Effect of variability of normalized differences calculated from multi-spectral lidar on individual tree species identification

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1. Introduction

Individual tree species identification is a key information in precision forest inventories and forest management. Multispectral airborne laser scanners (MALS) offer the opportunity to improve species identification compared to monospectral ALS, by opening the possibility of computing intensity features from two channels, each having different spectral information. Intensity features like ratios of channels or normalised differences (ND) are potentially less variable for a given species than the single channel absolute intensities, i.e., less prone to variations caused by external factors, such as scan angle, or variations in tree characteristics, such as tree height. The multispectral lidar Titan of Teledyne Optech Inc. incorporates three lasers (channels C1, C2, C3) that scan with different wavelengths (respectively 1550, 1064 and 532 nm), different scanning plane tilt angles (respectively 3.5°, 0° and 7°) and different beam divergence (0.35 mrad in C1 and C2, 0.7 mrad in C3). The objectives are 1) to analyse the variability of NDs calculated from multispectral lidar due to viewing geometry, 2) to evaluate the effect of intensity normalisation on ND values as well as on single tree species identification accuracy using ND features, 3) to evaluate the variability of ND related to tree characteristics such as the tree height.

2. Data and Methods

The multispectral lidar data were acquired in July 2015 in the York Regional Forest (YRF), Ontario, Canada using the Titan system. The flight height was about 800 m above ground, with 10 first returns m^{-2} for all three channels within each single flight line, and a mean of 20 first returns m^{-2} for overlapping flight lines. The data were captured with a maximum mirror lateral scan angle of 15 degrees. This resulted in a maximum net scan angle of 20 degrees due to the combination of the scanning plane tilt and the lateral scan angles. Reference data were acquired for six needleleaf tree species through field identification and photointerpretation of high-resolution images. Manual delineation of the sampled crowns was performed on the canopy height model. A large number of point cloud 3D features were calculated from normalized return heights. Moreover, intensity features were computed from the raw as well as from the range-normalized intensities of returns (Budei et al. 2018, Budei and St-Onge 2018). We here focus on ND intensity features that are calculated as combinations of two channels: NDG1 as (C2+C3)/(C2-C3); NDG2 as (C1+C3)/(C1-C3) and NDIR as (C1+C2)/(C1-C2). Several ND versions were calculated from different statistics (50th, 75th, 90th, 95th percentiles of the intensity distribution or mean of return intensities in each channel) applied on selections of return types (all returns, single returns or first returns). These were computed for the returns falling within 60% of the upper crown length. Random forest classification was used for tree species identification.

Because of the variations in viewing geometry caused by differences in net scan angles and beam divergence, the multispectral lidar NDs do not meet the assumptions generally accepted for indices

Published in: Markus Hollaus, Norbert Pfeifer (Eds.): Proceedings of the SilviLaser Conference 2021, Vienna, Austria, 28–30 September 2021. Technische Universität Wien, 2021. DOI: 10.34726/wim.1861
This paper was peer-reviewed. DOI of this paper: 10.34726/wim.1976

calculated from optical satellite images, where spectral values of the same pixel (e.g., the red and near infrared values of a given pixel) have the same footprint, the same resolution and the same viewing angle. Increase in scan angle causes a decrease in return intensity, a change in return distribution and a decrease in number of returns per pulse. These scan angle effects might concern ND values. For each of the three ND types, a mean scan angle was calculated between the averages of scan angle values of returns in corresponding channels for each tree crown. For the first objective, we computed ND values from individual flight lines and evaluated their correlation with corresponding mean scan angles. We trained a random forest algorithm with all trees and then compared the identification accuracy for three classes of mean scan angle values. For the second objective, we computed ND values from individual flight lines using first the raw intensities and second the normalized intensities. We compared the change in correlation values of NDs with mean scan angles between NDs using raw and normalized intensities. Moreover, after species identification, we compared identification results obtained respectively with raw and normalized intensities. For the third objective, ND values vary with intra-specific properties affected by age, such as tree size and shape. We therefore calculated the correlation of ND, computed from returns from all flight lines, with tree height and then evaluated whether this correlation influences identification accuracy.

3. Results

A scan angle below 20 degrees (and in the case of a topography having only small variations) had a low influence on ND values, with correlations remaining below |±0.2|. Figure 1 presents results of species identification with different feature selections from individual channels and pairs of channels (including ND and channel ratios). Results are given by scan angle class.

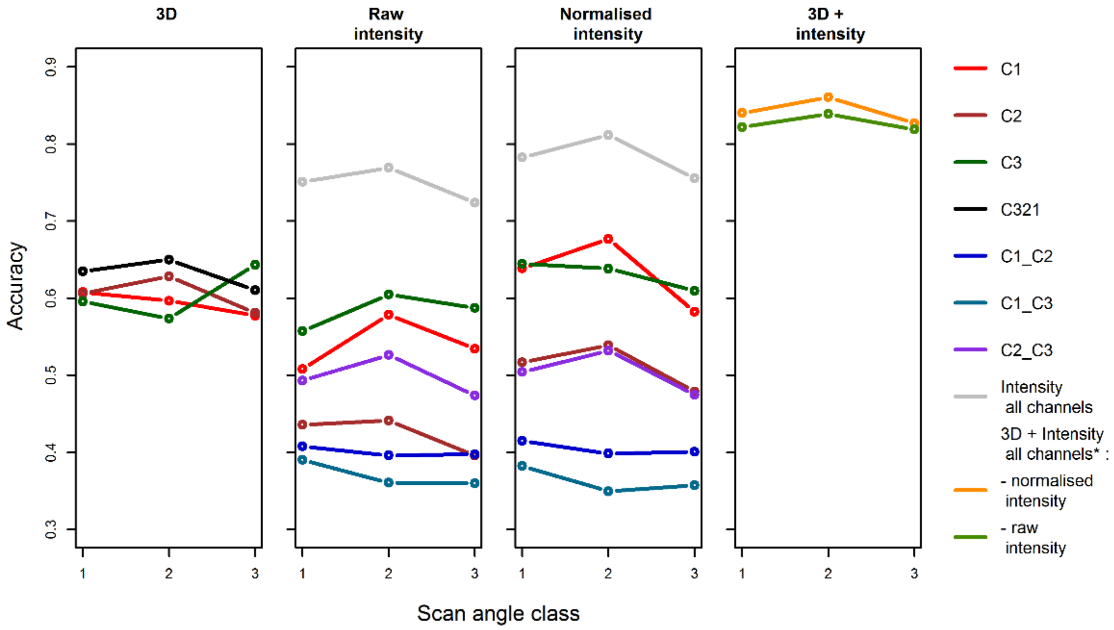

Figure 1: Random forest species identification accuracy by scan angle class: 1 = small scan angles near nadir, 2 = middle class scan angles, 3 = large scan angles. The classifications related to C1, C2, C3 used features from single channels, while those related to C1_C2, C1_C3, C2_C3 used NDs and ratios of intensity. C321 used 3D features with returns from all channels.

There is no significant difference between ND values computed from raw intensities compared to normalized intensities, and consequently, between identification accuracy using only NDs and channel ratios from raw and normalized intensities. By contrast, range normalization improved the accuracy of tree species identification by 8% when only single channel intensity features were used.

Even if ND features presented high correlation to tree height (Figure 2), these features are selected by the random forest model as within the best features for species identification.

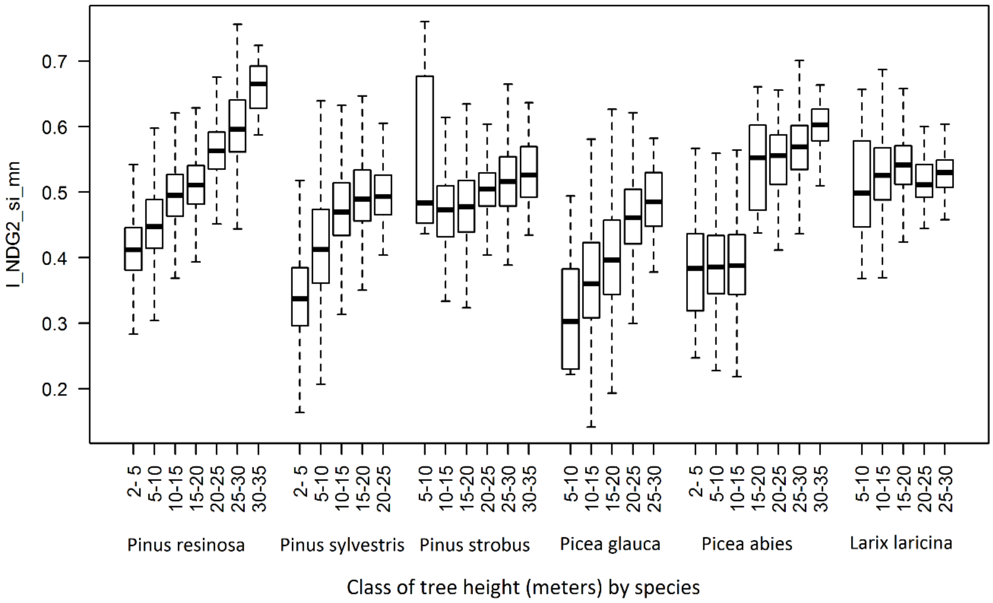

Figure 2: Variation of the feature I_NDG2_si_mn by height classes of 5 m. I_NDG2_si_mn represents the ND calculated between the mean (mn) intensity of the single (si) returns of middle IR (C1) and the green (C3) channels.

4. Discussion and conclusion

The inherent normalization formula of ND compensated to a certain measure for scan angle variation and for the lack of intensity normalization. This finding is useful since the intensity normalization of laser returns is often difficult, as necessary range information is lacking in the generally used LAS format.

The ND features presented a high variability as tree height changed. However, in an automatic ranking of variables using a random forest algorithm, ND features appeared to be among the most important ones for species classification, despite their variation with tree height. Even if random forest handled the high variability with tree height, attention must be given to sample representativity in each tree height class.

We conclude that NDs are robust variables that allow for an improvement in tree species identification even for a large range of tree heights, while at the same time reducing the need for intensity normalization.

Acknowledgements

We express our thanks to Teledyne Optech Incorporated (Vaughan, Canada) for graciously providing the Titan MALS dataset. This study was partially funded by the National Sciences and Engineering Research Council of Canada, by the AWARE project (NSERC File: CRDPJ 462973 – 14, Grantee: N.C. Coops, FRM, UBC), in collaboration with Canadian Wood Fiber Centre (CWFC) and FP-Innovations.

References

Budei BC, St-Onge B, Hopkinson C, and Audet FA, 2018, Identifying the genus or species of individual trees using a three-wavelength airborne lidar system, *Remote Sensing of Environment,* 204:632-647.

Budei BC, and St-Onge B, 2018, Variability of multispectral lidar 3D and intensity features with individual tree height and its influence on needleleaf tree species identification, *Canadian Journal of Remote Sensing,* 44 (4):263-286.