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Irmengard Rauch
Gerald F. Carr

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Meaning and value of information in biological systems

Alexei A. Sharov

Life is impossible without information processes. Even the most primitive living beings use genetic information for their growth, activity and self-reproduction. Humans reached the highest level of information processes: they obtained consciousness and language. We used to consider consciousness an obvious phenomenon, which needs no explanation. Moreover, information processes in animals and plants are often explained in terms of human mental activity. This approach is widely used in zoosemiotics (Sebeok 1972). This is an example of a simple phenomenon being explained on the basis of a more complicated one.

I consider human consciousness as the most mysterious phenomenon which requires explanation itself. Thus, it is necessary to develop a non-anthropomorphic semiotics. Here I present the following concept of information systems: 1) meaning and value are basic features of information which can exist without brain or even a nervous system; 2) the main function of information is the selection of system trajectories at unstable bifurcation points; and 3) information is selected itself (e.g., by natural selection).

I distinguish between actual and potential information (Sharov 1992). Actual information is integrated with a system whose behavior and/or development it regulates, while potential information is separated from the receiver, and thus, it is not active. Potential information should be acquired and transformed into actual form before it will be able to function. Examples of actual information are: genome of an organism, personal habits and knowledge. Examples of potential information are: sex pheromone, a telegram, a book. To understand the essence of information, we need to concentrate on actual information because it functions. Non-functioning systems cannot be understood (e.g., a fungus spore cannot be identified until it germinates and produces a fungus body). Thus, I want to change the basic example of information. Instead of a message (letter, telegram) I will consider genetic information (=genome) of an organism.

By information I mean a certain physical structure like a DNA molecule, not the contents which can be represented in different structures. The reason is that in primitive information systems, the contents cannot be separated from the physical structure. For example, a nucleotide sequence written on paper cannot be interpreted by a living cell. It has a meaning for the cell only when it is "written" in a DNA molecule.

Informational and non-informational physical structures can be distinguished by their physical scales. Every object has an infinite number of characters. However, only a limited set of them is responsible for object interaction with the outside world. These characters represent object shape and function and can be called

macro-characters. In living organisms, macro-characters taken together are called a phenotype (=phenome). Macro-characters can be considered separately from other characters because their dynamics is predictable along all stable trajectories. Micro-characters have very little effect which immediately disappears because the system promptly returns back to the stable trajectory. If the trajectory is stable, then micro-characters have no effect and can be ignored. Natural non-living objects have stable trajectories and can be described by a few macro-characters. They are predictable and "normal".

At unstable points, small effects of micro-characters can change system dynamics. Instability amplifies a micro-signal into a macro-effect. The more unstable points the system has, the more it deviates from a "normal" physical object. For example, it is easy to write an equation describing a falling rock, and difficult to predict animal or human behavior.

Information can function in any system with instability. However, instability often leads to system destruction. Thus, it will not appear unless it evolves simultaneously with information. Parallel evolution of macro- and micro-characters is the only way of information system development.

Meaning and value are basic features of information:

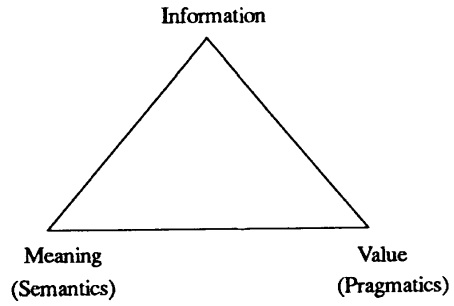

Fig. 1. Information and its basic features

Meaning represents the semantic aspect of information and value represents the pragmatic aspect (Sharov 1992).

Meaning is the trajectory of system change selected by information. For example, ontogenetic trajectory is the meaning of genetic information in a zygote. The meaning of received information how to get to the library is the actual trajectory of a man who follows given directions. I want to emphasize, that meaning is dynamic: it is a trajectory rather than a state. It is very close to the notion of interpretant (Peirce 1897).

If trajectory selection is random, then the meaning of information can be defined in terms of probability of trajectory selection. Then it is possible to apply quantitative information theory to estimate the entropy of trajectory selection.

Value is the ability of actual information to improve self-maintenance and/or self-reproduction of a system. Value is a more general term; it characterizes system persistence as a whole. Information value is the portion of total value which can be attributed to information. In order to have value, information should have meaning, otherwise it will not affect system behavior and persistence.

For example, genetic information increases organism's reproduction rate. Natural selection eliminates genotypes with low value. Thus, selection increases the average value of genetic information in the population. Information value depends on time scale. Gigantism may be beneficial in short periods, but it is fatal in the long evolutionary time scale.

In complex information systems only a small number of micro-characters has an effect on system persistence and self-reproduction (the concept of neutral evolution). Neutral micro-characters are not affected by natural selection, and thus, they have no objective value. However, they often are selected subjectively, forming a habit. Habits are persistent and can be reproduced genetically or by imitation. Thus, we can say that habits represent the subjective value of the system. Human semiotics is full of subjective values such as money, education, success, art, etc. This is because the question of the quality of living becomes much more important than the question of survival. Information could not appear and develop without having objective value. But at a certain level of system complexity, subjective values become dominating.

The triangle in Fig. 1 is substantially different from well-known triangles proposed by Frege (1892) and Pierce (1897). First, this triangle describes actual information while Frege and Pierce dealt with potential information. Second, there is no "object" or "Sinn" in my triangle, because the only object for actual information is the system itself. Third, nothing related to value is present in the categories of Frege and Pierce.

Self-regulation is the primary function of information. Communication develops later when it becomes beneficial for a system to regulate neighboring systems. The meaning and value of potential information (e.g., a message) depends on the possible receiver. For example, a calculus textbook has no meaning and value for the majority of human population in the world, but some students will read it and use it for achieving their subjective values (at least they will get a degree).

As a rule, communication is mutually beneficial, otherwise one of the partners will not respond. The signs that have positive value for both emitter and receiver can be called proper signs. For example, female moths release pheromone to attract males, and both sexes increase their reproductive ability due to this communication.

However, there are special cases when potential information has value for only

one partner in communication: 1) stimulus has the value for the receiver only, e.g., predator receives the smell of a prey; 2) pseudo-sign has value for the emitter only, e.g., mimicry.

Negative value of a pseudo-sign for the receiver is always balanced by a positive value of some other sign. For example, birds know that wasps are not edible and the wasp image becomes a sign with a positive value. The wasp-like image of edible insects is a pseudo-sign which is confused by birds with a proper sign presented by wasps.

Conclusions: Information can be defined without references to consciousness as a micro-state of a system which controls the selection of system trajectories at unstable points. Information has two characteristics: meaning represents the selected trajectory of system change, and value represents the role of this selection in self-maintenance and self-reproduction. The primary function of information is self-regulation rather than communication. Communication develops between systems if it has positive value for both emitter and receiver, or at least for one of them.

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