As Some Physicists Claim, Is Information the Fifth State of Matter? General Theory of Information Says No.

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***Abstract*—Some researchers suggest that the information is a form of matter calling it the fifth state of matter or the fifth element. In this paper, we use the general theory of information (GTI) to assert that information is not physical by itself although it has a physical representation. As a result, the representation of information in the form of a physical structure results in its materialization. Therefore, a bit of information does not have mass but the physical structure that represents the bit indeed has mass. Moreover, the same bit can have multiple representations in the form of a physical substance (e.g., a symbol on a paper or a state of a flip-flop circuit, or an electrical voltage or current pulse.) Naturally, these different physical representations can have different masses although the information will be the same.**

Keywords—information, general theory of information, knowledge, mass-energy-information-knowledge correspondence

I. Introduction

Physical science is a branch of natural science that studies non-living systems, in contrast to life science, which studies living things. On the other hand, information science, according to the Merriam-Webster dictionary, is primarily concerned with the analysis, collection, classification, manipulation, storage, retrieval, movement, dissemination, and protection of information. However, while mathematicians, philosophers, biologists, physicists, and information scientists to mention but a few, have all postulated various definitions of information since the notion of information emerged in human society, it is not an exaggeration to say that there is no consensus on what really information is.

Does information exist independently of our own existence? Does information processing require only living organisms or also other material structures in the physical world to process information? Unlike humans, do the technical information processing structures know that they are processing information? How is knowledge related to the information? While these are profound questions, the purpose of this paper is not to answer them. For answers, we refer the reader to the general theory of information (GTI) in [1-9] and in other related publications where these questions are studied and the answers are obtained.

In this paper, we investigate the mass-energy-information equivalence principle suggested in [10, 11] and the related claims that information has mass and it is the fifth state of matter. "For over 60 years, we have been trying unsuccessfully to detect, isolate or understand the mysterious dark matter," said Vopson. "If information indeed has mass, a digital informational universe would contain a lot of it, and perhaps this missing dark matter could be information." [11]. This statement is based on the mass-energy-information equivalence principle, which claims that information is transformed into mass or energy depending on its physical state. In addition, the existence of intrinsic information underpinning the fundamental characteristics of elementary particles in the Universe implies that stable, non-zero rest mass elementary particles store fixed and quantifiable information about themselves [10-16]. These so-called information conjectures also imply that the information is a form of matter, which is called the fifth state of matter or the fifth element [11].

To validate these and similar claims, we analyze the assumptions behind the formulated mass-energy-information equivalence principle using the GTI and demonstrate that information is not physical by itself but has a physical representation. Naturally, this physical representation has mass and complies with physical laws. We argue that the physical properties that Landauer [12-16], Vopson [11], and other researchers deduced ascribing them to information [17-19] are actually the properties of the physical representations of information. Information per se does not have mass but its representation in a form of a physical structure contains mass. In the physical world, the genes and neurons, for example, process information to convert it into knowledge. They communicate information represented as biological and neurological structures using chemical or electrical signals. In the digital world, a 'bit' of information does not have mass but a physical material that represents the bit has mass. The same bit can have multiple representations in the form of physical material (e.g., a symbol on a paper or a state of a flip-flop circuit, or an electrical voltage or current pulse). Information is carried by the physical structures.

Thus, the physical properties that Landauer and other researchers deduced ascribing them to information [10-19] are actually the properties of the physical representation of information. This is in a good agreement with what Landauer actually wrote [13] and not with his more far-reaching claims

The paper has the following structure. In section II, we present the ideas and conceptions from the GTI about information, its representation, and the relationship between information, mass, and knowledge. In Section III, we discuss the mass-energy-information equivalence principle in light of the GTI. In section IV, we put forward general observations from this study and conclusions.

II. General Theory of Information

The general theory of information (GTI) [1, 3] states that "knowledge to information is as the matter is to energy" while the material structures in the physical world carry the information that represents the state and the dynamics of the structure under consideration. In the physical world, material structures are governed by the transformation laws of matter and energy. Energy has the potential to create or change material structures. All physical and chemical structures created or changed by the transformation of matter and energy obey the laws governing their transformations. All physical structures contain potential information that characterizes their structure, the functions of their constituent parts interacting with each other and with their surroundings, and their behaviors when internal and external factors cause fluctuations in their interactions. In fact, it means that there is a definite relationship between the characteristics of physical objects allowing the possibility of the conversion of mass into the energy of physical objects described by these characteristics. The famous formula $E = mc^2$ connects the energy and mass of physical objects. However, in contrast to what many people think, this formula does not mean that substance is equal to energy but it shows the maximal amount of energy in a physical object with a given mass.

The states of physical structures and the laws governing their evolution are described by the laws of physics using mental structures created by humans (mainly by mathematicians and physicists). Living organisms have developed physical structures that exploit the matter and energy transformations to acquire a unique identity and the ability to sense and process information that is carried by material structures and convert it into knowledge in the form of mental structures. While all living organisms have varying degrees of ability to perceive, process, and convert information into knowledge, humans have developed the highest level of representing and managing the mental structures using the ideal structures in the form of named sets or fundamental triads [1]. The fundamental triad provides the schema and operations to create knowledge in the form of entities, their relationships, and their evolution consisting of event-driven behaviors [7-9]. Events are caused by fluctuations in the interactions among the components of the structures and their interaction with their environment. Thus functions, structure, and fluctuations play important roles in the system's microscopic and macroscopic behaviors [20].

It is important to note that the mental models created by processing information are observer-dependent.

According to [1, 3], the GTI places information per se in the ideal World of Structures, which is the scientific incarnation of the World of Plato's Ideas or Forms [4]. According to the Ontological Principle O2 and its additional forms in the GTI ([1, p. 99]; [3]), information plays the same role in the World of Structures as energy plays in the Physical (Material) World. While being associated with material structures in the physical world, the information does not belong to this world and can only be materialized in a physical form as it is asserted in the GTI [2].

According to the Ontological Representability Principle (Ontological Principle O4) of the GTI ([1, p. 123]; [3]), for any portion of the information I, there is always a representation Q of this portion of information for a system R. Often this representation is material, and as a result, being materially represented, information becomes, in some sense, physical. Consequently, a physical representation of information can be treated as the materialization of this information [2]. Thus, information being not physical by itself has a physical representation, and naturally, this physical representation complies with physical laws.

Moreover, according to the Ontological Embodiment Principle (Ontological Principle O3) of the GTI ([1, p. 120]; [3]), for any portion of the information I, there is always a carrier C of this portion of information for a system R. This carrier is, as a rule, material, and this makes information even more physical. A physical carrier of information can also be treated as the materialization of this information, or more precisely, the materialization of the second level. Materialization of information requires an agent or an observer and a process of materialization. An example is representing information as a symbol on a carrier which is a paper using a pen.

Note that any representation of some information I is also a carrier of this information but any carrier of some information I is also a representation of this information. For instance, the text of a letter is a representation of the information I in the letter. If this text is printed or written on paper, then it is a physical representation of I. At the same time, the envelope that contains this letter, or more exactly, the paper on which this text is printed or written is only a carrier but not a representation of the information in the letter.

The carrier of the information I, which is not a representation of this information, is called the *enveloping carrier* of I.

In the mental world created by living organisms, information received from the environment by means of the five senses is converted into mental structures formed of fundamental triads. There are two forms of mental structures – those that are derived from the external observations, and those that are created by the human mind representing the ideal structures. Mathematics is used to represent the ideal structures and operations with them as well as to model the material world, its states, and their evolution.

In a similar way, the mental reality (mental world) consists of various mental structures, which participate in the transformational processes involving information and knowledge. These transformational processes are defined by the physical information processing structures, which consist of genes and neurons. A similar to Einstein's mass-energy equivalence formula also exists in the information realm having the form $I = M_K \times p$ where $p > 0$ is the constant that connects the information I and knowledge K of mental systems just as energy and matter are connected in the physical world. This association makes it possible to introduce knowledge mass. Namely, the mass M_K of a knowledge unit K is the measure of the knowledge object inertia with respect to the structural movement in the mental world. Each knowledge mass contains the structural components, their relationships, and behaviors. One knowledge mass interacts with other knowledge masses by sharing information using various means of communication facilitated by the information processing physical structures (the genes and the neurons, which use chemical and neuronal signals).

This brings forth the equivalence between the theory of physical structures and the theory of mental structures. Each such structure with a certain mass interacts with other structures based on various relationships defined by interaction potentials. In such a way, each structure provides guidelines for a functional behavior and a network of structures provides guidelines for the collective behavior based on interactions between structures. Structural nodes, which are wired together, fire together to shape the collective behavior of the system. This allows us to represent the mental structures using the same mathematical representations of physical structures in the form of state vectors and their evolution.

This means that a knowledge network is a set of components with specific functions, which interact as structures and produce a stable behavior (equilibrium) when conditions are right. However, fluctuations change the interactions and cause non-equilibrium conditions. This leads to emergent behaviors such as chaos. However, biological systems have developed an overlay of information processing structures that monitor and manage the system stability, safety, sustenance, etc., while monitoring the impact of fluctuations.

III. GTI AND THE MASS-ENERGY-INFORMATION EQUIVALENCE PRINCIPLE

Armed with this knowledge about information, we can now respond to the questions: Is Information Physical, and does it have Mass? Answering the first question, we explain that the information is associated with physical and mental structures and can be embedded in other physical structures that act as carriers of information. Answering the second question, we clarify that the knowledge in mentality has mental mass just as the matter has physical mass while the information carriers (both physical and mental) have mass but not the information itself.

This puts us at odds with those researchers who claim information has mass [10-19]. For instance, Landauer claims that information is physical. However, at the beginning of his paper [13], he writes

"Information is inevitably tied to a physical representation."

It means that according to Landauer, information is only tied to its physical representation but this tells nothing about the essence of information *per se*.

Another sentence from his work "Information is not a disembodied abstract entity; it is always tied to a physical representation." asserts what information is not but tells nothing what, information *per se* is [11].

In a similar way, Melvin Vopson claims

"A computational process creates digital information via some sort of physical process, which obeys physical laws, including thermodynamics." [11]

This statement is misleading. The correct statement should be:

"A computational process creates digital information via some sort of physical process, which works with physical representations of digital information and obeys physical laws, including thermodynamics."

Namely, only by changing physical representations, the physical process changes information [2]. In particular, erasing information changes the physical objects that were carriers of this information, while writing information transforms some physical objects into the carriers of the written information.

Accordingly, the formula (6) from [11] can be interpreted not as the mass of a bit of information but as the mass of the physical representation of a bit of information.

Besides, there is a problem with the interpretation of Shannon's measure of information (information entropy) H. It measures information not directly but utilizes its physical representations – signals or texts. When this measure is applied to the states of physical systems, it means that the state of a physical system is a representation of information while the corresponding system is the carrier of this information.

As the result, there is no the mass-energy–information equivalence conjectured by Vopson in Figure 2 from [11] because the same portion of information can have different physical representations.

This situation is clearly explained by the general theory of information (GTI) mentioned above. Indeed, according to the Ontological Principle O4, for any portion of the information I, there is always a representation Q of this portion of information for a system R [1, 3]. Often this representation is material, and as a result, being materially represented, information becomes, in some sense, physical. In this context, a physical representation of information becomes the materialization of this information allowing people and other systems to get this information [2]. The process of DNA replication shows that not only living beings but also unanimated systems such as molecules can transform and transmit information from one physical representation to another one.

Thus, information is not physical by itself but has a physical representation and naturally, this physical representation complies with physical laws. This is in good agreement with what Landauer actually wrote and not with his more far-reaching claims.

Similarly, some people can say that thoughts or feelings are physical because they are in the brain, which is physical. However, all intelligent people know that the brain is only a carrier of thoughts and feelings, the nature of which is essentially not physical.

Thus, the physical properties that Landauer, Vopson, and other researchers deduced ascribing them to information [10-

19] are actually the properties of the physical representations of information.

IV. Conclusion

As it is possible to see from the discussion above, information is not physical by itself but has a physical representation and naturally, this physical representation complies with physical laws. This is in good agreement with what Landauer actually wrote and not with his more far-reaching claims. Thus, the physical properties that Landauer and other researchers deduced ascribing them to information [12-15] are actually the properties of the physical representation of information.

In addition to this paper, the true nature of information and its relation to physical reality is also explained in [1-5] and related publications.

To conclude our discussion, we remind that mathematicians were able to understand the difference between numbers and their representations by numerals a long time ago. Hopefully, information scientists and other researchers will also be able to understand the difference between information and its physical representations. More importantly, they will be able to use the GTI to improve how we use information and knowledge as well as to enhance our understanding of how nature operates and additionally design the digital world, which mimics living organisms with such behaviors as autopoiesis and cognitive reasoning [7 - 9].

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