AN ADAPTIVE TECHNOLOGY GEOINFORMATION MONITORING OF THE ENVIRONMENT

Ferdenant A. Mkrtchyan and Vladimir F.Krapivin

Institute of Radioengineering & Electronics RAS
1 Vvedensky Sq., Fryazino, Moscow reg., 141190 Russia
Email: ferd@ms.ire.rssi.ru

ABSTRACT

The basic scheme of collection and processing of the information in geoinformation monitoring system recognizes that effective monitoring of investigated object is possible under complex use of methods of simulation modeling, collection and processing of the information .
From the position of system analysis, the system of collection and processing of the information in geoinformation monitoring represents the structure uniting the computers of various classes, databases and the advanced problem-oriented software. Creation of such system demands the development of formalized description of the information flows and unique methodology of its processing.
Development of geoinformation monitoring systems requires the decision of a set of problems related to the formation of data measurements flows to be solved.
One of the basic tasks of geoinformation monitoring of an environment is automation of data processing of measurements with the principal goal of the task decision for phenomena detection and classification on a water surface. The methods and algorithms of cluster and discriminant analysis for the classification and qualitative interpretation of remote sensing data characterizing the water surface are considered. The problem of classification of aquatories using the remote sensing measurements is one of important among them. Various algorithms of the theory of images recognition, statistical decisions and cluster analysis are used to solve this problem. The mathematical model describing the background characteristics of water surface spottiness is proposed. Operative software for this model is realized. The results of the software application to the satellite data processing for the Atlantic and Pacific regions are given.

1. INTRODUCTION

The typical feature of the modern informative environment data base is the availability of measurements obtained at the ground stations and by means of the remote exploration facilities.
The ground data are notable for being discrete relative to space, valuation of local environmental processes state by means of them being merely possible.
The data of remote exploration are dynamic in time describing the spatial characteristics of natural systems rather fully. However they do not offer a possibility to arrange statistically uniform samplings of data, thus limiting applicability of classical methods of the statistical analysis.

It is evident that the complex investigation of data of ground and remote measurements may improve a certainty of valuations of the parameters of natural systems and solve the problems of planning these measurements.

The methods of overlapping data spreaded by space and time prove to be important as well as the methods of formation of referring to common time moment two-dimensional arrays of characteristics of geophysical, geochemical, ecological and other parameters of geosystems.

The problem of formation of natural monitoring systems including data base is a subject of many investigations. One of the perspective ideas in this field was proposed in(Armand et al., 1987; Mkrtchyan, 1987). The propopsed method is grounded on implementation of geoinformation monitoring system (GIMS) based on the synthesis of means of collection of environmental data, algorithmes of their processing and interpretation, models of climatical and ecological processes.

Realization of GIMS as a computer program package, describing aggregation of ecological processes and ensuring overlap of information sources with magnetic carrier offers a possibility to create an universal instrument for automatized monitoring of state of agricultural fields, melioration and water objects.

The problem of classification of aquatories using the remote sensing measurements is one of important among them. Various algorithms of the theory of images recognition, statistical decisions[Wald, 1960; Vapnik et al., 1974; Mkrtchyan, 1982) and cluster analysis(Solomon, 1980) are used to solve this problem.

2. ABOUT METHODS OF CLASSIFICATION

At present time there are many methods of recognition which are caused appreciably by variety of statements of concrete tasks. The problem of recognition consists in the division of some group of objects into the classes at the base of certain requirements. The objects having general properties are related to one class. An initial data for the solution of a recognition problem are results of some observations or the direct measurements, that are named initial attributes.

Method of taxonomy (clustering) is one of the important methods of recognition and classification of images.

Let's assume set of M it is required to divide by not crossed subsets (clusters), and the elements included in the same clusters should be close to each other enough from the point of view of the chosen criterion of nearness, and elements from different clusters should be far enough from each other. In one of many possible statements of this task two numbers a and b $(0 < a < b)$ are given. It is considered, that two elements x and y are close to each other enough, if $p(x,y) < a$, and are far enough from each other, if $p(x,y) > b$.

Kings method is one of well-known methods of taxonomy, which gives good results in those cases, when the quantity of the available information in assumed clusters is moderate. According to this method the distance between groups of points in space of attributes is defined as distance between centers of masses of these groups. Clustering in this case is based on the assumption that sites of the increased density in space of attributes correspond to similar situations.

3. MODEL OF SPOTTINESS

The feature of remote measurements is information acquisition, when the data of measurements, acquired during tracing of flying system along routes of survey, are directed to input of the processing system. As result the twodimensional image of investigated object is registered. Statistical model of spottiness for investigated space is one of models for this image.

In real conditions, the study of spots, the acquiring of their statistical characteristics and their using in a problem of detection is enough a complex problem. It is necessary to develop the criteria allowing the distinguishing the spots from other phenomena. For example, it is necessary to determine such threshold the exceeding of which is the spot indicator. Also it is necessary to develop model presentation of processes of spots detection.

The method of the thresholds determination in the most obvious and simple way for spots definition. In this case that part of space belongs to area of spots, on which the parameter of environment measured within the chosen channel exceeds value (l^+) or, on the contrary, does not exceed value (l^-) a threshold. Let $y = y\ (x_1, x_2)$ is function of coordinates (x_1, x_2) of points within considered region. If "level surface" $y=const$ is outlined at the region surface, then the closed curves of level y that bound the spots are projected on it.

Algorithms for simulation of spottiness are based on the numerical solution of the algebraic inequalities determining coordinates of internal points of spots. It is impossible to write the equation of spots contours in a general.

Therefore contours of spots are described by system of the simple algebraic equations connected among themselves by equation $\Sigma\ \varphi_i\ (x, y) =0$, where $\varphi_i\ (x, y)$ is the equation of an elementary curve. For simplification of software realization of simulation of spottiness image as the equations $\varphi_i\ (x, y)$ the equation of a circle with varied coordinates of the centre and radius is accepted. Complex forms of spots are formed by overlapping on a plane of the drawing of several circles with different parameters that is defined by system of inequalities of a kind:

$$\sum \{(x-a_i)^2 + (y-b_i)^2-r_i\} \le 0$$

Where x, y are the cartesian coordinates of internal points of spots, a_i, b_i, r_i are coordinates of the centre and radius *i*-th circle, respectively, n is quantity of the circles composing the modeled image. To simulate the randomness of background distribution for spottiness the spottiness model parameters a_i, b_i, r_i are set by means of random-number generators. By changing laws of distribution of random numbers and their statistical parameters, it is possible to receive statistically different spottiness images.

4. SOFTWARE

The list of software items of the simulation system of classification of the phenomena on a terrestrial surface is given in Table1. An important point of algorithms and the software of system is the possibility of spatial interpolation and data restoration using remote and in-situ measurements.

One of main aspects of the practical importance of developed system is qualitative interpretation and visualization of results of remote measurements. For primary processing of remote measurements it is useful to apply an owerage-connecting method of cluster analysis to detect the specific informational zones (Armand et al., 1987). That method is effective under small volumes of sampling. Two variants of this approach are realized to be distinguished by the organization form of algorithms and indeu spaces.

Table 1. Structure of the Software

Software name	The functional characteristic an software
REICM	Reduction of the experimental information in a computer memory.
DRHIM	Data reconstruction by means of the harmonics interpolation method
SIDSM	Spatial interpolation of the data by means of a spline method
DRMOT	A method of optimal interpolation.
CASRS	Cluster analysis focused on sings space of remote sensors.
CALRS	Cluster analysis focused on the account of local reading of sensors.
RSC	Research of spottiness. characteristics.
RRADA	Realization of recognition algorithm by a method of the discriminant analysis.
CSAIRM	Sorting and accumulation of the in-situ and remote measurements.
CMS	Computer mapping of the spots.

5. APPLICATION

Analysis of statistical characteristics of “spottiness” for three types of areas of Atlantic and Pacific oceans was conducted. These statistical characteristics were determined for the most informative thresholds. At that time statistical characteristics of "spottiness" for the same areas, selected using criteria of minimal value of coefficient of correlation for joint sample of positive and negative spots. Analyzis of these characteristics showed, that the statistical characteristics of "spottiness" coincide for areas with temperate sea roughness and storm zones. Minimum for the coefficient of correlation ρ_{min} is run down for a case of most informative thresholds. But for quiet area the situation is different.

Results of statistical data processing spottiness brightness temperatures on a wave of λ_1 =0,8 sm received by a method of the transect-analysis for area with a high pressure (1025 B) and speed of wind V < 5 m / sec (quiet area) (Data Space Satellite « Cosmos - 1500 » for 8-9 February, 1984) are submitted. The maximal value brightness temperatures Tя, max = 162,3 K, the minimal value brightness temperatures Tя,min = 144,2 K. The most informative are thresholds which values get in an interval from 149K up to 152 K.

For these thresholds the greatest rapprochement of the average sizes of positive and negative spots is marked. For a threshold X = 151,4 difference of average values of the sizes of spots makes ΔM = 1,18. The minimal value of factor of correlation is fixed also for the most informative thresholds. So, for a threshold X= 149,6, ρ_{min} = 0,074.

In this case with a high probability it is possible to approve, that distribution of positive and negative spots are independent.
It is possible to be limited to research one-dimensional histogram $(l^{+}, l-)$ - characteristics. The analysis of theoretical and empirical distribution of negative spots also has shown their independence for the most informative thresholds. So, average of theoretical and empirical distribution for value of a threshold $X = 149,6$ has made $\Delta = 0,048$, and for $X = 151,4$, $\Delta = 0,016$.
Statistical characteristics "spottiness" are submitted to water area of Pacific ocean for area with normal pressure 1010 and speed of a wind of $6\ m / sec \leq V \leq 10\ m / sec$ (moderate excitement). For this area extreme values brightness temperatures the following: *Тяmin = 156,8 K, Тяmax = 175,8 K.*
The most informative thresholds are in a range from 161K up to 164K. For the same thresholds the least sharpness of the average sizes of positive and negative spots is observed also. For $X = 161,8$ difference $\Delta M = 1,88$. The factor of correlation reaches(achieves) the minimal value $\rho = -0,02$ for a threshold $X = 163,7$, that testifies to independence of distribution of positive and negative spots. The average deviation(rejection) of theoretical and empirical joint distribution makes $\Delta = 0,01$, that also confirms it. For this threshold, and also for a threshold $X = 161,8$ $(\rho = -0,198)$ it is possible to be limited to research one-dimensional histograms, and for the others research bi-dimensional histograms is desirable.
Statistical characteristics "spottiness" water areas of Pacific ocean with low pressure (< 1005 Б) and speed of wind V ≈ 16 m /sec (a storm zone) for the channel $\lambda_1 = 0,8$ cm. Extreme values brightness temperatures the following: Тяmin = 160,6 K, Тяmax = 220,1K.
The most informative thresholds located in a range from *163K* up to *164K*. However, the average sizes of positive and negative spots are closest for a threshold $X = 166,5$ *and* $\Delta M = 0$, whereas for $X = 163,5$ $\Delta M = 3,5$. The factor of correlation reaches(achieves) the minimum $\rho_{min} = 0,034$ for a threshold X = 163,5, that testifies to independence of distributions positive (l^{+}) and negative (l^{-}) spots. For the same threshold the minimal deviation(rejection) of joint theoretical and empirical distribution $\Delta = 0,007$ is received, that confirms this independence.
Analyzing statistical characteristics "spottiness" three types of areas of Pacific ocean, received for the most informative thresholds, with statistical characteristics "spottiness" the same areas, selected on the minimal value of factor of correlation of joint sample of positive and negative spots it is possible to notice, that for areas with moderate excitement and storm zones statistical characteristics "spottiness" coincide, that is the minimum of factor of correlation ρ_{min} is reached(achieved) for the most informative thresholds. And for quiet area it not so.
From the aforesaid follows, that statistical characteristics "spottiness" brightness temperatures can be used at recognitions and classifications of the phenomena on a surface of the ocean, distinguished by a degree of excitement.
On fig. 1. the example of work of the automated system in a mode of monitoring of temperature of a surface of Northern Atlantic on data Space Satellite « Cosmos- 1151 » (8 - April, 14, 1980) is given. The system allows to receive maps of temperatures on enough rarefied grid of trajectory SS. Points on a map designate areas of realization of ship measurements. The analysis of satellite and contact measurements shows, that there is an appreciable regular understating satellite estimations of temperature of ocean concerning ship which on the average makes 1,6 K.
The root-mean-square deviation(rejection) of satellite estimations T from ship measuring on

all given sample makes *3,3K*. The dotted line on a map designates areas where the difference between ship and satellite measurements exceeds *4 K*. It is typical, that high overcast is registered in all these points (on the data weather forecasters). The root-mean-square deviation of satellite measurements of temperature from ship, designed without taking into account the allocated points, makes *1,4 K*.

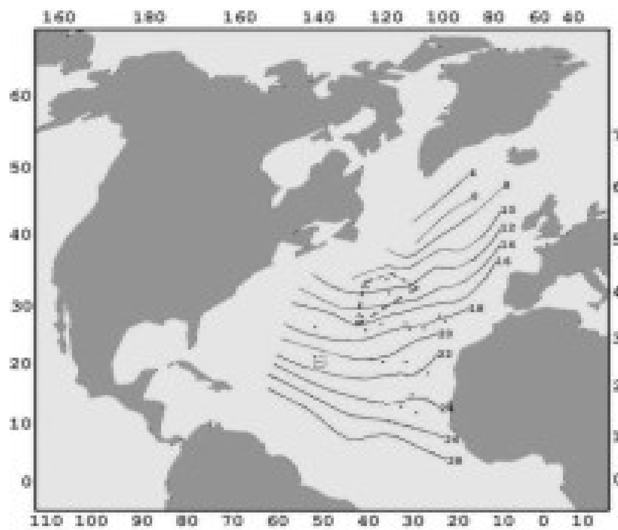

Fig.1. Map of temperature of Northern Atlantic.

From the aforesaid follows, that statistical characteristics for "spottiness" of brightness temperatures in microwaves can be used for detection and classification of the phenomena on a surface of the ocean, that was caused by a degree of sea roughness.

The analysis of empirical histograms for "spottiness of "brightness temperatures in microwaves" shows, that in most cases $(l^+, l-)$ - characteristics will be coordinated with exponential distribution, and amplitude characteristics will be coordinated with normal distribution. Therefore for detection and classification of the phenomena on a surface of ocean it is necessary to apply optimal algorithms for the COMPUTER training to taking statistical decisions for the aforesaid distributions (Armand et al., 1987; Mkrtchyan, 1982).

REFERENCES

Armand, N.A., Krapivin, V.F., Mкrtchyan, F.A. 1987. Methods of data processing of radiophysical research of an environment, Nauka, Moscow(in Russian).

Wald, A. 1960. The sequential analysis, Fizmatgiz, Moscow(in Russian).

Vapnik, V.N. and Chervonenkis, A.I. 1974. The theory of images recognition, Statistical problems of training. Nauka, Moscow(in Russian).

Mkrtchyan F.A. 1982. Optimal distinction of signals and monitoring problems, Nauka, Moscow(in Russian).

Solomon A., Methods depending on the data cluster analysis. " Classification and cluster ", Moscow,-pp.89-97,1980(in Russian).