From the epistemology to the ontology of information: Gradients of Abstraction on the quantum world

M-FIL/02

The quest for conceptual unification of the classical and quantum worlds is one of the most intriguing goals in the scientific community. Finding a unified concept of information could be pivotal to achieve this aim.

1. General presentation of the project and state of the art

In the last century, several proposals of a comprehensive definitions of information have been brought to the attention of the scientific community. (Hartley 1928, Shannon 1948, Carnap 1952). Shannon's (1948) definition of information is one of the most notable attempts. However, even Shannon's definition is not comprehensive, as it fails to describe (rather important) processes of information exchange. On the one hand, this model efficiently describes the exchange of information between machines. On the other hand, it does not consider the memory and prior knowledge of individuals within the process. For this reason, Carnap proposed a semantic definition of information (Carnap 1950; Carnap 1952). However, their proposal leads to a paradox, as semantic theory assigns maximum information to contradictory statements (Fresco and Micheal 2016; Gorsky 2018). An alternative approach to the one above is explaining information phenomena from an epistemic point of view. The strength of this approach is its applicability to a wide range of physically realistic scenarios. The approach, firstly proposed by Floridi (2008), is called the method of abstraction. Through an epistemic analysis, Floridi argued that information processes can be understood through levels of abstraction. The 'level of abstraction' (LoA, hereafter) is the building block of the method and can be defined as the level at which a system is considered or the specific perspective from which we analyse a system (Wolf & Grodzinsky, 2012).

LoAs can also be used to create an element called the 'gradient of abstraction' (GoA, hereafter), which is one of the key concepts in the application of the method of abstraction. (Ganascia, 2015).

2. Research objectives

My thesis hinges on two main questions that are still open in the literature.

The first concerns the adaptation of the method of abstraction to the cases that occur in the world of quantum mechanics (Messiah 1961, Nielsen 2010). A promising way to achieve such a goal is to link the observables of the method of abstraction with the homonymous concepts of quantum mechanics. Furthermore, the benefit of linking these concepts could lead to a new understanding of their application in real cases of quantum physics. For instance, it might provide a new explanation of what is happening in the field of quantum-like machine learning.

Machine learning is the branch of computer science that studies how to train machines to 'learn' from data (Duda 1973, Llyod 2013). The method of abstraction offers an appealing explanation of what happens during one of these processes: we can think of the whole process as changing a level of abstraction, where the observables are generated by applying the rule of the algorithm that is then learned by the computer.

Quantum-like machine learning arises from the possibility that classical computers can be inspired by the principles of quantum theory (Schuld & Petruccione 2018, 2021, Sergioli 2017, Wiitek 2014, Alpaydin 2004). This branch of machine learning does not use different hardware, nor does it change the processes. Rather, a change in the theoretical framework is implemented by constructing the elements (algorithm elements) used in the process through the application of quantum information theory. These algorithms show an increase in efficiency in terms of performance and can be explained by the method of abstraction, moving from an abstract LoA to a more concrete one.

The second problem on which my thesis hinges is the search for an ontological proposal that includes the structure of LoAs.

The first attempt starts from the definition of a more rigorous theory of semantic information (Floridi 2008, Cevolani 2011) to eliminate the Bar-Hillel-Carnap paradox. This leads us to the structuring of an ontology called Information Structural Realism (ISR, hereafter).

Such a view is heavily inspired by Ontic Structural Realism (Worrall 1989, Ladyman 2007), according to which the fundamental ontological components of scientific theories are structures and relations.

Ontological structural realism is a thesis that, according to the literature, fits well with the description of the quantum domain as it is mathematically described in the orthodox formulation of the theory (Muller 2015). Thus, from the ontology depicted by structural realism, one might find a definition of information that is applicable as to the quantum world as to the classical one.

3. expected results

A first result is a meaningful contribution to the debate about the philosophy of information, in the form of an application of the method of abstraction to quantum phenomena. Such an application, in turns, leads to a definition of information which is applicable to classical and quantum cases. Per se, this result would be huge insofar as it would provide a solid ground to compare information exchanges in different phenomena.

A second expected result is a contribution to the debate about scientific realism. By showing that the method of abstraction can bring forth a unified concept of information, and that ISR best describes its ontology, I want to argue that ISR must be preferred over other realist views. Finally, information is usually seen as an epistemic concept. By developing the concept as ontological, one obtains that those interpretations of quantum mechanics that are based on the concept of information can now be interpreted in realist terms (Dunlap 2022).

4. Methodology and planning

In the first year of my PhD, I focus on analysing the debate about the method of abstraction (Floridi 2004, Primiero 2009). I explore the analogy between the gradient of abstraction and the quantum state. In doing so, I aim to redefine a possible structure for the fundamental elements of the method that can describe both macroscopic and microscopic information processes. To achieve such a goal, I plan to deepen my studies of quantum mechanics and machine learning. The study of these topics will span the entire course of the PhD.

In the second year, I work on ontological proposals that fits best with the Method of Abstraction. I start by exploring informational structural realism (Floridi 2004, Coghill 2016), and I also look for possible applications of different versions of structural realism (French 2019, Dorato & Morganti 2022) to both quantum mechanical theory and the Method of Abstraction.

From the middle of the second year until the end of the PhD, I focus on revising the concept of information, which is common to both quantum and classical mechanics, with the aim of providing a comprehensive definition of information.

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