Towards a Unified Concept of Information: Presentation of a New Approach

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Abstract

The present publication is a contribution to the development of a unified concept of information. The paper begins with a short survey of the history of the concept of information. Then a list of open questions, something like a specification for the definition of the concept of information, will be given, followed by a summary of a new approach developed in [Flückiger 1995], enabling us to provide an answer to each of these questions. This approach takes its cue from modern neurobiology according to which all things perceived or thought by an individual are to be understood as constructed by the brains of these individuals. Using a thought experiment, it is shown how the gap between the seemingly contradictory statements of two very different information theories can be narrowed until they are finally reconciled on the basis of the new approach presented here.

Keywords

Information, semiotics, neurobiology, information carrier, measure of the information content, entropy.

Introduction

About 50 years ago, the concept of information received its technico-scientific definition in the treatises of Leo Szilard, Norbert Wiener, Dennis Gabor and particularly Claude E. Shannon, thus providing the theoretical basis for the construction of computers and for information science as a new discipline. The subsequent years were characterised by the transformation of various disciplines by the new concept of information according to their specific needs. Moreover, some efforts were made to draw up a universal definition in which the different discipline-specific aspects would be synthesised. Apart from a variety of verbal definitions and vague attempts at the development of new information theories, these efforts yielded little that was new and did not lead to a universally recognised definition.

The last few years have seen the publication of such books as Tom Stonier's "Information and the Internal Structure of the Universe", Keith J. Devlin's "Logic and Information" and several monographs and essays relevant to the subject and represent a turning point in the development of a unified concept of information. They stand for the serious attempt to define the concept of

information in a way that cuts across the borderlines of individual disciplines. Thus, issues such as “The Quest for a Unified Theory of Information”, the subject of the present conference, are foregrounded again. But the fact that such issues are still raised shows that recent attempts to unify the concept of information need to be examined very closely.

Requirements for a unified information theory

It is clear that a unified information theory has to be able to contain all the statements of existing information theories. Most of the surprisingly extensive body of work on this subject can be roughly divided into two seemingly irreconcilable types of information theories, the functional-cybernetic and the structural-attributive:

1. Functional-cybernetic information theories: In this category, information is understood as functionality, functional meaning or as a feature of organised or self-organising systems. Thus, the functional-cybernetic information theories explain the dynamic aspect of information. They have their roots in Claude E. Shannon's work "The Mathematical Theory of Communication." The model on which they base themselves is Shannon's general communication system (cf. [Shannon 1969, p. 33]), a schematic representation of the transmission of a message from an information source to its destination. Following Shannon, the "amount of information" or information content of functional-cybernetic information elements can be given in the form of a rarity value (probability): The less frequently an information element appears in a message, the higher is its information content. Typical representatives of this point of view are Johannes Peters, Fred I. Dretske and Werner Ebeling.
2. Structural-attributive information theories: In these theories, information is understood as structure, diversity, order, etc. They evolved from thought experiments conducted by Leo Szilard, Norbert Wiener and L. Brillouin, and were given their first definite form in Donald M. MacKay's "Information, Mechanism and Meaning." The model underlying his book says that each animate or inanimate individual has an inner structure, the diversity of which constitutes the individual's information content. Apart from MacKay, typical representatives of this approach are Doede Nauta jr., Keith J. Devlin and Tom Stonier.

The two types of information theories explain different aspects of information and both types have remained useful to this day. The functional-cybernetic approach, for instance, contributed considerably to the information-theoretical groundwork for the construction of computers and certain branches of software development. It remains important, being applied to the current theory of neuronal networks and self-organisation, and is used to explain information-theoretical aspects of neurobiology. Thanks to its close relationship to semiotics (cf. [Nauta 1970]), the structural-attributive approach was quickly taken up in the humanities, where it contributed to the further development of these disciplines. And in the technical sciences, the concepts of data modelling and object orientation, as well as the information-theoretical aspects of inheritance can be derived from structural-attributive statements.

Many issues remain objects of controversy between the different information theories, as the following survey shows:

- Does information, as the philosopher Hans Titze thinks, take place exclusively at the mental level, or is information situated in the world as information about structured reality, as postulated by John Barwise and Jon Perry?
- Can only true statements, that is, statements anchored in reality, be informative, as Fred I. Dretske suggests, or is truth merely an accidental feature of information, as Shannon claims?

- Is Shannon's entropy as the measure of the information content which can be transmitted in a given code, MacKay's descriptive information content, which measures the structural cardinality of the information element, or Stonier's approach using negative entropy the right method for measuring information?

Finally, let me mention here that certain fundamental problems are not treated by the different approaches at all or only in passing. For example, the existence of so-called "unaddressed" information, that is, information which an individual observes by accident in his or her environment[1], is accepted by some theories as an information phenomenon, but explained by none of them.

Presentation of a New Approach

[Flückiger 1995] presents a new unified concept of information, which I shall summarise and illustrate here. Issues that have remained controversial, such as the key questions listed in the preceding section, are given a consistent explanation in this new interdisciplinary information theory. It is based on the following ideas:

The different requirements for an information carrier can only be contained by the very general concept of the thing as a unit in perceptual and conceptual reality, and not, as often suggested, by the concept of the sign as proposed by the semiotician Charles W. Morris. This entails the development of a new understanding of the semiotic terms syntax, semantics and pragmatics. These no longer stand for fundamentally different concepts of relations between the things, but they merely designate the situation-specific characteristics of any kind of directed relation. In other words, I reject the autonomy of syntactical, semantic and pragmatic relations as proposed in semiotics and replace it by the view that each directed relation between two things can be interpreted syntactically, semantically and/or pragmatically depending on the thing that is analysed and its situation.

In [Flückiger 1995], this concept is first of all situated within the humanities with reference to Willard van Orman Quine's theoretical reflections on semantics and Jon Barwise and John Perry's theory of situation semantics. The subsequent presentation of various theories about learning and knowledge, in particular the presentation of insights into learning and knowledge gained in modern neurobiology, will illustrate that my thesis is compatible with modern epistemological and scientific evidence. What is more, evidence provided by neurobiology that everything that can be perceived or thought must be understood as a thinking subject's mental construction (cf. [Zeki 1992] and [Singer et al. 1990]) is an important pillar of the information theory proposed here. Thanks to this insight, similarities between the neuronal structure of the brain, the structure of knowledge and the structure of perceptual reality emerge clearly.

This provides the basis for a new, formalised information theory, with a conclusion in the form of a 'Law of Information Theory' which is very similar to the Second Law of Thermodynamics.

In the present paper, one of these ideas — namely the neurobiological basis of this new approach — will be tested in a thought experiment, designed to show whether it is capable of reconciling two very different theories about information, namely Tom Stonier's “Information and the Internal Structure of the Universe” and Claude E. Shannon's “The Mathematical Theory of Communication.” Modern neurobiology postulates that all things ever perceived or thought

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[1] An example of "unaddressed" information: A man is walking in a street on a very windy day. Chance would have it that a tile falls from a roof directly towards the man. If the man notices the tile, he will be informed without warning; not by binary selection from alternatives, neither by a sign, but merely by the situation of the tile falling towards him.

by individuals must be understood as brain constructs of these individuals and that these things can therefore also be the object of information, which we will for the moment understand intuitively. Whatever we see (the page just read), recognise (the contents of this page), experience (the behaviour pattern of the lecturer) and whatever thoughts are going through our minds, these are all things that only come into being by a process in our brains. Simply put, these things obey the following rules:

1) The thing is self-contained and can be clearly delimited from its surroundings.

2) The thing is associated with the individuals that construct it.
   This has the following consequences:
   a) The thing is subject to a time limit, with a maximum duration given by the individual's life span.
   b) The thing is a posteriori. Nevertheless, it always relates to a probable, a priori entity.

3) A thing may consist of other things and may itself be part of a more comprehensive thing.

4) The thing is surrounded by a closure of directed relations which link the thing to other things; however, the following should be noted:
   a) The direction of a relation is not to be understood as the direction in which a point can be reached, but is simply designed to distinguish between the "semantic" relations, pointing away from the thing and the "syntactic" relations pointing towards the thing.
   b) Any relation can have the function of a thing (with the corresponding structure) if it is perceptible or intelligible.

In the concept of information proposed here, things are thought as information carriers and the relations between these things as information elements. If a thing is related to other things, forming a coherent structure, this is called an information structure. According to Søren Brier, this lays the foundation for a so-called autopoietic concept of information.

This is sufficient to define the framework of a unified information theory. The structure of the thing as sketched above can map perceptual objects as well as recognisable events, with every conceivable figment of the imagination into the bargain.

The structural-attributive aspect is covered by rules 1, 3 and 4. Information as an organised structure, as it is proposed by Stonier, can in this sense be understood as a thing containing further things as its structural components. A structure may be enlarged by the integration of further things through an information process, automatically increasing (according to Stonier) the information content of the structure. Thus, for Stonier it is clear that the measure of information as an organised structure must be a negative entropy, because currently the (physical) entropy of a system is interpreted as a measure of the disorder of this system. The fact that Shannon proposes a positive entropy as the information content is for Stonier a reason for rejecting Shannon's communication theory as a basis for an information theory.

Now, the neurobiological view leads us to discuss rule 2, which complements rules 1, 3 and 4. According to this rule, a thing is always a thing for an individual whose brain has constructed this thing on the basis of its perceptions or its mental processes. — To illustrate this, let us look at the desk at which I am seated. My perceptions may lead me to say that it is made of wood, that its colour is brown and that it contains a set of three drawers. Anyone seeing this desk will very probably be able to agree to these statements. Nevertheless, the way in which my vis-à-vis perceives this desk will always remain a mystery to me. When seeing the brown colour, does he have the same sensations as I or does he on the contrary experience this colour as I would something coloured blue? I will never be able to answer such questions with certainty. I only know that my vis-à-vis gives the same names to the same objects and the same features as I.

The impression the desk creates will always remain his own, private perceptual experience, of which no other individual will ever have a glimpse.

Consequently, drawing on the neurobiological hypothesis above, we can construct a unified information theory in which information is considered as a thing and thus as an individual's private phenomenon. Information in Stonier's sense is therefore only an organised structure insofar as the individual in question recognises it as such. Thus, a text written in Finnish conveys much less information to me than to an individual who knows the Finnish language. And if we take our thought experiment to its logical conclusion, the information process, which according to Stonier leads to the enlargement of an existing organised structure, is also to be understood as an individual's private process. In other words: An information process supplements an individual's mental structures with new elements. Whether extra-mental structures are also formed and informed cannot be decided by us as individuals, if we accept the neurobiological hypothesis, since the existence of extra-mental phenomena may seem plausible to us, but cannot be proven.

For the time being, we can draw an interesting conclusion from this thought experiment: After such an information process has taken place, an individual will have more possibilities of informing her or his surroundings than before because the structural content of her or his mind has been increased. Thus we are faced with a constellation that is very similar to that in Shannon's communication model: The individual as information source can transmit all the more messages to his destination, the more structural elements for the production of such messages he has at his disposal. Shannon would give the amount of information of an information source as a positive entropy value. The fact that the entropy value increases in line with the structural content of the information source fits quite well with the results of our thought experiment.

This leaves us with the paradox that the same state of affairs which is measured by Stonier with a negative entropy is now, if we follow rule 2 and Shannon's communication theory, indicated by a positive entropy value. We are proposing measuring the content of an organised structure as a positive entropy, the value which is generally taken to represent a measure of the disorder of a system. This apparent contradiction is to be addressed next.

First of all, we have to ask whether entropy, according to many authors the most mysterious concept of modern physics, can really in all its applications be interpreted as the measure of the disorder of a system. In terms of our thought experiment, this question clearly has to be answered in the negative. Entropy would have to be interpreted not as the measure of the disorder of a system, but as an individual's capacity to interact with its surroundings. The greater its capacity to interact, the greater its entropy.

On closer examination we see that this interpretation of entropy can even be applied to physical problems. Let us, for instance, consider an ideal gas in a closely sealed container with an invariable volume. If this gas is heated, its entropy will of course increase. The traditional view has it that the concomitant increase in the disorder of the system manifests itself in the greater confusion created by the acceleration of the gas particles in the container. Alternatively, however, we could say that the capacity of individual particles to interact with the walls of the container and with other particles is increased by the higher particle speed. It seems that a generally valid interpretation of the concept of entropy has not been found yet and that earlier interpretations must not be extended to new applications without hesitation.

Nevertheless we are led to conclude that the concept of entropy proposed here agrees well with the second law of thermodynamics. Moreover, the formal part of [Flückiger 1995] shows in the definition of Theorem 3, entitled 'Law of Information Theory,' a possibility of deriving a

proposition from the information theoretical concept of entropy that is closely related to the second law of thermodynamics. It reveals affinities between thermodynamic processes and information processes.

Results

The thought experiment rehearsed in the preceding section has shown how a concept of information based on neurobiological findings can reconcile two seemingly very different information theories. The two theories were certainly not chosen at random, but it has been shown in [Flückiger 1995] that other traditional information theories can be integrated by this approach as well. Moreover, the new theory has other advantages. For example, the three questions posed above, which are answered contradictorily by different information theories, can be given consistent answers:

- The assertions made above, based on rule 2, lead us to conclude that information of whatever kind must be interpreted as a mental phenomenon. This has some interesting consequences: As a brain construct, language, which according to Barwise and Perry is only the carrier of information, has the same structure as the things of the external world and can thus be integrated in the new information theory in the same way. This applies equally to verbal utterances in the sense of organised sequences of well-defined words and to their content, which usually refers to other cognitive products of the brain that formulates them. These cognitive products are either representations of perceived reality or pure fictions fabricated by the individual brain. Among the latter are theoretical conclusions that are based on scientific findings as well as completely imaginary or deliberately false information.
- Because information as an individual's brain construct need not be anchored in reality, truth, however desirable it may be, must be considered as an accidental feature of information. This accommodates truthful information as well as conscious and unconscious misinformation in the same theory, which is welcome because it makes this information theory more comprehensive. Thus the statement '1+1=3' may contain information in different ways: To those who have not yet been introduced to the functioning of the '+' operator this statement will contain a first definition on the way to a full understanding of the operation of addition. Those who have already been introduced to this concept, on the other hand, will conclude that it is false and that the utterer either has no knowledge of the correct result or deliberately tries to deceive the destination.
- As a measure of the information content, Shannon's conception of statistical entropy is vastly to be preferred, because, first, it is an adequate representation of the observed data and, secondly, has proved superior in practice. Moreover it is the author's contention that information theory can be more easily integrated into the natural sciences with a generalised concept of entropy than with other conceptions (cf. [Flückiger 1995] chapter 4.5).

Even so-called unaddressed information can be explained with the new approach. According to rule 2, information is only unaddressed as long as it has not been recognised as such by a particular individual. Once it has been recognised, the individual awaiting the information in question becomes its addressee. This creates a normal information situation, which need not be treated separately.

Finally, an important advantage of the unified concept of information presented here should also be mentioned: The fact that, according to rule 2, the thing, and thus information, is always associated with the individual constructing the information means that the pragmatic component of information, which was often neglected in earlier theories, becomes an integral part of any piece of information and any information process.

Final remarks

In conclusion, I should like to add two remarks to relate this paper to other lectures at FIS 96:

- The present approach was misunderstood by several participants as being a contribution to an obsolete so-called syntactic information theory, probably because it proposes Shannon's concept of entropy as a measure for information. However, it is not the author's aim to revive Shannon's theory of communication, but to apply Shannon's conception of a measure for information to the information theory presented here. I want to present a theory, in which the semantic and the pragmatic aspects of information are considered as central (cf. [Flückiger 1995] chapter 3).
- The leading idea of our conference, Koichiro Matsuno's statement according to which a principle of information science is - unlike in physics - „actio non est reactio", whereby the difference between „actio" and „reactio" represents a measure of information, is to be concretised in the present article. An information process („actio"), which is to be understood as an individual's private process, doesn't primarily cause an adequate reaction, but leads to the enlargement of the individual's brain structure („non est reactio"). As an effect thereof we diagnose an augmentation of the individual's capacity to interact with its surroundings. From a phenomenological viewpoint it seems evident that this rather „mysterious" result may be quantified by the also „mysterious" concept of entropy.

With these statements I would like to conclude my all in all positive answer to the topic of our conference: „The Quest for a Unified Theory of Information".

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