Dr. P. CONSTANTINESCU
"Stefan Gheorghiu" Academy

Cybernetic Systems

Cybernetics, as it was defined initially by Norbert Wiener as "science of control and communication of information to machines and living beings" enriched continuously its methods, penetrating only in a few decades into all fields of nature and society. Norbert Wiener himself reconsidered his initial definition, investigating more and more systematically the possible applications of cybernetics in society and foreseeing the importance of studying the organization aspect of cybernetic systems for physics, and particularly for quantum mechanics [15].

The subsequent discovery of the *objective character of information* [4] in which the contribution of biology and genetics was decisive and which is one of the greatest, if not the greatest discoverry of this century, lead gradually to the fact that the anthropomorphic viewpoint from the definition of cybernetics makes room to the necessity of studying control and properties of information, on all levels of organization of matter.

The understanding of the interaction as having four sides: information (organization), matter (substance and field) or energy space and time, to which lead also the discoveries made especially in biology and genetics, allows us to prove the presence of information (beside energy) in the depths of matter [10], hence also on the physical, quantic (a.s.o.) level.

The proof is based upon the understanding of control (bundle of interactions) and thus as a system made up of a direct (informational) connexion [14] and on (informational) feedback (reaction), as in the cyclic-type representation in figure 1.

Modelling of the control through the equation system of the form:

$$\frac{dx}{dt} = f(x,\ y,\ t) \tag{1}$$

$$\frac{dy}{dt} = g(x,\ y,\ t)$$

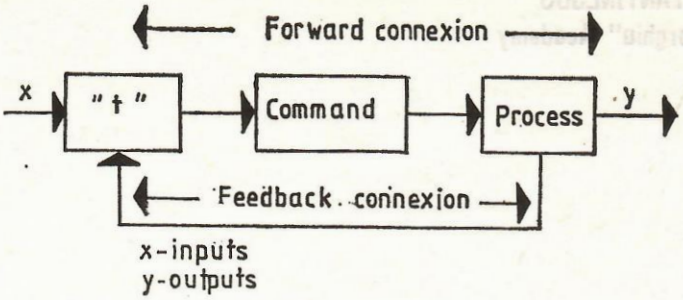


Fig. 1.

where x and y can be scalar, vectorial variables etc., allows the particularization of system (1) in the case of physical control 5:

$$\frac{\partial \varepsilon}{\partial t} + I(\varepsilon, S; t) = 0, \ \varepsilon = \varepsilon(q_1,...,q_n; t) \tag{2}$$

$$\frac{\partial S}{\partial t} + H(\varepsilon, S; t) = 0, S = S(q_1,...,q_n; t)$$

where q_i $(i = 1,...,n)$ are the generalized coordinates, S — action, ε — entropy, I — Wignerian associated to H — Hamiltonian [6]; system (2) allows to generalize Hamilton-Jacobi's formalism for entropic-informational aspects too, leads to the understanding of the fact that physical control is fundamental for physics, as it can be used in finding the axioms, of which all groups of different axioms, associated to the present-day fields in physics can be inferred [6], and implicitly to deduce the fundamental equations of state in classical mechanics, thermodynamics, electro-magnetism, restricted and generalized relativity and quantum mechanics, postulated in each separate case.

The presence of controls associated to information on the physical (quantic) level also results from the properties reflections, command, self-organization, selfreproduction and variability-stability (storage) of information, which were also emphasized, especially in biology, genetics, by associating these properties of information to the general property of reflecting, of the matter.

The storm which will be brought about by cybernetics in physics and hence in the sciences of nature, due to the clouds heaped up in the physics of elementary particles, can be stronger than the storm named relativity and quantum mechanics from this century, and which was brought about by the clouds which appeared on the "cloudless" sky of classical psysics, to the end of past century: Michelsohn-Morlay's experience, theorem of specific heats and ultraviolet catastrophe.

By systematically studying the structural-organizational aspects of the systems, close to the dynamic behaviour, to the functional aspects of the systems, which were dominantly studied by means of Newton's, Maxwell's, Boltzmann's Einstein's, Schrodinger's (a.s.o.) "equations of state", physics, using cybernetic methods, can start to explain the phenomena of substance generation, to

include as a constituent science, the physics of elementary particles and to draw up the theoretical and methodological base, for working out quantic, atomic, molecular technologies etc.

All the above mentioned technologies *can use*, *beside energy*, *also information*, hence can use the dual aspects in the nature, which are presupposed by these two levels and which we know better and better (but asymptotically) by means of measures and molecules, which include always new aspects from reality (potential, cynetic, thermal, magnetic, electric, free, bound, relativist ($E = mc^2$) energy, and the amount of information introduced by Shannon — proportional to Boltzmann's measure of entropy — the value of selection of information, the value of significance of information etc., respectively).

The working out of such a technology, which could use the infinite ocean of energy and information, linked together for obtaining free energy and information "free' for being able to generate in the interaction "information, energy (substance and field) space and time" new substances, hence practically to achieve the passage to the possesion of infinite resources, has particular ontologic implications and can open a new epoch in the history of mankind, can bring about the dawn of communism all over our planet, suppressing the danger of selfdestruction.

Cybernetics studies consequently the controls and information on all levels of matter organization. Cybernetic systems are hence also present on all levels in nature and society. But what is a cybernetic system?

We shall represent the cybernetic system with the help of control, in the same manner as we represented control with the help of information (of four-sided interaction).

We say that a system [7] is cybernetic if it contains at least a control at the level of the system, conseqently if inputs (x) in the control are inputs in the system and if outputs (y) from control are outputs from the system. We notice from the representation given to the cybernetic system that it may have two inputs (outputs) which are not inputs (outputs) in control. It is also not sufficient that a system contains a control (e.g. in a sub-system) for this system to be cybernetic, (for instance, a plane with automatic pilot is a cybernetic system; a plane without human or automatic pilot is not cybernetic, but in its structure there are numerous controls or cybernetic subsystems, respectively).

The presence of cybernetic systems on all levels of organization of matters (particles, atoms, molecules, cells, organisms, organizations, a.s.o.) compels us to an interdisciplinary approach in studying the dual, functional-organizational aspects of the cybernetic systems for a more profound investigation of the behaviour of control, with a view to better understanding the organization, development and management of cybernetic systems.

The conscious management by man of cybernetic systems is presented on the socio-economic level; the command within the controls, on the physical, chemical, biologic (etc.) level, is given by the play of nature's laws, of variational principles, of the interactions which are acting in the nature.

Controls, according to our experience in the last centuries, may have, both a stabilization, homeostatic character (of maintaining the values of

a magnitude between certain limits), of maintaining the dynamic balance (continuous combination of stability and change) etc., when we represent them as feedback controls, and character of amplification of some fluctuations or magnitudes within or from input or output of the process (Fig. 1), of (experimental) accumulating of some effects, when we represent them as controls with positive feedback.

The effects of controls with negative or positive feedback can be illustrated also by the dynamic balance achieved by nature in the ecological cycles. If we consider, for instance [2] the cycle: fishes-organic wastes- (putrefaction) bacteria-inorganic matters — algae — fishes, we can state the stabilizing effect of feedback, for instance in the case when, due to favourable conditions (e.g. prolonged warm, season,), the algae develop themselves quickly. This leads, on the one hand, to the reduction of the reserves of inorganic matters and, on the other hand, the fishes eat easier abundant algae, which also leads both, to the reduction of the population of algae, and to the compensation of inorganic matters through the links of the cycles: the inorganic wastes — bacteria accelerate the putrefaction process-inorganic products grow.

The effect of stabilization in the main cycle can be achieved, besides the play of the contrary (compensating) trends of the links, carried out by the effects of positive and negative feedbacks in the main (control) cycle, also by means of the speed differences in the subjacent and adjacent cycles, hence the effect of stabilization in the main cycle also results from the play of relative speeds, durations of the processes in the component cycles.

The time necessary for the appearance of a new fish generation may be a few months, with algae—a few days, with bacteria—a few hours. The durations of the metabolic and reproduction processes, from the cycles associated to each of these organisms are greater with adjacent cycles as against subjacent cycles (fishes as against algae, algae as against bacteria). The process speed (rate) at (dynamic) balance of the main cycle is correlated with the speed of the processes from the adjacent cycle within the main cycle, hence with the rate of reproduction and the metabolic processes of fishes, within the presented example. Any growth of the speed (duration) of reactions in the adjacent cycles, brings about disturbances in the main cycle, as the speed in the adjacent cycle calls for the speeds of reactions in the subjacent cycles. Thus, for instance, the speed by which fishes produce wastes determines the speed of bacterian decomposition reactions, hence determines the speed of oxygen consumption in water, for carrying out this decomposition.

If the decomposition process speed increases, e.g. by throwing organic wastes into the water, bacteria intensify their activity, the oxygen produced by algae is consumed in larger amount than with dynamic balance, fishes cannot any more find oxygen, and the ecologic system can be endangered. One remarks that the stability of the main cycle is both the result of the play of negative or positive feedback controls, which take part in its composition, and of the speeds (durations) of processes in adjacent and subjacent cycles.

The pollution of the environment is the result of the breaking of a link in the main cycle, so that the effects of positive and negative feedback controls cannot compensate themselves any longer, and the whole system moves

away from the dynamic balance state, reaching possibly the final destruction. The breaking of the main control cycle means the linear development of the processes in the links, a fact which could have as result, either the amplifying of some components, or the disappearance of some other ones, hence finally the breakdown of the ecologic system.

Though slower than the processes in water, the processes occuring in the soil or in the air have the same character as in the cycle mentioned above. The conscious organization of the cycles which could ensure the resuming of processes (e.g., the providing of the conditions of obtaining from wastes inorganic matters, or organic wastes able to allow the resuming of unpolluting cycles), in such a manner that polluting wastes do not accumulate linearly, is an important condition of rationally introducing technical progress, of achieving new objectives.

We can remark taking into account the above presented facts that *a main cycle is a cybernetic system.* We note also, in the above presented example, the play of the four sides of interaction: information, energy (substance and field), space and time, within the (main cycle) control.

But it results from the scientific and practical experience gathered up especially during the last centuries, that the controls may be classified, beside controls with positive or negative feedback, respectively, also as corrective or prospective controls.

The corrective controls carry out the correction of deviations, of random deviations, which should appear, from the trajectory (row of states) determined by nature's laws or consciously projected. The prospective or feed-before controls, command behaviours of the system on the basis of *possible* feedbacks of the environment, which are inscribed in scenaries stored in the respective organism. The prospective control is not met with at abiotical (inorganic or organic) level, but beginning from the lower monocellular forms of life, to which we have to deal with an active reflecting, with a cutting up, an anticipated image (reflexion) of the environment, of its variation before they may happen and jeopardise the existence of the organism. The cell protection mechanisms, the coded scenaries in the ADN molecule for producing certain proteins, or for self-reproduction etc., do illustrate the great spreading of the prospective controls in living matter. The programming, planning and prognosis methods use also prospective controls in all fields on the socio-economic level. We may infer, from the above presented facts, that the systems: particles, atoms, molecules, living cells, biologic organisms, industrial enterprises, economic units etc., are main cycles, hence are cybernetic systems.

The positive and negative, corrective and prospective feedback controls in the couplings, achieved within cybernetic systems (stabilizing controls being dominant in adjacent, and amplifying, selfcatalytic ones, in subjacent) make up the main mechanisms, the systems development motor, the motor of biological and socio-economic evolution.

As a matter of fact, the amplifications produced by the positive feedback controls in subjacent stabilized by the play of the negative feedback controls from adjacent, or the play of negative and positive feedback controls in the main cycle, which compensate the amplifying effects, may lead to the

development of the structure, to the organization of the system on various stable levels.

Prospective controls make up reservoirs of selective advantages [11] possessed by the systems, so as to avoid the practically infinite attempts to which one would have to ressort to, without using the selective advantage within evolution.

Eigen, as we showed [11], by associating as information selection value, the sequence

$$(W): W_1 < W_2 < ... < W_n < ...,$$

obtained the result that the development of species is carried out on the stable levels W_1, W_2,... in which the effects of negative feedback controls are dominant and are obtained through transition phases wherein the possitive feedback controls effect is dominating (Fig. 2).

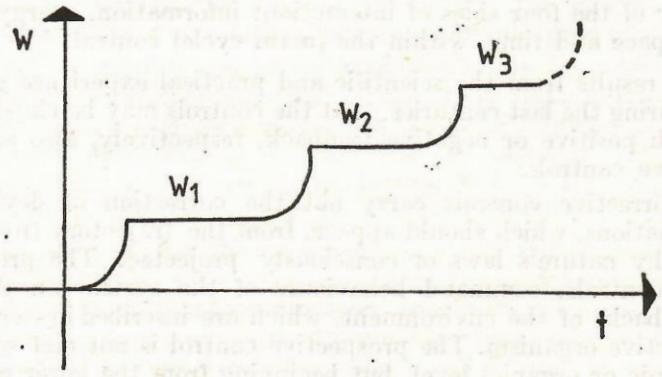


Fig. 2.

The information selection value does not describe the effect of prospective controls, of the thesaurus of genetic scenaries, which is essential in the processes associated to the evolution of species. As the author himself acknowledges, the information selection value, expressed by means of some measurable physical-chemical parameters, is only a first approximation on the way of modelling the evolution of species.

So as to improve and extend the measuring and modelling of the information, it is necessary for instance, to associate, in the development graph from Fig. 2, to the numbers W_1, W_2,..., also mathematical structures, which would reflect the concrete structures of the stable levels from this graph:

$$(S): \quad S_1 < S_2 < ... < S_n < ... \tag{3}$$

where $S_i - W_i$ and where $S_i < S_{i+1}$ means that structure S_i is included in structure S_{i+1} (for instance "$<$" can mean inclusion of seats, as for instance in the sequences of normal extension of bodies from Galvis' theory, but also the fact that for instance, the group structure is included in the ring structure, which is included in the body structure etc., or the lattice structure is included in the boolean algebra's structure and so on).

Moreover, the hierarchical formation of structures S_1, S_2,...,S_n, is not obtained by the destruction of the hierarchically subordinated structures, but by maintaining their properties of „closure", by losing, of course, certain degrees of liberty in the favour of the new system, hierarchically superior, with a more complex structure, in which the subordinated structures are included synergetically.

The preservation of the closure properties of the structures, within the process of building structures hierarchized on various stable levels in the development graph (Fig. 2), suggests the association of a third sequence of transformations, in correspondence with sequences (W) and (S):

$$(G):\ G_1 \supset G_2 \supset \ldots \supset G_n \supset \ldots \tag{4}$$

where $W_i \leftrightarrow S_i \leftrightarrow G_i (i = 1,2,\ldots,n,\ldots)$.

As a matter of fact, in the first place, the set of transformations which lets invariant for instance, structure S_2 (set of symmetrics)* is less than the set of transformations which lets invariant structure S_1, less complex, which presents fewer restrictions for the symmetrics.

Secondly, the set of transformations which lets invariant a structure S_i, forms a group (because the set of the transformations which let invariant a structure is closed as against the composition of transformations: if we compose, for instance, we carry out, one after another, two transformations which let invariant structure S_i, the result being a transformation which lets invariant structure S_i).

In the third place, let us show that G_{i+1} is a subgroup of G_i, for instance let us show that $G_1 \supset G_2$. It is necessary, to this end, to show that set G_2 is closed as against the composition of the transformations from G_1. But, as structure S_1 preserves itself (it keeps its closure properties) within the hierarchically higher structure S_2, it results that the set of transformations from G_2 must let invariant also structure S_1 (otherwise, it would not let invariant structure S_2), as such it is necessary that G_2 be closed as against the law of composition of the transformations from G_1.

If we can associate sequences (W), (S) and (G) in correspondence as in Fig. 1, to same phenomena of development of the cybernetic systems of structure, of their organization, on all levels of organization of matter, or of evolution of biological, socio-economic systems, then we shall say that $W_1, W_2,\ldots,$ $W_n,\ldots$ are signification values of information.

This measure, associated to the information or to the degree of organization of a system, represents in fact a measure of a semantic aspect of the movement of thought. Indeed, as Piaget [8] and the genesis school of psychology showed, a correspondence (isomorphism or homomorphism) can be established between *the concrete, the mathematical and the psychical structures.* On this basis, the information signification value from sequence (W) reflects also aspects of the progressive movement of thought, the psychical structures the latter operates with, and which are in correspondence with the concrete (mathematical) structures from sequence (S). This measure, although reflec-

* Symmetry, in Weyl sense means invariance (with respect to a set of transformations).

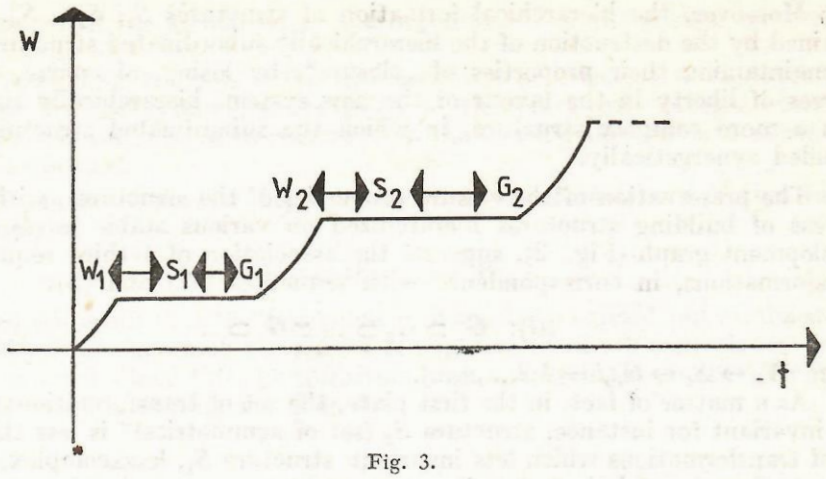


Fig. 3.

ting only a particular aspect, only one side of conscience, this measure can lead to a deeper understanding of the conscious organization processes, of understanding the "organization", such as Piaget described these processes. As the author showed [9] by using the information signification value and Galois' theory, new aspects can be explained, which are connected especially to the structural-organizational side of the systems — "chemical elements" — — from Mendeleyev's periodic system.

The deeper understanding of the organizational aspects of cybernetic systems, on all levels of organization of matter, can be adjusted by measures, of the type of signification value. Combining quantitative and structural aspects, which are necessary together for describing the qualities appearing from the quantitative accumulations, the measures of the type of signification value, in which the essential is the correspondence between numbers, structures and invariance properties (described by the three sequences), may add a new page to the two pages on which mathematics of numbers and of geometric objects, respectively, was written [13] whose correspondence could not be established rigorously but since about hundred years. This third page of structures necessary for cybernetic modelling of systems organization, on which more mathematics was written in the last century than on the other two pages, we believe, must be systematized also in the sense of the correspondence numbers-structures-invariance, hence of the correspondence with the page of numbers and with the page of geometric objects.

The gnoseologic implications of the tye of information significance value are important also for philosophy, for science and for practice. If we refer for instance, only to the manner how the methodology of determination of indicators in the socio-economic space [12] can be improved, not to speak about the efficiency of the scientific organization of the production processes of the

organization of innovating education [3] as a guarantee of better training of the future generations, hence using this *objective mean of selfcontrol of conscience*, we can have legitimately the justified feeling of the prospect of stengthening our dignity and of the possibility of suppressing the human alienation phenomena; these openings in "measuring" some aspects of the semantics, will allow gradually that the science, a force of production, become a conscious force of production, which will serve the new socialist humansim.

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