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The Cybernetics of Motivation

One of the peculiarities of inter-disciplinary research is the fact that some concepts and formalisations can be extrapolated from one domain of science into another. In the following pages we shall try to apply some data from the field of operations research and economic cybernetics in the sphere of psychology.

1. The permanent strategic objective of the activity of the nervous system is to secure optimum conditions for *the survival of the* living *organisms* and *the perpetuation of species* in their given ecologic environment. In man's case, the objective is more complex, for we must also consider the social environment, without which human existence becomes inconceivable.

The objective mentioned is being realised through two classes of strategies.

1. 1. The first refers to the totality of neuro-physiological and endocrine processes which ensure via the *internal medium* (proper to the respective organism) the maintenance of some structural or bio-chemical constants (e.g. the forms of bones, temperature, blood-pressure, glycemy, etc.)

All these strategies are grouped under the name of *homeostatic functions*. They impose a given invariant for the living organism, which is absolutely necessary to its existence.

1. 2. The second class of strategies refers to the processes ensuring the realisation of the homeostatic functions and adaptation to environment, with the aid of *mediums outside* the organism. These must be discovered, recognized, acquisitioned, used, a.s.o. In many cases, in order to obtain and use them, competitional situations may occur.

The totality of these strategies are defining what psychology has termed as *motivation*. It is the main factor of behaviour and is the "cornerstone of psychology" [2], [6].

1.2.a. In respect to all existing species, motivation includes the totality of "behaviour-techniques", used by the living organisms to satisfy their

needs, linked to some physiological necessities (e.g. the need to take water, food, the need of movement). This aspect of behaviour was named *biological motivation.*

Biological motivation includes a collection of decision sequences (or a collection of possible strategies) more or less stereotype. Every sequence leads to the realisation of a target, satisfying the need that had generated the respective motivational process.

For a long time, this collection of decision sequences was known under the term proposed and launched as far back as the XVIII-th century: *instinctive behaviour.* (see: Pernau and Réaumur). It has to be noticed that it has species characteristics and hence, its different terminology "specific species behaviour" [5]. This is always an "appetitive and consumer behaviour" directed towards a given aim.

Essential is the fact that biological motivation is being checked by a collection of determining *algorithms*, mostly of genetics data and only to a minor extent received through learning.

1.2.b. In the case of man, motivation also includes the totality of strategies used to comply with his needs as a member of society (e.g. the desire to secure a given living standard, to occupy a given position in social hierarchy, to satisfy one's cultural exigencies, a.s.o.) This is what has been termed as: *psychological motivation* or psycho-social motivation. It is a specifically human motivation.

Its complexity is much larger than that of the biological motivation. It is influenced not only by the factors from the natural biological environment, but also by the so highly sophisticated factors from the social environment, with their economic, social-cultural, historical and ideological determinants.

Psychological motivation is at the same time a collection of strategies. This time, they help each and every individual to pursue and realize his aims in society. It is based on a collection of *heuristics* every individual builds up for himself in a long process of data reception. Their acquisitioning takes place either via direct experience, or by taking over other's experience (education). Also implied is the cognizance of all restrictions — as genuine rules of the game — imposed by society.

We used the term of euristics to underline the fact that in the case of psychological motivation, algorithms can not be taken into account. The MAN system does not, in general, solve its motivational problems (either biological or psychological motivations) on the basis of exhaustive algorithms. Such algorithms can be incriminated only with the biological motivation of inferior animals (particularly with insects and at maximum development with hymenoptera).

With more subtle adaptation, biological motivation is controlled by defined algorithms on fuzzy multitudes. The programs grow vaguer and vaguer with evolution, reaching maximum level in man.

2. The general pattern we shall operate with to analyse motivation is the system-pattern. We consider every living being a S system, defined

by U multitude of inputs $\{u_i\}$, X multitude of states $\{x_k\}$, Y multitude of outputs $\{y_j\}$ and by f_1 functions of transition and f_2 of output.

$$S = (U, X, Y, f_1, f_2). \tag{1}$$

We admit, on the basis of observation and experimental data that the S system is not determined, but is probable or Markovian. It hereby results that f_1 has the shape of a stochastic matrix function, while f_2 has a structure of probability.

We shall also consider that the S system is not invariable in time. It changes, it follows the historic developments through *learning*. At the same time it changes in time in the process of organogenesis, *maturation* or *senectude*, (in the latest portion of existence). That is why a pattern will not stay valid for the entire existence of the system. The period of time or the T epoch will always have to be considered. The following defining operational relation results:

$$y_j(t + \tau) = [S]\, u_i(t) + y_0 \tag{2}$$

in which (S) represents the intervention of the system under the form of an operator, y_0 is the background noise, τ stands for latency, while t for time with the condition $t \in T$.

Within this system motivation appears linked to an under-system $S_\mu (S_\mu \subset S)$.

3. To analyze the motivational behaviour we resort to the methods of operational research.

We consider that a given *need* appears as an in-take signal, represented by vector $\bar{u}_l(u_1, u_2, \ldots, u_l \ldots u_k)$ $(l = 1, 2 \ldots L)$ more or less complex (e.g. the need to take food (hunger) is determined by the detection through some transducers — named glycoreceptors of the decrease in the glucose concentration in blood, a.s.o.)

This signal determines a state of motivation (in the given case the state of hunger, represented by the $\bar{x}_r (r = 1, 2 \ldots R)$ vector. With the existence of this state, the organism will act on the line of the objective need for the termination of the respective motivation.

This activity will appear in an a_r sequence of motor actions, a follow-up of a sequence of decision-making or of a *strategy*.

For every $\bar{x}_r$ state, the organism can choose an a_{rq} strategy from an A_r collection, finite by Q possible strategies:

$A_r = \{a_{rq}\}$ $(q = 1, 2 \ldots Q\}$ Every strategy or sequence determins a given Q_{rq} effect over the environment $[a_{rq} \rightarrow Q_{rz}\}$.

This effect can be characterized for the organism by some given features (the degree the respective need is satisfied, its duration, the efforts needed for its achievement, sacrifices, a.s.o.) Obviously, these must be appreciated in relationship with the $\bar{u}_l$ input signal. It results that the *utility function* F may be defined

$$F = F(\bar{u}_l, O_{rq}). \tag{3}$$

The representation of the above function can be done under the form of a matrix. Theoretically an exhaustive analitical decomposition into dis-

juncted elements may be achieved. (The Bool decomposition). In reality, this is not always possible due to the very high complexity of the variables implied.

The problem raised by function (3) is a stochastic problem, as the a_{rq} — $-O_{rq}$ is probabilistic. Every a_{rq} strategy can determine a finite number of G_{rq} — s of $O_{rq_g}(g = 1, 2 \ldots G_{rq})$ possible effects. Every determination g is characterized by a conditioned probability $p_{qg} = p(O_{rq_g} a_{rq})$.

We admit that any strategy determines an effect. Hence

$$\sum_{g=1}^{G} p_{qg} = 1.$$

In this case function (3) becomes:

$$F = F(\bar{u}_l, O_{rq_g}). \tag{4}$$

The function of utility renders a *value* V to each pair $(\bar{u}_1, O_{rq_g})$ taking into account the features characterizing it (profit in the biological of psychological acceptance, cost or risk.).

This distribution of values is not valid but for Z organism under consideration. Hence, due to the system's variability in time, we understand that it can be working only for a period, epoch T of its existence. Consequently, the system has a collection of values

$$V_{ZT} = \{V_{ZT_g}(\bar{u}r, O_{rq_g}\lambda). \tag{5}$$

Within motivation, the organism *optimizes* its behaviour. In other words it chooses the a_{rq} strategy which maximizes V_{ZTg}

$$V^*_{ZT} = max\ V_{ZTg} = \sum_{g=1}^{G} p_{qg},\quad F(\bar{u}_l, O_{rq_g}). \tag{6}$$

The pattern is not always simple, as relation (6) is working only in the case of the exhaustive decomposition into disjunctive elements. Otherwise, the pattern additionally implies the intervention of the "trading-off" functions, which, however does not lead to basic changes.

4. The organism is not always in the situation to cope with a single motivation. There may be cases when the organism is under the impact of two or more simultaneous motivational signals.

4.1. In some cases there is an *incompatibility* between the respective motivations. Then we have a *competition* between the motivational states. (Bouridan's monkey problem).

The organism's behaviour in this situation implies two decision-making periods. The first clarifies which motivation is of priority; the second is optimal for carrying through the chosen motivation.

Experimental psychology has revealed that a state of biological motivation is forcibly imposing itself (drive), this being a measurable category. The competition between two or more states of motivation will be won over by the state of the most intense drive.

We take two states of motivation x_1 and x_2 determined by the simultaneous in-take signals u_1 and u_2, while D_1 and D_2 are the "drive" values —in concord with:

$$D_1 = F_1(u_1 - \pi_1)$$
$$D_2 = F_2(u_2 - \pi_2) \tag{7}$$

where F_1 and F_2 are two non-liniary functions, while π_1 and π_2 are two thresholds.

Take p_1 for the probability of the system to pass in state x_1 under the joint effect of signals $u_1 + u_2$ and p_2 for the probability of the system to pass in state x_2 under the joint effect of both signals. It results:

$$p_1 = 1 \Rightarrow (D_1 - D_2) > \varepsilon + h'$$
$$p_1 = 0 \Rightarrow (D_1 - D_2) < \varepsilon + h'' \tag{8}$$
$$0 < p_1 < 1 \Rightarrow \varepsilon - h'' < (D_1 - D_2) < \varepsilon + h'$$

where ε, h' and h" are threshold values, expressible in values while $p_2 = 1 - p_1$.

Characteristic is, that is case of

$$|D_1 - D_2| < \varepsilon \tag{9}$$

the system starts oscillating.

This is one of the basic mechanisms generating *neurosis* [4].

4.2. In other cases more that one states of motivation may *co-exist* within the system. One can sit at the table having dinner (responding to the motivation of hunger) drinking, (responding to the motivation of thirst) and talking (responding to a psychological motivation). The system has to adopt a mixed strategy which will have to make it possible for it to comply in one given period of time with n objectives determined by n states of simultaneous motivation. Obviously, here again there's the problem of optimalisation.

5. The psychologic process of motivation is even more complex. Parallel with the under-system, which lies at the basis of motivation, there is also a psychologic under-system. We refer to the under-system of *emotional or affective states* [10]. They are correlated with a collection of life experiences, which creates a discrete bridge between a state of maximum discomfort and a state of maximum comfort, passing through a state of affective or emotional indiference.

The affective sub—system (The Wiener affective moodalizers) has for every couple $(\bar{u}_1, \bar{x}_2)$ a level of comfort or an emotional or affective state e_v $(v = 1,2 \ldots V)$. These levels of comfort may be considered as distributed affective values on a scale of values in the subjective plane of existence, but with multiple exteriorisations. (Vegetative reactions, gestures, a.s.o.).

These values are distributed by a *hedonic function* [3]:

$$E = E(\bar{u}_l, x_r, O_{ra_q}) \tag{10}$$

In most cases the e_v values are parallel with the pure motivational values (V_{ZTG}) upon which they even act as amplifiers. Many a time they are distinct. In this case the respective organism is confronted with decision-making as far as priorities are concerned; either to the function of utility F, or to the hedonic function E.

We consider that the two criteria (of utility and hedonic) are coming up with a given intensity (D_M^* and D_A^*). In this case the mathematic pattern of their confrontation is the same as in expressions (7), (8) and (9). We stress that granting priority to the affective criterion is, in general, with detriment to the organism (e.g. toxicomania). We also mention that in this case the conflict situation expressed in relation (9) generates the most significant class of neurosis.

6. The behaviour decisions made within motivation are optimizing the *hypothetical values*, to be achieved *in the future*. These hypothetical values are appreciated on the basis of data posessed by each and every individual in part. There is no perfect concord between the *expected values* and the *achieved values*. The difference between them measures the future capacity of extrapolation of the systems overall knowledge.

The efficiency of a motivational system will be the bigger it selects the biggest expected values (from within those distributed by function F of utility) the closer these hypothetic values are to the real values obtained after the selection and implementation of the chosen strategy and, obviously, the bigger is the system's feasability in the carrying through of the strategy chosen.

7. So far, we considered that the decisions taken by a motivational system are the only ones which may intervene. In reality, motivation operates within *competitional situations*, implying two or more individuals.

The competition concept includes both *cooperation* and *conflict* [1].

It is given an individual I_1 in the position to choose one of the a_r strategies ($r = 1, 2 \ldots R$) to achieve one of the O_g objectives ($g = 1, 2 \ldots G$); p_r stands for the probability of chosing strategy r and q_{rg} for the probability of achieving the objective O_g with strategy a_r. F_1 stands for the definitive utility function on r and g variables. The result is a medium V_1 motivational value, defined in

$$V_1^* = \sum_{r=1}^{K} \sum_{g=1}^{G} F_1(r, g)\ p_r q_{rg}. \tag{11}$$

If a second individual I_2 simultaneously intervenes on the same plane interfering with I_1, the q_{rg} probabilities will change, while I_1 changes his behaviour himself, consequently the p_r probabilities will change too. It results another medium value $\bar{V}_1^* \neq V_1^*$. The difference $D_{12} = \bar{V}_1^* - V_1^*$ measures the level of cooperation ($V_1^* > \bar{V}_1^*$ or of conflict ($V_1^* < \bar{V}^*$).

A similar difference $D_{21} = \bar{V}_2^* - V_2^*$ may be defined for the second individual.

In case of conflict Rapaport finds 3 possible variants:

A) Struggle — leading to the destruction of one of the individuals in competition,

B) Challenge — the aim being to overdo the opponent's gain,

C) Controversy — the aim: to change the intervention over the outstanding issue.

We stress that we have considered [3] that the environmental factors are not passive either; they are interfering as random factors.

To analyse the competitive situations of motivation, the *theory of games* offers us the most adequate formal framework.

We shall not examine in detail any such pattern. We shall only stress, that they stand valid for competitive situations at any level of motivational system complexity, starting with competition, from the existence of two very primitive biological entities in a very narrow ecologic strip, to the diplomatic negociations over the most important world issues. The mathematical patterns proposed within the framework of economic [13] or diplomatic [8] negociations describe competitive situations within some very complex forms of psychological or psycho-social motivation. Adaptation to the environment itself must be considered as a game with a random partner.

REFERENCES

1. ACKOFF R. and SASIENI M.: *Bazele cercetării operaționale.* (Fundamentals of Operations Research). Editura Tehnică, Bucharest, 1975.
2. ATKINSON J. W.: *An Introduction to Motivation.* D. V. Nostrand, N. Y., 1964.
3. BĂLĂCEANU C., and NICOLAU E.: *Les fondements cybernétiques de l'activité nerveuse.* Expansion scientifique, Paris, 1971.
4. BĂLĂCEANU C., BALLIF-NEGULICI E. and NICOLAU E.: *La neurocybernétique de la motivation.* V Congrès Int. de Cybernétique, 676—683, 1968.
5. BEACH F.: *Experimental Investigations of Species- Specific Behaviour.* Amer. Psychologist. 15. 1—18. 1960.
6. BOLLES R. C.: *Theory of Motivation.* Harper &Row, N. Y., 1967.
7. FRIEDMAN L. A.: *A Competitive Bidding Strategy.* Operations Research, 4. 104—112. 1957.
8. MALIȚA M.: *Teoria și practica negocierilor* (Theory and Practice of Negociations). Editura Politică, Bucharest, 1972.
9. MOSCOVITZ M. and ORGEL A.: *General Psychology.* Houghton Mifflin Co. Boston, 1969.
10. MURRAY E. Y.: *Motivation and Emotion.* Englewood Cliffs, Prentice Hall, N. Y., 1964.
11. RAPAPORT A.: *Critiques of Game Theory.* Behavioral Science, 4—49—66 1959.
12. RAPAPORT A.: *Fights, Games and Debates.* The Univ. of Michigan Press Annarbor. Mich. 1960.
13. ZEUTHEN F.: *Problems of Monopoly and Economic Welfare.* N. Y., 1930.