Rahimbaeva E. O. (Don State Technical University, Rostov-on-Don), **Atayan A. M.** (Don State Technical University, Rostov-on-Don) **Processing of noisy images and data based on recursive filtering**

Relatively recently, one of the main sources of data for the analysis and forecast of coastal and marine systems were the results of measurements of salinity, temperature, current velocities, etc. This application involves the use of large-scale expeditions using a research fleet. In parallel with this, the development of satellite constellations, unmanned aerial vehicles, in the last thirty years, remote sensing methods have been actively used. The advantage of such methods can be considered a wide coverage of the object of study, the ability to measure the parameters of the aquatic environment: the rise in the temperature level of the near-surface layer, the distribution of salts in it for vast water areas almost simultaneously. Therefore, there is a possibility of joint use of remote sensing data, including satellite and mathematical modeling of hydrophysical and hydrobiological processes in coastal systems.

The main objective of this work is to equip systems that simulate the change in processes that are analyzed and predicted with real input data, which will allow you to correctly set initial-boundary problems, which are systems of nonlinear equations with partial derivatives, as well as determine the coefficients of these equations and other functional dependencies, included in the constructed mathematical models [1]. The problem of obtaining the necessary data on-line can be solved by using satellite data from remote sensing of the Earth.

Earth remote sensing data allow not only to equip mathematical models with the necessary information (boundary, initial conditions, information about source functions), but also to assimilate the information received from the satellite by the constructed models in order to increase the accuracy and increase the reliability of predictive modeling. At the same time, it becomes necessary to develop and implement high-tech methods for assimilation and filtering of observational data for the studied aquatic ecosystem using satellite data used in the development and verification of mathematical models.

Image processing algorithm. Based on the constructed mathematical model of biogeochemical cycles, an algorithm for processing input data was developed. The input data are satellite images of the coastal systems of the South of Russia. On the basis of the algorithm , a software package was developed that is designed to highlight the boundaries of the object under consideration, taking into account interference and noise in the image (the influence of weather conditions at different times of the year) [2]. The developed software package is written in the Python programming language in the PyCharm development environment .

When working with images of the Sea of Azov, to build a grid and highlight boundaries, there was a problem of digital image processing, which is influenced by factors such as: environment; use of real equipment; interference and noise that appear during data transmission.

These factors degrade the quality of the resulting image, which leads to a loss of resolution and a decrease in the signal-to-noise ratio.

To solve problems in the field of image processing, it is required to apply special methods and algorithms, as well as repeated testing involving a wide database of different images to improve their visual perception and increase information content for vision systems.

There are various branches of digital imaging such as: linear image processing; non-linear image processing; recursive implementation of linear and non-linear image processing algorithms.

For further work, it was decided to use recursive filtering, since it is one of the most promising and widely used in the tasks of reducing computational costs in image processing.

Recursive filtering is based on the recursive relationship between the input and output variables of the system. For one-dimensional signals, a similar recurrence relation has the following form:

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$$r(m) = \sum_{j-1}^{J} a(i)f(n-j+1) - \sum_{k-2}^{K} b(k)r(m-k+1), \qquad (1)$$

where $f(n)$ – readings of the input sequence, $n = 1, 2, \ldots, N$; $r(m)$ – readings of the output sequence, $m = 1, 2, \ldots, N$; $a(i), b(k)$ – weight multipliers.

The key point here is that the m–th element of the output sequence depends not only on the last and $j-1$ penultimate elements of the input sequence, but also on $K-1$ previous elements of the output sequence [3].

There are various methods for recursive image processing, for example: interval integration; interval differentiation; quasioptimal filtering of small-sized objects from noise; trapezoidal impulse response; two-stage recursive – separable digital filter.

Since in our work there is a problem of processing noise in the image when transmitting images from a satellite, one of the most popular methods of digital image processing is the Kalman filter, which is one of the varieties of recursive filtering. This means that only the result of the previous iteration of the filter (in the form of an estimate of the state of the system and an estimate of the error in determining this state) and current observations are needed to calculate the current state of the system. This filter estimates the state vector of a dynamic system using a number of incomplete and noisy measurements.

The filter operation is divided into two stages: extrapolation – prediction of system values; adjusting system values.

When using the Kalman filter in our software package, a number of important tasks can be solved. For example, to track the dynamics of plankton populations in the coastal part of southern Russia, specifically the Taganrog Bay and the Sea of Azov.

Findings. The search for the best solution (taking into account the uncertainty of the input data and model parameters) can be carried out on the basis of a scenario approach. In addition, when forming a set of prognostic scenarios, this problem can be solved using technology based on the use of direct and inverse modeling methods, which is based on a combination of variational principles, decomposition, splitting and complexing methods. At the same time, the use of effective methods for processing input data for mathematical modeling of the state of aquatic ecosystems will, on the one hand, solve the problem of lack of data, and, on the other hand, improve the accuracy of forecasting changes in the state of the objects under study.

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