describes general knowledge a particular information system needs to know. The main objective of conceptual modeling is to obtain that description, which is called a conceptual schema.”*

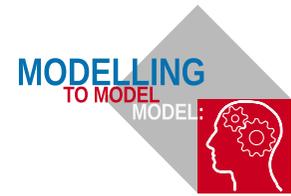
D. Embley (1998): *“Conceptual modeling is about organizing abstract ideas into concrete descriptions. ... a conceptual model ... describes a system that will be built.”*

Embley/Thalheim (2011): *“Conceptual modeling is about describing ‘syntax’, ‘semantics’ (, and ‘pragmatics’) of software applications at a high level of abstraction. Specifically, conceptual modelers (1) describe structure models in terms of entities, relationships, and constraints; (2) describe behavior or functional models in terms of states, transitions among states, and actions performed in states and transitions; and (3) describe interactions and user interfaces in terms of messages sent and received, information exchanged, and look-and-feel navigation and appearance.”*

... and Wikipedia: *A conceptual model is a representation of a system, made of the composition of concepts which are used to help people know, understand, or simulate a subject the model represents. Some models are physical objects; for example, a toy model which may be assembled, and may be made to work like the object it represents.*

The term conceptual model may be used to refer to models which are formed after a conceptualization or generalization process. Conceptual models are often abstractions of things in the real world whether physical or social. Semantics studies are relevant to various stages of concept formation and use as Semantics is basically about concepts, the meaning that thinking beings give to various elements of their experience.

Categories of Conceptual Model Notions



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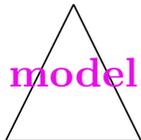
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Reality and world description: Conceptual modelling is the activity of formally describing some aspects of the physical and social world around us for purposes of understanding and communication. Such descriptions, often referred as conceptual schemata, require the adoption of a formal notation, a conceptual model in our terminology.

Community description: Conceptual modeling is about describing the semantics of software applications at a high level of abstraction. Specifically, conceptual modelers (1) describe structure models in terms of entities, relationships, and constraints; (2) describe behavior or functional models in terms of states, transitions among states, and actions performed in states and transitions; and (3) describe interactions and user interfaces in terms of messages sent and received and information exchanged. In their typical usage, conceptual-model diagrams are high-level abstractions that enable clients and analysts to understand one another, enable analysts to communicate successfully with application programmers, and in some cases automatically generate (parts of) the software application.

Conceptual database modelling: A data model is a collection of concepts that can be used to describe a set of data and operations to manipulate the data. When a data model describes a set of concepts from a given reality, we call it a conceptual model.

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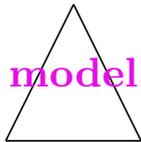
Instance-integrating conceptual modelling: A conceptual model consists of a conceptual schema and an information base. A conceptual schema provides a language for reasoning about an object system, and it specifies rules for the structure and the behaviour of the system. A description of a particular state is given in an information base, which is a set of type and attribute statements expressed in the language of the conceptual schema.

System-representation models: A conceptual model is a descriptive model of a system based on qualitative assumptions about its elements, their interrelationships, and system boundaries.

Representational models: A conceptual model is a type of diagram which shows of a set of relationships between factors that are believed to impact or lead to a target condition; a diagram that defines theoretical entities, objects, or conditions of a system and the relationships between them.

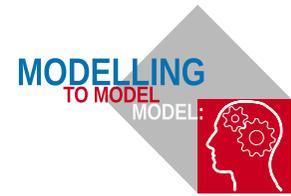
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Enterprise modelling and conceptual modelling : A conceptual is a model which represents a conceptual understanding (i.e. conceptualisation) of some domain for a particular purpose. A model is an artefact acknowledged by the observer as representing some domain for a particular purpose.

Holistic view : In most cases, a model is also a conceptual model.

Conceptual models as a result of an activity: We use the name of conceptual modeling for the activity that elicits and describes general knowledge a particular information system needs to know. The main objective of conceptual modeling is to obtain that description, which is called a conceptual schema.

Purpose-oriented modelling: Conceptual modelling is about abstracting a model that is fit-for-purpose and by this we mean a model that is valid, credible, feasible and useful.

Documentation-oriented conceptual model: A conceptual data model is a summary-level data model that is most often used on strategic data projects. It typically describes an entire enterprise. Due to its highly abstract nature, it may be referred to as a conceptual model.

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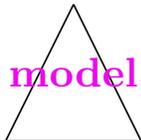
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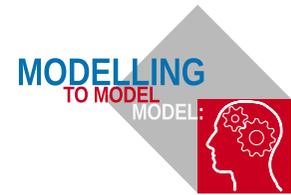
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Semiotics viewpoint: Conceptual modeling is about describing syntax, and semantics (potentially also pragmatics) of software applications at a high level of abstraction.

Documentation and understanding viewpoint: A conceptual model of an application is the model of the application that the designers want users to understand. By using the application, talking with other users, and reading the documentation, users build a model in their minds of how to use the application. Hopefully, the model that users build in their minds is close to the one the designers intended.

Ad-hoc conceptual model: A conceptual model uses a conceptual modelling language, partially describes the world within an application domain and solves a problem.

Conceptualisations of models: Conceptual models are nothing else as models that incorporate concepts and conceptions which are denoted by names in a given name space. A concept space consists of concepts as basic elements, constructors for inductive construction of complex elements called conceptions, a number of relations among elements that satisfy a number of axioms, and functions defined on elements.

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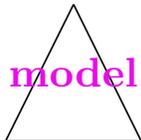
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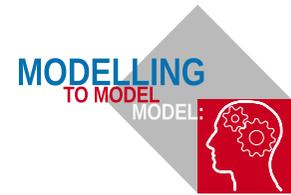
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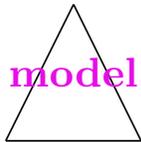
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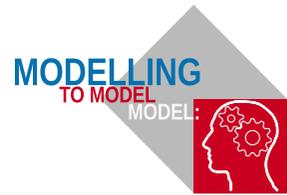
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approach	adequate	dependable	origin	function	scenario	concepts
reality, world	reflection, truncation	formal, reflection	world	describe	communication, understanding	n.g.
community	abstraction, mapping	semantic invariance	software application	describe	construction	n.g.
conceptual database	mapping, homomorphy	n.g.	data, operations	describe	construction, documentation	reality concepts
system & instance	mapping, abstraction	n.g.	system, objects	n.g.	construction	n.g.
system representation	reflection,	qualitative assumptions	system	describe	representation	system concepts
representational	mapping	n.g.	relationships	represent	visualisation	impact factors
enterprise	mapping, abstraction	faithful	domain	purpose-determined	understanding	concept space
result of activity	mapping,	n.g.	system knowledge	describe	acquisition, elicitation	domain knowledge
purpose-oriented	abstraction purposeful	viable, fit	any	elicitate	n.g.	n.g.
documentation	summary, abstraction	n.g.	data system	represent, survey	strategy development	n.g.
semiotics	syntax abstraction	semantics, pragmatics	software application	describe	representation	n.g.
document understand	mapping	closeness	application	understand by users	design	n.g.
conceptualise	formal representation	semantics	any	describe	representation	concept(ion) space
ad-hoc	selective mapping	n.g.	domain	consider problem	solving	n.g.

Models are functioning as instruments in scenarios.

Function, purpose, goal, cargo with determination and meaning, mission, ... of models.

Models have a capacity and potential!



Scenarios: What is the Use of Models? What's a Model NOT in Aid of?

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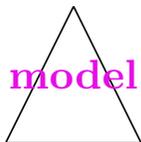
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Problem solving: in some problem and solution spaces (Polya)

mathematical modelling, hypotheses/theory development, simulation, investigation, prognosis, prediction, reasoning, retrospection, elaboration, experimentation, analysis, mining, *search*;

Engineering and construction of complex solutions for demands

description-prescription-realisation, programming, synthesis, specification, manufacturing, mastering, optimisation, variation, fault prevention, supplantation, reengineering, analysis, synthesis, design and action, validation, verification, testing, inspiration, modernisation, migration, integration, substitution, demonstration, strategy and tactics;

Understanding, communication and learning: complex issues are represented by models in dependence:

documentation, negotiation, discourses, explanation, exploration, reflection, introspection, demonstration, agreement, representation, visualisation, reflection, exhibition, agreement, comprehension, perception, comprehension, indication;

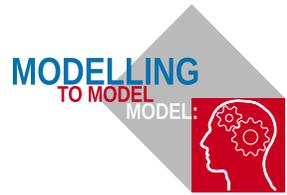
From empirics to theories: empirical observations are represented by models which are

middle-range theory instruments for conceptualisation, indication, mediation;

Human life: socialising, orientation, exhibition, appraisal, simplifying, guidance, ritual activities,

manipulation, aesthetic, art, cult, limbic system activation.

Specific model kinds with a general model property setting.



Central Property: Goals *G* / Purposes/Functions

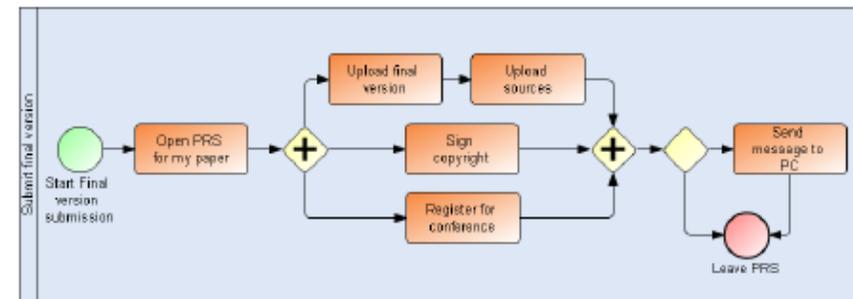
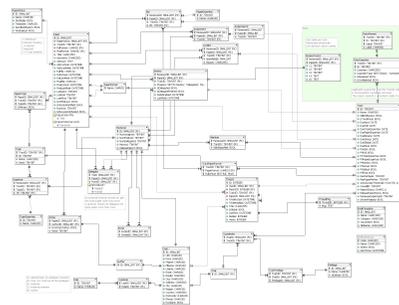
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explanation,
blueprint,
reconstruction,
illustration

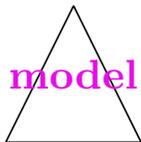
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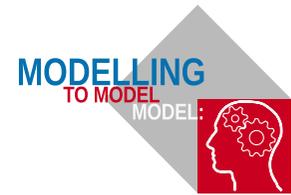


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communication,
fault prevention



easy explanation



Profile: Functions, Purposes, Goals

Goals, purposes, and functions: often considered to be synonyms

Goal of a model: ternary relation between initial states, final states and the community of practice (accepts the final state and considers the initial state);
aim, ambition, destination, end, intent, intention, objective, prompt, target;
not of interest: whether it is realistic;

Purpose of a model: extends goals by means (or instruments)
potentially enable the community of practice to achieve the goal;

Function of a model: embeds the model
into practices and scenarios of its application
extension of purpose by 'application games' (see Wittgenstein)
role and the play of a model in the scenarios
how, when, for which/what or why, at what/which etc.
often implicitly adds conventions of deployment, customs, exertions, habits,
specific usage and uses, and handling pattern to the purpose
functions in the scenarios within the given mould.

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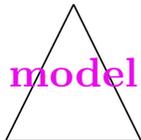
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The Mission and Nature of Conceptual Models Used for Information System Development

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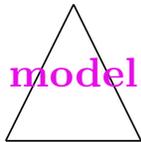
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Descriptive conceptual model

Deliverable of an **understandable** (*may be, able to apply or to practise*) and **formalised** (*or well-formed*) [*concept-based*], **unconditionally acceptable conceptualisation** of **perception** and **domain-situation models** for **interaction** and **discourses**.



Adequate and dependable instrument

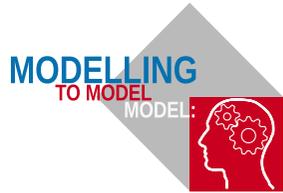
enhanced by concepts
from concept(ion) space,
given in well-formed formulations
in a CM language,
based on perception and
domain-situation models,
and oriented on a **matrix**.

Prescriptive conceptual model

Coding **supporter** as an **analysed** or *synthesised*, **ready-to-apply blueprint** because it can be **deployed**, it is **unconditionally accepted**, and **appraised** in a **deliberately and precise practice** as a **tacit tool** which provides **notion explanations** [*from descriptive conceptual models*].

Demarcation: what is a and what is not a CM!!

Conceptual Models in Description Scenarios

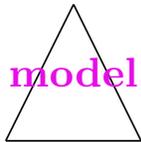


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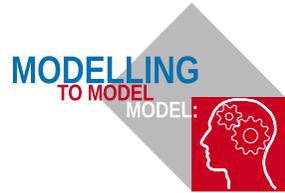


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adequate	
analog	integration of local perceptions at local scope
focus	determined by local perceptions, things of interest
purposeful	understandable, negotiable, harmonisation, reflection, common agreement
dependable	
justified	
corroborated	empirical explanation by origins (perception and domain-situation models, arguments coming from domain or situation)
rational coherent	representation of local viewpoints in the CM language, common practices
falsifiable	validateable against origins
stability	relative according to witnesses or prototypes (i.e. origins provided)
sufficient	
quality in use	full coverage of viewpoints, parsimony, full local scope, direct viewpoint representation, translation of viewpoints in their scope
external quality	completeness, explicitness, extensibility, maintainable, almost exact viewpoint matching
internal quality	inner coherence, derivable viewpoints
evaluation	feasibility within the algebra

Conceptual Models in Prescription Scenarios

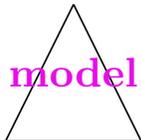


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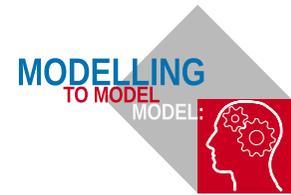
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adequate	
analog	homomorphic representability in code
focus	as model suite (structure, events, ...), aspect-oriented
purposeful	useful usable for realisation blueprint, companion, starting or inspiration point, coding guideline, verification source
dependable	
justified	
corroborated	by description model
rational coherent	within the model suite (fully supported), reflect norms and standards for CoP
falsifiable	verified and tested, analysed, synthesized
stability	evolution-prone, as masterpiece
sufficient	
quality in use	effective, well-defined, fully functioning, OR orientation, integrateability, transformer functionality,
external quality	full realisation profile, all views, extension-faithful, freeness of problematic restrictions, zoom, adaptability, exactness, error-robustness, maintainable
internal quality	correctness, validatable, analysable, synthesiseable, modularity
evaluation	tested

What is now the notion of conceptual model?

Is the notion too general or can it be specialised to one of the categories?

Should we orient ourselves on one of the notions?



Notions of Conceptual Model

Slim version: Conceptual Model \ni Model \uplus Concept(ion)s

That means that models are enhanced by concepts from a number of concept(ion) spaces.

Light version: Conceptual Model \ni Model \oplus Concept(ion)s:

A conceptual model is a concise and function-oriented consolidation (i.e. model) of a (or a number of) perception and/or domain-situation model(s) that uses a concept(ion) space.

Simulation research: *“A conceptual model is a concise and precise consolidation of all goal-relevant structural and behavioural features of a system under investigation presented in a predefined format.”*

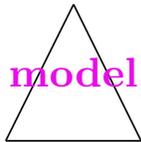
Concise version: Conceptual Model \ni (Model \oplus Concept(ion)s) \times Enabler

A **conceptual model is a model** that is **enhanced by concept(ion)s** from a concept(ion) space, is formulated in a **language** that allows well-structured formulations, is based on **mental/perception/situation models** with their embedded concept(ion)s, and is oriented on a **matrix** that is commonly accepted.

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Notion
Concepts
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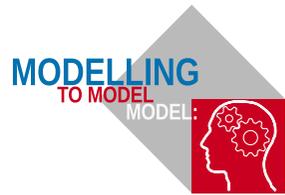
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Concepts: at least three meanings that should be separated.

“Concept” is used in various ways in different contexts.

The mathematical notion is often too strict.

Universal Concepts



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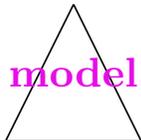
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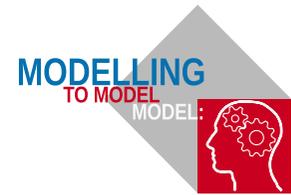
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- Person as juristical representation of a human
 - Identification of a human: Bernhard Karl Thalheim versus Abu Konrad, Umm Konrad, Klaus ibn Abi Konrad
personal identification number, social security number
 - Names
order: Bernhard Thalheim Molnar Andras
full: Oscar Pastor Lopez Amarakoon-mudiansalage Sankha
first names: Karl-Theodor Maria Nikolaus Johann Jacob Philipp Franz Joseph Sylvester
titles: Prof.Dr. rer. nat. habil. or Buhl-Freiherr von und zu Guttenberg
 - Addressing a person: Yasushi Kiyoki versus Kiyoki-sensei
- Enterprise
- Address as “the place where a person or organization can be found or communicated with” despite many other meanings (synonym.org: 9).



Modelling \oplus Concepts Conceptual Modelling



1. Typicality of the feature: (typical, moderately typical, atypical, borderline)

- necessary feature
- sufficient feature (in relation to other features), commonality of features
- measures of typicality, weights
- goodness of prototypes

2. Relevance of a feature

3. Importance of a feature:

- recognised
- used
- frequency of occurrence, number of individuals, effect of ideals

Constructing expressions: features with certain ordering

- hierarchical structuring
- containment relations (concept contains concept/knowledge): is_a, has_a_component, contains_another_concept
relations - has (content, part, possession, instances), belong to (container, assembly, owner, type [is a]), using, used, affect, affected

driver of car is a person, car contains engine, car is red

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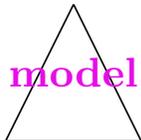
Concepts

Conceptualise

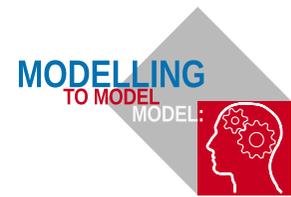
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Conceptional ≠ Conceptual

Concept: used for classification or are all the knowledge that the person has, and associates with, the concept's name (broad)

Conception: system of explanation.

“the creation of something in the mind”

“an abstract or general idea inferred or derived from specific instances” (Wordnet)

Conceptional modelling: performed by a modeller that directs the process based on his/her experience, education, understanding, intention and attitude

“being of the nature of a notion or concept” (Wordnet)

Conceptual: something is using/incorporating/integrating concepts

“being or characterized by concepts or their formation ” (Wordnet)

Conceptual model: product that is used by other stakeholders, incorporate concepts, use a language as a carrier, are restricted by the expressiveness of this carrier.

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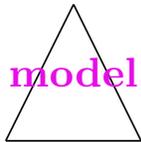
Concepts

Conceptualise

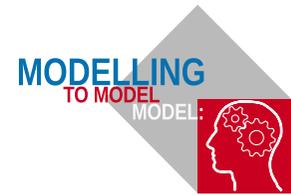
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Conceptions, Concepts and Conceptual Models

Mental world of a person is based on

- structures both implicit (e.g., background) and explicit and
- processes both implicit (e.g., background) and explicit.

Conceptual/notational structures include conceptions (concepts, theoretical statements (axioms, laws, theorems, definitions), models, theories, and tools).

Conceptual/notational processes include procedures and associated norms and rules.

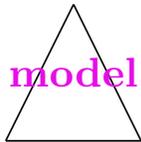
Both are based on **paradigms** (theories, science, assumptions, conditioning!!) which are **corroborated**.

Models support interaction, understanding, sharing, and collaboration among people! They depend on existing knowledge, the actual (ontological) state of the reality, the condition of the person's senses and state of mind, and the state of employed instruments.

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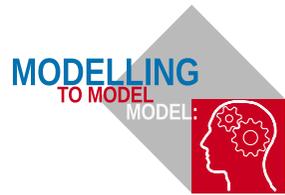
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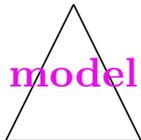
Defining a Notion of Concept??



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S: (n) concept, conception, construct (an abstract or general idea inferred or derived from specific instances)

direct hyponyms

- S: (n) **conceptualization**, conceptualisation, conceptuality (an elaborated concept)
- S: (n) **notion** (a general inclusive concept)
- S: (n) **category** (a general concept that marks divisions or coordinations in a conceptual scheme)
- S: (n) rule, regulation (a principle or condition that customarily governs behavior)
- S: (n) property, attribute, dimension (a construct whereby objects or individuals can be distinguished)
- S: (n) abstraction, abstract (a concept or idea not associated with any specific instance)
- S: (n) quantity (the concept that something has a magnitude and can be represented in mathematical expressions by a constant or a variable)
- S: (n) part, section, division (one of the portions into which something is regarded as divided and which together constitute a whole)
- S: (n) whole (all of something including all its component elements or parts)
- S: (n) law, natural law (a rule or body of rules of conduct inherent in human nature and essential to or binding upon human society)
- S: (n) law, law of nature (a generalization that describes recurring facts or events in nature)
- S: (n) lexicalized concept
- S: (n) hypothesis, possibility, theory (a tentative insight into the natural world; a concept that is not yet verified but that if true would explain certain facts or phenomena)
- S: (n) fact (a concept whose truth can be proved)
- S: (n) rule, linguistic rule ((linguistics) a rule describing (or prescribing) a linguistic practice)

direct hypernym

S: (n) **idea, thought** (the content of cognition; the main thing you are thinking about)

inherited hypernym category tree

the sum or range of what has been perceived, discovered, or learned

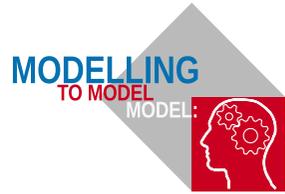
the psychological result of perception and learning and reasoning

a feature of the mental life of a living organism

a general concept formed by extracting common features from specific examples

that which is perceived or known or inferred to have its own distinct existence (living or nonliving)

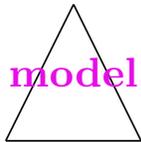
Perception, Reflection, Observation



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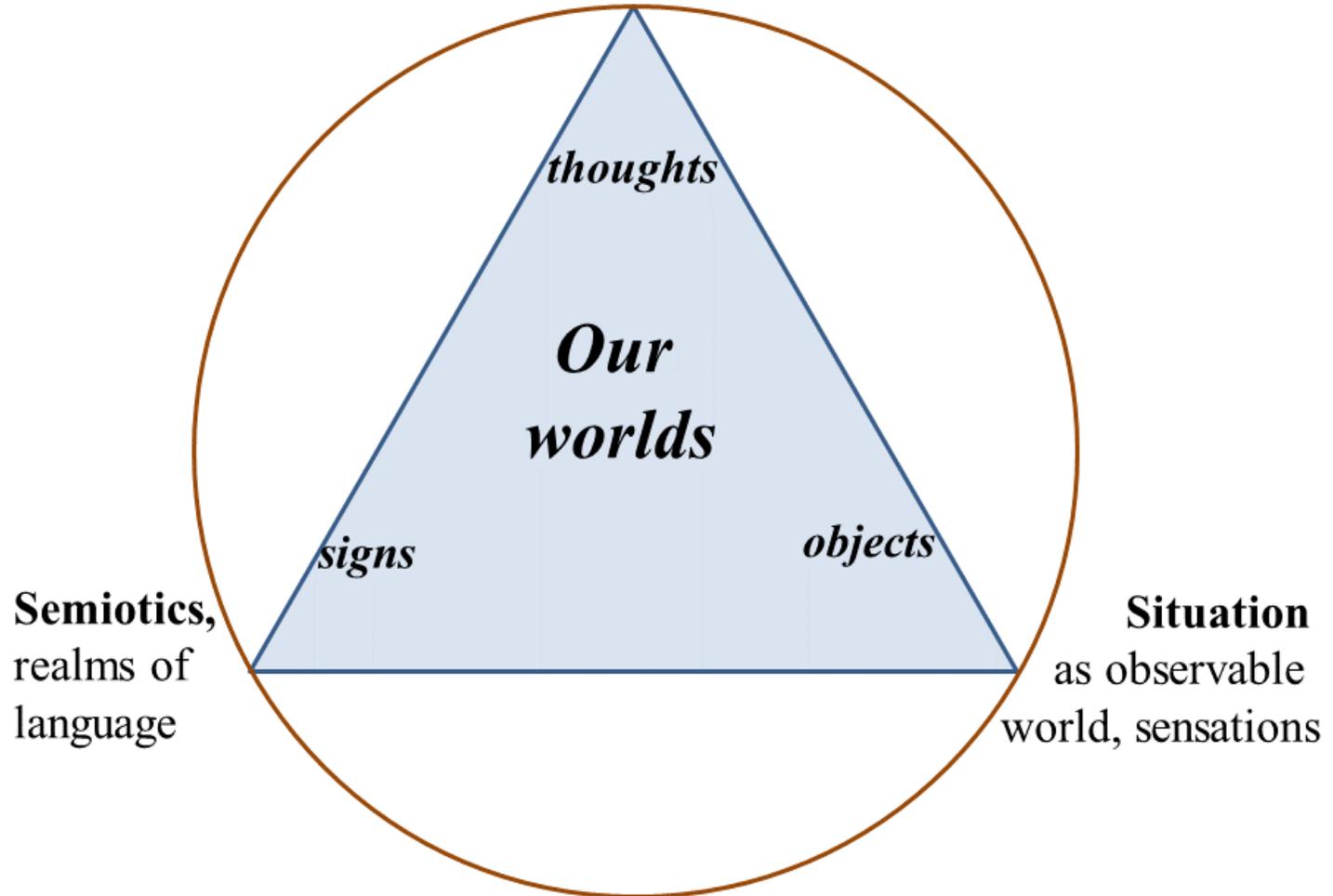
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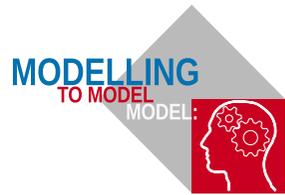
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Observations & phenomena & meaning & knowledge



See Aristoteles, Bolzano, Twardowsky, Carnap, Husserl, Ogden/Richards, Wittgenstein, ...

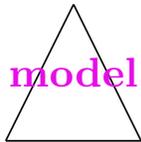
Models and Codifying of Concepts



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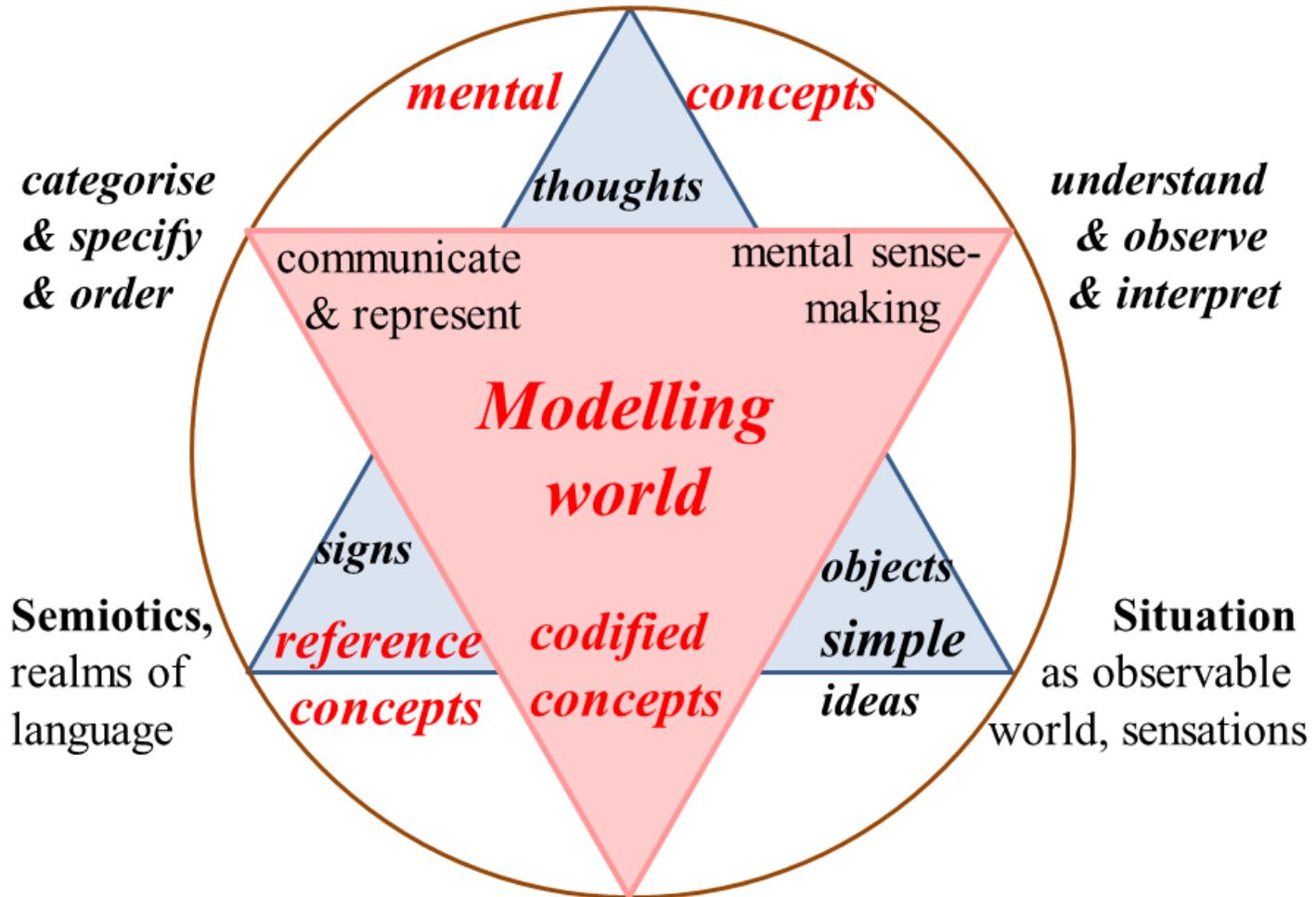
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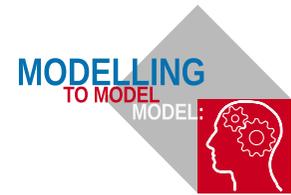
Observations & phenomena & meaning & knowledge



Models with codified concepts reflecting mental and reference ones

Conceptualisation of models:

Semantification, semiotification, sophistication, and interpretability of models as enhancement.



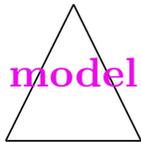
The Conceptualisation Principle in Conceptual Modelling

ISO TC97/SC5/WG587: “A conceptual schema should only include conceptually relevant aspects, both static and dynamic, of the universe of discourse, thus excluding all aspects of (external or internal) data representation, physical data organisation and access as well as all aspects of particular external user representation such as message formats, data structures, etc.” von Griethuysen, 1982

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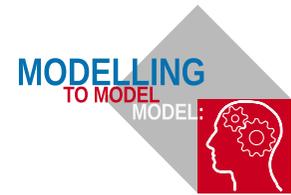
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- conceptual schema (only and exclusively) deals with the aspects of the underlying universe of discourse without implementation aspects
- each construct in the model corresponds to a reality construct representationally equivalent, it must reflect the way these users perceive their shared world
- representing complex structures in a natural way and not representing things in a flattened way (non-hierarchically)
- understanding on the fly the interpretation and representation conventions
- specific added value of the model
- based on examples from the user domain
- representing the normal cases but not neglecting other cases

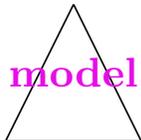
Grounding for the Deep Model: The Seven Fundamental Principles



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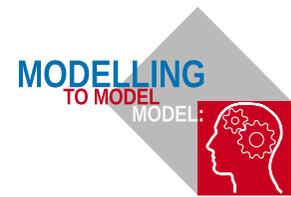
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- (1) **Helsinki Principle:** common vocabulary as a necessity for a semantic community
All utterances are to be interpreted as English utterances: Any meaningful exchange of utterances depends on the prior existence of an agreed set of semantic and syntactic rules. The recipients of the utterances must use only these rules to interpret the received utterances, if it is to mean the same as that which was meant by the utterer.
- (2) **Universe of discourse, Environment, and Information System** answer to the question: About what are we talking, with what are we talking, and for what or for whom? In other words, what are we modelling and why?
- (3) **The Metaphor of the Searchlights** answers whether there existed only one universe of discourse and whether we needed only one conceptual schema.
An individual can have more than one viewpoint, one for each subject in which he is interested or has to deal with.
- (4) **The 100% Principle and the Conceptualization Principle** selecting the necessary items in a conceptual schema is that they, although stating something about the universe of discourse, are relevant to controlling the consistency of the information and how it may be manipulated.
(4.1) 100 Percent principle:
All relevant general static and dynamic aspects, i.e., all rules, laws, etc., of the universe of discourse should be described in the conceptual schema. The information system cannot be held responsible for not meeting those described elsewhere, including in particular those in application programs.

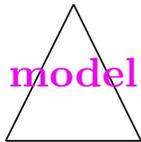


Grounding for the Deep Model: The Seven Fundamental Principles

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(4) The 100% Principle and the Conceptualization Principle

(4.2) Conceptualization principle:

A conceptual schema should only include conceptually relevant aspects, both static and dynamic, of the universe of discourse, thus excluding all aspects of (external or internal) data representation, physical data organization and access, as well as all aspects of particular external user representation such as message formats, data structures, etc.

(5) **Onion Principle:** The conceptual schema for an information system in practice can be perceived as being built up like some sort of onion – the inner layer of the onion being formed by the minimal conceptual schema based on the fundamentals of logic, the extensions representing the layers of the onion. The base and inner layers symbolize the conceptual schema for the outer layers.

(6) **The Three Level Architecture:** distinction between meaning (semantics) and form (syntax) of the information.

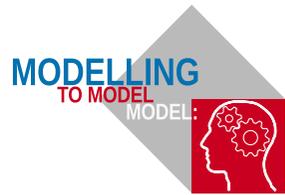
Typically we should concentrate on *what about what* we are communicating among each other, but we have to pay attention to *how with what* we do it. This is the first step: distinguishing between the *Conceptual level* and the representation level(s).

External level – visible or audible to us – forms and ways of usage

Internal level – internal in the used means and therefore invisible or inaudible to us

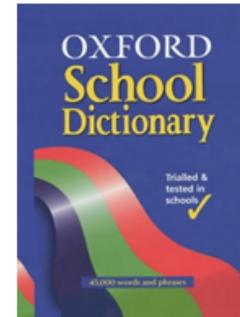
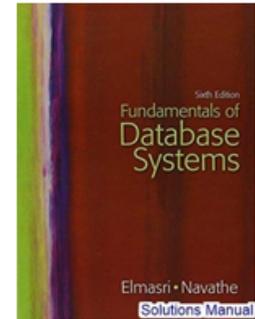
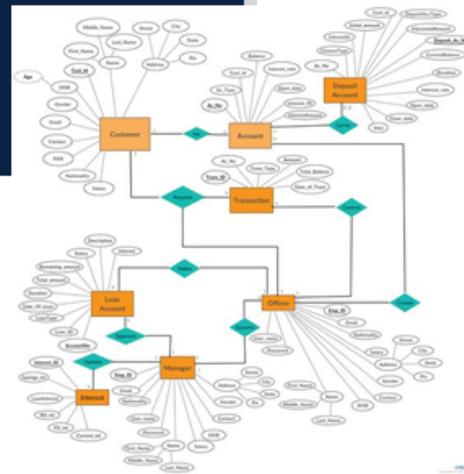
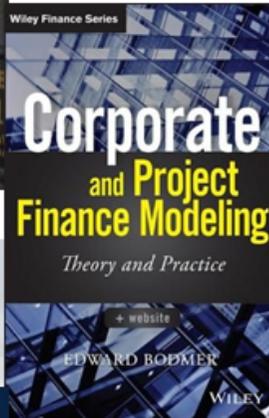
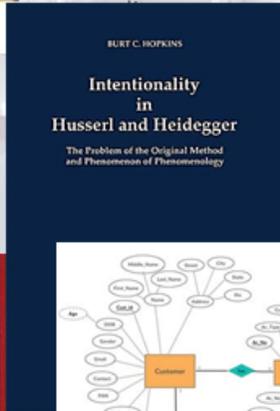
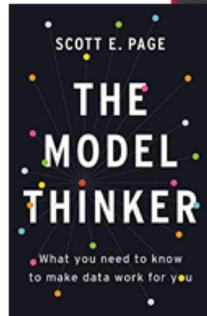
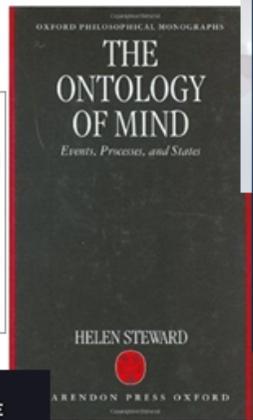
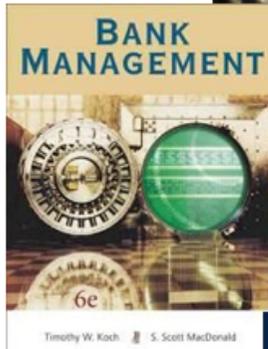
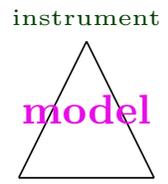
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Reuse, Integration, and Cannibalisation of Concept(ion) Spaces



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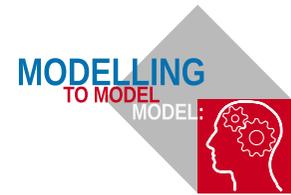


Are eER schemata conceptual models?

Yes and no!

May be parts of conceptual models!

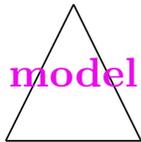
Database Structure Model = Database Schema + Views



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Communication and negotiation scenario: worthiness (surplus value), application area (wherein, wherefrom, for what, where, whence, what, how)

Conceptualisation scenario: why, what, which basis

Description scenario: what is presented, where used, purpose, goal (why, whereto, for when, for which reason, wherefore)

System construction scenario: how, when, where, how to do

Prescription scenario: how, when, where, how to do

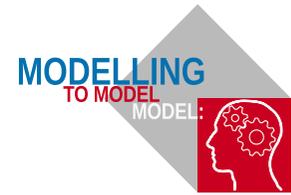
Documentation scenario: what will be, how used, by what means, in what way, supporting means, wherewith, surplus value, context (whereat, where about, wither, when), sources (whereof), activity (what in, what out), party (by whom, to whom, whichever)

Explanation and discovery scenario for applications: experience, generic pattern

Explanation and discovery scenario for systems: experience, generic pattern

Knowledge discovery and experience propagation scenario: what basis

Here: LAV paradigm of modelling

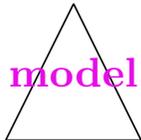


In Which Cases is an (e)ER Schema a Model ?

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Description scenario: describing all viewpoints of business users

Prescription scenario: providing a blueprint for database system construction

Explanation scenario: what can be found in the DB and what not

Documentation scenario: what is currently found in a database system

Communication scenario: understanding the database

Negotiation scenario: sufficiency and necessity of all constructions

Inspiration scenario: ideas for an implementation

Exploration scenario: discover all elements of the database system

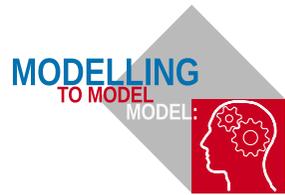
Definition scenario: define all elements in a proper form

Prognosis scenario: tell me what I could use in future

Reporting scenario: schema as a result of design

Informative scenario: why + wherefore + worthiness + wherewith

...



Enhancing the eER Schema

Conceptualisation scenario

conceptualisation of database applications
shuffled with discovery of phenomena of interest
analysis of main constructs
focus on relevant aspects within the application area.

incorporates concepts from the application domain
“why”, “what”, “which basis”

Conceptual database structure model:

database schema

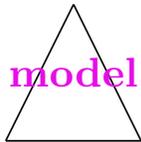
- ⊕ a collection of views for support of business users
- ⊕ mapping for schema elements to the common concept field
- ⊕ declaration of model adequacy and dependability

$(S, \mathfrak{V}, \mathcal{M}, \mathcal{A}, \mathcal{D})$

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Enhancing the eER Schema

Documentation scenario

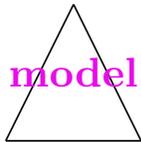
structure, purpose, operation, restrictions, and other requirements
 “what will be”, “how used”, “by what means”, “in what way”,
 “supporting means”, “wherewith”, surplus value,
 context (whereat, where about, wither, when), sources (whereof),
 activity (what in, what out), party (by whom, to whom, whichever)

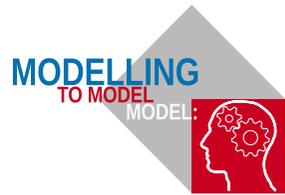
Conceptual database structure model: database schema

- ⊕ association to origin (relational, ...) schema
- ⊕ collection of views for both support of business users and system operating (option)
- ⊕ collection of operating structures (option)
- ⊕ interpretation of origin notions by concepts (option)
- ⊕ some kind of declaration for adequacy and dependability (option)

$$(\mathcal{S}, (\mathcal{R}, \mathcal{M}), [\mathfrak{V},][\mathfrak{D},][\mathcal{I},][\mathcal{A},][\mathcal{D}]) .$$

Many practitioners primarily use the eER model **this** way!!!





Enhancing the eER Schema

Description scenario

specification how the part of the reality of interest
augmentations of current reality are targeted

“what”: structure of an envisioned database; “where used”

“why”, “whereto”, “for when”, “for which reason”, “wherefore”

Conceptual database structure model: database schema

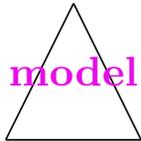
- ⊕ collection of views for support of business users
- ⊕ collection of a commonly accepted reality models
with explicit association to views
- ⊕ declaration of model adequacy and dependability

$(S, \mathfrak{V}, (\mathfrak{R}, \Psi), \mathcal{A}, \mathcal{D})$.

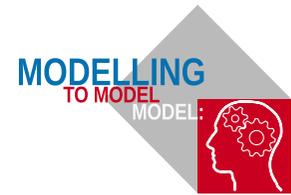
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Enhancing the eER Schema

Prescription scenario

blueprint for or prescription of a database application
especially structures and constraints in such applications
structure and how and where to construct the realisation
also with transformation profiles
“how”, “when”, “where”, “how to do”

Conceptual database structure model: database schema

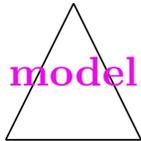
- ⊕ collection of views for both support of business users and system operating
- ⊕ realisation template
- ⊕ declaration of model adequacy and dependability

$(S, \mathcal{V}, T, A, D)$.

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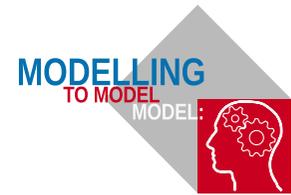


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**Despite the long history of conceptual
modelling:**

**Many open issues, many research
challenges, cohabitation of CM solutions
with technology advancement**

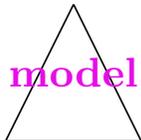
Successful Data CM Research



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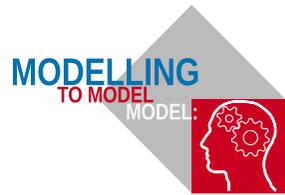


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- (1) The **linguistic foundation** of modelling has become a common framework in data modelling.
- (2) **Modelling methodologies** have reached maturity at ISO 33001 level 2 or 3.
- (3) **Distributed and federated database systems** have become well-supported by modelling.
- (4) Ontologies can be used for harmonization of viewpoints for **business users**.
- (5) Service architectures and provision have become the standard.
- (6) **Question-answer forms** combined with input-output forms provide an initial solution to the global communication problem.

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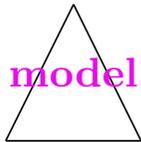
Continuing Data CM Research



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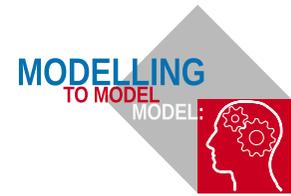
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- (1) Data modelling is still an **art** and has **not** become a **culture**. Each research and development group follows their **own approach**. The **integration** and **harmonization** of the variety of approaches hinder data integration in such collaboration projects.
- (2) **Model transformation** and active modelling has not yet become state-of-the-art.
- (3) **Co-evolution** of database systems and models is nowadays tackled by models-as-programs.
- (4) **Continuous modelling** in dependence on changes is still a major lacuna.

... Despite Many Already Closed Issues

- Modelling languages will not achieve the **expressivity** of natural languages.
- **Pragmatics** of modelling did not receive common treatment in dependence of users.
- Research on **object-oriented** database systems became the source for object-relational system technology.
- **Interoperability** of data-intensive systems and applications can only be provided for green-field application development and cannot be supported in migration and evolution scenarios.
- **Knowledge and information management** inside a database system is not supported.

Future Data CM Challenges

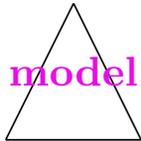


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- neglected foundations.
- model usage beyond the description purpose
- non-agreement in the community of practice
- the logical separation of syntax and semantics
- concentration on one abstraction level for data
- structure-behaviour separation
- M0-M1-M2 layering
- global-as-design

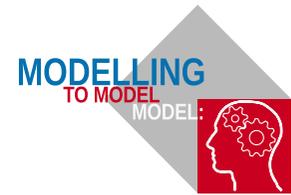
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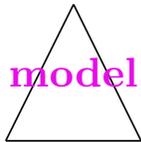
Current Data CM Research Issues



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Artificial Intelligence (AI) and Machine Learning (ML) as the key factors

Data Science

Non-structured data and pipeline-driven data integration

Traditional DB technologies are not disappearing – instead there is a hybrid mix of technologies

Robotic Process Automation

Transition from problem specific to **problem area specific solutions**

Growth of modelling complexity

Agile modelling – need to do more, faster, with less

Just-in-time data modelling and change management

Better automation and machine learning

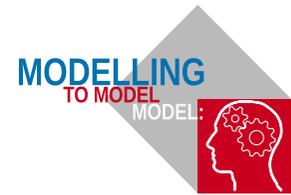
Focused data modelling

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Incremental combined with radical change

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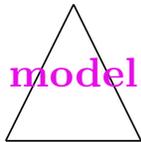
Revision and Modernization of Data CM



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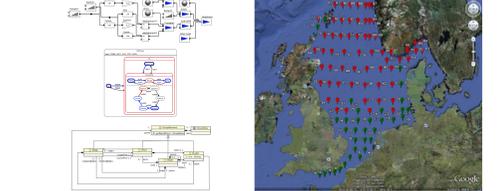
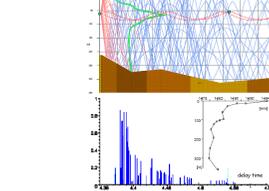
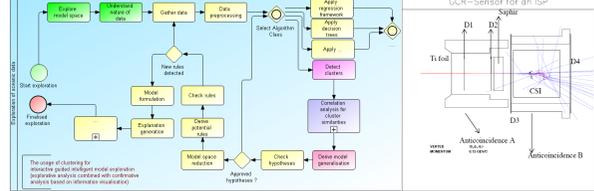
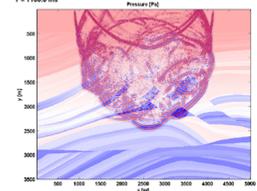
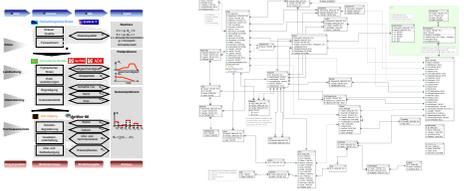
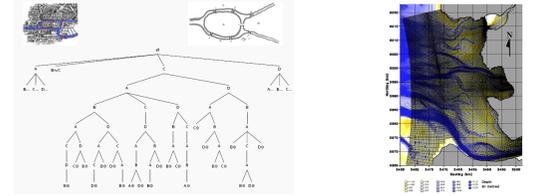
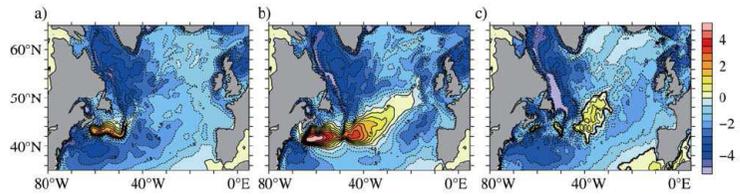
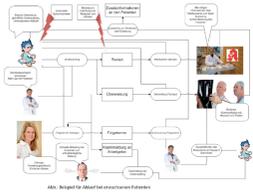
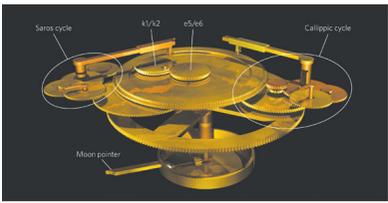
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- Flexible model transformation without information loss
- Large data models
- Weakly structured data
- Data models reflecting provenance and quality
- Adaptable and self-adapting data models Toughening the data model
- Heritage extraction models
- Just-in-time data models
- Data models reflecting storage are separated from data models supporting computation
- Special data models for special tasks
- Layman data models
- Harmonization of data modelling languages with computation features
- Standardisation of components
- Generic CM

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$$G_j \approx \sum_{i=0}^{k-1} \int_{(i-1)/n}^{i/n} \frac{(x-x_i)^j}{|j-1|!} dx \int_{(i-1)/n}^{i/n} \frac{D^j(x_i, y)}{|j-1|!} D^j(x_i, y) dy = (AB^j)$$

Thank you!

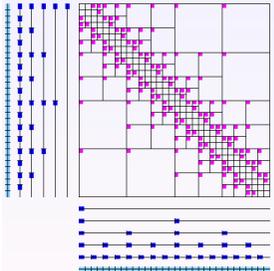
$$C = h \cdot E[I^+] + b \cdot E[I^-] + c \cdot E[Q^+] + c_1 \cdot E[Q^-]$$

$$IP_i = I_{i-1} + \sum_{j=i-2, L-1}^{L_i} Q_{i-1} + \sum_{j=i-1}^{L_i} Q_{i-1} = I_{i-1} + L_i \cdot Q + \sum_{j=i}^{L_i} Q_{i-1}$$

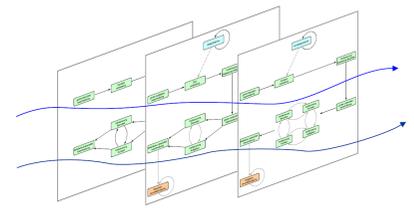
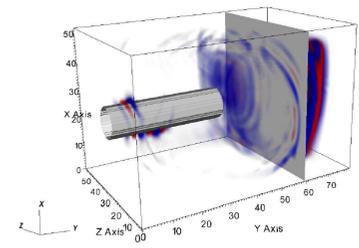
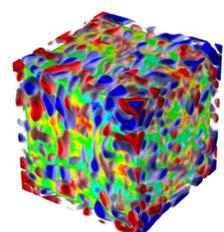
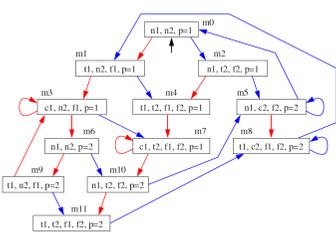
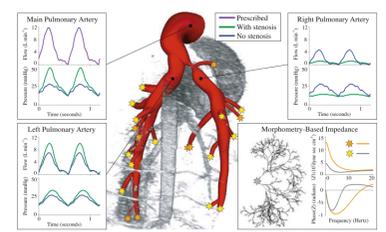
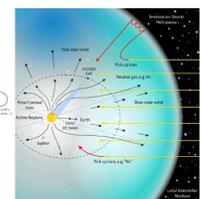
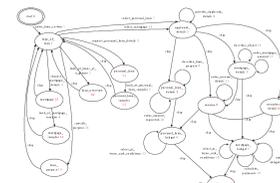
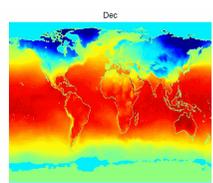
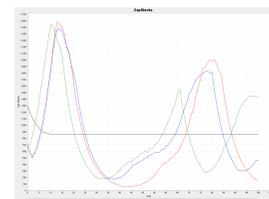
$$E[I^+(Q, S_i)] = \sum_{j=0}^{L_i} \sum_{i=j}^{L_i} (i-j) \cdot P[D(L_i+1) = j] \cdot \nu_i$$

$$E[I^-(Q, S_i)] = \sum_{j=0}^{L_i} \sum_{i=j}^{L_i} (j-i) \cdot P[D(L_i+1) = j] \cdot \nu_i$$

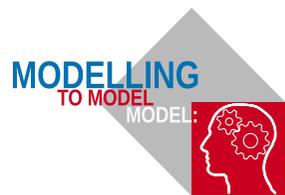
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Mississippi Ecosystem Service Supply	Assessment matrix and sub-model relations
High	High
Medium	Medium
Low	Low



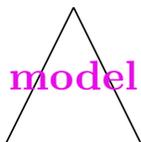
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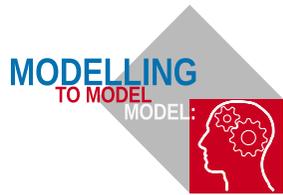
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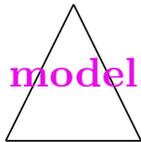
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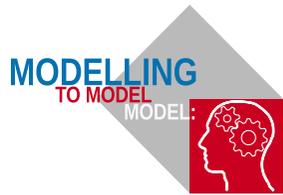
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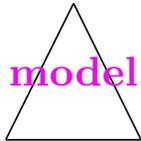
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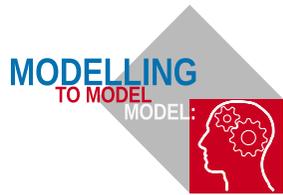
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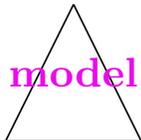
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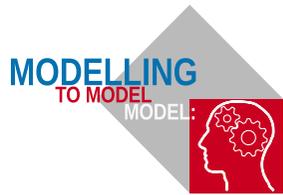
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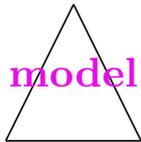
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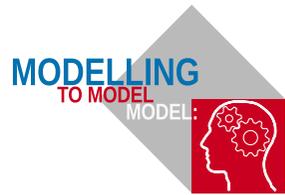
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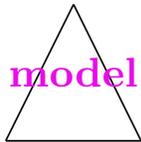
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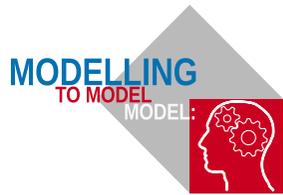
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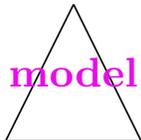
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