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| **Enhancing individual tree detection and species classification in an urban forest with semi-supervised deep learning models** |
| **Background:**  Individual tree characteristics including crown locations, extents, and species are important inputs for effective urban forest management. In recent years, deep learning models have emerged as a popular tool for deriving these characteristics from remotely sensed imagery. Compared with traditional methods, deep learning shows advantages in learning complex visual features, which benefits tree recognition across urban scenes. However, training deep learning models usually requires a large number of samples covering varied urban scenes and crown types. Manually labelling these samples from remote sensing imagery demands significant time and effort. As a result, data scarcity becomes a major issue impeding the wider application of deep learning models in the urban forest domain.  **Method/Result:**  This study addressed the data scarcity issue by applying several semi-supervised learning (SSL) algorithms to high-resolution aerial imagery for two tasks: individual tree detection and individual crown species classification. The SSL algorithms enable the deep learning model to train on a large number of unlabelled remote sensing images to supplement scarcer-labelled training samples.  The approaches were tested on summer aerial imagery from Auckland city, New Zealand, with a resolution of 7.5 cm/pixel. The results showed that SSL effectively improved accuracies for both tasks compared with supervised approaches that used the same labelled data. In individual tree detection, the SSL model improved the mean average precision (mAP) by 0.5% to 1.9% on comparisons made on different sizes of training datasets. For individual crown species classification, our SSL approach achieved an F1 score of 87.09%, showing a 7% improvement compared to the supervised model, in the classification of five species, using only 50 training images per class.  **Conclusion:**  Our research highlights the potential of SSL as an effective strategy for reducing reliance on manually labelled samples in individual tree analysis. This is particularly important in the context of the urban forest domain, where training samples are often limited. The findings presented here contribute to the ongoing efforts aimed at improving data efficiency and generalisability when applying deep learning models across urban forest environments. |