From leaf to label: a robust automated workflow for stomata detection.

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Abstract

1. Plant leaf stomata are the gatekeepers of the atmosphere-plant interface and are essential building blocks of land surface models as they control transpiration and photosynthesis. Although more stomatal trait data is needed to significantly reduce the error in these model predictions, recording these traits is time-consuming and no standardized protocol is currently available. Some attempts were made to automate stomatal detection from photomicrographs, however, these approaches have the disadvantage of using classic image processing or targeting a narrow taxonomic entity which makes these technologies less robust and generalizable to other plant species. We propose an easy-to-use and adaptable workflow from leaf to label. A methodology for automatic stomata detection was developed using deep neural networks according to the state-of-the-art and its applicability demonstrated across the phylogeny of the angiosperms. 2. We used a patch-based approach for training/tuning three different deep learning architectures. For training, we used 431 micrographs taken from leaf prints made according the nail polish method from herbarium specimens of 19 species. The best performing architecture was tested on 595 images of 16 additional species spread across the angiosperm phylogeny. 3. The nail polish method was successfully applied in 78% of the species sampled here. The VGG19 architecture slightly outperformed the basic shallow and deep architectures, with a confidence threshold equal to 0.7 resulting in an optimal trade-off between precision and recall. Applying this threshold the VGG19 architecture obtained an average F-score of 0.87, 0.89 and 0.67 on the training, validation and unseen test set, respectively. The average accuracy was very high (94%) for computed stomatal counts on unseen images of species used for training. 4. The leaf-to-label pipeline is an easy-to-use workflow for researchers of different areas of expertise interested in detecting stomata more efficiently. The described methodology was based on multiple species and well-established methods so that it can serve as a reference for future work.

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