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Information—Semantic Definition or Physical Entity? †

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Abstract: For an universal and scale-invariant definition of information the idea of a "smallest" information is discussed. Elementary information is defined. For the utilization of this approach the question of the further emergent development of elementary information is analyzed, a scheme for scale dependent emergence processes of information is suggested.

Keywords: definition of information; emergent information; elementary information; smallest information; pixel

1. Introduction

Although the term "information" is discussed in a lot of publications since decades, a generally accepted definition of information does not exist. The prevailing discourse focuses on semantic and technical definitions, but with the rising vision of quantum computing also physicists are more interested in understanding information. But still today semantic definitions seem to be stronger than physical concepts. The reason might be the experience, that information pervades all scales, from the quantum level to a railway signal. This fact may be addressed easier semantically, than by a physical entity. In a similar case like the entity "energy", it took nearly two centuries to receive a fundamental and finally accepted definition.

A physically correct and semantically useful definition of the term "information" has to be scale invariant and elementary enough to include most of the known definitions. It seems reasonable to identify this elementary information with a kind of "smallest" information, whatever this might be.

2. Initial Situation

The physical connotation of "smallest" and "elementary" is normally related to a measurable dimension of length or time. These criteria sometimes are also used to define the smallest information. The phenomenological idea behind is to disassemble the railway signal into its constituent molecules, which again will be disassembled via atoms in their quantum states, perhaps representing the smallest information unit of that macroscopic object. In terms of quantum theory the Planck length gives the smallest possible volume, and therefore the information density of that volume is a hot question among physicists. G. t'Hooft stated: "Then, even if infinities may cancel out, there still seem to be no obvious bounds as to how much information can sit in a tiny volume" [1]. While G. t'Hooft is arguing based on *information densities*, L. Susskind is trying to define information itself. He introduced a so-called "parton" as a new construct to project a light beam onto a screen creating pixels [2]. He called that partons "elementary structureless constituents" [2] and he mentioned, he would prefer the term "Bit". But Bit should be the unit of a parton. Finally Susskind shows as result one Bit per Planck volume, using pixel and partons in his calculation. On the other hand C.F. Weizsäcker [3] postulated so called ur-alternatives as initial elements of quantum states and designed a two-dimensional complex Hilbert space. Finally, that assumption should also lead to one Bit for a Planck volume.

But the density, which is the occurrence of information per volume, does not necessarily explain the information itself. The widely use of the unit "Bit" as measure of the smallest information does not compensate the missing definition.

3. Results and Discussion

Finally we are free to focus on an ontological reduction to reach a definition. The British biologist and cyberneticist G. Bateson did so in a subordinate clause by stating "*information would be the message from a change*" [4]. But he did not pursue this question. And it is not clear, why Bateson did use a two-step formulation with a tautological component. In its place a modified version will be taken as clear definition for elementary information:

- **Definition.** Elementary information is a change (of any entity).

If something is changed, automatically information is generated. In an unchanged situation, no information is generated. If we accept this as fundamental definition, we have to formulate the meaning of change as a conclusion out of that. Bateson's "message" may be the transmission of this information as a change to some recipient. The change might happen in a quantum state, or a railway signal. A very important semantic detail: The physical condition, e.g., the size, is a quality of the entity, but not of the information. This should be also true for the information density, which is characterizing the physical environment, but not the information itself. The knowledge about these environmental conditions might be interesting—we should call it meta-information, but has to be handled separately later. Further known definitions of information for specific purposes like potential, structural, biological etc. information can be based on that starting point. And information processing is transferring the elementary information as change itself from one environment to another. Today the physical environment of such a change is normally called "medium".

Prima facie, it looks like playing at semantics without a substantial physical value. But the exciting part of the definition can be found between the brackets. It stipulates, that not only physical entities like voltage and mass are sources for information, but everything. Only a change is needed.

However, before this option can be discussed more deeply (for an initial idea e.g., [5]) it has to be looked at the further emergence of the elementary information. In nature, we notice for a lot of environments evolutionary developments. If one change has happen, further changes may occur. The reason has to be discussed somewhere else, but if it happens, we can specify a very general systematics (Figure 1).

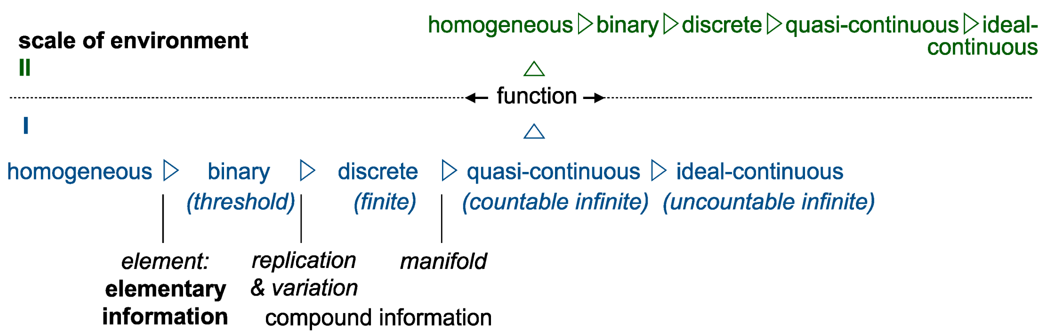

Figure 1. Generalized scheme of emergence for an unspecified entity. At the lower scale (**I**) a typical development happens, until an emergent function enables a step into a second scale.

An initial change in a certain environment (I) generates elementary information. By replication and variation a wider range of information may occur, still in discrete forms, which may be con-sidered as patterns. Further replication leads to quasi-continuous expansion towards an ideal-continuous phase. Beside of this development, an emergent functionality can arise. With this new functionality a new level of the environment (II) might be generated. The quasi-continuous structure in level I acts a new homogenious medium of leveI II. And there again an initial change as elementary information may start a cycle with the same systematic components at the next level again. A scale must characterize each level or environment. The increasing scale is a direct conclusion from the expansion to a quasi-continuous system.

To illustrate this scheme of information emergence, we can analyze the situation for pixel. Today's ubiquitous concept of a pixel is based on its technical use to characterize visual media technologies like scanners, displays and printers by their capability to represent information. In this context a pixel is defined as an elementary information, while the change is performed by the physical entity "optical contrast". This definition of a pixel addresses two key features: (1) It is defined as smallest addressable piece of information in a specific context of technology; (2) As additional requirement by the visual application a pixel has to be specified as small as it remains indistinguishable by the human eye. For the eye the single pixel does not exist, but the observer will be able to recognize structures of multiple pixels. And a wide variety of different structures with different functions may arise out of these individually invisible pixels, stepping into the next emergent level.

Under consideration of such a generalized emergent process for information (however it works in detail in each individual environment), we can additionally grasp a lemma.

- **Lemma:** Elementary information emerges in relation to a certain environment and scale. A further evolution to compound information may happen in that environment, but after an emergent step into a new environment, again elementary information may occur.

4. Conclusions

If accepting the definition of elementary information and the lemma of emergent information, then a lot of new questions arise. Here is not the place to discuss these questions. But two points may be emphasized: (1) The assumption of a one Bit Planck volume should be questioned. If information itself is independent from the physical environment, why the volume of a physical space should restrict it? (2) Among physicists the discussion about a discrete and a continuous reality is very intensive (good overview in [6]). The source of the contradictions might be the top-down approach of quantization. Trying to tell the story of physics bottom-up, based on the idea of an emergent information process, might solve some of the problems.

Conflicts of Interest: The author declares no conflict of interest.

References

1. Hooft, G. Nature's Book Keeping System. In *Space, Time and the Limits of Human Understanding*; Wuppuluri, S., Ghirardi, G., Eds.; Springer: Berlin, Germany, 2017; p. 130.
2. Susskind, L. The world as a hologram. *J. Math. Phys.* **1995**, *36*, 6377–6396.
3. Von Weizsäcker, C.F. *Aufbau der Physik*; Hanser: München, Germany, 1985. English version: *The Structure of Physics*; Hanser: Heidelberg, Germany, 2006.
4. Bateson, G. *Geist und Natur*; Suhrkamp: Frankfurt/M., Germany, 1984; p. 40. English version: *Mind and Nature*; Dutton Books: New York, NY, USA, 1979.
5. Hübler, A.C. The Dot, the Point, the Dot—the Intention. *FQXi Essay Contest* 2016. Available online: http://fqxi.org/community/forum/topic/2899 (accessed on 2 August 2017).
6. Lesne, A. The discrete versus continuous controversy in physics. *Math. Struct. Comput. Sci.* **2007**, *17*, 185–233.