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MULTISPECTRAL IMAGE SEGMENTATION FOR WATER BODY DETECTION

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This work explores the application of semantic segmentation methods based on Convolutional Neural Networks (CNN) for detecting water bodies in high-resolution multispectral imagery. This method was presented at the 6th CASSINI Hackathon, held in November 2023, aimed at finding innovative solutions to environmental issues using space data. Participants utilized satellite data from the Copernicus program to develop technologies in sustainable development and resource management [1].

The study shows that classification accuracy improves by incorporating Near Infra-Red (NIR) channels, which facilitates better differentiation between visually similar objects such as water surfaces and cloud shadows.

This research builds upon works [2] and [3], where a U-Net-like network trained on aerial images is used for effective identification of water regions in satellite imagery. To address the issue of misclassification caused by clouds and their shadows, the Normalized Difference Water Index (NDWI) is proposed as a reliable indicator to verify segmentation results [4]. NDWI employs green and near-infrared (NIR) wavelengths to monitor changes in water content within water bodies. We will use the NDWI metric proposed by McFeeters [5-6], which effectively highlights water objects in multispectral images:

$$\boldsymbol{NDWI} = \left(\boldsymbol{X_{green}} - \boldsymbol{X_{nir}}\right)/(\boldsymbol{X_{green}} + \boldsymbol{X_{nir}}), \tag{1}$$

where X_{green} and X_{nir} are intensities for green and NIR channels respectively.

For segmenting 4-channel multispectral images, a U-Net-like convolutional network was employed. The U-Net architecture, first introduced in [7], has a symmetrical structure where the contracting part (dimension reduction) is mirrored by the expanding part (dimension increase). This creates a U-shaped network that efficiently performs image segmentation using only convolutional layers without fully connected ones. To handle large images, these images are divided into smaller squares, and segmentation is performed sequentially for each square.

It has been proposed to increase the number of layers from 42 to 58 while maintaining the original architecture, resulting in good segmentation outcomes when working with 4-channel images (NIR+RGB). The focus is on detecting water bodies, thus simplifying segmentation to four classes: "Water," "Vegetation," "Soil," and "Other." The quality of water object segmentation is evaluated using NDWI calculated according to formula (1).

To ensure consistency and simplify comparisons with the results presented in [2], the same set of aerial photographs from dataset [8] was used for both training and validating the model, allowing for direct evaluation of the network's performance under similar conditions. For testing, images obtained from the Sentinel-2 spacecraft were used, consisting of 4-channel data from areas of the Earth's surface near the Kakhovka Hydroelectric Power Plant on June 5, 2023 (Figure 1a). For visual enhancement of the images, we used histogram equalization, which in this case improves contrast (Figure 1b). The results of semantic segmentation are presented in Figure 1c. Analyzing the images (Figure 1c), we observe several misclassified areas. The main reason for their occurrence is the presence of high-albedo areas such as clouds and surfaces lacking a topsoil layer. The use of NDWI effectively highlights water objects, while areas under cloud shadows are not classified as water (Figure 1d).

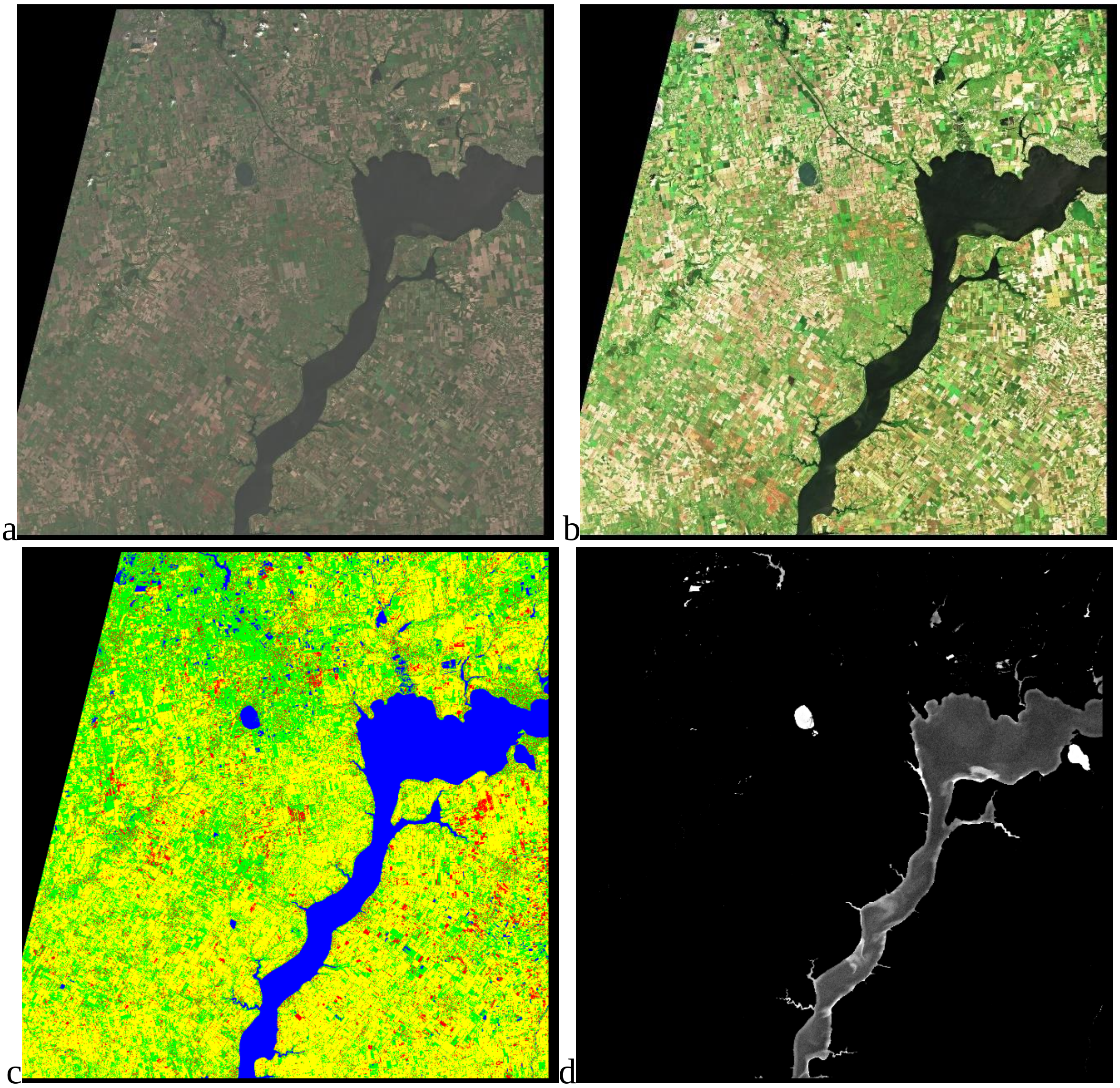
a b c d

Figure 1 – Segmentation results:
a) original image; b) enhanced image; c) labeled image; d) NDWI image

Thus, on the example of processing 4-channel multispectral satellite images, it is shown how semantic segmentation is performed using a U-Net-like network. The need to take into account the model of image formation and carry out retraining of the network for image processing of the corresponding nature is indicated. The quality of the segmentation of the zone of water bodies was evaluated in comparison with the use of the normalized differential vegetation index NDVI.

Analyzing the obtained results, it is shown that the results of semantic segmentation using a neural network are in good agreement with the results of threshold binarization of the NDVI index.

The reliable method of water segmentation proposed in the work is practical and effective, which allows the use of Earth observation data in environmental monitoring and management.

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