Combining Strategy and Sub-models for the Objectified Communication of Research Programs

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Abstract: Modeling is necessary for any kind of objectified planning and prognosis. A main problem of setting up and utilizing a generalized (objective) decision model is its demarcation to the correlated individual decision. The properties of the objective model can be generalized, as they have to be of general nature. The differences as well as the interaction between objective and (complementary) individual decisions can be investigated by subtracting the objective part from the whole decision problem. That is why the structure of objective models has to be investigated more in detail.

In the last century well known scientists have stated their demands on objectified models. From these demands the fundamental structure of an objective decision model will be derived.

The article does not aim at formulating general (objective) truth about reality but at providing a general tool for building *objective models* – without being able to avoid uncertainty with respect to real life. From this point of view objective models can have a strongly normative nature. The article concentrates on the product rather than the process of scientific discovery.

Many of the statements given in this article may sound trivial or at least well known. But combined as a structure it can be seen as a general model of objective models (meta-model), which can found a theory of formal decision systems as a formal representation of both the meta-model an its instantiations is in prospect. As the instantiations can found domain ontologies, the proposed meta-model can be seen as a meta-ontology.

Keywords: causal reasoning in model construction, computational models of model-based reasoning and scientific reasoning, conceptual combination and theory formation, logical analyses that may contribute to our understanding of the issues in model-based reasoning.

1 SCIENTIFIC OBJECTIVATION OF DECISION-MAKING

Epistemology is the study of the nature, origin, and limits of human knowledge (compare [1]). But the author takes the stance that – if knowledge is supposed to objectify nature – before knowing how to acquire knowledge the possibilities of *formulation and storage of an objective model (knowledge structure)* has to be clarified. Only on this basis the properties of an objective model can be derived and sketched how to acquire knowledge and transfer it into the respective knowledge structure.

This article does not try to carry on with the discussion of Bunge et al. [2] about who are the enemies of science and academic learning – teaching that there are no objective and universal truths or who 'smuggle in' fuzzy concepts, wild conjectures, or even ideology as scientific findings. Rather than analyzing *truth of reality* the possible *types of representation of truth* will be addressed in the following.

If we assume that modeling is necessary for the formulation of truth, the concept of models has to be analyzed in the beginning. Amigoni et al. [3] describe a model as follows:

> "A model is:
>
> I. *finite*: only a finite content of knowledge is drawn from the phenomenon, intended as a potentially infinite source of information, and is inserted in the model;
>
> II. *objective*: the model is so neat that everyone has the same understanding of the truth that is embedded in the model itself;
>
> III. *experimentable*: the model can be used in order to predict the happening of a new phenomenon.
>
> We think of a model as the result of a modeling activity, which consists in adopting a given *formalism* and in shaping within it a given *form*.
>
> A model has the following three properties:
>
> I. a model is *perfect* within itself, because the built up form is precisely described since the adopted formalism (such as mathematics, logic, etc.) provides exact shape definitions;
>
> II. a model is *imperfect* in knowing a phenomenon of reality, because the abduction is a creative process that expresses the knowledge embedded within the model, describing only some of the elements which contribute to the perception of the phenomenon; it is clear that the abduction cannot produce a model rich enough to describe the whole phenomenon;
>
> III. a model is *perfectibl*e, since it can be indefinitely substituted with a better (in the sense of less imperfect) model. The new model is the result of a new abduction (namely, of a pulse of creativity), which takes into account additional elements of the real phenomenon. The process can be iterated in order to obtain a sequence of

> models, each one better than the previous one, but worse than the subsequent one. However, when the phenomenon to be modeled is very complex, various models of such phenomenon are not necessarily arranged into a hierarchical (monotonous) order, but into a hierarchical (non-monotonous) order (in this case the alternative models are called *paradigms*)."

These definitions do not include individual models like the human brain. But since we want to describe objective models these attributes are supposed to apply.

A practical example of objective models will be given: The purpose of a knowledge-based system (KBS) in medicine is not the implementation of human creativity into machines, but the transfer of knowledge (acknowledged decision structures) into the daily routine for both researchers and practitioners (also compare [3]).

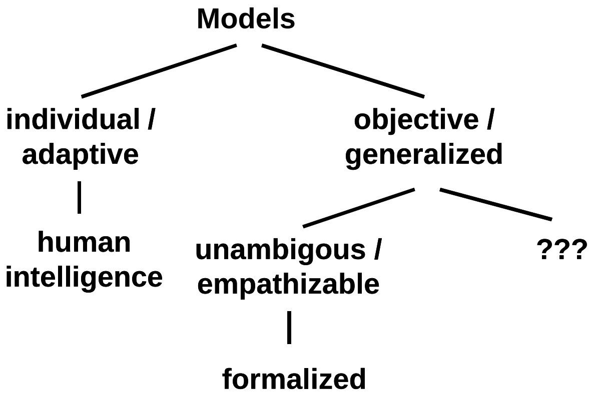

Figure 1: In contrast to individual models, objective models are supposed to unambiguously represent empathizable knowledge structures.

With other words, a perfect model is supposed to describe the transition from the initial to the intended state unambiguously (compare Figure 2). Thus, a KBS should perform as an *unambiguous communication platform* (compare [4,5]) – e.g. between researchers and practitioners. Hence, the decision-making should not be calculated in a mysterious "black-box"-system but be made transparent for all participants of the decision process.

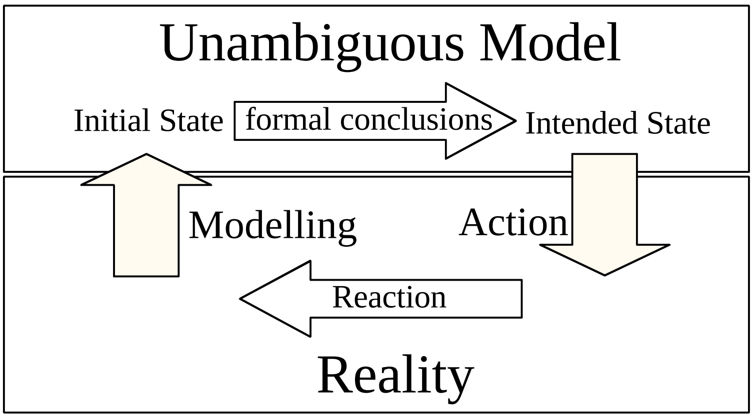

Figure 2: On the basis of a formalized model conclusions can be derived unambiguously. This formalized model can make the decision process transparent. The process of modeling as well as the action and its reaction cannot be part of the formal model.

It will be shown below that all kinds of perfect sub-models (e.g. a mathematical simulations) have to be embedded into a decision model to result in *one* comprehensive model – instead of fragmented partial models. So, before building a knowledge-based system the general properties of a *perfect decision-model* and the correlation to its *sub-models* are to be analyzed. This task will be the main point of this article.

Before discussing aspects of the representation of perfect decision models, the demands of well-known scientists with reference to the concept of objectivity will be treated more in detail. On their basis the fundamental structure of the representation of objective decision models can be concluded:

The concept of *objectivity* can be described with ‘strict matter-of-facts’ or ‘objective representation under maximum elimination of subjectivity’. So, together with the notion of ‘objectivity’, an objective representation and an elimination of subjectivity has to be discussed more in detail.

There are so many definitions related to *objectivity* that only very few can be consulted representatively: Popper attributes a certain absoluteness to the notion of objectivity: „According to my [...] thesis there are two different meanings of insight or thinking: (1) *Insight or thinking in a subjective meaning*: a state of mind and consciousness or a disposition of behaviors or reactions, and (2) *insight or thinking in an objective meaning*: problems, theories and arguments as such. The insight in this objective meaning is completely independent from anyone’s claim for insight, as well as any believe or any disposition to agree, to claim or to act. Insight in this objective meaning is insight without an observing person. It is *insight without a recognizing subject*“ ([6], p. 126, emphasizings in the original, translation by the author). Lakatos underlines this point of view: „[...] the objective scientific value of a theory is independent from the human mind, consciousness which creates or recognizes it“ ([7], emphasizings and translation by the author).

Heisenberg formulates a much more rigorous demand: „The first criterion for a ‚closed‘ theory is its inner freedom of contradiction. It has to be possible to *specify a notion derived from experience by definitions and axioms, fixed in their relations, so that mathematical symbols can be assigned to the notions to result in a contradiction-free system* [...]. [...] as long as [...] the notions are derived from experience like from daily life they are bound to the phenomenons and change with them; to some extent they nestle to nature. As soon as they are axiomized they become inflexible and brake away from experience. The concept of notions specified by the axioms still relates to a wide range of experiences; but in advance we can never be sure of a concept determined by definitions and relations how far we can get with it in association with nature. Therefore, the axiomatation of notions simultaneously limits it range of application.“ (from: the concept of a “closed theory”, [8,9], translation by the author).

Heisenberg`s demand for a formal freedom of contradiction can be correlated to the concept of causality: For Hessen an event can be predicted if it is causal, for Max Planck an event is causal if it can be predicted (both citations according to [10]). If the word causality is interpreted narrowly we also speak of a determinism meaning that fixed laws exist, predicting the future state of a system from its present state unambiguously (compare [8]. Therefore, the concept of causality is directly linked with the concept of prognosis.

On the other hand Russell claims that a thought is false if it cannot be integrated contradiction-free into the wholeness of our opinions. He concludes that true statements have to be a part of an enclosed system called ‘truth’ [11].

According to Simon decisions can be programmed if they occur repeatable and unchangingly. Decisions cannot be programmed if they are innovative, complex and hardly structured [12]. As a generalized decision model has to support repetitions, its inner decision structure must be representable as a program.

According to these statements an objective model is of perfect type as described above. So, the following considerations will concentrate on the development of a model of objective decision models where both the meta-model and its instantiation can generally be programmed. First, the structure of a *decision model* will be deduced. Later its relation to *other types of models* will be derived.

It will not be treated, which concrete real-life problems can be represented with an objective decision model or how precise an objective decision model can be with respect to reality as no objective criterion can be found outside of the objective decision model for assessment. The process of building an instantiation of the meta-model for the representation of a real-life domain (also compare [13]) is also not the main point of the following discussion. For that reason, techniques of acquiring and organizing coherent knowledge structure will not be considered.

2 STRATEGY: SUPERIOR STRUCTURE OF (DISCRETE) DECISIONS

To get an exhaustive and thus enclosed viewpoint onto formal decision models, the relation between the leading strategy and its adapted sub-models has to be analyzed:

In business-economics the concept of a *strategy* is used in combination with decision-making for leading an undertaking. Here, several representative numbers are set up for the derivation of a strategy and the respective action guideline for the board of directors (compare [14]). Schneeweiß defines the concept of a strategy as a 'sequence of planning decisions' [15].

From the point of view of computer science a *strategy* takes control over the order of the execution of partial tasks for a complex problem (compare: 'strategic layer', [16-18]).

Both definitions – in business-economics and computer science – have in common that the strategy consists of the superior decisions. In both viewpoints the notion of a strategy has a strongly subjective nuance as a precise demarcation to the adapted sub-models is missing.

Therefore, the following discussion tries to sketch a more precise concept of a strategy. On this basis the interaction between a strategy and its sub-models can be derived. Before this interaction can be analyzed, the role of a strategy in the context of the whole planning has to be defined.

2.1 Planning as an anticipation of decisions

From the point of view of economics planning is always related to an action. A model is needed for the prediction of the outcome and the assessment of the resulting states. Here, *planning* in its general meaning stands for the anticipation of decisions [19]. It can help raising the 'outcome quality'. Thus, the result of the actions can be estimated before actually acting. Therefore, during planning the notion of quality plays and important role: It describes the faultlessness of a solution or process. For Juran and Haux higher quality means: the reduction of errors, the reduction of reparation and loss, the reduction of customers dissatisfaction (patient dissatisfaction), the reduction of inspections and tests, the improvement of use and capacity with reference to financial expenses (compare [20] or [21]).

For the formulation of a general 'model of procedure' a '*planning of planning*' (meta-planning) is necessary. If alternative actions are provided during the application of this *meta-plan* (planning), a decision is necessary from the viewpoint of the 'ex-ante-design'. Herein, decision means the choice of a possible action out of several alternatives, which cannot be realized simultaneously (compare: 'field of decisions' in [15]). Therefore, a decision during planning is – in contrast to e.g. a legal decision – not retrospective but prospective (compare Juran's roadmap to quality management [20]).

In the following the description of the various aspects of result quality will not be the main point. The further analysis will concentrate on guaranteeing the structural and process quality of the planning itself. The author assumes that an unambiguous empathization of the planning cannot directly influence the result quality. But analyzing the decision structure and its process is of use for the scientific discussion and therefore for the quality management. So, in the following the demand is set up to empathize the structure of a objective planning model unambiguously. Therefore, an objective formulation of problem solutions should be strived as a basis for both communication and investigation of any scientific problem solution.

Starting from the strategy as the superior decision level a top-down approach for an objective decision model as well as the fundamental boundaries of this kind of model have to be set up.

2.2 Fundamental properties of a decision-strategy

As observed above a strategy should be empathizable unambiguously. To be able to make a choice within the discrete solution spectrum, decisions have to have a finite amount of solution alternatives[i]. We will start with the smallest unit of decision-making:

Each binary decision can be represented by a bit. The bit is well known to be smallest unit of information [22]. Accordingly, the binary decision has to be the smallest unit of decision[ii]. If a decision is interpreted as being a classification of the solution space, the binary decision accordingly can be called the smallest unit of classification.

From a formal point, of view each sequence of binary sub-decisions can be joined to one discrete decision with more than two decision alternatives[iii] (compare figure 2). This encapsulation can be called ‘information hiding’.

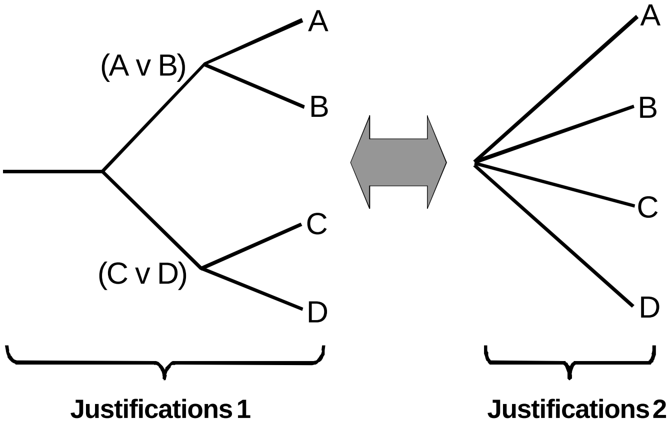

Figure 3: Each decision can be analyzed into a sequence of binary decision. On the other hand a decision sequence can be summarized to one single decision. From a formal point of view these types of representation are equivalent. But the justifications for the single decision steps will vary.

On the other hand, a decision with more than two decision alternatives can be divided in different ways:

$$A \vee B \vee C \vee D = (A \vee B) \vee (C \vee D) = (A \vee B \vee C) \vee D$$

These different types of representation for the same decision problem cannot be distinguished from a formal point of view, as there are no formal criteria (within the formal model!) preferring one of these types of representation[iv].

But the justifications for the single decisions will vary between these types of representation, as the context is different. An example for such a kind of decision-sequence can be given on the basis of a classification for scientific research programs (compare Figure 4). Herein, several competing and cooperating models, called *paradigms*, can be integrated (compare [23]).

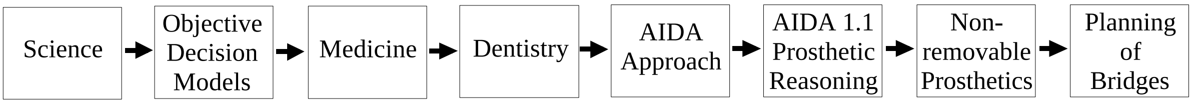

Figure 4: A research program can be classified within its field of application. Vice versa, decisions have to be made for the application of these models. Other kinds of classification are possible, but here an agreement is necessary to guarantee the same basis for reasoning.

Within a research program the decision alternatives can again be divided into distinct levels of decision-making. E.g. a mathematical *model* can describe the *gap* between two teeth. If the gap is larger than x then *do plan replacement*. Here, the output of the *gap model* serves as an input to the *replacement model*.

Like this one sub-model delivers information for the decision about the choice of the following sub-model and provides the necessary information for further planning.

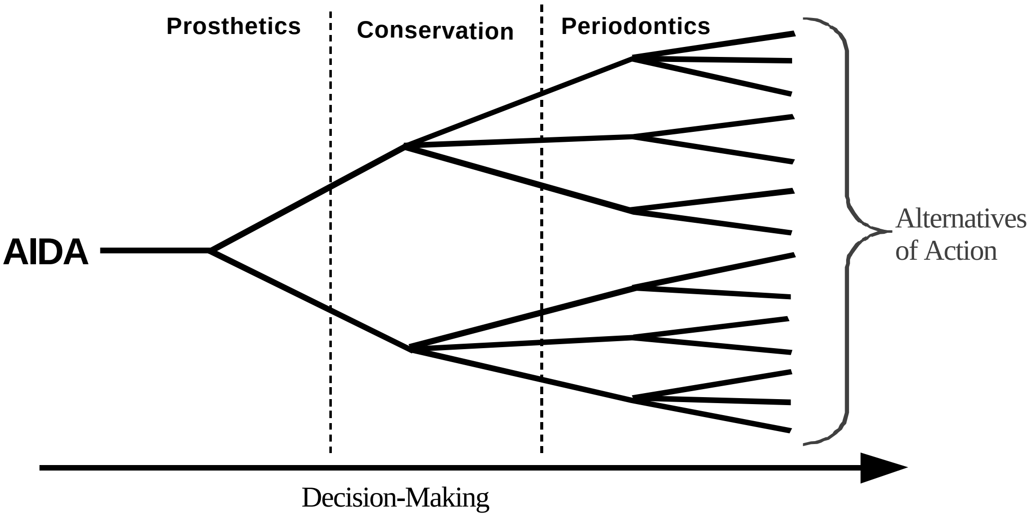

Figure 5: The sample decision sequence can be depicted as a decision tree. The decision alternatives represent a discrete, finite solution space.

Vice versa, decisions are necessary for the location of both the application and the extension of a research program. With other words, a *classification* and a *decision* have complementary character but depend on the same underlying decision structure[v].

As a result, the choice of a sub-model can be called the *strategy*. The underlying decision-structure (including the research classification and the decision for the respective sub-model) can be called *strategy classification* or *paradigm* (scientific viewpoint, cf. [7]). Here, only the *choice* of a sub-model can be objectified, but not necessarily its motivation.

Still it has not been clarified whether the respective sub-model itself is unambiguously formulated. An according analysis of objective sub-models will be made in the following.

3 EMBEDDING OF SUB-MODELS INTO THE DECISION-STRUCTURE

Besides the strategy there are further types of objective modeling. Mathematical and logical models[vi] can also be empathized unambiguously and therefore can be consulted for objective modeling. As a stringent model aims at representing *one* unified structure – not an assemblage of loose partial models –, the interaction between a strategy and mathematical sub-models has to be discussed in the following.

A mathematical model – like any other model – is a simplification of reality because a mathematical function cannot cope with all aspects even of a fraction of the world exactly (cf. [24,25]). Therefore, it has to be clarified, in which cases a sub-model can be integrated into a decision model. A logical structure is required, which decides about the application of a mathematical model. To result in an overall objective model a mathematical model should be integrated into a decision model to objectify its application. Worded differently, a causal model can support the confinement of the problem space and assigns a domain to the mathematical sub-model.

As the appropriateness of a mathematical function has to be verified by humans building the decision structure, only a discrete amount of recognized mathematical models can be available[vii]. Accordingly, only a finite amount of decisions about the application of a mathematical model is possible and necessary respectively. Thus, it can be expected to get a finite decision model about the application of mathematical models.

In the following the integration of different types of mathematical models into the strategic decision structure has to be clarified. In these considerations only (a) mathematical models with continuous and (b) such with discrete solution space will be distinguished.

3.1 Sub-models with continuous solutions space

A decision describing the application of a mathematical model with a continuous solution space can be objectified on the basis of a formal decision model. But the integration of this kind of model into the *middle* of a decision structure is not possible as its solutions space is incompatible with the continuation of the decision structure.

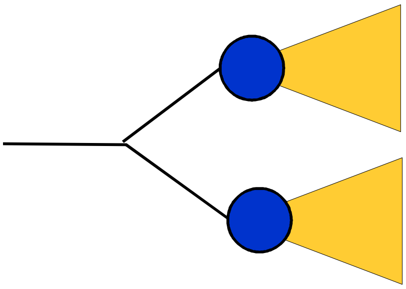

Figure 6: A mathematical model (circle) with a continuous solution spectrum (yellow) cannot be bound *into* a decision structure (lines) but only at its end as a its solution spectrum is incompatible with the discrete decision structure. But the continuous solution spectrum (function) can help at the end of a decision structure to carry out an action (e.g. guide a medical operation).

An example for such a mathematical sub-model can be used for the inquiry of the tooth gap.

As far as no further measures are taken to generate a discrete number of solution alternatives from the solution spectrum the decision methodology has to terminate at this point.

3.2 Mathematical models with discrete solution space

If the continuous solution spectrum of the mathematical model is classified, a discrete solution spectrum results[viii]. A decision about the application of a mathematical model with a discrete solution space is still possible and necessary. But as this kind of mathematical model provides a discrete amount of solution alternatives, its integration into the *middle* of a decision structure is possible without further measures. Each of its discrete solutions makes further alternatives in the decision structure possible.

From a different perspective the decision structure can be drawn including the alternatives from the mathematical model. From this point of view the mathematical model only assists the specific decisions [compare Figure 7].

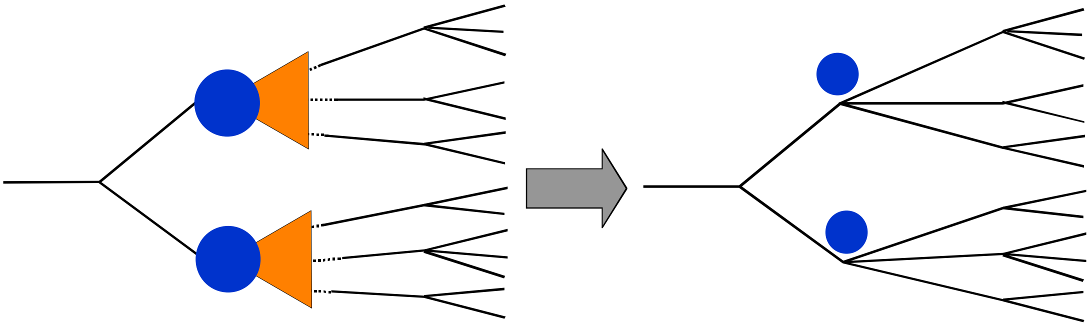

Figure 7: By classifying the solution space of the mathematical function the solution can be divided into discrete sections. From the point of view of the referring decision the mathematical function acts decision supporting.

4 EMBEDDING OF INTRA-INDIVIDUAL PREFERENCES INTO THE DECISION MODEL

Not all aspects of a problem can be modeled formally[ix]. Up to now is has not been clarified how these ‘intra-individual preferences’ can be added to the formal decision model. On one hand they cannot be bound to the formal decision model formally as they underline the influences and interpretations of individuals and therefore do not satisfy the criteria of objectivity. On the other hand they are necessary for the application of a decision methodology as they can support decisions, which cannot be predefined by mathematical functions.

But they can show the relation of the formal decision model to reality and thus guide the individual sub-decision. This type of guidance will be called “decision motivation” in the following. As a decision has a discrete solution spectrum – as shown above – only a discrete amount of different motivations is required for each sub-decision of the formal model.

One could hit upon the idea to build a formal model for a stringent motivation of a decision to get a strictly logical deduction of partial decisions. But this kind of sub-model could directly be integrated into the formal decision model because of its direct correlation. With other words it would lead to a simple extension of the strategy. Like this the problem of explaining the relation between the formal decision model and reality is not solved. Like this it can be made plausible that motivations are necessary which cannot be bound to the formal model formally.

An arbitrary formulation of motivations does not make sense as it could be interpreted arbitrarily. But even if a motivation cannot be included formally, it can be deposited explicitly[x]. So, it can be reproduced at any time. It can be stored on the basis of a formal convention – e.g. in a specific file format. This is correlated with a technical convention of storage and transmission and not the formalization of the interpretation within the decision methodology. Therefore, the formalization has only an indirect connection to the process of decision-making, as it does not capture semantics.

The motivation can also initiate an action[xi]. This action is not predefined precisely but necessary anyway.

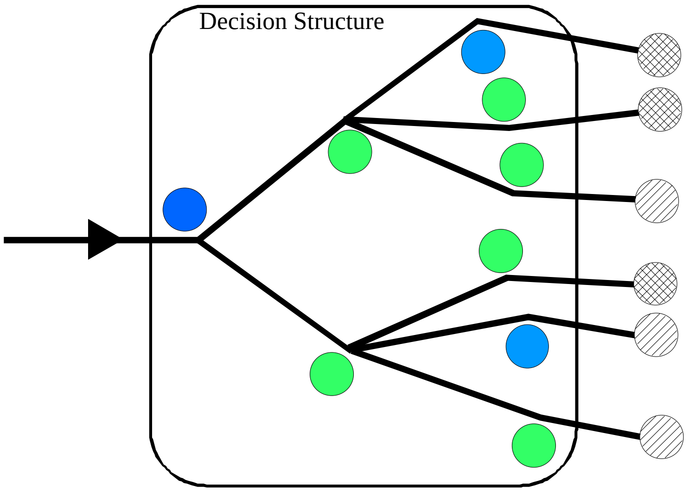

Figure 8: The relation of each partial decision to reality can be achieved on the basis of formally bound models (blue) or non-formally bound models (green). Each of these partial sub-models can also initiate an action. The models at the end of the decision methodology on the other hand can *only* describe actions (formal sub-models = cross-hatched, non-formal motivations = checked).

5 GENERATING INDIVIDUAL PROBLEM SOLUTIONS WITH THE DECISION MODEL

After the general structure of the decision model has been described, the individual decisions have to be derived on its basis. The user has to be able to get concrete action alternatives by the application of the decision model. In addition he needs decision motivations to be able to explain the single decisions and to find the optimal solution. The conscious decision can also be concluded at the end of a decision sequence that no action is necessary or useful. Though several repetitions of statements they will be shown from the perspective of the applying specialist[xii].

5.1 Empathizing a decision structure

Before a decision structure can be consulted for the solution of an individual decision problem, a principle decision about its application has to be made. As this decision cannot be derived from the decision model itself, it cannot be objective from the point of view of the decision methodology. Even the correlation of each part of the formal model to reality cannot be proven, as it cannot be a part of the formal model itself (compare figure 6).

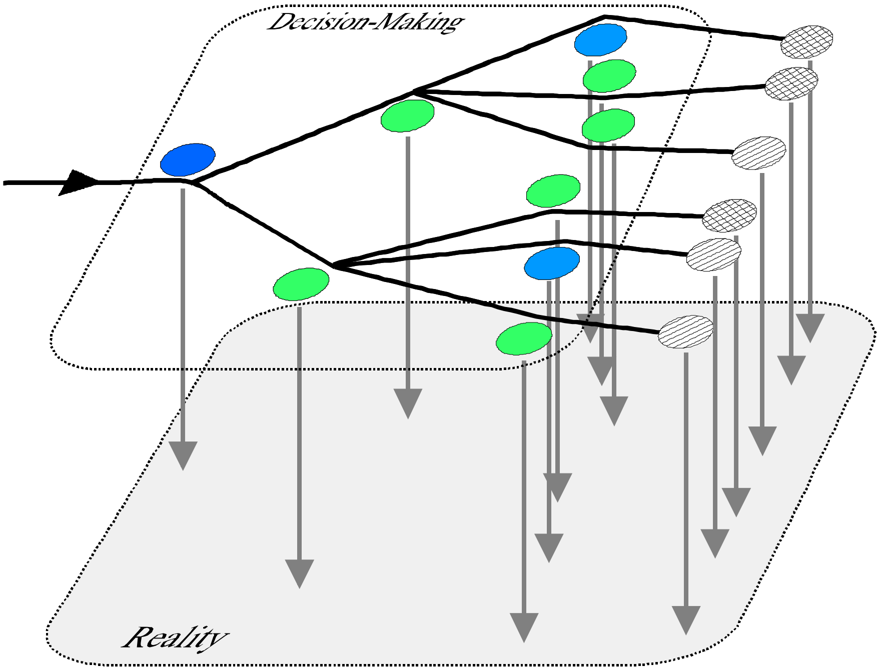

Figure 9: Each component of the objective decision methodology (black lines) has its specific relation to reality, which can be illustrated by appropriate explanations (gray arrows). These explanations can be deposited formally, but do not have a formal relation to the decision-structure.

If a decision about the application of a formal decision model has been made, the decision structure can be empathized step by step for the specification of individual solutions. Here, each partial decision makes a choice from the alternatives from the current decision step. Each partial decision can be made either intuitively (supported by decision motivations) or be derived on the basis of a respective mathematical function (compare chapters 3 and 4).

In decision models binary decision can often be found as they represent the existence or non-existence of an object. The ex-post decision about these two alternatives of the binary decision can be seen as the smallest unit of ex-post decisions. In general it is also called ‘diagnosis’. The simplest type of decision therefore is a single diagnosis.

5.2 Application of sub-models

It has not been clarified yet, where the information comes from, which is inserted into the mathematical function for the derivation of the decision and the respective action. This kind of information cannot origin from the formal model itself and therefore has to be deduced from an observation. In other words an ex-post link of an observation with a scale is necessary. This procedure is usually called ‘measurement’. In addition a binary decision about the success of a measurement is necessary and assigns the measured value to the decision model.

5.3 Guiding an action by a sub-model

Generally, a mathematical model can be support both, an action and the preparation of a decision (if there is a classification, which makes the integration into the decision methodology possible). Both of these types of usage can be handled separately as they do not interact.

Summarizing the formal decision structure can be depicted as a decision tree where a mathematical models support a single decision and

(a) acts *both* decision-supporting at the point of decision *and* leads into an action or
(b) serves as a guideline for action at the of a decision structure *exclusively*.

A mechanical action e.g. can be described by a function. Generally, for spatial or temporal problems it is not possible to carry out the planned action exactly[xiii]. Worded differently there is an *uncertainty of action* between the mathematical model of action and the spatial and temporal action.

6 SUMMARY AND PROSPECTS

Based on the demands of well-known scientists on the concept of perfect models and objectivity, a general structure of an objective decision model has been derived. As the objective model has to be empathizable and therefore represented formally, conclusions can be drawn for the fundamental structure of its meta-model. The relation of an objective model to reality cannot be objectified, as it cannot be a part of the conclusive model itself.

It could be shown that mathematical sub-models and decision motivations can support a decision structure. Here, the analysis concentrated on the product of a formal decision model.

Several aspects of objective models have to be emphasized: (a) the process of acquiring the formal decision model has not been described in this article. (b) A concrete decision model not necessarily has to utilize all possibilities of the meta-modeling for decision-making as described above. With other words, simplified versions can be built *only* consisting of e.g. a single mathematical model[xiv] or merely a formal decision structure[xv]. But to enhance a precise communication of the knowledge it should be headed for a far-reaching formalization of the model.

An instantiation of the developed meta-structure can serve as a domain-ontology (also compare [26,27]) and a communication platform (also compare [28]) between scientists (also compare [29]). With appropriate tools managing these domain models and their multidimensional classification it should be possible to identify both redundancies and lacks in the worldwide research.

A computer system seems to be most appropriate for the representation of such a decision-model and its sub-models as all of its parts can be represented on the basis of (i) formal logics, (ii) mathematics (also compare [13]) or (iii) free text. Together they can form what Minsky called an agency of agents [23].

In the AIDA-project [30-32] a respective solution for modeling dental decision-making is based on the general structures described in this article.

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[i] This demand distinguishes from other notions of strategy, which presume a meta-modeling *either* in mathematical *or* logical manner (compare [14]).

[ii] This fact does not mean that its reasoning has to be trivial.

[iii] For each type of representation the justifications of the decisions will be different.

[iv] Whether the minimal resulting tree (minimum number of branches and leaves) serves as the best representation of the real life problem cannot be defined a priori.

[v] One can imagine other sequences for the classification of the AIDA project than shown in Figure 4. But such an alternative classification can be classified within the super-structure – as long as it is of scientific nature. Like this, an intuitive decision has to be made either to use the scientific model or an alternative one. With other words both models can be structured within a collective (super-posed) ‘root’ where the decision process starts. This does not alter the fact that a classification is possible and necessary.

[vi] E.g.: mechanical models and biometric models can be a combination of logical and mathematical nature. Here a similar structure to *if x is larger than y then follows z* can be found.

[vii] The mathematical model might be specified by variables, but here the function will still remain the same.

[viii] E.g. the solution space of a biometric model can be partitioned by a “confidence interval” of 95%. Here, the solution space is divided into two or three sections respectively.

[ix] E.g. the decision about the appropriateness of the decision model in an individual case.

[x] Text, pictures, sound, etc. .

[xi] E.g.: if the patient has not been disinfected yet, the nurse has to wash the wound.

[xii] In the previous chapters it has been shown from the perspective of the constructing expert.

[xiii] In technical term we usually talk about ‘tolerance’ e.g. of a piece of work.

[xiv] These types of modeling can mostly be found in natural sciences.

[xv] Most of the formal humanities concentrate on the construction of decision models. This becomes obvious in the law studies.