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Communication

Matching Role of Observation and its Replication Model in Managing Intelligent Paradigms and Monitoring Natural and Artificial Complexities

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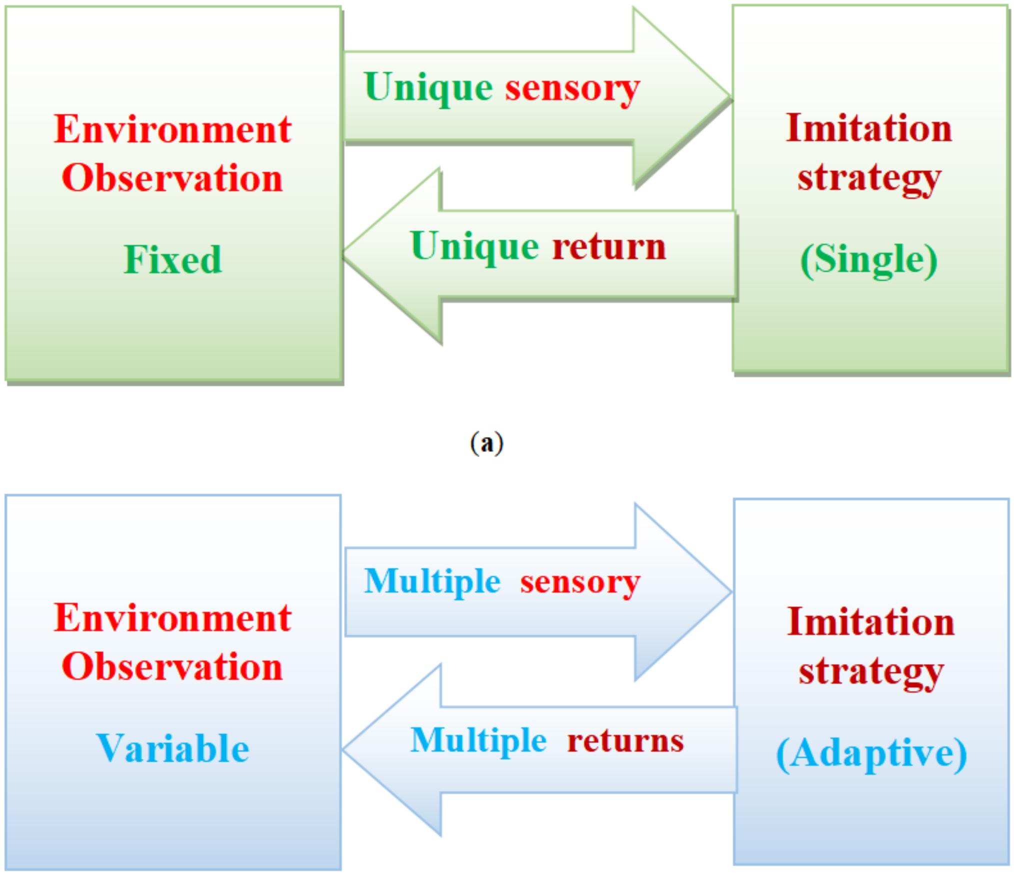
Abstract: This contribution aims to shed light on the character of the observation-modeling link, and the role of the matching of its faces, in the management of different events. These include intelligent theories and digital tools, as well as the complexity of dynamic processes of natural and artificial phenomena. Such matching in the link could be practiced in offline or real-time mode. Offline mode mainly concerns the governance of intelligent theories and digital tools mimicking physical paradigms. Real-time mode concerns dynamic processes involving a significant degree of complexity. This exists in natural events like wildlife and human biology. It is also present in autonomous supervised artificial procedures, which involve complex real phenomena mathematically replicated by coupled multiphysics in the framework of matched real-virtual pairs. This communication involves analyses and discussions of these different pairings and their affected events, supported by examples allied to the literature. This corresponds to cases of intelligent theories, computational tools mimicking physics, real-time matching in natural wildlife and human biology, as well as twins supervising complex artificial procedures.

Keywords: Observation-Virtual Duo; Smart Theories; Intelligent Digital Tools; Natural Matched Processes; Complex Procedures; Matched Twins

1. Introduction

The link observation - modeling characterizes a relation between its two faces, which can be actions, entities, or phenomena. Observation denotes also experience, real, actual, etc. Modeling indicates too theory, virtual, prediction, deduction, etc. In such real-virtual duo, the virtual side is a replication, imitation, image, etc. of the real side. Such a duo is often used in pairing or corresponding one face with the other. It frequently operates consistent with an activity of matching or imitating simulation. This activity appears to be the oldest survival strategy practiced in our world. It has always been and is practiced to protect oneself from the danger of a predator as well as to take advantage of the vulnerability of a victim. It is based on observation and reaction deduction, which can be readjusted by new observation. For instance, in wildlife, built on observation, circumstances of imitative reproduction strategy are recurrent permitting camouflage (Bates, H. W. 1862) [1]. This allows individuals to merge into their environments. This could comprise a unique matching or lively adjusting one. These two situations correspond respectively to a fixed environment (unchanged target) and variable environment (mutant target). Figure 1 shows a schematic of camouflage considering the link environment observation—imitation strategy and its two-way connection (sensory-return) in the cases of (a) fixed environment (offline matching) and (b) variable environment (real-time matching).



(a)

(b)

Figure 1. Schematic of camouflage considering the link, environment observation-imitation strategy, and its two-way connection (sensory-return): (**a**) Fixed environment (offline single matching), (**b**) Variable environment (real-time adaptive matching).

In general, the pairing in the observation - modeling link can be practiced in two modes, offline and in real-time. These two modes are respectively correlated to the last mentioned camouflage in fixed and variable environments.

Offline mode can be used in the management (validation, invalidation, explanation and unification) of universal intelligent theories. This mode describes also the base of digital tools mimicking physical paradigms such as neuromorphic and quantum-computing tools originating straightly from two paradigms belonging to neurosciences and quantum physics.

The real-time matching mode of the observation—modeling link can be reflected in several physical complex processes involved in natural phenomena, and innovative synthetic treatments associated with the control of automatic and compound procedures. The two faces of the matched link reflect in general uncertainties concerning observation detections and modeling precision. In the case of natural processes, these perform under circumstances of uncertainty to reach the optimum advocated through iterative predictive pairing. In the case of artificial procedures, the involved uncertainties must be reduced to accomplish enhanced control.

This communication aims to illustrate the role of the matching in the observation-modeling duo, in the management of smart theories and digital tools, as well as the complexity supervision in dynamic procedures in natural and artificial phenomena. First, we will examine the governance of smart theories and digital tools mimicking physical paradigms. Second, we will analyze dynamic complex processes in natural events like wildlife and human biology as well as in autonomous supervised artificial procedures. The involved analyses in this communication will be supported by examples associated to literature, of the different mentioned matched events.

2. Management of Universal Intelligent Theories

As explained previously, the management of intelligent theories concerns their validation, invalidation, explanation and unification. Most universal theories are established theoretically and are only founded once experimentally validated. Furthermore, these theories remain recognized until they are invalidated by experience. In both cases, virtual theories must be matched offline to real experiments. A second category of matching concerns experimental findings. These involve different laws and principles established by experiment or experimental phenomena discovered via serendipity (by chance). In both cases, matching with corresponding theoretical developments allow for a more universal understanding. Following, examples of these four cases are given to illustrate the essential role of offline correspondence.

2.1. Validating a Theory by Observation

A typical example in this category is that of theory of superposition states in quantum mechanics suggested by Schrödinger in 1926 [2], (Nobel 1933). The ion traps of Winelands [3] and the cavity quantum electrodynamics of Haroche [4] permitted the validation of this theory slightly before 2000 (shared Nobel 2012). A second example is that of Lee and Yang [5] (Nobel 1957) suggested parity violation in weak interactions after experimental confirmation (by Wu) [6].

It was only after such validations that these theories were founded until possible future invalidations.

2.2. Invalidating a Theory by Observation

A well-known example in this case is the "Hall Effect" suggested by Hall in 1879 that resulting from experiment; it relates to the effect of the force on the current in a conductor. This invalidated part of the "treatise on electricity and magnetism" projected by Maxwell in 1873 [7]. Hall exposed and experimentally established in his thesis, the effect on current (distribution) of force in a conductor submerged in a magnetic field [8]. Maxwell believed there was no such effect.

2.3. Observation Explained by Theory

An emblematic illustration of this case is the discovery of superconductivity by Kamerlingh Onnes, (Nobel 1913) [9]. He was experimenting the effects of low temperatures on electronics when he observed by serendipity such phenomenon. All the theories approving and clarifying the superconductivity tailed his discovery.

2.4. Generalizing and Unifying Observations by a Theory

One of the most distinguished compound theories is the set of equations initiated by James Clerk Maxwell (1831–1879) that combine a union of three experimental laws, discovered earlier by Carl Friedrich Gauss (1777–1855), André-Marie Ampère (1775–1836) and Michael Faraday (1791–1867). This union of equations was only achievable due to the introduction in one of the equations a missing link, named displacement current, which ensures the consistency of the unified theory [7].

3. Digital Tools Mimicking Physical Paradigms

The two computing neuromorphic and quantum technologies are characteristic modeling tools based on replications of physical paradigms belonging respectively to neurosciences and quantum physics.

Neuromorphic computations use inspired brain biologically replicated or artificial neural networks [10]. The growing demand of deep learning and neural networks has motivated advancing artificial intelligence hardware dedicated to neural network calculations [11].

The notion of states in quantum mechanics is the basis of quantum computations. An n-qubit quantum computer can operate instantaneously on the 2n possibilities; however, a customary computer with n bits can only function on one of these 2n possibilities at a time. Experts agree that quantum computers are in theory exponentially quicker than classical technology [12, 13].

4. Dynamic Matching in Natural Events

There are many different examples of real-time matching of real—virtual links in complex natural processes in the field of biodiversity in general. In addition to the example of camouflage mentioned previously (figure 1) [1], we can cite the case of brain functioning described by the Bayesian theory widely recognized in neuroscience. In summary, it specifies that following a cerebral sensory observation (vision, hearing, smell, etc.), the predictive cerebral model iteratively propagates, based on historically learned and collected information, the cerebral perceptions of this observation. This iterative and complex dynamic observation-prediction link is managed by a high-level computational "human brain" involving 10^{11} neurons each connected to 10^4 others, equipped with cognitive capacities to work under conditions of uncertainty to achieve the assisted optimum by Bayesian approaches [14]. Such cognitive capacities express a very close relationship between observation and reasoning. Thus, e.g., retrospective observation during mental stimulation can even reflect causal reasoning [15].

Bayesian inference works at the level of cortical macrocircuits, which are structured in a hierarchy where brain activity will be near the top. The observation-prediction duo works using a real-time two-way matching procedure, in which predictions are directed down the hierarchy and prediction errors are fed back in a dynamic process [16]. Figure 2 shows such a real-time observation-prediction process.

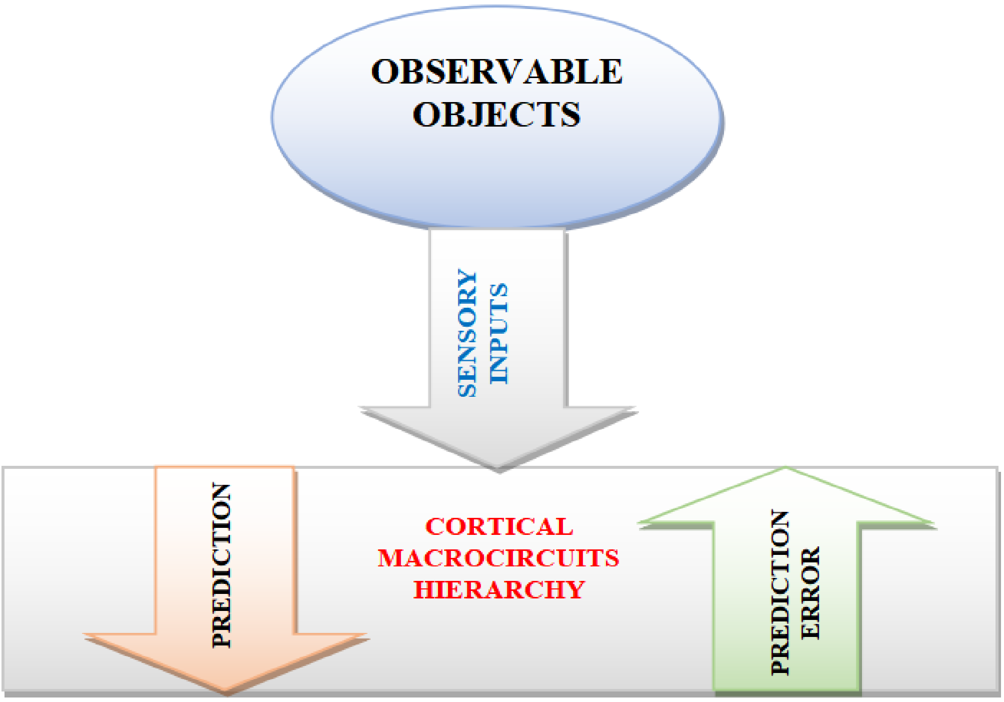


Figure 2. Schematics of Bayesian brain theory real-time two-way matching process.

5. Supervision of Artificial Complex Procedures via Matched Real-Virtual Pairs

Matched real-virtual pairs that account for complexity, typically related to multiphysics, could reduce uncertainty and manage real-time monitoring of complex artificial procedures. The matching action will depend on the quality of the virtual model, which is linked to its ability to account for multiphysics phenomena linked to the real complexity of the procedures. Additionally, sensing, processing, and control qualities would also affect matching. Tools such as the Internet of Things (IoT) or engineering-aided design (EAD) could help with monitoring, focusing on the physical and digital spheres respectively. However, it is crucial to moderate and limit erratic and unnecessary behaviors that can occur during complex procedures. Achieving such a goal requires a matched observation model twin experienced in the relevant procedure [17], as illustrated in Figure 3 depicting the characteristics of a digital twin (DT). It focuses on both the physical and digital spheres. The real DT part involves complexity [18] linked to multiphysics phenomena, while its virtual side includes a coupled reduced model [19] and both sides reflect uncertainties. DT real-time matching processing can use the learned historical and collected data. The link between the observation face and the model face is bidirectional. The observation side provides the sensor measurements in processed form to the virtual part while the latter directs the process and control data to the observation part. Thus, each party corrects and improves the other and the correspondence will reduce uncertainties on both sides.

The DT concept is used in many applications belonging to several fields involving manufacturing industry, public health, control, security, aerospace, transportation, etc. [20–26].

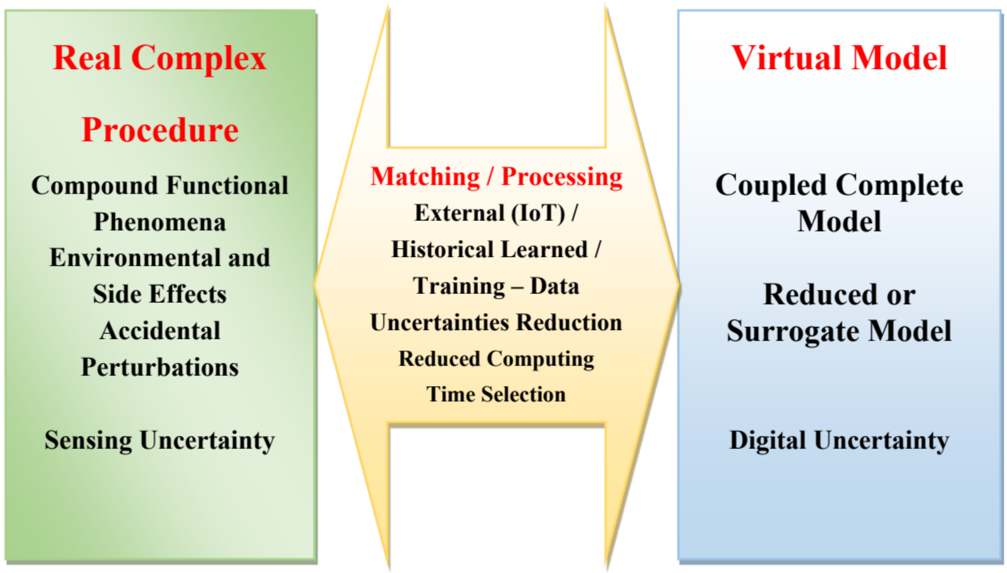


Figure 3. Summarized illustration of a matched monitoring of a complex procedure with its virtual model.

6. Discussion

The main fundamentals of this contribution relating to the observation-modeling link can be summarized as follows:

- Offline matching is exercised to manage intelligent theories and digital tools mimicking physical paradigms.
- Real-time matching is trained to supervise complex natural and artificial procedures.

These different explores, in addition to the diverse concepts involved, call on different skills linked to the next respects:

- Considering the actual complexity through multiphysics phenomena [18].
- Enhancing the precision of the virtual models through multiphysics coupling [27].
- Speeding up of matching via models reduction or surrogate modeling [28, 29].
- Reducing uncertainties in both DT sides via its two-way matching link [17].

The explorations proposed in this communication have highlighted certain notions allowing a more in-depth understanding of the correspondence in the observation—virtual link in general; thereby helping to guide and reinforce the skills mentioned above.

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Conflicts of Interest

The authors declare no conflict of interest.

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