Forest Stand Delineation Using Airborne LiDAR and Hyperspectral Data

H. Xiong[1,2], Y. Pang[1,2], W. Jia[1,2], Y. Bai[1,2]

[1] Institute of Forest Resource Information Techniques, Chinese Academy of Forestry, Beijing 100091, China
2Key Laboratory of Forestry Remote Sensing and Information System, National Forestry and Grassland, Beijing 100091, China
Email: 13545903512@163.com, pangy@ifrit.ac.cn

1. Introduction

Forest stands are fundamental to forestry management. Forest stands are defined as large forested areas of homogeneous tree attributes and are traditionally delineated by operators through visual analysis of very high-resolution images, which is tedious and highly time-consuming. Therefore, this task could be automated for scalability and efficient updating purposes (Haara et al 2002).

With respect to existing methods, it appears that there are few studies focused on automatic delineation of forest stands based on multi-source remote sensing data. Also, tree species information with high accuracy is not fully used in recent methods. In this paper, a method based on the fusion of airborne LiDAR and hyperspectral data was proposed. The hyperspectral data give access to the dominant tree species of the forest stands while CHM derived from airborne LiDAR data provides geometric information of forest stands such as mean tree height and canopy closure.

2. Data and Methods

2.1 Study area

The study area is in Mengjiagang Forest Farm, Heilongjiang Province, China. The geographical coordinates are 130°32’-130°52’E and 46°20’-46°30’N. The major tree species of this farm include Korean pine (*Pinus koraiensis*), Spruce (*Picea asperata*), Mongolian pine (*Pinus sylvestris*), and larch (*Larix olgensis*), which approximately account for 80% of the forest area.

2.2 Data

The airborne data were collected in 2017 by LiCHy airborne observation system (Pang et al., 2016). The canopy height model (CHM) was obtained from the LiDAR point cloud data with 1 m spatial resolution. The tree species map was obtained by classification of hyperspectral images, with an overall accuracy of 91.28% and Kappa of 0.88. (Li et al., 2018).

2.3 Methods

There are three main steps of the stand delineating method: (i) the 1 m resolution CHM was down-sampled to 5 m, filtered by Minimum Variance Filter and over-segmented to get large amounts of segments smaller than the forest stand size; (ii) the attributes of segments were calculated, including mean canopy height, canopy closure, dominant tree species, the proportion of dominant tree species and so on; (iii) Two rules (merging homogeneous segments and eliminating small segments) were used to merge segments toward final forest stands. The workflow was presented in Figure 1.

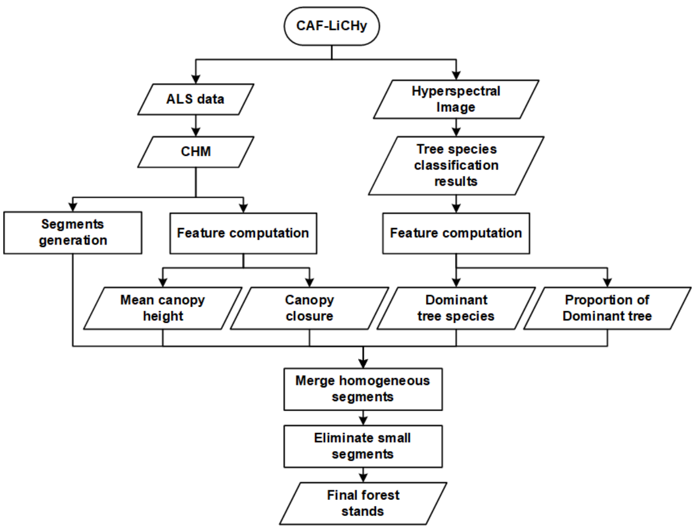

Figure 1: The flowchart of automatic delineation of forest stands based on CHM and tree species.

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.1985

To reduce the noise in homogeneous forest stands. The CHM was down-sampled to 3m, 5m, 7m, 10m respectively and filtered by several edge-remaining smoothing filters in different window sizes. Then the MVF filter was selected. The result was segmented by object-oriented multi-resolution segmentation with eCognition developer software.

Six attributes were derived from the CHM and the tree species map, which were mean tree height, canopy closure, dominant tree species, the proportion of dominant tree species, stand area, and length of common edge.

In the first merging step, a threshold of the maximum stand area was used to evaluate the sum of each segment and its neighbors. Then each pair of segments and neighbors would be judged whether they have the same dominant tree species, whether the difference of the two tree proportions was less than TP1 (Tree proportion threshold), the difference between their canopy closure was less than 0.2 and the difference between their CHM values was less than SH1 (Stand height threshold). The satisfactory segments were merged to their most suitable neighbors.

After that, there were still some segments that did not have any acceptable adjacent segment. A threshold value of minimum stand area was applied, and all of those smaller than the fixed threshold would be merged to one of their adjacent segments. Three attributes were used in this rule to ensure there was no repetition and no omission, including tree species, tree proportion, stand height, and length of common side.

The delineating results were verified in two ways for accuracy. The manual forest stands, the logging forest stands and the forest stands delineated based on DOM of 0.1 m spatial resolution were used as reference data. The intersection over union ratio (IoU) (Nowozin et al., 2014) was introduced to compare the overlapping between automatically delineated forest stands and reference forest stands. The explained variance of mean DBH, mean tree height and mean canopy height of 5 m×5 m cells were used to evaluate the homogeneity of each forest stand and the heterogeneity between different forest stands (Pukkala et al., 2019a, 2019b; Jia et al., 2020). The closer the interpretable variance is to 1, the higher the forest stands' consistency are and the greater the variability among different forest stands are.

3. Results and Discussion

The delineating results of different scales were shown in Figure 2. The final automatically delineated forest stands were compared with the manual forest stands in Figure 3. The proportions of the final forest stands with IoU greater than 0.7 were 24%, 48%, and 64% for manual, logging and DOM mapping forest stands and 41%, 67%, and 82% for automatic forest stands with IoU greater than 0.5, respectively. The explained variances of mean DBH and mean height of the final forest stands were 97% and 98%, the same as manual forest stands. Our method explained 81.8% of the variation in mean canopy height in 5 m×5 m cells, which was 7.31% higher than the manual forest stands, 2.31% higher than the multiresolution segmentation results.

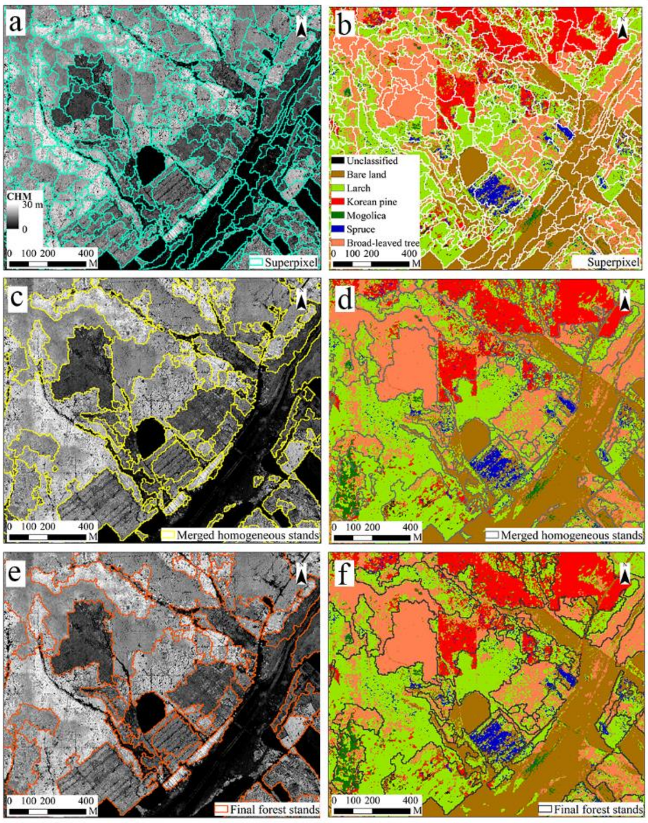

Figure 2: Segments, merged segments and final forest stands.

(a)Segments on CHM, (b)The merged segments on CHM, (c)The final forest stands on CHM, (d)Segments on tree species map, (e)The merged segments on tree species map (f) The final forest stands on tree species map.

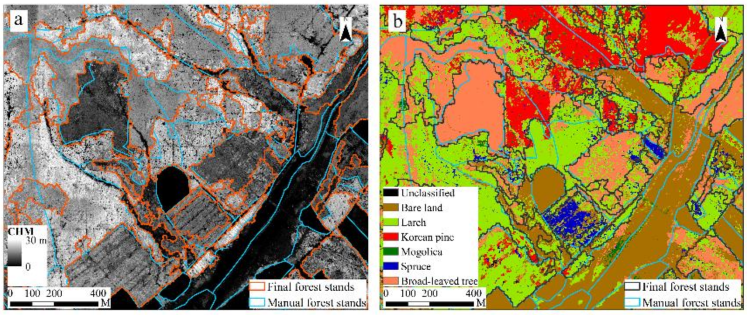

Figure 3: The final forest stands and manual forest stands.
(a)The final and manual forest stands on CHM, (b)The final and manual forest stands on tree species map.

4. Conclusions

It turned out that our results were generally similar to the manual forest stands. The forest stands automatically delineated by multiresolution segmentation method with CHM and tree species information derived from hyperspectral image have obvious advantages in terms of internal consistency, boundary accuracy and were more consistent with the distribution of trees at the boundaries. This method is timesaving and increases the accuracy of forest stand delineation, which can support fine forest management planning.

Acknowledgements

This study was supported by National Key Research and Development Program (2017YFD0600404 & 2020YFE0200800).

References

Dechesne, C., C. Mallet, A. Le Bris and V. Gouet-Brunet,2017, Semantic segmentation of forest stands of pure species combining airborne lidar data and very high resolution multispectral imagery. ISPRS Journal of Photogrammetry and Remote Sensing 126: 129-145.

Haara A, Haarala M, 2002, Tree species classification using semi-automatic delineation of trees on aerial images. Scandinavian Journal of Forest Research, 17(6): 556-565.

Koch, B., C. Straub, M. Dees, Y. Wang and H. Weinacker, 2009, "Airborne laser data for stand delineation and information extraction." International Journal Of Remote Sensing 30(4): 935-963.

Leppänen, V., T. Tokola, M. Maltamo, L. Mehtätalo, T. Pusa and J. Mustonen, 2008, Automatic delineation of forest stands from lidar data. GEOBIA: 05-08.

Li J, Pang Y, Li Z, et al. Tree Species Classification of Airborne Hyperspectral Image in Cloud Shadow Area, International Symposium of Space Optical Instrument and Application. Springer, Cham, 2018: 389-398.

Mora, B., M. A. Wulder and J. C. White, 2010, Segment-constrained regression tree estimation of forest stand height from very high spatial resolution panchromatic imagery over a boreal environment. Remote Sensing Of Environment 114(11): 2474-2484.

Mustonen, J., P. Packalen and A. Kangas, 2008, "Automatic segmentation of forest stands using a canopy height model and aerial photography." Scandinavian Journal of Forest Research 23(6): 534-545.

Pang Y, Li Z, Ju H, et al, 2016, LiCHy: The CAF's LiDAR, CCD and hyperspectral integrated airborne observation system[J]. Remote Sensing, 8(5): 398.

Pukkala, T., 2019a, Optimized cellular automaton for stand delineation. Journal of Forestry Research 30(1): 107-119.

Pukkala, T., 2019b, Using ALS raster data in forest planning. Journal of Forestry Research 30(5): 1581-1593.

Pukkala, T., 2020, Delineating forest stands from grid data. Forest Ecosystems 7(1): 1-14.

Wu, Z., V. Heikkinen, M. Hauta-Kasari, J. Parkkinen and T. Tokola, 2014, ALS data based forest stand delineation with a coarse-to-fine segmentation approach. 2014 7th International Congress on Image and Signal Processing, IEEE.

Wulder, M. A., J. C. White, G. J. Hay and G. Castilla, 2008, Towards automated segmentation of forest inventory polygons on high spatial resolution satellite imagery. Forestry Chronicle 84(2): 221-230.