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Integrating Mobile Laser Scanner System and Unmanned Aerial Vehicle to Measure Tree Characteristics

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Abstract

Forest resource inventories corresponded with models according to the purpose of survey equipment and management. With the advancement of science and technology, manual survey mode can be changed into a survey mode of high technology equipment. In this paper, the practical operation is used to explore the application of Handheld Mobile Laser Scanning (HMLS) and Unmanned Aerial Vehicle (UAV) in forest resource inventories. Further, we use Terrestrial Laser Scanning (TLS) as the valid data to compare the accuracy. With advantage of handheld mobile laser scanners (HMLS) and UAV, we discuss with estimating limitations and potentials of forest plot surveys. Using TLS data as ground true data, we combine the HMLS point cloud and UAV point cloud data to estimate the tree height of 43 trees. As One-way ANOVA results displayed, the tree height results between HMLS (11.8±2.1 m) and TLS (15.9±3.2 m) has significant differences ($P<0.01$), but after we combined the UAV point cloud and HMLS point cloud, the results shows no differences ($P>0.05$) with combined point cloud data (16.7±3.7 m) and TLS (15.9±3.2 m) point cloud data. For the TLS method, it has much more limitations for our investigation in Taiwan including time consuming and few conveniences. Combined point cloud data has more flexible procedure with high accuracy instead of time-consuming TLS method.

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High accuracy of forest inventories often supplies important information for forest management decisions. The accuracy of a forest inventory is determined by the forest sampling design, measurement and data analyzing. Whereas, when the forest decision-makers try to use the forest information for planning, having dilemmas about the allocations of funds, manpower, space and time are inevitable. In general experience of carrying out forest inventories, there were specific models limited by instruments and management purposes. With the progress of science and technology, the labor-intensive mode of traditional inventory has now been transformed into the high-tech mode by the use of new instruments. The purpose of this study is to investigate the application, advantages, limitations, and potential of Terrestrial Laser Scanning system (TLS) and Unmanned Aerial Vehicles (UAV) in forest plot areas. According to the one-way variation analysis and 1:1 linear regression analysis shows that the average diameter at breast height (DBH) of sample plots is no significant difference between HMLS and TLS and show a highly positive correlation with the coefficient of determination (R^2=0.98). The integration the point clouds of HMLS and UAV and to use it to estimate the tree height that shows the average height of the stand is no significant difference between HMLS+UAS and TLS and shows highly positive correlation with the coefficient of determination (R^2=0.93).

Keyword: Laser Scanning system, Unmanned Aerial Vehicle, Point Cloud Data Merging

Introduction

Light Detection and Ranging, as known as Lidar, has many advantages including penetrable, multi-echoes and high accuracy. With different platforms and functions, it can retrieve different types of 3 dimension point cloud data. Using Lidar technology in forest field is well-known as an new technology for forest resources monitoring and surveying. It developed rapidly and make the measurement more objective, high level accuracy and the data can be examined exactly amount that tree grows.
although Tripod Laser scanning system shows with high accuracy. In situation of complicated terrain, not suitable as the forest survey in mountain area. It needs more tools and human resources to complete the scanning procedures. Recently, using Hand-held Mobile Laser Scanner (HMLS) is a new conception for laser scanning. It needs less tools and human resources to complete the procedures. According to the characteristics of HMLS, it makes less occlusion because it can scan every angles for our research. But its limitation is that scanning distance will be fewer than Tripod Lidar(lower than 6 meters).
In last decade, the technology of Unmanned Aerial Vehicle (UAV), both in hardware and software has rapidly developed and cost down to consumer level. In software, the mosaic techniques and the interpolation method of point cloud already has lots of development and researches. They shows that UAV techniques can be used in forest measurement, especially from tree above side. The point cloud data, interpolation from UAV, can blend with HMLS point cloud data by ground control point. This breakthrough provide a whole new conception for tree volume estimation. In order to acquire data from forest land, for instance 4th National Forest Inventory (NFI), these two high efficiency equipment provide a new chance to store data. With characteristics for point cloud examination, the point cloud data can be examined and storage. This is a new conception for NFI because NFI is implemented in Taiwan 15 years each period. We need to check the possibility and credibility in measuring tree characteristics by combining HMLS and UAV point cloud data. Therefore, our aim is assessing the accuracy for integrating HMLS and UAV point cloud data. It will be helpful

Material and Method

As importance of 大葉桃花心木, when the government noticed the commercial characteristics, it is a well-known and popular species for public forest and private forest. We choose 大葉桃花心木 as our study target tree species with plantation built by Taiwan Sugar Corporation in Chaozou, Pingtung. We use TLS data as ground

true data for plantations including DBH and tree height. However, HMLS is known that height measurement is limited due to the hardware. Therefore, we integrate UAV point cloud data and HMLS point cloud data with Real Time Kinematic Global Position System (RTK GPS). We literally combined two types of point cloud data to make up the HMLS tree height limitation issue. We compare the differences between TLS point cloud data and HMLS+UAV point cloud data to assess the possibility and credibility in measuring tree characteristics. We do the correlation analysis and one-way ANOVA analysis to assess the relationship and differences between two types of point cloud data.

Results and Discussions

We use HMLS scanning data and TLS scanning data to measure DBH and tree height by 366 samples of trees. Through pair T-test correlation analysis results, we can see the relationship between two types data of DBH and tree height. The results shows in figure 1.

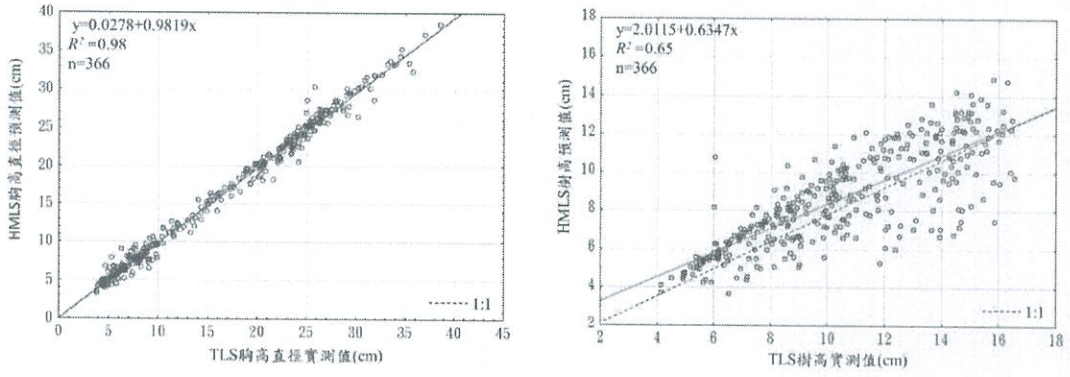

Figure 1. Correlation between HMLS and TLS data (left: DBH, right: tree height)

Table 1. Regression results between HMLS and TLS in DBH and tree height

Characteristics	n	R	R^2	RMSE
DBH(cm)	366	0.99	0.98	0.97
Tree height(m)	366	0.80	0.65	2.59

Table 2. Results of different methods to retrieve tree height

Methods	Average (m)	Minimum (m)	Maximum (m)	Standard Deviation(m)
TLS	10.36 [a]	4.13	16.46	3.20
HMLS*	8.53 [b]	3.70	14.90	2.51
HMLS+UAV	10.48 [a]	3.84	16.65	3.28

*represent $p<0.05$ significant differences

Krause *et al.*(2019) results demonstrated that the UAV point cloud tree height can be displayed tree height with RMSE = 0.47 m. That means UAV point cloud data is suitable and reliable for retrieving tree height with high accuracy.

This research result correspond to Giannetti *et al.*(2018) that R^2 increase obviously by conducting UAV point cloud data to retrieve the tree height instead using HMLS point cloud data only.

Conclusion

Integrating HMLS and UAV point cloud data is suitable and reliable for retrieving tree characteristics especially tree height. This new conception improve the tree height measurement of plantation measurement. It helps massively to the timber volume estimation method.

References

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