Variation and directional anisotropy of reflectance at the crown scale – implications for tree species classification in digital aerial images

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Tree species classification is solved at insufficient reliability in applications that combine in situ and airborne optical data. Directional reflectance anisotropy hampers image-based solutions in frame sensors. Line cameras provide linear subsets of possible view-illumination geometries. Besides anisotropy, the within-species variation of reflectance in trees is high. We examined these phenomena with the airborne ADS40 line sensor, which provides four-band image data in two directions. ADS40 is the first photogrammetric sensor to provide target reflectance images. An experiment in southern Finland, consisting of georeferenced trees was imaged from four altitudes. The crown envelopes of 15 197 pine, spruce, and birch trees were accurately modeled in LiDAR data. A sample of 3D points on the crown envelope was mapped to the images for pixel data. A method for determining camera visibility and illumination conditions for these points was developed. It employs ray-tracing in LiDAR point clouds. Using it, the crowns could be partitioned into camera-visible and occluded areas and according to illumination classes.

We first examined the precision of the ADS40 reflectance data, using well-defined surfaces and trees as targets. Anisotropy was studied by illumination conditions, tree species, and band. Within-species reflectance variation was quantified for tree and stand variables, including also the effects by adjacent trees. Within-crown variation in image brightness was also examined. Finally, species classification was tested in monoscopic data, using various cross-validation methods to assess the performance. The precision of the 1−4-km ADS40 reflectance images was 2−10% in well-defined targets. The range of reflectance anisotropy factors was 0.7−1.3 for trees near the solar principal plane, where between-species differences were marginal. Reflectance differences were however observed across the view-illumination geometry between species, band, and illumination conditions. The most important factor explaining reflectance variation was the relative height. The overall between-stand variation explained 1−19% of the within-species reflectance variation, especially in NIR. There were between-species differences in the brightness patterns of crowns, which could potentially be used as a high-order image feature for species classification. The effects by adjacent trees were significant in NIR and this variation hampers spectral classification. Species classification accuracy of 80% was obtained, using monoscopic 4-km data, which showed the high potential of line sensors and the ADS40.

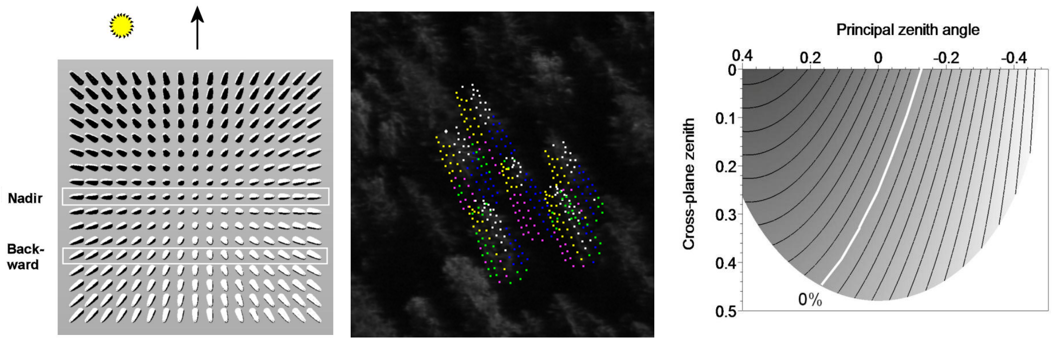

Fig. 1. View geometry of the ADS40 (left). Within-canopy illumination classes in different colors. Pine−spruce separability suggested by directional reflectance surfaces in NIR (right).