Abstract

Contemporary hydrological research faces numerous social, climatic, technological, and analytical challenges. The aim of the activities described in this dissertation was to develop new methods supporting hydrological observations using unmanned aerial vehicles (UAVs) and machine learning techniques, with the goal of introducing innovative solutions in this field. Three methods were developed as part of this doctoral work.

The first method addresses the problem of disturbances in digital terrain models (DSMs) in small streams. Artificial intelligence was applied to interpret these disturbances and estimate water levels based on photogrammetric data. A convolutional neural network trained using supervised learning was employed for this purpose. Two model variants were tested: the first, simpler, used an encoder to transform the image into a single water level value, and a more complex method predicted a weight mask, which was then used for sampling the DSM, improving the accuracy and the explainability of the solution. In this second approach, a custom loss function was implemented, allowing the neural network to be trained without reference weight masks. Training data came from five case studies, and two cross-validation methods were used to evaluate the solution. One of them was the all-in-case-out method, allowing the model's effectiveness to be tested on a subset of data from a case study whose data was not used for training, confirming the model's ability to generalize. Depending on the case study and validation stringency, the proposed solution achieved a root mean square error (RMSE) ranging from 2 cm to 16 cm. This method outperforms traditional approaches based on simple photogrammetric DSM sampling, achieving an average of 62% lower RMSE for rigorous all-in-case-out validation. Using data from other studies, the proposed solution was compared in the same case study with other UAV-based methods. It achieved accuracy comparable to radar-based methods, considered the most accurate available for measuring water levels in small rivers using UAVs.

The second method dealt with the issue of low temperature measurement accuracy using thermal cameras mounted on UAVs. Limitations related to the maximum payload of UAVs necessitate the use of lightweight, uncooled thermal cameras whose internal components are not thermally stabilized. This leads to an increase in temperature measurement error from ±0.5 °C in laboratory conditions to ±5 °C in unstable flight conditions. The dissertation describes a data processing procedure that minimizes these undesirable effects. It consists of the following steps: (i) vignette removal using a single-image vignette correction algorithm, (ii) georeferencing using image metadata and gradient-based optimization, and (iii) optimizing

temperature consistency between overlapping thermal images using gradient-based optimization. The solution was tested in several river areas, where natural water bodies were used as a reference point for temperature. In the tests, the proposed method significantly improved measurement precision. The mean squared error (RMSE) decreased by an average of 39%, and the mean absolute error (MAE) by 40.5%. The proposed algorithm can be described as self-calibrating since it operates fully automatically, using only field data from standard aerial surveys and does not require additional calibration equipment or manual operator intervention.

The third project involved adapting the Priestley-Taylor Jet Propulsion Laboratory (PT-JPL) algorithm, originally developed for estimating evapotranspiration based on data from the ECOSTRESS satellite mission, for evapotranspiration calculations using data collected via UAVs. A two-day measurement campaign was conducted, during which data was collected from both UAVs and a meteorological station. This data was used to calculate evapotranspiration using the adapted PT-JPL algorithm and the eddy covariance method, which served as a reference measurement. The results showed high agreement with reference measurements, preliminarily confirming that the PT-JPL algorithm can be applied to measurements performed using UAVs.

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Radosław Szostak