A Study on Measurement of Street Trees Using Mobile Mapping System to Acquire 360-degree Image

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Abstract: We examined a method to evaluate street trees using mobile mapping system (MMS) which can acquire 360-degree image to analyze three dimensional position data. We measured tree heights and diameters at breast heights (DBHs) by using MMS and by field survey. As a result, the root mean square error (RMSE) of tree height and DBH were, on average, 1.07m and 0.033m, respectively. Although MMS is not equipped with a laser scanner, RMSE of DBH was comparable with the result of previous study. The heights were underestimated where the trees' canopies covered the sky which resulted in large RMSE of the height.

Keywords: mobile mapping system (MMS), 360-degree image, tree height, diameter at breast height (DBH), Suginami Ward

1. Introduction

The evaluation of the state of green in urban area is an important issue. Urban greens reduce air pollution and the effects of heat island, retain local ecosystems and biodiversity, and moreover form a landscape and environmental awareness of the residents. In Tokyo, a survey called "survey on the actual status of green" is made by the wards and the cities about every five years. In such survey, mainly two kinds of way, i.e., field survey and interpretation of aerial photograph are used. The former way is suitable to grasp the detailed status of green, however it takes a lot of time and cost. The latter way can grasp wide range of green easily, however it is hard to know the status of each tree.

Therefore, we considered to use mobile mapping system (MMS) to grasp green efficiently from the ground. MMS is a system which can acquire various geospatial information by mounted sensors on vehicles. Jaakkola et al. (2010) and Holopainen et al. (2011), for example, examined a measurement of trees using MMS which was equipped with a laser scanner. However, another method is available to estimate three-dimensional (3D) position using MMS; using cameras in place of the laser scanner. We can measure 3D position of the objects visually while looking at the image in the method. We tried to measure tree heights and diameter at breast heights (DBHs) of street trees using the MMS which acquire 360-degree image.

2. Methods

We selected Suginami Ward, Tokyo as the study area (Fig. 1). The region has a lot of street trees, especially Nakasugi-dori Avenue is famous for the large-scale zelkova trees. We selected four sections of streets in the area (A - D in Fig. 1).

In this study, we used MMS named "IP-S2 Lite", which is made by TOPCON CORPORATION (Fig. 2). The system equips six cameras, GNSS (Global Navigation Satellite System) and main unit with IMU (inertial measurement unit) on the carrier of car. It takes 16 shots of 360-degree photographs per second

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while driving.

We made field surveys using the MMS three times, on December 20, 2013, on April 11, 2014, and on July 17, 2014, to get the data while driving on the road. From the acquired image, we estimated the 3D position information by extracting and calculating feature points (Camera Vectors) in the image. After the process, we measured tree heights and DBHs of 107 trees in total. We also measured tree heights and DBHs of the same trees as a reference data with a portable laser rangefinder (TruPulse 360) and a caliper gauge, respectively. The reference data and the measurement by MMS were compared by calculating root mean square error (RMSE).

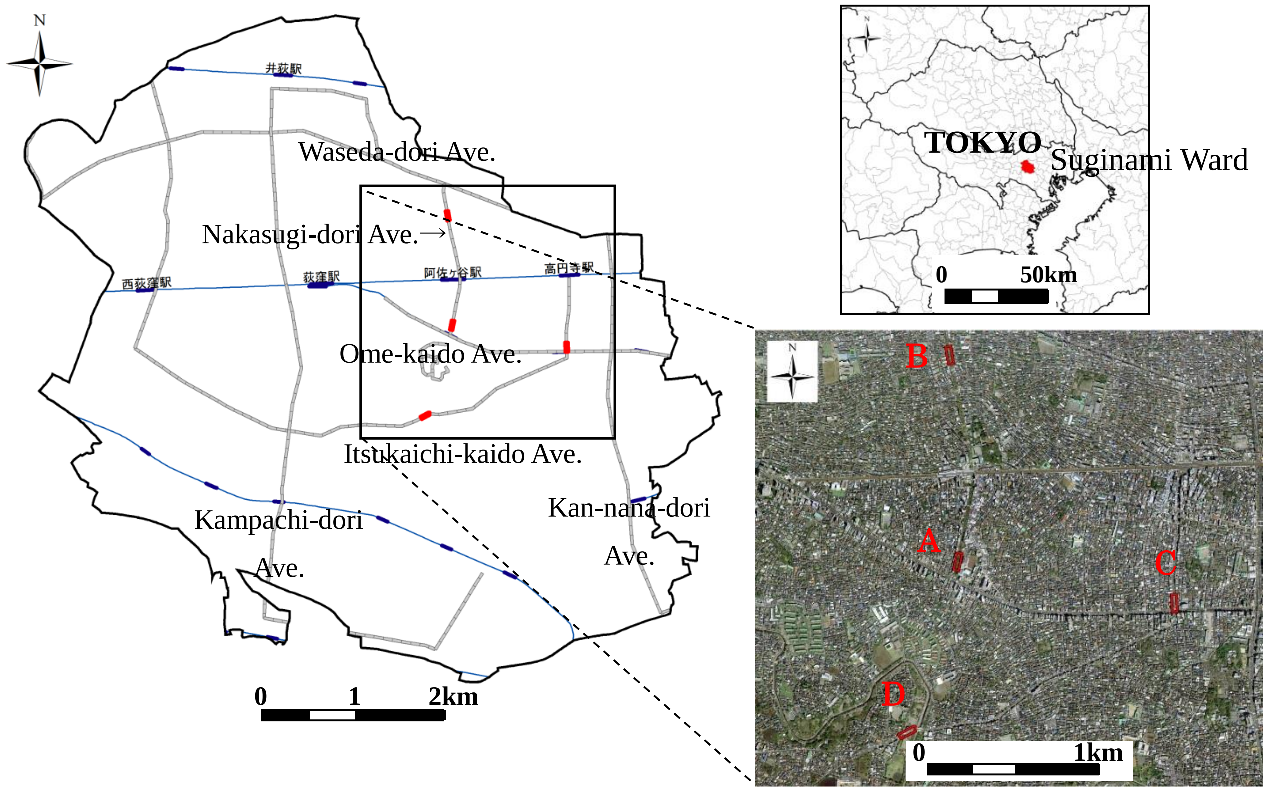


Fig. 1 Study area and sections of streets

A: Nakasugi-dori (south), B: Nakasugi-dori (north), C: Street in front of Koenji Sta., D: Itsukaichi-kaido

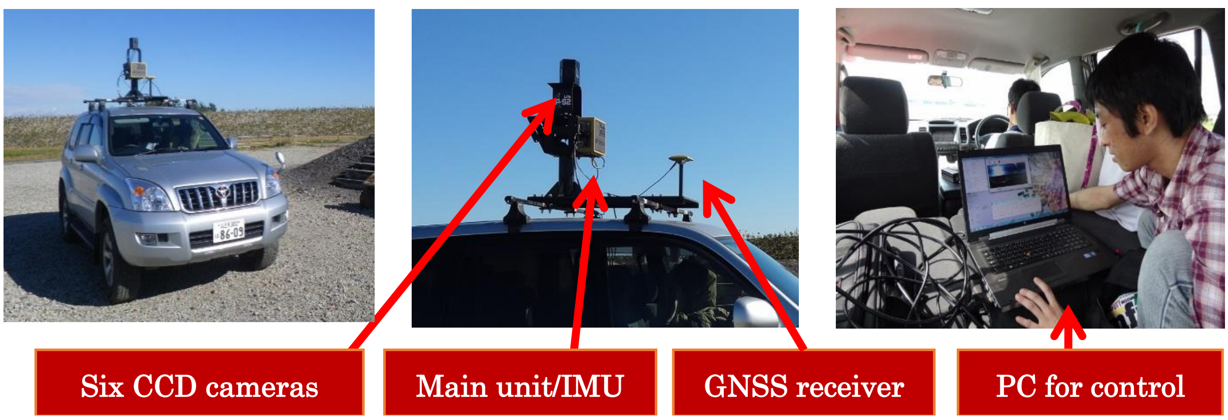
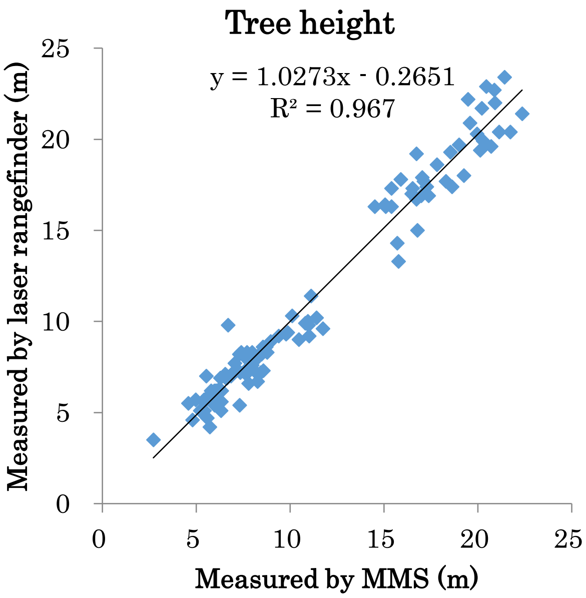


Fig. 2 Overview of the MMS used in this study

3. Results

The results of measurements were shown in Fig. 3 and Table 1. At the mean value of all trees, the difference (MMS- laser rangefinder) for tree height was -0.042m. Measurements of MMS was underestimation of 4cm. The RMSE of tree height was 1.07m. For DBH, the difference was +0.003m, i.e. overestimation of 3mm. The RMSE of DBH was 0.033m.



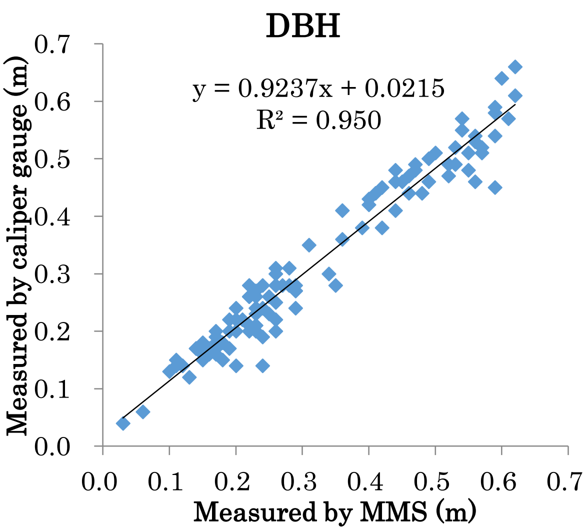


Fig. 3 Scatter diagram of measurements of tree height (upper) and DBH (lower)

Table 1 Measurements of street trees (unit: meters)

	Tree height	DBH
Mean (laser rangefinder and caliper gauge)	11.269	0.319
Mean (MMS)	11.227	0.322
Difference	-0.042	0.003
RMSE	1.067	0.033

4. Discussion

In the previous study (Holopainen et al., 2011), RMSE of DBH was 2.8cm. It was measured by MMS equipped with a laser scanner. Therefore, the measurement of this study has a comparable accuracy, considering the MMS is not equipped with a laser scanner.

Further, the measurements classified by size were shown in Table 2. Looking at the RMSEs of tree height, “less than 10m” is 0.771m, “10-20m” is 1.187m, and “over 20m” is 1.637m. We find a tendency that the error becomes larger as the height increases. A possible explanation is that, as the height gets taller, the error of each method increases because it becomes more difficult to look through the top of the tree. The tendency was remarkable in this study because tall trees have large canopies in the study area. The examples of 360-degree images of trees are shown in Fig. 4.

Moreover, when looking at the differences in the mean values, it tends to be underestimated as the height is greater. As described above, it is difficult to grasp the top of the trees with large canopies. For this reason, we tended to measure the lower portions than the top of the trees.

On DBHs, on the other hand, the tendency by size was not observed. DBHs had less difference in the difficulty of measurement by size. This is a reason why

Table 2 Measurements classified by size (unit: meters)

		Mean (laser rangefinder and caliper gauge)	Mean (MMS)	Difference	RMSE
Tree height	Less than 10m	6.97	7.17	0.20	0.771
	10-20m	16.50	16.38	-0.12	1.187
	Over 20m	21.66	20.72	-0.94	1.637
	All trees	11.27	11.23	-0.04	1.067
DBH	Less than 20cm	0.151	0.151	0.000	0.032
	20-40cm	0.258	0.255	-0.003	0.031
	Over 40cm	0.501	0.513	0.012	0.037
	All trees	0.319	0.322	0.003	0.033

Fig. 4 Examples of 360-degree images at the site with tall trees (upper) and short trees (lower).

there was no significant difference in measurement error by size.

5. Conclusion

From the results of this study, the MMS which acquires and analyzes the 360-degree image is possible to measure trees, i.e., tree heights and diameter at breast height of street trees. The accuracy of measurements is practical as compared with the result by the MMS which equips a laser scanner. However, it is difficult to measure the trees which have large canopies to cover the sky.

In the future study, it is necessary to consider the method to measure the top of the trees which have large canopies. In addition, it is also necessary to examine how the error differs depending on the distance from the driving line of the MMS.

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