Problems of Statistical Decisions for Remote Monitoring of the Environment

F. A. Mkrtchyan
Institute of Radioengineering and Electronics, RAS
Vvedensky sq. 1, Fryazino, Moscow Region, Russia

Abstract— The basic sense of the concept of remote monitoring consists in connection in system of means of data gathering, methods of their processing, mathematical models of natural objects, computer implementers of algorithms and models with a wide spectrum of service maintenance at visualization of results of monitoring. It is obvious that complex research of the given land and remote measurements can raise reliability of estimations of parameters of natural systems and solve a problem of planning of these measurements. Application of means of remote monitoring in many cases is connected with acceptance of the statistical decision on presence on a surveyed part of studied space of this or that phenomenon. One of features of conditions of gathering of the information for such decision is the impossibility of reception statistical samples great volumes. Therefore working out and research of optimum algorithms of distinction of the casual signals characterized by samples of the limited volume, in the conditions of parametrical aprioristic indefinite are necessary.

One of the important features for the detection and classification of phenomena on the sea surface of the sea is a “spottiness” of the sea surface. Therefore the study of the statistical characteristics of “spottiness” is important. In this paper the analysis of the statistical characteristics of “spottiness” for certain areas of the Pacific ocean. These statistical characteristics were determined for the most informative thresholds.

1. INTRODUCTION

In connection with technical progress and growth of the population of a planet the anthropogenous stress on biosphere sharply amplifies. Therefore the role of remote monitoring allowing sharply raises to receive an estimation and the forecast of anthropogenous changes, to reveal sources of influence and the reasons of these changes. Modern scientific and technical level gives sufficient means for remote monitoring [1, 2].

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The organization of remote monitoring systems (RMS) is exclusively difficult, complex, multiplane problem. In its decision the important role is played by experimental methods of research of environment. Paramount value at realization of such experiments is got by the organization of mass gathering of the information on studied object, efficiency of its processing and authentic interpretation of the given supervision on the basis of analytical and numerical mathematical models. Therefore within the limits of RMS it is possible to allocate the systems of the automated radio physical experiment intended for performance of following functions [1]:

- Gathering and trustworthy information storage about studied object.
- The preprocessing of the data including the identification, decoding and preliminary control of the given supervision with reduction of this data to some standard forms.
- The secondary data processing including various mathematical and statistical methods, intended for the decision of the identification, classification and definition of typical characteristics of investigated object.
- The forecast of a condition of studied object on the basis of interpretation of the received information with use of the developed mathematical methods.

Effective realization of these functions in modern conditions assumes wide automation (radio physical) experiment, with use of last achievements of experimental technics and methods of data processing of supervision. Automation radio physical methods of research of environment opens new possibilities before the researcher, namely:

- Considerably reduces terms of carrying out of researches.
- Raises efficiency of experiments.
- Provides complex and rational use of the expensive equipment.
- Uses qualitatively new methods of processing and interpretation.
- The experimental information.
- Releases the researcher from routine work.

Now we will short stop on principles of designing of the automated systems of gathering and processing of the information on environment. At designing of the automated systems of gathering and processing of the information within the limits of RMS it is necessary to start with following features of radio physical methods of research of environment:

- Huge volume of the information both continuous and fast increase in this volume.
- Difficult and various structure of information streams.
- Diversity of radio physical experiment.
- Evolutionary character of experiment.
- Uncertainty of experiment.
- Active participation of the person in the course of research.
- A considerable quantity of users with various inquiries.

The enormous volume of the information demands attraction difficult technical and the software providing effective processing, storage and search of the necessary information on objects. For successful carrying out of experiment often happens it is necessary to involve a considerable quantity of the aprioristic information. Hence, the organization of long storage of great volume of the data and maintenance of reference service about presence of that or other data is necessary.

The difficult and various structure of information streams in radio physical experiment is caused by following reasons: technical complexity of devices of data recording, a variety of these devices and multistage character of researches. It demands the coordination of streams of the information between various stages of processing and the analysis, and also working out of optimum methods of processing of the information, containing conditions of the operative coordination of the COMPUTER of various types and data recording devices.

Multistage radio physical experiment means that it as research process consists of many stages (steps). And, the maintenance of the next stage essentially depends on results of the previous. It defines an important place of the organization of managerial process in systems of the automated experiment. Evolutionary character of radio physical experiment is defined by constant perfection and application of methods of research, mathematical methods of data processing and development of computing means and the software. Necessity of a modularity of systems of the automated radio physical experiment that means presence of functionally independent and conveniently interfaced blocks from this follows.

2. REMOTE MONITORING SYSTEMS OF DETECTION OF ANOMALIES ON THE SEA SURFACE

One of function RMS is detection and classification of the abnormal phenomena on investigated space. Important circumstances in a considered problem is the account of presence of conditions of uncertainty in a residence and possible dynamic behavior of anomaly. Limitation of parameters of the means applied at inspection of environment, it should be considered in procedures of decision-making on presence or absence of anomaly. This many-sided nature of a problem of global detection of anomalies in biosphere demands for the decision of application of the system approach allowing from uniform positions to consider all complex of local problems and to approach to formation of monitoring system of the detection provided with reliable function of self-checking.

Limitation of means, memory size and speed of onboard computers dictates a partition of monitoring system on three subsystems (Fig. 1): a fixing block, a solving block and the selector. The last share on subsystems — the blocks which functions consist in the following: 1) periodic viewing of elements of the sea surface; 2) fixing of suspicious elements in memory; 3) formation from suspicious elements of traces of moving anomaly; 4) accumulation in time of the data about the fixed elements of a terrestrial surface for the purpose of the statistical analysis for decision-making on noise or signal character of the fixed suspicious elements; 5) multistage localization of procedure of search of anomaly.

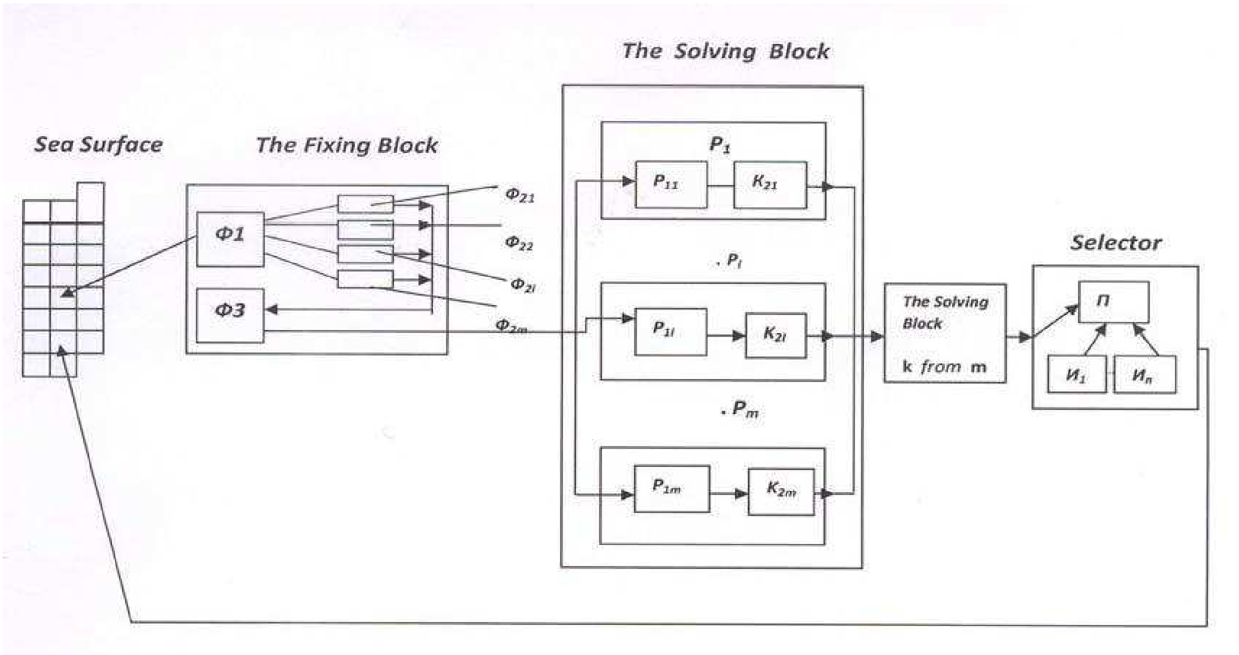

Figure 1: Block diagram RMS of search of anomalies on a sea surface.

Owing to dynamic change of anomalies the monitoring system should carry out much faster these changes scanning of elements of space and have time to process a stream of the statistical information. Therefore there is a problem of an estimation of efficiency of monitoring system as to function of its parameters.

Let the memory size of monitoring system is limited by M cells, and the information stream simultaneously proceeds from N space elements. In each element the source of the information defined by stochastic function $\xi_i(t)$. If $M \geq N$ the decision of a problem of the statistical analysis of an information stream is reduced to accumulation of the data in cells of memory and its subsequent processing by methods of mathematical statistics. In case of $M < N$ it is necessary to develop some algorithm of accumulation of statistics only about "suspicious" elements of an information stream.

Let depending on the relation a signal/noise a stochastic function $\xi_i(t)$ is defined by density of probabilities $f_a(x)$. And let the choice of "suspicious" elements in memory of monitoring system is made for storing in case of $\xi > X$, where X — the set threshold. Thus, if $a = a_0$ at noise character of stream $\xi_i(t)$ and $a = a_1$ in the presence of a signal and noise probabilities of fixing of noise and alarm elements will be equal accordingly

$$p_N = \int_X^\infty f_{a0}(x)dx, \quad p_C = \int_X^\infty f_{a1}(x)dx$$

Let's assume that shares of alarm and noise elements at the moment of time t are equal in space $1-\gamma(t)$ and $\gamma(t)$. Then fixed during the moment t random number $\kappa(t)$ "suspicious" elements will have distribution:

$$P[\kappa(t) = k] = P_{N\gamma,pN}(k_1) \cdot P_{N[1-\gamma],pC}(k_2), \quad P_{n,p}(m) = C_n^m p^m (1-p)^{n-m}.$$

Accepting for a time unit an interval necessary for realization of one viewing of all surveyed space, we will calculate probability of overflow during the moment t memories of monitoring system $P[\mu(t) > M]$. We will consider a case of discrete time, when the moments of occurrence and the termination of processing of a noise or signal element.

Are identified with the nearest integer. Let each arisen element is processed in a separate cell of memory up to the moment of removal of the final decision about its noise or alarm character then the memory cell is cleared and can perceive other information. Thus number $\mu(t)$ occupied during the moment t memory cells is casual integer function.

Let's enter making functions

$$g_t(x) = \sum_{k=0}^{\infty} P[\kappa(t) = k]x^k, \quad G_t(x) = \sum_{m=0}^{\infty} P[\mu(t) = m]x^m$$

Let's consider that processing time during the moment $t = s$ one element is random variable $\nu(s)$ set distribution $P[\nu(s) < t] = F_s(t)$. Then we have:

$$G_t(x) = \prod_{s=h}^{t} g_s \left\{1 + [1 - F_s(t - s)](x - 1)\right\}$$

Further we receive expressions for an average and a dispersion:

$$\begin{aligned} E\mu(t) &= \sum_{s=h}^{t} E\kappa(s)[1 - F_s(t - s)] \\ D\mu(t) &= E\mu(t) + \sum_{s=h}^{t} [D\kappa(s) - E\kappa(s)][1 - F_s(t - s)]^2 \end{aligned}$$

If $\kappa(s)$ has distribution of Puasson with parameter $\lambda(s) = E\kappa(s) = D\kappa(s)$, also it is distributed under the Puasson law with parameter $\Lambda(t) = E\mu(t)$.

All these reasonings were fair at M. If $M = \text{const} > \Lambda(t)$, $\mu(t)$ has the truncated distribution of Puasson:

$$P[\mu(t) = m;\ M = \text{const}] = P_{\Lambda(t),M}(m) = (\Lambda^m(t)/m!/\sum_{l=0}^{m} \Lambda^l(t)/l!, \quad m < M$$

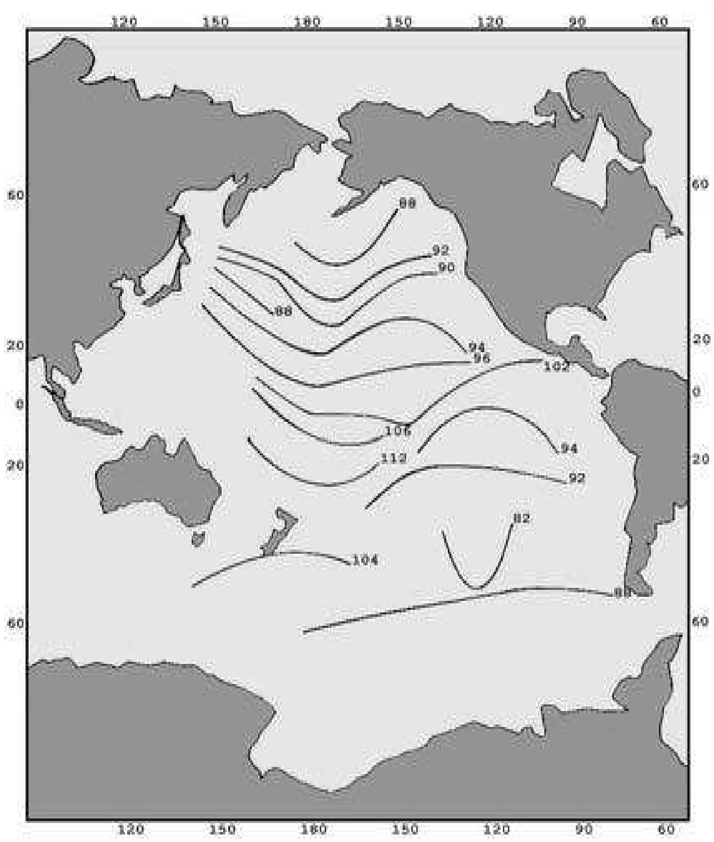

Figure 2: Map of brightness temperature of Pacific Ocean.

Hence, efficiency of monitoring system is defined by probability of overflow of its memory, i.e., probability of loss of the information. In the more general case for an estimation of efficiency of monitoring system of detection of anomalies on a terrestrial surface it is necessary to consider work of all its subsystems taking into account individual restrictions of memory available for them and speed of data processing.

3. APPLICATIONS

Criteria of an estimation of efficiency of monitoring systems finally are defined by probability of performance by them of the problems which is difficult function of parameters of systems and environment. By theoretical considerations the important role is played by environment model. One of possible this sort of models is under construction on the basis of use of concept of "spottiness" of studied space. Mobile anomaly breaks spottiness structure and as a result that its trace is formed. As stains can have the various nature the effective algorithm of detection should be multichannel, capable to analyze the hydrophysical, biological, acoustic, optical and physical and chemical information.

On Fig. 2 the example of application of RMS for monitoring of brightness temperature of a surface of Pacific Oceans on date Space Satellite (SS) "Intercosmos-21" (20–22, February 1979) is given. The system allows to receive maps of temperatures on enough rarefied grid of trajectory SS.

As can be seen from the map in the area ($-30°$ S. Lat. $-50°$ S. Lat., $110°$ W. Long., $130°$ W. Long.) is an anomalous phenomenon.

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.

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 [2, 3].

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