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COMPARATIVE INVESTIGATION OF NEURAL AND LOCALLY BINARY ALGORITHMS FOR IMAGE IDENTIFICATION OF PLANKTON POPULATIONS*

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The work is devoted to the «neural network-lbp» method of processing satellite images of multispectral water coastal systems for identification of phytoplankton populations of spotted structure: determination of their boundaries, distribution of color gradations and, based on this, determination of the distribution of phytoplankton concentrations inside the spots and the location of the center of mass. The efficiency and effectiveness of the proposed neural network-lbp method is investigated in comparison with the method based on the use of a three-layer neural network. For the analysis, a test set of images is involved – flat shapes with rather complex boundaries, which will allow us to quantify the quality of the algorithms being compared. The results of the work show an increase in recognition accuracy by 1.5-3% when using the proposed method.

Keywords: mathematical modeling, local binary patterns, neural network, shallow water reservoir, satellite sensing data.

Introduction. Phytoplankton populations are the basis of marine trophic pyramids, including coastal and ocean systems, according to the source [1]. In moderate concentrations, many types of plankton are necessary for the sustainable development of the trophic pyramid of the coastal or marine system. With its lack, degradation of the aquatic ecosystem is possible, and with their sharp growth caused, for example, by a significant increase in the volume of incoming nutrients – nitrogen compounds, phosphorus, silicon, etc. – blooming of the reservoir occurs, with the formation of oxygen deficiency zones – hypoxia zones. For various water areas, including the Azov Sea, the problem of blooming is very acute [2].

The task of monitoring the water surface in order to detect phytoplankton «spots» involves the creation and verification of effective methods for clustering these objects on the surface of reservoirs, in particular, restoring their boundaries based on remote sensing data. The article uses multispectral satellite images as sounding data. Based on the obtained images of plankton populations, the initial conditions for mathematical models of biogeochemical cycles can be determined, on the basis of which prognostic calculations are performed. Research in the field of processing and assimilation of space sensing data of marine systems has been carried out by groups of researchers in Russia over the past 30 years (Marchuk G.I. [3], Dymnikov V.P. [4], Shutyaev V.P. [5-7], Parmuzin E.I. [6-7], Agoshkov V.I. [7]. Sukhinov A.I. [8-13], Nikitina A.V. [1, 8-9, 11], Chistyakov A.E. [9-11], Bondur V.G. [14-17]).

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2. The research problem. Currently, the available satellite groupings make it possible to obtain sensing data for most of the Earth's surface and transmit remote sensing data in real time. As an example, Figure 1 shows color-synthesized multispectral images obtained from the satellites WorldView [18], Canopus-B [19] and Sentinel-2 L2A [20], in July-August 2020 for the eastern part of the Azov Sea. The image illustrates the distribution of blue-green plankton populations forming stable structures under the influence of circulation-type currents (the so-called S-flow structures)

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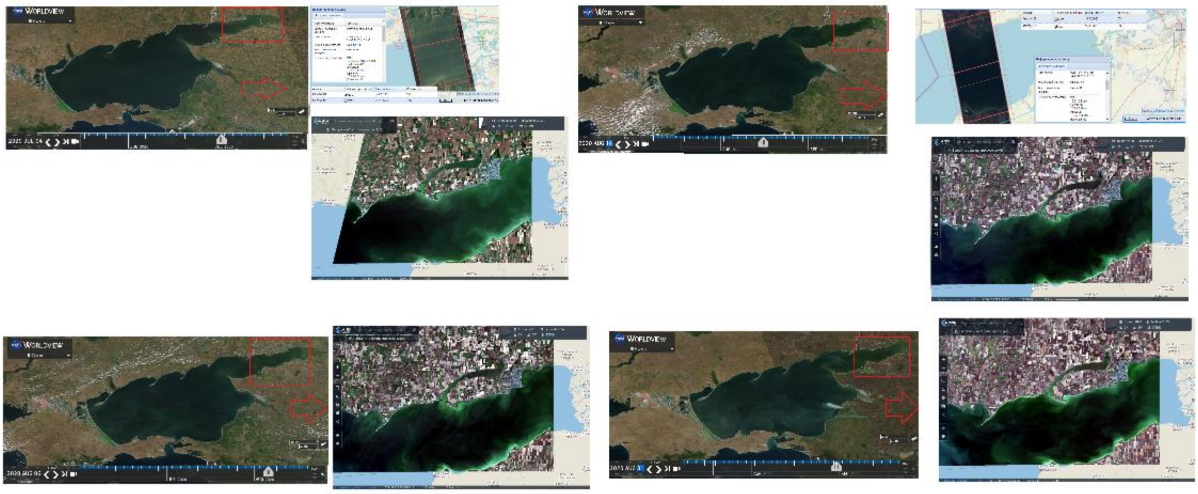


Fig. 1. The impurities distribution with the known coordinates: satellite WorldView; Canopus-B; Sentinel-2L 2A

The method is used, which is a sequential application of the neural network approach and the LBP algorithm for image contour reconstruction, which will be further referred to as «neural network-lbp» for brevity as a software implementation of the image processing algorithm.

The neural network-lbp method is described in detail in the source [2] and implemented by an algorithm (Fig. 2), which allows determining the boundaries of phytoplankton populations of a spotted structure, the distribution of color gradations and, based on this, determining the distribution of phytoplankton concentrations inside the spots and the location of the center of mass. These characteristics make it possible, having a series of processed images of the same water area for different time points (dates), to determine the rate of change in the boundaries of spots and their concentrations, the displacement of the center of mass due to the influence of the movement of the aquatic environment and the processes of growth-death of phytoplankton.

Results. The efficiency and effectiveness of the proposed «neural network-lbp» method is investigated in comparison with the method based on the use of a three-layer neural network (hereinafter referred to as the neural network). For the analysis, a test set of images is involved – flat shapes with rather complex boundaries, which will allow us to quantify the quality of the algorithms being compared.

The comparison tool uses an array of the scipy.misc Python library [21-22], which performs quantitative assessment of image matrices, in the case of the algorithms being compared, and calculates the norms of their difference.

The scipy.misc library allows you to evaluate the similarity of consecutive frames by converting them into sequences of grayscale pixels. The distance between two consecutive frames is measured. The distance on the histograms of two frames is calculated by the formula:

$$d(p,q) = \sum_i p(i)\log\frac{p(i)}{q(i)} \quad (1)$$

where *p(i)* and *q(i)* are the values of the components of the frame histograms. The threshold is set at *0.2*.

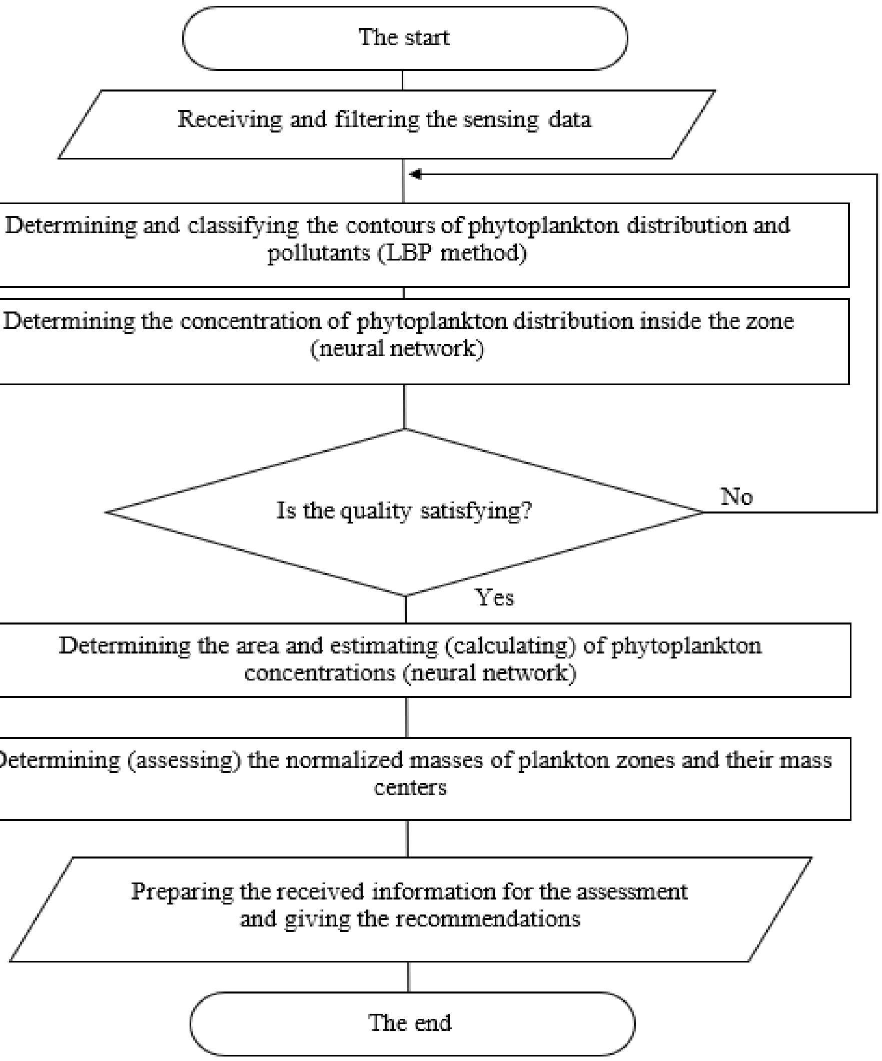
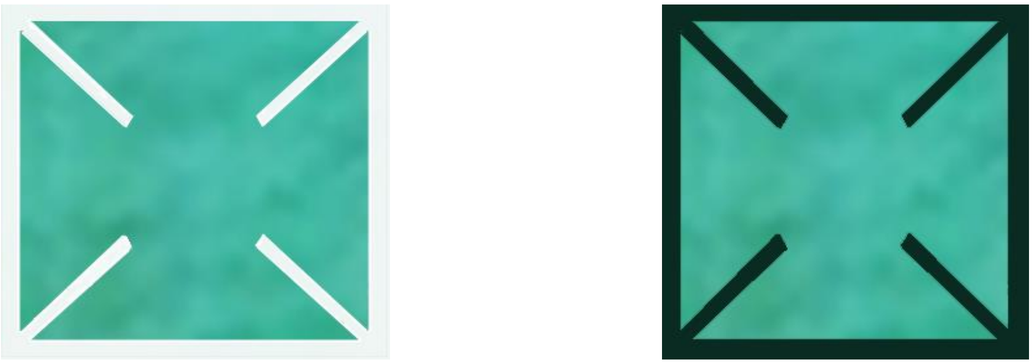


Fig. 2. Algorithm of the developed program

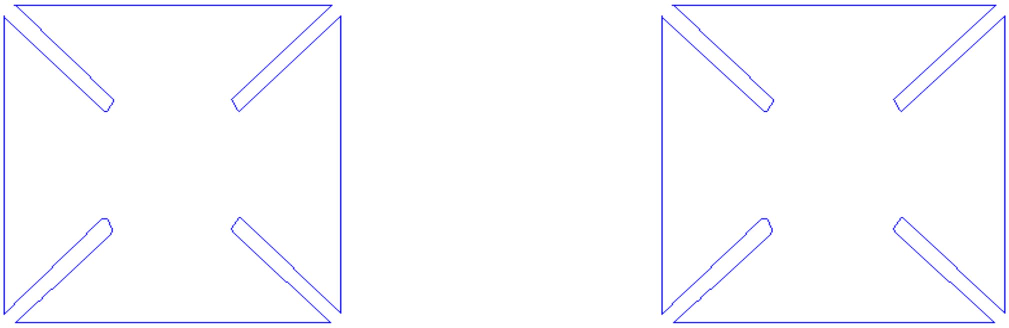
Based on neural network training using shades of green, which act as biological indicators of the Azov Sea for tests, then an image with the appropriate shade of green is used. The first test figure is the Maltese cross, which has a complex shape due to the presence of sharp corners. Considering that real images may have backgrounds of different origins, which affects the probability of correct recognition of the boundaries of the tested shapes. Figure 3a shows image without background, and Figure 3b with background.



a) b)

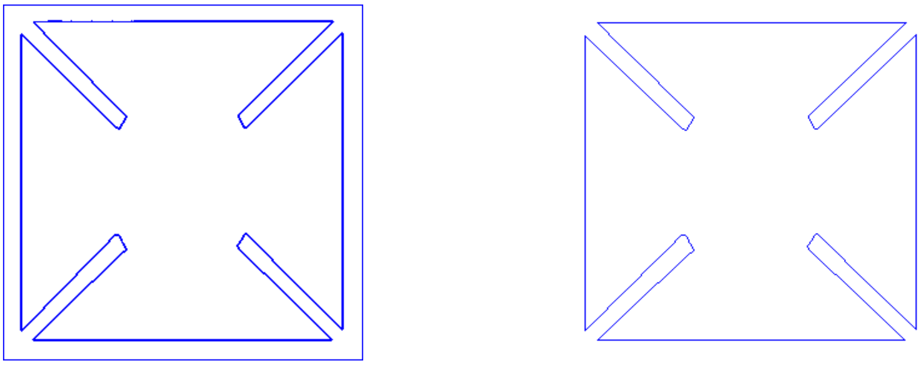
Fig. 3. Test figure with sharp and rounded corners:
a) The figure «Maltese cross» on white background
b) The figure «Maltese cross» on dark brown-green background

Fig. 4 shows the computer experiment result with image without background. Fig. 5 shows the computer experiment result with image with background. Judging by the appearance, both contours correspond quite well to the original. We will conduct quantitative assessment of this correspondence.



a) b)

Fig. 4. The result of the program, in the absence of background:
a) The contour of the figure created by the neural network algorithm
b) The contour of the figure created by the algorithm «neural network-lbp»



a) b)

Fig. 5. The result of the program with background:
a) The contour of the figure created by the neural network algorithm
b) The contour of the figure created by the algorithm «neural network-lbp»

Fig. 3 shows an image from the library with an absolute match (accuracy – *100%*), since this image serves as a reference. The results of the evaluation of the proximity of images for the case of the absence of a background: when using a neural network algorithm – *96.1%*, for the algorithm «neural network-lbp» – *96.21%*.

It can be concluded that in the absence of a background, both algorithms demonstrate similar results. However, if there is a background, the result is completely different. Therefore, due to the proximity of the indicators in the absence of a background and the fact that real images with backgrounds of different origins were used in further work, subsequent test figures are considered only with a background.

With the complication of the boundaries of the image of the test figure (Fig. 6), as a result, the neural network indicators, Fig. 7a, – 80.1%, and the algorithm «neural network-lbp», Fig. 7b, – 83.44%.

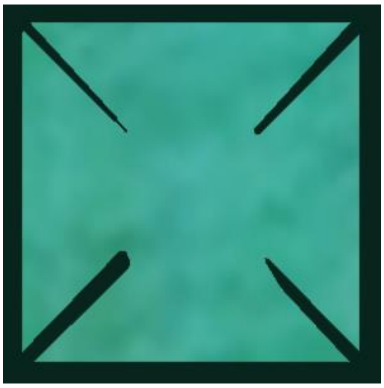
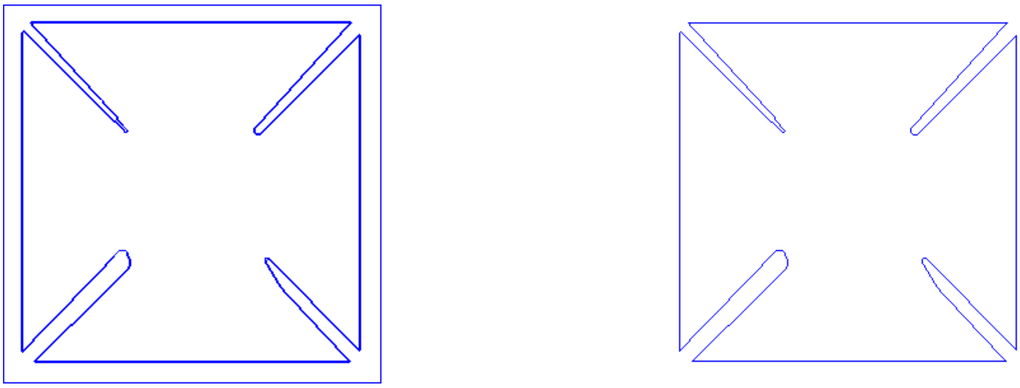


Fig. 6. Complicated test figure

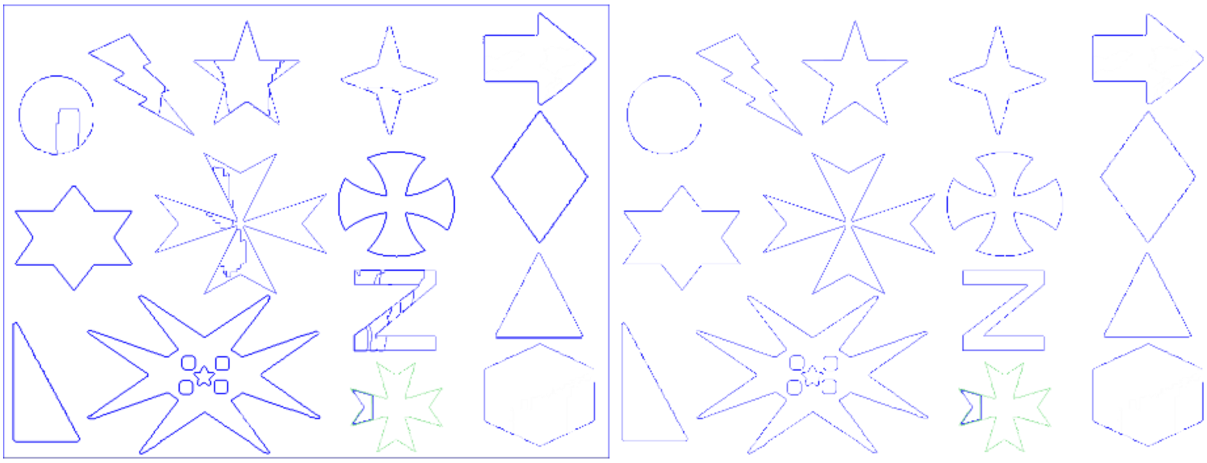


a) b)

Fig. 7. The result of the program:
a) The contour of the figure created by the neural network algorithm
b) The contour of the figure created by the algorithm «neural network-lbp»

If we add images of figures and various shades of green as backgrounds (Fig. 8) found in real satellite images, the following recognition quality results are obtained: for the neural network algorithm, – 97.22% (Fig. 9a); for the algorithm «neural network-lbp» (Fig. 9b) – 98.78%.

Fig. 8. Set of various test figures



a) b)

Fig. 9. The result of the program:
a) The contour of the figure created by the neural network algorithm
b) The contour of the figure created by the algorithm «neural network-lbp»

The available experimental results demonstrate the advantage in accuracy of the neural network-lbp algorithm compared to the algorithm based on the use of a three-layer neural network.

Additional confirmation of the obtained conclusions is demonstrated when processing satellite images of the eastern part of the Azov Sea, the calculation of the image of the water area was made provided that the flowering area was selected in advance (Fig. 10), the image obtained for July 4, 2020. Fig. 11 and 12 demonstrate the results of the selection of the contours of the regions (boundaries) by the neural network (92.7%) and the algorithm «neural network-lbp» (94.19%), respectively.

Fig. 10. Test image, in the highlighted definition area

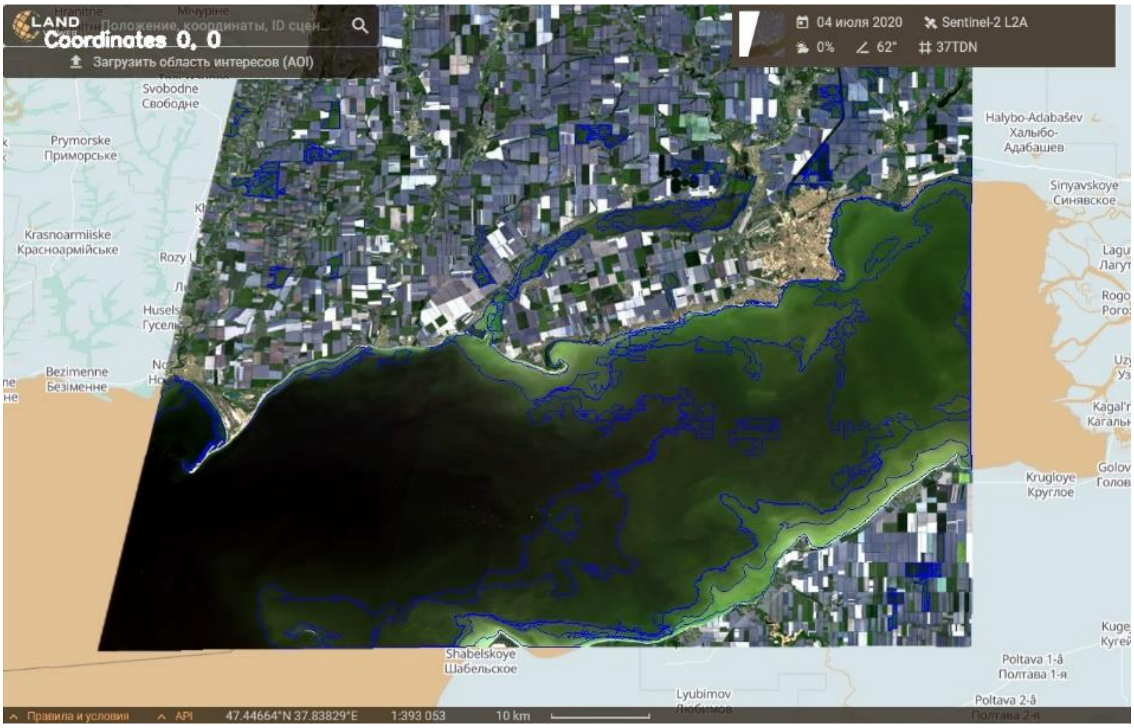


Fig. 11. Operation of the neural network algorithm

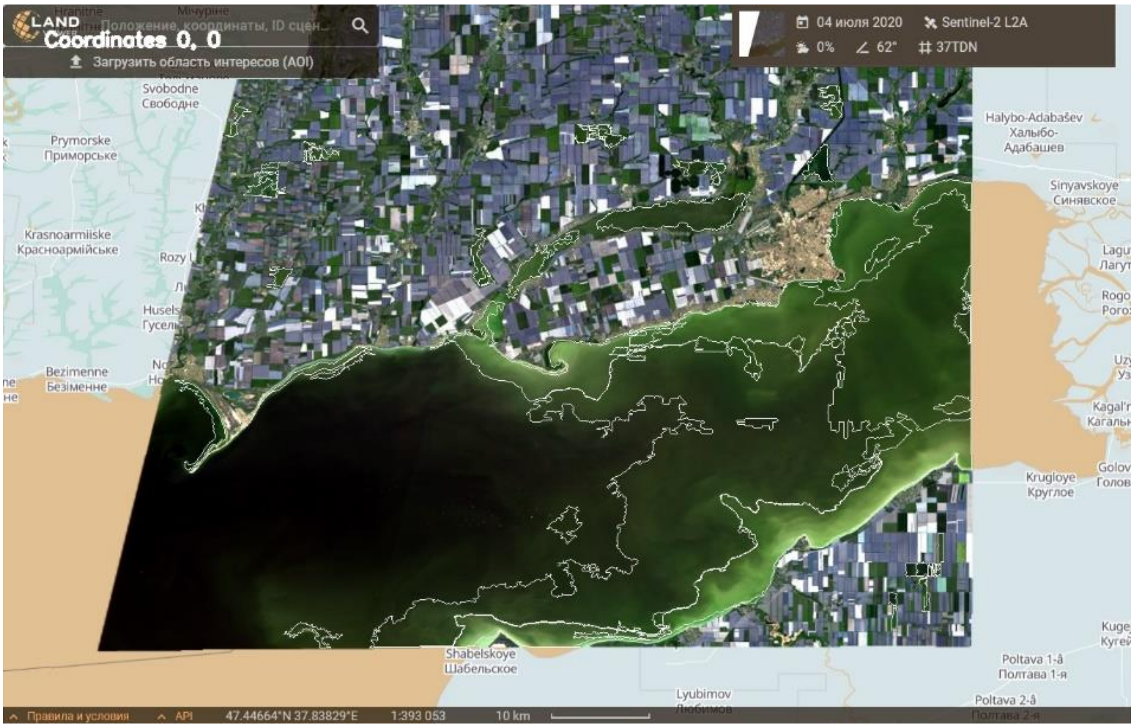


Fig. 12. Working with the «neural network-lbp» algorithm

The results obtained from a series of images (for July 4, 2020, August 6, 2020, August 16, 2020, August 18 and August 31, 2020) allow us to show a comparison of the recognition results of the contours (borders) of the regions, (Fig.13.)

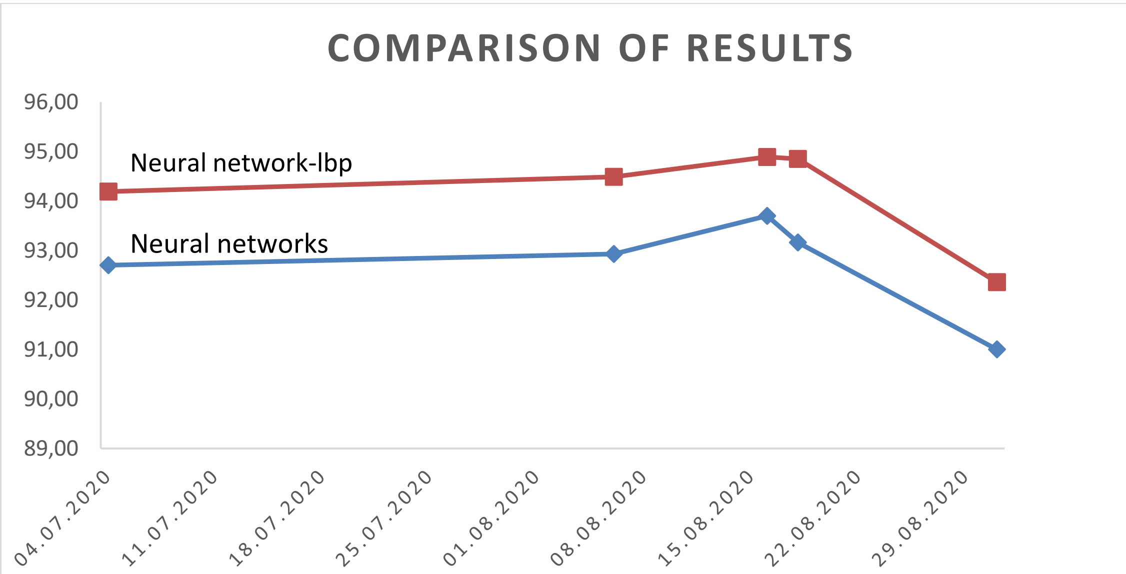


Fig. 13. Recognition results comparison of regions contours (borders)

Discussion and conclusions. Thus, computer experiments have proved the effectiveness of the «neural network-lbp» method for recognizing objects consisting of curved contours. The method is characterized by high detail and sharpness of the boundaries. Recognition accuracy increases by 1.5-3%.

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СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ НЕЙРОННЫХ И ЛОКАЛЬНО-БИНАРНЫХ АЛГОРИТМОВ ИДЕНТИФИКАЦИИ ИЗОБРАЖЕНИЙ ПЛАНКТОННЫХ ПОПУЛЯЦИЙ*

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Работа посвящена методу «нейросеть-lbp» обработки спутниковых снимков водных прибрежных систем многоспектральной съемки для идентификации фитопланктонных популяций пятнистой структуры: определения их границ, распределения градаций цвета и на основе этого – определение распределения концентраций фитопланктона внутри пятен и расположения центра масс. Исследуется работоспособность и эффективность предложенного метода «нейросеть-lbp» в сравнении с методом, базирующимся на использовании трехслойной нейронной сети. Для анализа привлекается тестовый набор изображений –плоских фигур с достаточно сложными границами, что позволит количественно оценить качество сравниваемых алгоритмов. Результаты работы показывают возрастание точности распознавания на 1,5-3 % при применении предложенного метода.

Ключевые слова: математическое моделирование, локальные бинарные шаблоны, нейронная сеть, мелководный водоем, данные спутникового зондирования.

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