

# Information Metaphors and Classification of Information Sciences

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**Abstract**—The paper considers the methodological basis for information sciences including terminological base and the issue of defining the notion of information. Both the problem of classifying information sciences and the analysis of metaphorical understanding of the notion of information in evolutionary biophysics, often referred to as “bioinformatics”, are studied. The analysis is essential for the classification of information sciences based on the initial (functional cybernetic) and metaphorical view of information. Theoretical bases which can be common for all information sciences are dwelt upon.

**Keywords**—methodology; information sciences; classification; evolutionary biophysics; information; metaphor

## I. INTRODUCTION

Repeated discussion on classifying information sciences and their theoretical bases, in particular at conferences, allows drawing a conclusion that even with a very fixed seminar plan it can never go without speaking on “general information” topics including the inevitable question as to what information actually is [1]. It has to do not only with a poor methodological base of the seminar participants. Methodological and philosophical questions in scientific work cannot always be successfully distinguished between, even more so when it is the area of information sciences and their scientific classification. Defining information as “data, or knowledge (of events, facts, phenomena, etc.)” looks “tautological” for many specialists in the field of natural sciences [2][3]. Indeed, from the logic standpoint this is a typical definition of one notion through another as vague as the former. However, this “tautological” definition, criticized as it might be, remains the most popular in socio-economical sciences, and even in the social sphere. The reasons for its not being accepted by natural sciences specialists as well as

its popularity in social sphere are from methodological point of view quite obvious. They lay in the specific character of the tasks solved, in which the term information is used in natural sciences and social sphere. As far as the latter is concerned information serves for decision making in object management tasks in economics and social sphere, or serves for communication in society and interpersonal relationships. As far as natural scientific tasks are concerned information as a rule “serves for nothing”. The term information is used there in composite experiments of thought serving to explain cooperative and “summarized” behaviour of micro objects in ideal gas (through negative entropy), or inheritance of marked changes in the structure of protein macromolecules in evolutionary biophysics. The article further considers both questions of classifying information sciences and the analysis of metaphorical understanding of information in evolutionary biophysics often referred to as “bioinformatics”. This analysis is essential for classification of information sciences based on the initial (functional cybernetic) and metaphorical view of information.

## II. GENERAL AND THEORETICAL INFORMATION SCIENCES

Basically, many subjects laying their claim upon the role of a special information science are the “sciences” about digital information technologies, which are applied in many branches of science, technology and economics. The subject of these disciplines is information, which is used in a certain branch, the object being the methods of parent sciences, which are implemented with the help of computations and digital modifications, the basis of which is made by computational mathematics and programming. That means these disciplines have essentially no object of their own.

Consequently, these disciplines can only claim the role of knowledge of a certain kind. Since different branches of science and engineering are rich to a great extent on various digital technologies, and the latter are becoming more and more complex and effective, the role of the knowledge in the educational scientific sphere is very important and is increasing. Through the part of parent methods being assimilated with digital technologies the former also gain the role of general scientific knowledge and integrating comprehensive educational discipline. Geographic information systems (GIS), which were developed due to the needs of mapmaking and are in essence multilayer digital maps (i.e. databases stored in computers), can serve as an example of assimilation. GIS in the field of parent science of geodesy and cartography were first used in economic geography, later in demography, and so on. So, they assimilated through information technologies from parent science into other sciences.

A special place in Russian information science is occupied by “applied informatics” (according to different branches). It is the most widespread educational line in higher professional education. It covers information technologies applied in many branches of economics, manufacture, and in social sphere. The most important and difficult field of study considered within applied informatics is design of information systems used in different branches of economics. This field of study has the widest range of “information operations”, from collection, processing, search, storage of information up to presentation or transmission of information. This is the distinctive feature of economic information systems as compared with information systems used in other subject areas of technical and social spheres, where the range of information operations used is much lower (more fragmental).

In the field of economic information systems design the widest range of theories is used as compared with all other information genres both in separate scientific fields of study and in technologies. The range includes logic (classification theory), semiotics, and relation algebra. The latter is borrowed from mathematics and is used both for analysis of subject field and for databases development. A special feature of the theory is abstracting from the information objects under consideration, the “entities”. Essential requirements of economic information systems design practice led to distracting from philosophical and information semantics issues, which complicate solving concrete tasks, to abstracting from them. Relation algebra, whose development goes back to medieval scholasticism, allows for doing it, so that is why it was successfully developed back in 1970s by American mathematicians. At this point it is necessary to mention that the most important step in economic information systems design is the so-called “infological modelling”. It comes down to making an information logical model of a subject field. The method of infological modelling is the only one for modern informatics that has not been borrowed from other sciences as semiotic, classificatory, or relational. It appeared in record management on the basis of document flow schemes studying.

In other spheres theoretical bases not that diverse are being used so far. In engineering Shannon’s communication theory and mathematical methods are widely used. Still not well-known is Bondarevskiy’s information operations theory, which develops Léon Brillouin’s views and has not yet become widely used [4]. In physical informatics Shannon’s theory, quantum mechanical atom model, and mathematical methods are used. Since bioinformatics uses its own evolutionary biological definition of information, it has developed its own theoretical bases, which are all unique, except for Shannon’s theory. In respect to biology Sergey Grinchenko put forward a “system memory of the living and social” theory, in which the system memory is considered as a “substrate” of information [5]. In social sphere theories related to record management including Arkadiy Sokolov’s social communication and information needs theories are well-known and widely used.

All the above-mentioned theoretical bases are used in separate information sciences and technologies, and as a rule lay no claim upon popularity in cognate fields of study. Apart from Popper’s Three Worlds, there is another environmental concept that develops Popper’s theory and that was put forward by Konstantin Kolin and still another two Russian theories claiming to be of more popularity and importance [6]. These are Gennadiy Zverev’s “theoretical informatics” and Petr Kolychev’s “relative information theory” [7] [8]. Karl Popper’s theory is of purely descriptive character, which defines the global interconnection of the three worlds (ontologies): natural, mental, and artificial. The two Russian theories are not that widely known. One of them is essentially an extended semiotic theory; the other only dwells upon one side of information phenomena, namely their relativity. One of Luciano Floridi’s theorems raises the question of the possibility of developing one common information theory [9]. The methodological importance of solving this problem, in its turn, brings up the question of the possibility of theoretical bases common for all information sciences. To speak of them would be for the moment ahead of time. Yet, from methodological point of view it is essential to study various theories used in different information sciences. It is essential to analyze them from the classificatory point of view at least: namely, the way these theoretical bases are interrelated with the definitions and views of information that are covered by a certain information science. Without it the contents of the “Theoretical Informatics” course becomes eclectic and methodologically non-justified. This is exactly what multiple examples of “Theoretical Informatics” educational programs prove, some of which claim to be a “Theoretical Computer Sciences” course useful for programmers (Doctor of Physical and Mathematical Sciences, A. N. Razborov), other provide the basics of computational mathematics for engineers, still other provide in-depth mathematical sub-disciplines from the comprehensive informatics course (in a best-case scenario).

The absence of unified theoretical bases for different information sciences sets up a methodologically important task of creating a scientifically proved classification of information sciences, including the consideration of the metaphorical view of information used in informatics. Apart

from that, the task to consider philosophy and history of informatics and informational approach, which are common for all information sciences, is set up. The solutions suggested for the tasks make up the “General and Theoretical Informatics” course introduced in Moscow State University of Geodesy and Cartography in 2014 alongside the well-known theories of information revolutions, information needs, and their relation to information theories used in certain information sciences. In the Appendix the reader can find a summary of the course.

### III. INFORMATION METAPHOR IN EVOLUTIONARY BIOPHYSICS

It is impossible, as Arkadiy Ursul puts it, to find “the right way” in the homonymy chaos of defining information without making clear the relation of the general and multiple concrete scientific definitions of the notion [10]. The problem is, though, that providing a substantial definition of the notion would be rather difficult: in classical logic large volume (extension) of the notion corresponds to its narrow content (intension) as a result of the “inverse ratio” law [11]. For instance, the volume of the notion in question is to a great extent larger than the volume of the notion document, for which it is also difficult to find a single definition and which has several definitions with different level of generalization, including “broad” and “the broadest” [12]. This methodical procedure can be used for the notion of information as well and several levels of explicating the definition can be suggested [13]. The top level is quite complete with the general definition given by Norbert Wiener, which runs “information is the contents of relationships, of interacting subjects” [14]. The lower levels should “contain” interdisciplinary and concrete scientific definitions. Their volume will correspond to narrower subject fields of concrete scientific disciplines. It is necessary to set up certain requirements for their contents, that means for the sets of features (properties) covered by them. The first requirement is the correspondence of the properties set of the subject field. The second requirement is not that obvious since modern science lacks examples of properties set description of general scientific view of information, known to the authors [15] [16][17]. The properties set for concrete scientific notions should be broader since the corresponding subject fields are essentially narrower. Moreover, it should include all the properties from the general scientific properties set for the given notion. The properties set for the general scientific notion suggested in our article can be summed up to include the following properties [18]:

- Expression of information in characters and signs;
- The independence of information from the form of its expression;
- The conservation principle, the commutative law, and additive law do not work;
- Dependence of information on the code dimensions; non-correspondence of quantity and quality;

- Stochastic character of reception and its relativity, its dependence on the receiver.

Especially important becomes the definition of information in bioinformatics in as “a memorized choice” because in the modern Encyclopedia of Epistemology and Philosophy of Science it is wrongly classified as general scientific definition [19] [20]. Evolutionary biophysics considers the transition from inanimate nature to self-organizing protein macromolecules with reproductive capacity. Its unique character is in the fact that it allows viewing the interconnection of attributive and functional cybernetic information. The modifications occurring in the diversity (“of multiple entities”) of organic molecule types should be reflected in the complexity development of new molecule types as compared with the previous types. One of the attributive definitions of information in has to do with the notion of diversity: “information is transmission of diversity”[21]. At the moment of “dramatic increase of complexity” when enormous protein molecules with reduplication mechanism appear the character of reflection is to change, there should appear a reflection in inanimate nature. Also, after the “dramatic increase” the most complex enormous protein molecules with reduplication mechanism get a reason to exist. The reason is reproduction.

The above-mentioned hypothetical transition from a reflection in inanimate nature to a reflection in animate nature is very schematic and relative. Nevertheless, it allows making a supposition as to a specific limit of the reflection in organo-molecular interaction, the last environment in inanimate nature where reflection mechanisms can be considered [22]. The limit is the high complexity of the structure of organic molecules, whose further development is minimal. Further complication happens due to supra-macromolecular modifications and appearance of primitive organisms, in which biological reflection mechanisms work, genetic and pre-psychic. Biophysics is important to study of the way the metaphoric understanding of information appears. Firstly, biophysics accepts a very vivid metaphoric view of information, namely “information is a memorized choice”. Secondly, this metaphor appeared in biophysics after Karl Shannon’s mathematical theory had been developed in late 1940s. It is related directly to the view of information metaphoric the way it is: “information is unveiled uncertainty”. Dmitriy Chernavskiy’s article is important also because it dwells upon methodologically important definitions of the notion information itself [23]. The appearance of the metaphor “memorized choice” has to do with the mental modelling of the appearance of self-developing protein macromolecules from simpler organic molecules, this process being modelled up as a row of random processes of the structure complication [24]. The complexity of molecules grows from step to step. These macromolecular objects (protein molecules) of random processes have become the object of biophysicists’ mental experiments, who explain the self-induced and drastic complication of the structure through the long time and special conditions of the flow of the random processes where the increase of complexity (up to the appearance of reduplication mechanism) happens due to random

complication (choice) being remembered by the molecule's structure.

Making everything clear in the way metaphoric view of information appears is only possible when one specifies and accepts its initial understanding as "certain data reported to the subject". This specification should be made up to the level of decomposition (the term used in systems theory and practice), which can be useful for other potential metaphoric views of information as well. One of the "elementary logical" levels borrowed from psychology and other scientific disciplines is distinguishable elementary modification (or distinction). Then the previously decomposed definition of information can be worded as follows: information is a modification in the subject's mind with their inner and outer communication which can cause changes in their behaviour (activities) aimed at the subject's adjusting to the outer environment. Here outer communication stands for the participation of the subject in subject-subject and subject-object relations. Let us consider Norbert Wiener's definition, "information is the contents of relationships, of interacting subjects", which he suggested in relation to any self-organizing systems, including animate and artificial. It is obvious that it refers to any subject-subject and subject-object relations [25]. Consequently, this definition of information is broader than the initial one that defines it as "data". The detailed definition suggested does not contradict the above-mentioned functional cybernetic definition. Let us consider the previously mentioned definition from evolutionary biophysics, which is given in the foundational book: "information is a memorized choice" [26]. Within the systemic evolutionary approach it is necessary to take into account the influence of the theories and understandings that prevailed in the scientific world back then. Henry Quastler's book was written in 1963 on the basis of his lectures. That was the time when many sciences, biophysics including, were under the great influence of Karl Shannon's mathematical communication theory. Communication tasks solved by Shannon presuppose a communication channel and a receiver, which not only receives informational signals but also stores them for the time enough for their reception and processing. The receiver, which the just received information immediately leaves, is from the technical point of view unnecessary and pointless. That means the conditions of solving communication tasks include "by default" the possession of certain amount of memory by the receiver itself, or by the operator working with it. Consequently, evolutionary biophysicists definitely had something to borrow from Shannon's theory "for memorizing", intuitively at least. Already in 1950s the view of information as "unveiled uncertainty" was popular [27]. The subject may indeed be uncertain when making a decision and the uncertainty is often all about choosing from a number of options. Consequently, an instance of the subject's outer communication with the use of communication channels can be "reconstructed" when there appears a change in the subject's mind that results in the change of their behaviour, the subject makes a decision, or a choice. Possession of memory is an obligatory property of the mind. It is obvious that this wording of the definition of information, "after Shannon", does not contradict the

"detailed" one. It is worth mentioning that communication tasks consider technogenic communication, which by default has a code form of expressing information in the communication channel. The above-mentioned facts make it obvious that the information in Karl Shannon's communication theory corresponds to the functional cybernetic understanding, and also to the maximum properties set suggested in [28].

Let us come back to the "memorized choice", though. The problem is that the "after Shannon" reconstruction of the definition suggested above presupposes the subject's participation in subject-subject relations at least, and biophysicists "removed" in their vivid metaphor not only the subject-subject relations but also the subject of the choice. In their tasks of mental consideration (modelling) of possible evolution scenarios of organic molecules towards self-organizing living matter it is not simply acceptable but inevitable. Otherwise we will have to admit that organic molecules are subjects and have a conscious choice. They do not have their choice, though; it is merely a random choice. Thus, the vivid information metaphor, "the memorized choice", is in its meaning only related to the initial definition of the notion in that it has the background related to that of the metaphor "unveiled uncertainty". In conclusion let us compare the properties sets corresponding to the definition of information in technical informatics, which is the "unveiled uncertainty", and in bioinformatics, namely the "memorized choice". The "unveiled uncertainty" metaphor has all the known properties from the maximum set for a functional cybernetic definition: expression of information in characters and signs; the independence of information from the form of its expression; the conservation principle, the commutative law, and additive law not working; dependence of information on the code dimensions; non-correspondence of quantity and quality; stochastic character of reception and its relativity, its dependence on the receiver [29] [30]. The "memorized choice" metaphor only has the property of stochastic character from the above-mentioned set, which character is rather "degenerate" because there can be no communication in intermolecular interaction in the true sense; it is the interaction of objects. It is quite obvious that this metaphor is in its meaning the farthest from the original definition. Therefore, the "memorized choice" metaphor cannot claim even the status of interdisciplinary definition of the notion information and is only applicable in its own subject field, which is bioinformatics.

The all above-mentioned allows making the following conclusions, as to:

- - The necessity of using several explication levels of defining the general scientific notion of information because of the broad and diverse area of its use;
- - The possibility of studying homonymic relations of different definitions of information ("metaphors") using the systemic evolutionary approach;
- - The development of evolutionary biological metaphor of information on the basis of another metaphor, namely "the unveiled uncertainty";

- - The impossibility of giving the evolutionary biological definition of information a broader status than that of a concrete scientific definition, and the limitation of its meaning to the field of evolutionary biophysics only [31].

#### IV. CONCLUSION

At the moment a methodologically justified classification of information sciences has all the necessary conditions; and there are several reasons why a classification like that is topical. One of the reasons is the question of NBIC-convergence (short for nanotechnology, biotechnology, information technology and cognitive science), which has different views and understanding of information. Other are related to the questions of the development of the information sciences themselves, which are formulated by English philosopher Luciano Floridi in his famous theorems [32]. The most developed information sciences are those which base themselves upon functional cybernetic understanding of information and which further include social economic information sciences as well as various applied sciences (different branches). They are corresponded to by concrete scientific definitions of information which are in accordance with at least five properties from the general scientific definition properties set. Theories used in them include logic (classification theory), semiotics, and relation algebra borrowed from mathematics, as are sections related to programming [33]. Alongside logical semiotic methods and mathematical methods in social economic information sciences the method of infologic modelling is used. Shannon's mathematical communication theory is used in technical sphere mainly.

Apart from the generally recognized Popper's three worlds and the known environmental concept, further developing Popper's theory, suggested by Konstantin Kolin there are no theoretical bases common for all information sciences based on functional cybernetic and attributive understanding of information [34]. Using the example of the "memorized choice" understanding of information used in evolutionary biophysics it is shown that this understanding is a metaphor of the initial functional cybernetic understanding of information. Essentially, certain metaphors of information are used in quite a variety of attributive understandings of information. This fact allows dividing the classification of information sciences into two lines, those that use functional cybernetic understanding and those using metaphoric understanding of information (including "bioinformatics" and physical informatics).

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