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Automatic Identification of Aquatic Insects Based on Deep Learning and Computer Vision

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Abstract : Mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) (collectively referred to as EPT) are key participants in most freshwater habitats and often exhibit high diversity. Moreover, their presence and relative abundance are used in freshwater ecological and biomonitoring studies. Current methods for freshwater ecosystem biomonitoring follow a traditional approach of taxa monitoring based on morphological characters, which is time-consuming, and often generates data sets with low taxonomic resolution and unverifiable identification precision. To assist in solving identification problems and contribute to the knowledge of the distribution of many species, there was a need to develop alternative approaches in macroinvertebrate sample identification. Here, we establish an automatic machine-based identification approach for EPT taxa (Insect) using deep Convolutional Neural Networks (CNNs) and computer vision to increase the efficiency and taxonomic resolution in biomonitoring. The 5 550 specimens were collected from freshwater ecosystems of Serbia, and the deep model was built upon 90 EPT taxa. The protocol for obtaining images included the following stages: taxonomic identification by human experts and DNA barcoding validation, mounting the larvae, and photographing the dorsal side using a stereomicroscope and camera (16 650 individuals). The most informative image regions (the dorsal segments of individuals) for the decision-making process in the deep learning model were visualized using Gradient Weighted Class Activation Mapping (Grad-CAM). After training the artificial neural network, a CNN model was then built that was able to classify the 90 EPT taxa into their respective taxonomic categories automatically with 98.7%. Our approach offers a straightforward and efficient solution for routine monitoring programs, focusing on key biotic descriptors, such as EPT taxa. In addition, this application provides a streamlined solution that not only saves time, reduces equipment and expert requirements but also significantly enhances reliability and information content. The identification of the EPT larvae is difficult because of the variation of morphological features even within a single genus or the close resemblance of several species, and therefore, future research should focus on increasing the number of entities (species) in the model.

Keywords : convolutional neural networks, DNA barcoding, EPT taxa, biomonitoring
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