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# THERMODYNAMICS OF IRREVERSIBLE PROCESSES AND SELF-ORGANIZATION IN INFORMATION FLOWS

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***ABSTRACT.***The basic equations of thermodynamics of irreversible processes and self-organization are applied to describe documentary information flows. The model of interaction of informatics and science of science is shown, unveiling the ways of search of regularities of development of science on the basis of bio-bibliography, and also the place of information flows and bio-bibliography in this model. Synergetic effects at the intersection of information and science of science are discussed. Nine main problems on the way of search of regularities of development of science by means of research of documentary information flows are formulated by the author.

***Key words*:** information flows, documents, thermodynamics of irreversible processes, self-organization, science of science, bio-bibliography, synergistic effects, laws of science development.

The original manifestation of complex integration phenomena in modern scientific creativity is the use of the apparatus and of the conclusions of the thermodynamics of irreversible physical, chemical and biological processes to the simulation of the dynamics of science in general and of documentary information flows (DIF) in particular [1, 2]. “We are going through a period of scientific revolution, when the place and the very essence of the scientific approach is subjected to a radical reassessment; this period somewhat reminiscent of the emergence of the scientific approach in Ancient Greece or its revival in the time of Galileo” [3]. It is no coincidence that the author of this article came to the idea of using the apparatus of thermodynamics of irreversible processes to describe DIF 30 years ago [4] independently of A.I.Yablonsky [2], V.I.Gor’kova [5], A.K.Aylamazyan [1] and other researchers.

According to these studies, the methodology of DIF structural and dynamic study is based on the idea of DIF as an open dynamic self-organizing system with a dissipative structure, as well as on the information concept of the development of scientific knowledge.

The mathematical model of the development of the DIF-system in the form of a nonlinear differential equation reflects the behavior of the system in time and space:

$$dH/dt = \lambda(t)H - \rho(t)H^2, \quad (1)$$

where are: H – the entropy of the DIF-system (measure of order or organization of the system); λ – the intensity of growth of the number of elements in the DIF; ρ – intensity of use of elements; λ(t) – reflects the patterns of growth in the number of elements (including publications); ρ(t) – reflects the aging patterns of publications.

This approach explains the self-organization of the DIF-systems as the evolution of its structures towards the optimal organization of the elements and it is completely based on the conclusions of the thermodynamics of irreversible processes (TIP), which is created by the works of L.Onsager, M.Eigen and I.Prigogine and described in numerous publications [for example: 2, 3, 6-15].

The essence of TIP is to consider most systems as open, i.e. exchanging matter, energy and information with the environment.All subsystems and elements of systems constantly fluctuate, and a separate fluctuation or a combination of fluctuations can become (as a result of positive feedback) so strong that the original fluctuation does not stand and begins to collapse.At this critical juncture, which is called the bifurcation point, the system goes into a state that it is fundamentally impossible to predict in which direction its further development will go: whether the state of the system will become chaotic, or it will move to a higher level of order or organization, i.e. it will be transformed into a dissipative structure.Order and organization may spontaneously emerge from disorder and chaos as a result of the process of self-organization of the system.

Given the fact that biological and social systems are among the open, and that the question of the relationship of information with thermodynamic entropy and information theory with non-equilibrium thermodynamics and synergetics has long been beyond doubt,DIF-systems can be calculated by the method of system analysis (SA) on the basis of the TIP.The mathematical apparatus for such calculations is prompted by the idea of G.Weil: “Whenever you have to deal with some object ... endowed with structure, try to determine ... the transformations that leave all structural relations unchanged. You can count on the fact that in this way you will be able to penetrate deeply into the inner structure of the object...”.

UsingthisG.Weil'srecommendation, weformulatethe*centraltenet*toimplementmodelsoftherelationshipsbetweeninformaticsandsc ienceofscienceresearch: it is possible to determine such transformations that leave the structural components of the DIF-system <informatics – science of science – bio-bibliography> unchanged.For calculations of these transformations weare used (in contrast to the description of documentary flows by the model of quantum gas on the distributions of J.Boseand E.Fermi [16]) mathematical apparatus of O.Heaviside operational calculus and the system of differential equations with partial derivatives of J.Maxwell electrodynamics, which is given to the mind:

$$div\vec{E} = 4\pi\rho;\ div\vec{H} = 0;\ rot\vec{E} = -\frac{1}{c}\times\frac{\partial\vec{H}}{\partial t};\ rotH = \frac{4\pi}{c}\vec{j} + \frac{1}{c}\frac{\partial\vec{E}}{\partial t}. \quad (2)$$

Thesearchforanalogiesinthecharacteristicsof DIFvaluesincludedin (2), carriedoutonalargenumberofpublicationsofNobelPrizelaureatesinChemistry [17], suggestedthat: $\vec{E}$ – is the vector of the DIF filling (similar to the intensity of the electric field); *ρ* – is the instantaneous number of units in a given DIF similar to the charge density); $\vec{H}$ – is the vector of ordering of the DIF elements (similar to the magnetic field tension or, according to equation (2), to the entropy of the DIFsystem); *c* – is *const*.; *t* – is the time; $\vec{j}$ – is the vector of density changes of DIF (similar to the electric current density); *ε* – is the bio-bibliographic*const*. (similar to the dielectric constant of the medium); *μ* – is the scientometric or bibliometric*const.* (similar tothe magnetic permeability of the medium). Transformations of equations (2) also involve: $\vec{D} = \varepsilon\vec{E}$ – is the bifurcation vector (similar to the electric inductionof field); $\vec{B} = \mu H$ – is the dissipation vector (similar to the magnetic induction of field).

Important characteristics of DIP flows follow from equations (2).The flow of information $\vec{E}$ through any closed surface (cross-section of the fund acquisition system) is proportional to the charges inside that are an instantaneous amount of units of information (as a product of publishing). This follows from the first equation. The following equation is the corresponding general pattern for the ordering of the DIF. Since each new information cannot be measured without its use, the flow of information elements $\vec{H}$ through any closed surface is always zero.

The third equation, which has an analogue of M.Faraday's law for electromagnetic induction, shows a direct proportional dependence of the fullness of a given DIF on the rate of change in time of the order of the DIF elements (information flow through the circuit).

The fourth equation in (2), which has an analogue of the law of conservation of electric charge, shows the dependence of the ordering of DIF elements on its density and fullness.

The solutions of the four equations in (2) are:

$$\vec{E} = -div\varphi - \frac{\partial \vec{A}}{\partial t}; \quad \vec{H} = rot\vec{A}; \tag{3}$$

$$\varphi(1,t) = \int \frac{\rho(2, t - r_{12}/c)}{4\pi\varepsilon_0 r_{12}} dV_2; \; \vec{A}(1,t) = \int \frac{\vec{j}(2, t - r_{12}/c)}{4\pi\varepsilon_0 c^2 r_{12}} dV_2,$$

where: $\varphi$ and $\vec{A}$ are scalar and vector values of changes in fullness and density of DIF (analogue of the electric potential); $r_{12}$ is the distance from point 2 to point 1 in the flow of DIF; (1,$t$) is the instantaneous number of units of DIF at point 1 at time $t$; (2,$t$–$r_{12}/c$) is the instantaneous number of units of DIF at point 2 at the time ($t - r_{12}/c$).

Introduction to equations (2) of DIF structures bifurcation $\vec{D}$ and dissipation $\vec{B}$ vectors translates consideration of information flow patterns into a non-equilibrium region and makes them dependent on bio-bibliographic and scientometric (or bibliometric) parameters that are responsible for DIF filling and using by its creators and consumers.

A model based on calculations using equations (2) and (3) is shown in Figure 1.

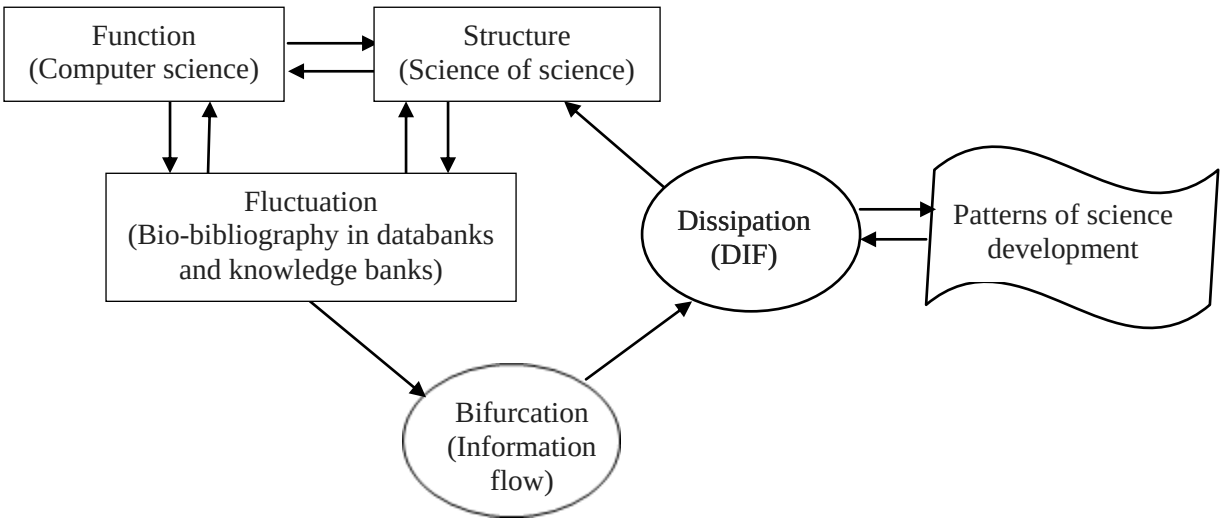


Fig.1. The model of interaction between computer science and science of science, showing the ways to find patterns of science development based on bio-bibliography

Analysis of data and models allows the author to put a series of problems in the search for patterns of science development with the help of the research of DIF:

1) information processes on the basis of DIF are irreversible, therefore, they must obey the laws of TIP, including “flows” and “forces”, according to L.Onsager. What features of “flows” and “forces” lead to the laws of the development of science? How does this fit into the typology of the laws of development of science [17]? Do its dock with the semantic analysis of the development of individual sciences, for example, according to [18, 19]?;

2) what is the informational and scientometrics sense of the quantities $\varepsilon$ and $\mu$ in equations (3)?;

3) fluctuations occurin the process of the functioning of an open system of DIF leading to the self-organization of information structures, up to the analogy with the neural networks of the human brain system. Is it possible to link these processes with virtual and artificial information, biological, physical, chemical, social and other processes? Do these ideas suggest ways to create models of the development of civilization in general?;

4) the accumulation of DIF (in one or different scientific areas) leads to bifurcation and dissipation, those the transition to a higher level of organization of information. Where is the limit of DIF complication? Maybe in the union with the thought processes of humanity and the transition to the undocumented exchange of information?;

5) dissipative DIF-structures can arise spontaneously, by analogy with the spontaneous ordering of matter and energy in the process of self-organization, according to I.Prigogine and M.Eigen. Is this a criterion for assessing the prematurity of certain scientific discoveries with all the logical consequences that this entails?;

6) the synergistic effect of the mutual influence of the entire hierarchy of bifurcations of DIF is clearly manifestedat all stages of the considered chain. Is this a confirmation of the need for a comprehensive transition to new information carriers, combining the concepts of “DIF” and “Knowledge”?;

7) is it possible to identify the generalized patterns of filling the DIF structures that would maintain balance on a significant amount of factual material? What is the predictive power of these laws for the development of science?;

8) the usefulness of the use of physical analogies in computer science and science studies is clearly seen in the considered models. Is this fact evidence of the emergence of a new

integral science?One element of such an integrality has already appeared and is developing, this is nobelistics [20];

9) another new direction in scientific research and the scientific literature follows from the ideas considered in this paper, this is scientometric biography, i.e. study of the activities of individual scientists and scientific communities based on scientometric and bibliometric analyzes (see, for example, [21]). How does this trend fit into the aggregate of ideas for the search for patterns in the development of science?

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