A STUDY ON MULTI-POINT OBSERVATION METHOD USING GROUND BASED LASER SCANNING FOR DETECTING FOREST STRUCTURES

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ABSTRACT:

Remote sensing technology that uses the observation from satellite sensor is necessary for the global estimation of forest biomass. However, a wide range of ground based measurements (e.g., diameter at breast height (DBH), crown height, crown width, tree height) is required for the algorithm development and verification of satellite based estimation of biomass. These ground based measurements are time consuming, laborious and costly as well. Ground based laser scanning method which can provide various measurements and structural analysis of the forest can be an alternative method to traditional ground based measurements. However, some problems exist on ground based laser scanner. For example, it is impossible to estimate the shape of invisible tree where ground based laser cannot reach. In this case, high density laser scanned data can be acquired by overlapping the scanning data by measuring from multi-observational points. As a result, the problem of invisible area in the forest could be solved. However, it is also problem to take more observation points than the optimum observational points because the requirements of labor, time increase with the increase in observational points. Therefore, this study aims to optimize the multi observation points of the ground based laser scanning system in a forest. The meaning of optimization is to sufficiently observe the targeted area without any invisible area with the lowest possible observation points. In this idea of optimization, arrangement of observational points which can overlap the observed area by reducing the invisible are is important. This paper presents the method and result of overlapping the laser scanning area with optimization of multi observation points.

1. INTRODUCTION

Remote sensing technology that uses the observation from satellite sensor is necessary for the global estimation of forest biomass. However, a wide range of ground based measurements (e.g., diameter at breast height (DBH), crown height, crown width, tree height) is required for the algorithm development and verification of satellite based estimation of biomass. These ground based measurements are time consuming, laborious and costly as well. Ground based laser scanning method which can provide various measurements and structural analysis of the forest can be an alternative method to traditional ground based measurements. For example, diameter at breast height (DBH) and tree position has been measured using ground based laser scanner so far (Yone, 2008). However, some problems exist on ground based laser scanner. For example, it is impossible to estimate the shape of invisible tree where ground based laser cannot reach. In this case, high density laser scanned data can be acquired by overlapping the scanning data by measuring from multi-observational points. As a result, the problem of invisible area in the forest could be solved. However, again the time, labor, and cost increase because of larger observation points. Therefore, it is necessary to optimize the observation points. To solve this problem, this study applies a cylinder target within a range of observation area in order to verify and match the overlapping of the scanned area. Thus, the scanned data can be overlapped by scanning a common cylinder acquired with multi-observation points. Therefore, the scanning of the invisible area within target area could be acquired by least possible observation points. This paper presents the methods and results of overlapping the scanning area with optimization of multi observation points.

2. METHODS AND MEASUREMENTS

Three dimensional data of forest structure was acquired by the laser scanner measuring from multi observational points. Measurement method and standard cylindrical target area have been shown in Figure 1 and Figure 2 respectively.

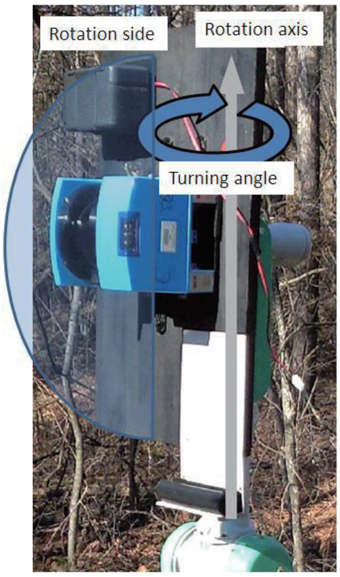

Figure 1. Measurement method using laser scanner

Figure 2. Standard cylindrical cylinder

In this study, three dimensional laser data were acquired by laser scanner (LMS- 200) and robotic arm (PA-10), which was used to move the laser scanner at 360º. It is necessary to rotate the scanner at the equi-angular speed in order to obtain three dimension data of the forest because the scanner used in this study can scan the area within 180° by one measurement. As shown in Figure 1, three dimensional information of the surrounding area was acquired by rotating laser scanner at 360° around a perpendicular axis of the robotic arm.

The measurement data were acquired by the following methods. A standard target of cylindrical cylinder of 15 cm in diameter (Figure 2) was arranged from all the observation points within a visible area. A standard target was used in the invisible area in an earlier study during measured by wide range laser scanner though the sphere was used (Watanabe et al., 2009). For such reasons, a center axis was assumed with the straight line cylinder even it was interrupted partially by tree. Therefore, a cylinder can be used as a standard target.

The measurement data was overlapped by using a standard target in every observation points. It is necessary to arrange a standard target at the position in which the measurement data that can be acquired by calculating a center axis of the cylinder from multi-observation points. To establish the position of standard target, the range that can be arranged was worked out by calculating the spot diameter and spot interval of the laser scanner used. In this experiment, a standard target common to the distance where the spot diameter is able to measure five line standard targets were arranged. Measurement was done by using two measurement points and the overlapping method by using cylinder was examined (Figure 3). The experimental location was in Yachimata city, Chiba prefecture, Japan (Figure 4).

In order to overlap three dimensional data of two observation points acquired the method of the geometric transformation was used by calculating the reference point. The straight line type of a center axis in each observation point was calculated from the range of cylinder data acquired from different observation point. The calculation method requests the straight line type by dividing the cylinder as shown in the diagrammatic illustration in Figure 5 for a center point of the cylinder. In addition, the inclination of the reference line in each observation point was calculated from the requested straight line type.

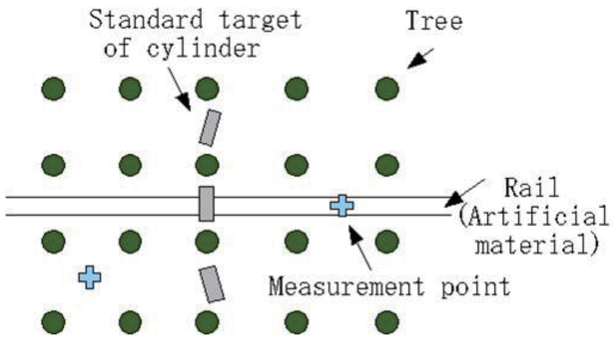

Figure 3. Observation place outline chart

Figure 4. Experimental location scenery

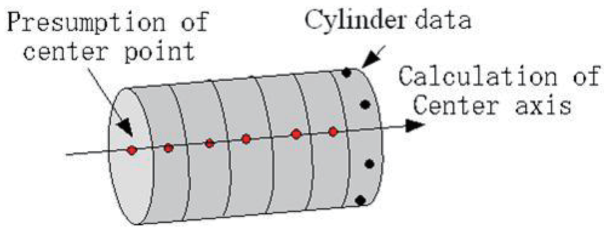

Figure 5. The diagrammatic illustration of the calculation method

The difference of x, y, and z coordinates from a center point of the requested cylinder by other observation points were obtained. Thus, the target area was overlapped by using the difference between these requested inclinations and x, y, and z coordinates of the conversion type. In this experiment, the laser scanner was horizontally arranged with a spirit level. Therefore, it was assumed that robotic arm had horizontal rotation and overlapping.

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & -\sin\omega \\ 0 & \sin\omega & \cos\omega \end{pmatrix} \begin{pmatrix} \cos\varphi & 0 & \sin\varphi \\ 0 & 1 & 0 \\ -\sin\varphi & 0 & \cos\varphi \end{pmatrix} \begin{pmatrix} \cos\kappa & -\sin\kappa & 0 \\ \sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} u \\ v \\ w \end{pmatrix} + \begin{pmatrix} x_0 \\ y_0 \\ z_0 \end{pmatrix}$$

(X,Y,Z) : Coodinate value after it converts it
(u,v,w) : Coodinate value before it converts it
(ω,φ,κ) : ω is rotation of X axis. φ is rotation of Y axis. κ is rotation of Z axis
(x_0,y_0,z_0) : Parallel movement element

3. RESULTS AND DISCUSSIONS

As for the arrangement of the observation point, the tree was placed at equal intervals like the lattice in this experimental location. It is like the case where this lattice stand chart is presumed from the measurement data of the multi observation point. In that case, the factor of the error margin is examined by presuming positional coordinates from the outcome of an experiment. Demonstration of an observation point and the result of overlapping have been shown in Figure 6 and Figure 7. From these, overlapping method was evaluated.

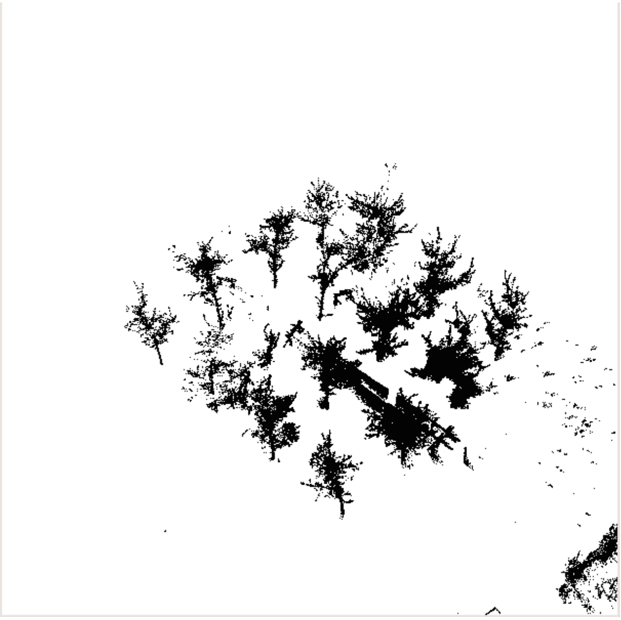

Figure 6. Result of one observation point

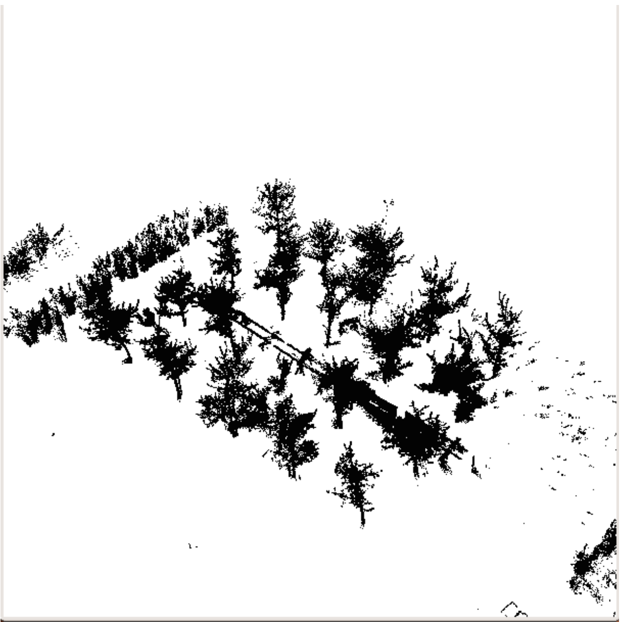

Figure 7. Result of overlapping

The evaluation method requests the difference of center coordinates of the tree that can be presumed together by each observation point. Result has been shown in Figure 8. The generation factor of the error margin was considered from these results.

As shown in Figure 8, the error margin was caused by the inclination of the straight line due to overlapping because the error margin was increased by the distance from the observation point. Therefore, the presumption accuracy of the reference point and the reference line greatly influences the occurring error margin. However, ±1.5 cm error was caused in the measurement by scanner. This error was caused because of the presumption of the reference point. Therefore, the error margin of ±1.431 degrees was caused in the angle of the reference line. Additionally, the error of the parallel movement element influences the error margin. The error margin was caused from these two elements. Therefore, it is necessary to presume the reference point more accurately according to the demand accuracy. For that, the use of the cylinder and other standard targets is important.

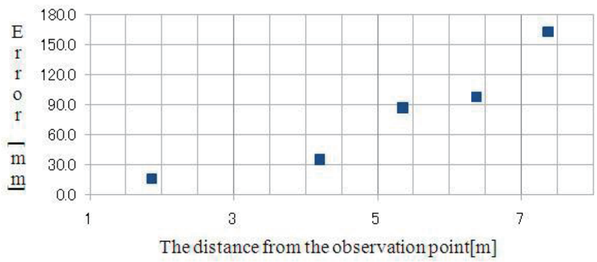

Figure 8. Error evaluation in overlapping

4. CONCLUSION AND FUTURE TASKS

There was a problem that a wide-ranging tree was not able to be presumed because there was an invisibility area where the laser scanner did not reach in one observation point measurement of the research so far. To solve this problem, the methodology by overlapping the measurement data from the multi-observation points was shown. Even if a standard target can measure only a portion of area by using a standard target of the cylinder, the reference point and the reference line can be calculated.

Therefore, overlapping could be possible and the measurement of wide-ranging tree became possible. However, it is necessary to presume an accurate reference point and the reference line for overlapping. As future tasks, it is necessary to improve the method because the calculation result of the reference point used may exert a big influence on accuracy in the cylinder target. As the solution, it is thought that the reference point can be calculated more accurately by arranging other shapes than cylinder at the same time and using the location information. It is necessary to investigate whether the spot diameter and the measurement frequency change the presumption accuracy. Additionally, more study on the arrangement of cylinders and appropriate measurement by laser scanner is necessary. It is also thought that the arrangement of the best standard target in a wide-ranging observation can be examined.

References

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