Levels of Abstraction As Family Resemblances From the Classical to the Quantum Mechanical Representation of Reality

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Abstract

This paper explores the challenges in expressing quantum mechanics using natural language and proposes a solution through the application of the Method of Abstraction. Quantum mechanics, deviating from classical physics, presents difficulties in language expression due to phenomena like the double-slit experiment and entanglement. The paper introduces the concept of Levels of Abstraction (LoA) as a framework to analyze information processes. Wittgenstein's ideas on language as a practical tool, shared activity, and the rejection of pictorial representation are invoked. The Method of Abstraction is extended to the quantum domain, resulting in Quantum Levels of Abstraction (QLoA) and Quantum Gradient of Abstraction (QGoA) models. These models provide a structured approach to understanding quantum properties and serve as a bridge between microscopic and macroscopic realms. The revised Method of Abstraction aids in capturing the informational processes in the quantum world, emphasizing the limitations of natural language and the importance of specialized languages, such as mathematics, in comprehending quantum phenomena. The proposed approach aligns with Wittgenstein's paradigm shift in recognizing the role of language rules in understanding different "games" or aspects of reality.

1. Introduction: the two worlds

Quantum mechanics is the field of physics where things happen in a way that is very different to our classical view of the world. Quantum Mechanics is the most accurate description of the world that we have access to. At the same time, however, it is also the most difficult description to understand. This is because the results of quantum mechanics do not seem to fit the categories of our language. Let us elaborate on this slowly.

From the perspective of quantum mechanics, it is possible to notice the limits of the language that we use every day or in the scientific description of the macroscopic world. Some definitions of the natural language are intrinsically different from the ones that we can derive from the theory of quantum mechanics.To give a taste of this difference, we can mention two examples: a famous experiment and a very strange quantum property.

One of the most famous experiments in the history of quantum mechanics is the *double-slit experiment*. In this experiment, we shoot multiple electrons through a double-slit plate in a wall. Without a detector that measures the

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electrons passing through the plate, it is impossible to determine where each single electron is passed, and what is only observed is the wave behavior that can be seen in the wall. Instead, with the observation things changed completely: it is possible to detect the slit where each electron is passed, but the interference of the electrons is no more visible.In this example, something very strange for the macroscopic world seems to be happening but it is possible to explain this phenomena with the help of one of the principles of quantum mechanics: the complementary principle proposed by Niels Bohr in 1928.

The principle can be expressed as follows: when dealing with microscopic objects in any experiment, the observer gains insights not into the inherent properties of the objects themselves. Instead, the obtained information pertains to the properties of the objects within a specific context, which includes the use of measuring instruments. Information acquired about the object under particular conditions should be viewed as supplementary to information gathered under alternative conditions. It's crucial to recognize that information obtained in diverse circumstances cannot be merely aggregated or combined to form a unified depiction. Instead, they mirror distinct (complementary) facets of a singular reality, each corresponding to a specific aspect of the object under examination.

This principle seems very different compared to the macroscopic world. However, things are different: the complementary principle applies to every size of matter, while at the macroscopic level it is ignored, in the microscopic world it is not still negligible. Given that, since our language is arranged on a macroscopic scale, it seems unable to account for the parity principle. Differently, the best way to interpret this principle is by using the language of math.

The use of math allows us to understand the situation that is happening during the experiment because it is impossible to measure the two properties when we go under the number at the right of the equation. The world of quantum mechanics becomes very clear if you use mathematics to explain the problems of the lack of direct observation, the use of the Hilbert Space is a great way to understand what seems difficult to catch without the tool of the numbers.

Another typical quantum property that helps to understand the problem of using natural language is entanglement.

Quantum entanglement was first formulated in 1935 by Einstein, Podolsky and Rosen in the famous *EPR paradox*:

> "When two systems, of which we know the states by their respective representatives, enter into temporary physical interaction due to known forces between them, and when after a time of mutual influence the systems separate again, then they can no longer be described in the same way as before, … By the interaction, the two representatives [the quantum states] have become entangled." (Schrödinger, 1935: 555)

This is a typical quantum property, which has no counterpart in the classical world, but which has several consequences in the theory of the microscopic world; it is impossible to reduce this phenomenon to classical mechanics.

The natural language created by the observation of the macroscopic world is incapable of capturing what this property shows. The only way to talk about it is to use the proper language of physics or, again, the language of mathematics.

If we want to talk about the strange things that happen in quantum mechanics, we need to bridge the specific language of the microscopic world and our natural language as used for the macroscopic world, in doing so the auspicious result is to obtain a correlation between the "two worlds" and a way to reach a better knowledge about quantum phenomena.

The "strange" thing is that at first sight, it seems that the problem lies in the fact that the two systems communicate with each other instantaneously, but this is impossible because it would mean that the communication had traveled faster than light, and according to the principles of special relativity, nothing can break this limit. But this also means that the correlation between the two cannot be explained by the measurement in the classical sense. Entanglement is something deeply different from a classical property. Once again we see the limits of natural language for describing the properties of quantum mechanics.

All the properties of entanglement seem impossible, not only for natural language, but also for a theory of the macroscopic world such as general relativity, which is the best theory of gravity we have. Consider that general relativity not only improves classical mechanics by extending its physical range (to speeds comparable to those of light and to strong gravitational fields), and not only provides the cosmological model that best describes the evolution of our universe as a whole, but is also the theory whose field equations, once solved, are potentially capable of providing an infinity of cosmological models describing as many physically possible universes.

2. Language as a practical tool

The fundamental inquiry underlying this discourse is the interpretation of the entanglement as a representation of reality. Does it denote something tangible or remain abstract? This age-old question has guided and still guides the debate regarding the ontology underlying quantum mechanics. The cogency of this question grounds in the widely shared assumption according to which every representation that is true corresponds to a matter of fact that makes it true. According to the famous Aristotelian formula, it makes sense to say that a representation is true because it corresponds to facts, while it makes no sense to say that it corresponds to facts because it is true. In this vein, if the quantum entanglement is to be understood as a truthful description of the way the constituents of matter behave, it is assumed that it corresponds to the facts, just as a photograph corresponds to its subject. According to the “pictorial theory of meaning”, a meaningful sentence must share a pictorial form with whatever state of affairs it reports. In this view, the elements of a linguistic representation correspond to elements of the situation they represent, and that the structure of the sentence is shared with that of the situation. However, it is precisely this "pictorial" correspondence that is problematic.

Wittgenstein, in his later work, dismisses his own pictorial representation theory of reality, asserting that the meaning of a proposition lies in usage rather than in the pictorial representation. According to this perspective, the quantum entanglement does not function as a depiction of reality; the crucial aspect is physicists' capacity for calculations, leading to testable predictions. The emphasis is not solely on the measurements, as a positivist might argue, but on the conduct of physicists. The language and mathematics employed serve as tools for regulating and influencing collective human actions to accomplish meaningful work.

Essentially, all the valuable information generated by science exists as forms of the scientific activity, namely, as results of experimentation or calculation. Wittgenstein illustrates this by stating that determining the length of an object involves an activity rather than mere learning of theories and definitions.This perspective implies that understanding quantum physics involves learning how to make scientific activity with it, and vice versa.

Wittgenstein further suggests that mathematics is a shared activity. He poses a hypothetical scenario questioning the belief that “twice two is five,” emphasizing the role of a shared technique that might not be labeled as calculating (RFM I, 168). Accordingly, if we do not perform the correct activity, that is, if we do not use the appropriate set of rules, it is impossible to understand the procedure of mathematical theorems. In this view, mathematics and natural language can be seen as sharing a series of similarities that allow us to consider them as part of the same family resemblance.

As the use of words in language, according to Wittgenstein, also the use of symbols in mathematics is governed by conventions. Following Wittgenstein,, mathematical entities and truths are not discovered, but rather “invented” or created by humans based on conventions that allow shared activities. In other words, mathematical statements and concepts are considered to be human-made activities or agreements rather than reflections of some inherent, objective reality.

Following this suggestion, to inquire about the meaning of quantum entanglement without specifying the corresponding activity – an experiment – is like asking about the sound of a falling tree without a context. Such a question is deemed nonsensical in this philosophical framework.

3. From actions to levels of abstraction

Any language can also be considered as a process of information exchange between people, objects, computers. With this consideration we can take an epistemic structure made in the philosophy of information, which tries to create a way to define all possible processes where there is an exchange of information.

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The core definition of this structure is the *Level of Abstraction*.

> "A Level of Abstraction, LoA, is a finite but non-empty set of observables. No order is assigned to the observables, which are expected to be the building blocks in a theory characterized by their very definition." (Floridi 2011: 52)

This definition was created by Luciano Floridi and first presented in the *Method of Abstraction* (2004). This structure is capable of analysing any type of information process that can be extracted from a set of observations, from those closest to nature (such as the colour of things) to abstract exchanges of information (prices, analyses of social characteristics).

The main elements of the method are used to define the level at which a system is considered, since each level of abstraction provides a quantified commitment to the type and amount of information that can be extracted from the set under consideration.

An interesting implementation of the method is to analyse the information processes that can be derived from the observables of a given mathematical set, and this can be done with a simple implementation of the elements of the method. Thanks to this we have a method to analyse different sets of observables (like numbers, objects, properties...) and also to make comparisons with them, because we can easily compare the elements of LoA with the well-known rules of set theory, as a result of the definition of LoA as a set.

Another interesting point is that Floridi thinks that his method is not a prerogative of the human species, everyone can use different types of LoA.

> "Since they deal with observables, LoAs are not an anthropocentric prerogative but allow a more general (or indeed less biased) approach. We do not have to limit ourselves to human beings or to communities of speakers. Different sorts of empirical or abstract agents, not only human beings but also computers, animals, plants, scientific theories, measurement instruments etc., operate and deal with the world (or, better, with the data they glean from it) at some LoAs. By neatly decoupling LoAs

> from the agents that implement or use them, we avoid confusion between CSs, the languages in which they are formulated or embodied, and the agents that use them." (Floridi 2011: 72)

LoAs are not mandatory for each subject, but the possibility of understanding different levels of abstraction is opened up. It is possible to make a comparison with the definition of *family resemblance*:

> "I can think of no better expression to characterize these similarities than "family resemblances"; for the various resemblances between members of a family: build, features, colour of eyes, gait, temperament, etc. etc. overlap and criss-cross in the same way. – And I shall say: 'games' form a family" (PI 2009: 56).

From this definition each GoA can be seen as a family resemblance and the sum of the LoAs can be seen as a game.

If it is possible to capture the informational processes between mathematical observations, what about the quantum world, which seems to be accessible only through a particular language and a particular mathematics?

The Method of Abstraction can be applied to cases in the world of quantum mechanics, and its explanatory power can be utilized there as well. To achieve this, a promising approach is to link the observables of the method of abstraction with the corresponding concepts in quantum mechanics.

The original version of the Method of Abstraction defines the observable, which can be rearranged using the observable concept in orthodox quantum mechanics. This results in a new observable with more constraints based on physical theory. It is used to define the notion of observable in quantum mechanics as the total energy of a particle with mass m in a real potential field V. To rearrange the Method of Abstraction for quantum mechanics, we must define the observables in that way. So using this definition, various sets of observables can be created according to the rules of quantum mechanics. and these sets can be referred to as observables.

4. The Quantum levels of Abstraction

The *Quantum-Levels of Abstraction* (QLoA) model allows us to map all observables starting from a set of variables and the rules of quantum mechanics. Each QLoA shows us the observables that have the same properties in common. The model maintains the same structure as the original Method of Abstraction, allowing for the creation of multiple QLoAs with different observables. Quantum Levels of Abstraction can be viewed as a sequence of exponentiations of sets. The QLoA that is closer to the observables, less abstract in Floridi's terminology, is the set that contains the observables derived using the self-adjoint operator.

From there, we can take another step and use the notion of *Gradient of Abstraction* (GoA), taken from the original formulation of the Method, to construct similar objects for quantum mechanics.

A GoA is:

> "A collection of different LoAs that focus on a particular system or feature forms a gradient of abstraction (GoA)." (Wolf 2012: 24)

The quantum counterpart is a collection of the QLoAs and can be called the *Quantum-Gradient of Abstraction* (QGoA). It can be compared to a quantum state in quantum mechanics. A quantum state is defined as the wave function that encodes all information about a system.The correlation can be identified by observing that each QLoA represents a portion of the information of a specific quantum state, such as position or energy. The set of all QLoAs creates a QGoA that contains all the information of a system. This reformulation gives the QGoA a foundational state compared to the GoA, where this structure is not an axiom of the theory and is intended to aid the analysis of information derived from large collections of LoAs.

By accepting the modification of the Method of Abstraction, it becomes possible to explain the emergence of quantum properties. This is due to the fact that LoAs, which take into account the laws of quantum mechanics, create rules for determining an observable that are not used in a less complex LoA. The latter is used to gain simplicity, such as the LoA that uses the rules of classical physics for macroscopic objects.

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The revisitation of the Method of Abstraction can help us understand certain aspects of quantum mechanics that are difficult to express in natural language. It provides a way to bridge the gap between the language we use and the world and language of quantum mechanics. QLoA and QGoA aim to create a bridge between the information processes in the microscopic world and our comprehension.

By reconsidering the concept of linguistic game as a means of analysing the information that can be conveyed, one can comprehend the importance of mathematics as a tool for comprehending phenomena in the microscopic realm, as well as the essential paradigm shift of Bohr's Principle.

Phenomena such as the double slit and entanglement demonstrate the limitations of natural language in capturing precise observations. Therefore, specific tools are necessary to accurately represent reality. The revisited Method of Abstraction enables us to capture both the formal language of mathematics, used to describe quantum phenomena, and the natural language we use for communication, in a common field. This allows for a unified approach, with an high order formal language, to obtaining information from the world, despite the differences between the two theories.

5. Conclusion

Considering these factors, expressing quantum mechanics in natural language may seem impossible. The double-slit experiment and entanglement highlight the difficulty in comprehending the microscopic world without a precise conceptual framework or specific terminology. By incorporating the Method of Abstraction into the quantum realm, we can create a model of the informational processes that serves as a bridge between macroscopic and microscopic situations. This model shows that the limitations of natural language tools derived from the Level of Abstraction that we used and highlights the importance of mathematics and specialised languages in understanding the quantum world. By embracing this paradigm shift, we follow Wittgenstein's ideas of changing the rules of the language in different games and recognising the crucial role of language in comprehending reality.

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