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Information Ecology in the Context of General Ecology

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Abstract: The ecological approach studied in this paper is a new level of information studies. It allows for achieving a better understanding of information processes in society as well as more efficient creation of information processing systems. At first, in Section 2, we describe and analyze ecological studies in different areas ranging from biology to technology to sociology to knowledge and information. Then, in Section 3, we present elements of general ecology building methodological and philosophical foundation for information ecology. In Sections 4 and 5, we elaborate a concise definition of information ecology and further develop information ecology as a methodological base for information studies in general based on the concepts and principles of the general theory of information.

Keywords: information; ecology; process; environment; interrelations; subject information; object information; model; structure; pattern

1. Introduction

Information is a very complex phenomenon. It is possible to study information on several levels.

The first level is oriented at information as a fundamental phenomenon in nature, society and technology exploring properties and relations of information. Examples of theories from the first level are the general theory of information [1] and qualitative information theory [2]. The fundamental essence and intrinsic nature of information is of the primary importance for scientific research. There have been many discussions and various suggestions related to these issues. The most advanced and comprehensive answer is obtained in the general theory of information.

The research regarding the second level investigates information processes. Shannon's information theory [3,4], theories of information flow developed by Dretske, Barwise and Seligman [5–7] and operator information theory [8,9] are examples of theories from the second level. Dynamics of information has prevalent significance for contemporary society because humankind came to the information era.

On the third level, researchers investigate information systems and processes going in these systems making emphasis on the products and services of information process and the interrelations between information and the products/services in the information environment. The ecological approach to information belongs to this level [10–13].

The research in information ecology is based on the global view on existing interrelations between information, knowledge, data and information processing systems. Ecological approach in information studies presupposes synthesis of knowledge and cognition from the first two levels developing the most comprehensive and wide-ranging picture of information reality.

This paper is aimed at building foundations of information ecology using principles of general ecology developed by Burgin [14] because any science in general and information ecology, in particular, need sound and flexible foundations.

It is necessary to understand that there are many interesting and important problems related to studies of information. However, because information is one of the basic phenomena of the world, everything is more or less related to information. The scope of information ecology does not include all phenomena of the world. By the same token, celestial mechanics studies dynamics of planets but tells nothing about people living on one of these planets. Plant ecology does not discuss atoms and molecules although all plants consist of atoms and molecules. This is the scientific approach when each science has its own domain and we build information ecology as a scientific discipline.

That is why, for example, here we do not discuss the diversity of definitions of information suggested by different researchers but base our work on the axiomatic definition from the general theory of information as the most advanced and encompassing theoretical model of information [1].

2. A Brief History of Ecological Studies

The basic for ecological studies concept of ecosystem appeared in 1864 in the book "Man and Nature" by George Perkins Marsh. However, according to [15], the term ecosystem was derived much later by Arthur Roy Clapham by Tansley's request [16].

German scientist Ernst Haeckel (1834–1919) coined the term *ecology*, or *Ökologie* in German, in 1866 constructing it from two Greek words. The first of them *oikos* is in English is translated as *house*, or more generally, *habitat* or place of living. At the same time, the second word, *logos* was used by ancient Greeks signifying such concepts as *order*, *meaning*, *foundation* or *mind* [17]. Haeckel's approach encouraged European botanists to study plant populations related to definite areas and their interdependencies. This gave birth to the early science of ecology, which was studying not only plants but also animals and other living beings. Later this field has become biological ecology comprising more living organisms.

In the contemporary context, ecology is mostly understood as a holistic exploration of living systems with their connections to their environment by finding patterns of, processes in and interrelationships between these systems and their surroundings.

It is important that ecology, or more exactly, biological ecology, as a whole contains two subfields—plant ecology and animal ecology.

Plant ecology explores the allocation and profusion of plants, the impact of environmental factors upon systems of plants, and the interactions among and between plants and other organisms [18].

Animal ecology is a scientific field that explores the allocation and profusion of animals interacting with each other, as well as with their surroundings, which controls the dispersal and abundance of living organisms.

Together these two scientific fields constitute *natural ecology*, or *biological ecology*, which is often simply called ecology. Later researchers also created other ecological disciplines. One of the most basic is *human ecology*. It is defined as an interdisciplinary and transdisciplinary research of the relationships between humans and their natural, social, and technological surroundings. It engages an assortment of disciplines such as sociology, anthropology, psychology, zoology, public health, epidemiology, home economics, geography, and natural ecology, among others [19].

In contrast to traditional ecology, which is dealing only with natural systems, the new field of *industrial ecology* emerged. It studies industrial manufacturing as part of larger organizations and processes, which include industrial functioning and biogeochemical reactions as a part of an arrangement, and aims at reduction of the negative environmental effects of manufacturing, expenditure, and disposal.

There is also *business ecology*, which studies business organizations in the context of *business ecosystems*. Theyare dynamic networks of mutually dependent organizations that rely on each other. Such components as compartments separated by the organization's walls, distribution channels and direct suppliers are investigated in business ecology. Other constituents that can have a significant effect on the core business such as trade associations, direct customers, standards bodies, regulatory bodies, suppliers of complementary products, unions, investors, are also included in business ecosystems.

Yixin Zhong initiated studies of *information ecology* in China [10]. Independently, Western researchers started their exploration of information ecology [12,13]. Information ecology has the foremost importance for information area as a holistic methodology to knowledge acquisition about the nature and behavior of information processing systems, as well as for improved comprehension of information processes in all realms of the world. If ecology of animals studies the processes and interrelations in systems of animals, information ecology investigates the processes and interrelations in associations of information processing systems and configurations.

Researchers also study *knowledge ecology* [20–23]. It is a methodology of knowledge management, which is aimed at advancing the dynamic development of knowledge contacts between organizations to improve decision-making and innovation using superior evolutionary networks of cooperation. In comparison with the merely directive-oriented management, which tries either to administer or to control outcomes, knowledge ecosystems promote knowledge strategies that concentrate more on enabling adaptable self-organization and self-improvement reacting to changing surroundings.

Introduction and utilization of the concept *digital ecosystem* instigated the development of *digital ecology* [24]. A digital ecosystem is a distributed, flexible, adaptive, amenable socio-technical system with features of self-organization, self-operation, scalability and sustainability motivated by the concept of natural ecosystems.

Specialization of the concept digital ecosystem brought forth digital health ecosystems [25,26], digital service ecosystems [27], digital transportation ecosystems [28] and digital business ecosystems [29]. The latter are defined as combinations of digital systems used in the business, the people that interact with them, and related business processes and technology environment. A digital business ecosystem emerges in coupling of digital business ecosystems to the socio-economic system of its users [30].

Mark Burgin introduced and studied *techno-ecology* [31].

Damiani, Uden and Trisnawaty introduced E-learning ecosystems [32].

Gregory Bateson introduced *ecology of mind* [33].

In a similar way, American anarchist and libertarian socialist author Murray Bookchin originated the field called *social ecology*, which is a critical study of the existing society [34].

3. Fundamentals of General Ecology

The fundamental concept of *ecosystem* (*ecological system*), which is pivotal for different ecological disciplines, wasproposed by the English ecologist Arthur Tansley in the context of natural ecology. Here we define this concept in a much broader context comprising the existing diversity of ecological disciplines. With this goal in mind, we demonstrate the impact of the global structure of the world on the organization of ecosystems.

There are different models of the world where people live. Some assume that only material (physical) reality exists. Others add to it individual mentality called Mind. Here we based our study on the most advanced large-scale structure of the world, which has the form of the *Existential Triad* [1]. It is given in Figure 1 being scientifically elucidated in the book [35].

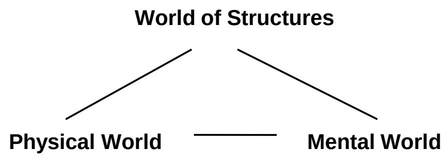

Figure 1. A graphical representation of the Existential Triad of the World.

The three worlds, which constitute the Existential Triad, are not disconnected realities: they interact and traverse. The mental world includes individual mentality. It is based on the brain, which is a material thing, but includes mind. Mind-Brain relations have been discussed by many philosophers in the context of the mind-body problem and there is no mutual consent on this problem. However, here we are not going to discuss all different approaches and opinions in this area because this is not the goal of this paper. Besides, it is necessary to understand that this problem belongs to the second level of information and cognitive studies while information ecology bring these studies on the higher, third level. At the same time, many physicists think that mentality impacts physical world (cf., for example, [36]). This is only a working hypothesis but it is definitely established that our knowledge of the physical reality principally depends on interface between mental and physical worlds. Note that in the context of the Existential Triad of the World, there is no fundamental distinction between material and physical worlds.

However, not only people but also all forms of information processing systems have their specific mentality. For instance, the content of the computer's memory can be logically considered as the inherent mentality of this computer. Thus, the operating system or word processor is a basic part of the mentality of the computer.

The World of Structures provides a scientific embodiment of Plato's World of Ideas/Forms because ideas or forms are properly associated with structures [37]. As it is demonstrated in [35], existence of structures is validated by observations and experiments in a similar way as it is done for material things, such as tables, chairs, or buildings. As a result, structures form the *structural level* and *component* of the world. When it is necessary to, it is done, as a rule, by means of knowledge of structures is vital for learning or creating systems and processes. Structures, which also include different interrelations and geometric forms, shape material things in their existence and comprehension.

Ecological approach allows explication of homological processes in the physical and mental worlds. In the physical world, the growth of organization and complexity goes through the following stages:

Energy begets **matter**, while **matter** begets **life**

In the mental world, the growth of organization and complexity goes through the following stages:

Information begets **knowledge**, while **knowledge** begets **intelligence**

These stages form two triadic structures:

$$\textbf{energy} \xrightarrow{\text{begets}} \textbf{matter} \xrightarrow{\text{begets}} \textbf{life} \tag{1}$$

$$\textbf{Information} \xrightarrow{\text{begets}} \textbf{knowledge} \xrightarrow{\text{begets}} \textbf{intelligence} \tag{2}$$

In more detail, these relations are validated, studied and explained in the book [1].

The global structure of the world in the form of the Existential Triad brings on three categories of ecosystems:

- *Physical ecosystems* comprise physical systems, arrangements and processes as its elements, parts and components
- *Mental ecosystems* encompass mental schemas, arrangements and processes as its elements, parts and components
- *Structure ecosystems* consist of structures of physical systems, arrangements and processes as its elements, parts and components

For instance, a mathematical model of a material ecosystem is a structure ecosystem, while a mental model of a material ecosystem is a mental ecosystem. Other examples of structure ecosystems are mathematical models of scientific theories when the processes going in these systems are included in the model (cf. [38–41]).

Combining all three components of the world stratification in one system, we come to a *total ecosystem*. Total ecosystems have three basic constituents:

- The *physical constituent* of the ecological system and its environment comprises physical systems, arrangements and processes
- The *structural constituent* of the ecological system and its environment consists of structures of physical systems, arrangements and processes
- The *mental constituent* of the ecological system and its environment encompasses mental schemas, arrangements and processes

A general ecosystem is determined by three characteristics:

- A section in the physical (mental or structural) space (or a region on a scientific sphere), i.e., it is presumed that all elements and components of an ecological system belong to a definite section in the space (or a definite region on a scientific sphere).
- The key categories of its elements, parts and components, i.e., it is determined what elements, parts and components of the specified ecological system are treated as the most imperative from the perspective of ecological studies.
- The principal sorts of connections and interrelations between its elements, parts and components, including processes as dynamic connections, i.e., it is determined what relationships, ties and processes in the specified ecological system are treated the most basic from the perspective of ecological studies.

For instance, living beings constitute the primary class of elements in natural ecosystems and a selected area on the Earth molds the section in the space of these ecosystems. In this framework, a natural ecosystem is built of the dynamically interacting constituents including primary living beings in a given area, which interact with each other and with their non-living surrounding.

To formally define an ecosystem, we consider three classes:

- A class R of regions in the space, for example, forest region or desert region on the Earth
- A class E of elements and components, for example, animals living in the region, plants growing in the region and abiotic elements, such as rivers or mountains, in the region
- A class C of ties and relations between its elements/components including processes as dynamic ties

Definition 1. *An (R, E, C)-ecosystem is a system of elements from E, which belong to a region r from R and tied/interrelated in the system by connections from C.*

Information processing systems constitute the primary type of elements in an information ecosystem and a selected area on the Earth (may be the whole Earth) forms the section in the space where information processing systems are interacting with each other as well as with their surroundings. Besides, investigation of information ecosystems contemplates information processes going in or related to the system.

It is necessary to remark that there are various kinds and sorts of information processing systems such as living information processing systems, technical information processing systems, human information processing systems, digital information processing systems and so on.

There are three grades of (types of) parts, components and elements in information ecosystems:

- *Primary* or *leading* parts, components and elements
- *Secondary* or *auxiliary* parts, components and elements
- *Tertiary* or *background* parts, components and elements

Ecological studies in all fields are oriented at understanding existence and behavior of the primary parts, components and elements of ecosystems, as well as critical connections, ties, interrelations and processes in considered ecosystems.

Primary and other elements of ecosystems belong to populations of similar entities. For instance, in natural ecosystems, elements belong to populations of human beings, animals, plants and viruses.

4. Methodological Issues of Information Studies

It is well-known that information is a category of critically important resources for human beings as well as for all kinds of living beings. As a result, humans have information processing and utilization organs, which are able to handle information: (1) the sensing organs receive information from the environment; (2) the nervous system including the brain processes and transmitting information from one point to another within human body producing knowledge and intelligent strategies for problem solving; and (3) action organs, which are controlled by information coming from the nervous system, execute strategies developed in the brain. In addition, people have created an abundance of technical information devices and instruments for enhancing functions of human information organs in information handling. Examples of such systems are different kinds of sensors, communication systems and networks for information transmission and distribution, computer systems for information processing, artificial intelligence systems producing knowledge and making decisions, control systems for strategy execution, and so on.

However, there is contrast between functioning of the human information organs and operations in technical information systems. On the one hand, assuming a satisfactory state of the whole organism, human information organs have always been working effectively and smoothly with well-balanced interrelationships among them continuously facilitating the development of people. On the other hand, various kinds of technical information systems constructed for enhancing human information organs were not able to achieve sufficient harmony between technical systems, human beings and the environment.

The problem lies in establishing relevant connections between technical information systems. At the beginning, many such systems, e.g., computers were designed without interconnections between them. Later with the advance of local and global computer networks such as the Internet and local networks, technical information systems have become more and more interconnected but they still did not achieve harmony and efficiency of information processing system of human beings.

5. Ecological Approach as a New Methodology for Information Studies

Let us consider information ecology as a methodology for information studies. It will allow us to understand what progresses could be achieved based on this methodology and what opportunities can be gained in applications.

5.1. The Concept of Information Ecology

As usual, the definition for a new terminology is necessarily needed first so that the understanding and the application of the terminology in the future can be precise as well as reliable. The definition of information ecology shall, of course, keep the spirit of the definition of the general ecology.

Definition 2. *Information ecology is a holistic study of information processing systems in the context of their surroundings by explicating patterns of, processes in and interrelationships between these systems and their components in the context of their environment.*

The efficacy of this definition is demonstrated by application of ecological principles in other areas, such as plant ecology, animal ecology and other kinds of ecology considered in Section 2. For instance, importance of relationships between the system and its environment is well explained in the book [17] and it is not necessary to repeat those arguments here.

Defining information ecology, we do not define information or information processing because the definition of information and information processing belongs to Level 1 of information studies, while information ecology is Level 3 of information studies. That is why in this paper, we do not discuss different approaches to the definition of information but take as the basic the definition of information from the general theory of information, the most detailed exposition of which is given in the book [1].

From the perspective of scientific research, there are two basic approaches to the studied phenomena—reductionism and holism. The major feature of reductionism is dividing a complex system into elements and reducing the theory of the system to the theory of its elements. Holism goes in the opposite direction assuming that basic properties and functioning of a complex system cannot be deduced from properties and behavior of its elements.

Ecological theory in general and information ecology in particular base their studies on holistic approach because relations, connections and processes uniting separate elements in an integrated system produce synergy making the whole system irreducible to its elements. Ignoring these regularities of system science can cause various misconceptions and result in waste of time and energy in human society.

5.2. Information Ecology as a Research Model

A critical issue of any research in general and information studies, in particular, is correct selection of an adequate basic structure for representation, modeling and exploration of the research domain. An important innovation of information ecology is introduction of the triadic structure "subject–object-interaction" as the basic system of information studies [42,43]. This structure is described in Figure 2.

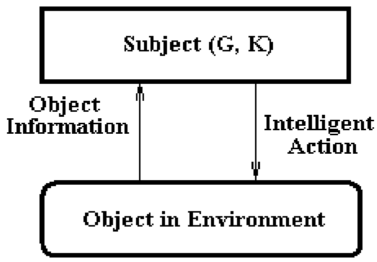

Figure 2. The triadic informational structure "subject–object-interaction".

The structure "subject–object-interaction" consists of three components:

- *Subject* can be any intelligent system possessing knowledge and goals and treated from the information perspective although the most typical, most characteristic, and thus, the most meaningful, subjects are human beings who have complex goals and enough knowledge.
- *Object* can be any information processing system imbedded in its environment.
- *Interaction* consists of processes that go between the Subject and the Object.

Triadic structures, such as "subject–object-interaction" are very important. As Lao Tse writes:

The Way produces one;
one begets two;
two begets three;
and three brings about the whole world.

Lao Tse, *Tao TeChing*

In a more general context, the structure "subject–object-interaction" is an important kind of bidirectional fundamental triad, which is also called a bidirectional named set [44,45]. Identifying "subject–object-interaction" as a fundamental triad or a named set allows using mathematical theory of named sets developed in [44] for modeling and exploration of cognitive processes.

This shows fundamentality of "subject–object-interaction" because it is proved [44,46,47] that fundamental triads constitute the most critical structure in nature, mathematics, society and cognition supporting the insight of Lao Tse. In addition, it is demonstrated that fundamental triadsare indispensable for a diversity of domains including information theory, mathematics, chemistry, physics, networks and networking, logic, AI, database theory and practice, mathematical linguistics, biology, epistemology, philosophy and methodology of science, to mention a few.

In the graphical representation (cf. Figure 3), a *basic fundamental triad* or a *basic named set* has the following appearance:

$$A \xrightarrow{\quad c \quad} B$$

Figure 3. A basic fundamental triad or a basic named set.

In the symbolic representation, a basic fundamental triad has the form $\mathbf{X} = (A, c, B)$ where A and B are two objects and c is a tie or correspondence (e.g., a binary relation) between A and B. In fundamental triad $\mathbf{X}$, the object A is called the *support* of $\mathbf{X}$, the object B is called the *component of names* (*reflector*) or *set of names* of $\mathbf{X}$, and c is called the *naming correspondence* (or *reflection*) of the triad $\mathbf{X}$. It is necessary to understand that in the fundamental triad $\mathbf{X}$, c is not always a function or a mapping.

In the typical example of a basic named set (fundamental triad), the object A consists of people, the object B consists of their names and c is the connection between people and their names. Another example is a basic named set (fundamental triad) the object A comprises books, the object B comprises their titles and c is the association between books and their titles.

In the graphical representation (cf. Figure 4), a *bidirectional fundamental triad* or a *bidirectional named set* has the following appearance:

$$A \xleftrightarrow{\quad c \quad} B$$

Figure 4. A basic fundamental triad or a basic named set.

In the symbolic representation, a bidirectional fundamental triad has the form $\mathbf{X} = (A, c, B)$ where A and B are two objects and c is a tie or correspondence (e.g., a binary relation) between A and B which goes in two directions.

An important example of a bidirectional named set (a bidirectional fundamental triad) is given by two people who are communicating, i.e., exchanging messages, e.g., by e-mails, using messaging or talking to one to another. In this bidirectional fundamental triad, A and B are people while c consists of messages going from one person to another.

In situations when mathematicians, physicists or computer scientists utilize connections or ties without definite direction, such as edges in general graphs, in essence, these ties have both directions as in a bidirectional fundamental triad.

Thus, we can see that the structure "subject–object interaction" (see Figure 2) is in fact a comprising model in the world of information providing efficient means for information studies in general and information ecology as their methodology.

The triad "subject–object interaction" explicates the situation when the object contains information for the subject and it is natural to call it "object information". In the process of interaction, the subject, having received the object information, often acts on the object physically, structurally or/and mentally.

The action produced by the subject should be sufficiently intelligent to avoid certain risks. Intelligent action must satisfy two conditions:

(1) It has to be aimed at achieving the subject's goal;
(2) The interaction of the system and the environment should be harmonious.

Another point worth of mentioning is that the subject in the triad "subject–object interaction" is not necessarily a single individual person. Instead, it may be a group people, an organization, or even the entire society as long as it has the common goal and knowledge.

While the model of information studies based on the triad "subject–object interaction" is fundamental, it is extremely abstract. To be closer to the scientific research in information discipline and even more to information processing practice, it must be specified in more detail giving an expanded picture and efficient structure of information processing systems and their dynamics in an adequate environment.

Living beings, such as people, animals and plants, consume energy, for example, energy coming from the Sun, and material things, such as water or air, with the goal to produce energy and substance for sustaining themselves and producing other material things. In a similar way, information processing systems consume information and structural objects, such as data and knowledge for producing new information and knowledge and achieving intelligence. These processes provide for the construction of the next level of the model for information studies, which is presented in Figure 5 [42].

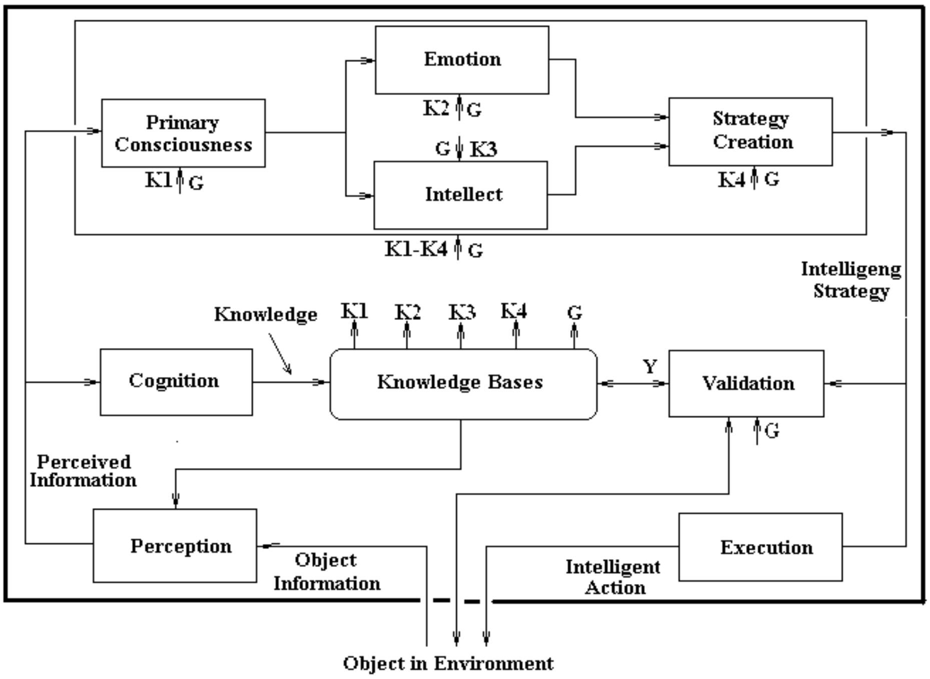

Figure 5. A detailed model for processes in information studies.

As we can see, the model in Figure 5 can be treated as an expansion of the model in Figure 2 by specification of the subject and processes in the triad "subject–object interaction". As a result, we have the following processes:

(1) The object information is converted to perceived information by perception mechanisms.
(2) The perceived information is transformed into knowledge by the mind.
(3) The perceived information, complemented by the related knowledge and directed by subject's goals, is successively generates consciousness, emotions, and intellect, which are integrated in the brain and in turn, generate intelligent strategy.

(4) Intelligent strategy is converted to intelligent action via execution mechanisms.
(5) The created intelligent action is finally applied to the object, forming the first cycle the subject–object interaction.

We call this process the *perception-processing-action cycle* because it is repeated in intellectual activity of people.

If the result caused by the intelligent action differs from the goal, the subject receives information about the error and repeats the perception-processing-action cycle. This cycle is also repeated for obtaining more knowledge, optimizing the strategy and getting a better result with a smaller error and/or decreasing consumption of resources.

The model for information studies presented in Figure 3 indicates that information discipline is a large extremely complex system involving diverse human information activities.

It is necessary to remark that there are three levels of perception.

The first level is *reception* of information transmitted from a sender to a receiver. On this level, only information transmission without information processing takes place.

The second level is *perception* of information that comes from a container/source of information to the recipient. On this level, information transmission is followed by information processing.

The third level is *cognition* when the cognizer extracts/obtains information from a container of information. On this level, information extraction involves essential information processing and production of new information.

5.3. Ecological Approach in Information Studies

After elaborating a general model for information studies on the third level considered in Introduction, we develop a *research technological approach* based on this model.

There have been a number of different approaches adopted in information study: structural approach, functional approach, and behavioral approach, to name a few. Each of them has made some progress while also has faced challenges. Which one would be the most appropriate to the information study?

As is stressed above, the focus of the information ecology as methodology is the study of the interrelation between information processing systems within an organization. From the model of information discipline in Figures 2 and 5, it is possible to see that the essence of information processes is the information flow, which converts object information into perceived information proceeding to knowledge, elaborating an intelligent strategy for action and finally, resulting in intelligent actions. This structure forms the basic loop of the flow, which constitutes the lifeline of information processing system. The crucial problem for information processing system is how to construct a mechanism via which the information flow can successfully be realized, controlled and operated.

As a matter of fact, the role that the *structure* and the *function* of an information processing system can play is to serve for, and support to, the mechanism of the system so that the information flow can be realized while the *behavior* of the system is the outcome of the mechanism implementation. The soul of the flights is the principle of air dynamics, not the specific structure of the bird. Similarly, the soul of information processing systems is the mechanism with which the information flow of a system can be produced, instead of the structure, functions, or behavior of the system itself [48].

It is clear from the performed analysis that the approach, which consists of series of information conversions, is the most appropriate approach to information studies. This is the essence of information ecology as a methodology in the information discipline.

5.4. Basic Relations and Processes in Information Ecological Systems

Based on the described guidelines of information ecology as a methodology and the model for the study of information discipline, it is possible to explicate several important categories of interrelations in the information ecological model [49].

Here we analyze interrelations between object information and perceived information, which form the first category of basic interrelations according to information ecology. Our analysis is based on the axiomatic definition of information elaborated in the general theory of information [1].

For a long time, most researchers thought that human sensing organs and technical sensors perform the corresponding conversion of object information into perceived information. Nevertheless, this is not true. For instance, the concept of information defined in Shannon's information theory does not provide a comprehensive representation of perceived information, but reflects only one of its components. Therefore, it is necessary to clarify what is object information and what is perceived information before doing other things.

Definition 3. *Object information is information contained in an object.*

It is obvious that every object in reality is producing and presenting its object information all the time. Object information is a kind of pervasive phenomenon and is determined only by the object, and has nothing to do with the subject's factors. This is why that object information is sometimes named as ontological information.

Definition 4. *Perceived information is information perceived by the subject, i.e., received, accepted and preprocessed.*

Perceived information is also called *epistemological information*.

As we can see from this definition, the perceived information has three components: syntactic information related to the form of the object, semantic information related to the meaning (or content) of the object, and pragmatic information related to the utility of the object with respect to the subject's goal. For any subject, the three mentioned components form a triad. It is rare in reality, often even impossible, that a subject in general and human subject, in particular, is interested only in the form of an object without taking into account its meaning and utility.

Thus, what are interrelations between the object information and perceived information?

The answer can be found by utilization of the model from Figure 5, which shows how three components of perceived information are produced by human beings and in the components of other intelligent systems.

As we can see from Figure 6, object information is applied to subject and then the subject produces perceived information expressed with its three components in order: syntactic, pragmatic, and semantic information successively. This schema is essential for all kinds of cognitive processes.

More specifically, there are three steps in human beings and other information processing systems for conversion of the object information to perceived information (cf. Figure 4):

(1) Syntactic information production

The syntactic information on the lexical level is first produced by sensing organs information preprocessing and is formed in sensual data. After this production, obtained data, which contain syntactic information, are organized in higher syntactic structures by preprocessing.

(2) Pragmatic information production

(2-1) If the subject has experienced the object before and pragmatic object information has been stored in the subject's memory as {syntactic (n), pragmatic (n)} where n is the name of the object, then it is very easy to produce pragmatic information via recalling, that is, by using the syntactic information obtained at step (1) in the same way as key words are used for retrieving information from the memory. As long as the "syntactic (n)" is matched with the key words, pragmatic (n), which is related to syntactic (n), is pragmatic object information.

(2-2) If the object is a new one and the subject has never experienced it before having no information in the form {syntactic (n), pragmatic (n)} stored in memory. Then there is no possibility to produce the pragmatic information through recalling. In this case, the pragmatic information can be produced via direct testing—making a real experiment to see if the object has any utility related to the subject's goal.

(3) The semantic information production

According to [10], subject's semantic information about the object is the subject's understanding of the object's meaning. So, semantic object information can be produced by the process of abstracting the system {syntactic (n), pragmatic (n)}, which is established in steps (1) and (2), into the semantic space.

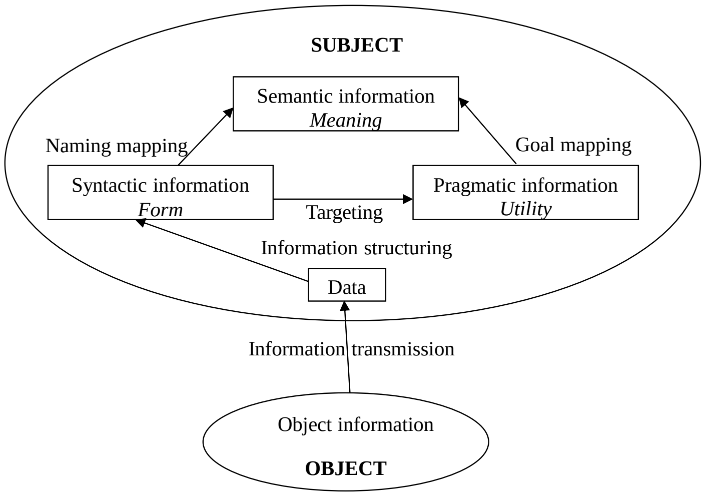

Figure 6. Conversion of object information into perceived information in intelligent systems.

As a result, after the steps (1), (2), and (3) were successively performed, all three components of perceived information—syntactic information, pragmatic information, and semantic information—have been produced and available. This shows that interrelations between object information and perceived information are properly described by three steps, which are described above.

It is interesting to note that steps (1) and (2) are easy to understand whereas step (3) is much more complicated. This is caused by the fact that both syntactic information and pragmatic information are specific and thus, can be produced directly using sensing organs and recalling whereas the semantic information is abstract in nature and can only be produced via the abstraction of both syntactic and pragmatic information.

Note also that if syntactic information is denoted by the symbol X, pragmatic information by the symbol Z, and semantic information by the symbol Y, then according to Figure 6, the essence Y can be derived from X and Z, which is possible to represent by the following expression:

$$\mathrm{Y} = \lambda(\mathrm{X}, \mathrm{Z}) \tag{1}$$

The symbol λ in Expression (1) stands for an operator of *abstraction* and *naming*, which are basic operation in the theory of named sets [44]. In fact, Expression (1) can be regarded as a strict definition of semantic information improving understanding that existed before.

In addition, Expression (1) implies that semantic information can represent the union of both syntactic and pragmatic information. Consequently, whenever semantic information is obtained, syntactic and pragmatic information are also obtained. This explains why people are mostly concerned with semantic information and less with syntactic and pragmatic information.

As a matter of fact, there is already large number of works related to and discussing syntactic, semantic and pragmatic information in the context of the research field called "semiotics". Unfortunately, they pay too little attention to the study of relationships between the three types of information in spite of their fundamentality and importance for semiotics.

Information studies have paid more attention to syntactic, semantic and pragmatic information. In information theory, there are developed theories of these types of information (cf., [1]) although the main emphasis is, as a rule, made on one type of information. Information ecology aims at systemic exploration of systems that include syntactic, semantic and pragmatic information as their subsystems.

6. Conclusions

We have discussed advantages of information ecology as a methodology for information studies in the context of general ecology. The background, the concept, the progresses achieved, and the significance related to the new methodology have been described.

At the same time, one paper cannot include everything from the scope of information ecology. Other problems are considered elsewhere. Note that having understood the model expressing the interrelation between object information and perceived information in humans in Figure 4, it is essential to investigate whether the interrelation between object information and perceived information can be implemented technically. This will be done in subsequent publications of the authors.

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