THE PRINCIPLE OF CONSERVATION OF INFORMATION ENERGY: A HYPOTHESIS

By DEMETRIOS XOURIS Ph. D.

Graduate Industrial School of Thessaloniki, Greece, and Laval University, School of Business Administration, Quebec, P.Q., Canada

A few months ago I was speculating about «information» in the universe and its vitality to sociological systems as well as to the animate subsystems (human etc.). I came to the conclusion that «information» was as basic to humans as physical energy. In other words, the consumption of information energy by the sociological systems and the animate subsystems along with the consumption of physical energy constitutes the basis for their preservation.

Although we are quite aware of the processes of physical energy by the biological portion of the animate subsystems, we are not aware of the processes of information energy.

This speculative study will attempt to establish the «Principle of Conservation of Information Energy» by analogy to the principle of conservation of physical energy.

By information energy, I imply any processing activity of the raw event data relating to the system (sociological or human) or to its environment. By process, I regard any occurance, during which, by any sort of transformation of redistribution of energy, an effect is produced. For example : The human as a system transforms great portions of inanimate energy (raw event data) into useful consumable information energy according to its needs and take-into-account abilities and susceptibilities.

Before we proceed with the establishment of the principle of conservation of information let us briefly review the First Law of Thermodynamics, which states : «While energy may be transferred to or from a system in various manners or be stored within the system in varied forms, in so doing, it may not be destroyed or created and its total thus remains constant».

At this point I would like to define two useful terms: *system* and *open system*.

I define «system» as a region of space within a prescribed boundary. I define «open system» as a region of space within a boundary which energy may cross.

Therefore, an open system is a control system which interacts with its surroundings. By surroundings (environment) I imply those things outside the system which in some way interact with the system or affect the behavior of the system. Therefore animate systems are open systems which also implies control systems since they are in continuous interaction with their environment by continuously processing potential information energy to consumable information energy useful toward its needs and anticipated goals.

This process of transformation of inanimate energy to useful consumable information energy dictates an analogous formulation of the principle of conservation of information which can be stated as follows : *Accounting for all forms in which the potential information energy (raw event data) may appear, the total amount of potential information energy which enters the system must equal the amount which leaves the system plus any accumulation or minus any diminution of the information energy that is stored within the sustems.* This is equivalent to the statement that the increase in the information energy stored in a system is equal to the net transfer of energy into the system.

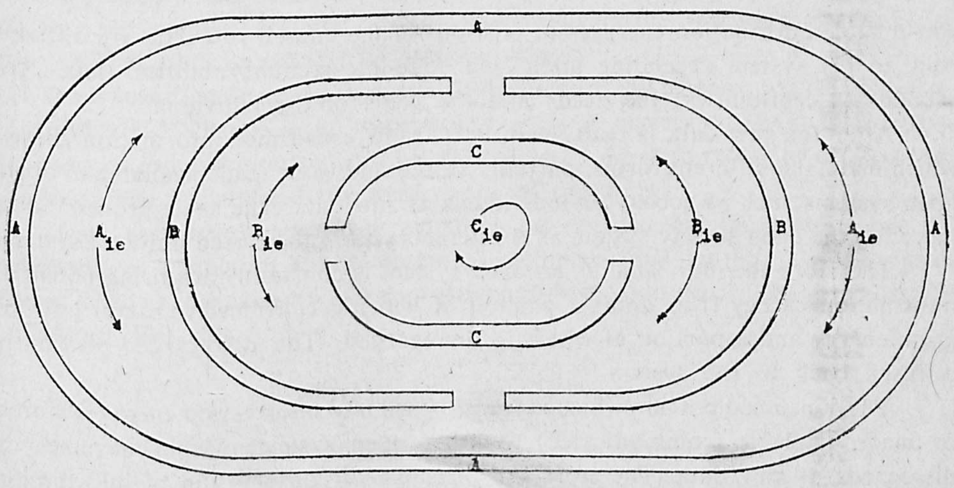
It is also equivalent to the statement that information energy can be neither created nor destroyed although it can be stored in various forms and can be transferred from one system to another. Therefore the animate systems increase their state of order (negentropy) or information or organization by increasing the amount of disorder (positive entropy) or randomness in their environment.

In this sense the animate systems like human beings are increasingly changing their environment according to their needs or goals.

Although there is a great argument about the application of both principles of thermodynamics to open systems such as animate systems since they were originally derived based on closed systems, I feel that an open system can be considered a part of a larger closed system and can be closed momentarily when necessary in order to determine certain quantities. Therefore, let us assume that the animate systems are part of a large closed system; the universe.

This statement can raise many questions such as : Is the universe bounded or infinite? or Does energy or entropy escape in or out? etc. These questions and many more of the same nature cannot be answered within our present state of knowledge. There is speculation that our universe is expanding and if this is the case, then energy or entropy cannot remain constant within its expanding boundaries. So it is meaningless to talk about the energy or entropy of the universe. Therefore, instead of dangerously generalizing by breaking the assumptions of the physical laws, let us stay within our limits unless we broadly revise our thermodynamic laws to include the still unknown universe.

At the present I can only say that the universe is far too large for our limited thermodynamic laws. So let us view the universe as the boundaries of our closed system and the animate systems as open systems within it. Therefore we can present the following model to explain the principle of conservation of information energy.



LEGEND

A = Universe-closed system, primary information energy source.

B = Society-open system, secondary information energy source.

C = Individual-open system, secontary information energy source.

A_{ie} = Potential information energy available as raw data.

B_{ie} = Consumed and potential information energy available as raw data, at the societal level.

C_{ie} = Consumed and potential information energy available as raw data, at the individual level.

This model dictates that the universe and especially our surroundings is a closed system which is a primary information energy source. Within this closed system we have two open systems; society and the individual who are secondary information energy sources.

The state of the information energy source of the closed Universe system is that of potential information energy available as raw data. The state of the information energy source of the open society system is that of consumed (or stored) and potential information energy available as raw data. The state of the information energy source of the open individual system is that of consumed (or stored) and potential information energy available as raw data. The three inclusive systems are namely : society, universe and the individual are in continuous communication.

The individual as an open system is continually consuming the raw data of the society or universe and transforming it to useful information energy capable of fulfilling his needs and goals.

The raw data that the individual acquires is not totally transformed into consumable information energy, but portions of the unused raw data are diffused back to the system depending upon the take-into-account abilities, take-into-account susceptibilities; the needs and the goals of the individual.

After the raw data is consumed, it is transformed into information energy which may take different forms, partially stored and to be made available to other open systems such as society or individuals as raw data. The same process takes place for the open society system as it interacts within the closed universe system.

Therefore the individual as an open system is constantly acquiring potential information energy (raw data) a portion of which is consumed to useful information energy and a portion of which is disregarded. The disregarded portion is diffused back to the system.

The consumed portion which is transformed into information energy is stored or made available (communicated) to other open systems which consumes or disregards as raw data. Therefore the principle of conservation of information energy applies since potential information energy (raw data) is equal to consumed raw data plus disregarded data.

I am sure that the questions many could raise are «What about man's creativity», or «Are you trying to say that the information available stays constant», or «What about all this tremendous progress through the ages of human and sociological knowledge?». The principle of conservation of information is not in contradiction with human creativity. Creativity is a result of change of form of the information energy consumed. But change of form does not imply newly created absolute information energy.

The growth of human knowledge through the ages is merely transformations of information energy and the acquiring and storage of greater amounts due to the irreversibility of the system and making it available at greater amounts at the *expense* of the primary source which is far more than what is necessary for the survival of the animate system. In a sense this is analogous to what Gibb established in thermodynamics by calling this growth «free energy» which implies the entropy growth due to the irreversibility of the system.

We know more now, but there is less to be known as we keep acquiring more and more. Our creativity lies in our abilities in consuming the raw data and transforming it to different and complex forms of information energy. We express this creativity by what we create (material things) by what we communicate and by what we think.

DIMENSIONAL ANALYSIS-POSSIBLE APPLICATIONS

It is definitely very hard to conceive and understand all the complexities involved in various levels of transformation of the potential information energy to different forms of consumable information energy which contributes to action and change in behalf of the system.

By observing the input and output of the system that is the continuous convertibility of potential information energy to consumable information energy we may form an adequate foundation for conceptualizing the operation of change in open systems such as society or the individual.

I am sure that several people would argue with my attempt to conceptualize the operation of change in an open system such as society or the individual by observing its input and output, but let me ask you : Am I to refuse to eat because I do not fully understand the mechanism of digestion?

If we were to assume, in establishing the notion, that information energy per system is a function of the amount of acquired information, (the take-into-account abilities, the take-into-account susceptibilities, and need) then the equation would look like this :

$I_E = f(I_a, A, S, N)$ where

I_E = Information energy

I_a = Information acquired

A = take-into-account abilities

S = take-into-account susceptibilities

N = need (toward goal satisfaction, e.g. economic, power, etc.).

But the situation is never so simple, most likely there are many variables to be considered. For example : The variable A (take-into-account abilities) may be a result of many variables affecting it. The question is : in what way do those variables combine so that they can form the resultant variable A? The same argument applies to the other variables such as I_a, S, and N. Variables of this kind can represent categories of many variables which should be considered and an attempt should be made to determine their combinations and arrive at some functions which are combinations of variables. Therefore, instead of dealing with 15 variables, we can deal with 3 which represent all the 15 variables.

The technique known as dimensional analysis, is a method of procedure which allows a group of variables comprising of a physical relationship to be arranged so that they throw some light on the general behaviour of a system. Thus a particular relationship may be determined by n variables Q, which may be stated formally by means of the equation, $Q_1 = f(Q_2, Q_3, .., Q_n)$. Now, if the number of variables is large, even as many as fifteen, there may be considerable difficulty in plotting the relationship of several variables without recourse to several separate graphs which cannot be assimilated together. Dimensional analysis is a logical formal procedure for grouping the variables into a smaller number of dimensionless groups each containing two or more variables, the number of such groups being the minimum necessary to include all the variables at least once and to represent the relationship between them.

The basis of dimensional analysis as a formal procedure is the Π-theorem which states that a complete equation may be expressed in the form of a number of Π-terms, each Π-term representing a product of powers of some of the Q's which in terms of the primary dimensions form a dimensionless group. Thus the equation :

$$Q_1 = f(Q_2, Q_3, Q_4 \ldots\ldots Q_n)$$

may be expressed as

$$\Pi_1 = \Phi(\Pi_2, \Pi_3, \Pi_4, \ldots, \Pi_{n-k})$$

where each indepedent $\Pi = Q_1^a, Q_2^b \ldots Q_\pi^x$, with the resulting product being dimensionless when each Q is expressed in terms of the primary dimensions. In each Π some of the exponents a, b, ...x will be zero and thus each will contain only some of the variables. The number of Π-terms, n-k, is less than the number of variables n and there are various ways of determining the value of k. Some are precise although mathematically involved and some simpler, but although correct in the great majority of cases, there ane some exceptions which are occasionally troublesome. k can never exceed m, where m is the number of dimensions, and in a large number of cases k = m. The (n-k) Π-terms are the greatest number of independent Π's which will represent the equation as although other Π's are possible, they can be formed from a combination of powers of two or more of the original Q's, which being dimen sionless will in this way form a dimensionless product together. There are several was in which the Π-terms can be found in a logical manner and one that appears to be the most convenient is given here.

CALCULATION OF Π-TERMS

The problem is to combine n Q's into (n-k) dimensionless groups of Π's. If kQ's which do not by themselves form a dimensionless product are taken and combined with the remaining Q's in turn to form a dimensionless product, then (n-k) Π-terms will be obtained. The Q's will have unknown exponents and when each Q is expressed in primary dimensions, a condition must be applied to make the product dimensionless. Suppose for example, the equation is $Q_1 = f(Q_2, Q_3, Q_4, Q_5, Q_6)$, that is six variables to be expressed in terms of three primary dimensions. Then n-k = 6-3 = 3 Π's will be necessary. Arbitrarily selecting Q_1, Q_2 and Q_3, these are combined with Q_4 and Q_5 and Q_6 in turn to give 3 Π's, so that each Q appears in the dimensional form as a P term,

$$\Pi_1 = P_1^{a_1} \; P_2^{b_1} \; P_3^{c_1} \; P_4^{d_1}$$

$$\Pi_2 = P_1^{a_1} \; P_2^{b_1} \; P_3^{c_1} \; P_5^{d_1}$$

$$\Pi_3 = P_1^{a_1} \; P_2^{b_1} \; P_3^{c_1} \; P_6^{d_1}$$

Now each of these equations must be dimensionless and this condition can be started by setting each group of P's equal to M^0, L^0, T^0 thus :

$$P_1^{a_1} \; P_2^{b_1} \; F_3^{c_1} \; P_4^{d_1} = M^0 \, L^0 \, T^0$$

$$P_1^{a_1} \; P_2^{b_1} \; b_3^{c_1} \; P_5^{d_1} = M^0 \, L^0 \, T^0$$

$$P_1^{a_1} \; P_2^{b_1} \; P_3^{c_1} \; P_6^{d_1} = M^0 \, L^0 \, T^0$$

Simultaneous equations can be formed for the exponents of M L and T, but this results in three equations and four unknowns. However, one unknown exponent can be eliminated by raising each side to a power equal to the reciprocal of this exponent, since each side is dimensionless. It is convenient to eliminate the exponent of the P term which is combined in turn; thus for the example given, each side is raised to the power of 1/d giving for the first equation :

$$P_1^{a_1/d_1} \quad P_2^{b_1/d_1} \quad P_3^{c_1/d_1} \quad P_4 = M^0 \, L^0 \, T^0$$

or

$$P_1^{a} \quad P_2^{b} \quad P_3^{c} \quad P_4 = M^0 \, L^0 \, T^0$$

This is equivalent to taking the exponent of P_4, P_5 and P_6 equal to unity in the first instance. There are then three equations with three unknowns a, b and c and these can be solved very simply.

Let us illustrate this method with an example. Suppose it is required to perform the operation of dimensional analysis on the relationship of pressure loss Δ_p for flow in a pipe, with respect to the fluid velocity V, the fluid density p, the fluid viscosity μ, the pipe length b and the pipe diameter d.

$$\Delta_p = f(V, \, p, \, \mu, \, b, \, d)$$

Selecting V, p and d as 3Q's which will not form a dimensionless product themselves, then the Π's are set up as follows. After putting each Q into its proper dimension of M,L,T, combining V, p and d with Δ_p, μ and b in turn.

$$\Pi_1 = P_1^a \; P_2^b \; P_3^c \; P_4 = \left(\frac{L}{T}\right)^a \left(\frac{M}{T^3}\right)^b (L)^c \left(\frac{M}{LT^2}\right) = M^0 \, L^0 \, T^0$$

$$\Pi_2 = P_1^a \; P_2^b \; P_3^c \; P_5 = \left(\frac{L}{T}\right)^a \left(\frac{M}{L^3}\right)^b (L)^c \left(\frac{M}{LT}\right) = M^0 \, L^0 \, T^0$$

$$\Pi_3 = P_1^a \; P_2^b \; P_3^c \; P_6 = \left(\frac{L}{T}\right)^a \left(\frac{M}{L^3}\right)^b (L)^c \left(L\right) = M^0 \, L^0 \, T^0$$

Forming the simultaneous equations from the exponents for Π.

$$M: b + 1 = 0 \quad * \quad b = -1$$

$$L: a - 3b + c - 1 = 0 * c = 0$$

$$T: -a - 2 = 0 \quad * \; a = -2$$

Hence $\Pi_1 = P_1^{-2} \quad P_2^{-1} \quad P_3^{0} \quad P_4$

and in terms of the variables Q

$$\Pi_1 = (V)^{-2} \quad (p)^{-1} \quad (d)^{0} \quad (\Delta_p) = \frac{\Delta_p}{pV^2}$$

Similarly for Π_2

$$M: b + 1 = 0 \quad * \quad b = -1$$

$$L: a - 3b + c - 1 = 0 \quad * \quad c = -1$$

$$T: -a - 1 = 0 \quad * \quad a = -1$$

hence $\Pi_2 = \frac{\mu}{pVd}$

For Π_3

$$M: b = 0$$

$$L: a - 3b + c + 1 = 0$$

$$T: -a = 0 \quad * \; c = -1$$

hence $\Pi_3 = \frac{b}{d}$

$\Pi_1 = \frac{p}{pV^2}$ may be recognized as a commonly used parameter, the «dimensionless» pressure loss, that is the loss in terms of the dynamic head. Π_2 inverted to $\frac{pVd}{\mu}$ is recognized as the Reynolds number. $\Pi_3 = b/d$ is simply the length/diameter ratio of the pipe. Finally then, there results $\frac{\Delta_p}{pV^2} = \varphi\left(\frac{pVd}{\mu}, \frac{b}{d}\right)$

This is as far as dimensional analysis will provide information; that is, the form of the function is unknown and must be determined experimentally. It has however reduced the variables from six separate ones to three groups which can be handled much more readily, both experimentally and in the form of plotted results. Thus in any unknown problem, it may be necessary to find all the possible Π's and then select n-k of them for the final relationship. This can be done systematically by repeating the above procedure for all possible combinations of the three initia- variables, but this is somewhat tedious. However, because the Π's are dimensionl less, it is possible to raise them to different powers and multiply and divide them together to form other groups. In an unknown problem, this procedure can be adopted, aided by intelligent perceptions to see if more convenient or recognizable groups are possible. It has been pointed out by Van Driest that the number of possible combinations of n variables taken $k + 1$ at a time is given by $\frac{n!}{(k+1)!\,(n\text{-}k\text{-}1)!}$

With $k = 3$, five variables yield five cominations, six variables yield 15, seven variables yield 35 and so on. The limitations of the method must, however, be duly recognized. It does not give any information on the form of the function and furthermore, it will not reveal the omission of any significant variable which affects the relationship unless this omission will not allow any dimensionless groups at all to be formed.

The converse is also true, that variables which do not affect the physical behavior are not automatically excluded from the dimensionless groups. Experiments would show that they have no effect, but their inclusion complicates the interpretation of Π-terms.

Thus it is apparent that some degree of experience is needed in setting up the relationship, but in reality, the problem is not very difficult if there is a knowledge of the general field of the behavior in question. Dimensional analysis is also useful in showing the basic validity or invalidity of possible doubtful assumptions. Again, it is useful in showing a logical grouping of variables towards which the analysis may be directed.

So far, in this example and analysis, I have dealt with a physical system. The question is, not whether this method is applicable to an open living system, but whether a similar method can be invented according to which, after the identification of the variables relevant to the system are specified, we can logically group together, to form fewer variables which can be used in identifying the behavior of the system. Unfortunately we seem to talk about such variables as : take-into-account abilities or susceptibilities of an open system, but what are these variables which form such combinations of variables, as take-into-account abilities etc. If we know these variables, in what ways are they interrelated? How can we observe them so we can arrive at some useful relations other than pure speculative notions contemplated by sitting in an arm chair?

I do not necessarily propose measurement because I would agree with what Jacob Viner once said : «When you can measure it, when you can express it in numbers, your knowledge is still of a meager and unsatisfactory kind». What I would like to see is some deductive approach similar to dimensional analysis used in physical systems where we can come to grips with the numerous variables which affect and determine an open system.

Pure speculative and ethereal reasoning may not be enough. It all depends upon what we want to do and why.

The key advantage of dimensional analysis in its application to physical systems is the fact that all the variables can be specified in terms of some combination of three basic dimensions, that is : Mass, length and time (MLT). For example, in the previous physical example, velocity-V was expressed in terms of $\frac{L}{T}$ (length over time), density p was expressed in terms of $\frac{M}{L^3}$ (mass per unit volume). Therefore whenever we deal with a living open system, is it possible to determine two or three «dimensions» or elements through which we can express all the different variables involved? If this is possible, then we can study the behavior of an open system such as society in a more systematic and constructive way.

In summary, I have tried in this paper to describe information energy, its nature and behavior in an open system. Following that, I tried to put across the idea that we should try to develop some way of conceptualizing the different variables of a system which are responsible for the consumption and procession of the information energy and in turn, responsible for the behavior of the system itself. This was done by presenting the method of dimensional analysis applicable to a physical system and by raising the question of the possibility toward a similar direction by recognizing all the variables of the system, which is the function of information energy and reducing them to a few primary variables to represent functional combinations of all the original variables.

The key question is, whether we can invent two or three basic «dimensions» which can help us to identify each variable so we can arrive at a few primary variables which represent relative combinations of the numerous original ones.