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# Application of convolutional neural networks in the processing of hemispherical photos of the canopy

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*Motivation and Aim*: The study of solar radiation transmittance in the forest canopy is necessary for a wide range of tasks, including identification of natural regeneration conditions, analysis of the biological cycle, analysis of the impact of global climate change on forest ecosystems [1, 2] and monitoring the condition of forest ecosystems [3]. Making direct measurements of light transmittance of the forest canopy is difficult due to the high level of spatial and temporal variability of the measured parameters [1]. Consequently, to estimate the solar radiation transmittance of the forest canopy, it is necessary to use indirect methods, one of which is hemispherical photography. The first stage of processing such photographs is binarization, i.e., separating the pixels related to the sky from all other pixels. The resulting black and white image is then used as a mask to calculate which fraction of incoming light passes through this mask, allowing the transmission of diffuse and direct radiation to be estimated.
In the classical approach used for binarization of images, only the blue RGB channel is analyzed. This is due to the fact that foliage elements have much lower reflectance and transmittance in the blue region of visible electromagnetic spectrum [4, 5, 3], while the brightness difference between clouds and blue sky in this region of the spectrum is minimal. Due to the fact that the manually selected threshold value can be a source of errors due to its subjectivity [6, 7], a large number of methods have been developed for automatic calculation of the binarization threshold. The most common in the processing of canopy photographs are the Ridler-Calvard algorithm [8] based on the image histogram analysis, and the Nobis-Hunziker algorithm [9] based on the edge detection. As these methods are based on pixel brightness analysis, they appear to be sensitive to photographic exposure. For example, in images taken with automatic exposure, these algorithms underestimate the fraction of gaps in low-density canopies, while overestimating the fraction of gaps in medium- and high-density canopies [5]. Currently, the use of convolutional neural networks (NN) in tasks related to image segmentation is widespread. This is due to the fact that this type of NN is characterized not only by the accuracy of image processing, but also by its stability in the presence of various image defects, such as extraneous noise, blurred borders, or improperly chosen exposure. However, the quality of such NN strongly depends on the volume and quality of the training data set, while the creation of a high-quality set of masks of hemispherical canopy photos is an extremely time-consuming process.
*Methods and Algorithms*: We developed a convolutional NN based on U-Net, whose architecture consists of a constricting path to capture the context and a symmetric expanding path that allows precise localization. To train the developed NN, a dataset consisting of only 240 hemispherical photographs taken in different stands was used,

whereas typically the minimum training sample size for the NN is 3000-5000 images. In order to compensate for the small number of images used in training, we applied a data augmentation image preprocessing technique, which included random crop to obtain a random image fragment of a given dimensionality, as well as contrast and brightness changes. This allowed us to qualitatively expand the training dataset and avoid overtraining the model. To validate the proposed NN at the points of continuous monitoring of photosynthetically active radiation, we obtained hemispherical photographs of the canopy taken at different exposures. Binary masks were created from these photos using the classical approach (the Nobis-Hunziker algorithm) and the developed NN, and then the weighted average radiation transmittance global light index was calculated from these masks, which was compared with the measured data.
*Results and Conclusion*: The validation showed that the use of the proposed approach allowed us to qualitatively train the developed NN for the binarization of hemispherical photographs of the canopy on a small training sample. The developed NN turned out to be stable to varying exposure of photographs and blurring of image edges arising as a result of lens distortions. At the same time, it should be noted that in the presence of the Sun in the frame, there are extensive areas in which the brightness of all pixels is maximal. Consequently, such images cannot be correctly binarized either by classical methods or by methods based on the application of NN.
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