Model of a Secure Data Transmission Channel of the Sea Surface Monitoring System

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Abstract. The Sea Surface Monitoring System (SSMS) is of great importance as a means of ensuring environmental safety. This system is based on monitoring the surface of the seas of oceans using satellites. The structure of the SMMP is a distributed system. This system includes independent data storage, system management, a system of dynamic ratings and forecasting, a management system, an information system (IS) that processes monitoring data. IP monitoring refers to a problem-oriented system. These information systems include specialized database models. All monitoring systems use sets of models that allow you to build complex enterprise models. The article discusses the technology of the control model of the sea surface monitoring system. The structural diagrams of the control model and their brief characteristics are given. The principle of operation and the purpose of the sea surface monitoring system are described.

1. Introduction
Every year, the organization of effective environmental monitoring of industrial enterprises on the sea shelf is becoming increasingly important. First of all, it is connected with the expansion of extraction and transportation of raw materials, which in emergency situations can lead to negative consequences for coastal areas. According to the Maritime Doctrine of the Russian Federation for the period up to 2020, approved by Presidential Decree No. PR-1387 of July 27, 2001, “prevention of pollution of the marine environment” is one of the main provisions relating to ensuring national interests in the oceans. One of the principles of the national marine policy is “the development of monitoring systems for the state of the marine environment and coastal areas”. The timely detection and adoption of emergency measures to prevent the spread of pollution can significantly reduce the damage. In this regard, great importance is attached to the creation of systems for detecting and controlling pollution of the sea surface. The activities of effective environmental monitoring systems must ensure a guaranteed result.
The basis of the activity can be considered the decision of the decision maker (DM); Therefore, an adequate mathematical model for solving a decision maker is of scientific and practical interest.

2. Formulation of the problem
An important part of environmental monitoring is satellite monitoring, which allows to obtain information on the pollution of the sea surface, regardless of the light level and cloud cover, with high spatial resolution and in a wide viewing band. The organization of satellite monitoring takes into account the specific features of pollution sources and the dynamics of the aquatic environment. More than 1,100 satellite images of the visible, infrared and microwave ranges of Meteor-M No. 1 satellite, Canopus-B No. 1, TERRA, AQUA, NOAA, Jason, Landsat-8, MetOp-A and Meteosat-10 are annually accepted and processed. The system of continuous monitoring of subsoil use objects in marine areas should provide information on the key parameters of the marine environment in real time in order to assess current impacts. The sea surface monitoring system (SSMS) includes maps of marine pollution of the seas with oil products, water circulation, distribution of phytoplankton and algae, sea surface temperatures, driving wind, sea level changes, etc. The SSMS data can be used by an authorized person to form a solution. At the same time, in the process of achieving the goal of satellite monitoring activities, there may be a problem of establishing a link between these SMPPs and the decision model of the LDP. It is impossible to guarantee the achievement of the goal of an activity without having the methodological basis for solving the tasks of managing satellite monitoring of the sea surface in the form of the condition of the process.

3. General approach to the synthesis of a solution model in the management of a sea surface monitoring system
The decision maker is always at the core of the management of the SMPP. The person makes a decision based on the model. By object model, we mean a description or representation of an object that corresponds to an object and allows us to obtain characteristics about this object. In this case, the solution is a model of the process with which the person works. A process is an object in action at a fixed purpose. For the synthesis of the use of EPP, based on the SSCO.

The law of preserving the integrity of an object is a stable, repetitive relationship between the properties of an object and properties of an action for a fixed purpose. The SCCA is manifested in the mutual transformation of the properties of the object and the properties of its action for a fixed purpose.

In accordance with the developed EPP, each process should be represented by three components corresponding to the properties “objectivity”, “integrity” and “variability” (or the concepts “object”, “purpose” and “action”, respectively). These three components are arranged horizontally. They can be interpreted in three different levels of the knowledge of the world (abstract, abstract concrete, concrete). This approach determines the presence of three levels vertically.

We introduce a number of definitions.
A managerial decision is a condition for the realization of the purpose of an object that he manages in an appropriate environment in order to achieve the goal of management.

Situation - a set of factors and conditions in which the activity is carried out.
Information and analytical work - the continuous acquisition, collection, study, display and analysis of data on the situation.
Expanding the concept of "management decision" into three basic elements - "situation", "information and analytical work" and "decision", it is necessary to proceed to the synthesis of the decision model.

From system engineering it is known that only two approaches to building a model are possible: development based on analysis and based on synthesis. The analysis approach has a significant drawback: it does not allow the formation of processes with preassigned properties, which is especially important in satellite monitoring conditions. The synthesis based approach makes it possible to obtain a guarantee of achieving the goal and is deprived of the main drawback of the analysis
approach, which predetermined the need to apply a synthesis of the control model of the sea surface monitoring process in this work.

Guided by the principles of the three-component of knowledge, integrity and knowability, let's carry out the synthesis of the model. At the first level, using the decomposition method, we divide the solution into three elements ("furnishings", "solution" and "informational and analytical work") that correspond to "object", "purpose" and "action". Applying the method of abstraction at the second level, we identify the "object" ("furnishings") with the frequency of the problem in front of a person ($\Delta t_{pp}$). "Purpose" ("Solution") is identified with the frequency of neutralizing the problem (average time of adequate response to the problem) by a person ($\Delta t_{np}$). "Action" ("information and analytical work") is identified with the frequency of identifying the problem (average time to recognize the situation) ($\Delta t_{ip}$). Temporary characteristics are justified by the fact that only temporary resources for a person are irreplaceable. Note that the results of research in the theory of functional systems of Academician of the Academy of Sciences of the USSR P.K. Anokhin showed that the decision of a person is formed in the scheme of "arousal", "recognition", "reaction to the situation". Therefore, in this paper, we use the diagram of changes in the basic components of the formation of a solution model, shown in Figure 1.

\[ P = F(\Delta t_{pp}, \Delta t_{ip}, \Delta t_{np}) \]  \hspace{1cm} (1)

This is a condition for the existence of a process for managing the monitoring of the sea surface. Due to the fact that the basic model of a management decision has three elements, we will present a block diagram of management as follows (Figure 2).
\( \lambda \) – the inverse of the average time of the problem;
\( v_1 \) – the inverse of the average problem identification time;
\( v_2 \) – the inverse of the average time to neutralize the problem.

In the case of management, the decision maker can perform two functions in various combinations:
- identify (recognize) the problem;
- neutralize (utilize water supply resources) the problem.

Therefore, the model decision maker describes four basic states:
- \( A_{00} \) - the decision maker does not identify or neutralize;
- \( A_{10} \) - the decision maker identifies and does not neutralize;
- \( A_{01} \) - decision maker does not identify and neutralizes;
- \( A_{11} \) - decision maker identifies and neutralizes.

In accordance with the described feature of the management decision, it is necessary to introduce the probabilities of finding our management system in these four states. We respectively obtain four probabilities \( P_{00}, P_{10}, P_{01}, P_{11} \), corresponding to the presence of the system in the states \( A_{00}, A_{10}, A_{01}, A_{11} \).

The process of forming a solution can be considered as a Markov chain. Since this approach does not allow sufficiently to take into account the dynamics of the process, it is advisable to use continuous Markov chains. To implement this approach, it is necessary to create a system of Kolmogorov-Chapman differential equations. Therefore, the transition characteristics of the system will be presented in Figure 3.

![Figure 3. State graph, the process of forming a management decision.](image)

Assume that the system is in the initial state \( A_{00} \). When a problem occurs under the influence of intensity \( \lambda \) it passes to the state \( A_{10} \), i.e. in the state of recognizing the problem. From this state, the system under the influence of intensity \( v_1 \) is transferred to state \( A_{01} \), in which the system begins the process of neutralizing the problem with intensity \( v_2 \) and transfers the system to state \( A_{00} \). This situation is possible if the problem is neutralized, and yet another problem has not yet formed. If a problem is formed, under the influence of intensity \( \lambda \) the system changes to state \( A_{11} \). Being in state \( A_{11} \), under the influence of intensity \( v_1 \) the system changes to state \( A_{01} \), if the problem is recognized, and transitions to state \( A_{10} \) under the influence of intensity \( v_1 \), if one problem is neutralized. Next comes the next problem and it needs to be recognized. The process is repeated.

To describe the process of state change on a graph, it is necessary to make the following assumptions and assumptions.

1. The scheme of forming a person’s decision in the form of an information management system is being reviewed. Based on the solution, a system for monitoring the sea surface is being formed.
2. The time interval between the moments of detection of facts of the manifestation of problems are random quantities.
3. The discovered facts in time form a stream close to the Poisson stream.
4. The processing time of the data about the desired feature is a random value.
5. The data on the signs are distributed further between the allocated resources that solve the corresponding target tasks for managing the monitoring of the sea surface.
6. The case is considered when the residence time of the required signs (facts) in the scope of the system (person) is very limited and commensurate with the time required for their identification, as well as data processing and taking adequate actions on these signs.
7. The system is prepared for solving problems of recognizing and neutralizing problems.
8. The system being developed (human solution) is designed to assess the potential capabilities of the sea surface monitoring system depending on the situation.

The introduced assumptions and assumptions allow us to use the system of Kolmogorov differential equations.

Then we compose a Kolmogorov control system for our situation. It will look like this:

\[
\frac{d}{dt} P_{00}(t) = -P_{01}(t) \lambda + P_{11}(t) \nu_2 \\
\frac{d}{dt} P_{01}(t) = -P_{02}(t) (\lambda + \nu_2) + P_{11}(t) \nu_1 + P_{10}(t) \nu_1 \\
\frac{d}{dt} P_{20}(t) = P_{20}(t) \lambda - P_{01}(t) \nu_1 + P_{11}(t) \nu_1 \\
\frac{d}{dt} P_{11}(t) = P_{21}(t) \lambda - P_{11}(t) (\nu_1 + \nu_2) \tag{2}
\]

If we assume that we have a stationary process, then our original system of differential equations is transformed into a system of linear homogeneous algebraic equations of the following form:

\[
-P_{00}(t) \lambda + P_{01}(t) \nu_2 = 0; \\
-P_{01}(t) (\lambda + \nu_2) + P_{11}(t) \nu_1 + P_{10}(t) \nu_1 = 0; \\
P_{00}(t) \lambda - P_{12}(t) \nu_1 + P_{11}(t) \nu_2 = 0; \\
P_{01}(t) \lambda - P_{11}(t) (\nu_1 + \nu_2) = 0. \tag{3}
\]

This is a system of linear algebraic equations for the four unknowns $P_{00}, P_{10}, P_{01}, P_{11}$ which are related by the following relation $P_{00} + P_{10} + P_{01} + P_{11} = 1$.

The desired probabilities are no longer dependent on time. The solution of this linear algebraic system of equations is the following relations:

\[
P_{00} = \frac{\nu_1 \nu_2}{\lambda (\lambda + \nu_1 + \nu_2) + \nu_1 \nu_2} \tag{4}
\]

\[
P_{10} = \frac{\lambda \nu_2 (\lambda + \nu_1 + \nu_2)}{(\nu_1 + \nu_2) \lambda (\lambda + \nu_1 + \nu_2) + \nu_1 \nu_2} \tag{5}
\]

\[
P_{01} = \frac{\lambda \nu_1}{\lambda (\lambda + \nu_1 + \nu_2) + \nu_1 \nu_2} \tag{6}
\]

\[
P_{11} = \frac{\lambda \nu_1}{(\nu_1 + \nu_2) \lambda (\lambda + \nu_1 + \nu_2) + \nu_1 \nu_2} \tag{7}
\]

Having obtained relationships that determine the probabilities of a system being in states $A_{00}, A_{10}, A_{01}, A_{11}$, we can work out requirements for the properties of the process of recognizing a problem that has arisen in the system and for the properties of the process of neutralizing this problem in a water management system. That is, the probability of identifying and neutralizing the problem that has arisen is determined from the ratio (8)

\[
P_{00} = P_{\infty} = \frac{\nu_1 \nu_2}{\lambda (\lambda + \nu_1 + \nu_2) + \nu_1 \nu_2} \tag{8}
\]

There are three parameters in this relationship. Thus, we have established the analytical dependence of the generalized characteristics of the situation ($\Delta tp$) information-analytical activity ($\Delta ip$) and the neutralization of the problem ($\Delta np$), that has arisen in water management. Following the work of academician Anokhin P.K., we have obtained the system-forming factor of creating a water management system in the form of the relation (8).
In general, the condition of the existence of the process (8) with knowledge of the final probabilities allows us to identify the required characteristics of the situation when managing the SSMS. In this case, the characteristics satisfy the conditions for the existence of the SSMS control process. And thus guarantee the achievement of the goal of the activity of the monitoring system of the sea surface.

In ratio (8)

\[ P_{00} = \frac{\nu_1 \cdot \nu_2}{\lambda} \]

- \( P_{00} \) is an indicator of the effectiveness of the functioning of the SSMS management system;
- \( \lambda = 0.036 \) – the intensity of the problem;
- \( \nu_1 = 0.365 \) – is the intensity of problem identification;
- \( \nu_2 = 0.046 \) – is the intensity of neutralizing the problem;

Substitute all the values in the expression (8) and find the probability of identifying and neutralizing the problem.

\[ P_{00} = \frac{0.365 \cdot 0.046}{(0.036 \cdot 0.036 + 0.365 + 0.046) + 0.365 \cdot 0.046} = 0.01679/0.032882 = 0.51061370962 \]

Calculations show that with an increase in the numbers of successful fulfillment of forecasts, the probability of \( P_{00} \) increases, and consequently the demand for a prediction technique for the SSMS management system increases.

5. Findings

The paper proposes the basics of building technology management SSMS. The synthesis of a monitoring system for monitoring the sea surface based on a system of differential equations will make it possible to implement a guaranteed approach to managing the SSMS. The management model may be further complicated by the introduction of additional feedbacks taking into account other conditions.

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