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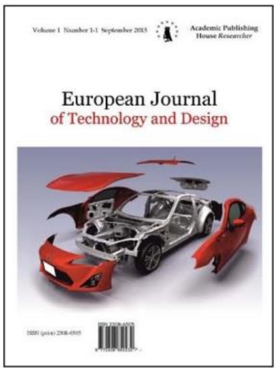

System Information

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Abstract

The article analyzes the system information as a particular type of information, describing complex systems. It is shown that system information can only exist in complex systems with the property of emergence. The work describes the basic formal descriptions of complex systems. This article describes the evolution of the linear description of complex systems. The article contains set-theoretical descriptions of complex systems. Descriptions of complex systems, including system information explicitly, have been obtained. The article provides insight into the contents of the system information. The article introduces the definition of system information.

Keywords: information, complex system, system approach, system description, system information.

1. Introduction

System information can be interpreted in different ways. The first concept. Systematized information, which has the properties of systematization and can be considered as a system. Information as a system is rather data system (Marz, 2015; Naghshtabrizi, 2008), although there are continuous discussions on the difference and similarity between "data" and "information" concepts (Pras, 2002). The second concept. Information, which describes the system signs (Kaleem, 2012; Cohen, 2016). The third concept. Information, describing a complex system (Johnson, 2006; Funtowicz, 1994). The fourth concept. Information, which creates the property of emergence in a complex system (Damper, 2000; Steed, 2012). Let's focus on the last variant: system information as characteristic of systematization and emergence of a complex system.

2. Materials and Methods

Numerous papers on system analysis, emergence and general systems theory have been used as materials. System and phenomenological analyses have been used as methods.

Formal Description of Complex Systems

In many descriptions of complex system (Funtowicz, 1994; Hall, 1956; Bar-Yam, 1997), there in no place for information, especially for system information. The simplest description of complex system includes the structure of the system, elements and relations.

$$SYS = < Pr, Str, E, C, R>, (1)$$

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where (1) *Pr* – combination of parts of the system. *Str* – system structure. *E* – set of elements in the system; *C* – set of links in the system. *R* – set of relations between elements, parts and subsystems. This definition indicates, that the system is composed of different-type parts and has a structure.

When moving from an abstract complex system (*SYS*) to the application system (*AS*), it is required to include the existence of a goal. In this definition let's add to the already considered list (1) the set of goals (*G*). In this case, the application goal-defined system has the following description:

$$AS = <Ps, Pr, Str, E, C, R, G>, (2)$$

Ps – set of subsystems; *G* – set of goals, and all other parameters are the same as in (1). Expression (2) characterizes the goal-defined system. Alternative goal-defined systems are comprehensive multipurpose systems.

If to include the inputs and outputs into the description, then we will get open system description.

$$AS = <Ps, Pr, Str, E, C, R, G, int, out>, (3)$$

where *int* – set of inputs, *out* – set of outputs of the system. Availability of inputs and outputs of the system separates the system from the environment and allows to simulate the informational and physical interaction of the system with the environment. The boundaries of interactive system with many inputs and outputs are, in many cases, rather difficult to be defined. As a criterion, allowing to define those boundaries, force of relations between elements may be selected. This allows to separate from the system the internal elements and boundary elements. Boundary elements define the boundaries of the system. A system exists only when the force of relations between elements is stronger than the force of relations with the environment. In some cases, the concepts "closed" (2) and "open" (3) system are used, implying the presence or absence of relations with the environment. Closed systems can be considered as some abstraction, used for local research purposes.

In a number of targets, the time of performance of operations in the system or by the system is very important. The functioning of the system occurs within a certain range of time – interval (ΔT). In this case, the processes, occurring in the system and in the environment, are considered, and the dynamics of the system functioning is taken into account. These concepts are not used for abstract complex system. It appears for the application system (*AS*). In this case, description (3) should be supplemented by parameter ΔT – time of operational response of the application system:

$$AS(t) = <Ps, Pr, Str, E, C, R, G, int, out, \Delta T >, (4)$$

Inclusion of the cognitive factor *Cog* in the system generates a human-machine system (*HMS*), which can be described as follows:

$$HMS = <Ps, Pr, Str, E, C, R, G, int, out, \Delta T, Cog >, (5)$$

Expression (5) describes a model of the system and shows that *HMS* is the evolution and complexity of a complex system. Complex objects, such as company, public authority, public fund, etc, are often used as *HMS*.

The dynamic system *DS(t)* is characterized by changing of some parameters after a while and inclusion of time as an argument

$$DS(t) = <Ps, Pr(t), Str(t), E, C(t), R(t), G(t), int, out, \Delta T >, (6)$$

Proceeding from the fact, that the system has the property of emergence, it cannot be studied only on the basis of an analysis of its parts or components. Study of the system only by the decomposition method, i.e. the method of decomposition of an integer into parts, is not sufficient, because it is limited to study of only parts thereof. An emergent system (*ES*) can be described by using the following expression

$$ES(t) = <Ps, Pr(t), Str(t), E, C(t), R(t), G(t), int, out, \Delta T, \ SI[E, C(t), R(t), t] >, (7)$$

Where *SI* - system information. It occurs in the presence of nonlinear combination of system components and characterizes the emergence of the system. During decomposition of the system into parts, the system information disappears.

Expressions (1-7) are linear descriptions and allow subsequent modifications. For example, sometimes the goals are divided into external and internal goals or into goals of functioning and development.

$$G(t) \rightarrow G(t)int + G(t)out$$

Resources of the system, which define its life cycle, can be included into descriptions (2-7). System status, which is divided into internal and external statuses, can be included into descriptions (2-7). In case of description of a system in an external environment, it comes to the concept of information situation as micro-environment, which significantly interacts with the system.

All considered descriptions of complex systems (1-7) refer to the linear descriptions. The principle of formulation of expressions (1-7) is linear. In case of occurrence of a new property or feature of the system, it is denoted by ID and included into the set (1-7) describing a complex system. The fundamental thing in the analysis of descriptions of complex systems is the identification of system information as an explicit factor in the expression (7).

There are more complex descriptions of systems. They include not one, but several expressions, which describe a complex system. For example, let's consider the approach of Mesarovich and Takahara (Mesarovic, 1960, Mesarovic, 1975, Mesarovic, 2000), who introduce the concept of system theory at the set-theoretical level.

The peculiarity of the approach in the work is the introduction of auxiliary objects, which are called state objects. The elements of these objects are called the system states. In information interpretation of these concepts, they can be compared to the information situation and information position. Relation on non-empty sets is called common system.

$$S \subset \otimes \{Vi \ ; \ i \in I\} \quad (8)$$

where ⊗ - symbol of Cartesian product, and *I* – set of indexes. Set *Vj* is called the system object. If the set, of course, then (8) it takes the following form

$$S \subset V1 \otimes V2 \otimes \quad \otimes \ Vn \ \ (9)$$

An example of such system is the Cartesian coordinate system (*CS*)

$$CS \ \subset X \otimes Y \otimes Z$$

Mesarovich introduces the concepts of input set (I*x*) and output set (I*y*), which is much wider than the concepts of input and output.

$$Ix \ \subset I; Iy \ \subset I; Ix \ \cap Iy = \emptyset; Ix \ \cup Iy = I;$$

Set $X = \ \otimes \{Vi \ ; \ i \in Ix\}$ is called the input object, and set = $\otimes \{Vi \ ; \ i \in Ix\}$ is called the output object of the system. These are basically input and output sets. In this case, *S* is defined by the following relation

$$S \subset X \otimes Y \ (10)$$

If *S* is a function, then the expression (10) is transformed into the functional relation

$$S: X \rightarrow Y \ (11)$$

In case of the description according to (11), the system is called functional. This approach is used in the stratification of the systems. However, it should be noted that in this approach and description there was no pace for the features of emergence and system information.

Despite the widespread use of approach of Mesarovich and Takahara, in their theory there are also some problems. There is no concept of composition and syntactics.

Let's consider the approach to the system theory of Yu.A. Urmantsev. He introduced the concept of the law of composition into a system definition in 1968. This allows to consider the system as an ordered set of objects. It introduced the concepts of "object" and "object-system".

Object *is* any material or ideal object of thought, as well as properties and relations: quantity and quality, preservation and change, essence and phenomenon.

Object-system is uniformity, built by relations of set {R}, laws of composition, set {Z} out of “primary” elements of set {M*)}*, selected on the basis of set *{A)}* out of the universe *U*.

The method of integration, which allows to synthesize the integer out of the elements of the system, applies for the object-system. Such approach provides for formation of the whole picture of the system and its comprehensive system analysis.

Subject to the approach of Yu.A. Urmantsev (Urmantsev, 2017), construction of abstract complex system includes the stages.

I. Selection from the universe *U* and primary set *M* by a single base $Ai^{(0)}$ of some set of elements $Mi^{(0)}$ – hereinafter referred to as the set of primary elements. In the theory of measurement, it is called the information collection.

II. Imposition on the primary elements of certain relations of uniformity $Ri^{(0)}$ and as a result on the formation of the set of compositions $Mi^{(1)}$ under the law $Zi^{(0)}$. Relations of uniformity create a coherent combination and system property of system integrity.

III. Changing of compositions of set $Mi^{(1)}$ according to the relations ($Ri^{(2)}$, $Ri^{(3)}$,. . . $Ri^{(s+1)}$) and the laws of composition ($Zi^{(2)}$, $Zi^{(3)}$, $Zi^{(4)}$, . . . $Zi^{(s+1)}$ and such derivation of sets of compositions ($Mi^{(2)}$, $Mi^{(3)}$, . . . $Mi^{(4)}$, $Mi^{(s+1)}$), whereby the compositions of all these sets turn out to be built out of primary elements of the same set $Mi^{(0)}$.

IV. Joining of all objects of the set *Mi* possible for *Ai* , *Ri* , *Zi* , in the form of unified system *Si* , = $Mi = \{ Mi^{(0)}, Mi^{(1)}, \dots Mi^{(s+1)}, \}$.

Urmantsev gives the following definition of an abstract system. System *S* is the *i-th* set of compositions *Mi*, built on relations *rj* of the set of relations *{R;}*, the laws of compositions z*j* of the set of laws of compositions *{Zi,}* out of primary elements k^s of the set, selected on the basis of $Ai^{(0)}$ out of set *M*. Primary elements k^s in the theory of information technologies are called the information units.

However, this definition has no place for system information and even relations. Therefore, let’s develop this definition more completely.

System *S* is the set of compositions *Mi*, built for relations of the set of relations {R*i*}, the laws of the set of laws of compositions {Z*i*,} which contains the set of links {C*i*}, uses the set of reasons {$Ai^{(0)}$} for the building, and contains emergent (system) information {EI*i* }.

Therefore, according to this definition, in order to form the complex emergent system, the following rules (1-6) are to be performed:

1) select some base $Ai^{(0)}$, and based on it select the set of primary elements $Mi^{(0)}$;
2) impose on it the relations of uniformity of the set {R*i*},
3) subject these relations and related operations to the laws of the composition of set {Z*i*};
4) fix the connections {C*i*}
5) extract the emergent (system) information {EI*i* };
6) receive system S*i*.

System *Si* is heterogeneous and has the structural type (a-f):

a) $Si = \{ Mi^{(0)}, Mi^{(1)}, \dots Mi^{(s+1)}\}$, components
b) $\{ Ai \} =\{ Ai^{(0)} , RAi^{(1)} , Ai^{(2)}, \dots Ai^{(s+1)} \}$ information units
c) $\{Ci\}= \{ Ci^{(0)}, Ci^{(1)}, \dots Ci^{(s+1)}\}$ connections
d) $\{Ri\},= \{ Ri^{(0)} Ri^{(1)} Ri^{(2)}, \dots Ri^{(s+1)} \}$ relations
e) $\{Zi,\}= \{ Zi^{(0)}, Zi^{(1)}, Zi^{(2)}, \dots Zi^{(s+1)}\}$ composition rules
f) $\{EIi\} = \{ IMZi^{(s+1)}, IAZi^{(s+1)}, ICi^{(s+1)}, IRi^{(s+1)}, IZi^{(s+1} \}$ system information

This description of the system includes the rules of composition as the rules of system building (syntactics). This description of the system includes the emergent information. Not every system is built according to certain rules (1-6). Not every system has a structural type corresponding to items (a-f). But only systems, which are built according to rules (1-6), have the property of emergence and system information.

Let’s define the system information as a nonlinear form of description of the properties of the system, caused by non-linear combination of relations of uniformity, connections, structure and rules of composition in this system. System information is the content of emergence property.

3. Discussion

System information is defined upon certain approaches and methods of descriptions of the complex system. System information describes the system properties. However, it cannot be equated with the terms of the system building. System information appears explicitly in complex system descriptions. For linear descriptions this is the expression (7) and its modifications. For set-theoretical descriptions, these are the rules (1-6) and structure (a-f). Explicit form or set of forms of description of system information is beyond the scope of this study. The analysis, performed in this work, shows only the method for defining system information.

4. Conclusion

Development of systems analysis and systems theory arrived at the need for introduction of the concept of system information and simulation of emergence. This is partly due to the success in the fields of study of developing and self-organizing systems. This is dictated by the requirements of artificial intelligence, which also needs the introduction of the concept of emergence and simulation of emergence, as well as introduction of concepts of system information as a non-linear phenomenon, defining the system properties.

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