



HAL
open science

Analysis of the Properties of Smart Theories and Their Revisited Realistic Modeling

Adel Razek

► **To cite this version:**

Adel Razek. Analysis of the Properties of Smart Theories and Their Revisited Realistic Modeling. International Journal of Cultural Heritage, 2021, 6, pp.1-5. hal-04310965

HAL Id: hal-04310965

<https://cnrs.hal.science/hal-04310965>

Submitted on 27 Nov 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Analysis of the Properties of Smart Theories and Their Revisited Realistic Modeling

ADEL RAZEK

Group of electrical engineering of Paris - GeePs

CNRS, Univ. Paris Saclay and Sorbonne Univ.

Gif-sur-Yvette, FRANCE

a.razek@ieee.org

Abstract—In this paper, we have evaluated the image of smartness in theories by means of different examples in different fields. We analyzed the fruitful and uncomfortable aspects of such elegance. This last unaccommodating facet concerns the unreliability of smart theories in the direct management of realistic circumstances. To alleviate this divergence, we have investigated a possible solution adapted to realistic situations. This involved the adjusting of the models offered by the elegant theories. The impact of these modified models was highlighted through a major review. As in the case of elegance in theories, we evaluated the constructive and weak characteristics of the adjusted models.

Keywords— smart theories, unifying, rationalizing, realistic models.

1. Introduction

The base of fundamental theoretical exploration is founded on elegant and coherent theories, which is essential for advanced science for civilization. These theories are generally assigned to autonomous scientific fields. The reliability of a specified theory in a particular principal scientific topic emanates from the occurrence of disregarding diverse smaller significant happenings existent in the actual sphere. Such suggestions compress and enhance the present veracity. These minor occurrences are usually concomitant to the surrounding circumstances and comportment of materials. They are in general governed by extra consequent topics of science. Models based on coherent theories function perfectly in certain circumstances wherever the relative assumptions are in consistency.

As regards the smartness in theories, we have many instances e.g. Newton's second law of motion, Maxwell equations in electromagnetics, Schrödinger equation (quantum superposition states) in quantum mechanics, Bayesian Brain theory in neuroscience... Diverse features can characterize the concerned smartness in theories as rationalizing, generalizing, amalgamating ... An illustration of smartness could be seen in one of the famous elegant fused theories: the group of Maxwell equations [1], which integrated three experimental laws found by Gauss, Ampère and Faraday.

The impact of elegance in theories is undisputable. Yet, despite smartness, a theory could be in disagreement with reality. Short time after Francis Crick co-discovered the DNA double helix and shortly earlier to his co-attaining a Nobel Prize, he indicated concerning smartness of theories that [2] the same is not automatically exact for wholly science accomplishments "In biology, it is likely to be elegant and to be incorrect".

In the present paper after examining the perception of elegance of theories through different examples in different fields, we will underline the constructive and uncooperative aspects of such elegance. This last disobliging facet regards the inconstancy of smart theories in treating realistic landscapes. We will discuss then how remedying such conflict. This will be discussed through amending of models provided by elegant theories. As in the case of elegance, we will assess the positive and negative features of the amended models.

2. Theoretical Elegance

Concerning the idea of smartness in theories, when we think about a theory expressing an event comprehensibly and directly, we identify it as elegant. Moreover, a concept easy to comprehend allows accounting for a great quantity of knowledge and satisfying many demands. Therefore, the elegance description as easiness plus more capacity looks just. Such easiness and capability may involve rationalizing, generalizing, amalgamating or simplifying. We will give in the next lines three examples to illustrate such elegance.

2.1. Unifying in Theories

An example of the finest elegant compound theories as mentioned in the introduction is the Maxwell equations. These equations originated by James Clerk Maxwell (1831-1879) embrace a union of three experimental laws found by three of his forerunners. These are Carl Friedrich Gauss (1777-1855), André-Marie Ampère (1775-1836) and Michael Faraday (1791-1867). The association of Maxwell equations was only feasible, as Maxwell perceived how to proceed ahead of the work of his precursors, by introducing into one equation a deficient-link, stated displacement current, whose occurrence guarantees the consistency of the integrated configuration. This displays a considerable feature of the union smartness, [1].

2.2. Universal Constants

A second example concerns the definition of universal constants for the smartness of theories is given for the case of vacuum permeability μ_0 .

In magnetostatics, Ampère's theorem makes it possible to determine the value of the magnetic field thanks to the value of electric currents. Coulomb's law expresses, in electrostatics, the force of the electrical interaction between two electrically charged particles. Ampere's theorem is expressed as a function of the vacuum permeability μ_0 and Coulomb's law is as a function of the vacuum permittivity ϵ_0 .

The exact value of the vacuum permeability has been set at $\mu_0=4\pi \times 10^{-7} \text{ kg m A}^{-2} \text{ s}^{-2}$ to simplify the expression of Ampère's theorem. This is for a definition of the ampere approved at the General Congress of Weights and Measures of 1948. Thus, we see that the definition of the value of μ_0 was decided only to have an elegant expression of Ampère's theorem.

Since May 20, 2019 a new definition of the ampere, linked to the definition of the elementary charge e , which has been chosen as exact. For this new definition, the value of the permeability has become approximate.

The equations established by Maxwell revealed a propagation speed of electromagnetic waves c as a function of the product $\epsilon_0 \mu_0$. Therefore, for the approximate value of μ_0 we have an approximate value of ϵ_0 of defined by:

$$\epsilon_0=1/(\mu_0 c^2) \approx 8,854 187 82 \times 10^{-12} \text{ A}^2 \text{ s}^4 \text{ k g}^{-1} \text{ m}^{-3}.$$

2.3 Rationalizing of a Natural Process

The third example regards the biological Bayesian Brain theory in neuroscience. To illustrate the rationalizing aspect of this theory we will summarize its function.

Bayesian strategies for brain actions assess the aptitude of the neural organization to function under situations of uncertainty to come collectively with the finest outcome supported by Bayesian statistics [3]. The theory of Bayesian Brain in neuroscience normally tries to relieve the cognitive aptitudes of the brain established on statistical methods where it is deliberated that the neural construction holds internal probabilistic models adjusted by sensory communication via neural treatment by means of Bayesian probability [4]. It is supposed that Bayesian inference works at the cortical macrocircuits level. These circuits are structured with an organization that designates the classified assemblage of the observable stuffs round us. The brain tutors a model of such items and engenders predictions regarding their sensory input; that is the playacted predictive coding. The overall fonts of the scenery, including items, will be assigned by achievements in areas of the brain nearby to the superior hierarchy. The links from the upper zones to the inferior ones subsequently set into code a model revealing how the prospects enclose objects as well as the forms of these objects. The bottommost level predictions are matched to sensory input and the prediction error is expanded up in the hierarchy. These areas are hierarchically structured such that the lower level conveyed prediction error generates the input of an upper-level region. Simultaneously, the return from the upper-level slice communicates the former convictions for the lower level one. In this circumstance, the prediction error stipulates that the current model has not wholly accounted for the input. Readjusting the next level can enhance correctness and temper the prediction error [5-6]. However, if not, higher-level adjustments are required. Generally, upper

levels offer data to inferior ones and ensure inner consistency of presumed sources of sensory input at different levels. This occurs simultaneously at all hierarchical stages. The predictions are conveyed down and their errors are directed back up in a dynamic procedure.

From the last description of the Bayesian Brain theory, we see that the organization of neural system in conditions of uncertainty expresses a real-time matching two-way process. The elegance of the theory embraces a top-down management of observation through minimization of prediction error process. All the levels of the neural assembly enclose probabilistic predictions revised by sensory observed information through neural processing iterative matching.

3. Pluses and Handicaps of Elegance

In general, one can think a theory only founded after validation by observation. Furthermore, such a theory stays valid until divergence with observation. This illustrates the evidence that the theory-observation couple is unavoidably constantly associated. The elegance of a theory does not alter this imperative. We may evoke the famous statement of Richard Phillips Feynman, father of Quantum electrodynamics (Nobel 1965) and one of the firsts proposing Quantum computing, "No matter how beautiful your theory is, No matter how smart you are, No matter if you're famous ...If your theory is not in tune with experience, It is wrong. That's all."

Moreover, the validation of an elegant theory is as hard as its establishment. This is due to the complexity of experimental conditions concerning the elegance. Such conditions are in fact very far from classical experimental settings. Often one has to develop original apparatus and teste routines.

A typical case illustrating that in spite of elegance a theory could be in conflict with reality and only sophisticated observation permits highlighting such evidence. Short time after Maxwell has advertised his Treatise in 1873, a young scientist has invalidated a part of the Treatise, Edwin Herbert Hall (1855-1938). He has revealed and confirmed in his thesis work, the principle named Hall Effect in 1879. This suggestion reached from observation by experience regards the relation between the force and the current in a conductor immersed in a magnetic field. Maxwell thought this nonexistent. We remark at this point that the elegance owing to mathematical treatment of observed laws has been upgraded because of observation indubitably.

It should be noted that an elegant theory is reputed founded only after validation by an adequate observation. This could be realized by sophisticated experimental sets running in the same idealized conditions postulated in the theory. Furthermore as mentioned before, such a theory stays valid until divergence with observation.

3.1. Reverberations of Elegance

It is undoubtedly evident that elegant theories are essential for humanity. They allow a continuous evolution of knowledge. For example, the theories mentioned in the last paragraphs are a typical illustration of this. Maxwell's equations and the Hall Effect weighed heavily in subsequent research, mainly in restraint relativity and quantum mechanics.

On the other hand, as mentioned above, the development of original devices and test routines for the validation of elegant theories, allows new investigations. It might even lead to new theories by serendipity. This clearly illustrates the symbioses of theoretical and observational items in science.

3.2. Cure for Elegance

Generally, in applications involving quantifiable real systems, elegant theories could be in discrepancy with reality and not each time applicable straightaway. In such circumstances, we need to amend the model fashioned on a theory of a main field, by combining the presumed unimportant fields, neglected for elegance, in an amended model.

4. Realistic Modeling

Think about a real objective problem that could be mathematically signified by a given global function, which is the fusion or union of sub-functions, each of which relates to a particular sub-field of science. For the objective of modeling this real problem, it is generally necessary to account for the various aspects related to the sub-functions in the zones corresponding to the global function. In addition, often one sub-area is more involved than the others are; let us call it the main sub-area. In general, we tend to consider this main subdomain solo for modeling. Meanwhile, virtually all theories generally fall under a single area of science. In addition, establishing rational and friendly theories usually requires postulations that distort and idealize the actual context of the investigation. Therefore, the consistency of a theory requires idealized assumptions occurring in an abbreviated main sub-area function. Consequently, the validation of this theory, which allows its foundation, must also be done under these conditions [7].

Therefore, when we model a real situation by soloing the shortened main sub-zone function, the result would often be wrong. This is due to the limitation of the two approximations shown. In such a context, in order to cure this situation, it is necessary to follow an inverse approximation technique, which reintroduces into the model all the abandoned aspects.

4.1 Amended Models

As mentioned before, founded theories point out a key attention to elegance concept. In uses for real schemes, such theories could be in conflict with veracity. In such circumstances, we have to move from elegance to reality reviewing the corresponding committed approximations. We are accordingly inclining to revise the model erected on a main field theory, by connecting the lesser fields in an amended model [8-9]. The context of “cancel out approximation” reintegrating ignored affects into the model evidently performs as a kind of a coupled problem.

4.2. Coupled Problems and Solution Strategy

Generally, coupled problems actions entail solution of mathematical equations governing diverse natural or artificial phenomena corresponding to distinct topics of theoretical sphere. The comportments of these phenomena and their mutual dependence as well as the intimacy of their temporal evolution are wholly linked to the methodology to solve the related ruling equations. In such a procedure, the treatment of the equations could vary widely. Within one limit, the equations are solved

almost separately. For the other limit, they are solved completely simultaneously.

Generally, modeling of a realistic device comprises more or less complex characteristics. These involve geometrical character, substance comportment laws and temporal behaviors. Such happening turn into further sharp once implicating coupling of distinct phenomena. In this circumstance, we have to count for different specific treatments, which are more complicated compared to those for simplified devices that can be governed by elegant theories.

Consider the case of electromagnetic systems that governed mainly by the elegant compound theory of the set of Maxwell equations mentioned early. This example permits to illustrate the solution strategy involving the mentioned specific treatments. These electromagnetic systems are present in many societal applications such as mobility, health, safety, communication. They behave not only due to Maxwell equations but generally in four instances: electrical, magnetic, mechanical and thermal. Different examples involving the solution strategy accounting for one or several of these instances could found in the literature. In the circumstance of electromagnetic generally, see e.g. [10-25]. In the circumstance involving with electromagnetic, the mechanical instance, see e.g. [20] [26-28]. In the case comprising the thermal instance, see e.g. [18] [29-31]. In the case of material intrinsic couplings (for smart materials), see e.g. [32-35].

All the coupled models involved in the mentioned studies are supposed validated as in case of smart theories. These validations could be practiced in two successive steps. The primary could be by means of analytical solution applied to simplified structures and behaviors when possible. The second validation that is mandatory has to be done with the help of precise experimental sets. These are less sophisticated than those used for the validation of smart theories. This is because the conditions for running of the sets in the case of realistic models are easier to attain.

4.3 Natures of Models

The amended models mentioned above make it possible to evaluate real phenomena, in natural processes [3-6] or artificial settings [36-40]. The most important task in developing such models is the coupling of different theories considering their postulations and their interdependence. In addition, these theoretical models are generally based on numerical analysis. The improvement of these models requires techniques allowing greater precision, less computer memory, faster calculations and more generalizing functions. Therefore, one important aspect of enhancement of these models is relative to their digital performance.

This could be performed through new mathematical formulations by means of the choice of the most suitable physical variable practiced in the best-acclimatized spatial-temporal behaviors. In addition, one can use innovative algorithms adapted to the considered problems as well as the computation and control available tools.

One of the most difficult aspect in the field of numerical modeling is the capacity to extend investigations to processes

possess not well-known mathematical functions or phenomena with random behaviors.

Unlike the elegant theories associated with their sophisticated validation experimental sets, the investigation in numerical modeling does not allow as largescale consequent added continuous inventions.

5. Conclusions

In the present study, we evaluated the concept of elegance in theories. The analysis of the character of these theories has highlighted their beneficial aspect allowing for future research. At the same time, such a character has been found not to be suitable for application on realistic operating systems. We have proposed to take into account the hypotheses idealizing intelligent theories by modifying their models to address realistic situations. These improved models combine the idealized model resulting from the theory with those representing the abandoned phenomena in view of elegance. We have considered the example of electromagnetic systems to illustrate such an approach. A major review of the construction strategies of the improved realistic models in this case was carried out. Analysis of these modified realistic models illustrates their crucial importance in designing real systems for everyday applications. However, in this case, the aspect allowing for future investigations is not as ambitious as in the case of intelligent theories.

Tghgt gpegu

- [1] Maxwell J C (1865) A dynamical theory of the electromagnetic field. Philosophical Transactions of the Royal Society of London 155: 459-512.
- [2] Crick F. H. C., Griffith J. S, and Orgel L. E. (1957) Codes without Commas. PNAS 43 (5): 416-421 <https://doi.org/10.1073/pnas.43.5.416>
- [3] Knill D.C. and Pouget A. (2004) The Bayesian brain: the role of uncertainty in neural coding and computation. Trends in Neurosciences 27(12):712-719.
- [4] Penny W. (2012) Bayesian Models of Brain and Behavior (Review). ISRN Biomathematics 2012: 1-19.
- [5] Beck J.M., Ma W.J., Latham P.E. (2013) Probabilistic brains: knowns and unknowns. Nature Neuroscience 16(9):1170-1178.
- [6] Hohwy J. (2017) Priors in perception: Top-down modulation, Bayesian perceptual learning rate, and prediction error minimization. Consciousness and Cognition 47: 75-85.
- [7] Razek A (2020) Review of the Involvement of the Duo Observation-Modeling in Advanced Theoretical and Societal Concepts. Engineering World 2: 82-85.
- [8] Razek A (2020) The elegant theory, the observed societal reality and the potentialities of coupled models (Invited). International Symposium on Numerical Modeling towards Digital Twin in Electrical Engineering, Beijing, China, from January 5 to 7.
- [9] Razek A (2020) The Observable, the Theory, and Prospective Revised Models for Societal Concerns. Athens Journal of Sciences 7(1): 1-14.
- [10] Bottauscio O, Manzin A (2013) Comparison of multiscale models for eddy current computation in granular magnetic materials. Journal of Computational Physics - Elsevier 253:1-17.
- [11] Carpes W P, Pichon L, Razek A (2000) A 3D finite element method for the modelling of bounded and unbounded electromagnetic problems in the time domain. International Journal of Numerical Modelling: Electronic Networks, Devices and Fields 13(6): 527-540.
- [12] Razek A (2019) Assessment of Supervised Drug Release in Cordial Embedded Therapeutics. Athens Journal of Technology and Engineering 6 (2): 77-91. <https://doi.org/10.30958/ajte.6-2-1>
- [13] Ouchetto O, Zouhdi S, Bossavit A, Griso G, Miara B, Razek A (2007) Homogenization of structured electromagnetic materials and metamaterials. Journal of materials processing technology 181(1-3): 225-229.
- [14] Ren Z, Razek A (1990) New technique for solving three-dimensional multiply connected eddy-current problems. IEE Proceedings A: Physical Science, Measurement and Instr....137(3):135-140.
- [15] Ren Z, Razek A (2000) Comparison of some 3D eddy current formulations in dual systems. IEEE Transactions on Magnetics 36 (4): 751-755.
- [16] Li C, Ren Z, Razek A (1994) An approach to adaptive mesh refinement for three-dimensional eddy-current computations. IEEE transactions on magnetics 30 (1): 113-117.
- [17] Tsuboi H, Asahara T, Kobayashi F and Misaki (1998) Adaptive triangular mesh generation for boundary element method in three-dimensional electrostatic problems. IEEE Transactions on Magnetics 34(5):3379-3382.
- [18] Sekkak A, Pichon L, Razek A (1994) 3-D FEM magneto-thermal analysis in microwave ovens. IEEE Transactions on Magnetics 30 (5): 3347-3350.
- [19] Piriou F, Razek A (1992) A non-linear coupled 3D model for magnetic field and electric circuit equations. IEEE Transactions on Magnetics 28 (2):1295-1298.
- [20] Ren Z, Razek A (1990) A coupled electromagnetic-mechanical model for thin conductive plate deflection analysis. IEEE transactions on magnetics 26 (5): 1650-1652.
- [21] Renyuan T, Shenghui W, Yan L, Xiulian W and Xiang C (2000) Transient simulation of power transformers using 3D finite element model coupled to electric circuit equations. IEEE Transactions on Magnetics 36(4):1417-1420.25.
- [22] Alotto P., Guarnieri M.and Moro F. (2007) A Boundary Integral Formulation on Unstructured Dual Grids for Eddy-Current Analysis in Thin Shields. IEEE Transactions on Magnetics 43(4):1173-1176.
- [23] Piriou F, Razek A (1990) Numerical simulation of a nonconventional alternator connected to a rectifier. IEEE transactions on energy conversion 5 (3):512-518.
- [24] De Gersem H. and Weiland T. (2004) Harmonic weighting functions at the sliding interface of a finite-element machine model incorporating angular displacement. IEEE Trans. Magn. 40(2):545-548.
- [25] Antunes OJ, Bastos JPA, Sadowski N, Razek A, Santandrea L, Bouillault F, Rapetti F (2005) Using hierarchic interpolation with mortar element method for electrical machines analysis. IEEE transactions on magnetics 41 (5):1472-1475.
- [26] Antunes OJ, Bastos JPA, Sadowski N, Razek A, Santandrea L, Bouillault F, Rapetti F (2006) Comparison between nonconforming movement methods. IEEE Transactions on magnetics 42 (4): 599-602.
- [27] Zec M, Uhlig R P, Ziolkowski M and Brauer H (2013) Finite Element Analysis of Nondestructive Testing Eddy Current Problems with Moving Parts. IEEE Transactions on Magnetics 49(8):4785-4794.
- [28] Ren Z, Razek A (1994) A strong coupled model for analyzing dynamic behaviors of non-linear electromechanical systems. IEEE Transactions on magnetics 30 (5):3252-3255.
- [29] Bay F., Labbe V., Favennec Y.and. Chenot J. L (2003) A numerical model for induction heating processes coupling electromagnetism and thermomechanics. Int. J. Numer. Meth. Engng 58:839-867
- [30] Simoni L, Beschi M, Legnani G and Visioli A (2019) Modelling the temperature in joint friction of industrial manipulators. Robotica 37(5): 906-927.
- [31] Kopyt P & Celuch M (2006) Coupled Electromagnetic-Thermodynamic Simulations of Microwave Heating Problems Using the FDTD Algorithm. Journal of Microwave Power and Electromagnetic Energy 41(4): 18-29.
- [32] Hariri H, Bernard Y, Razek A (2015) Dual piezoelectric beam robot: The effect of piezoelectric patches' positions. Journal of Intelligent Material Systems and Structures 26 (18): 2577-2590.
- [33] Rios S A, Fleming A J and Yong Y K (2017) Miniature Resonant Ambulatory Robot. IEEE Robotics and Automation Letters 2(1):337-343.
- [34] Besbes M, Ren Z, Razek (2001) A generalized finite element model of magnetostriction phenomena. IEEE Transactions on Magnetics 37 (5):3324-3328.

- [35] Bottauscio O., Roccatò P. E. and Zucca M. (2010) Modeling the Dynamic Behavior of Magnetostrictive Actuators. *IEEE Transactions on Magnetics* 46(8):3022-3028.
- [36] He B and Bai K (2020) Digital twin-based sustainable intelligent manufacturing (review). *Adv. Manuf.*, <https://doi.org/10.1007/s40436-020-00302-5>.
- [37] El Moucary C, Mendes E, and Razek A (2002) Decoupled Direct Control for PWM Inverter-Fed Induction Motor Drives. *IEEE transactions on industry applications* 38(5):1307-1315.
- [38] Mendes E, Baba A and Razek A (1995) Losses minimization of a field oriented controlled induction machine. *Seventh International Conference on Electrical Machines and Drives (IET)*: 310 – 314.
- [39] Tao F, Sui F, Liu A, Qi Q, Zhang M, Song B, Guo Z, Lu S C.-Y., and Nee A. Y.C (2019) Digital twin-driven product design framework. *International journal of Production Research* 57: 3935-3953.
- [40] Razek A (2021) Pragmatic Association of the Two Evaluation Concepts of Operational Observation and Mathematical Modeling. *Athens Journal of Sciences* 8 (1), 23-36.