# CYBERNETICS AND REMOTE SENSING METHODOLOGY
## A Dialectic, Interdisciplinary and Integrated Appoach

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Abstract:
In this paper, the basic concepts of Cybernetics and their interrelationship with the fundamental characteristics of Remote Sensing Methodology are analyzed and documented, taking into consideration all the existing and prospected types of R.S. data and systems.
The dialectic and integrated nature of the natural and socio-economic environment, presupposes and demands, corresponding and/or equivalent methods and approaches of sensing, monitoring, processing, analyzing and evaluating the multidimensional qualitative and quantitative Remote Sensing data on Land, Oceans and Environment. Interdisciplinary collaboration becomes more than ever, the necessary infrastructure for the optimization of the results of a Remote Sensing Project.

### 1. Fundamental Concepts of Cybernetics

Since André Marie Ampère's (1775-1836) vision in his treatise on the philosophy of science, for a new political science:Cybernetics,(that its purpose would be the study of the regulation laws of the society), till the foundation of the science of Cybernetics by Norbert Wiener (1948),(for the control mechanisms and communication in the living organisms and machines), but also before and after them, many important mathematicians, physicists and philosophers considered systematically the following basic question :

> "Under specific external conditions, a material system being either a living organism, a social organization or a non-living organism, what kind of reactions does it indicate ?"

Ampère, approached the knowledge of the external world in two levels:
In the level of immediate perception of the phenomena through the senses and in the level of investigation of the objective causes of these phenomena, which are revealed through the intellectual process of hypothesis formulation for specific real material beings, which are explained by their properties.

So, Ampère was driven from the phenomena to the experimental knowledge and from the experimental knowledge to the formulation of the theory.

Winer, from his point of view, detected the resemblance between the control mechanisms of animals and machines and contributed to the creation of a relevant background of knowledge that would objectively benefit as much the biologists and physiologists as the control engineers.

Information theory and Automatic Control Systems theory, which had been rapidly developed in the mean time, were marked out by the facts to be the basic tools of Cybernetics.

Information theory was initially used for the solution of such problem as e.g. the transmission of messages through the wireless radio, their encoding and the treatment of the noise of line, a factor that enters in every message transmission and results to a loss of part of the information that the message initially contained.

In Cybernetics the mathematical concept of Information as a quantity that takes specified values in every case, gets the same meaning that energy has in Mechanics and Physics.

The absolutely equal and of the opposite sign to the Information quantity is called Entropy and, like the Information, it also has a statistical character. Entropy is nothing else but a measure of disordering or uncertainty for the system that is described each time.

In the Information theory is valid the axiom that the Entropy of a message during its transmission is always increased.

Cybernetics examines the behaviour of various material systems, living organisms or machines through the investigation of the variation of the information :

(a) as it becomes immediately recognizable as impression that is perceived by human senses,
(b) as it is transformed to nervous excitations by them, and
(c) as it is transmitted in sequence through the nervous system to the brain, where it finally gets a meaning using experiences that already have been registered in the memory.

N.Wiener and other scientists of Cybernetics discovered important correspondences between the human nervous system and the automatic machines and more specifically the Computers.

The Computers, up to the point they can be properly programmed, behave to a high degree as the brain does.

They contain memory and an ability to think logically. Both systems, the human brain and the computer have self-regulating mechanisms that function on the basis of feedback. Feedback is nothing else than an action that is applied by the signal which exits a living or a non-living material system, to the input of the same system.

The most complex feedback system are the living organisms that contain like e.g. man, an immense amount of adjusters and control systems both in their internal structure and function and their dialectical relationship with the external space of their natural and built environment.

The purpose of the information in Cybernetics is the control, or the adjustment of the various systems so that they can perform a specific piece of work.

Basic mathematical tool for this is the Automatic Control Systems theory.

It is obvious that an engineer who would like to design a feedback system for an automatic machine, would be decisively assisted by the investigation and the deep knowledge of a corrensponding/similar system of a living organism.

If the above engineer will in sequence be able to formulate the problem and to define the system through mathematical terms, then the same mathematics will objectively be a valuable tool also for the neurologist who could, in his turn, describe the feedback system of Physiology with a better accuracy and reliability.

As it can easily be concluded from the above the Probability theory and Statistics are extremely useful tools for Cybernetics.

## 2. Cybernetics Aspects of Remote Sensing and Remote Sensing Methodology

Here we will attempt to formulate theoretically, in a proper way, the definition of Remote Sensing and Remote Sensing Methodology, so that using the fundamental concepts of Cybernetics we summarized above, to be able to detect and investigate their deeper relationships and correspondence and to dialectically estimate in a more integrated way the prospects of the relevant developments. Remote Sensing is the science and technique through which both man (and more generally the living organisms) and machines (photographic cameras, remote sensing systems and systems for digital image processing) can :

1) Communicate at a distance with the external world of the natural and built environment, but also with concrete specific objects, phenomena, facts and events,
sense them
systematically observe them
distinguish
understand
detect
recognize
measure
record, but also monitor the variations/diversities of their structural and functional, physical, chemical and biological characteristics and properties in the space and through the time

2) Thus collect and/or reveal an immense amount of qualitative and metric information for both their specific natural and socio-economic reality and their interactions, and for their change trends in time.

3) Process and correlate intellectually/logicaly/computationaly, in a proper way and using the scientific methodology this information and result in evaluation and more generally in useful conclusions for a series of applications in special scientific fields or in Integrated Surveys of the natural and human resources of a country/region, which consist the most valuable infracture for development planning.

4) Design and properly and correnspondingly perform specific feedback at specified phases of the above procedures but also at specified reference levels so that the accuracy, reliability,

completeness and integration of the evaluations and the answers for the specified problems to prospectively increase and to be optimized.

We could now uphold that the Remote Sensing Methodology has as a kernel the organic synthesis of the "sensible" with the "logic" through the scientific methodology and so that we can always be able, in a dialectic way, to approach the dialectic character of the natural and socioeconomic reality, but also their interactions, interrelations and variations through the time.

We could thus regard the Remote Sensing Methodology as the necessary integration of "empirical knowledge", "logic" and specific scientific knowledge in the process of investigation of the problems of the external world, and that is because :

(a) Not the "empirical knowledge" alone in the one-sided view of the dogma that "the experience of the senses consists the only source of knowledge",

(b) Not the "rationalism" alone, in the equivalently one-sided view that "logic is the only source of knowledge", (outside and apart from the mutual relationships, dependencies and interactions of the objects, facts and phenomena) but also

(c) Not the scientific knowledge alone in one or more than one scientific-technologic fields, are enough to entirely activate to the maximum degree the objective abilities of man, both as a self-sufficient, (analogically) Remote Sensing system,(due to his vision,touch,etc) and as a designer and user of the Remote Sensing Methodology, (each time through the use of the proper "machines", Remote Sensing systems, Computers)at the moment he tries to understand and estimate the significance of the objective reality that surrounds him and with which he multidimensionally transacts and interacts in a natural, technical, economical, social and cultural level.

## 2.1. Presuppositions and Supporting Infrastructure, of Remote Sensing Methodology

Based on the above the necessary presuppositions and supporting Infrastructure of Remote Sensing Methodology are :

(a) The general knowledge of the region under consideration and acquisition and proper use of all the existing available data (e.g. Topographic, Cadastral and Thematic Maps, tables, diagrams, records, bibliographic, statistical, meteorological and climatological data, aerial photos and other Remote Sensing Imagery etc) in their analog or digital form.

(b) The special knowledge of specific regional characteristics (e.g. Geological Structure, building systems, main Land Use categories etc)

(c) The special knowledge of the objective possibilities but also of the limitations of both the human and the special Remote Sensing systems (and their combination) with respect to the spectral,spatial and time diversities/changes of the specific properties and characteristics that dominate the region or the space of the object under investigation.

(d) The special knowledge of the scientific field(s), that under their point of view the relevant investigation is carried out, always on the basis of the interdisciplinary and integrated approach of the problems and
(e) The proper planning and the accomplishment of the necessary ground control and sampling (always with respect to the quality of the aerial photos/Remote Sensing Imagery available, their scale, their resolution the experience of the photointerpreter, the conditions that dominate the space of the object, the degree of general and special knowledge of the area, the required accuracy, the type of analysis/processing and interpretation of the data etc).

## 2.2. Factors that influence the functions of man as a Photointerpreter

The function of man, either as a self-sufficient, integrated organic Remote Sensing System (vision+memory/experiences/photointerpretation Keys+intellectual, logical, correlation, analysis and processing+computations), or as analyst and photointerpreter of Remote Sensing Imagery depends upon :
(a) The degree and the magnitude of the relevant psychological stimulation that is caused to him by the specific Imagery,
(b) The ability, promptness and accuracy of his response and reaction to specific pictures, relationships and characterictics.
(c) His ability to correlate, measure, appreciate, estimate and evaluate quantitative and qualitative image information and judge their significance,
(d) His ability to find out the identity, or the minimum possible alternative identities of objects from the analysis of their images.

Thus two concepts of fundamental importance that determine to a high degree the above functions of man as a Remote Sensing System identifying in a unique organic system the communication and control procedures that are investigated by Cybernetics are the concepts of Imagery and Association.

As "Imagery"we consider the integrated procedure of formation of images, sounds, smells, touch, texture and patterns senses using as tools the memory of already registered experiences of the senses, logical thought and dialectic approach.

Imagery can be used consciously to assist the investigation process of the internal relationships, dependencies and influences, as well as the knowledge process of objects,phenomena, facts and events, that form specific parts or even the total natural and socioeconomic reality of a certain region.

As "Association"we consider the conscious or unconscious connection (and reference) of an idea, a word, a form, a figure, a structure, a function, a fact, a phenomenon, an event, a motion, or more generally of a certain change process and of another one.

The concept of "Association" is known since the age of the Greek philosopher Aristotle in the forms of :

(a) "Association" due to similarity
(b) "Association" due to contrast and
(c) "Association" due to contact, neighbouring or succession.

"Imagery" and in extension "Association" that the human Remote Sensing System can compose are objectively subjected to limitations that refer to natural and other parameters. More specifically, the human eye, being an organic photographic machine receipts the light that is reflected by an object.

The light passes through the cornea and is focused by the lens in retina that contains 130.000.000 light "sockets" as a reversed continous picture of the object. It then affects the photosensitive cells that contain rods for black and white vision and cones that are sensitive to the colours, causing chemical changes that are transformed in sequence to nervous pulses, which arrive at the brain through the optical nerves , transforming the pictures to upright and three-dimensional images.

2.3. Man and Remote Sensing - Possibilities and Limitations

The eye like the photographic camera,(the late through the photochemical process)transforms the diversities/variations of the reflected radiation to differences of tones/colours. The eye and the photographic camera record the space to a high degree of details and geometric integration. On the contrary, electronic Remote Sensing systems which are, compared to the photographic cameras, more complex and more expensive, transform the diversities /variations of the reflected/emitted radiation to electric signals. In practice, digital Remote Sensing Imagery consist two-dimensional matrices of $\nu$ lines and $\mu$ columns of picture elements (pixels) of which the values/digital numbers, correnspond to the magnitudes of the intensities of the electric signals to which the differences/variations of the intensities of the reflected/emitted radiation, from the correspondent areas of the natural earth surface are transformed.

The human eye is limited as a Remote Sensing System :
(a) By its sensitivity solely to the visible area of the electromagnetic radiation spectrum
(b) By its inability to interprete many tone variations
(c) By its inability to simultaneously analyze more than one images that have been taken in various bands of the spectrum.

An electronic multispectral Remote Sensing System which has a longer sensitivity in more spectral bands, better calibration capacity, and ability of electronic transmission of elements/messages/information with respect to a photographic camera, can form a digital Imagery by recording the correspondent digital numbers (sets of the integer numbers) in intervals of width:0-(n-1) for ($n=2^{\mu}$ and $\mu=6,7,8,9,...$ for a 6-bit,7-bit,8-bit,9-bit...etc binary coded scale corresnpondingly. The prospects of increase of the sensitivity and simultaneously of more reliable recording of the diversities/variations of the reflected/emitted electromagnetic radiation for the Integrated Remote Sensing Multispectral Scanning and Digital Image Processing Systems are open.
Just a partial and indicative only measure of their evaluation could be the ratio $\frac{80}{10}=8$ of the improvement of the resolution

of the pan mode multispectral scanner HRV of SPOT (1986) with respect to the MSS of LANDSAT (1972).

In order for the man to function as an integrated system of taking and processing of Remote Sensing Images and also as a Photointerpreter of photographic Remote Sensing Images,that have been received by some other systems, he will have to undergo an extensive and intensive training and practice and the exclusive application of the "optical" photointerpretation Methodology by him consists (given the limitations that already were mentioned) an object of "intensiveness" of work. Nevertheless, concerning the unity Remote Sensing processing/analysis, in other words the processing/analysis of a single scene,the right educated scientist /engineer photointerpreter takes the advantage over any kind of machine, due to the exceptional ability of the human mind to evaluate the qualitative spatial characteristics as they are multidimensionally expressed every time, by the specific quantities and relationships, interdependencies and interactions of the natural and socioeconomic reality but also by their change trends in time. On the contrary, a machine, and more specifically the Computer, can imitate the Photointerpretation Methodology and can give satisfactory results to applications in which the spectral quantities in many spectral bands can answer to more questions concerning the "nature","structure" and "function" of the objects, phenomena or events under investigation.

Obviously, this imitation will tend to be optimized in parallel and according to the progress and the development of the "expert systems", or in other words, of the software which, using the expert´s knowledge in the correspondent scientific fields and the dialectic intellectual inference process attempts to answer questions that only man with the analogous knowledge and experience could handle.

Suppose we have (to solve) the problem to recognize an object, phenomenon or event, in its natural or built environment, using its analog and/or digital Remote Sensing Image(s)that were taken under specified and known or even unknown conditions by one or more Remote Sensing Systems or combinations of Remote Sensing Systems:

It is obvious that when we do not have special information for this problem a number of possible answers, is assigned objectively on the basis of :
(1) the special points of view of the specific scientific fields under which it is investigated,
(2) the specific abilities of every Remote Sensing System to "understand" these or the others variatons/diversities of some physical, chemical or biological properties of the "parts" of which it is composed, or, finally, of
(3) the fundamental logical/intellectual procedures inductive or deductive that take into account both the main recognition elements,two-or three- dimensional, (tone/colour, shape, size, shadow, texture, patterns, location and relationship with the environment) and the comparison with the traditional Photointerpretation Keys or a sequence of rules on the basis of (1) and (2).
If we can acquire a reliable information about the problem by some method or process, then the number of possible/probable alternative answers can decrease,

And if we could have perspectively or theoretically, an "Integrated information" for the problem, then we could reach eventually its only one and unique possible answer, or the deeper meaning of the laws that dominate it, at the specified space and time.

That is because, according to Brillouin, "Information is a function of the relationship of the possible answers after and before its acquisition", but the "Integrated information"(Rokos) for a problem, element or system of the specific objective reality, approaches it with the maximum possible reliability, accuracy and completeness since it also understands simultaneously its dialectic relationships and interactions with the natural and socioeconomic environment, in which it is allocated, exists, "is performed" or is dynamically developed.

3. Structural elements of the Photointerpretation/Remote Sensing Methodology Optimization

On the basis of the above we could attempt a special consideration of the dialectic relationships of"organic" and "non-organic" Remote Sensing Systems and the natural and socioeconomic reality through the analytical approach and reformulation of some fundamental parameters that objectively influence today and will influence more and more in the future the optimization possibilities of the Remote Sensing Methodology.

These parameters are:

(a) Detection ability : That is the ability of a Remote Sensing System, organic or non-organic, to be properly sensitive, to "understand" and to record the presence or absence of an element/object/characteristic of the natural or built environment, even if its identity can not be immediately verified.
An object can be detected in a Remote Sensing image even if it is smaller than the resolution of the system.

(b) Resolution : That is the ability of a Remote Sensing System organic or non-organic to distinguish between signals that are spatially close or of similar spectral characteristics.
Resolution is a subjective quantity, which depends on the "vision" and "mental" characteristics, of man or R.S.System.

(c) Image Recognition Ability :That is the ability of identification of an element/object/characteristic, from its Remote Sensing Image recording. It has to be emphasized that it is possible for an element/object/characteristic of the natural or the built environment not to be able to be recognized, although it may be able to be detected and resolved from its adjacent in a Remote Sensing Image.

(d) Image Correlation Ability : That is the ability of a Remote Sensing System, (organic or non-organic), or of a combination of them :

1) To understand and "memorize" properly point, linear areal and spatial elements, patterns, properties and characteristics with thier geometric and/or their spectral and their space/time dimension).

2) To ensure the proper conditions for their systematic correlation with the elements:of one or more (of one or more types, of one or more dates, of the same or different scale,etc) Remote Sensing Images, in an organic or automatic way,and by internal or consequential procedures.

(e) Image Understanding Ability :That is the ability of a Remote Sensing System organic or non-organic, or of a combination of them, using all the proper tools, to understand,estimate, evaluate and to judge the meaning of Information related to the natural and socioeconomic reality of a region that is imaged.
It is obvious that towards the direction of optimization of the Photointerpretation/Remote Sensing Methodology, the optimization of each of the above parameters, must be attempted and still, both in a metric/quantitative and qualitative level, and in the level of the specified steps of the relevant approaching technique.

## 4. Steps of the approaching technique of the Photointerpretation/ Remote Sensing Methodology

The steps of the approaching technique of the Photointerpretation /Remote Sensing Method, independently of the special point of view that the relevant investigation is carried out, could be summarized in the following order:
(a) Recognition of elements, unities of elements,similarities and diversities/variations in the space under investigation.
(b) Analysis of the similarities and the diversities/variations, search of their relationships, interactions and interdependencies and evaluation of their significance.
(c) Proper correlations with the environment, with Photointerpretation Keys, with the results of terrestrial/control sample techniques and with the properly "memorized" metric and qualitative rules and elements, by intellectual/logical, or by automatic processing.
(d) Classification of the similarities and the diversities, according to the each time proper and specific specifications, by using either optical/mental, or automatic procedures, or even various more specific combinations of them,
(e) Evaluation and characterization of the inferences concerning the unities of elements that were immediately detected, or form logical alternative probabilities, with the purpose to prepare a new cycle of more detailed and extensive analysis
(f) Feedback using the inferences of all this initial phase and repetition of the whole process of the approaching technique for more accurate, reliable and integrated identifications.

## 5. Some Conclusions

From the point of view of Cybernetics , Remote Sensing and Remote Sensing Methodology prospects and developments, depends, more and more, on research developments for the "expert systems". To a high degree, Remote Sensing improved and integrated the abilities of the "organic" Remote Sensing system, the human eye. It now remains that the Image Understanding Systems will approach the possibility of dialectic consideration and interpretation of the natural and the socioeconomic reality (but also of their relationships, interdependencies, interactions, and change trends) that man only, through the use of logic, experience and scientific knowledge is in a position to integrate.
So, the technical procedures of the Object and Pattern Recognition, the Segmentation and Classification, the rule based knowledge, but also the relevant techniques (Clustering, Spliting and Merging, Edge detection etc) will have to be investigated deeper, also from the point of view of Cybernetics, so that they will be able to prospectively contribute to the optimization of the Image Understanding System. The concept,structure and function of the Integrated Cadastral Land Information System could become a useful tool of reference.

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