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| **Tree species classification using automatically annotated multispectral aerial laser scanner data.** |
| Understanding tree species composition is critical in forest assessments. While Convolutional Neural Networks (CNNs) and Aerial Laser Scanner (ALS) can be effective modelling tools, annotating tree-level data proves itself challenging and time-consuming. On the other hand, spatially explicit data on forests, as harvester production reports (HPR), can become more common in the future and be used for annotation. Thus, we propose a method of tree species classification that uses automatically annotated multispectral ALS point clouds.  The ALS data was collected in 17 stands in southern Sweden (59°46´N, 14°31´E). The stands were scanned in September 2021 using the Finnish Geospatial Institute’s multispectral ALS system (Hakula et al., 2023) composed by two sensors, the Riegl miniVUX-1UAV 905 nm (Channel 1), and the Riegl VUX-1HA 1550 nm (Channel 2). The resulting point cloud had approximately 1000 points/m2. The ALS point clouds were segmented into individual trees according to Holmgren et al. (2022).  Between November 2021 and October 2022, 69,253 trees were harvested from the 17 stands using harvesters equipped with a positioning system. The HPR files stored 4 species classes, “Norway spruce”, “Scots pine”, “Birch”, and “Other broadleaves”. The “Birch” and “Other broadleaves” classes were combined into a single “Deciduous” class. The trees segmented from the ALS data were automatically linked to the tree positions present in the harvester files based on the distance between the trees in both datasets, creating an annotated ALS dataset. Altogether, 45,516 harvested trees were linked to an ALS derived tree segment.  After linking both datasets, a CNN originally designed for 2D image classification was employed for predicting tree species. To adapt 3D point clouds for this 2D-CNN, we converted them into images from four perspectives. This transformation was done by rasterizing point clouds along the X (Lat.) vs. Z (Height) axis, generating four 2D representations per tree, each rotated around the Z axis at 45° intervals. The CNN was trained to classify 3 tree species classes according to the harvester data used for annotation, namely Pine, Spruce and Deciduous. The images were created using an RGB false color composite combining channels 1 and 2. In each pixel, the red color was assigned the mean intensity of channel 1 (905 nm), green as the mean intensity of channel 2 (1550 nm), and blue as the Normalized Near Infrared Index (NDII), calculated using channels 1 and 2. Finally, the resulting RGB images were resized to the standard dimension of 160 (width) by 320 (height) pixels.  The tree species classification had an overall accuracy of 93.2%. The tree species classes showed F1 scores ranging from 0.923 to 0.942 from Spruce to Deciduous, resulting in a macro F1 of 0.934. In summary, spatially explicit harvester production reports can be efficiently used to annotate remote sensing based models at individual tree-level.  Hakula, A., Ruoppa, L., Lehtomäki, M., Yu, X., Kukko, A., Kaartinen, H., Taher, J., Matikainen, L., Hyyppä, E., Luoma, V., Holopainen, M., Kankare, V., Hyyppä, J., 2023. Individual tree segmentation and species classification using high-density close-range multispectral laser scanning data. ISPRS Open J. Photogramm. Remote Sens. 9. https://doi.org/10.1016/j.ophoto.2023.100039  Holmgren, J., Lindberg, E., Olofsson, K., Persson, H.J., 2022. Tree crown segmentation in three dimensions using density models derived from airborne laser scanning. Int. J. Remote Sens. 43, 299–329. https://doi.org/10.1080/01431161.2021.2018149 |