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Review of the involvement of the Duo Observation-Modeling in Advanced Theoretical and Societal Concepts

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Abstract— Modern developments in several theoretical and societal concepts are closely associated to the relation of operational observation to mathematical modeling. The interdependence of these two evaluation notions appears, in such concepts, as matching, mimicking, corroborating, and/or complementary duo. In this paper, we undertake to illustrate through different examples of such concepts the significant role of the duo observation-modeling in the functioning of these concepts. The investigated cases concern the industrial concept of digital twins, the Bayesian Brain theory in neuroscience, neuromorphic technology computing, quantum computing, and the clinical case of contagion infections by unknown mutant virus.

Keywords— duo observation-modeling, matching, mimicking, Bayesian, Neuromorphic, computing, digital twins, clinical, concepts.

I. Introduction

Topical outcomes in plentiful theoretical and societal conceptions are deeply linked to the duo observation-modeling (DOM). These tow assessment concepts could be utilized individually or in a matching, imitating, validating and/or complementing duo. This paper targets to inspect how observables and their models are intimate to each other and how the two concerns of observation and modeling are mutually supporting and forming a duo; the DOM.

An observable real entity behaves conferring to observable environmental occurrences. We can describe the model of this real entity plus its environment, across the source and the outcome of its observed comportment. Such a predominance is mostly in relation to a science or a phenomenon involved in a science. We can perform the investigation of a real entity and its comportment along with real environmental happenings by observation and/or modeling. Observation or modeling can be self-contained in fields of exploration that we regularly count unrealistically ideal . In the common situation of true societal panoramas, we practice the two concerns of investigation in a basis of complementarity. Consequently, yet in the fields needing usually observation, this is generally not autonomous and observation needs modeling for deeper investigations. Claude Lévi-Strauss (1908-2009) mentioned, regarding isolated observation, in Structural Anthropology [1], that Structural researches in the social sciences are indirect consequences of modern mathematics: logic, sets, groups and topology.

Furthermore, for the fields requiring commonly modeling, this is generally also not self-contained and modeling needs validating observation, simply to be credible. The philosopher Maurice Merleau-Ponty (1908-1961) stated, concerning isolated modeling, that, science takes the world as an object of knowledge "dissociated" from the existing subject, also that the model and the mind are matched and scientists see the world with a spirit related only to the model, see e.g. [2].

Regarding the situations of dissimilarity of a real observable and its model, we understand that the first is true (reference) and that it is required to adjust the model to come near reality. The majority of mathematical models initiate of rational and pleasing theories regarding one field of science with idealizing postulations regarding the environmental circumstances as temperature, pressure, etc., and the character of materials such as viscosity, linearity, homogeneity,…In the actual societal circumstances, the environs and stuff hardly meet such idyllic circumstances. Generally, the deficiencies of the scientific concerned field involve other scientific fields. Furthermore, in several societal scenes, different domains of science may rule the concerned comportment. In such cases, the revised ultimate model will be a coupled model subsequent to the alliance of diverse scientific fields [3], [4].

For instance, consider the case of electromagnetic systems. The scenery of the phenomena ruling such systems is composite and a comprehensive model should consider in general the magnetic, electrical, mechanical and thermal properties, see e.g. [5], [6]. The involved variables might be interdependent and the parameters could vary caused by the behavior of these variables. The revised model will be, more or fewer coupled in function of the significance of the related phenomena interdependence [7].

From the last, we can see that the assessment concepts of observation and modeling are closely associated. In addition, in theoretical research it is commonly admitted that theories are subject to essential basic rulings regarding the Theory-Observation couple. Thus, in general, a theory is considered only founded after validation by observation. Furthermore, such a theory stays effective until divergence with observation.

Consequently, the theory-observation couple is necessarily always associated. The resulting duo of this couple, the DOM, could be utilized in the conception of several theoretical researches, industrial settings or clinical cares.

The present paper concerns such utilizations. Relating to recent industrial concepts based on the DOM, we will consider the concept of digital twins (DT), that is constructed of a matched real observable (process, product or facility) with a real-time numerical item (model) that is a duplication of the real observable, and their connections. We will then consider the most popular theory relative to brain functioning in neuroscience the Bayesian Brain, where sensory predictions are matched to observation data to recognize observables. We will also discuss the neuromorphic technology computing where electronics are used to mimic neuro-biological assemblies present in the nervous system. Another case will be studied that relative to quantum computing where computers use qubits through the laws of quantum mechanics relative to the states of particles. A last example concerns the clinical situation of contagion infections by an unknown mutant virus. In such a case and due to the unknown behavior of the object, the DOM will applies in an adapted way.

II. DIGITAL TWINS (DT)

DT is dissimilar from both of Computer-aided design (CAD), which entirely concentrates on the digital domain, and Internet of things (IoT) that strongly concentrates on the physical one by means of straight data gathering in real-time. The three components of a DT, as mentioned before, are the matched real observable with a real-time duplicated numerical item and their connections. DT is categorized by a gainful two-way communications between the digital and physical domains. From one side, the physical product can be made more “smart” to dynamically regulate its real-time behavior corresponding to the “endorsements” made by the digital item. From the other side, the digital item can be made more “objective” to correctly replicate the real-domain state of the physical product. Therefore, it provides a smart association of the physical and the digital domains [8].

Digital twins concept is particularly employed for fault diagnosis, predictive maintenance, performance analysis and product design [9]. This concerns various societal domains as heath care, mobility, energy and generally innovative industrial devices.

We can see that DT technology is fully using the DOM where observation (physical object) and modeling (digital item) are interconnected in a real-time two-way communications. Here the DOM is acting as an amalgam of (matching, imitating and validating) duo.

III. BAYESIAN BRAIN

Bayesian methodologies for brain behavior examine the ability of the neural system to function under circumstances of uncertainty to meet the optimum suggested by Bayesian statistics [10]. Bayesian brain theory in neuroscience often attempts to explain the cognitive abilities of the brain based on statistical principles where it is assumed that the neural structure maintains interior probabilistic models updated by sensory information through neural processing using the Bayesian probability [11].

It is assumed that Bayesian implication operates at the level of cortical macrocircuits. Such circuits are organized according to a hierarchy that considers the categorized configuration of the observable objects around us. The brain encodes a model of these objects and makes predictions about their sensory input: predictive coding. The general characteristics of the scene, including objects, will be represented by activity in areas of the brain close to the upper hierarchy. The links from the upper areas to the lower areas then encode a model describing how the scenes involve objects and the characteristics of the objects. The lowest level predictions are compared to sensory input and the prediction error is spread up in the hierarchy. These areas are organized hierarchically such that the prediction error issued by a lower level system develops the input of a higher-level area. Simultaneously, the reaction from the higher-level area delivers the previous convictions for the lower level area. In this context, the indicator of the prediction error is a sign indicating that the existing model has not totally taken into account the input. Readjusting the next level can increase accuracy and reduce prediction error [12], [13]. However, if not, higher-level modifications are needed.

In general, higher levels deliver advice to lower levels and guarantee inside reliability of deduced sources of sensory input at various levels. This happens simultaneously at all hierarchical levels. The predictions are sent down and the prediction errors are sent back up in a dynamic process.

From the last description of the functioning of neural system under circumstances of uncertainty, it is clear that the DOM is fully implicated in a real time matching two way process. This involves a top-down adjustment of perception through minimization of prediction error construction. All the levels of the neural structure comprise probabilistic models updated by sensory observed information through neural processing iterative matching.

IV. NEUROMORPHIC COMPUTING

The brain is an extremely complicated system involving non-linear parallel information processing. It achieves duties as pattern recognition, perception, and movement control, much time rapider than the quickest digital computers.

Neuromorphic computing uses brain-inspired models. This biologically inspired methodology has fashioned greatly connected artificial neurons and synapses that can be used to model neuroscience theories and to solve machine-learning problems.

Neuromorphic computing concept is not newborn, it is progressed by Carver Mead in the end of the 1980s, correlating the exercise of very-large-scale integration (VLSI) systems enfolding analog circuits to mimic neuro-biological constructions present in the nervous system [14].

Neuromorphic computing involve operations that are constructed on biologically inspired or artificial neural networks. These neuromorphic constructions are greatly

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connected and parallel, necessitating small power. Therefore, Neuromorphic computers can execute complicated computations quicker, higher power-efficiency, and with smaller size than traditional architectures. These features offer captivating motives for elaborating hardware that utilizes neuromorphic constructions. Machine learning offers an essential motive for solid concern in neuromorphic computing. They have the ability of evolving real-time learning algorithms that are qualified for on-line operation comparable to true brains..

The up-to-date progresses in the artificial intelligence (AI) have introduced again awareness in neuromorphic computing. This last has shown potential because of resemblances of biological and artificial neural networks (BNN and ANN) [15]. The growing attraction of deep learning and neural networks has encouraged a race to develop AI hardware dedicated for neural network computations [16]. These tools are largely used in optimization, diagnostics, images, machine learning, AI…

The neuromorphic computing expertise is quite large, involving a diversity of fields, such as materials science, neuroscience, electrical engineering, computer engineering.

This section shows clearly how the concept of neuromorphic computing uses the DOM as a mimic duo. This involves two levels of the resemblances of biological and artificial items: neural networks and intelligence (Brain and AI).

V. QUANTUM COMPUTING

The origin of the idea of quantum computing emerged at the birth of the last century. Max Planck proposed that a "perfect black body" radiates and absorbs electromagnetic waves in the form of discrete energy packages called "quanta". It was the advent of quantum mechanics. This offered to scientists remarkable tools for the elucidation of the atomic domain. Afterward, the concept of states of quantum mechanics founds the footing of "Quantum computers», term invented by Richard Feynman [17].

A conventional computer executes calculations using bits that is 0 indicating "off" and 1 denoting "on". It exploits transistors to treat information in the mode of sequences of zeros and ones named computer binary language. Further transistors relate to more processing capacity. A quantum computer uses qubits across the laws of quantum mechanics relative to the states of particles. For a qubit, a particle can be in several states simultaneously; this phenomenon is named superposition. A different phenomenon affects the particles states called entanglement. This signifies when two qubits in a superposition associate with one another; denoting the state of one depends on the state of the other. Due to these phenomena, a quantum computer can accomplish 0, 1, or both states at the same time for a qubit or an entanglement of qubits. Thus, a quantum computer with n qubits can instantaneously operate on all the 2n possibilities; however, a standard computer with n bits can function on solitary one of those 2n possibilities at a time. So, the first offering us more processing power. Scientists approve that quantum computers are theoretically exponentially quicker and much cleverer in breaking codes that are apparently impossible for classic technology to realize [18], [19].

The previous discussion shows evidently the stretched relation between the observed reality and the mathematical modeling (quantum physics - quantum computing).

VI. INFECTIONS BY AN UNKNOWN MUTANT VIRUS

This section concerns the use of modeling for the prediction of future behaviors of a phenomenon that is not well known, or owning behavior varying arbitrary.

Prediction is profitably maneuvered in many reliable circumstances where it is linked to observation to yield accurate suitable result. The theory of the Bayesian brain in neuroscience and the concept of Digital Twins are representative specimens of such a circumstance, as we have seen in the last sections. Moreover, the prediction is frequently utilized in the control of industrial devices and allows linked to observation, to achieve precise and quick execution, see e.g. [20].

In dissimilarity, the alliance prediction-observation has to be exercised with restriction in some special situations. This is the case of infections by an unknown mutant virus . As stated before mathematical modeling can be only accomplished with proven and corroborated theories. In circumstance of problems where the theoretical behavior is not well known, or phenomenon behavior fluctuating random, it is obvious that the practice of lonely mathematical modeling would be desperate and uncertain. In such instance, the usage of inductive prediction: this is when one might derive a deduction regarding the future by means of knowledge from the past, would guide to mistaken result [21]. A representative instance of such an inacceptable prediction could be faced in the modeling of complicated infection behaviors such as contaminations by an unknown mutant virus [22]. In such a circumstance one requires to suppose an approximated mathematical behavior of the endemic contagion [23] by the mutant unidentified virus from the situation of several infected subjects to operate it for future contaminations of others. Such practice may assist in the orientatation of research procedures but not in gaining confident results. The observation will be the main concern to elucidate such category of problems supported by prediction. This will be through the adjustment of the clinical protocol.

In this clinical case, the prediction plays a tendency role while the observation plays the main issue of treatment across protocol adjustment. This a typical case of complementarity assisted by corroboration through the DOM.

VII. CONCLUSIONS

The proposed study endeavored to demonstrate the importance of the role of the duo observation-modeling DOM in different domains of research and societal applications as industrial concepts and health care. This has been exposed in the functioning of these different investigated cases. It has been shown that the duo DOM uses its own resources of matching, mimicking, corroborating and/or complementing for achieving the required functioning.

In the case of Digital Twins, the DOM items are interconnected in a real-time two-way communications and acting as an amalgam of (matching, imitating and validating) duo.

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For the case of Bayesian Brain theory, the DOM is fully involved in a real time iterative matching two-way process containing adjustment of perception through minimization of prediction error.

In the two cases of neuromorphic and quantum computing, theoretical computations are directly using devices mimicking observed phenomena in neuro-biology and quantum physics.

In the clinical case of infection by an unknown mutant virus, the prediction indicates a tendency while the observation plays the main issue of treatment across protocol adjustment corresponding to the prediction. This a distinctive case of complementarity assisted by corroboration through the DOM.

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