A NOVEL APPROACH TO THE CONCEPT OF SYSTEM INFORMATION

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ABSTRACT

This paper represents a novel approach to the system information correlating General System Theory, Cybernetic and the Theory of Information. The main objective is to investigate whether "information" is a subjective concept or an objective entity in the physical reality. In this quest, system has been identified as an abstract model for observation and the perception of the world by the human mind. Based on this definition, every phenomenon that can be observed or imagined is perceived as a system. Where there is a system, there should be an observer and hence there exist information in between.

Combination of system elements as a whole is explained by System Dynamics. Based on this assertion, the system is in a continuous change and transmutation; a conceptual process that is independent of time and space. In this perspective, time and space are conceived not as the background but the outcomes of the inherent dynamics of the system. It is shown how the time could be considered as sequence of events and the space as relation between system elements.

System structure is modeled based on Binary graph as the fundamental topology for combinatory pattern of the system. A new System Algebra is defined, based on which the System Information Matrix (SIM) is introduced to demonstrate information imbedded in a system. This model is also used to evaluate the amount of system information based on Entropy as defined in thermodynamics and in the information theory. Complexity is another parameter of the system that is represented here based on multi-functionality of system elements. This new definition provides basis to quantify this feature of the system.

Cybernetic systems categorized as life, machines and composite systems with high degree of complexity such as human societies, are all shown to be distinguishable by exchange of information. In these systems, information flows through different components the same way as it would from any system to the observer. It is concluded that information realized by the observer is a relative objective entity in a system. However, in cybernetic systems having controllers as internal observers, the information is physical and objective regardless of any external observer.

Keywords: System Information, System Theory, Information Theory, System Dynamics, Information Matrix, Time and Space, Entropy, Complexity, Cybernetics.

INTRODUCTION

The term "Information" is extensively used in most modern human activities. We find this word almost everywhere, not only in its common meanings as being informed or getting the news, but also in some new concepts that view the Information as a material media handled by machines and technical facilities in many social affairs.

The later meaning reminds us of something like electricity or radio waves; a quantity measured in Bits or Megabytes, stored on a silicon chip, transferred by digital signals and processed in computing machines. Information seems as a physical entity with multitude of applications in Telecommunications, Broadcasting, Control and Automation, Computer Science, Genetics and other fields that use Information Technology.

Information is not actually a new term such as Electron, Laser or Gene in contemporary language. It has a historical background as old as human societies and languages. Information has found its meaning from the first pre-historical periods that man tried to use some verbal sound or visual symbols to acknowledge each other by exchanging the news and transferring messages. Then how has the meaning of this term nowadays developed from a conceptual quality to an objective quantity? Is there any measurable objectivity to information similar to those properties of material such as mass, energy, space and time or it's a subjective category such as perception and knowledge?

Questions of this kind lead us to philosophical abstracts. In this brief we will focus on the objectivity of the information and attempt to clarify its relations with the matter. To achieve this goal, we will not enter deeply into the abstract philosophical arguments, nor will discuss the practical terms of computer science or communication technology, but will follow our objectives through the General System Theory that is a new perspective in the modern science.

General System theory together with the Information Theory and Cybernetics is one of those theories of the 20th century that has opened new windows to modern day science. These frontiers were achieved by the efforts of the great scientists such as Ludwic Van Bertalanfy, Claude Shannon and Norbert Wiener.

General System Theory introduces system as a general category with a high level of abstraction that is applicable to any phenomenon. Meanwhile, it considers the specific definitions of a system in different sciences such as physics, biology, psychology, sociology and economy. Hence, the system theory is considered as a bridge between philosophy and the modern sciences.

1. REALITY OF THE SYSTEM

System is perceived as a window for looking out to the world. In other words, here system is a model for observation or a tool for realization of anything inside or outside of the mind. With this meaning, system could be considered as a subjective concept dependent on the observer. But we can argue that System is not subjective because the solar system for instance, has had existed a long time before human appears on the earth to observe it. It is true, as we know, that sun and its planets had always co-existed by their gravitational fields as a system, but if we think of their existence as objects by themselves while excluding the human mind from the observation circle, what then remains will be a formless type of absolute “existence”. From this view, the objects only exist as abstract beings without any property to be assumed about them and without any “Why” or “How” to be asked about their relations. Hence, the sun and moon are “objective” as far as their absolute “being” is independent from us, but what about their relations as a system?

If we dream that we are walking on a golden planet we can still talk about this reality, but as a “subjective being”, because its existence totally depends on (or caused by) our observing mind. Now a scientist (specially a theoretical physicist) may say that a golden planet also is objective since its existence is not against the rules of physic and it can exist even if we have not yet observed one [Ref.12].

For the science methodology, anything that is logically possible and/or potentially observable is considered “objective”. That is why the mathematical entities such as numbers or geometrical shapes are supposed as “objective beings” although they are only abstract concepts. It is in this meaning that system and information associated with it could be considered as “objective” realities.

2. SYSTEM PARAMETERS

As a simple definition, we can say that system is any being observed as a whole by combination of its distinguished elements, and it is a dynamic entity that is always in change and evolution. From this perspective, everything can be considered as a system, whether it is subjective or objective, material or spiritual.

Every system can be distinguished by three main parameters as following:

a) *Base* is the collection of system elements regardless of their combination or interactions. By this definition, “base” is the material or the substance within the system that is a fixed quantity in a closed system.

Base is very essential to classify the types of different systems. For instance, the base of a physical system is Matter in various formations. The base of a social system is the human in the form of individuals or groups, and the base of a conceptual system is the mental images, ideas and concepts.

b) *Function* is the sum of the interactions of all system elements and parts (subsystems). Function is the major parameter of system that determines the reaction of the system against its environment. A system with the same base may be considered as different systems regarding its function. For instance, man is a mechanical system when he is running, a biological system when he is eating, and is a social system when he is speaking.

c) *Structure* is the formation of system elements in a framework set by the intrinsic rules of that system. Therefore, the structure of mechanical systems is determined by the rules of mechanics and that of organisms is set by the rules of biology and biochemistry.

Any single element in a system can be considered as a system. In general, any object can be continuously divides in smaller parts and reduced to a system of smaller elements. Elements are subsystems recognized by their Bases and Functions. In other words, element is a stable system with a certain base and function that enables it to interact with other elements in that system.

Main parameters of the system as well as other parameters such as Boundary, Level, Layer, Subsystem and Element are simplistically illustrated in Fig.1.

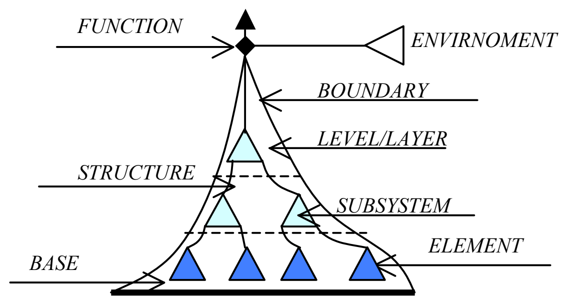


Fig.1.Hierarchical structure of the system and its main parameters

3. DYNAMICS OF THE SYSTEM

System by its definition is a dynamic and active entity , so that the system concept is conceived by its dynamics. A general system theory could not be complete without representing an adequate description of the system dynamics.

Dynamics of a system is an abstract concept with a more general meaning than its motion in time and space. By this meaning, dynamics of a system is a category that includes any kind of change (transmutation) or evolution. The essence of this dynamics appearing in observation is a continuous conversion between the unitary concept of the system as a whole and the multiplicity of its consisting parts or elements.

To clarify this concept, let's consider the simple system C as combination of two parts or elements demonstrated as A+B=C. As we see, in one side of this equation there are two entities and in the other side there is only one. Now in a logical sense two things cannot equal to one! This contradiction does not show up in the numerical quantities. That is, the arithmetic equation 2+3=5 always seems true. But for the system, it is a contradiction that can only be explained as the alternation between unity and multiplicity that provides the dynamics of the system. In other words, the two elements of A and B are united as the system C and, at the same time, the unique system C is divided in two individual elements A and B. Dynamics of system is the result of this continuous alternation between system as combination of parts and system as a unified whole.

As a physical analogy, we can observe this conversion in the process of ionization. In ionization, the molecules are divided into the free ions and floating in the electrolyte by the electrochemical forces. At the same time, the ions have tendency to join back together to rebuild the original molecules [Ref. 2].

4. COMBINATION AND MIX PROCESSES

Combination process of the system elements takes place according to the system dynamics. The simple principle that explains this process is the general laws of reflection and mutual effects as conceived by common sense. According to this principle, the two elements “A” and “B” of a system combine when “A” affects “B” by its function “a” producing a reactive function “b” in “B” and, at the same time, this reactive function “b” affects “A” in its own turn, so that neither “A” nor “B” can stay stable unless they join together forming system “C” with a new function “c”.

A combination is a reversible process conceived as either congregation or separation of elements. From the logical perspective of system dynamics, these two concepts are equivalent since there is no time direction in this process. Therefore, a combination shown as A+B=C in one direction could equally be shown as C=A+B in other direction. The core concept in this process is identity of the individual elements “A” and “B” that is always conserved beside the identity of “C” as the whole.

By the way, we can think of an irreversible or one-directional kind of combination called “Mix” process in which the initial elements lose their identity in the combination. That is, when two elements are “mixed”, they will loose their ability to separate back to their original elements and will remain as one element in the system. In other words, the mixed elements are replaced by a newly emerged element. As an example, mixture of Hydrogen and Oxygen provides a mixture of two gases that could not be easily separated. But combination of these two gases produces water and heat that could be decomposed to the primary elements by means of electrical energy.

As a basic condition for any combination, the two element or systems should potentially be capable to affect each other by their respective functions. This first condition is generally determined by the base and structure of the systems and the governing rules for their interaction. For instance, according to the natural rules of survival, a wolf hunts a rabbit while it does not hunt a tiger. As another example, Oxygen produces water when combined with Hydrogen while it will not produce the same results with Helium. There is also a second condition for combination of two systems or elements according to that they must either regularly or accidentally come in contact with each other. A wolf cannot hunt any rabbit unless it meets one. Also, Oxygen cannot synthesize with Hydrogen unless they are put together under certain physical conditions.

Both these two conditions are subject of probability and could be interpreted by a chance factor or probability denoted as “P”. According to this statement, there is a probability p_c associated with functionality of any system like C that is a function of probabilities of its individual elements:

$$P_c=f(P_a\,,\,P_b) \qquad \text{where } \; C=A+B \qquad (1)$$

Hence, we can summarize these two conditions of combination by saying that “A” and “B” may combine as “C” if and only if:

1. “C” can essentially be a combination of A and B (Necessary condition): $P_c>0$
2. “A” and “B” can come in contact (Sufficient condition): $P_a>0$ & $P_b>0$

5. BINARY CONFIGURATION PATH

System configuration can be modeled as a combinatory pattern of the system elements using a binary path.

As a logical consequence of the combination process, the elements of a system combine in different stages called Layers. In the first layer; the process begins with mutual effects of only two bodies, forming a part of two, which can in turn combine with another elements or subsystems in later stages forming larger parts in the system and so on. It should be noted that these are logical stages with no time sequence considered for the process.

Binary combination as interaction of only two elements or parts is a fundamental concept in combination process and the building block of system structure. The reason is that a system of two elements is the smallest system, and two is the smallest integer number that can be divided into two other integers (2=1+1). Modeling of the system based on the initial combination of three or more elements is also possible, but they can ultimately be reduced to binary combinations.

Configuration path of a system can be represented by a graph of binary-tree as shown in Fig. 2. In this graph, the two-by two combinations of the elements and parts (subsystems) through their interactive functions take place in different "Layers" of the system structure. Therefore, binary path provides a hierarchical structure for the system in which each combination is taken place in a layer and the layers of the same number of elements are located in the "Levels" as shown in Fig 2 and Fig. 3.

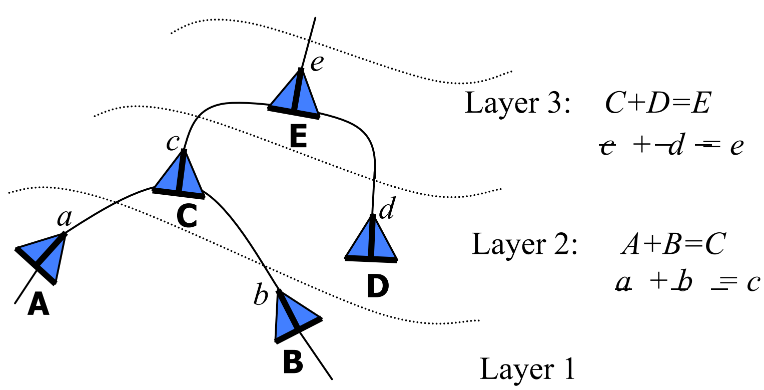


Fig.2. Configuration path of the System Structure

6. SYSTEM ALGEBRA

When two or more systems integrate in a combination process, their bases add up as scalar quantities. That is, the base of the combined system is equal to the algebraic sum of the bases of the component systems. This fact is obvious in the physical systems from the conservation principles of the mass, energy, momentum, electric charge, etc. But functions interact more like the ambiguous vectors, so that there is no general principal for combination of the function, unless we say that the ultimate function of a system is somehow the outcome of all the partial functions of its elements. Hence, any mathematical formula used to represent the combination process must include these characteristics.

By introducing the operator $\perp$, we can demonstrate system combination by the formulas like $A \perp B = C$. The operating symbol $\perp$ in this formula means the base of C is the scalar summation of the A and B bases and the function of C is outcome resultant of the A and B functions shown as a, b, c in Fig.2.

There might always be elements that do not combine with other elements or parts of the system in some particular combinations. For these cases, we assume a fictitious neutral element, known as "Zero-Element" (0 or A_0) that extensively neutralizes the functions of the elements or parts to which it combines. Same a "Zero" in conventional multiplication, this neutralizing function of the zero-element is a contagious effect that extends from layer to layer neutralizing any further element or part that comes in contact with, so that the resultant system includes a bunch of non-combined branches beside the combined elements. (i.e. B_1 in Fig. 3)

Here, using the combination operator $\perp$ and the system zero-element "A_0" with its neutralizing function denoted as $\perp^0$, we introduce a special algebra for the system "S" combinations defined by the following basic principals:

a) Closure law: if $A_1 \subset S$ and $A_2 \subset S$ then $(A_1 \perp A_2) \subset S$

b) Commutative law: $(A_1 \perp A_2) = (A_2 \perp A_1)$

c) Non-associative law: $(A_1 \perp A_2) \perp A_3 \neq A_1 \perp (A_2 \perp A_3)$

d) Neutralization law: $(A_0 \perp A_1) = A^0_1$, $A^0_1 \perp (A_2 \perp A_3) = A_1 \perp^0 (A_2 \perp A_3)$

In system equations, elements inside parentheses indicate parts or subsystems. Symbol $\perp^0$ always locates out of parenthesis indicating a neutralized connection between elements or parts beside that.

By this special algebra, it would be possible to formulate any combination of system elements depicted as a binary-tree path.

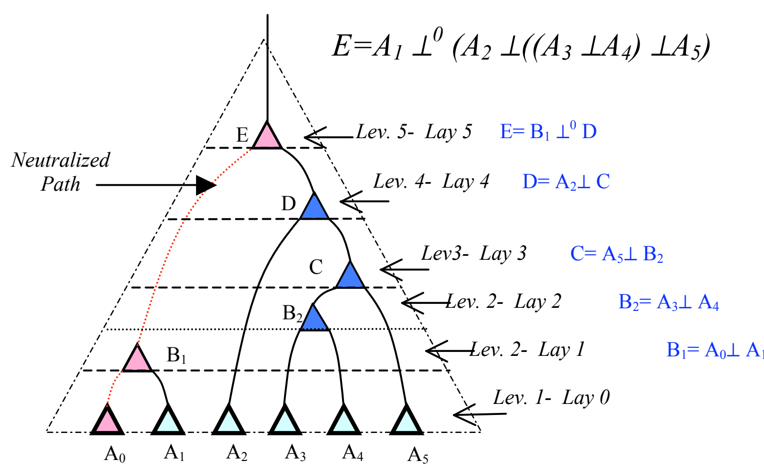


Fig.3. Binary path of an event in a five-element system

Fig. 3 shows the binary path of one possible combination of six elements (five real elements and one zero element) in a system represented by an equation employing system algebra. As indicated by symbol $\perp^0$ in this equation, A_1 neutralized by A_0 stays apart from the rest of combinations in this particular combination. This fact is shown in binary graph by dotted lines used for combination path of A_1.

7. SYSTEM EVENTS

Any combination of system elements holding the principles of system algebra is called an Event. System elements can provide many different events in this binary path. The total number of possible events in a system increases drastically by increase of the number of elements. This total number can be represented as a function of the numbers of system elements "*n*" as shown in equation (2)*:

$$E_n = \frac{k \times (2n)!}{n \times 2^n \times n!} \qquad (2)$$

Employing this formula, the total number of all possible events for some values of "n" is estimated as following examples:

$E_1=1$, $E_2=2$, $E_3=7$, $E_4=37$, $E_5=265$, $E_6=2426$, $E_7=27027$, $E_8=3.55 \times 10^5$, $E_{16}=1.68\times10^{16}$, $E_{32}=4.91\times10^{42}$, $E_{64}=3.60\times10^{105}$

Recalling the probability factor P in the combination process, we can say that any event e_i of a system is associated with a probability that could be determined as a function of the individual probabilities of the element in that event.

$$Pe_i = f_i(P_{A1}, P_{A2}, P_{A3}, \dots P_{An}) \qquad (3)$$

Based on this definition, different events of a system have different chances to occur, and a system normally happens in its most probable events. In other words, the events of a system for which $P_e=0$, are basically impossible to happen and are eliminated. Many other events having low probability might never find chance to happen in the system's life. Therefore, in a real system most of these combination possibilities are eliminated according to the rules and structure of that system.

System is a dynamic entity that does not appear as only one event, but occurs as a sequence of various events. A system of "n" elements appearing in "t" sequential events can be represented as following set:

$$\boldsymbol{S}_{n,t} = \{(A_1, A_2, \dots, A_n) \setminus e_1, e_2, \dots, e_t\} \qquad (4)$$

The notation means that the elements A_1 to A_n of system S are combined to form events e_1 to e_t sequentially from 1 to t. Note that order of the events is essential for every unique system. Thus, a system by this definition is a set of sequential events occurring in a particular order.

*) This equation is obtained considering the fact that for each event in a system of "*n*" elements, number of nodes or branches "*m*" in its binary graph is $m=2n+1$ including the zero element. To add one element to this system, there will be "*m*" locations for this new element in each original event, to make a new event. Hence, number of events in the new system will be $E_{(n+1)}=(2n+1)E_n$ or $E_n=(2n-1)\,E_{(n-1)}$. Assuming $E_0=1$ we can make a

sequence of the number of events E_i in which continuously substituting E_i by $E_{(i-1)}$. Therefore, with some manipulations, the number of all possible arrangements in the binary tree will appear as: $E_n=(2n)! / 2^n n!$

Now, considering similar combinations produced by separating function of zero-element proportional to n, the identical evens could be eliminated by a factor of k/n. In the above examples, k is estimated as 1.4 for n>3.

8. SYSTEM INFORMATION MATRIX (SIM)

System defined as the sequence of events demonstrated by the binary paths can be represented by a three dimensional (3D) matrix called SIM. Every event of a system is represented as a two dimensional (2D) matrix. The columns of this matrix represent system elements and the rows show the layers of combinations of elements in that event. It can be proven that the number of parts or layers corresponding to the nodes in a binary path is equal to the number of elements of that system, thus, making this matrix square. As an example, the 2D matrix of the particular event of Fig.3 is shown in Fig. 4 below.

Frequency _	2	2	2	4	4	3	Level _
5	0	1	1	1	1	1	5
4	0	0	1	1	1	1	4
3	0	0	0	1	1	1	3
2	0	0	0	1	1	0	2
1	1	1	0	0	0	0	2
0	1	0	0	0	0	0	1
Layer _	A_0	A_1	A_2	A_3	A_4	A_5	Elements n

Fig. 4. SIM of the event shown in Fig. 3

As shown in this example, in each layer of this matrix the states of participating elements in combinations are designated as number "1" and state of uncombined elements as "0". Zero element A_0 located in the first column always appears as 1 in the first layer 0, and as 0 in the last layer. Layer numbers "_" in this matrix are sequential from "0" to "n", and level numbers "_" are equal to summation of the numbers "1" in each row. Any layer "_" located in a certain level "_" represents a part or subsystem with combination of "_" numbers of active elements designated by number "1". The sum of the numbers in a column "$_i$" represents the frequency of participation of a particular element in that event. For instance, $_0 =2$ shows that zero element has been activated 2 times and created 2 separate parts in this event. The activity of elements in this matrix appears per priority of the order of elements in the sequential layers. That is for instance, the $A_0 \perp A_1$ combination comes in layer 1 prior to $A_3 \perp A_4$ in layer 2 since 0 is prior to 3. These rules make it possible to depict each event as a unique matrix and obtain required information to rebuild relation of elements in that event as a binary graph or represent it as a system equation.

Referring to the probability factor p in formula (6), if the probability function f_i is known, we may use the real values of $p<1$ instead of 1 in this matrix, showing the probability of the event in the last layer as the function (mostly as a product) of the probability of individual combinations in that event. However, for the events of the past that have actually happened, we can always assume $p=1$ for the occurred and $p=0$ for all other non-occurred combinations as shown in the above example matrix.

For a system in which no separation between its parts is assumed, it will be easier to ignore the zero element and simplify the SIM for that system. As a simple example, Fig. 5 shows the 3D-SIM for a non-separate system of three elements in three periodic events together with the algebraic formulas and the binary paths of those events.

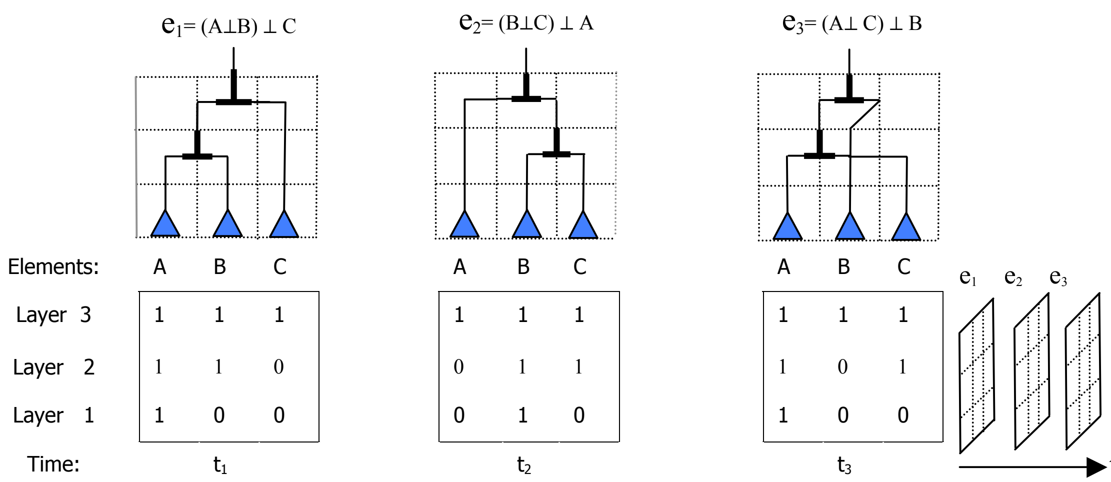


Fig. 5. Matrix of Information for a 3 elements-3 events system $S_{3,3}$:{ (A , B, C)\ e_1, e_2 , e_3}

System Information Matrix (SIM) contains any information about the structure, functions and elements of a system. Element is a stable part in a system. However, an element is also a system that may decompose to smaller elements increasing the total element of the main system. Also in opposite way, any part or subsystem that is always repeated with the same configuration of certain elements can be considered as a stable element in that system. These phenomena always happen in the nature when molecules of mater decompose to smaller molecules or atoms, and in the opposite way, when some parts or elements are composed in larger structures to provide the material objects. Consequently, number of elements in a system is a relative quantity depending to the view point of the observation.

9. SEQUENCE OF TIME

From the perspective of modern science, everything can be expressed in terms of the relation between objects and not between an object and some predetermined background [Ref.11]. From the system point of view, time and space are not preconditions (a priory) for system dynamics, but some system properties that can be defined as the consequences of the system dynamics.

We have defined the system as a set of events that happen sequentially. From this point of view, *time is the sequence of the system events in the same order as they occur*. As explained in the system dynamics, system is both a combination of parts and a unique entity appearing as a whole. In fact, system is the subject of observation that alternatively appears as a whole and as the parts. In this alternation, the elements disappear when the system is observed as a whole, and re-appear when it is distinguished by its parts, each time as a different event with a possibly different arrangement of elements. Here is where time is generated when system jumps from one event to other.

We, as the observer and human beings are biological systems with a natural sense of passing time. In reality we live in the moment of present, while we can memorialize the past and imagine the future. We are even capable to conceptualize the time as a forth dimension in which a subject is visualized as a set of lined-up events all existing at once. In fact, what we actually observe is a “Becoming” world whereas we conceptually perceive it as a “Being” world. If the world is really a “Being” one, then it should be timeless, a system that its events exist all together at once.

From our observing point of view, events of the past have certainly happened, while an expected event of the future may or may not get chances to occur. Hence, we can say that for an observer, certainty is assurance of the past while probability is a matter of uncertainty about the future. In this regards, we can say that probability is not an inherent property of the system, but it is the fact of observation related to the lack of information about the system in [Ref. 13].

Time is usually considered as being coextensive with “Causation”. From the system perspective, “Causation” principle is not always concerned, and we do not necessarily have to explain every event as an inevitable consequence of the previous events or to consider it as a cause for the following events. This assertion may have different interpretations for different systems, so that the validity of the causation principle may depend on the type and the size of the system. For instance, events in the macroscopic world could be explained based on causation as defined for instance by the Newtonian mechanics, while this principal has not the same significance in the subatomic events as interpreted by the quantum mechanics.

10. SYSTEM SPACE

Similar to the time, space also is not a precondition for the system dynamics but can be perceived as a byproduct of that. Space is all about relation between objects and the way they are located beside each others [Ref. 8]. We already demonstrated these relations in the format of a binary graph. Here also, we can consider the space as a topological network produced by superposing of total binary graphs of all system events (Total Space). This provides a large multilevel network of nodes and branches on which the system appears at any time on a binary path. This superposing network which we can call it Supernetwork is actually a space-time manifold, because it is an overall pattern for all system events during periods of time.

As an example, supernetwork of a system with three elements is illustrated in Fig. 6. In this simple topological space, the elements are located on the vertices of a triangle, second level subsystems on the sides, and the ultimate system in the center. As "n", the number of elements increase, the supernetwork topology gets more complicated.

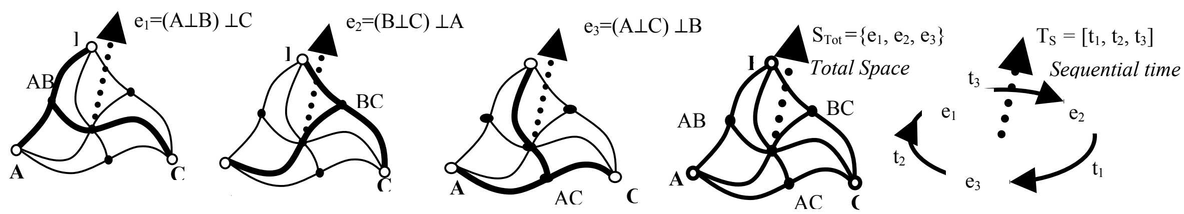


Fig. 6. Topological space of a three element system as the superposition of its *three events.*

Real systems do not usually posses all possible events of their total space, but only a portion of the total network can be considered as the Real Space determined by the rules and limitations of that system. This makes the supernetwork of real space less complicated than that of total space since most branches are eliminated due to real connections in the system. Real systems in the nature have definite structures and usually display a periodical behavior or repeating motions in their real space. For instance, the atoms of any element having certain number of electrons and nucleons all provide the same spectrum indicating similar interactions between their subatomic particles. As other examples, the years follow the same repeating seasons by the periodical revolution of the earth around the sun, and generation of species on the earth is repeated for long periods according to the rules of genetics.

In a homogenous system with symmetrical structure such as crystal or fractal, the space network shows repeating textures in all levels. In this case, the lowest levels of this network after which the combination pattern is repeated, could be considered as a model space that typically demonstrates all direct connection of elements and parts.

It should be noted that the system space is a mathematical concept that is different from the physical space. Physical space, as the relation between physical elements, is not apart from the physical objects. In other words, space is realized as a physical reality that its parameters could accurately be measured by implying mathematical models such as Euclidean geometry. Now, if we consider a geometrical space as a symmetrical system consisting of abstract elements such as dots, lines, planes and volumes then the physical space to which this geometry is assigned could be better realized as a supernetwork or a System Space.

11. GEOMETRY OF SPACE

In order to represent a geometrical space as a system, we have to re-identify main geometrical parameters of a space such as dimension, extension, continuation, distance, neighborhood, etc. in the symmetrical structure of simple spaces such as lines, planes and volumes, and generalize them to a multi-dimensional space.

Starting with a line as a one dimensional system, if we cut a line "L" in two sections, we will have a system of two elements "L_1" and "L_2" joined in a common point O. The line-system in this case can be represented as combination of two parts in one event as shown in Fig.7-a_1. Since the line is continuous, it can be infinitely divided in parts, so that its elements become as small as points, while they are still tiny lines. In this case, the first level combination network of a line could be depicted as a chain of nodes in which any element is connected to only two other elements (1-pair) on that space (Fig.7-a_2). This set of two elements called the *Neighborhood* identifies *Extension* of elements in two opposite *Directions*. Hence, we can say that a system has a 1D space if the neighborhood of each of its elements includes 1-pair of nodes on the network of its system space. Number of branches between any two nodes on this network space determines *Distance* between two points on that line.

Now we consider a plane as a two-dimensional system. Unlike the line, plane is divided by a line (l_1) that is a one-dimensional system consisting of two line pieces connected through the point O. This plane could also be divided with at least one other line (l_2) crossing at the same point O on the plane. Hence, two lines are alternatively cutting the plane, and two times two (2^2=4) plane pieces are produced. The plane system in this case can be represented by combination of the produced sectors P_1, P_2, P_3, P_4 as two events as shown in Fig.7-b_1.

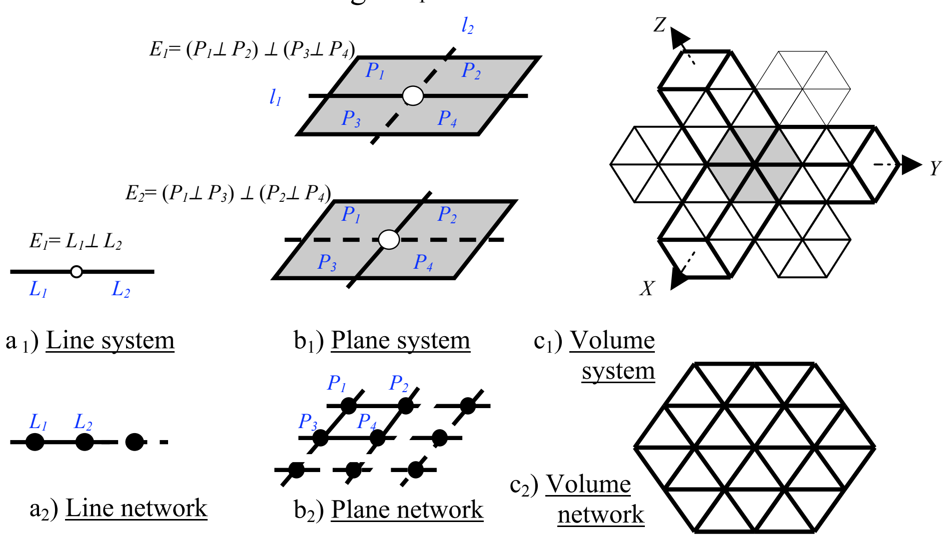


Fig. 7. Network space of Line, Plane and Volume as geometrical spaces.

Same as the line, any of those plane sectors could repeatedly be divided in four sectors utilizing pairs of crossing lines. If the same crossing lines cut the adjacent areas in the plane (i.e. in Cartesian Space) each sub-sector will have no more than four other areas in its neighborhood. In this regards, the plane could be depicted as a net of nodes and branches in which any element is connected to only four other elements on that space (Fig.7-b_2). This neighborhood of four elements identifies extension of each element in four directions so that we can say that in a 2D system the neighborhood of each element includes 2-pair (four) nodes on the network of its system space.

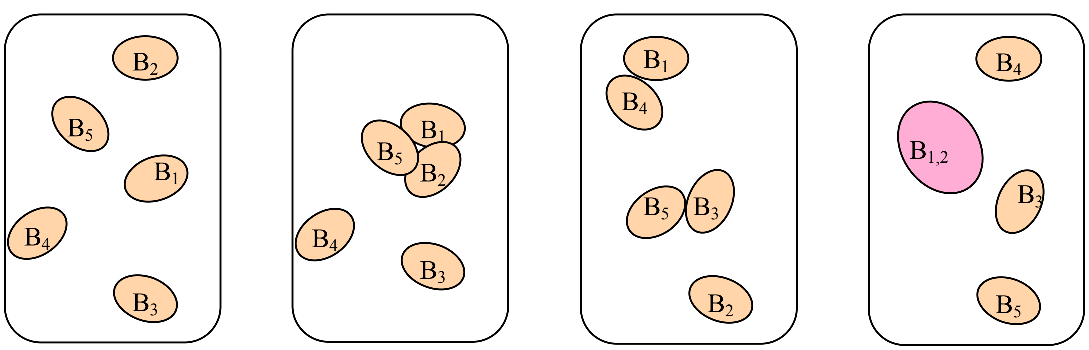
Similarly, three planes cut a volume in eight (2^3) segments (Fig.7-c_1) providing a network space with six directions as illustrated in Fig.7-c_2. Hence, we may generalize these rules to say that a system takes place in a nD space if the neighborhood of each of its elements includes n-pairs of nodes on the network of its system space.

It should be noted that all systems do not have a symmetrical structure like a geometrical space, and it will not be easy to determine dimension or other parameters of their spaces. But, by studying the properties of their non-homogenous networks, it might be possible to represent dimensionality of these systems as a decimal number similar to what has been defined as the *fractal dimension*.

12. ENTROPY

Entropy is a significant parameter of the system and a measure for the information embedded in the system. Entropy was first introduced in thermodynamic as a measure of an energy that is unavailable to perform work in a process [Ref. 7]. As a physical system cools down and the temperature of its difference parts moderates, its entropy increases and the system lose its capability to produce work. Studying the statistical relations of the system elements such as gas molecules has revealed that entropy can be considered as a measure for disorder of the system elements. In other words, the higher is the entropy the less system elements are in order and less information is available in that. This interpretation provides links between the two concepts "entropy" and "information". In this term order and disorder are relative concepts depending to the way an observer determines system parameters.

As an example, consider a closed system consisting of numbers of balls B_1, B_2, …B_n filled with gas molecules of various temperatures T_1, T_2, …T_n. The balls having different kinetic energies are moving around and randomly hit each other, the same way as the gas molecules do in a gas container. When two or more balls get in contact they exchange some amounts of thermal and kinetic energy depending to the coefficients of their elasticity and heat conductivity. Fig.8 shows four possible events in this system.



$e_1 = B_1 \perp^0 B_2 \perp^0 B_3 \perp^0 B_4 \perp^0 B_5$ $e_2 = ((B_1 \perp B_2) \perp B_5) \perp^0 B_4 \perp^0 B_3$ $e_3 = (B_1 \perp B_4) \perp^0 (B_3 \perp B_5) \perp^0 B_2$ $e_4 = B_{12} \perp^0 B_3 \perp^0 B_4 \perp^0 B_5$

FIG. 8. Increase of entropy in a gas system during four evens.

We can assume that under some random circumstances such as a specific collision, the collided balls penetrate each others so that their skins open and rejoin as a single surface. When this happens, the gas of two balls are Mixed and a larger ball is emerged with total mass and energy, and the average temperature of the primary gases of those mixed elements. This new element is shown as $B_{1,2}$ in the e_4 event in Fig.8.

In this event, the two gases with different classification as B_1, B_2 are mixed in an irreversible process as already described. They have lost their identity as individual elements and could not be distinguished from one another anymore in the system. In other words, their information is lost, although may not be destroyed. Their molecules of the primary elements are now moving in a larger space of randomness and ambiguity. Consequence of this process is that as the time passes number of system elements (floating balls) decreases while the total amount of its mass and energy will not be changed.

From the thermodynamic point of view, entropy of this system increases over the time by moderating its temperature and distributing its energy over the whole system. This process is a general tendency of the nature that happens almost everywhere in universe as determined by the 2nd principle of thermodynamics.

13. VOLUME OF INFORMATION

Entropy is a controversial category as defined in thermodynamics and in the information theory. System entropy in this regards is usually considered as the information in the system that is invisible to the observer [Ref. 3]. Therefore, the visible or available information in the system is called Nontropy or Negentropy [Ref. 1] to be consistent with thermodynamics definition of this term.

According to the Shannon's Theory of Information, the available information in a system (Negentropy) is the value of information in Bit, required to identify the status of the system through all its possible situations [Ref. 4]. Similar to the entropy calculations in thermodynamics, this value of information is also calculated statistically. That is, if the probability of occurring of a system in a certain event e_i among its all possible events is "P_{ei}" then the value of information of that system "H" is the number of the bits of information needed to recognize that event, and it is calculated by following formula considering the based-2 logarithm of all probabilities [Ref. 7]:

$$H = -\sum_{i=1}^{t} P_{ei} \log P_{ei} \qquad \text{where:} \qquad \sum_{i=1}^{t} P_{ei} = 1 \qquad (5)$$

In this formula P_{ei} is the probability factor of each event, and $t= E_n$ is number of all possible events of a certain system as determined in the equations (2), (3) and (4).

Systems usually do not occur with the same probability in all of their possible events and they follow a certain Pattern of Probabilities that depends on their structure and the dominating rules. But for many systems with random configuration such as gas molecules or motion of the balls in our last example, the probabilities for all possible events could be assumed as equal and non-zero. Hence, all terms within the _ in equation (5) will be equal and the formula will be simplified as following:

$$P_{e1}=P_{e2}= \dots =P_{et}=1/E_n \quad \Rightarrow \quad H=-t(1/E_n)\log(1/E_n) \quad \Rightarrow \quad H=\log E_n \quad (6)$$

If we apply equation (6) to the number of all possible events E_n in equation (2), utilizing Stirling's approximation for the logarithm of factorials as: $\ln X!=X\ln X-X$ [Ref. 6], then the volume of information for systems with large number of elements could be roughly estimated as following:

$$H=logE_n= log[k(2n)!]-[n+logn+log(n !)] \;\Rightarrow\; H=\sim n \log n \quad (7)$$

As formula (7) shows, the value of available information in a system (H) varies in the same direction as the number of distinguished elements in that system. As the number of elements decrease, SIM gets smaller, diversity of possible combinations in the system is reduced and less information gets available to the observer.

Reduction of number of parts in a system is usually the consequence of a mixing process in which the entropy increases as we saw in the balls example. Meanwhile, in a symmetrical system with low entropy such as crystal in which the combination pattern is repeated in certain levels, information is not actually decreased or lost but it is concentrated in some computable format known as Algorithmic Complexity.

14. COMPLEXITY

Complexity is a category that is simple to express and complicate to define! This is a controversial concept that can be interpreted from many different perspectives. An unknown problem that looks complicated in the beginning becomes simple after being solved, and a digital watch having less devices than a mechanical one includes more complexity since it is comprised of more advanced technology.

Complexity is usually considered as the property of systems with compact information that can be expanded in a Computational process. By this interpretation, there is more complexity in a compact disk containing the whole content of a book than the book itself. Also, a computer program generating figures of a large set by a few programming sentences is the subject of complexity [Ref. 10].

Now let's consider this category from our system theory point of view. System as per our definition is sequence of some events. We may think that the complexity of a system increases as the order of its elements gets more complicated. But the order of system elements is determined by entropy and we should not confuse it with complexity. In this regards, let us compare the various states of the load of bricks used in a building. How could one claim that they have more complexity when regularly packed in the store, randomly dumped in a pile at the construction site, or orderly laid out in the building? The key answer might be in the functionality of the bricks in these different events.

System function as we defined is aggregation of individual functions of system elements in a hierarchical structure or radial binary-tree path without any loop. But we can also talk about the Multi-functional systems in which some elements having two or more simultaneous functions interact with more than one other element or part at a time. This generates closed loops in the binary paths of system events. A closed loop implies feedback to which an element adjusts its position against two or more other elements. This self-adjustment implies a form of computation that creates complexity.

There are many examples for multi functional systems. A person who is member of different associations is a kind of multi functional element. Roaring of a lion that is attractive for its mate and frightening for other animals is an example of multi-functionality. Complementary behavior of photon as wave and particle as expressed in quantum physics could be considered as multi functionality of this particle. Also an electrically charged massive substance such as a proton that is involved in different force fields of gravitation, electromagnetism and nuclear at the same time is another example of multi functionality since no unified field theory is elaborated yet.

It should be noted that time-simultaneity is a subject of observation and it is relative. Sometimes two very close events seem to be simultaneous while there is very short time interval between them. However, we can think of events happening in chaotic condition for which the terms "before" and "after" have no meaning. Conditions such as extremely dense environments like black holes, or ultimately fast motions close to the speed of light ($3*10^{10}$cm/Sec), or times shorter than Plank's time limit (10^{-44} Sec). These are some physical cases that can be considered as *Actual Simultaneity*.

Now imagine a small system of three elements A, B, and C in which B is a bi-functional element that makes a loop with two other elements in an event e_1 as shown in figure 9. We can consider this event as two actually-simultaneous events e_{11} and e_{12} and call them *sub-events*. SIM of this event will consist of two parallel matrices each associated with one sub event. The number of sub events in a system depends to the number of multifunctional elements and the degree of their multi-functionality that can be Bi-functional, Tri-functional, Quadra-functional etc.

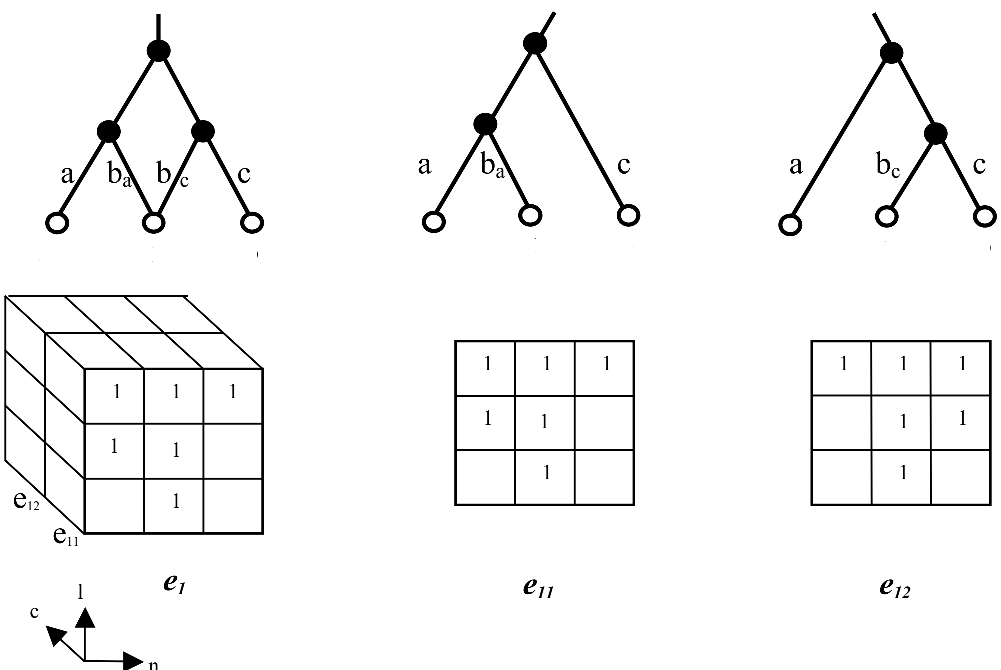


Fig. 9. Multifunctional System

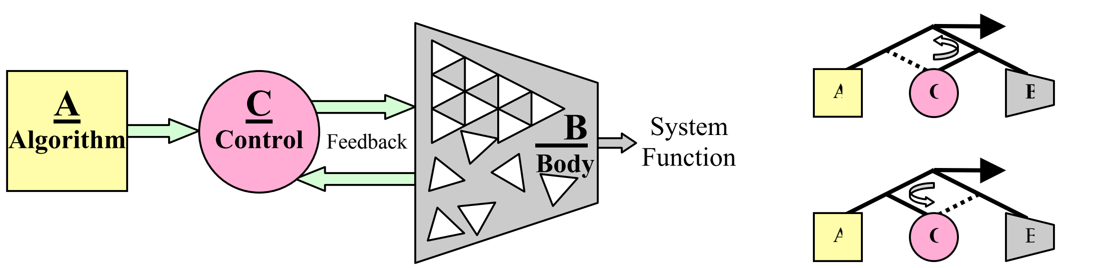
Multi-functionality of elements settles information in the new dimensions as shown in the Fig.9. These additional dimensions of SIM represent degrees of complexity that could be considered as a measure to quantify this parameter of the system. If we compare this complex system with the simple one shown in Fig. 5, we will see that the two events of that simple system are compressed here in one event consisting of two components (sub events). In this case, the total number of possible events is reduced from 3 to 2 and complexity increased while entropy or value of system information correlated to number of system elements is not changed. In this complex system b_a and b_c , the coincident functions of B, are balanced so that we can say one is computed as the feedback of the other.

Complexity in this sense is about functionality and quality of system structure while entropy depicts the variety and quantity of system elements. This complexity may sometimes dictate that the adjusted elements get more in order and the entropy of system decreases over the time. This is the case that happens in the natural bio systems or in general to those systems recalled in Cybernetics.

15. CYBERNETICS

Cybernetics introduced by Norbert Weiner in the mid 20th century as the science of control in the nature and machine, considers the motion in the controlled system.

Controlled system is a system that follows a certain goal by a function that is controlled through a feedback loop [Ref. 9]. The specific feature of these systems is that they have a particular part or a subsystem as Controller that controls the system function to achieve the identified goal by supervising the arrangement of the system elements according to a pattern called Algorithm. Controller in this term can be considered as a sort of observer inside the system that collects and develops system information. The consequence of this process is that the system elements are driven to approach a certain order, entropy of system decreases, and value of the available information in the system increases as time passes. Main parameters of a cybernetic system are shown in Fig. 10-a below.



10-a. Cyber System main parameters

10-b. Control Multi-functions

Fig. 10. Cybernetic System

Controller "C" in this system is a Multi-functional element that simultaneously interacts with the algorithm and the body of the system. Superposing these simultaneous functions provides a closed loop known as *feedback* that is the main feature of a cybernetic system (Fig. 10-b).

In the conventional systems as we show, information is a parameter of the order of system elements correlating to the system entropy. It means that anything conceived as a system contains values of available information that can be measured in terms of entropy and represented in the form of SIM. We can call this as Formal information since relates to the formation or configuration of system elements. In this term, formal information is not an active parameter of the system and is not a cause of changes in the system, but varies itself as entropy or distribution of energy in the system increases or decreases and the order of system elements changes over the time.

In the cybernetic systems in other hand, there is a kind of observer inside the system that re-arranges the order of elements by running active and energetic information between the parts of the system. Hence, we can say that the information in a cybernetic system is not only a static or formal parameter such as in the physical systems but it is a dynamic parameter with values of complexity and quality that takes an active role in driving the system towards a more complex organization.

CONCLUSION

In this synopsis, a new perception about the system information was introduced from the perspective of general system theory. It was shown that intrinsic system information maybe modeled as combinatory patterns of system elements using binary configuration paths. A novel system algebra was introduced and utilized as a tool in formulation and analyses of system events based on System Information Matrix (SIM) defined here. Time and Space have been interpreted from the perspective of this system theory as relation between system elements and its parameters.

We also showed that information in a system is a relative parameter dependent to the position of the observer. In other words, the value of the information depends on the way that system is identified by its elements and their combinations. We showed that the value of information contained in a system is directly related to the number of elements of the system and the level at which the system is being observed. Therefore, the deeper we go into the structure of a system the higher would appear the information within the system.

Information by this interpretation is an objective entity since it is an interpretation of formation of system elements. It is an objective category existing by itself, although it is a relative quantity viewed by an observer. Here we have to distinguish between the terms “objective” and “relative”. That is, space, time, and mass are relative values while they are still objective realities. As we have learned from the principles of the quantum theory and the theory of relativity, many physical properties and effects are relative quantities and depend on the position of the observer [Ref. 5]. The same argument is valid about the information. In fact, if we argue that “objectivity” refers to what exists absolutely independent of the observer, then we would not be able to justify other properties of material such as mass, time and space as objective categories. By a counter argument, if we can say that these material properties are objective entities that can exist in the absence of the observer, then the same can be said about information.

Now, in the cybernetic systems and particularly in the natural bio systems that have been evolved independent from the human control, interpretation of this category "information" can be different and even more definite. With the cybernetic system there always exists an observer (controller) inside the system that processes the information. Without information there would be no control. This information may still be related to the observer, but its observer is a part of the system. Thus, we can say that in the cybernetic systems, information exists independent of an outside observer and hence it is more certainly an objective entity.

* * *

REFERENCES

[1] Casti, John l; (2000); Five more golden rules, the Shannon Coding Theorem; John Willy and Sons Inc. ; USA and Canada

[2] Dean (ed), J.A.; (1992); Lange's Handbook of Chemistry; McGraw-Hill, 14th edition; New York

[3] Lloyd, Seth; (2007); Programming the Universe; Vintage Books; US.

[4] Mansurpur, Massud; (1987); Introduction to information theory; Prentice Hall Inc. publish; USA

[5] Nadeau, Robert and Kafatos, Menas; (1999); The Non-local Universe, the new physics and matters of mind; Oxford University Press Inc; New York

[6] Ness, H.C.Van; (1969);Understanding thermodynamics; Dover publication Inc.; New York

[7] Pierce, John R.; (1980); An introduction to Information Theory, Symbols, Systems and Noise; 2nd revised Edition, Dover Publication Inc.; NY

[8] Reicherbach, Hans; (1958); The philosophy of Space & Time; General Publishing Company Ltd; Canada [6]

[9] Schwarzenbach, L. and Gill, K. F; (1984); System Modeling and Control; Second Edition, Edward Arnold Publish Ltd; London [4]

[10] Siegfried, Tom; (2001); The Bit and the Pendulum, from Quantum Computing to M-Theory, the new physics of Information; Published by John Wiley & Sons Inc.; USA.

[11] Smolin, Lee; (2001); Three Roads to Quantum Gravity; Basic Books; US.

[12] Susskind, Leonard; (2006); The Cosmic Landscape-String theory and the illusion of intelligent design; Published by Back Bay Books; New York, USA

[13] Tribus, Myron; (19..); Some observations on System, Probability, Entropy and Management; published on the Internet.