Journal of International Scientific Publications:
Materials, Methods & Technologies, Volume 5, Part 1
ISSN 1313-2539, Published at: http://www.science-journals.eu

MATERIALS FOR THE INFORMATION THEORY ELABORATION
1. INFORMATION QUANTITY AND QUALITY MEASURES

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Abstract

The five stage of international controversy on information nature and its quantitative and qualitative description had been revealed. Measures for information quantity estimation, various interpretations of "the information" and "the data" at the base of publications had been analyzed; the information properties had been summarized and described. This analysis allowed to formalize "the information" and collection of its properties, presenting at the tensor aspect. The new linear spaces of vector belonging functions allowed to register well-grounded that theory of information will be work out with the help of tensor analysis and fussy theory.

Key worlds*: theory of information, information, data, measures for information's quality and quantity, information properties, tensor interpretation of information, T- and S-norms.*

1. INTRODUCTION

A unified concept of information in contemporary information-oriented society [1] has not been defined unambiguously so far. Debate on the problem has already passed through five stages. The term was not used before the beginning of the XXth century, which is documented by many researchers [1-3], though the term "information" has been known by people since ancient times. The first stage at the beginning of the XXth century led to the formation of the attributive concepts of information [1, 4-6], according to which information is inherent in all objects of the Universe, and the term itself was defined as reflected diversity of a model forming a common structure with matter and energy. At the second stage in 1940s-1960s there dominated functional (cybernetic) concepts, which were formed after the publication of N.Viner's and K.A.Shannon's classical works. The third stage in 1960s-1970s led to the emergence of anthropocentric (sociocentric) concepts which attributed the concept of information to human society only, i.e. understood it as semantic information [4]. The mentioned period also witnessed the surge of attention of Soviet philosophers towards understanding the essence and nature of information (A.D.Ursul, Yu.A.Shreider, B.V.Biryukov, etc.). During the fourth stage (in the 1980s – 1990s) the biological and semantic types of information were supplemented by a third type – computer information functioning in rapidly developing computer technology. This stage made the situation even more confusing as every author gave their own definition of information. The term spread widely to all spheres of human activities, an information-oriented society was forming, but the meaning of information, its quantitative and qualitative evaluation remained unsystematic. A lot of measures of quantitative evaluation of information were used in scientific and educational contexts (table 1).

ISSN 1313-2539, Published at: http://www.science-journals.eu

Table 1. Measures used to evaluate the information quantity

K.A.Shannon [7]	$H = -\sum_{i=1}^{n} p_i \log p_i$	H - measure of uncertainty of the probabilistic ensemble ($p_1, \dots, p_n$)
R.Fisher [8]	$I(\vartheta) = E_\vartheta([L'_\vartheta x/\vartheta)]]^2 =$ $= \int_O [L'_\vartheta x/\vartheta)]^2 \, g(x/\vartheta) dx$	ϑ - evaluated parameter; $g(x/\vartheta)$ - conditional sampling distribution (plausibility function); $L'_\vartheta x/\vartheta) = \frac{g'(x/\vartheta)}{g(x/\vartheta)}$ - arithmetical derivative of the plausibility function; E_ϑ - the symbol of mathematical expectation.
R.Fano [8]	$I(x_k, y_i) = \log \frac{P(x_k, y_i)}{P(x_k)}$	x_k, y_i - the elements of the ensemble, X and Y accordingly; $P(x_k)$ - probability of the element $x_k \in X$; $P(x_k, y_i)$ - conditional probability of the element $x_k \in X$ given at the condition of y_i
S.Kulback [9]	$I(1:2) = \int_O \log \frac{f_1(x)}{f_2(x)} d\mu_1(x),$ $I(2:1) = \int_O \log \frac{f_2(x)}{f_1(x)} d\mu_2(x)$	$I(1:2)$ - the average amount of information for difference H_1 from H_2 at the measure μ_1; $I(2:1)$ - the average amount of information for difference H_2 from H_1 at the measure μ_2
Ya.A.Rips [10]	$I(x_i, y_k) = [-lnL(y_k)] - -[-lnL(x_i/y_k)]$	$X = \{x_i\}$ - discrete ensemble; $Y = \{y_k\}$ - discrete ensemble; $-lnL(y_k)$ - improbability of the effect y_k; $-lnL(x_i/y_k)$ - improbability of the cause x_i from the point of view of effect observed y_k; $I(x_i, y_k)$ - information about the cause x_i in the observed effect y_k .

G.Hacken [11]	$-\frac{dI_f}{d\alpha} = -\alpha\langle\xi^2\rangle + \alpha\langle\xi\rangle + + \beta\langle\xi^2\rangle\langle\xi^4\rangle - \beta\langle\xi^6\rangle$	$\langle\xi^2\rangle$ - measure of work performed by the system; α - command qualifier; β - coefficient.

The attempts to solve the problem of the information nature not only from the quantitative but also from the semantic point of view are described in [2-18]. One of the authors of this article took part in the process [19, 20], having introduced systems concept of information (by combining the attributive and functional approaches) through its visualization (unsurveying), and qualitative, surviving and realized components.

The fifth stage of the debate about information (the beginning of the XXI century) is characterized by the return to the reconsideration of the nature of information, its quantitative and semantic aspects [1-6, 21-29]. The most often used interpretations of the term "information" are given in table 2.

Table 2. Interpretations of the term "information"

Source	Definition
[30]	(Notification, explanation, description) – in a wide sense it is an abstract notion having a lot of meanings depending on the context. In a narrower sense it means data (messages, facts) regardless of the form of their presentation
[31]	In a system-cybernetic sense it is a body of data: about the control object and environment (information about the condition); about the situation to be achieved (target information); about the way (plan) to achieve the target formed by the control object (command information); the body of data describing the rules of transforming state information (in compliance with the targets of the system operation) into command information (procedure information). On the one hand it represents the degree of space-time inhomogeneity of matter (the emphasis is on the source of information), on the other hand it is the property of the matter closely connected with the concept of reflection (here the emphasis is on the mode of getting information).
[32]	Any kind of data about objects, facts, concepts from the object domain.
[33]	Message, notification about a situation, data about something, which are exchanged among people
[34]	Meaningful (semantic) interpretation and correlation of a definite body of data for the purpose of making decisions.
[35]	Data about people, objects, facts, events, phenomena and processes regardless of the form of their presentation.
[36]	The body (system) of knowledge about a definite subject of perception, i.e. concepts about it.
[37]	Data about the objects and phenomena of the environment, their characteristics, properties and conditions which reduces the degree of uncertainty, incompleteness of knowledge.

The analysis of Table 2 allows concluding that the term "information" is defined with the following words: data, intelligence, messages, knowledge. However, these words: data, intelligence, messages, knowledge – have their own definitions. Table 3 gives definitions of the term "data" taken from

various sources. It is evident that in most cases given the term "data" is defined through the notion "information". The logical circle becomes faulty: information is defined as data, and data is defined as information [21].

Table 3. Some definitions of the term "data"

Source	Definition
[14]	Presentation of information in a formalized way allowing transmitting, store and processing it in the data network, computer network, information network.
[17]	Information presented in a formalized way fit for its interpretation, processing and transmitting by a person or a technical device.
[19]	Information presented in a way fit for its processing by an automatic device with a possibility of a person's participation
[21]	Information presented in a formalized way fit for its processing by an automatic device with a possibility of a person's participation
[23]	Description of a phenomenon (or an idea) which seems valuable enough to be formulated and accurately recorded.
[24]	Presentation of information in a formalized way suitable for its sending, collecting, storing and processing.
[22]	Separate facts characterizing some objects, processes or phenomena of the object domain as well as their properties.
[10]	Information prepared for definite purposes.

If we go on to analyze the definitions of the terms "intelligence", "messages" and "knowledge" it will complicate the situation even more as definitions of these notions also contain the word "information".

Thus we arrive at a tentative conclusion that symbols, data, intelligence, messages and knowledge can carry information, but they will be informative only for a certain person or group of people. In other words things that appear to be information for one person may not be such for another. One can agree with the opinion [5], that "an image can become information only when it is perceived and recognized by a cybernetic system, a human being, for example."

2. DEFINITION OF INFORMATION AND ITS PROPERTIES

The analysis of sources [30-44] allows making a set of requirements which information needs to meet. Otherwise, we deal not with information but with different ways of presenting it by means of symbols, data, intelligence, messages, knowledge, etc.

Table 4 gives a set of requirements which the category named "information" possesses.

ISSN 1313-2539, Published at: http://www.science-journals.eu

Table 4. A set of properties of information

№	Property	Description
1	Definite orientation	Information always bears relationship to at least one of the following things: "who about" or "what about", "whom to" (possibly "what for" and "how").
2	Polyvalency	There are quantitative, semantic and pragmatic aspects of information study
3	Measurability	During any aspects of its study information can be evaluated on the basis of a metric (quantitative) measurement scale introduced by the subject.
4	Dynamics of form	The ability of information to change with time: any fixed information soon becomes out-dated.
5	Formality of existence	Being nonmaterial information needs a material medium (form). These are usually signal-symbol systems describing objective reality with certain exactness. Formality of information existence (any form is always a limitation) makes information fixed in any form "inexact".
6	Transformability	Ability of information to change its form, place and currency on the basis of operators introduced by the subject.
7	Reproducibility	It is mainly understood as a multitude of channels of its expansion (perception) and also as "simplicity" of copying and wide availability.
8	Persistence	Being one of the properties of matter it is also characteristic for information which appears through interaction with matter. It allows drawing an important methodological conclusion about a possibility of forecasting all aspects of information changes.
9	Interconnectivity	This property is genetically and methodologically similar to persistence. While all real processes have a unique cause-effect foundation, it also refers to information and the possibility of its "calculation".
10	Destoyability	Theoretically information like matter cannot be destroyed (i.e. it can be "calculated" by its results – tracks of destruction, restore by its "primary source", define by some other interconnected information, etc.). But in practice, it means fighting against heavy odds.
11	Objectivity	It means that information is independent of anybody's opinion or mind.
12	Completeness	Information can be considered complete if it contains a minimum number of indicators which is sufficient for making a correct decision.
13	Credibility	The property of information to be properly perceived. Objective information is always credible, but credible information can be both objective and subjective. The reasons for its incredibility can be its deliberate perversion (misinformation), unintentional distortion of a subjective character, a distortion as a result of interference, mistakes in information fixation. Generally credibility of information is achieved by fixing the time of the events reported, by comparing data received from different sources, by timely disclosure of misinformation, by exclusion of distorted information, etc.
14	Adequacy	The degree to which information corresponds to the objective situation in reality.
15	Availability	The possibility to get any piece of information.
16	Currency	The degree to which information corresponds to the current situation and place.
17	Content-richness	The property which is inherent in information and remains intact when it is relocated from one system into another.

18	Importance	The property of being important for the consumer.
19	Identity	Information corresponds to the state of the object.
20	Cumulativity	The property of information to be concentrated in an array of small volume.
21	Protectability	The quality characteristic of information which exists or is used only in a definite system.
22	Identifiability	Its property to be identified under certain conditions.
23	Controllability	Its ability to be produced, transmitted, saved, relocated, changes, etc. by the subject.
24	Accuracy	It corresponds to the demand or requirement of the consumer.

As it is evident from Table 4 one of the properties of information is its measurability, approaches to its evaluation were shown in Table 1. It should also be emphasized that it is only one of the properties. The given set of properties cannot be considered exhaustive.

3. INFORMATION QUANTITY MEASURE

Now let's try and formalize the category of information. Let's introduce into consideration the first-order object as part of the category subject to formalization:

$$I = \{I_1, I_2, .., I_n\}, \tag{1}$$

where I_1 is a symbol, I_2 is a datum, I_3 is a fact, I_4 is a message, and so on.

Now let's introduce the second-order object which characterizes properties given in Table 4, their value, and has the form:

$$S_{ij} = \begin{Bmatrix} S_{11}, .., S_{1n} \\ S_{m1}, .., S_{mn} \end{Bmatrix}, \; i = \overline{1,m}, \; j = \overline{1,n} \tag{2}$$

To emphasize the diversity of implementation modes of objects I, let's introduce into consideration the second-order object

$$I_{tl} = \begin{Bmatrix} I_{11}, .., I_{1q} \\ I_{n1}, .., I_{nq} \end{Bmatrix}, \; t = \overline{1,n}, \; l = \overline{1,q} \tag{3}$$

where each line is an implementation mode of object I, $t = \overline{1,n}$.

Thus, we have got an opportunity to correlate each l-variant of I_t with a definite set of properties, considering the third-order object S_{ijl} for this purpose. Thus, speaking of the category of "information" we can characterize it as a collection of elements (1) or as a set of properties S_{ijl} described in Table 4. The use of index notation can be interpreted the following way: I – information

as a whole; I_i - information as a collection of separate elements; I_{il} – different implementations of *i*-element.

It is reasonable to introduce into consideration a third-order object with an index notation of I_{tlr}. The third-order object can be understood as a detailed description of a certain class of objects. In this case I_{tlr} can be considered as a class of objects *I*. I_{il} is a part of objects of class I_{tlr}, which integrates a number of types of objects of this class. Then, examining the compression of object S_{ij}, we can come to the conclusion that *S* is a measure. Thus, the construction I_{ijk} is a set of projections of object *I* in a system of imaging it through its elements (figure 1), and the construction S_{plr} is a set of projections of the same object *I* in the system of imaging it through its properties (figure 2).

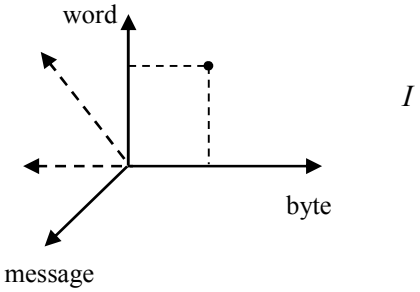


fig. 1

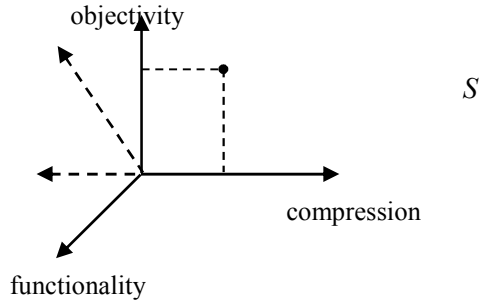


fig. 2

As index constructions I_{ijk} and S_{plr} are different representations of the same object there must be a relation between them which can be defined by the following correlation:

$$S_{ijk} = C_{ip}C_{jl}C_{kr}I_{plr},$$

where C_{ip}, C_{jl}, C_{ip}, C_{kr} are transition matrixes made up of transformation coefficients of projections of imaging objects.

4. INFORMATION QUALITY MEASURE

The transformation which was introduced into consideration allows examining a number of philosophic categories, whose formalization in tensor interpretation is given in Table 5.

There are quite a number of well-known measures to evaluate the quantity of information as was shown in Table 1. However, these measures do not take into account either the semantic content or the properties of information given in Table 4.

Let us consider the construction of measure *S*. To do it let us give each of the properties described in Table 4 a corresponding linguistic variable. Let us introduce into consideration linguistic variables A_i in a form of a tuple $< A_i, T_i, G_i, M_i >$, $i = \overline{1,n}$, where A_i is the name of the linguistic variable (Table 4); T_i is the multitude of its meanings representing the names of fuzzy variables the definitional

domain of each of them is multitude X_i ; G_i is the syntactic procedure which allows to operate the elements of the set theory T_i , in particular to generate new terms; M_i is the semantic procedure which allows to transform each new meaning of the linguistic variable obtained through procedure G into a lexical variable, i.e. to form a corresponding lexical multitude.

Table 5. Traditional and tensor interpretation of philosophic categories

Category	Traditional interpretation	Tensor interpretation	
		Formal	Contention
Essence	The main, basic, defining thing in the content of an object, the reason inherent in an object for all changes taking place during its interaction with other objects	c_{ip}	The organizes system of inner connections of an object, expressed in forces, processes, interactions and relations of its parts.
Form	The scheme, mode of an object's structure	$c_{ip}c_{jq}$	The combination of real inner connections of an object with the structure regulating them.
Quality	The inner and outward specificity of an object, the system of its characteristic features, after losing it the object stops being what it is, integrity identical to the basic law of an object	$c_{ip}c_{jq}c_{kr}$	The collection of inner connections of an object, organized in a certain structure according to a definite archetype being the basic law of its structure and development.
Content	Everything that is present in an object, including its part, relations, connections, processes and tendencies of development, i.e. vectors and gradients of changes in its properties.	$c_{ip}c_{jq}c_{kr}I_{pqr}$	The collection of parts and components of the object, combined by inner relations, organized in a definite structure according to a definite archetype being the basic law of its structure and development.
Whole	The form of existence and cooperation of parts, complex unity of simple, qualitative definiteness of interrelated components.	pq $c_{ip}c$	The collection of parts combined as a whole by a multitude of inner connections organized by a given structure.
		$c_{ip}I_p$	The collection of parts combined as a whole by an organized multitude of inner connections.
Part	What the whole consists of and what it can be divided into or break into.	I_{pqr}	A class of objects of objective reality as a part of the multitude – the universe of all objects
		I_{pq}	The collection of objects-isomers, a part of a class of objects
		I_p	The collection of parts of the whole or a part of the collection of objects-isomers.
Quantity	The outward definiteness of an object	$S_{i..}$	The projection of the object on the perception system axis or its representation by the collection of its inherent properties
Phenomenon	The outward form of existence of an object, the form of manifestation of its nature.	S_{ij}	The projection of the object on the perception system or its representation by the collection of its inherent properties

ISSN 1313-2539, Published at: http://www.science-journals.eu

Using procedure M_i let us define on the multitudes X_i corresponding fuzzy subsets $A_{ij}, i=\overline{1,n}, j=\overline{1,k}$ introducing membership functions $\mu_{A_{ij}}(x_i),\ x_i \in X_i$ for this [45-48]. To work with these membership functions it is reasonable in each case to use corresponding *T*- and *S*-norms, some of which are given in Table 6.

Table 6. Examples of most often used *T*- and *S*-norms

$T(a,b)$	$S(a,b)$	Characteristics
$\min\{a,b\}$	$\max\{a,b\}$	-
$a \cdot b$	$a+b-a\cdot b$	-
$\max\{0,a+b-1\}$	$\min\{1,a+b\}$	-
$\begin{cases} a, & if\ b=1 \\ b, & if\ a=1 \\ 0, & if\ a,b<1 \end{cases}$	$\begin{cases} a, & if\ b=0 \\ b, & if\ a=0 \\ 0, & if\ a,b>0 \end{cases}$	-
$\frac{ab}{\max\{a,b,\gamma\}}$	$\frac{(1-a)(1-b)}{\max\{(1-a),(1-b),\gamma\}}$	$\gamma \in [0,1]$
$\frac{ab}{\gamma+(1-\gamma)(a+b-ab)}$	$\frac{a+b-(2-\gamma)ab}{\gamma-(1-\gamma)ab}$	$\gamma > 0$
$\frac{1}{1+\left(\left(\frac{1}{a}-1\right)^{\gamma}+\left(\frac{1}{b}-1\right)^{\gamma}\right)^{\frac{1}{\gamma}}}$	$\frac{1}{1+\left(\left(\frac{1}{a}-1\right)^{-\gamma}+\left(\frac{1}{b}-1\right)^{-\gamma}\right)^{\frac{1}{\gamma}}}$	$\gamma > 0$
$\frac{1}{\left(\frac{1}{a^{\gamma}}+\frac{1}{b^{\gamma}}\right)^{\frac{1}{\gamma}}-1}$	$1-\frac{1}{\left(\frac{1}{(1-a)^{\gamma}}+\frac{1}{(1-b)^{\gamma}}\right)^{\frac{1}{\gamma}}}$	$\gamma > 1$
$1-((1-a)^{\gamma}+(1-b)^{\gamma}-(1-a)^{\gamma}(1-b)^{\gamma})^{\frac{1}{\gamma}}$	$(a^{\gamma}+b^{\gamma}-a^{\gamma}b^{\gamma})^{\frac{1}{\gamma}}$	$\gamma > 0$
$\max\left\{0,1-((1-a)^{\gamma}+(1-b)^{\gamma})^{\frac{1}{\gamma}}\right\}$	$\min\left\{1,(a^{\gamma}+b^{\gamma})^{\frac{1}{\gamma}}\right\}$	$\gamma \geq 1$
$\log_{\gamma}\left(1+\frac{(\gamma^{a}-1)(\gamma^{b}-1)}{\gamma-1}\right)$	$1-\log_{\gamma}\left(1+\frac{\gamma^{1-a}+\gamma^{1-b}}{\gamma-1}\right)$	$\gamma > 0,$ $\gamma \neq 1$
$\max\{0,(\gamma-1)(a+b)-1-\gamma ab\}$	$\min\{1,a+b+\gamma ab\}$	$\gamma > -1$

In this table *a, b* are corresponding membership functions. Choosing *T*- and *S*-norms and also selecting superstructural characteristics subject to imposed restrictions we can get the results which are close enough to those that are obtained by experts.

Pay attention to the fact that each linguistic variable A_i $card(T_i) = j_i$. Thus, we can give each linguistic variable A_i a corresponding vector with coordinates $\mu_{A_i} = \begin{Bmatrix} \mu_{A_i}^{j_i}(x_i) \\ \mu_{A_i}^{j_i}(x_i) \end{Bmatrix}$.

Let us introduce into consideration a multitude of vectors $\mu_{A_i}(x_i)$ and let it be defined two vector addition operations in L_1 and multiplication of vectors by elements of field *K*. It means that $\mu_{A_i}(x_i) + \mu_{A_i}(x_{i+1})_1, T\left(\mu_{A_i}(x_i), \mu_{A_i}(x_{i+1})\right)$ is installed for $\forall \mu_{A_i}(x_i)$ and $\mu_{A_i}(x_i)_1$, and $T\left(\lambda, \mu_{A_i}(x_i)\right) \in L$ is installed for $\forall \mu_{A_i}(x_i)$, $\forall \lambda \in K$, and properties are satisfied according [48]. Then multitude L_1 with given operations is called linear space.

5. CONCLUSION

Thus, we have got the opportunity to establish relations between *I* and *S* by transforming corresponding coordinates, whose value is defined by the magnitude of membership functions.

By introducing into consideration linear space, in general linear spaces, whose elements are vector membership fuzzy functions, we can definitely show that information is a tensor magnitude, i.e. when corresponding basis changes its coordinates change linearly. So we have developed necessary background for the information theory elaboration which will be based on the methods of tensor analysis and theory of fuzzy multitudes.

REFERENCES

1. Belonogov G, Gilyarevskij R, Khoroshilov A. On the nature of information. Nauch.-techn. information. Ser.2. Inform. processes and systems (Moscow) 2009; 1: 1-6.
2. Chernyj A Magic figures and information. Internat. forum on information 2009; 1: 22-26.
3. Sokolov A. Information ontology. Philosophic essays. Nauch.-techn. information. Ser.1. Organiz. and methodic of inform. work (Moscow) 2010; 2: 1-21.
4. Sokolov A. Information: concept, categories, ambivalent character. Philosophic essays. Nauch.-techn. information. Ser.1. Organiz. and methodic of inform. work (Moscow) 2010; 5: 1-13.
5. Partiko Z. Modern paradigm of information science – informology. Nauch.-techn. information. Ser.2. Inform. processes and systems (Moscow) 2009; 11: 1-9.

6. Belonogov G, Gilyarevskij R. On the gnosiological status of the concept "information" again. Nauch.-techn. information. Ser.2. Inform. processes and systems (Moscow) 2009; 2: 1-6.
7. Shennon K. Works on information theory and cybernetics. Moscow, 1963. P.243-668.
8. Fano R. Transmitting information. Statistic communication theory. Moscow, 1965. 438 p.
9. Kulbuck S. Information theory and statistics. Moscow, 1967. 408 p.
10. Rips Ja. Optimization of planning and assessing the controlling apparatus reliability test results. Moscow, 1976. 80 p.
11. Haken G. Information and self-organization. A macroscopic approach to complex systems. – 2nd ed. Moscow, 2005. 248 p.
12. Bongard M. On the concept "useful information". In: Problems of cybernetics. Issue 9. Moscow, 1963. P.71-102.
13. Kharkevich A. On the importance of information. In: Problems of cybernetics. Issue 4. Moscow, 1960. P.53-57.
14. Hurtley R. Information transmission. In: Information theory and its applications. Moscow, 1959. P5-35.
15. Schrejder Ju. On one of the models of information semantic theory. In: Problems of cybernetics. Issue 13. Moscow, 1965. P.233-240.
16. Eshby U. Introduction into cybernetics. Moscow, 1959. 432 p.
17. Ursul A. On the problem of information in modern science. Moscow, 1975. 287 p.
18. Stratonovich R. Information theory. Moscow, 1975. 424 p.
19. Tyutyunnik V, Doronkin V, Dyachek A, Smolkov V. From conceptions of information to the understanding of information science. In: Information science and science of science. Tambov, 1986. P.2-5.
20. Tyutyunnik V. Interdependence of information science and science of science: the data analysis and models. Tambov, 1989. P.1-3, 29-35.
21. Gilyarevskij R. Information culture in higher education institutions. Nauch.-techn. information. Ser.1. Organiz. and methodic of inform. work (Moscow) 2007; 2: 18-22.
22. Romanenko V, Nikitina G. The concept of "information". In: Network information retrieval: manual. S.-Petersburg, 2005. P.36-40.
23. Kolin K. Philosophy of information and fundamental problems of modern information science. Russia's information resources (Moscow) 2010; 1: 25-28.
24. Maksimov N. Infomedia of science and education: from information service to distributed system of knowledge control. Inform. society (Moscow) 2009; 6: 58-67.
25. Maksimov N. Information and knowledge: nature, conceptual model. Nauch.-techn. information. Ser.2. Inform. processes and systems (Moscow) 2010; 7: 1-10.
26. Klimeshova D. Transformation of data, information and knowledge. Intern. forum on information 2009; 4: 3-8.
27. Gurevich I. Information as universal discontinuity. Inform. technologies. 2010; 4: 66-74.

28. Volchenkov E. On the nature of information: physical-semantic approach. Nauch.-techn. information (Moscow) 2010; 3: 1-7.
29. Vyatkin V. A synergetic approach to defining the quantity of information. Inform. technologies 2009; 12: 68-73.
30. Bushuev S, Osadchij A, Frolov V. Theoretical foundations of building information-technical systems. S.-Petersburg, 1998. 404 p.
31. Branch standard of State Committee of Higher Education of Russian Federation 01.002-95. Information technologies in Higher education institutions. Terms and definitions. Introduction date 01.03.96.
32. Gorskij D, Ivin A, Nikiforov A. Abridged dictionary on logics. Moscow, 1991. 208 p.
33. Artificial intelligence: Application in integrated manufacturing systems. Moscow, 1991. 544 p.
34. Law of Russian Federation № 24-ФЗ "On information, informatization and information security". 1995. 20 Febr.
35. Rostovtsev Ju. Foundations of building of automated data-gathering and processing systems: textbook. S.-Petersburg, 1992. 718 p.
36. Information science: textbook. Ed. N.Makarova. Moscow, 1997. 768 p.
37. Dictionary of terminology on the problem "Data bases in computer networks". Moscow, 1984.
38. Architecture, interfaces and protocols of computer networks (basic list of terms). Riga, 1988. 119 p.
39. Pershikov V. Glossary on information science. Moscow, 1991. 543 p.
40. Jakubajtis E. Information networks and systems: reference book. Moscow, 1996. 368 p.
41. Tsikridis D, Lohovsky F. Data models. Moscow, 1985. 344 p.
42. Gavrilova T, Horoshevskij V. Databases of intellectual systems. S.-Petersburg, 2000. 384 p.
43. Glossary on computer systems. Moscow, 1991. 560 p.
44. Kofman A. Introduction into the theory of fuzzy multitudes. Moscow, 1982. 432 p.
45. Kuzmin V. Group decision construction in spaces of well-defined and fuzzy binary relations. Moscow, 1982. 168 p.
46. Averkin A, Batyrshin I, Blishun A. Fuzzy sets in management and artificial intellect models. Moscow, 1986. 312 p.
47. Borisov A et al. Processing fuzzy information in decision-making systems. Moscow, 1989. 304 p.
48. Manturov O. Elements of tensor calculus: teaching aid for students of physics and mathematics of teachers' training institutes. Moscow, 1991. 255 p.