Models for Communication, Understanding, Search, and Analysis

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Abstract. Models are one of the universal instruments of humans. They are equally important as languages. Models often use languages for their representation. Other models are conscious, subconscious or preconscious and have no proper language representation. The wide use in all kinds of human activities allows to distinguish different kinds of models in dependence on their utilisation scenarios. In this keynote we consider only four specific utilisation scenarios for models. We show that these scenarios can be properly supported by a number of model construction conceptions. The development of proper and well-applicable models can be governed by various methodologies in dependence on the specific objectives and aims of model utilisation.

1 Introduction

Models are widely used in life, technology and sciences. Their development is still a mastership of an artisan and not yet systematically guided and managed. The main advantage of model-based reasoning is based on two properties of models: they are focused on the issue under consideration and are thus far simpler than the application world and they are reliable instruments since both the problem and the solution to the problem can be expressed by means of the model due to its dependability. Models must be sufficiently comprehensive for the representation of the domain under consideration, efficient for the solution computation of problems, accurate at least within the scope, and must function within an application scenario.

The Notion of Model

Let us first briefly repeat our approach to the notion of model:

A **model** *is a well-formed, adequate, and dependable instrument that represents origins and that functions in utilisation scenarios* [6, 24, 25].

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 [23] 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.

Model Deployment Scenarios are Multi-Facetted

The model notion can be seen as an initialisation for more concrete notions. We observe that model utilisation follows mainly four different kinds of scenarios (see Figure 1). The four scenarios do not occur in its pure and undiffused form they are interleaved. We can however distinguish between:

Problem solving scenarios: Problem solving is a well investigated and well organised scenario (see, for instance, [1, 8]). It is based on (1) a problem space that allows to specify some problem in an application in an *invariant* form and (2) a solution space that *faithfully* allows to back-propagate the solution to the application. We may distinguish three specific scenarios: perception & utilisation; understanding & sense-making, and making your own.

Engineering scenarios: Models are widely used in engineering. They are also one of the main instruments in software and information systems development, especially for system construction scenario. We may distinguish three specific scenarios depending on the level of sophistication: direct application:, managed application, and application according to well-understood technology.

Science scenarios: Sciences have developed a number the distinctive form in which a scenario is organised. Sciences make wide use of mathematical modelling. The methodology of often based on specific moulds that are commonly accepted in the disciplinary community of practice, e.g. [1]. We may distinguish three specific scenarios: comprehension, computation and automatic detection for instance in data science, and intellectual adsorption.

Social scenarios: Social scenarios are less investigated although cognitive linguistics, visualisation approaches, and communication research have contributed a lot. Social models might be used for the development of an understanding of the environment, for agreement on behavioural and cultural pattern, for consensus development, and for social education.

We may distinguish three specific scenarios: development of social acceptance, internalisation & emotional organisation, and concordance & judgement.

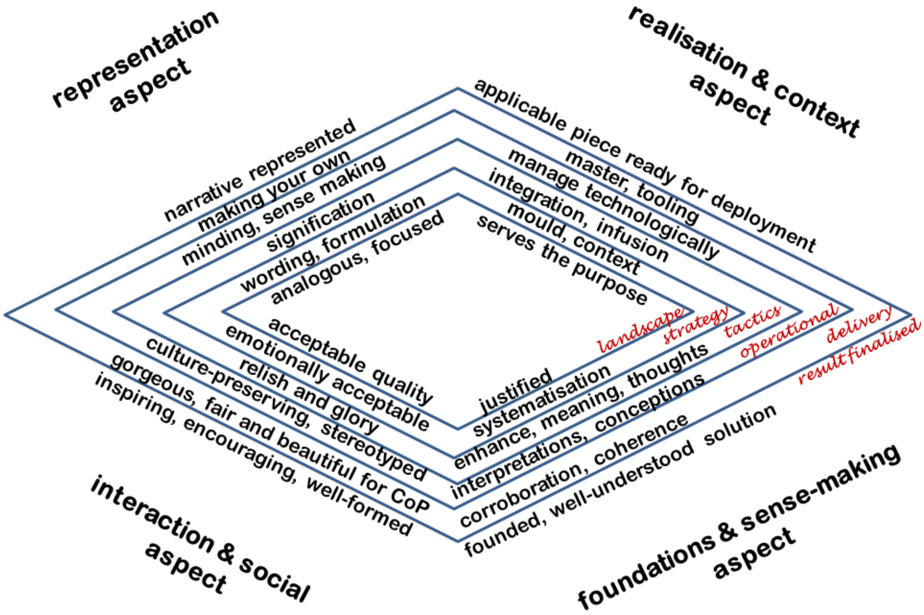

Fig. 1. The four aspects of model scenarios: problem solving, engineering, science, social scenarios. Each of the scenarios combines initialisation by exploring the landscape, strategy, tactics, operational, and delivery layers. Each of these layers adds quality characteristics and specific activities to the previous layer in dependence on the aspects considered

The notion of model mainly reflects the initialisation or landscape layer. Depending on the needs and demands to model utilisation we may distinguish various layers from initialisation towards delivery. The strategy, tactics, operational, and delivery layers are essentially refinements and extensions of the initialisation. The dependability and especially the sufficiency are based on other criteria while the landscape layer is permanent for all models due to the consideration of the concern, the issue, and the specific adaptation to the community of practice, . The strategy layer is governed by the context (e.g. the discipline) and the mould for model utilisation, and the matrix (including methodologies and commonly accepted approaches to modelling). The tactics layer depends on the settlement of the strategy and initialisation layers considers the well-acknowledged experience (e.g. generic approaches), the school of thought or more generally the background, and the framing of the modelling. Which origin(al)s are reflected and which are of less importance is determined in the operational layer that orients on the design and on mastering the modelling process. Finally the model is delivered and form for its application in scenarios that are considered. We thus observe various specific quality characteristics for each of these aspects and layers.

Do We Need a Science of Models and Modelling?

Since everybody is using models and has developed a specific approach to models and modelling within the tasks to be solved, it seems that the answer is "no". From the other side we deeply depend on decisions and understandings that are based on models. We thus might ask a number of questions ourselves. Can models be misleading, wrong, or indoctrinating? Astrophysics uses a Standard Model that has not been essentially changed during the last half century. Shall we revise this model? When? What was really wrong with the previous models? Many sciences use modelling languages in religious manner, e.g. think about UML and other language wars. What is the potential and capacity of a modelling languages? What not? What are their restrictions and hidden assumptions? Why climate models have been deeply changing and gave opposite results compared to the previous ones? Why we should limit our research on impacts of substances to a singleton substance? What is the impact of engineering in this case? What has been wrong with the two models on post-evolution of open cool mines after deployment in Germany which led to the decision that revegetation is far better than water flooding? Why was iron manuring a disaster decision for the Humboldt stream ocean engineering? What will be the impact of the IPCC/NGO/EDF/TWAS proposal for Solar Radiation Management (SRM) for substantial stratosphere obscuration for some centuries on the basis of reflection aerosols (on silver, sulfate, photophoretic etc. basis)? Why reasoning on metaphors as annotations to models may mislead? Are "all models wrong"[1]?

Developing a science of models and modelling would allow us to answer questions like the following one: What is a model in which science under which conditions for whom for which usage at a given time frame? What are necessary and sufficient criteria for an artefact to become a model? What is the difference between models and not-yet-models or pre-models? What is not yet a model? How are models definable in sciences, engineering, culture, ...? Under which conditions we can rely on and believe in models? Logical reasoning: which calculus? Similarity, regularity, fruitfulness, simplicity, what else (Carnap)? Treatment, development, deployment of models: is there something general in common? Models should be useful! What does it mean? Is there any handling of usage,

[1] "All models are wrong. ... Obtain a 'correct' one. ... Alert to what is importantly wrong." [2] We claim: *Models might be 'wrong'. But they are* ***useful***.

usefulness, and utility? What is the difference between an object, a model, and a pre-model? What might be then wrong with mathematical models? What is the problem in digging results through data mining methods?

The Storyline of this Paper

Models are the first reasoning and comprehension instruments of humans. Later other instruments are developed. The main one is language. Models then often become language-based if they have to be used for collaboration. Others will remain to be conscious, preconscious or subconscious. Based on the clarification of the given notion of model and a clarification of the model-being we explore in this paper what are the constituents of models, how models are composed, and what are conceptions for model constructions. Since models are used in scenarios and should function sufficiently well in these scenarios we start with an exploration of specific nature of models in four scenarios. We are not presenting all details for a theory of models[2].

2 Case Study on some Scenarios for Model Utilisation

Models are used in various *utilisation scenarios* such as construction of systems, verification, optimization, explanation, and documentation. *In these scenarios* they *function* as *instruments* and thus satisfy a number of properties [7, 26–28].

Models for Communication

The model is used for exchange of meanings through a common understanding of notations, signs and symbols within an application area. It can also be used in a back-and-forth process in which interested parties with different interests find a way to reconcile or compromise to come up with an agreement.

The model has several functions in this scenario: (personal/public/group) *recorder of settled or arranged issues*, *transmitter of information*, *dialogue service*, and *pre-binding*. Users act in the speaker, hearer, or digest mode.

The communication act is composed of six sub-activities: derive for communication, transfer, receive, recognise and filter against knowledge and experience, understand, and integrate. We may distinguish two models at the speaker side and six models at the hearer side: speaker's extracted model for transfer, transferred model for both, hearer's received model, hearer's understanding and recognition model, hearer's filtered model, hearer's understood model, and hearer's integration model. These models form some kind of a model ensemble. Some are extensions or detailing ones; others are zooming ones. Communication is based on some common understanding or at least on transformation of one model to another one.

[2] Collections of papers wich are used as background for this paper is downloadable via Research Gate. Notions and definitions we used can be fetched there.

Models for Understanding

Models may be used for understanding the conceptions behind. For instance, conceptualisation is typically shuffled with discovery of phenomena of interest, analysis of main constructs and focus on relevant aspects within the application area. The specification incorporates concepts injected from the application domain.

The function of a model within these scenario is *semantification* or *meaning association* by means of concepts or conceptions. The model becomes enhanced what allows to regard the meaning in the concept.

Models tacitly integrate knowledge and culture of design, of well-forming and well-underpinning of such models and of experience gained so far, e.g. meta-artifacts, pattern and reference models. This experience and knowledge is continuously enhanced during development and after evaluation of constructs.

Models are functioning for *elaboration, exploration, detection*, and *acquisition* of tacit knowledge behind the origins which might be products, theories, or engineering activities. They allow to understand what is behind drawn curtain.

Models for Search

Users often face the problem that their mental model and their fact space are insufficient to answer more complex questions [12]. Therefore, they seek information in their environment, e.g. from systems that are available. Information is data that have been shaped into a form that is meaningful and useful for human beings. Information consists of data that are represented in form that is useful and significant for a group of humans. This information search is based on their on the *information need*, i.e. a perceived lack of some information that is desirable or useful. The information is used to derive the current *information demand*, i.e. information that is missing, unknown, necessary for task completion, and directly requested. Is is thus related to the task portfolio under consideration and to the intents.

Search is one of the most common facilities in daily life, engineering, and science. It requires to examine the data and information on hand and to carefully look at or through or into the data and the information.

There is a large variety of information search [5] such as:

1. querying data sets (by providing query expressions in the informed search approach),
2. seeking for information on data (by browsing, understanding and compiling),
3. questing data formally (by providing appropriate search terms during stepwise refinement),
4. ferreting out necessary data (by discovering the information requested by searching out or browsing through the data),
5. searching by associations and drilling down (by appropriate refinement of the search terms),
6. casting about and digging into the data (with a transformation of the query and the data to a common form), and
7. zapping through data sets (by jumping through provided data, e.g., by partially uninformed search).

Models for Analysis

Data analysis, data mining or general analysis combines engineering and (systematic) mathematical problem solving [20]. The model development process combines problem specification and setting with formulation of the analysis tasks by means of macro-models, integration of generic models, selection of the analysis strategy and tactics based on methodology models, models for preparation of the analysis space, and model combination approaches for development of the final model society as the analysis result [16, 14]. The typical process model that governs the analysis process is based on a layering approach, e.g. initial setting, strategy, tactics with generic (or general parameterised models), analysis initialisation, puzzling the analysis results, and final compilation. It is similar to experiment planning in Natural Sciences. The analysis puzzling may follow a number of specific scenarios such as pipe scenarios [19].

3 Model Conceptions for These Scenarios

It seems that these scenarios require completely different kinds of models. This is however often not the case. We can develop stereotypes which are going to be refined to pattern and later to templates as the basis for model development. We demonstrate for the four scenarios (communication, understanding, search, analysis) how models can be composed in a specific form and which kind of support we need for model-backed collaboration.

Deep Models

A typical model consists of a normal (or surface) sub-model and of deep (implicit, supplanted) sub-models which represent the disciplinary assumptions, the background, and the context. The deep models are the intrinsic components of the model. Conceptualisation might be four-dimensional: sign, social embedding, context, and meaning spaces. The deep model is relatively stable. In science and engineering it forms the disciplinary background. It is often assumed without mentioning it. For instance, database modelling uses the paradigms, postulates, assumptions, commonsense, restrictions, theories, culture, foundations, practices, and languages as carrier within the given thought community and thought style, methodology, pattern, and routines. This background is assumed as being unquestionable given. The normal model mainly represents those origins that are really of interest.

The deep model combines the unchangeable part of a model and is determined by (i) the grounding for modelling (paradigms, postulates, restrictions, theories, culture, foundations, conventions, authorities), (ii) the outer directives (context and community of practice), and (iii) the basis (assumptions, general concept space, practices, language as carrier, thought community and thought style, methodology, pattern, routines, commonsense) of modelling. The deep model can be dependent on mould principles such as the conceptualisation principle [9].

A typical set of deep models are (the models and) foundations behind the origins which are inherited by the models of those origins. Also modelling languages have there specific deep parts. As well as methodologies or more generally moulds of model utilisation stories.

Model Capsules

Model capsules follow a global-as-design approach (see Figure 2). A model has a number of sub-models that can be used for exchange in collaboration or communication scenarios. A model capsule consists of a main model and exchange sub-models. Model capsules are stored and managed by their owners. Exchange sub-models are either derived from the main model in dependence on the viewpoint, on foci and scales, on scope, on aspects and on purposes of partners or are sub-models provided by partners and transformed according to the main model. A sub-model might be used as an export sub-model (e.g. $A_{4,E}$) that is delivered to the partner on the basis of the import sub-model (e.g. $B_{4,I}$). The sub-models received are typically transformed. We thus use the E(xtract)T(ransform)L(oad) paradigm where extraction and loading is dependent on the language of the sending or receiving model and where transformation allows adaptation of the export sub-model to the import sub-model.

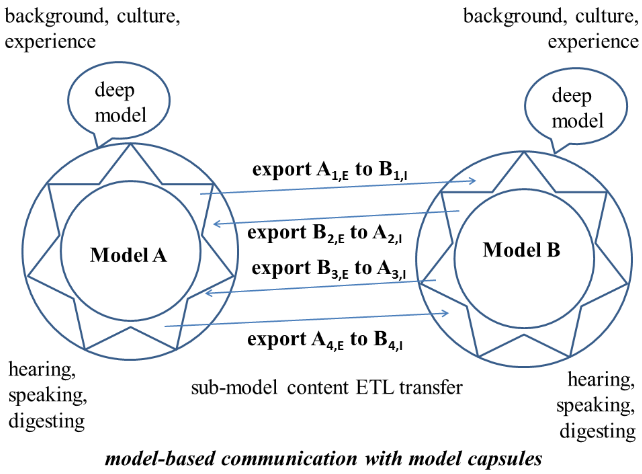

Fig. 2. Exchange on the basis of model capsules with sub-models in model-based ETL-oriented communication scenarios

Model Suites

Most disciplines simultaneously integrate a variety of models or a *society of models*, e.g. [3, 11]. The four aspects in Figure 1 are often given in a separate form as an integrated society of models. Models developed vary in their scopes, aspects and facets they represent and their abstraction.

A typical case are the four aspects that might coexist within a complex model. For instance, models in Egyptology [4] [3] can be considered have four aspects where each of the aspects has its specific model. The entire model is an integrated combination of (1,2) signs in textual representation and an extending it hieroglyph form (both as representation), (3) interpretation pattern (as the foundation and integration into the thoughts), (4) social determination (as the social aspect), and (5) a context or realisation models into which the model is embedded. The co-design framework for information systems development (integrated design of structuring, functionality, interaction, and distribution) uses four different interrelated and interoperating modelling languages. These modelling languages are at the same level of abstraction and may be combined with additional orientation on usage (as a social component, e.g. represented by storyboards [21]). In this case, the foundational aspect is hidden within the modelling language and within the origins of the models, for instance in the conceptualisation. Following the four aspects in Figure 1, we derive now models that consider one, two, three, or all four aspects (Figure 3).

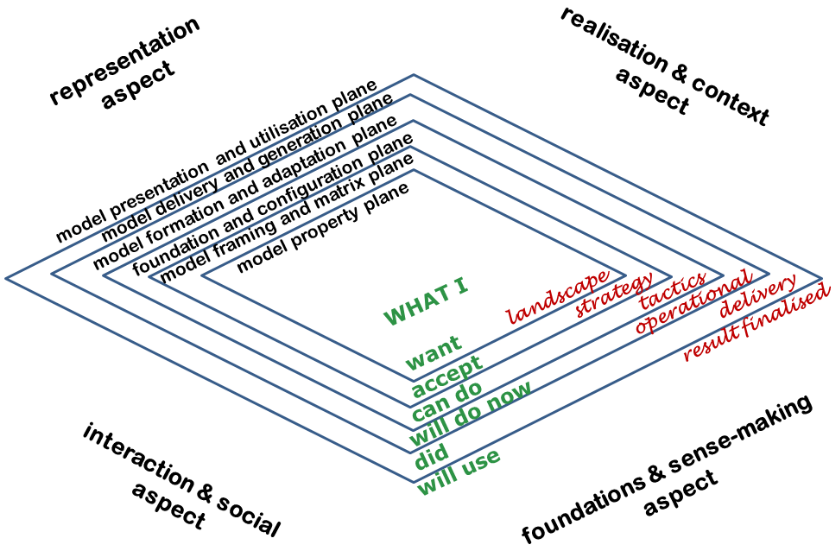

Fig. 3. The four aspect model suite and the corresponding planes for the layers within a model. Activities are governed at each plane by the WHAT I <actually_consider> as main activity.

A *model suite* consists of set of models $\{M_1, ..., M_n\}$, of an association or collaboration schema among the models, of controllers that maintain consistency or coherence of the model suite, of application schemata for explicit maintenance

[3] The rich body of knowledge resulted in [22] or the encyclopedia with [17].

and evolution of the model suite, and of tracers for the establishment of the coherence.

Model suites typically follow a local-as-design paradigm of modelling, i.e. there must not exist a global model which combines all models. In some cases we might however construct the global model as a model that is derived from the models in a model suite. The two approaches to model-based exchange can be combined. A model capsule can be horizontally bound to another capsule within a horizontal model suite or vertically associated to other model capsules. Model capsules are handled locally by members in a team. For instance, model capsules are based on models A and B that use corresponding scientific disciplines and corresponding theories as a part of their background. The models have three derived exchange sub-models that are exported to the other capsule and that are integrated into the model in such a way that the imported sub-model can be reflected by the model of the capsule.

Model Scenes

Model scenes for the development process may be specified in a similar way as storyboarding [21]. A scene is used by members of the community of practice, follows a certain modelling mould, considers a typical ensemble of origin(al)s, inherits certain stereotypes and pattern, is embedded into a context and the tasks, and uses the deep model as the background for model development. These parameters govern and thus control the scene. The developer or modeller is involved into this scene. The input for the scene is the current model, the specific properties of the ensemble of origin(al)s, and especially the experience gained so far. This experience may be collected in a library or generalised to generic models. The output is an enhanced model. We notice that model utilisation scenes can be specified in a similar way.

Figure 4 displays the embedding of a model scene into the model mould or more specifically into the methodology as a macro-model for development.

A model scene is an element of a model story. We imagine that the story can be represented as a graph. A model scene considers an actual or normal model and at the same time the desired embedding into the deep model. The scene is relevant for the community of practice. The model should be accepted by this community. The model scene also embeds the deep model. The scene has its cargo [18], i.e. its mission, determination, meaning, and specific identity. The cargo allows to determine the utility that the model gained so far.

Model Stories

Model development and utilisation can be described as a graph of scenes. Let us consider the model development for search scenarios [12, 13] in Figure 5. This story can be used for derivation of a waterfall-like approach in Figure 6. We start with initialisation of the search landscape. The result is a search guideline (or search activity meta-model). The information demand is transferred to a search question. The search strategy is configured out of the seven kinds of search. The

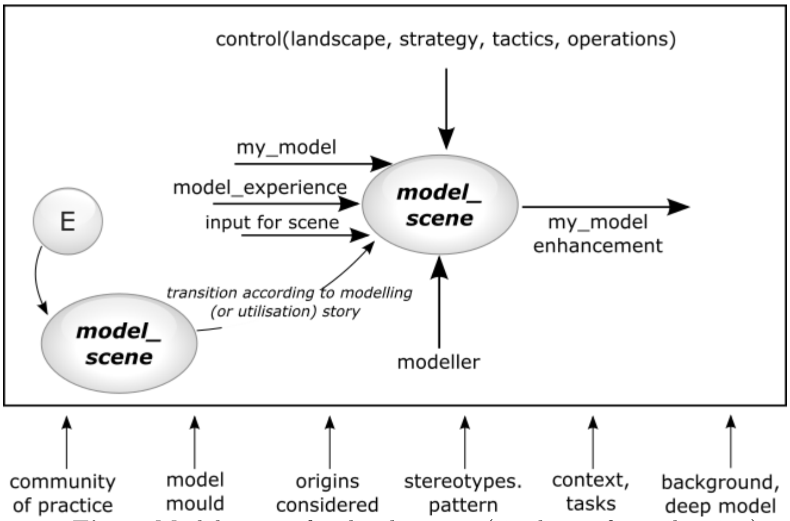

Fig. 4. Model scenes for development (similar to for utilisation)

result is a macro-search model. Selection of the search pattern depends on system information and on the data that is available. The result is a search meso-model, for instance, question-answer forms. Finally we may derive a model on the basis of the data. We might also reconsider the intermediate results and preview or prefetch the potential solutions.

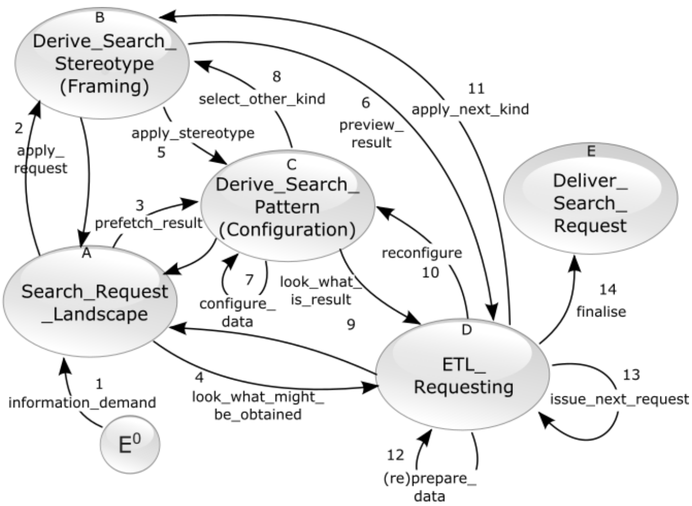

Fig. 5. The layered search story that is used for general search

This story is similar to data mining stories [13, 15]. Data mining uses macro-models as methodological foundation. Frameworks for data mining start with problem specification and setting, continue with formulation of data mining tasks by means of macro-models, reuse generic models according to required adequacy and dependability, next then select appropriate algorithms according to the capacity and potential of algorithms, prepare furthermore the data mining as a process, and finally apply this process. The data mining mould can be supported by controllers and selectors.

Spaces for Models

Figures 1 and 3 use six planes for detailing models. Each of the planes has it specific quality requirements, support tools, and tasks. At the landscape layer we determine the orientation of the model that should be developed, its problem space, its focus and scope, its integration into the value chain of the application (domain), and its stakeholder from the community of practice with their specific interests and their responsibilities, We rely on mental and codified concepts which are often provided by the world of the origins that a model should properly reflect. The strategic layer adds to this the 'normal way' of development for utilisation of models as methodologies or mould, the embedding into the context and especially the infrastructure, the disciplinary school of thought or more generally the background of the model. The tactics plane embeds the foundations into the modelling process, for instance, by deep model incorporation. It also allows to sketch and to configure the model. The operational plane orients on the formation of the model and the adaptation to the relevant origin(al)s that are going to represented by the model(s). The main issue for the delivery plane is the design of the model(s). The last plane orients utilisation of the model(s) that have been developed. This outer plane might also be structured according to the added value that a model has for the utilisation scenario. Each plane allows to evaluate the model according to quality characteristics used in the sufficiency portfolio.

The model planes have their own workspace and workplaces which are part of the infrastructure for modelling and utilisation.

4 Model Development

Model Development Story

The modelling story consists of the development story and of the utilisation story. The model development story integrates activities like

1. a selection and construction of an appropriate model according to the function of the model and depending on the task and on the properties we are targeting as well as depending on the context of the intended outcome and thus of the language appropriate for the outcome,
2. a workmanship on the model for detection of additional information about the original and of improved model,
3. an analogy conclusion or other derivations on the model and its relationship to the application world, and

4. a preparation of the model for its use in systems, for future evolution, and for change.

Model utilisation additionally uses assured elementary deployment that includes testing and model detailing and improvement. It may be extended to paradigmatic and systematic recapitulation due to deficiencies from rational and empirical perspectives by the way(s) incommensurability to be resolved. Model deployment also orients on the added value in dependence on the model function in given scenarios. A typical model mould is the mathematics approach to modelling based on (1) exploration of the problem situation, (2) development of an adequate and dependable model, (3) transformation of the first model to a mathematical one that is invariant for the problem formulation and is faithful for the solution inverse mapping to the problem domain, (4) mathematical problem solution, (5) mathematical verification of the solution and validation in the problem domain, and (6) evaluation of the solution in the problem domain [1].

Greenfield Development

Although development from scratch is rather seldom in practice nd daily life we will start with the activities for model development. These activities can be organised in an explorative, iterative, or sequential order in the way depicted in Figure 3. We can separate activities into[4]:

(1) Exploration of the origin(al)s what results in a well-understood domain-situation and perception models: The origin(al)s will be disassembled into a collection of units. We ensemble (or monstrate) and manifest the insight gained so far in a domain-situation model and develop nominal or perception models for the community of practice. It is based on a plausible model proposition, on a selection of appropriate language and of theories, on generic models, and on commonsense structuring.

(2) Model amalgamation and adduction is going to result in a plausible model proposition according to the selected aspects of the four aspects. Amalgamation and adduction are based on an appropriate empirical investigation on origin(al)s, on agreed consensus in the school of thought within the community of practice, on hypothetical reasoning, and on investigative design.

(3) Final model formulation results in an adequate and dependable model that will properly function in the given scenarios. We use appropriate depictions for a viable but incomplete model formulation, extend it by corroborated refinements and modifications, and rationally extrapolate the model in dependence on the given ensemble of origin(al)s. In order to guarantee sufficiency of the model, we assess by elementary and prototypical deployment for proper structuring and dependability, within the application domain, within the boundaries of the background, and within the meta-model or mould for model organisation.

[4] As a generalisation, reconsideration of [10]

A number of moulds can be used for refinement of this development meta-model such as agile or experience-backed methodologies Modelling experience knowledge development might be collected in a later rigor cycle (see design science, for instance, [29]). Model development is an engineering activity and thus tolerates insufficiencies and deficiencies outside the quality requirements. A model must not be true. It must only be sufficient and justified. It can be imperfect.

The result of development can also be a model suite or a model capsule. For instance, information system modelling results in a conceptual structure model, a conceptual functionality model, a logical structure and functionality model, and a physical structure and functionality model. It starts with a business data and process viewpoint model.

Model development can be based on a strictly layered approach in Figure 6 that follows the mould in Figure 5 based on planes in Figure 3.

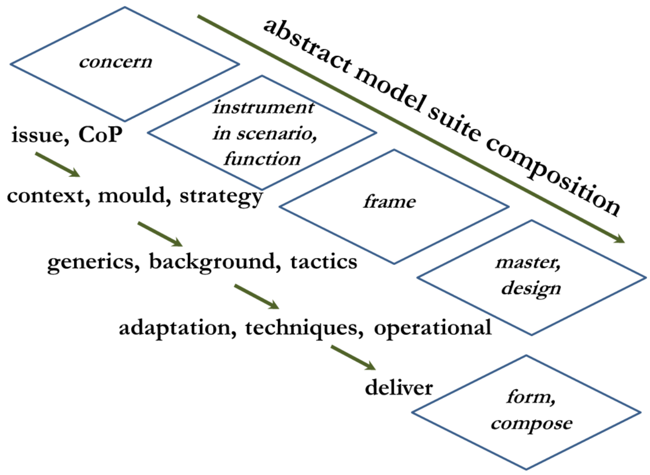

Fig. 6. Model suite development mould for some of the four aspects in Figure 1

Brownfield Development

Modelling by starting from scratch ('greenfield') must be extended by methods for 'brownfield' development that reuses and re-engineers models for legacy systems and within modernisation, evolution, and migration strategies The corresponding model already exists and must be revised. It may also need a revision of its deep sub-model, its basis and grounding, and its ensemble of origin(al)s. All activities used for greenfield development might be reconsidered and revised.

5 Conclusion

Models are widely used and therefore many-facetted, many-functioning, many-dimensional in their deployment, and. Based on a notion of model developed at Kiel university in a group of more than 40 chairs from almost all faculties, we explore now the ingredients of models. The model-being has at least four dimensions which can be grouped into four aspects: *representation* of origins and their specific properties, providing essential *foundations* and thus *sense-making* of origins, relishing and glorifying models as things for *interaction and social collaboration*, and blueprint for *realisation* and constructions within a *context*. This four-aspect consideration directly governs us during introduction of model suites as a model or model capsules. The utilisation scenario and the function of a given model (suite) determine which of the four aspects are represented by a normal model and which aspects are entirely encapsulated in the deep model .

Models are embedded into their life, disciplinary, and technical environment, and their culture. They reuse intentionally or edified (or enlightened) existing sub-models, pre-model, reference model, or generic models. A model typically combines an intrinsic sub-model and an extrinsic extrinsic sub-model. The first sub-model forms the deep model. For instance, database modelling is based on a good number of hidden postulates, paradigms, and assumptions.

The model-being is thus dependent on the scenarios in which models should function properly. We considered here four central scenarios in which models are widely used: communication, understanding, search, and analysis. These four utilisation scenarios can be supported by specific stereotypes of models which model assembling and construction allows a layered mastering of models. The mastering studio has its workspace and its workplace, i.e. in general space for models.

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