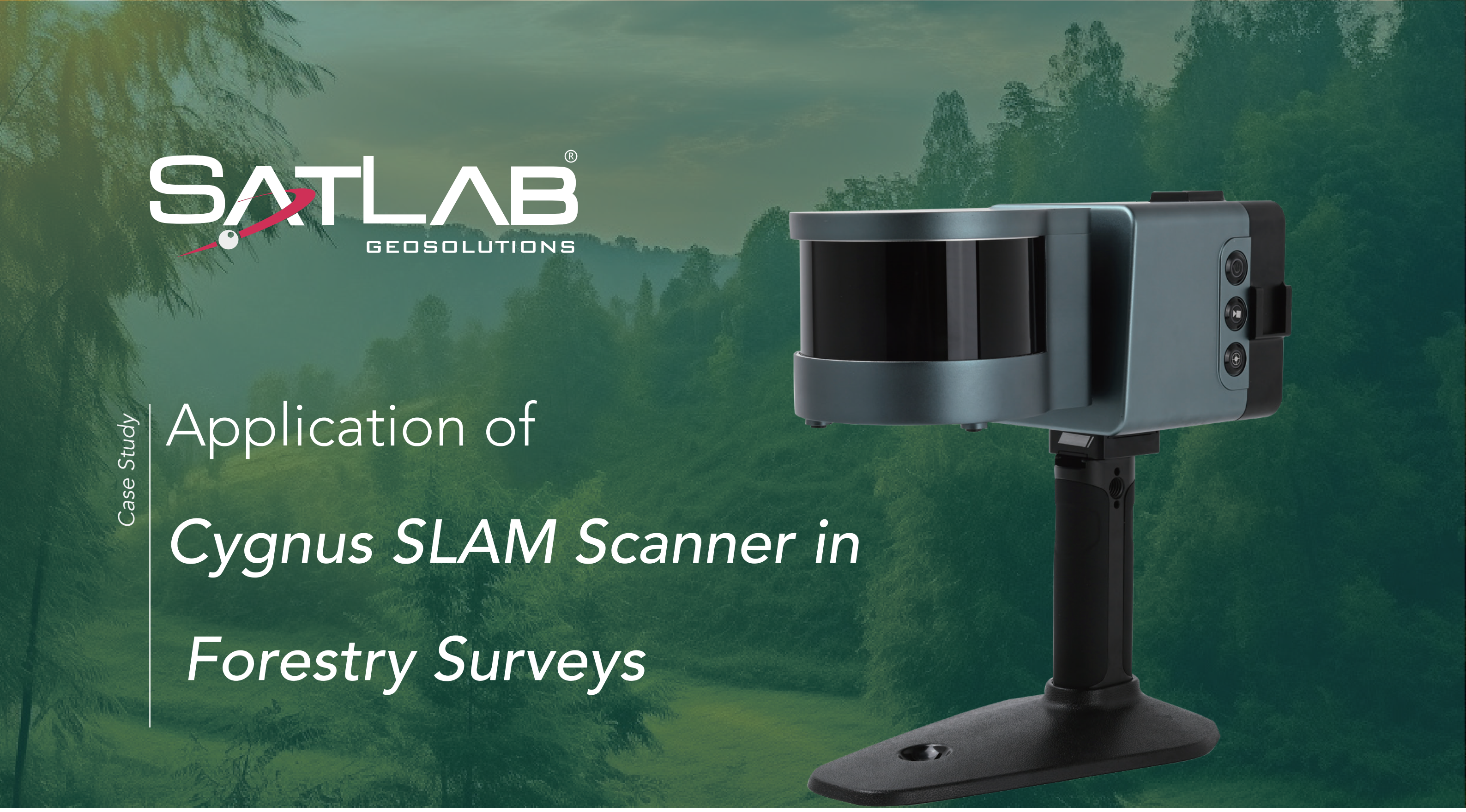


Case Study

Application of *Cygnus SLAM Scanner in Forestry Surveys*

Project Background

Point clouds reflect the positional relationship of target objects in three-dimensional space and are one of the important data forms for extracting forest resource information.

With the deepening of forest resource survey, the spatial information acquisition method based on single platform lidar data has the shortcomings of low accuracy and poor data integrity, which cannot meet the requirements of precision forestry for high accuracy of forest information extraction.

Solution overview

Based on the preliminary survey of forest area, we choose a low-cost UAV LiDAR and mobile SLAM system as a solution for collecting the more complete tree information through the fusion of air and ground data.

In order to merge the data, mobile SLAM system we select the Cygnus backpack system with RTK. Due to the poor local network signal, our backpack SLAM RTK share the same base station with drone LiDAR system, the communication is connected through external radio station mode.

The two methods are collected at the same time. The drone captures the area about 11 minutes, and the backpack SLAM scanning including 2 scans and one scan takes 30 minutes. The scanning trajectory of mobile SLAM adopts a snake-shaped trajectory around the tree, and the scanning gap not exceed 10m according to the terrain conditions. For the problem that RTK cannot be fixed due to tree occlusion from time to time, we try to repeat the scan as much as possible in the case of fixed RTK to increase the constraints of fixed RTK observations on the SLAM trajectory.

Comparison of multi-platform LiDAR systems

Due to the complex forest environment and dense occlusion, the operation of a single LiDAR platform is limited, and the scanning range cannot cover the entire forest area, resulting in a data hole in spatial information acquisition, making it difficult to apply in complex forest areas. To obtain more detailed forest point clouds, the combination of LiDAR platforms is usually used.

LIDAR Plaform	Pros	Cons
Terrestrial Laser scanning	Data accuracy can reach milimeter level	Small scanning area Low measurement efficiency Easily obstructed by trees and other ground objects
Airborne Laser scanning & UAV Laser scanning	Capable of scanning the ultra large area and high-resolution with single operation. & High collection efficiency Relatively simple workflow	The initial cost is expensive The operation is difficult In sufficient scanning ability for the lower canopy layer The frequency of operation is limited by weather and cost & The accuracy of data collection below the canopy is low The stability of the equipment is extremely high
Mobile SLAM Laser scanning	Single tree acquisition speed is fast High accuracy path plannig is flexible Good Data integrity	Low efficiency of large-scale collection
Mobile Mapping system (Vehicle mounted)	Flexible and efficient data acquisition	Driving trajectory and scanning angle are limited by terrain The equipment cost is relatively expensive

Chart1 Comparison of advantages and disadvantages of 3D LiDAR systems

UAV LiDAR data

For the UAV LiDAR system, we use the SatLab S1 UAV LiDAR, which can collect the point cloud and image data in the same time. After processing the RINEX data, we import the GNSS, IMU, laser and image data into SatLiDAR software for one-click data combing and export the final color point cloud (*.las file).

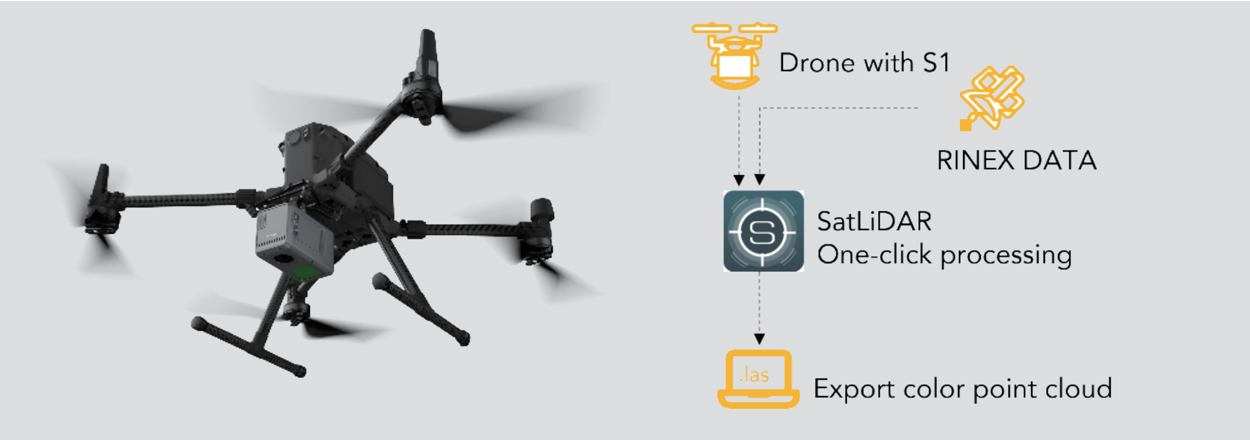


Figure 1 SatLab S1 UAV LiDAR Workflow

The drone has a flight time of about 11 minutes, the point cloud density is 508.79 pts/m2. The UAV LiDAR point cloud and cross section are shown as followed. Missing data can be seen below the canopy.

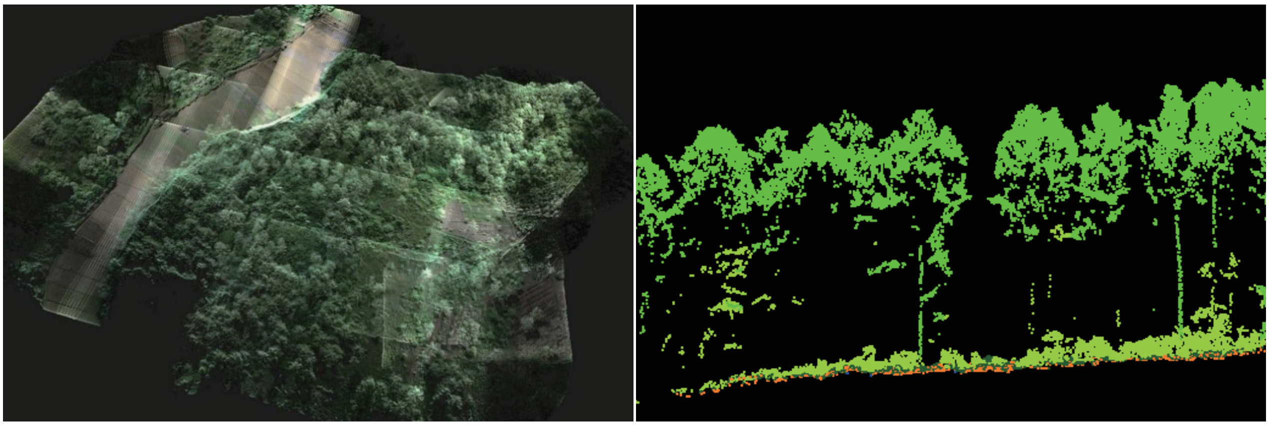


Figure 2 UAV LiDAR Point Cloud

Backpack SLAM data

The SatLab Cygnus backpack SLAM system can be seen on Figure 2, the output SLAM data can be transformed to local coordinate for georeferencing. The SLAM point cloud is shown in figure 10. The point cloud density is around 2539.59 pts/m2.

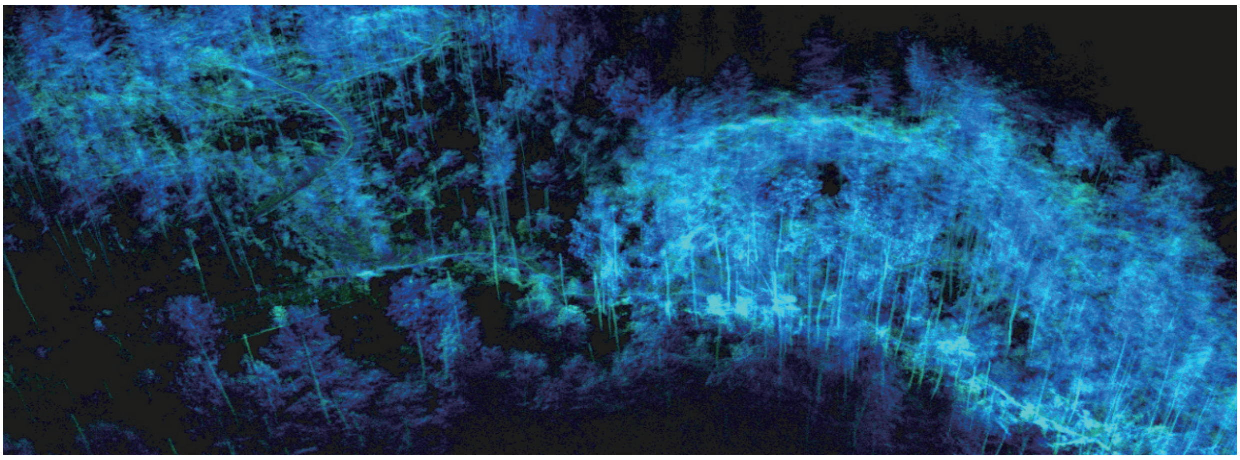
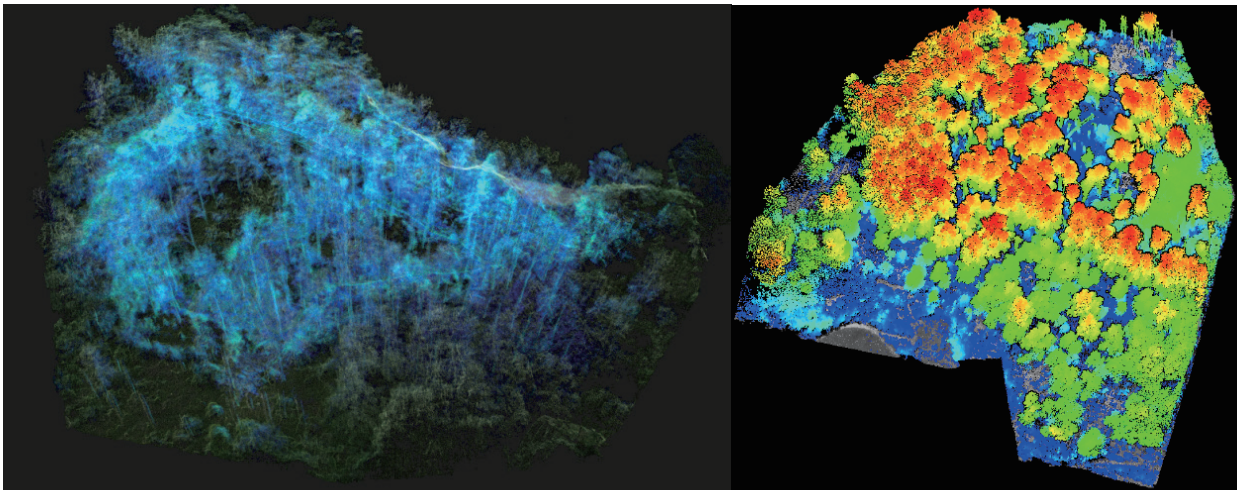


Figure 3 SLAM Point Cloud

Data fusion and Processing

We put the UAV LiDAR point cloud and the SLAM point cloud into same coordinate system and segment the interesting area to extract the forest information. The fusion of UAV LiDAR point cloud and SLAM point cloud and the cross section of the fusion data are shown in figure 11. The combination of the two methods shows the complete structure of the tree. The fusion point cloud density is 4701.48 pts/m2.



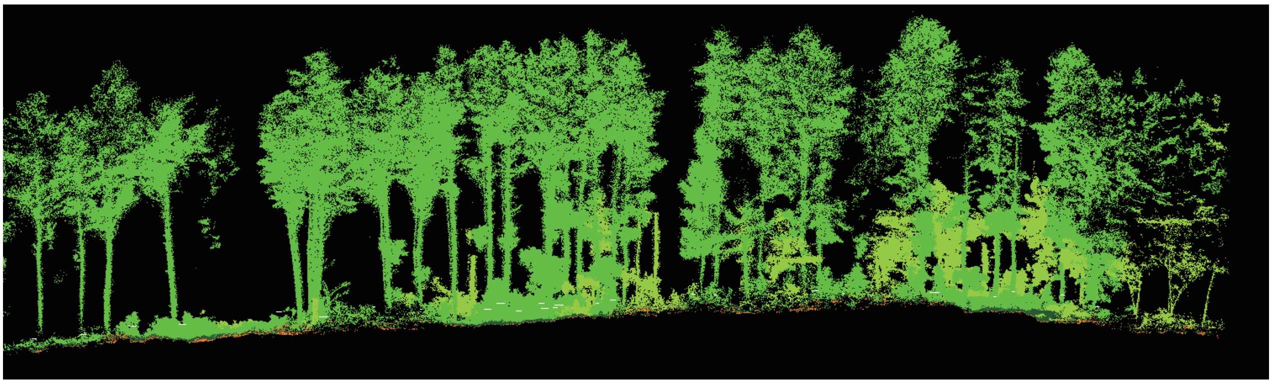


Figure 4 Fusion Point Cloud

Considering that massive point cloud processing consumes a large amount of computing resources, we divided the fusion point cloud into blocks and through resampling and denoising to get the relatively clean data. And then we use the cloth simulation filter (CSF) and progressive TIN densification (PTD) as ground filtering to classify ground point cloud. Based on the ground point, we generate DEM. After calculating the point cloud normalization, we use single tree segmentation algorithm to classify tree point cloud. And some trees that were segmented wrong can be manually edited.

According to the result of segmentation, we can extract the tree species, position, tree height, diameter at breast height (DBH), etc. of a single tree. And the vector of the tree structure can be generated as well.

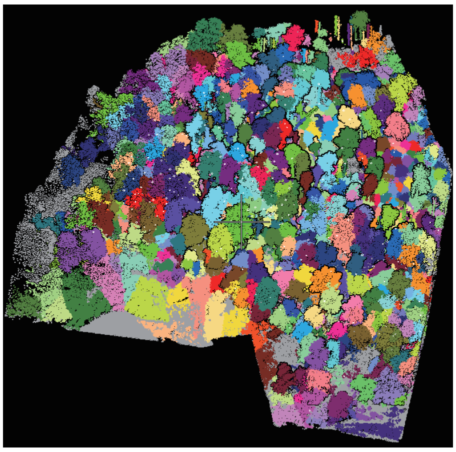


Figure 5 Tree segmentation result

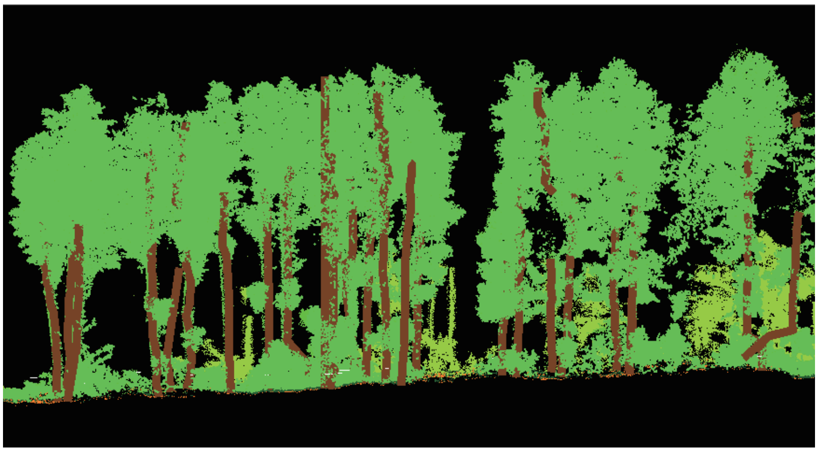


Figure 6 Tree vectorization result

Easting	Northing	Ground Z	Distance	Canopy width	Trunk diameter
783175.628	9263570.610	567.532	28.236	14.9	0.41
783156.025	9263570.682	567.413	24.182	16.7	0.71
783168.303	9263584.470	569.347	27.641	12.7	0.77
783173.802	9263568.904	567.176	26.434	12.3	0.34
783153.933	9263575.362	567.606	25.241	16.2	0.50
783165.675	9263581.158	569.220	27.723	10.3	0.49
783156.900	9263582.753	569.297	18.668	11.3	0.31
783153.355	9263573.509	567.426	23.268	23.4	0.53
783169.185	9263586.058	569.415	25.357	11.0	0.49
783168.941	9263593.036	570.674	23.726	12.7	0.57
783175.844	9263592.281	571.361	23.179	6.1	0.41
783183.615	9263594.130	570.987	28.864	12.3	0.82
783186.107	9263607.230	571.505	25.859	17.5	0.68
783173.265	9263586.678	569.663	27.300	9.2	0.57

Figure 7 Tree information extraction results

Conclusion

Through the combination of the UAV LiDAR and the various data obtained by the mobile SLAM scanner in the forest area, it is possible to quickly obtain high-precision forest vertical structure, and to extract the parameters of the single tree structure of the sample plot more accurately and efficiently.

Compared with traditional survey methods, it significantly reduces labor intensity and costs, enriches data types, and improves monitoring quality. At the same time, it is necessary to reasonably plan the scanning path when using platforms such as ULS (UAV Laser Scanning) and BLS (backpack Laser Scanning) to improve the efficiency and integrity of data collection and increase the possibility of obtaining large-scale forest information in less time.

This new application of ground-to-air LiDAR data fusion, has strong practical significance.