LEAF AREA INDEX (LAI) ESTIMATION BASED ON VEHICLE-BASED LASER SCANNING

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1. INTRODUCTION

Canopy is essential for energy balancing and matter cycling through photosynthesis, respiration and transpiration, and knowledge of the relevant biophysical and biochemical properties can help to understand and improve these functions for better ecological environments. Leaf area index (LAI), defined as the one sided leaf area per unit ground area, serves as such a statistical parameter to characterize canopy architecture [1]. Besides various follow-up applications e.g. [2], how to accurately and efficiently measure LAI is another research hot-point [3-4], which has experienced a long exploration process but still not well solved up till now.

The point-quadrat technique [5], which is implemented by many-times insertions of the probe into the goal canopy, was first developed as an indirect approach of measuring LAI, notwithstanding laborious. The gap fraction based methods [6] become much labor-relaxed through e.g. a camera with a fish-eye lens, but the overlapping or clumped leaves usually lead to an underestimation of LAI. Then Lidar-based metrics [7-10] began to be employed on forest inventory. However, the current Lidars mostly can sample just several points/m^2 and receive only the first and last echoes, and so the fine structure especially the inner part of canopy is involved not enough. Terrestrial laser scanning (TLS) recently has been advanced as a promising means [10-11], e.g. the voxel-based canopy profiling (VCP) method [12], for accurate estimation of LAI, but this field-investigation mode is restricted in efficiency with the need of moving TLS apparatuses stand by stand.

Vehicle-based laser scanning (VLS) [13], developed quickly in recent several years with higher sampling density and flexible mobility, seems to be a well alternative settlement for this issue, but VLS-based LAI estimation has not been paid much attention. This paper strives to explore the feasibility of VLS for LAI derivation as the first try in this topic. Given the fact that TLS-based measurement has given a convincing result [12], the schematic of this study is to check whether the points of all crowns collected by VLS have a positive ratio with the related ones by TLS. If the layered distributions of sampling points within canopy keep in consistency further, VLS can be primarily validated as an efficient methodology for LAI estimation in fine scales. Moreover, TLS can supply the reference data of isolated trees to calibrate the estimated LAIs by VLS in practice.

2. MATERIALS

The data for numerical analysis was acquired with Sensei VLS system developed in Finnish Geodetic Institute (FGI) and Leica HDS6000 TLS system [14]. Sensei consists of a Faro LS 880 laser scanner with the sampling frequency of 120 kHz, and the scanner can operate in the multi-echoes mode of recording up to three returns per pulse. Based on the mechanism of phase-shift, HDS6000 has the fast scan rates up to 500,000 points per second with high precision.

The data was collected at the Espoolahti test site, Finland on May 6, June 8, and July 2, 2009, which correspond to different foliating phases. The point plots of 12 single trees were sampled by TLS and VLS synchronically and segmented out as e.g. in figure 1, and LAIs related with the two measurement means are derived separately.

3. METHODOLOGY

The planned schematic of VLS-based LAI estimation is to assume the voxelized space of sampling points as the presentation of leaves distribution, and the cumulative LAI (CLAI) from top to bottom is applied as the indicative variable for assessing the precision of derivation. These operations are deployed on VLS and TLS points to seek the correspondence, which can confirm the feasibility of VLS for LAI prediction with TLS results as an effective intermediate bridge.

The multi-factor based uniformization needs to be executed firstly before the statistical comparison, since VLS and TLS scannings have too many differences in mechanism. Various parameters, e.g. scanning interval, ranging distance, mean leaf inclination, foliage density and tree category, all will impact the final results about the mutual relevance. The associated CLAIs can be modified by adding the unifying coefficients individually to the layered numbers counted from the 3-D voxel models, and then the relationship between leaf areas retrieved by VLS and TLS can be figured out by statistics.

The multi-echo specialty of Sensei VLS system acts as another fundamental element to improve the accuracy of LAI prediction, as this function may supply the relatively redundant leaf information. If the number relating with only the first or the first and second echoes received by VLS has a positive ratio with the results yielded by TLS, LAI estimated by VLS can be closer to the real situation by accounting for the third echoes. This is an advantage of Sensei VLS system with the capability of capturing multi-echoes per pulse.

4. CONCLUSION

The experimental results demonstrate that there is a positive relationship between the number of VLS and VLS sampling points from the same crowns. The work in this paper basically validate that VLS can be applied for LAI estimation with high accuracy and efficiency, although there are still many inner factors needed to be modified or unified.

5. REFERENCES

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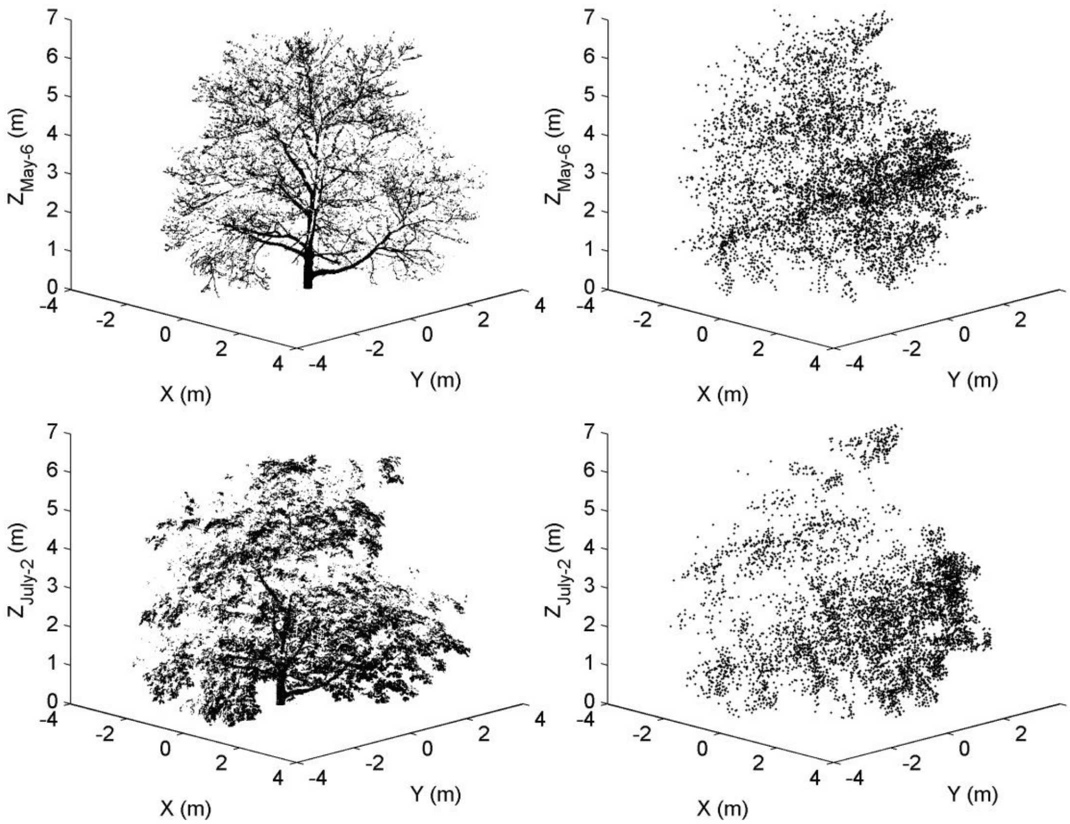

Fig. 1. Illustrations of SPMs of the same crown sampled by VLS and TLS on May 6 and July 2, 2009. The reflection degree of crowns during different foliation phases can be compared explicitly.

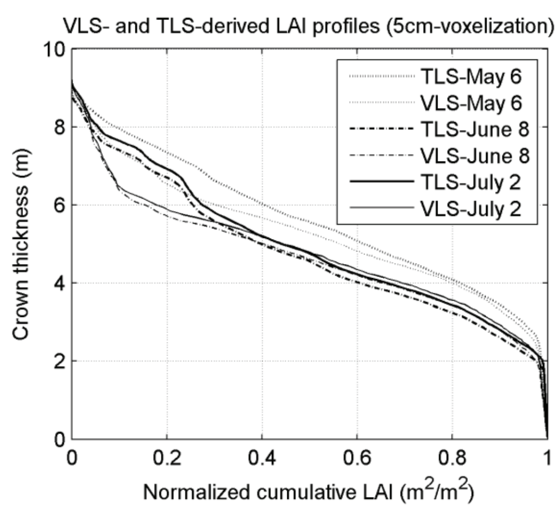

Fig. 2. CLAI correspondence between VLS and TLS samplings for different sampling time.