Survey of amended smart theories and their predictions involving knowledge uncertainty

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Abstract— In this article, we evaluate the modeling of an actual operation of an existing system using the appropriate conforming theory. We demonstrate that the theories usually used directly do not relate to reality because these elegant theories were founded on unrealistic backgrounds. The need to adapt these bases to the real circumstances of the landscape necessitates modifying the models used. The approach to building such models from elegant theories is considered and emphasized through a review of examples in electromagnetic systems. The importance of the concept of revised models has been revealed in predictive modeling applied to natural and man-made processes. This is illustrated by a demonstration in the case of prediction in practices related to the uncertainty of knowledge. This demonstration is carried out through a review of instances acting in both natural and artificial processes.

Keywords— elegant theories, knowledge uncertainty, postulations, prediction modeling.

1. Introduction

The foundation of essential theoretical investigation is based on elegant and rational theories, which is indispensable for modern science of civilization. These theories are usually designated to self-sufficient scientific fields. The consistency of a given theory in a given foremost scientific area comes from the circumstance of ignoring different less important phenomena present in the real world. Such hypotheses squeeze and idealize the current reality. These lesser phenomena are normally associated to the environmental conditions and behavior of matter. These inferior phenomena are generally ruled by other subsequent fields of science. Comprehensible theories operate impeccably to particular situations where the relative suppositions are in phase. If not, to model a real circumstance, using main field theory, where reducing suppositions appear illegitimate, we need to backtrack from these postulations.

The problem of model exactness and being reality matching belongs to uncertainty problematics. Uncertainties can be generally classified as random or epistemic. This last is the one involved in model exactness. Such knowledge uncertainty is concerned in the prediction of functions or processes owning well-known behaviors. The management of this uncertainty could be achieved by improving the model used for the prediction.

Regarding the elegance in theories, there are many examples e.g. Newton's second law of motion, Maxwell equations… Different aspects can characterize the involved elegance as simplifying, generalizing, blending… An example of the best well-known elegant amalgamated theories is the set of Maxwell equations [1], which unified three experimental principles found by Gauss, Ampère and Faraday.

The contribution of elegance in theories is irrefutable. Nevertheless, in spite of elegance a theory could be in conflict with reality. Few years after Francis Crick co-discovered the DNA double helix and few years before he co-won a Nobel Prize, he reached that [2] the same is not necessarily true for all science activities "In biology, it is possible to be elegant and to be wrong".

Most of founded theories illustrate an important interest of elegancy concept. However, in the application to real systems such theories could be in contradiction with reality and not always applicable straightaway. In such cases, we have to do a turnaround from elegance to reality reconsidering the conforming consigned approximations. We are consequently tending to adjust the model built on the theory of the foremost field, by associating the subordinate fields in an amended model [3], [4]. Such a reformed model consequential to “retrograde postulations” paradoxically appears to characterize the real context.

In the present paper after discussing the notion of elegancy of theories, we will illustrate the necessary postulations to achieve such elegancy. Then we will discuss the need of amending the models to remedy for approaching postulations. The proposed strategy for developing revised models will be illustrated through implication into prediction modeling of processes linked to knowledge uncertainty. These concern natural or artificial phenomena owning identified behaviors.

2. Elegant Theories and Postulations

When we encounter a difficult and complicated behavior of a given phenomenon, we tend to represent it by a mathematical model. This model could be based on observation (experience) or theoretical representation. Each of the two problems has advantages and disadvantages. In the case of observation, the main advantage is the proximity to reality. The main drawback of such a problem is the implication of empirical constants varying according to the different parameters of the observed set. In the case of theoretical representation, elegance and universal aspects are the vital advantages of this question. The invasive flaw in such a case arises from the involvement of several postulations, which result in an idealized model valid under idealized conditions. The elegant theory obtained, even universal, characterizes a false model of a true daily system.

Regarding the notion of elegance in theories, when we consider a theory describing a phenomenon intelligibly and straight, we label it as elegant. Furthermore, a concept simple to understand permits to account for a great quantity of knowledge and satisfy many requests. Hence, the elegance characterization as easiness plus more capability looks just.

2.1 Example of Elegance

As mentioned before, an example of the best well-known elegant compound theories is the set of Maxwell equations. These equations derived by James Clerk Maxwell (1831-1879) comprise an alliance of three experimental principles found by three of his precursors. These are Carl Friedrich Gauss (1777-1855), André-Marie Ampère (1775-1836) and Michael Faraday (1791-1867). The organization of Maxwell equations was only possible as Maxwell saw how to progress forward of the task of his precursors, by hosting into an equation a lacking-link, so-called displacement current, whose incidence assurances the reliability of the unified organization. This shows a substantial mark of the alliance elegancy, [1].

Nevertheless, in spite of elegance a theory could be in conflict with reality as mentioned before. Few years after Maxwell has published his Treatise in 1873, a young scientist has disproved a part of the contribution, Edwin Herbert Hall (1855-1938). He has introduced and proven in his thesis work, the principle called Hall Effect in 1879. This proposition attained from observation (experience) regards the relation involving the force and the current in a conductor bathed in a magnetic field, which was believed nonexistent by Maxwell. We notice at this point that the elegance due to mathematical handling of observed laws has been improved thanks to observation indubitably. The Maxwell equations and the Hall Effect have much contributed to posterior research particularly in restraint relativity and quantum mechanics.

2.2 Elegance Postulation Reductions and its Reverse

Generally, as mentioned before, in the application to real systems elegant theories could be in inconsistency with reality and not always applicable straightaway. In such cases, we have to adjust the model constructed on the theory of the foremost field, by associating the secondary fields, neglected for elegance, in an amended model.

Consider a real societal physical problem that could be represented mathematically by the function A which, is the association or the union of the functions B, C, D…Each of these functions relates to a different domain or area of science. In order to model this real problem, we need generally to consider different aspects related to different areas of science relative to the function A. On the other hand, often a domain is more concerned by the problem than the others did, let us call it the foremost domain and represent it by the function B. In general, one tend to consider this main area alone to practice modeling. In the meantime, almost all scientific theories generally relate to a single area of science. In addition, founding coherent and agreeable theories habitually requires postulations that squeeze and idealize the actual context of the investigation. Thus, the consistency and "elegance" of a theory requires idealized assumptions resulting in a simplified B function denoted by B’. Accordingly, such a theory could only be used correctly under the same conditions of these hypotheses (corresponding to B’). Moreover, the validation of this theory, which allows its foundation, must also be done under these conditions [5].

Therefore, when we model a real problem using only principal domain theory, the result would often be wrong. This is due to the constraint of two approximations. The first results of neglecting the other domains influences (replacing A by B) and the second comes from using idealizing postulations (replacing B by B’).The further these two approximations are inexcusable apropos the concrete conditions, the attained outcomes using the main domain will be far away from the veracity. In such a circumstance, in order to adjust this situation, we have to track a reverse approximating method that to re-integer in the model all the neglected aspects resulting from the used approximations.

We can note that, the reduction of the function A to a principal domain signified by the function B as described above could operate in the same manner on the functions C, D…Therefore, we can study a given problem from different sides corresponding to different reductions involving different approximations. For example, if we consider a problem involving thermal and chemical domains. When studying thermal performance, one may tend to introduce chemical approximations for reduction and reciprocally.

Figure 1 illustrates a summarized representation of postulations applied to real setting fields resulting in an elegant theory of the main field and its reverse. This last shows how to use the elegant theory correctly through mathematical coupling to model the real setting.

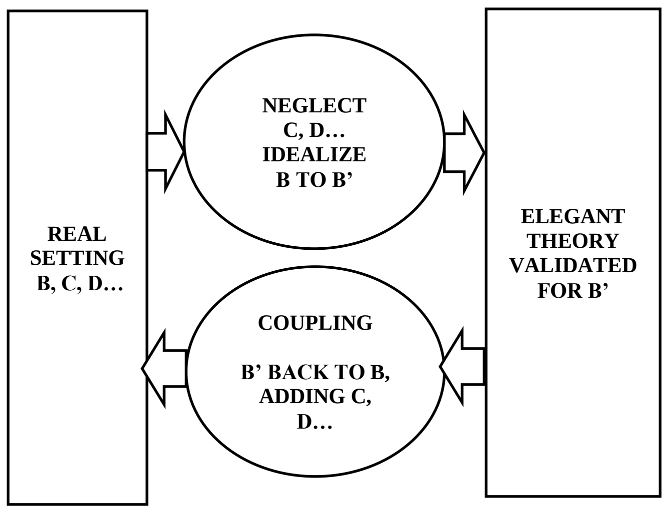

Fig. 1 Representation of postulations applied to real setting fields resulting in an elegant theory of the main field and its reverse. B main field, C, D… secondary fields, B' main idealized field.

3. Revised Models and Knowledge Uncertainty

The reverse approximation procedure will go through some kind of revised model comprising the main theory combined with the other theories involved, all taking real conditions into account, see figure 1. In addition, it could include other elements related to specific mathematical formulations, adequate boundary conditions, particular numerical techniques…. The revised model should account for these elements using an appropriate procedure for solving the integrated equations. This procedure concerns the notion of the solutions of coupled phenomena consequent to the association of diverse scientific topics [3], [4].

In the prediction modeling of natural or artificial phenomena owning identified behaviors we are undertaking an uncertainty problem related to the precision of the model. This knowledge uncertainty is closely related to the notion of amended model. Note that such prediction process does not concern phenomena owning unknown or aleatory behaviors governed by random uncertainty.

2.1 Coupled Problems and Solution Strategy

At large, coupled problems arrangements consist of mathematical solution of equations ruling different natural or artificial phenomena in sets act under rules fitting to individual topics of theoretical sphere. The behaviors of these phenomena and their interdependence as well as the closeness of their temporal evolution (time constants) are directly related to the approach to solve the corresponding governing equations. Such approach could vary from solving the governing equations individually to strongly coupled simultaneous solution of equations.

The circumstance of the inverse approximation process reintegrating into the model all the ignored features obviously appears as a kind of a coupled problem.

Generally, modeling of a physical realistic problem involves relatively complex features. These comprise geometrical nature, matter behavior laws and temporal conducts. Such occurrence becomes more incisive when the problem implicate coupling of different phenomena. In this situation, we have to consider different specific elements. An essential facet of these elements concerns the form of the handled equations and their solution strategy. In general, the source nature, the matter behavior and the geometry in real problems are more complex than these reflected in theory and hence the corresponding equations are more complicated compared to elegant theories. Such complex system of equations does not permit analytical solutions and often we require considering a discretized form in space and time of the equations. In such case, the theories will operate locally in finite discrete domains for which the global solution of the assembly will be effected in the discretized time domain. The space local non-linearity and the time evolution are considered through iterative procedures.

3.2 Application in Case of Electromagnetic Systems

We can illustrate the described solution strategy from the example of the case of electromagnetic systems that present in many societal applications such as mobility, health, safety, communication. The main theoretical topic in this case is relative to the example mentioned before of the elegant compound theory of the set of Maxwell equations (section II). However, these systems behave generally in four instances: electrical, magnetic, mechanical and thermal. Many works have been published involving the solution strategy accounting for one or several of these instances. As for example in the case of electromagnetic generally, see [6]-[20]. In the case involving the mechanical aspect see e.g. [21]-[24]. In the case comprising the thermal aspect see e.g. [14,] [25]-[27]. In the case of material intrinsic couplings (for smart materials), see e.g. [28]-[31].

4. Prediction in Processes Linked to Knowledge Uncertainty

In the present section, we extend the illustration generally for the prediction modeling in processes related to the problematic of knowledge uncertainty. These concern prediction modeling of natural or artificial phenomena owning known behaviors. Before illustrating such prediction modeling, we will first introduce the link prediction-observation.

Numerous new experimental methodologies in different sciences require the development of modeling. These models provide a quantitative understanding and predictive simulations of the corresponding processes, their response to various constraints that cannot be achieved by studies based on observation or experimentation alone. Conversely, the validation of predictive models by the development and implementation of new experimental approaches represents an essential investment in these sciences. These clarifications illustrate the importance of the link prediction-observation [32].

Moreover, in the link prediction-observation, the observed behavior and its model are regularly matched. When the observed behavior and its model are contrasting, we are tackling a problem of knowledge uncertainty. Furthermore, in this link, the scientific disciplines that can be trained involve experimental, computational and theoretical investigations. Besides, the prediction (or estimation) is often employed in the control of industrial systems and permits associated to observation (estimator-observer control), to obtain precise and quick performance, see e.g. [33]. The prediction-observation link concerns different sciences and research areas as biology, environmental sciences, physics, chemistry, mathematical and computer modeling, processing and assimilation of experimental data, scientific computing, AI...

The concerned uses of the link prediction-observation are involved in natural theoretical sciences and widely disseminated in industrial processes, Digital Twins, healthcare protocols, mobility vehicles, security, medical and technical imaging…We will consider prediction modeling in processes related to the problematic of knowledge uncertainty in cases of natural and artificial phenomena owning known behaviors. For this, we will discuss the natural biological phenomenon involved in the Bayesian Brain theory in neuroscience and the artificial industrial concept of Digital Twins. We will see that in both of these two cases, the link prediction-observation plays almost the same function. In fact, in both situations we are in presence of a real time two way interconnected matched process. Such matching involves an observed item and a predictive one. The observed item corrects the prediction error and the predictive item rectifies the sensory observed inputs. It is worthy to note once more that phenomena owning unknown or aleatory behaviors, which are not governed by knowledge uncertainty but by random uncertainty, are outside the scope of the presented methodology.

4.1 Biological Bayesian Brain Theory in Neuroscience

Bayesian tactics for brain acts evaluate the capacity of the neural structure to operate under circumstances of uncertainty to come together with the optimal advocated by Bayesian statistics [34]. Bayesian brain theory in neuroscience commonly attempts to lighten the cognitive abilities of the brain founded on statistical procedures where it is considered that the neural assembly retains inner probabilistic models revised by sensory information via neural handling by means of Bayesian probability [35]. It is assumed that Bayesian implication operates at the cortical macrocircuits echelon. These circuits are organized along with an order that indicates the categorized collection of the observable things around us. The brain trains a model of these objects and generates predictions concerning their sensory input; that is the pretended predictive coding. The global characters of the panorama, including objects, will be designated by accomplishment in regions of the brain neighboring to the upper hierarchy. The connects from the higher zones to the lower ones afterward put into code a model elucidating how the sights contain objects and the forms of these objects. The lowest level predictions are accorded to sensory input and the prediction mistake is spread up in the hierarchy. These regions are hierarchically organized such that the inferior level delivered prediction error produces the input of a higher-level zone. At the same time, the restore from the upper-level portion communicates the previous beliefs for the inferior level one. In this condition, the prediction error specifies that the present model has not entirely taken into account the input. Readapting the following level can improve exactness and moderate the prediction error [36], [37]. However, if not, upper-level amendments are necessary. Largely, higher levels provide data to lower ones and guarantee inside reliability of assumed sources of sensory input at diverse levels. This happens simultaneously at all hierarchical levels. The predictions are sent downward and their errors are sent backward up in a dynamic process, see figure 2.

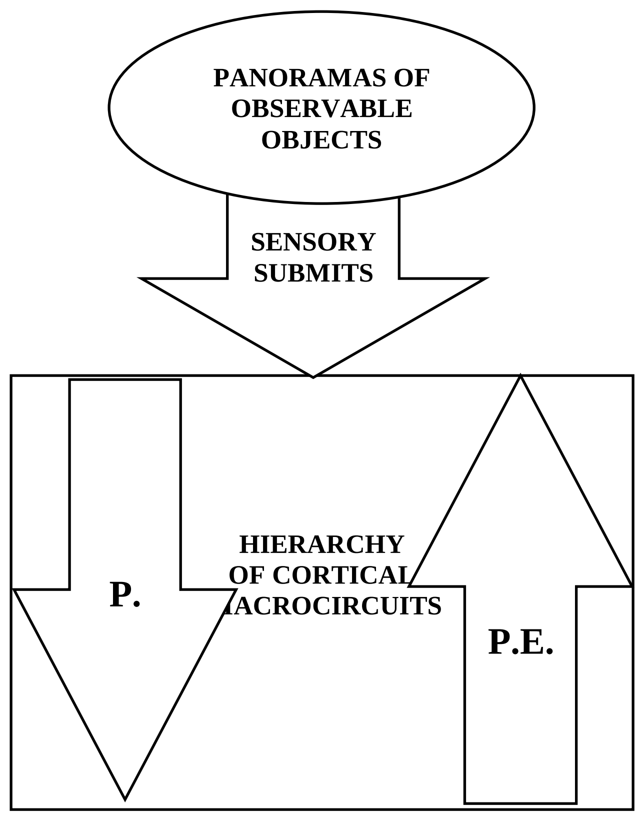

Fig. 2 Representation of real time two way matching process. Predictions **(P.)** downward and their errors **(P.E.)** backward up

Therefore, the managing of neural system in circumstances of uncertainty relates to a real time matching two way process. This embraces a top down regulation of observation via minimization of prediction error process. All the levels of the neural arrangement contain probabilistic models (predictions) reviewed by sensory observed data across neural processing iterative matching.

4.2 Artificial Industrial Concept of Digital Twins

Reflecting the instance of Digital Twins DT, that is acknowledged by a beneficial two-way interaction among the digital and physical domains. DT is dissimilar equally of Computer aided design (CAD), which entirely concentrates on the digital ground, and Internet of things (IoT) that strongly reflects on the physical one via straight data gathering in real time. The three constituents of a DT are a matched physical observable, a real time replicated numerical element and their sensorial and matching connections, see figure 3.

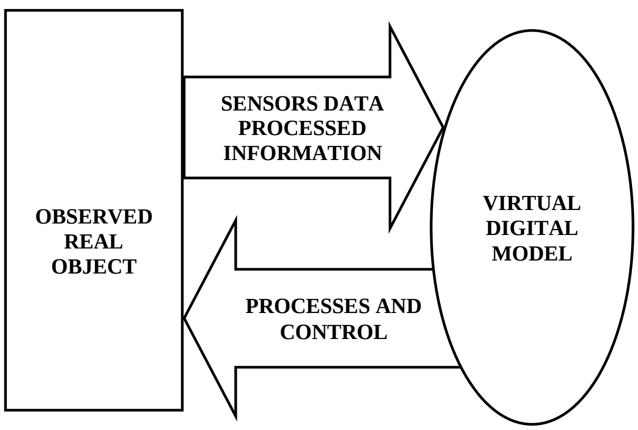

Fig. 3 Representation of matched observation-model twin

The physical item performs more "smart" that dynamically accommodate its real time behavior matching to the "advocacies" made by the digital one. While, the digital item executes more "factual" to appropriately reproduce the real ground state of the physical product. This could be convoyed by a knowledge uncertainty achievement via an amended model. Consequently, the DT offers a smart union of the physical and the digital domains [38]. Therefore, in the DT technology, the physical observation and the prediction modeling are interrelated in a real time two-way exchanges performing as a mixture of (matching, imitating and corroborating) connection. The DT concept is predominantly used for fault diagnosis, predictive maintenance, performance analysis and product design [39]. This relates to various societal spheres for example health care, mobility, energy and generally innovative industrial devices [40]-[42].

5. Conclusion

In the presented study, the view of elegance of theories and the postulations required to accomplish such elegance have been deliberated. The requirement to amend models to remedy such postulations has been emphasized for the modeling of real applications on phenomena or settings involved in natural or artificial processes. Such an adaptation requires backward postulations for elegance. We have shown that these revised models are of the same character as the modeling of coupled phenomena. The latter are practiced when natural or manufactured processes are governed by several fields of science.

The significance of the proposed strategy of revised models has been illuminated in the scope of prediction in processes linked to knowledge uncertainty. Such processes concern natural or artificial phenomena owning identified behaviors. Two examples of natural and artificial processes have been demonstrated in the present work. These are the biological Bayesian Brain theory in neuroscience and the artificial industrial concept of Digital Twins.

As a conclusion of this exploration, we can say that in both cases of Bayesian Brain and Digital Twins, we tackle a real time two way interconnected matched process. Such matching involves an observed item and a predictive one. The observed item corrects the prediction error and the predictive item rectifies the sensory observed inputs. This iterative process leads to more objective and smarter association. We can remark that this common process of the two examined cases is independent of their nature (natural biological and artificial). Moreover, it is obvious that the notion of revised model for prediction is managed in the two cases through their philosophies (principles), the Bayesian Brain theory and Digital Twins concept. This is handled via the matching process involved in the link prediction-observation.

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