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TECHNOLOGICAL SUPPORT FOR ECOLOGY

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ABSTRACT

Tele-detection offers great possibilities for the accomplishment of progress in the knowledge of Nature. However, all expected benefits have not yet been obtained since improvement in matters of data space, spectral and temporal resolution still need to be made. In addition, greater scientific rigor in the interpretation of the results obtained is needed, attempting not to draw definite conclusions from existent environmental studies made by means of Tele-detection techniques.

Models developed to process Tele-detection data will have to aim at eliminating the effects caused by the variability in the conditions of data collection, the distortion caused by the atmosphere, and the influence of parameters such as the position of the Sun, slope, exhibition and altitude.

The present article attempts to look at the different and various applications of Tele-detection to the residuum control for energetic and environmental purposes.

RESUMEN

La Teledetección ofrece grandes posibilidades para la realización de progresos en el conocimiento de la naturaleza, aunque todavía no se ha logrado todo lo que de ella se esperaba debido a que se debe realizar perfeccionamientos en materia de resolución espacial, espectral y temporal de los datos. Además, es necesario un mayor rigor científico en la interpretación de los resultados obtenidos, tratando de no extraer conclusiones definitivas de los estudios medioambientales realizados mediante técnicas de Teledetección.

Los modelos que se elaboran para interpretar los datos de Teledetección deberán tener como objetivo eliminar los efectos ocasionados por la variabilidad en las condiciones de captación, la distorsión provocada por la atmósfera, y la influencia de parámetros tales como la posición del Sol, pendiente, exposición, y altitud.

En este artículo voy a intentar desgranar las diversas y múltiples aplicaciones de la técnica de la Teledetección en el control de los residuos con efectos energéticos y medioambientales.

KEY WORDS: Tele-detection, technology, environment, communications satellites.

1, INTRODUCTION

Citizens' preoccupation with the increasing shortage of natural and power resources and the environmental degradation caused by the human being's (often irrational and against Natura) actions have raised worldwide the essential need to a better knowledge of the natural habitat.

Present circumstances demand suitable planning of human activities; such planning must involve realizing a more comprehensive and updated inventory of national and international natural wealth, whether agricultural, forestal, hydrological, mining, etc. Similarly, environmental monitoring must be intensified. This measure will lead to a reduction of the impact suffered by the environment to date .

Data coming from the service known as Tele-detection constitute a valuable information source and plays an important role in the attainment of the two objectives noted previously.

In the particular case of Spain, some of the most important actions must aim at water quality and fire detection, two of the many existing problems. Water, indispensable to life and ontogeny of the human being, is one of the greatest portions of Iberian Peninsula wealth; if its quality is deteriorated, everything (men, animals and plants) will suffer the consequences.

Preserving and improving our rivers water quality means taking care of the environment on behalf of everybody and everything. Spanish rivers have an overall length of 172,000 kilometers, more than four times the circumference of the globe. Monitoring their situation and preventing any pollution spill require a modern analysis system employing the latest communication technology. It is worrying that at present, according to information provided by the Publication Center of the Ministry of the Environment, a third of the length of our rivers needs attention and immediate cleaning.

Planned global actions for the regulation of resources is necessary in order for everyone to have water in the precise amount and where necessary. Additionally, it is essential to conserve water quality by depurating it and, at the same time, monitoring its quality to prevent it from deterioration. Such task must be performed 24 hours a day everyday in a continuous way.

Another matter of special concern relates to the urban spills. In a little more than ten years, most large Spanish cities have taken care of this problem, along with that of residual water depuration. By mid-80s, 60% of Spanish population had access to water depuration systems. European directive 91/271/CAE posed important challenges: every town with more than 10,000 inhabitants had to depurate their water before year 2000 and, before year 2005, towns with more than 2,000 inhabitants had to do so, too.

Spanish public and private companies will not be able to compete neither in Europe nor in the inner market if they do not assume the depuration costs. Because of that, the Regularization Plan of Spill Authorizations and Canon Management, anticipated in the National Hydrological Plan, needs to be grounded in highly reliable control and monitoring systems.

The use of fertilizers and pesticides in agriculture causes serious alterations in water quality. In consonance with the guidelines on nitrate contamination, both the Spanish Ministry of Environment and the Ministry of Agriculture are developing the necessary norms.

Thanks to work done by means of the SAICA system (Automatic System of Water Quality Information), possible via HISPASAT since 1994, residual water reusability has become a basic action in matters of water quality (important pilot programs already exist in the Canary Islands and Madrid). This new water usage allows releasing increasingly greater resources for supplying and other uses such as satisfying the water needs of agriculture, guarantying parks and gardens irrigation, and aquifer recharge.

The close relationship between the Complutense University of Madrid and the HISPASAT S.A. Society has allowed collecting very detailed information on what constitutes the core of this article on environment: the Automatic System of Water Quality Information (SAICA). The following is a summary of some of the most important objectives of this national program (they will be explained in greater depth afterwards):

1. - To detect and control rivers and aquifers contamination with a preventive character.

2. - To observe and make others observe the European Union Directives on water quality.

3. –To exercise exhaustive control of quality levels by sections of river based on the requirements established for each use (land irrigation, pisciculture, etc.) and accomplish the final quality objectives of the River Basin Hydrological Plans.

4. – To prevent spills 24 hours a day with respect to certain specific uses, mainly supply to population centers.

5. – To apply the Spanish norm efficiently, particularly the Law of Water, by sanctioning promptly the enterprise or private citizen responsible for contamination spills.

6. –To develop new technology and modern management procedures that allow, with little human monitoring, controlling our hydrographical network in an efficient and continuous way.
The SAICA constitutes, within its field, one of the most advanced pioneering systems, in terms of conception and technology, in Europe. At the same time, it is an extremely economical system that allows covering all our hydrographical basins with a budget of 10,000 million pesetas, sustained by European Union funds. This system has received assent from the European Commission.

The SAICA is a system of national scope that receives and processes information coming from the hydrographical basins quality control integral networks 24 hours a day. This system enables to exercise continuous and systematic control over the river water amount and quality in order to satisfy the requirements of its different uses : supply, land irrigation, etc.

The SAICA System allows obtaining real and immediate information of what happens in our rivers and aquifers. These are some of its functions:

1ª. - Automatic protection alert, mainly for supply.
2ª. - Continuous quality diagnoses by sections of river, suitable for each land segment use
.3ª. - Statistical Data and thematic information following up different types and levels of contamination.
4ª. - Strategies for controlling and monitoring contamination spills, and sanction.
5ª. -Simplification of procedures, computerization, greater promptitude in spill authorizations and sanctioning files.
6ª. – Reports to the European Union for the fulfillment of the different water quality directives.

As a general note in this introduction, which will be developed in more detail later, we will point out that the SAICA system has a water quality information network at each hydrographical basin. In total, the system consists of

-1.000 Periodic Sampling Stations (EMP).
-200 Occasional Sampling Stations (EMO).
-115 Automatic Alert stations (EAA).
-9 Peripheral Processing Centers (CPP), one in each hydrographical basin.
- A Central Unit in the Ministry of Public Works and Transport.
- The connection between all the systems is made by means of the HISPASAT system.

The “automatic alert stations" measure the different selected water quality parameters in a continuous way. Those stations issue the alert when they detect that certain quality parameters surpass the values demanded by the present norm.

Once the alarm has been set off, the system starts automatically mechanisms which interrupt water supply to towns. Simultaneously, it performs analysis which allow identifying the spill causing the alarm as well as its possible origin and, in this manner, facilitating sanctioning measures.

Control Stations, installed at the most troubled points of the rivers, transmit the information on water quality to the Process Centers of each basin and the Central Unit of the Ministry of Environment through Spanish satellite HISPASAT, by means of the VSAT system. In the Control Centers, the causes are investigated, the possible consequences of each type of contamination are analyzed, and the Inspectorate is notified. In this way, the Water Police mechanisms stipulated by our law are implemented.

At the moment, the on-speed operation of the SAICA system is considered to be the best option to maintain and improve the water quality of our aquifers and rivers. This system considers the cleaning and depuration responsibilities of the local and autonomic administration. Also, it enables coordination with the State Central Administration, which is responsible for controlling, monitoring and conserving the hydraulic public domain. In this way, it guarantees the quality of continental water.
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This system contributes substantially to the accomplishment of the National Hydrological Plan, turning Spain into one of the European countries with the most and best hydrological resources, in spite of the last years prolonged drought. In sum, a good inheritance for the next generations, if they know how to take advantage of it in a rational and coherent way.

Aside from the SAICA system, this article will look at the most recent advances in "Tele-detection", a field of technology influencing the study of environmental impacts. We will begin by pointing out some of its antecedents, characteristics of the Tele-detection statistical data, and natural resources satellites prior to HISPASAT. Afterwards, we will explain the SAICA in more depth.

2. THE ROLE OF TELEDETECTION IN THE STUDY OF THE ENVIRONMENT

Natural resources Tele-detection is based on a remote data acquisition system above the biosphere. Such a system makes use of electromagnetic radiation properties and their interaction with terrestrial surface material.

All of the elements of Nature have their own spectral response called "spectral signature". Tele-detection studies the spatial and temporal spectral variations of the electromagnetic waves, and shows the existing correlations between these and the characteristics of the different terrestrial materials. The main objective of Tele-detection is to identify terrestrial surface materials and the phenomena occurring on the terrestrial surface through its spectral signature.

Information is gathered from either aerial or space observation platforms since data collected from Earth-based systems constitute a preparatory stage of Tele-detection itself, and they are considered land campaigns .

The observation platforms carry detectors. Detectors are instruments that can receive and measure the intensity of radiation coming from the ground in a certain range of wavelengths, as well as transform it into a signal that allows locating, registering and digitalizing the information in the form of either photographs or PC-compatible taped numerical images (CCT).

The detectors can be cameras, multispectral pushbroom scanning radiometers (MSS), radars and lasers. These devices generate images by analyzing radiation emitted or reflected by the forms and objects of the terrestrial surface. Such forms and objects are analyzed by means of the wavelengths they are sensitive to (ultraviolet, visible, close infrared, technical infrared, hyper frequencies) for the purpose of recognizing the varied range of forms and objects.

2.1 Landsat natural resources satellites

For the purpose of giving a brief historical overview of Environment Monitoring Satellites, we will begin this section by looking at one of the pioneer systems: the LANDSAT, first natural resources satellite launched by the NASA in July in distant 1972. After this launch, LANDSAT 2 and LANDSAT 3 satellites were put into orbit (in January 1975 and March of 1978, respectively) with the objective of assuring data collection for latter studies. LANDSAT Satellites have an almost polar and sun synchronous orbit at 920 kilometers height. They complete an orbit in 103 minutes, sweep the terrestrial surface every 18 days, and obtain simultaneous information from Earth zones of 185 km. by 185 km. (approximately 34,000 km).

LANDSAT Satellites are provided with remote sensors of several types. First, it is the RBU (Return Beam Vidicon) that consists essentially of a system of television cameras. The second sensor is a multispectral push-broom scanning device or MSS (Multispectral Scanner) that registers the energy reflected by the terrestrial surface on the green, red, and infrared regions of the electromagnetic spectrum. The elementary information unit has a spatial resolution of 79 meters.

The analogical signals registered by the sensors are converted to digital format and transmitted to Earth. Data collected by the LANDSAT satellite are commercialized in the form of either photographic product, or PC-compatible taped digital images.

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2.2 Characteristics of teledetection data

The set of data collected by means of aircraft or spacecraft Tele-detection procedures always entails three types of information (Goillot, 1976):

1ª. - Spatial information that represents the arrangement of elements constituting an image within a physical space.
2ª. - Spectral information which can lead to and characterizes the knowledge of the terrestrial surface nature.
3ª. - Temporal information that allows detecting changes on the Earth surface with the passage of time.

In addition, remote sensors, specially LANDSAT multispectral push-broom scanning radiometers, perform a very particular register of the Environment and landscape characterized by an image homogenization which is a function of the sensor or detector resolution level.

At the beginning of the 80s, the elementary information or *pixel* (acronym of "picture element") size on the ground for the LANDSAT satellite was 56 m. by 79 m. These informative units are arranged on the terrestrial surface as a geometric mesh with a certain inclination with respect to meridians and parallel, looking like the UTM or LAMBERT mesh to a certain extent. The LANDSAT mesh has no relation to the geographic limits of the objects located on the terrestrial surface.

Under these circumstances, it is understandable for a pixel to have a heterogeneous nature, being able to comprise, in the case of an urban zone, a block of houses, a garden, or a freeway. Local differences will be diluted in the average response, and this effect generates the illusion of the existence of transition and gradual contact zones between different landscape units. This effect does not occur when an abrupt resistance between two contiguous uses of the ground exists, for example, a recent earthwork in a closed forest. The existence of an abrupt resistance can allow observing objects of less size than the size of a *pixel* in an image.
Finally, data collected through Tele-detection have the following characteristics (Tricart, 1979):

1ª. - Possibility of obtaining data on aspects of the environment that escape the senses (radar wave, LANDSAT infrared, etc.). The “natural" man’s experience is, therefore, null in these spectral domains; this is why "visualizations" (called *images* to avoid confusion) having an analogous function and utility to that of the aerial photography are made .

2ª. – This information, which measures the amount of energy reflected or emitted by the natural objects that compose the landscape and is registered by sensors, is of a numerical type and allows a mathematical treatment. On the other hand, its extreme abundance makes the use of big computers and very sophisticated and powerful data processing methods necessary.
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3ª. – Data extracted from the Tele-detection services reveal certain aspects of the ecosystems that are difficult to study and practically unknown, contributing in an effective way to their knowledge and development (detection of diseases in plants, effects of stress due to the lack of water, sweating, thermal regime, etc.).

4ª. - Finally, Tele-detection allows keeping track of the evolution of the great forest extensions that still exist on the surface of the globe, having a broad view on the effects of great catastrophes (such as the frightful droughts in the Saharan regions of Africa), and recognizing certain large-scale pollution phenomena in the sea and sky.

2.3 Spatial resolution of environment protection satellites

In the 70s, most of the satellite images used in the study of terrestrial phenomena belonged to the LANDSAT series satellites.

Many scientists have developed applications using these images, mainly in the United States. On the other hand, many others have decided to wait due to the low spatial resolution of these images with respect to the conventional aerial photography. Most of the natural resources satellites that have been designed and built for the purpose of being sent to space in the 80s have provided substantially improved images in terms of spatial resolution in comparison to the pioneering satellites.

The need of images with better spatial definition was partly satisfied with the launch of the LANDSAT D satellite in 1982 and by the SPOT satellite (Experimental Earth Observation System) put into orbit in 1984. In addition, the launch of the space shuttle Columbia had metric cameras with resolutions less than 10 meters.

These advances in Remote Sensor Technology enabled Allan to predict that, towards mid-80s, amplification of the great areas from satellite images would be widely extended (Allan,1977).

In the beginning, images used to be constructed by means of the movement of a mirror located cross-sectionally with respect to the satellite orbit . The final image used to be constituted by a matrix of image elements or pixels. This method was used in the MSS multispectral scanning system of the LANDSAT 1, 2 and 3 satellites, as well as in the thematic mapping of LANDSAT D. In the push-broom scanning radiometers, the oscillating mirror mentioned above is not necessary since a "monolithic silicone chip" has hundreds or thousands of in-line detectors with amplifiers and multiplexed electronic circuits (Thompson, 1979).

These detectors perform a sampling electronically in such a way that a vector containing a whole image line is registered as the satellite moves a resolution element along the orbit.

Highways and rivers less than 79 meters wide are frequently detectable in LANDSAT images. The objects alignment is also very important and the detection effectiveness depends very much on where the central axis of the object is: at the middle of a push-broom line, or on the border between two push-broom lines. In the second case, detection is more difficult.

As long as there are objects less than 79 meters which can be detected, many objects of same or greater size are not detectable. LANDSAT images have shown that low-resistance objects are only detectable if they have a length greater than 250 meters.

An obvious consequence of all this is that the sensor capability to detect objects depends on both the resistance to the environs and the detector sensitivity to detect small differences. The minimum detectable size of an object in an image is determined by the local atmospheric conditions (González Alonso and Cuevas Gózalo, 1982).

Finally, for a better understanding of satellites utilization and a more efficient design of future systems, Townshend pointed out the need to study two main areas (Townshend,1981):
1ª. - Elaboration of resolution measures that reflect more efficiently the amount and quality of information that can be extracted from the data.
2ª. - Development of indices for measuring spatial properties of land attributes (vegetation, geology, etc.).

3. TREATMENT METHODS FOR INFORMATION EXTRACTION FROM TELEDETECTION DATA

The launch of the LANDSAT 1 satellite in 1972 was the beginning of a new era for environmental studies providing high quality data that can be obtained at frequent intervals above any terrestrial surface zone. Nevertheless, the capacity for obtaining data from satellites is greater than the capacity that until recently existed for analyzing and processing data in the most effective way.

In the initial times of the LANDSAT program, a sort of deaf people's dialogue between the Tele-detection promoters (who often possessed technical or higher education background in engineering, physics, or computer science) and the potential users (geologists, geographers, forest agronomists, hydrologists, etc.) was established. The reason for that situation was that the first group interpreted the images too ingenuously, in the users' opinions who, in turn, displayed great skepticism, fed by a certain inertia facing its necessary recycling.

In a progressive way, these barriers tend to disappear and, in this manner, more and more people of very different academic background tend to collaborate mutually and exchange information. In addition, in the field of Tele-detection, a great interaction between techniques and applications quite often takes place because the second ones allow frequent reframing of the methods used.

Data processing techniques based on Tele-detection aim at helping the researcher in the interpretation of data coming from remote sensors.

3.1 Man-machine interaction

For more than a decade, efforts made to extract information from multispectral remote sensors have been giving results progressively.

Such efforts have been centered essentially on the application of automatic pattern recognition techniques to the multispectral measurements characterizing the resolution elements. Generally, scenes are classified pixel by pixel based on the spectral measurement vectors associated to the elements that compose the image, using computers and programs developed to that end in this process.

The fully-automatized digital image treatment systems have not provided completely satisfactory results with regards to the applications for land-use mapping.

The human eye is marvelous; the role that the analyst plays as a photo-interpreter is essential for both the interpretation of the photographic images and automated processing of digital images. For that reason, Treatment Systems are being designed in such a way that environmental science specialists become more actively involved in the design process

The specialists' role entails incorporating their knowledge of the environment into the system, particularly the image regional in question, locating in the space the different cover types or other phenomena consistent with the ecological and/or anthropogenic relations that can be observed in the images.

Progress achieved in the matter of numerical treatment consists of the completion of visualization devices which enable a permanent dialogue between the researcher and the computer. The researcher, thus, can choose the suitable numerical treatments and, once those have been applied, control the results, observing the concordance between these results and his knowledge. (Tricart, 1979).

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