Article

What is Life? The Observer Prescriptive

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Abstract: Quantum mechanics introduces the concept of an observer who selects a measuring device and reads the outputs. This measurement process is irreversible. Lately, scholars on quantum collapse phenomena have presented a quantum-like formalism describing the measurement results as an interpretation of the measured object. Note that an observer must read the interpretation results after the interpretation process. Therefore, we propose that the definition of the concept of life should be expanded based on the following concept: A living system decreases entropy, measured results are interpreted, and an internal observer reads the commentary.
In this study, we derived the mathematical tools for this description. Specifically, we demonstrated that this process reduces entropy, according to the conventional theories defining life.

Keywords: Interpretation; State construction; Entropy reduction, Observer

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I. Introduction

In his famous book, "What is Life?" [1–3], Erwin Schrödinger linked thermodynamic processes to define life. He presents life as a decreasing entropy process. This reduction does not contradict the second law of thermodynamics because the environment surrounding living systems increases entropy to compensate for the decrease in entropy in the local system. As this description suggests, life-sustaining processes are part of spontaneous physical processes. However, decreasing entropy does not describe only living processes. In nature, not all systems that evolve into an order stage can be defined as a living system. For example, a liquid solidifying in a cold environment and biometric materials [4], respectively, represent simple and complex examples of systems that reduce entropy but are not alive. In this work, we describe living systems using the conventional life definition as entropy-reducing. Additionally, we add the concept of the observer who interprets reality in a quantum-like measurement.

The analysis of cognitive behavior using physics tools was presented in a quantum-like model, where the term "quantum-like" distinguishes these models from actual physical processes [5]. We observed these ideas from a physical perspective, such as the thermodynamics view.

Following the principle of objectivity in science, the behavioral sciences assume that results discovered under controlled conditions also apply outside the laboratory (uniformity assumption) [6]. The term "interpretation" refers to what is known as "private events," which refers to behavioral phenomena observable only to the behaving organism. These phenomena pose a challenge in experimental science because the agreement between observers of such events according to traditional science is impossible [6,7]. In our description of a living system, we dismissed the objective approach and associated our system with the ability to perform interpretations. Furthermore, our living interpreting system can act according to the interpreted subject. Consequently, our analysis, which is based on the quantum measurement theory, defined an observer that would be part of the living system frame.

Interpretation plays a crucial role in several aspects of life.[8]. Indeed, a considerable part of the communication between people in a social context relies on their personal interpretations [8].

We propose a quantum-like formalism to describe the process of interpretation. The process is based on quantum tools, such as measurement theories [10–12], and various representations of states. We associated each observer with an individuality. We show that this individuality is attributable to collapse phenomena in quantum measurements [10–12] because the only one who reads the collapse output is the observer of a living organism (like the definition provided for the term "private event"[6,7]). In the following section, we introduce the interpretation process based on which we derived thermodynamics related to the interpretation process presented in the study.

II. Review - Interpretation Activities

In this section, we review the quantum-like approach for describing the interpretation process[13] The perception process occurs in three phases: selection, organization, and interpretation [14,15]. In this study, we considered all these activities as an expression of interpretation. Based on quantum formalism, we selected slightly different phases: state construction, classified representation, representation, and determination. We demonstrated these definitions using the duck-rabbit figure shown in Fig. 1 [16–20]. The figure is an ambiguous picture, which, according to Merriam-Webster, is the picture of a subject that the viewer may see as either of two different things or as the same subject from either of two different viewpoints, depending on how the total configuration is interpreted [**?**]. The

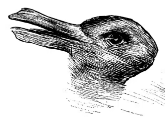

Figure 1. Ambiguous figure: Is it a rabbit or a duck?

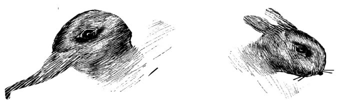

Figure 2. On the left: a duck figure. On the right: a rabbit

adapted quantum-like stages of the interpretation processes are as follows.

i. **State Construction**
In state construction, the system transforms the items to be interpreted into a state in a Hilbert space. This state is denoted as $|\pi(Item)\rangle$. In this study, the transformation of an object (such as a simple image) into a state was not examined. However, a procedure for generating coherence was described in Ref. [22], where a nonlinear approach was implemented.

As demonstrated,

ii. **Classified representation** The system defines the states (concepts) to be used to interpret the information received.
The concepts are defined by the states $|I_i\rangle$, where i is the label of the state in the corresponding Hilbert space. As demonstrated in this study, the classified concepts generated a space describing animals using the corresponding states, $|d\rangle$ and $|r\rangle$, where $j = d$ and $k = r$, and $\forall i \neq j,k \quad i = 0$ denote "duck" and "rabbit", respectively.
As demonstrated,

$\Big|\pi\Big($  $\Big)\Big\rangle \xrightarrow{\text{is classified as}} \begin{cases} \forall i = j,k & |d\rangle \ or \ |r\rangle \\ \forall i \neq j,k & 0 \end{cases}$

iii. **Representation**
The constructed state is represented in terms of classification states. Defining

$$\mathbb{R} \stackrel{\text{def}}{=} \sum_i |I_i\rangle\langle I_i| \tag{1}$$

as a classification operator, we obtained

$$\mathbb{R}|\pi\,(Item)\rangle = \sum_i \alpha_i |I_i\rangle, \tag{2}$$

with,

$$\alpha_i = \langle I_i | \pi\,(item)\rangle \tag{3}$$

In the demonstration, we consider $|I_j\rangle = \Big|$  $\Big\rangle$ and $|I_k\rangle = \Big|$  $\Big\rangle$ to obtain:

$\alpha_j = \Big\langle$  $\Big|$  $\Big\rangle$, $\alpha_k = \Big\langle$  $\Big|$  $\Big\rangle$ (4)

$\forall i \neq k, j \;\; \alpha_i = 0$

where, according to quantum formalism, $|\alpha_j|^2$ and $|\alpha_k|^2$ are the probabilities for  to be interpreted as a duck or a rabbit, respectively.

iv. **Determination**
The state collapses into one of the classification states to complete the interpretation. We used the observable

$$\mathbb{D} = \sum_i \iota_i |I_i\rangle\langle I_i|, \tag{5}$$

where, similar to Ref. [23], ι_i are *eigenconcepts* that serve as the measurement output. In the determination process, out of N alternatives, only one value, which we marked it with the letter p, was obtained. Then, we have

$$\mathbb{D}|\pi\,(item)\rangle \xrightarrow{\text{Collapse-like process}} \begin{cases} for\ i = p & \iota_p|I_p\rangle \\ \forall i \neq p & \iota_i = 0 \end{cases} \tag{6}$$

These are the interpretation results provided to the observer.
As we demonstrated,

$\mathbb{D}\Big|$  $\Big\rangle \xrightarrow{\text{Collapse-like process}}$  $\Big|$  $\Big\rangle$ or  $\Big|$  $\Big\rangle$ (7)

0-for all other animals

where  and  are the eigenconcepts.

III. Organism reaction

Eq. 5 describes an observable that performs an interpretation using the result ι_i. It is possible to replace the numerical values of ι_i with a variable representing sensations that the observer will experience. For example, the sensing observer of an image (shown in eq. 7) or a sound can react accordingly. In instinctive reactions, ι_i will be replaced by the operator representing the reaction. Using the rabbit-duck example, we demonstrated the triple options:

i. As a result of the interpretation, the observer saw a duck

$\mathbb{D}\Big|$  $\Big\rangle \xrightarrow{\text{Collapse-like process}}$  $\Big|$  $\Big\rangle$ (8)

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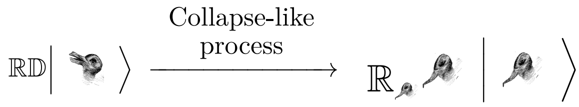
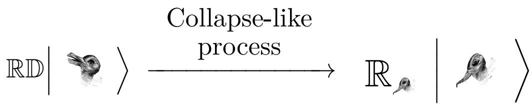
ii. After interpreting the image as a duck, the observer reacted (represented by the operator $\mathbb{R}$)



(9)

where $\mathbb{R}$ is the response for the duck result. 78

iii. The observer responded without knowing he detected a duck:



(10)

IV. Density operator 79

In interpreting Figure 1, we noticed an ambiguity in determining whether the object is a duck or rabbit. Before the determination stage, a scenario existed in which the observer was aware of the ambiguity. We demonstrated that the density matrix mathematically describes this state of mind. The representation stage is a pure state, in which $|\pi(item)\rangle$ is expressed as a superposition of the classified states. In the duck-rabbit example, the image represents the status of both images and the density matrix are a mathematical representation of that scenario.
The pure-state density matrix describing the representation stage is

$$\rho = \sum_i \alpha_i |I_i\rangle \sum_i \overset{*}{\alpha}_i \langle I_i| = \overbrace{\sum_i |\alpha_i|^2 |i\rangle\langle i|}^{\text{Distinguishable terms}} + \overbrace{\sum_{i\neq k} \alpha_i \overset{*}{\alpha}_k |i\rangle\langle k|}^{\text{Interference part}} . \tag{11}$$

The first sum represents the parts where the different items (concepts) are distinguishable. In our example, there is a distinction between rabbits and ducks. The second term describes an interference scenario, which is why the concepts are indistinguishable, i.e., ambiguous. Because the interference terms contain relative phases, a dissipative environment could randomize them such that on average, we obtained

$$\overline{\rho} = \overbrace{\sum_i |\alpha_i|^2 |i\rangle\langle i|}^{\text{Distinguishable terms}} . \tag{12}$$

If the average density matrix is valid for the observer before the measurement process, we assumed that they were aware of the system ambiguities. Ambiguities are resolved by measuring them through a collapse-like process. The randomization process agrees with the second law of thermodynamics. Thus, we calculated the spontaneous entropy increase as

$$S = -K_B \ \text{Trace}\{\overline{\rho} \ln(\overline{\rho})\} \tag{13}$$

where K_B is the Boltzmann constant. $\overline{\rho}$ is diagonal; therefore, we obtained

$$S = -K_B \sum_i |\alpha_i|^2 \ln\left(|\alpha_i|^2\right) \tag{14}$$

V. Heat Emitted in the Determination Process 80

It is well known that life is a manifestation of the second law of thermodynamics [1,3,24]. Further, we considered a spontaneous interpretation process in the design of a machine, capable of implementing the proposed interpretation process. The proposed machine obeys the second law of thermodynamics of increasing entropy in a closed system. Assuming that the system was already in an incoherent stage before the measurement (as presented in the previous section by the density matrix), the final stage of determination, in which the

system collapsed into one of the concept states, reduced the entropy. The entropy reduction violates the second law of thermodynamics unless the environment surrounding the system increases the entropy to compensate for the decrease in the disorder of the interpretation system [25].
After the determination stage where the system collapsed into a single value, implying that $S_a = 0$ (a for after), and based on the second law of thermodynamics, the entropy decrease must be compensated by an increase in disorder in other parts of the system, which is usually triggered by heat emission to the surroundings. Implementing the relationship $\Delta S = \frac{Q}{T}$, where Q is the emitted heat, T is the temperature, and S_p is the entropy before determination, as in Eq. 14, we obtained

$$Q = k_B T(S_p - S_a) = -K_B T \sum_i |\alpha_i|^2 \ln\left\{|\alpha_i|^2\right\} - 0 = \\ = -K_B T \sum_i |\alpha_i|^2 \ln\left\{|\alpha_i|^2\right\}. \tag{15}$$

Thus, the interpretation process emits heat to the surroundings.

VI. Environment Role

The transition between the pure density ρ and mixed state matrices $\bar{\rho}$ involves averaging over the terms α_i, $\overset{*}{\alpha}_j$. The process occurs in a diffuse environment that violates the coherence between states[26]. The following example demonstrates why a dispersive environment is an important part of the interpreting system. Observe the ambiguous Figures [16–19] presented in Fig 3. Is it the letter B or number 13? In our formalism, state $\left|\pi\left(\right.\right.$  $\left.\left.\right)\right\rangle$ can be expressed in terms of the number "13" and the letter B with superposition:

$$\left|\pi\left(\right.\right.$$  $$\left.\left.\right)\right\rangle = \alpha_{13}|13\rangle + \alpha_B|B\rangle. \tag{16}$$

We adapted the average density matrix, $\overline{\rho} = |\alpha_{13}|^2 |13\rangle\langle 13| + |\alpha_B|^2 |B\rangle\langle B|$., thus eliminating the interference terms. This enabled us to interpret a distinct image of the number 13 (middle-side) or the letter B (right-side). Thus, we arrived at two conclusions. First, the expansion coefficients depend on external circumstances such as the location of the image. Second, the interpretation variation between the right-middle-left sides of Fig 3 occurs in the interpretation system, implying that the environment is an internal property of the interpreting system.

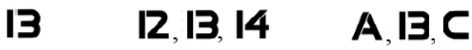


Figure 3. Left side, an ambiguous figure: Is it the letter B or the number 13? Middle of the image is interpreted as number 13. Right side, the image is identified with the letter B

This,  - example leads us to conclude that a machine with a self-interpreting feature must be divided into two parts: the interpretive part, in which the states are defined and through which the input is interpreted (such as the duck or the rabbit in our example), and the environment, which helps refine the concepts, i.e., determine the density matrix.

VII. Summary

In this article, we expanded the definition of life. Following on from extant definitions of living systems as entropy-reducing systems, we expanded the definition of a living system as a system that interprets measurements made on the environment. Beyond that, the system also reacts according to the interpretation results. Our system's response is quantum-like; therefore, we assumed that an observer reads the measurements and reacts accordingly. We attributed the personality trait of the organism to the observer. We demonstrated that interpretation reduces the entropy of the living system by emitting heat into the environment. In biology, this process is known as the homeostasis process. Furthermore, entropy reduction is connected to the information field. If we define entropy as Shannon's entropy, it can be conjectured that information is added to the system in the process of entropy reduction [27].

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