AXIOLOGICAL PRINCIPLES OF THE GENERAL THEORY OF INFORMATION

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Abstract. The main goal of the general theory of information is the explication of an adequate definition of information. This theory is built as a system of two classes of principles (ontological and sociological) and their consequences. In addition, this paper introduces six axiological principles, which explain how to measure and evaluate information and information processes. These principles systematize also different approaches relative to the construction of information measures. As a consequence, the dual nature of the information (subjective and objective) is explained as a mixed systemic concept.

1. INTRODUCTION

In order to create a framework for the study of the information's theory[1], it is mandatory to provide the answer to two main problems related to it. The first one is to define what the information is and to find which its basic properties are. The second problem is how to measure and evaluate the information. From the beginning of the development of the information's theory, it was more known how to measure it than what exactly information is. Hartley and Shannon revealed effective formulas for measuring the quantity of information. However, without understanding the phenomenon of information, these formulas bring misleading results when applied to irrelevant domains. Meantime, a variety of definitions of information have been introduced. Being mostly vague and limited, these definitions have brought confusion into the information studies ([1], [2]).

The existing confusion with the term information is increased when researchers call in this way a measure of information or even a value of such a measure. For example, many call by the name "information" Shannon's quantity of information [3] $H(p) = -\sum_{i=1}^{N} p_i \log p_i$ or Renyi's measure of information [4] $H_\alpha^R(p) = (1-\alpha)^{-1} \log \sum_k p_k^\alpha$, both expressed by entropies as functions of the probability of events occurrence. At the same time, some researchers (for example, Kolmogorov [5] never did this). That is why it is so important to explain and to understand the distinctions between some phenomena and their measures.

Even if we would have an answer to the question related to the definition domain of information, it was not sufficient for practical purposes of for processing

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1 In this paper we refer to information only in the sense given by Shannon, as knowledge on a specific experiment obtained by reducing the incertitude on its evolution.

the information. The main problem, from this perspective, is how to measure or, at least, to evaluate information. The results of Burgin [6], who describes information as a general phenomenon and discusses its basic properties in terms of ontological principles, provide a base for the development of a unified theory regarding the information's evaluation and measurement, grounded in the axiological component of the general theory of information. This component is analyzed on the base of axiomatic methodology and of the basic axiological principles necessary for the information's evaluation and measurement. Basic axiological principles explain what the basic properties of the measures are and also estimate the information. These principles systematize and unify different approaches, either existent or just possible, of the construction and utilization of the information's measures. This axiological aspect of the theory is not less important than the ontological one because the methods of modern sciences emphasize the importance of measurement and evaluation, which are technical tools for observation and experiment within science, as well as engineering.

2. BASIC AXIOLOGICAL PRINCIPLES FOR THE EVALUATION OF INFORMATION

Basic axiological principles explain how to evaluate information and what measures of information are, necessarily. According to the ontological principles [7] the information causes change either in the whole system **R** that receives information or in an informational subsystem IF(**R**) of this system. Consequently, it is natural to assume that the measure of information is determined by the results that are caused by the reception of the corresponding portion of information.

Axiological Principle A1. A measure of information **I** for a system **R** is some measure of changes caused by **I** in **R** (for information in the strict sense, in the informational system IF(**R**)).

Next principles describe what information's measures reflect. This implies several classifications for information measures.

The first criterion of the measure's classification is the time of changes.

Axiological Principle A2. According to time orientation, there are three temporal types of measures of information: 1) potential or perspective; 2) existential or synchronic; 3) actual or retrospective.

Definition 1. Potential or perspective measures of information **I** determine (reflects) what changes (namely, their extent) may be caused by **I** in **R**.

Definition 2. Existential or synchronic measures of information **I** determine (reflects) what changes (namely, their extent) are going in **R** during some fixed interval of time after receiving **I**. This interval of time may be considered as the present time.

Definition 3. Actual or retrospective measures of information **I** determine (reflects) what changes (namely, their extent) were actually caused by **I** in the system **R**.

Different types of information measures can estimate information in separate informational systems. For example, synchronic measures reflect the changes of the short-term memory, while retrospective measures represent transformations in the long-term memory of a human being.

The second criterion for measure's classification is derived from the system separation triad denoted (**R, l, E**). Here, **R** is a system which receives information and **E** is the environment of this system and **l** represent different links between **R** and **E**.

Axiological Principle A3. There are three structural types of measures of information: external, intermediate, and internal.

Definition 4. An internal information measure reflects the extent of inner changes caused by **I**. An example is the change of the length (the extent) of a thesaurus.

Definition 5. An intermediate information measure reflects the extent of changes caused by **I** in the links between **R** and **E**. Examples are given by the change of the probability $p(\mathbf{R}, g)$ of achievement of a particular goal g by the system **R**. This information measure was suggested by Harkevich [8] and is called the quality of information.

Definition 6. An external information measure reflects the extent of outer changes caused by **I**, i.e., the extent of changes in **W**.

Examples are given by the change of the dynamics (functioning, behavior) of the system **R** or by the complexity of changing **R**.

Axiological Principle A4. There are three constructive types of measures of information: abstract, realistic, and experiential.

Definition 7. An abstract information measure is determined theoretically under general assumptions.

Examples are given by the change of the length (the extent) of a thesaurus.

Definition 8. A realistic information measure is determined theoretically subject to realistic conditions.

Quality of information is an example of such measure.

Those people who worked with the information's technology and dealt with problems of information security and reliability have discovered the difference between abstract and realistic measures of information. They found that if one has an encrypted message, he (she) knows that the information gathered in this message is available. Those who know the cipher can get it. However, if you do not possess this cipher and do not have working algorithms for deciphering, then this information is inaccessible to you. To reflect this situation, exact concepts of available and acceptable information have been introduced. Available information is measured by abstract information measures, while acceptable information is measured by realistic information measures.

The third type of measures from the Principle A4 is defined as follows.

Definition 9. An experiential information measure is obtained through experimentation.

Note. In some cases, one information measure may belong to different types. In other words, classes of information measures overlap.

As an example of such a measure, we may take the measure that is used to estimate the computer memory content as well as the extent of a free memory in computer or on the disk. Namely, information in computers is represented as strings of binary symbols and the measure of such a string is the number n of these symbols. The length of the string is taken as the value of its information measure. The unit of such a measure is called a bit. Computer memory is measured in bits, bytes, Kilobytes, Megabytes, and so on. This reflects the length of the strings of symbols can be stored in a memory. This is the simplest measure of symbolic information. However, this measure is necessary because storage devices (such as computer disks) have to be relevant to needs in information storage.

It is necessary to remark that different information measures may give different values for the same string. For example, according to the measures used in the algorithmic information theory, the algorithmic measure of this string having length n may be much less that n [9].

Let us look how this measure relates to the axiological principles of the general theory of information. When such a string is written into the computer memory, it means that some information is stored in the memory. Changes in the memory content might be measured in a different way. The simplest is to measure the work that has been performed when the string has been written. The simplest way to do this is to count how many elementary actions of writing unit symbols have been performed. However, this number is just the number of bits in this string. So, conventional measure of the size of a memory and its information content correlates with the axiological principles of the general theory of information.

Let us take classifications of measures that are presented in the axiological principles A2-A4 and apply it to the conventional measure of the size of a memory. We see that it is an internal measure (cf. Principle A3), both abstract and realistic measure (cf. Principle A4), and belong to all three classes of potential, existential and actual measures (cf. Principle A2).

The axiological principles A2-A4 have the following consequences.

A unique measure of information exists only for oversimplified system. Any complex system **R** with a developed informational subsystem IF(**R**) has many parameters that may be changed. So, such systems demand many different measures of information in order to reflect the full variety of these systems properties as well as of conditions in which these systems function. Thus, the problem of finding one universal measure for information is unrealistic.

Uncertainty elimination (which is measured by the Shannon's quantity of information) is only one of the possible changes, which are useful to measure for information. Another important property is a possibility to obtain a better solution of a problem (which is more complete, more adequate, demands less resources, for example, time, for achievement a goal). Changes of this possibility reflect the utility of information. Different kinds of such measures of information are introduced in the theory of information utility and in the algorithmic approach in the theory of information.

Axiological Principle A5. Measure of information **I**, which is transmitted from **C** to a system **R**, depends on interaction between **C** and **R**.

Stone [10] gives an interesting example of this property: distortions of human voice, on one hand, are tolerable in an extremely wide spectrum, but on the other hand, even small amounts of distortion create changes in interactive styles.

Axiological Principle A6. Measure of information transmission reflects a relation (like ratio, difference etc.) between measures of information that is accepted by the system **R** in the process of transmission and information that is presented by **C** in the same process.

It is known that the receiver accepts not all information that is transmitted by a sender. Besides, there are different distortions of transmitted information. For example, there is a myth that the intended understanding may be entirely transmitted from a sender to a receiver. In almost every process of information transmission the characteristic attitudes of the receiver "interfere" in the process of comprehension. People make things meaningful for themselves by adapting them to their preconceptions. Ideas come to us raw, and we dress and cook them. The standard term for this process is selective perception. We see what we wish to see, and we twist messages around to suit ourselves.

3. THE DUAL NATURE OF THE INFORMATION

3.1. THE MEANINGS OF THE CONCEPT OF INFORMATION

As information technology (IT) has been developed, improved, and applied in organisations, the information has become recognised as a basic resource in society. The use of IT is considered to be a vital component of successful organisations. At the same time, the increased application of IT has also increased the amount of information available for organisations and their employees, even to the point of "information overload". A major challenge for our global informational society is therefore to manage the information resources.

The meaning of "information systems" has grown in diversity and complexity; therefore a first step in the description of a systemic notion of information is to identify the meaning of information. In the following the word "meaning" is used in its pragmatic sense, i.e. the *meaning* looking for the term "information" will be in the same time its conceptual definition.

The term "information" has been widely and increasingly used, but not always with a clear idea about its meaning. The word "information" is one of the most used, and even abused, words. Different scientific disciplines and engineering fields provide diverse meanings to the word, which is becoming the umbrella of divergent, and sometimes dissimilar and incoherent homonyms. When concepts are not clear, the use of homonyms might be intellectually and pragmatically dangerous. We will try, here, to make an initial step, attempting first a conceptual definition of information that underlines its two aspects: subjective and objective.

Information has been frequently defined as "interpreted data" and, therefore, the same data might cause different interpretations. This kind of definition is frequently found in Information Systems textbooks, especially those ones oriented towards the Information Systems Development and Managerial Information Systems (MIS). Data in a MIS should provide some meaning to some managers in order to fulfill its reason or justification of existence. An interpretation is, by its own nature, *subjective*. Consequently, it is easy to conclude that according to this kind of definition there is no IS without a subjective sub-system, i.e. any IS should have at least two subsystems: an *objective* (mechanical and/or electronic data processing subsystem) and a *subjective* one (biological/human data/information processing: a user, a manager, etc). One can consider that the objective information is external to human beings, but is created by them. What might be called *objective information* is a representation of the real information, which always is a subjective one in its origin and essence. Therefore, the conclusion is evident: information is generated inside the mind of a person or a subject. It is not an objective entity independent of any person. It is dependent on the person while it is generated by the data stimulus, as well as on his/her individual experience. Callaos [11] defined information as "decision-relevant data", which makes of it something requiring a special kind of subjectivity, a strict subjectivity that exclude the possibility of trans-subjectivity, due to the personal nature of "decision" and "relevant decision", because decisions are always subjective, and their relevancy is always related to a given subject. Consequently, we can observe that subjective reception of the data is a *necessary* condition for the in-formation's generation, but it is not a *sufficient* one. It is important to find out the additional conditions that data should comply with, in order to be informative. Floridi [12] comes up with an essential condition. He points out that information is provided when data *answer* an explicit or an implicit *question* made by the data receptor. Accordingly, the data, in order to be informative should be associated with a relevant question. Computers might process data (a datum can be defined as an answer without question), but the information can be processed just by the computer user, the individual, the person, the subject. So, we can draw the following conclusions:

- a datum is a "*given*" thing, not any "given" thing, but the one that makes a *difference*
- information is a cognitive content, not any cognitive content, but the one related to the *association of data and a relevant question*, be it implicit or explicit
- data and information are like the two sides of the same coin: datum is the *objective* side of the coin and information is its *subjective* side. This relation might be seen as analogous to the relation between the *signifier* (the objective/material side of a sign) and the *signified* (its subjective/mental side), in terms of semiology.

3.2. THE ETYMOLOGICAL BACKGROUND OF THE WORD "INFORMATION"

Let's now add an etymological comment. The term *information* originated from the Latin term "*informare*" that means "shape, form an idea of". To form an idea is always in the mind of a person, of a subject. On the other hand, "*informare*" is a composite of "*in"* and "*form*." The last term means "shape" or "mold". The term *in-* is used in combination mainly with verbs and their derivatives, with the senses of "in, into, within". Accordingly, "to inform" would mean "to form in", "to form into" or "to form within" a person, a subject, or in other words information is the inward-forming of a person that result from engagement with data.

The notion of form has a long philosophical, logical and methodological history. The Greek philosophers used the term "form" to distinguish between external and internal features. The Greek term "ειδωσ" (*eidos*) has been translated into Latin as "*idea*" or "*forma*", i.e. "Idea" and "form" have been taken as synonyms in order to translate *eidos*. This sense of the word was the one meant by Plato. Aristotle introduced several connotations that proved to be very important to us, afterwards. He expanded the meaning of "form" by including the objective world in its domain. He worked with the pair matter/form in an analogical way to what, later, has been meant through the pair content/form. An object has matter and form, tangible and intangible presence. He also conceived four causes: the material, the formal, the efficient and the final. The final cause (the purpose) determines the idea, the form, according to the efficient cause acts on the material cause in order to produce what is sought for. In this way, the form, which can be a mental idea first, might generate its objective counterpart, and vice versa. This conception is very important in our attempt to transcend the implicit definitional war existing between theorists from the information area, and to invite to a debate on a systemic integrative meaning of information, which will be done below.

4. THE CONCEPT OF INFORMATION AS AN OBJECTIVE FORM OR ORDER

An increasing number of authors are showing an objectivist bias in their views concerning the notion of "information". Shannon, in his 1948 paper, "A

Mathematical Theory of Communication," proposed the use of binary digits for coding information. To do so, he gave a mathematical definition to "information", relating it to a signal probability. In this context, the "quantity of information" maintains an inverse relation to the signal's probability, in a logarithmic function. This mathematical definition of information opened the doors for many scientific and technological advances. Nor the Computer Science or the Information Technology could have been developed without the seminal Shannon's contribution. But, Shannon's information theory, also opened the door for a lot of abuse of the word "information" and a dangerous twist of the related concept. Shannon made a *mathematical* definition of "information" in order to measure it, in the context of electronic communication systems, not a *conceptual* one. Many authors emphasized the huge difference between these two definitions. Leibniz, for example, distinguished emphatically between *real* definitions and *mathematical* or *nominal* ones. The former ones show clearly that one thing is possible, while the latter do not; the former ones are arbitrary, while the later do not. Shannon's definition is arbitrary. What is the justification of the logarithmic function if not its mathematical suitability?

Another important problem is related to the metric of information. We cannot confuse a *measure* of a thing with the thing measured or to confuse the *metric*, with the thing measured by it. Similarly, we should not confuse Shannon's metric, or the measure we achieve with it, with the concept of information. Shannon considered his contribution to be a theory of communication – i.e. a theory of information transport. The formula derived by Shannon for the average information contained in a long series of symbols is really a measure for the *statistical rarity* of a course of message signs. Shannon's Theory provided the grounds for a strong support to the objectivist position, where information is conceived as completely independent from their senders and receivers and as a neutral reflection of the real world's structure or order. The identification of the information with negative entropy created the foundation of the increasing emphasis in the objectivist conception of information. Shannon found out that his equation was isomorphic with Boltzmann's equation of entropy. This made sense, because since entropy is conceived as *disorder*, negative entropy and information (its mathematical isomorphic) might be both seen as *order*. This explains the increasing number of authors endorsing the objectivist position. Some of them equate the ubiquity of information in the physical world to energy and matter. Furthermore, any changes in the systems must take into account not only changes in matter and energy, but also changes in the information content of the system.

On the other hand, in the information technologies world, the locution "information processing" is frequently used indistinctly to "data processing." At the beginning of computing the locution most used, to refer to computer systems, was "Electronic Data Processing" (EDP), which was the right term to use. But, after the appearance of the expression "Management Information Systems" (MIS), which is also a very adequate one because it refers to managerial, hence human, information, an increasing number of vendors, first, and then consultant and academics, started using “information processing” as synonym, instead of “data processing”. This fact was reinforced by the explicit or implicit semantic effort to differentiate between the software from the realm of data bases, data base management systems (DBMS) and data base servers, between applications software, and middleware. Data processing has been called, lately and frequently, “information processing” and the expression “data processing” has been usually used in the DBMS and data server realm. This way of using the word “information” contrasts and is in conflict with its meaning in the realm of MIS, DSS (Decision Support Systems) and EIS (Executive Information Systems). In MIS/DSS/EIS realm, information is always subjective, but in non-applications software and middleware, realm information is always objective.

5. INSTEAD OF CONCLUSIONS: A SYSTEMIC DEFINITION OF INFORMATION

Let’s now define a mixed concept. Subjectivist and objectivist conceptions of information are quite definitely opposite, but we consider that they are not contradictory. In our opinion they are *polar opposites*. This systemic approach dissolves the objective-subjective dichotomy and focus on what relates and communicates them, i.e. what is common to both of them.

Definition 12. A systemic notion of information would place it not just in the subject, or in the object, but in both of them and in what relates them.

Objective and subjective information relates to each other as north and south poles, as masculine and feminine categories. They are dynamically related in a never ending tensioned creative process, in which they reciprocally feedback and feed-forward by the means of the relations of perception and action. The subject perceives order and organization in the object, receiving some information from it (with its respective noise), then the subject acts on this order, by means of his/her experience/ knowledge/ rational filters, and by re-ordering it according to his/her objectives. Then, the subject acts on the objective world by means of his/her verbal and written language, participating to the creative act of knowledge, social organizations and the technological world. In doing so, he/she sends information to the objective and transpersonal world, augmenting and/or modifying the information inside them.

The most important consequence of the proposed interpretation could bring an amount of uncertainty concerning Shannon’s equation and could also be effective in measuring subjective information, if we replace the objective probability with a subjective one. This extension showed how wrong the Information Technology community was to confuse data with information. A signal or a datum is mathematically the independent variable in Shannon’s equation, while information is the dependent variable. So, Shannon’s equation could be, at least, used to measure some kind of subjective information, or one aspect of it.

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