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Philosophical Foundations for the Concept of Information: Selective and Structural Information

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Abstract. The most fundamental question in the philosophy of information "What is information?" has not received yet a definite answer free from commonly recognized deficiencies. In my earlier work I have proposed a definition of information as an identification of the variety. The definition is based on the concept of the one-many relation, a philosophical theme as old as philosophy itself. The rich tradition of the theme established through the centuries of philosophical discourse is in a clear contrast to the common sense concepts such as "uncertainty" usually utilized in attempts to set foundations for the concept of information.

An identification of the variety can have two basic forms of a selection of one out many in the variety, or of the structure uniting the variety (many) into one. The distinction of the forms of identification leads to the distinction between the selective and structural information. However, since every occurrence of one type of information is always accompanied by the other, selective and structural information can be considered just different manifestations of the uniform concept of information. The selective information can be easily identified with the concept of information in its usual understanding. The structural manifestation of information has been considered usually in the context of integration of information.

In the present paper the analysis of the concept of information based on the one-many relation is being carried out in the three perspectives. First, the philosophical aspects of information are considered. Then, the concept of information is being identified in a selection of very different domains. For instance, Hutcheson's concept of beauty dominating classical aesthetics since 18th century, understood as "unity in variety," provides an example of an idea very close to structural information. Integration of the neuronal activity in the brain considered as a basis for consciousness by Edelman and his collaborators can be also viewed as an example of structural information in a different domain. Finally, an attempt is being made to identify a mathematical formalism which reflects the distinction of the selective and structural information.

Key Words: Philosophy of Information, Definition of Information, Selective and Structural Information, One-Many Relation.

Introduction

In this article I am revisiting my earlier proposal of an answer to the question "What is information?" in the conceptual framework of the one-many relation [1]. The definition that I have proposed leads to the distinction of selective and structural manifestations of information. The former can be easily identified with the subject of typical study of information, although the definition based on the one-many relation gives selective information essentially different meaning detached from communication or philosophically questionable concepts such as "uncertainty." The latter, considered only sporadically in the literature of information science, but identifiable in several intellectual or practical disciplines, is of special interest for the foundations of information science due to its association with integration of information, and therefore with the study of consciousness.

In spite of the frequent occurrence of the word "information" in a large variety of contexts, there is no commonly accepted answer to the question about its meaning. Even worse, there is no agreement whether it is possible to provide a uniform answer independent from the context in which the word "information" is used. The views are scattered between the two extreme positions, between the belief that there are as many meanings of the word "information" as domains of its application, and the view that different contexts differentiate only manifestations of the uniform entity which can and should be clearly and properly defined. While I belong to supporters of the latter position, I cannot accept any of the numerous former attempts to define the meaning of this uniform concept of information. In particular, I cannot accept the two most popular formulations of the definition of information as a "resolution, reduction of uncertainty" [2] or as a "difference which makes a difference" [3], as their logical status and explanatory value are not much different from the expressions of desperation in dozens of other attempts to grasp the meaning of information such as "We conclude that we are not able to say confidently of anything that it could not be information" [4], or "Information is anything that we can count or use as information" [5].

I have provided several critical arguments against the earlier attempts to define information elsewhere [1,6], therefore in the present paper I will focus rather on the concepts and ideas which in my opinion can contribute to understanding information, than on what in the past obscured this concept. Here, I will mention only main sources of confusion identified in my earlier works. Knowing these sources may help to steer away from the obstacles in which so many earlier attempts have been trapped.

One of the most common errors in the attempts to grasp the meaning of information was an extrapolation of the conceptual and analytic framework of the study of communication (carried within the "conduit metaphor of information"[7]) in which information is a relative concept, to the study of information itself. Another, quite common error has been an assumption that simple, generic vocabulary is most suitable for the explanation of very general and therefore apparently very simple concepts. It is true that words such as "uncertainty" or "difference" are familiar to everyone, and can be understood easily. But their easy comprehension is based on the fact that we are using them frequently in a very limited context of our everyday experience. Once we try to apply these words in the contexts detached from our experience in which the word "information" is frequently used, the explanation involving these words becomes meaningless. Thus, the best source for powerful explanatory concepts is not in our daily life vocabulary, but in the conceptual frameworks which have extensive philosophical tradition.

An escape from the two sources of confusion does not guarantee success. There were some earlier attempts to put the concept of information into a philosophically sound frame. The etymology of the word "information" derived from mediaeval Latin "to shape or give a form," suggests the concept of form as a suitable point of departure for the study of information. This led Paul Young [8] to the identification of information with form: "[…] in each and every case what we know as information is the precise equivalent of what traditionally has been referred to as form." He is not entirely consistent in his approach, as on the same page he writes "[…] information must be viewed as a flow of mass-energy forms" and a few dozens pages later "It is clear, however, that information and form are not simply equivalent. While all information processes appear to be form activities, the reverse is not true." Neither of Young's adjustments of his identification of the concepts of information and form make it more convincing. If information and form are identical, why do we make the distinction by using different words? However, the observation made in his book that "[…] it will quickly become apparent that in all information processes in physical, chemical, and biological systems, the information stored, transmitted, or manipulated is identical with one or another of the above definitions of form – shape, configuration, pattern, arrangement, order, organization, or relations – so that whatever information is, it appears to be in all senses a form phenomenon," will be relevant for our considerations of the structural manifestation of information, as an example of clearly expressed need for the complementary to selective form of information.

At the moment, we may conclude that the use of the philosophically legitimate concept of form as just a substitute for information has not resolved the problem of what information is. Other attempts to refer to the concept of form have not been much more successful.

Since I could not find in the literature of the subject any definition of information which in my opinion meets the criteria of logical correctness and which includes all that I believe is information, while excluding all that is not, I have proposed to define information as the identification of a variety [1]. The identification is understood in terms of the one-many relation as a characteristic or complex of characteristics of the element of a variety (the "many") which select, distinguish one out of many, or alternatively, as an internal structure of the many which gives the variety its unity. This alternative produces apparent opposition of the two forms of information, selective and structural. The opposition is only apparent, as the two types are inseparable. The elements of the variety can have distinct internal or individual characteristics only if they have their own internal structures. The structure of the variety carrying "structural information" can always be considered one of a variety of potential structures out of which it is selected. Thus, the selective and structural forms of information are rather dual manifestations of the uniform concept of information derived from the dual relationship of one and many. The selective aspect of information is more salient when the identification of the one out of many is predominant through its own individual characteristics, while the structural aspect is salient when the identification is rather through the participation of the element in the structure of the variety. Both aspects can be present at the same time, as for example in the way of selecting "the first red ball on the left". When we refer to the color of the ball, we refer to the selective aspect, when we refer to the location in the variety of balls “the first on the left,” we use the structural aspect of information.

Thus, we can consider information only when there is some predefined variety (the “many”) and when with this many there is associated some unity (the “one”). The association of the one with the many is information. Sometimes there is no such association, and the quantitative characteristic of the information is zero. For instance if the variety consists of the six possible outcomes of casting an “honest” die, and the one is the actual outcome of the cast, there is no association of the one and the many. The measure of information in this case is zero. If the die is “loaded” so that in every cast only the outcome six appears, the association is strongest and the quantitative characteristic of information is maximal. With an appropriate choice of the measure we can for instance assign the value to this case $\log_2 6$. The die can be partially loaded, and the value of the measure would vary between the two extremes. This simple example is signalizing the difference between the usual quantitative characteristic of information in terms of entropy which corresponds to the concept of information derived from “uncertainty” or “surprise”, and more compatible with the one-many based approach to information, alternative measure [6]. However, as long as we are searching for the conceptual framework for information the discussion of its quantitative aspects is not necessary. I will return to the alternative measure of information in the last section of this article.

My choice of terminology “selective information” and “structural information” should not be taken as evidence for affinity to the former instances of their use in literature. The most deceiving could be association with the views of David M. Mackay who was using both the terms along with the third term “metrical information,” but whose understanding of information heavily dependent on the “conduit metaphor” was different [9]. For MacKay, information could be considered only in the context of “making representations,” and it “[…] may be defined in the most general sense as that which adds to a representation” [9]. In his description of the measures of information, the selective information content is “[a] measure of the unforeseeableness of a representation” [9], while the structural information content is “[t]he number of independently variable features or degrees of freedom of a representation” [9].

In his later works MacKay emphasized different criteria for the classification as selective and structural information: “In communication engineering the form of a received message can be determined in one of two ways: (1) by a process of construction, as when the form of a television picture is built out of light-spots; or (2) by a process of selection from a range of pre-constructed forms in obedience to a code signal which has no necessary isomorphism with the form selected but merely specifies its address, as in Morse code” [10]. MacKay’s terminology in the description of the division into selective and structural information, or even his examples of the two types may at the first sight seem similar to those used in my definition based on the one-many relation, but the similarity is only apparent. For instance, he is using the word “form” to describe both types of information, with the distinction that in the former case the form is constructed, in the latter is selected. But no matter how close are the similarities of the words, MacKay’s distinction can be only applied when information is understood as representation.

Actually, the distinction made by MacKay describes very accurately different division of great importance for information transmission, the division into analog and digital information transmission or representation which also had quite turbulent history.

Almost 50 years ago John von Neumann was clarifying at that time new division of computing machines into analog and digital type: “This subdivision arises according to the way in which the numbers, on which the machine operates, are represented. […] In an analog machine each number is represented by a suitable physical quantity, whose value, measured in some pre-assigned units, is equal to the number in question. […] In a decimal, digital machine each number is represented […] as a sequence of decimal digits” [11]. With the computer technology becoming omnipresent in the domains where association with numbers would be incomprehensible, the distinction of analog and digital computing machines gradually has been transferred into a more general distinction of analog/digital information transmission, recording, or processing. However, typical explanation of the distinction is based on the confusing, accidental features of these processes. Thus, in usual explanation analog is a synonym of continuous, digital of discrete. MacKay’s description of the division, although introduced with different intention, much more accurately grasps the characteristics of the two types. In the analog transmission of information, the message at the destination is constructed by the signal, in the digital transmission, it is selected by the signal from the pre-constructed units.

One-Many Relation

Is the one-many relation a legitimate philosophical framework for information? Yes, if we assume that legitimacy is derived from the well formulated theme of philosophical discourse with, if only possible, an extensive tradition of study. From that point of view the one-many relation is exceptionally well suited. It is probably the most universal (in the sense of the cross-cultural spread) and the oldest theme of philosophical considerations.

There is no space in this article to provide an actual review of the subject which due to the rich tradition would take multiple volumes. I will provide just a few examples of the philosophical systems of great importance for the humanity in which the one-many relation has a prominent position.

To start from the historically earliest attempts to rationalize human experience, in the Vedantic tradition of Indian philosophy, the issue of one-many relation has its most clear expression in the discussion of the unity of *brahman* and *atman*. Both concepts are the results of the search for the unity in the varieties of phenomenological (external) and psychological (internal) experiences of human intellect. The orthodox Vedantic position makes the ultimate step towards absolute unity of the apparent variety in form of identity of *brahman* and *atman*. The discussion has continued leading to the deviations from orthodoxy to some forms of duality. The issue of the relationship between phenomenological multiplicity of the world and unity of the intellect involved the study of the concept of knowledge. It is interesting that knowledge has been frequently invoked in the context of the power uniting the many into one.

In religious systems which often in their origins openly disregarded philosophy, but which came out to existence in opposition to the Vedantic religious tradition, the discussion of one-many relation has been induced by its importance in Vedas. For instance, the main principle of Buddhism from the very beginning of its existence has been that everything composite (and therefore of the status of the many) must be transient. This principle must have been of special importance for the Buddha Sakyamuni, as his last words before entering nirvana, which could be interpreted as the oldest metaphoric expression of the Second Law of Thermodynamics, were “Everything composite must pass away.” The unity as opposed to multiplicity has become the goal for attaining real (although in this case not necessarily rational) knowledge.

In Chinese philosophical tradition there was no place for psychological analysis or a theory of intellectual powers of the human mind. The philosophical discourse has been typically centered on the relationship of the individual human being (one) and the society (many) as, for example, in Confucianism. But even systems which disregarded social issues, such as Taoism, addressed the topic of one-many relationship in terms of either yin-yang duality or the five agents (*wu-hsing*.) In Chinese tradition the most characteristic form of resolution for the one-many opposition has been harmony understood as a perfect form of the structure, either for all reality, or for human society.

In Greek tradition, pre-Socratic philosophy has been preoccupied with overcoming variety symbolizing ignorance in the search of unity associated with wisdom. In a moderate form, the resolution has been achieved through the reduction of the myriad of phenomenological experiences to the few basic elements from which by mixing ingredients in different proportions the objects of experience could be reconstructed. In the extreme approach of Parmenides, popularized by his disciple Zeno of Elei, the variety has been given the status of illusion. True reality, or rather “being,” was identified with absolute unity.

For Plato, the one-many relationship was important enough to be a subject of a separate dialog “Philebus.” It is interesting that unlike in other dialogs in which Socrates was one of personae, here Parmenides remains unchallenged. For our considerations the following words of Socrates in this dialog are of special interest: “We say that the one and many become identified by thought, and that now, as in time past, they run about together, in and out of every word which is uttered, and that this union of them will never cease, and is not now beginning, but is, as I believe, an everlasting quality of thought itself, which never grows old.“ [12] The Eleatic tradition, and the explicit presence of the one-many topic can be found also in another of Plato’s dialogs “Parmenides” in which Socrates talks to Parmenides about his views and views of Zeno: “For you, in your poems, say the all is one, and of this you adduce excellent proofs; and he on the other hand days that there is no many; and on behalf of this he offers overwhelming evidence. You affirm unity, he denies plurality.” [13]

The Classical Period of Greek philosophy has brought so many contributions to the discussion of the one-many relation, that going beyond that point in our short excursion in the search for examples ends here. Concluding this section, one more voice in the discussion should not be missed. Aristotle, whose influence on mediaeval philosophy was immense, can be considered ultimately responsible for the word “information.” In his twofold characteristic of the substance by the matter and form, it is the form which is responsible for the identity of the object. Although form itself cannot exist separately without being carried by the indefinite, unknowable matter, its priority in acquiring knowledge is clear. To know about some object, its form has to be transmitted giving form to our thought, and we are becoming “informed.” Here is the clear association between knowledge and information which remained in European philosophy for centuries until Shannon in his famous paper declared the divorce of information from meaning, and therefore from knowledge [14].

The one-many relation continues to attract attention of philosophers, although with increasing specialization of the philosophical discourse its discussion is usually in more specific context [15].

Structural Information

Of the two manifestations of information, the structural is of most interest, as it was clearly neglected in the literature of information science. I have mentioned above Young's approach to define information simply as an equivalent of form. Although this view is very difficult to accept, it exemplifies the existent recognition of the importance of the structural aspect of information. The fact that Young and others who were referring to form in their study of information considered their approach as opposite to the orthodox approach or in contradiction to orthodoxy shows that the existing study of information has been judged inadequate to grasp the structural aspects. Rene Thom in his opus magnum "Morphogenesis" writes: "However, even when the present use of 'information' is incorrect and unjustifiable, the word does express a useful and legitimate concept. Here we set ourselves the problem of giving this word a scientific content and releasing it from the stochastic prison in which it is now held." [16]

When the definition of information is based on the one-many relation, there is no need to oppose selective and structural manifestations of the concept. Thus, Thom's view that "[…] any geometric form whatsoever can be the carrier of information, and in the set of geometric forms carrying information of the same type the topological complexity of the form is the quantitative scalar measure of information" [16] can, at least in principle, be incorporated into the same approach to understanding information.

The structural aspects of information have remained on the margin of information studies. However, indirect references to structural information understood in terms of the one-many relation can be found in several disciplines, in particular in the context of human perception or cognition. In most of cases the references are to some process of integration of a variety to unity.

The striking example of such an indirect reference can be found in European aesthetics, especially in the synthetic, concise statement by Francis Hutcheson in his "Enquiry into the Original of Our Ideas of Beauty and Virtue" published in 1725: "Beauty is in the unity of the variety" [17, 18]. Later several different criteria of beauty have been introduced into aesthetics and the art criticism shifted its focus from formal aspects towards expressiveness. However, if any of aesthetical principles could serve as a single sentence characteristic of beauty, it would be probably Hutcheson's "unity of the variety," quoted equally frequently today as in the past.

Looking at the other end of human intellectual activity, at the development of set theory on which all modern mathematics is standing, we can find today frequently forgotten discussion of philosophical status of the concept of a set. Not only "lay person", but an average mathematician who uses set theory in his or her everyday practice, but whose expertise is not related to foundations or logic, often cannot even explain differences between the distinct axiomatics of set theory. Typical belief is that with establishing axiomatic set theory (who cares with what axioms) the problem disappeared. It is no wonder that today the question about in what sense we can say that a set exists, in particular infinite set, is rarely asked. But in the end of 19^{th} and the beginning of 20^{th} century it was a central theme of philosophical discussion. The discussion began with the view expressed by George Cantor, whose work set the firm foundation for set theory as a separate mathematical theory, on understanding a set as "[…] any multiplicity which can be thought as one, i.e. any aggregate of determinate elements which can be united into a whole by some law" [19]. Strong criticism from the side of mathematicians such as Leopold Kronecker, who believed that for the existence of a set it is necessary to establish a definite construction in a finite number of steps which incorporates elements one by one into a whole, brought the issue of how to understand the unification of the variety of elements into unity into the attention of mathematicians and philosophers alike. Edmund Husserl participated in the discussion writing from the philosophical perspective: "Any talk of sets or multiplicities necessarily involves the combination of the individual elements into a whole, a unity containing the individual objects as parts. And though the combination involved may be very loose, there is a particular sort of unification there which would also have to have been noticed as such since the concept of set could never have arisen otherwise.[…] if our view is correct, the concept of set arises through reflection on the particular […] way in which the contents are unified together […] in a way analogous to the manner in which the concept of any other kind of whole arises through reflection upon the mode of combination peculiar to it." [20]

According to historians studying his intellectual biography Husserl has become convinced that the process of integration is of psychological character: "The concept of collection in Brentano's sense, Husserl explained, was to arise through reflection on the concept of collecting. Sets, he thus reasoned, arose out of collective combination, in being conceived as one. This combining process involved when objects are brought together to make a whole only consists in that one thinks of them 'together' and was obviously not grounded in the content of the disparate items collected into the set. It could not be physical, so it must be psychological, a unique kind of mental act connecting the contents of a whole." [21]

The issue became more puzzling when Bertrand Russell in his famous paradox of a collection of sets which are not elements of themselves showed that the assumption that every definable collection is a set must be false. If the process of integration is purely psychological, why can some collections be integrated into sets, but not others?

An axiomatic approach to set theory removed the problem of paradoxes, but the issue of justification for the infinite selection of elements for sets (Axiom of Choice) has remained a source of discussions until long period of everyday mathematical practice has made its paradoxal consequences (e.g. Banach-Tarski Paradox) more acceptable than the poverty of mathematical toolkit. Thus, the problem of integration of the variety of elements into the unity of a set has become rather a subject of study for historians of the philosophy of mathematics, being eliminated from the agenda of philosophical discussions not through a decisive resolution, but because of the decline in interest of both the parties, mathematicians and philosophers. The former group lost interest because of the (false) assumption that once some axiomatic set theory has been introduced there is no reason to inquire into the status of sets as it is irrelevant for the mathematical practice, the latter has become too much intimidated by the formalisms of axiomatic approach to pay attention to further developments in set theory.

Dead or alive as a philosophical problem, the unification of a variety of elements into a set, as well as aesthetical judgment of beauty as the unity in the variety are good examples of what can be interpreted as human mind's processing of the structural aspects of information. It is psychology, or more specifically study of consciousness where these aspects appear in most salient form. At the same time when the issue of integration of elements into sets was so vigorously discussed, William James in his analysis of consciousness which he understood as process or stream established its fundamental property of high level of unification or integration [22]. We are not able to break down a conscious scene into more elementary fragments existing independently. It has very clear "all or nothing" character.

The recognition of this fundamental property of consciousness had a great impact on the further development of psychology, leading to the rise and fall of Gestalt Psychology and continuing discussions of the precedence of "the forest or of the trees" [23]. From our point of view the unresolved yet problem of the precedence of the global or local features in visual perception [24] is of secondary interest. Much more interesting would have been the decisive resolution of the problem whether the lateralization of the brain is followed by the distinction of the cognitive styles into the holistic (for the right hemisphere) and analytic (for the left). But even this problem is at this point marginal.

The actual primary issue of the unity of consciousness has not been until recently even clearly formulated as a research problem. Probably the main reason for such an oversight can be blamed on the "computer metaphor" of the brain dominating study of consciousness. With the focus on the question whether the computer can become conscious, the functions of the brain frequently are analyzed in comparison to those of computers. The functions which does not allow for comparison are simply neglected. The fundamental property of the unity of consciousness, recognized more than a century ago by James, is today forgotten for the simple reason that there are no available conceptual tools to formulate objections to the deficiency of artificial intelligence. Does computer lack unity of consciousness? What does it mean? If it is conscious, then unity is unnecessary. If not, then what is not integrated? Thus, it is not so much a problem of unity or integration of consciousness, for which it is a sine qua non condition. What then is united or integrated? My answer is that consciousness requires an ability to integrate information, or in other words, ability to process structural information. As long as we consider only selective aspects of information, the functioning of the brain does not differ essentially from that of computer. However, because computers have been designed to process exclusively selective information, lack of its ability to integrate information which makes it incomparable with the brain has never been recognized. In the tasks which require processing structural information the computer is supported by the human agent (programmer) who using the duality of selective and structural information translates structural information into selective one. Instead of integration of the local features of the face into a whole (face itself), the programmer teaches computer to compare the particular collection of features with all other combinations of features to select the right match. Because of the dominating "computer metaphor," it is usually assumed that the same process takes place in the brain.

But what are the arguments against such a "computer metaphor" of cognition? The detailed discussion of the arguments is beyond the scope of the present article. But not to leave the question completely unanswered I will give an example of the answer. If the recognition of patterns is based on the computer style matching selecting the right combination out of all possible, why do we have so limited capacity to recognize only configuration of up to about seven elements in the pattern? Why do we need "chunking" of the information? What actually is chunking? With our memory of so huge volume, the limitation to seven elements seems difficult to explain or to justify.

The issue of integration of information has been recently recognized in the works of Gerald M. Edelman, Giulio Tononi, and their collaborators. They started from the fundamental principle of the unity of consciousness which Edelman assigned one of two most important features: "One extraordinary phenomenal feature of conscious experience is that usually it is all of a piece – it is unitary […] One way of describing this is to say that while conscious experience is highly integrated, it is at the same time highly differentiated" [25]. The direction of their extensive research program has an objective to find the mechanism in the brain which can be responsible for such a unity. They identified this unity with the integration of information in the form of correlations of firings of neurons responsible for conscious experience grouped in clusters. To measure this functional clustering they applied the methods of information theory: "Consider a jth subset of k elements (X^k_j) taken from an isolated neural system X, and its complement ($X- X^k_j$). Interactions between the subset and the rest of the system introduce statistical dependence between the two. This is measured most generally by their mutual information $MI(X^k_j ; X- X^k_j) = H(X^k_j) + H(X- X^k_j) – H(X)$, which captures the extent to which the entropy of X^k_j is accounted for by the entropy of $X- X^k_j$ and vice versa. The statistical dependence within a subset can be measured by a generalization of mutual information, which is called integration and is given by $I (X^k_j) = \sum H(x_i) – H(X^k_j)$, where $H(x_i)$ is the entropy of each element x_i considered independently. We then define the functional cluster index $CI(X^k_j) = I (X^k_j)/ MI(X^k_j ; X- X^k_j)$ as a ratio of the statistical dependence within the subset and the statistical dependence between that subset and the rest of the system. Based on this definition, a subset of neural elements that has a CI value muvh higher than 1 and does not itself contain any smaller subset with a higher CI value constitutes a functional cluster. This is a single, integrated neural process that cannot be decomposed into independent or nearly independent components." [26]

The works of Edelman, Tononi and their collaborators constitute the first research program systematically investigating the integrative functions of the brain. Their approach can be questioned from the formal point of view (in what sense can we apply the methods of the analysis of random variables to the sets of occurrences of neural firings?) However, the idea underlying the program is quite clear.

Research on functional clustering of neurons can be associated with structural aspects of information due to its objective of detecting the mechanisms of information integration. Certainly, the fact that conscious experience is correlated with the structural pattern of neuron firings does not explain yet the mechanism of integration. Moreover, the use of the methods derived from the analysis of selective information may obscure such a mechanism. However, the recognition of the role of integrating mechanisms makes this research very promising.

Alternative Measure of Information as a Framework for Structural Information

The use of entropy as measure of information had several consequences for the conceptual analysis of this concept. While in the mathematical analysis of communication or information transmission entropy meets all expectations, its use outside of the "conduit metaphor" leads to paradoxes. In an earlier work I have proposed an alternative measure of information which is more appropriate in the context outside of the "conduit metaphor" [6]. The measure in the finite, discrete case has the form

$$Inf(n,p) = \sum_{i=1}^{n} p_i \log_2(np_i).$$

Its relationship with entropy is very simple. It can be easily derived from entropy in the reference to maximal entropy $Inf(p) = H_{max} - H(p)$. However, it is completely independent from entropy, and can be considered as a primary measure from which entropy can be derived: $H(p) = Inf(n)_{max} - Inf(n,p)$.

The alternative measure has some formal properties superior to entropy, and is more suitable for measuring information in an absolute way (as opposite to relative character of entropy).

For our study of structural information one of properties of the alternative measure seems especially important [Thm.2 in 6]:

Let S be a disjoint union of the family of probability spaces $\{A_i: i = 1,\dots,m; A_i \cap A_k = \varnothing$, if $i \neq k\}$, each with probability distribution $p^{(i)}$. Let n indicates the number of elements in S, and n_i of elements in A_i. We can define a probability distribution p(x) on S the following way.

For every x in S, $p(x) = a_i p^{(i)}(x)$, where i is selected by the fact that x belongs to A_i and $a_1+\dots+a_m = 1$. Of course, $a_i = p(A_i)$ and we can write $p(x) = p(A_i) p^{(i)}(x)$.

Then,

$$Inf(n,p) = \sum_{i=1}^{m} p(A_i)Inf(n_i,p^{(i)}) + \sum_{i=1}^{m} p(A_i) \log_2[(n/n_i) p(A_i)].$$

If all sets A_i have the same size k, then the formula for Inf(n,p) becomes much simpler:

$$Inf(n,p) = \sum_{i=1}^{m} p(A_i)Inf(k,p^{(i)}) + \sum_{i=1}^{m} p(A_i) \log_2[m\, p(A_i)].$$

The property of the alternative measure can be interpreted in this case as an assertion that the total information amount Inf(n,p) can be separated into information identifying the element of the partition A_i, plus the average information identifying an element within subsets of the partition.

The property turns out to be crucial in the axiomatic formulation of the alternative measure. By analogy to Fadeev's axioms for entropy, the property above together with the assumption of continuity and appropriate calibration (information is zero when all outcomes are equiprobable) characterizes the alternative measure uniquely.

Now, the distinction of the two major terms in the formula for Inf(n,p) can be associated with the distinction of the two manifestations of information, selective and structural.

For instance, in the analysis of neuronal firings the choice of the cluster index CI as ratio of the integration I to the mutual information MI is rather ad hoc characteristic of the role of clusters. Moreover, the division into clusters is made one by one. It is possible to consider such a quantitative characteristic derived from the formula above as a ratio of the second major term to the total of information. Not only is clustering considered globally in this case, but the quantitative characteristic has a simple, intuitive interpretation as a fraction of information which accounts for clusters.

The same approach can be used in the analysis of symmetry or other collective properties of the compound systems.

Conclusion

The definition of information based on the one-many relation not only gives us a consistent approach to understanding information, but also opens a venue to an incorporation of the two different aspects of information, selective and structural. The latter seems particularly interesting in the context of the study of consciousness. Brain's ability to integrate information can be associated with processing structural information. This ability seems to constitute the fundamental difference between the natural and artificial intelligence, at least when the current architecture of computers is considered.

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