Automated Identification technology of Trees Endangering to Distribution Facilities by using Mobile Mapping System

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ABSTRACT

In general, electric power companies trim trees on a regular basis to prevent the failure of power distribution equipment as a result of contact with trees. Currently, the process of trimming trees around power distribution equipment involves visual observation to determine trees that need to be trimmed and manually creating instruction documents for trimming. These methods have issues from the perspectives of quality and effort.

On the other hand, practical use of 3D laser scanners has grown in recent years, and certain electric power companies in Europe and North America manage their tree trimming activity using a UAV (Unmanned Aerial Vehicle) that is equipped with 3D laser scanners. However, since power distribution equipment is set up roughly 10m above ground, if trees are covering the top of medium-voltage lines, it would be difficult to measure the separation from above. There are also issues with legal compliance for flight UAV, since the equipment tends to be constructed near residential homes and streets.

Therefore, this study focused on MMS (Mobile Mapping Systems) that combine on-board 3D laser scanners with complete perimeter cameras and conducted actual measurements under various conditions. Additionally, we developed an automated system that uses 3D data to determine which trees need to be trimmed, measure their volume, and create a trimming instruction document and evaluated how suitable it is to be applied for work.

1. INTRODUCTION

Although the sales of electricity in Japan has become stagnant due to the spreading highly-efficient appliances. On the other hand, distributed energy resources in rural-forest regions have increased, and equipment that require the management of tree-trimming are increasing year after year (**Fig 1**).

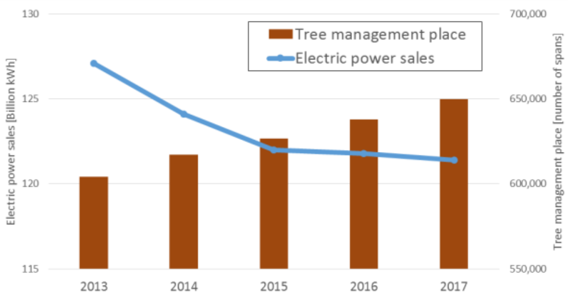

Fig 1: Sales of electric and tree management place

However, as tree-trimming technicians in the electrical field continue to age, labor is expected to become more difficult to secure in the future.

Due to these circumstances, it is necessary to handle increasing locations requiring tree-trimming with limited human resources, while keeping costs low.

2. CONVENTIONAL METHOD

2-1 Methodology

Currently, Chubu Electric Power Co., Inc. (CEPCO) manages tree-trimming related to distribution equipment by repeating the following 4 steps on a 5-year cycle (**Fig 2**).

2-1-(1) Step1　Investigation：

Visually observe the proximity of trees (unit of 0.1m) and determine when the trees will be trimmed.

2-1-(2) Step2　Design：

Create an instruction document for trimming (on paper) to inform the processing company about the location, count, and processing methods for the corresponding trees.

2-1-(3) Step3　Negotiation：

Use the instruction document to negotiate with the owners of the trees to receive approval to trim the trees.

2-1-(4) Step4 Execution :

Based on the instruction document, identify the owner of the trees and execute the trimming that was agreed upon.

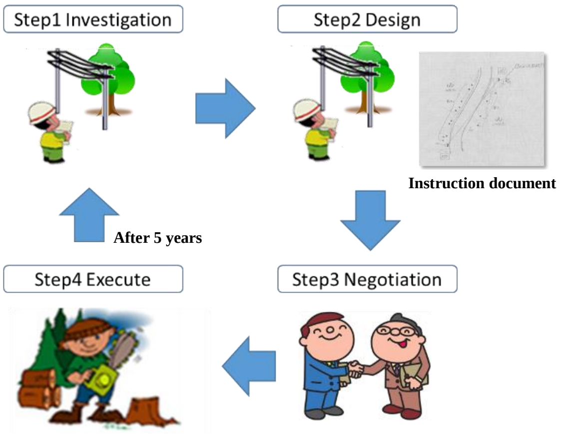

Fig 2: Conventional Work flow

2-2 Issue

2-2-(1) Efficiency and Safety

Under the current methods, it is necessary to travel to each location by car and walk to a distance where it is possible to conduct visual observations. Therefore, the processes of investigation and design are time-consuming. There are also safety issues, as workers have slipped down slopes and been stung by bees.

2-2-(2) Accuracy and Understanding of Volume

Since the observations are made visually, there are discrepancies between individuals, mistaken observations, and missed observations. In order to optimally utilize limited budgets and human resources, it is important to determine the priority and gauge proximity precisely.

In addition, workers create plans and prepare the necessary equipment based on the expected amount of work, but the current instruction documents have issues with accuracy, such as discrepancies regarding the location of the corresponding trees.

Further, the number of trims and logging tree can be counted, but there is no way to know their volume. As a result, deviating from the work plans results in decreased efficiency.

3. PROPOSED METHOD

3-1 Basic concept

By automating Steps 1 (investigation) and 2 (design) using 3D laser scanners, which are being more widely used in recent years, investigation and design can be carried out accurately, safely and rapidly.

In this instance, Hitachi's object extraction technology is used for automated extraction of power distribution equipment, and methods were formulated for this evaluation based on the know-how of CEPCO for analysis of the trees to be trimmed (**Fig 3**).

Fig 3: Study outline

As a method to use 3D laser scanners to capture images, certain electric power companies in Europe and North America use UAV. However, in many cases, trees cover and shield the top of medium-voltage power lines in Japan.

Additionally, due to legal compliance and cost issues, we concluded that capturing images from above would be difficult to be applied to medium-voltage power distribution equipment at the moment.

On the other hand, the practical usage of MMS has been advancing in recent years with the purpose of utilization in the field of 3D map creation for self-driving vehicles.

In many cases, power distribution equipment in Japan is constructed along roads. So we decided to focus this research on the acquisition of 3D data using MMS, with an eye on the utilization of 3D data that has been captured by road administrator and other companies in the future.

3-2 System configuration

3-2-(1) Hardware

MMS is being developed by a number of vendors, but the "IP-S3 HD1" by Topcon was used for this research. Details regarding the configuration of the hardware are listed in **Table 1** and **Fig 4.**

Table 1: MMS hardware configuration

Laser scanner	
Measurement rate	700,000 points/sec
Range	100m
Perimeter camera	
Camera unit	CCD camera (6 pcs.)
Maximum resolution	8,000×4,000 pixels
Maximum capture speed	10fps
GNSS	
Number of channels	226 Universal Channels, GPS, L1/L2, GLONASS
Data update rate	10Hz
IMU	
Gyro Bias Stability	1° /hr
Acceleration Bias Stability	7.5mg

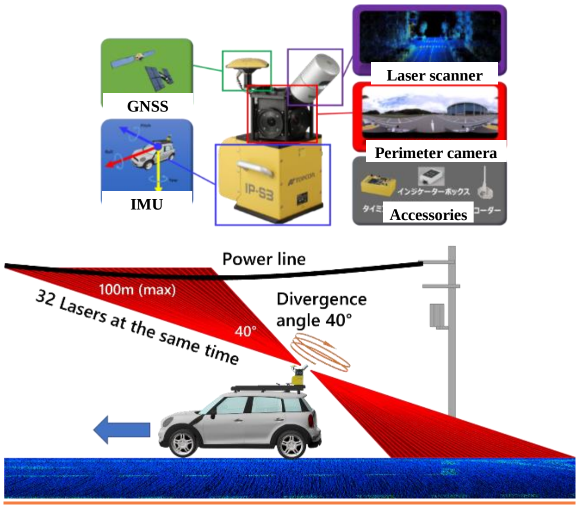

Fig 4: MMS hardware image

3-2-(2) Software

Object extraction software owned by Hitachi was used for automatic extraction of utility poles and power lines from the 3D data acquired through MMS.

3-(3) Methodology

The work flow using MMS would be as follows (**Fig 5**).

3-3-(1) Step1 Investigation and design：

In addition to acquiring 3D data and automatically determining trees that are approaching power lines by running MMS, timelines for the next tree-trimming activities are determined. In addition, if trimming is necessary within the fiscal year, an instruction document (3D electronic map) that indicates the location, count, and trimming methods of the corresponding trees will be created automatically.

3-3-(2) Step2 Negotiation：

Based on the instruction document, negotiation will be carried out with the owner of the trees for approval to trim the trees. In this instance, the location information obtained through MMS will make it easier to identify the owner of the trees, and the images from the complete perimeter cameras can be used to explain to the owners.

3-3-(3) Step3 Execution：

Based on the content of the instruction document, trees are trimmed. In this instance, the 3D data, complete perimeter images, and volume that have been acquired through MMS allow execution plans to be created with higher precision than conventional method.

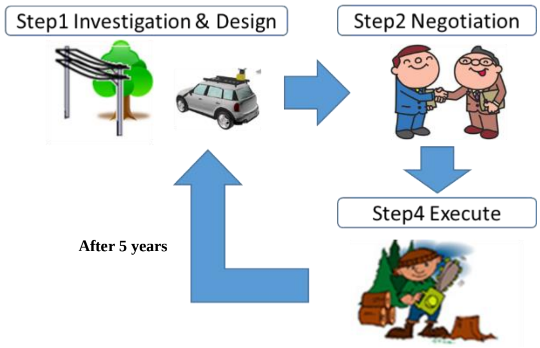

Fig 5: Work flow using MMS

4. VERIFICATION

4-1 Analysis Algorithm

In this evaluation, utility poles are first extracted from the 3D data, and then the power lines connecting utility poles are extracted. The existence of trees that are approaching the extracted power lines is determined, and the count and volume of trees that are in proximity of the power lines are calculated. Analysis was conducted by outputting the calculation results to an instruction document or GIS (**Fig 6**).

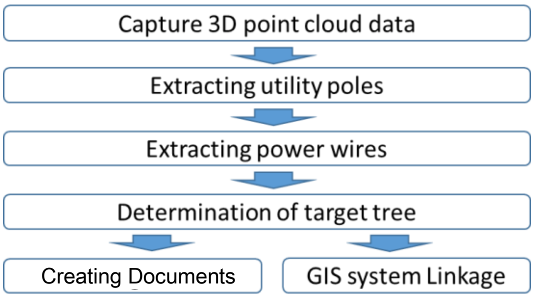

Fig 6: Outline of automatic analysis system

4-2 Evaluation area

In order to evaluate how the system can be applied under various conditions, evaluation took place in areas including suburbs and rural-forests regions (**Fig 7**).

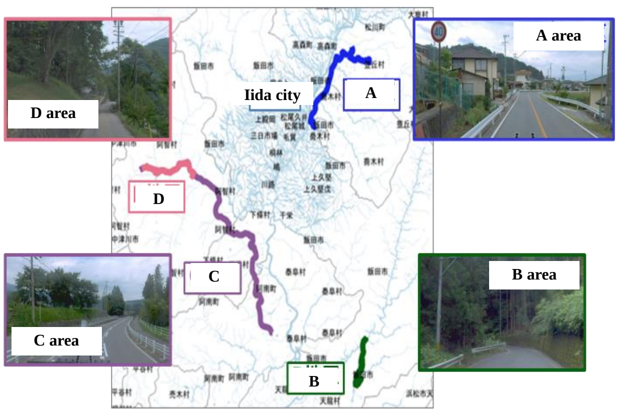

Fig 7: Evaluation area

4-3 Evaluation conditions

The average speed, measurement distance, and weather conditions for MMS measurement are listed in **Table 2**..

Table2: Evaluation conditions

	A	B	C	D
Average speed [km/h]	31.5	24.1	34.0	24.7
Maximum speed [km/h]	50.0	51.5	53.5	47.2
Measurement distance [km]	16.4	13.8	34.4	11.5
Weather	Cloudy (June 2018)			

4-4 Evaluation Results

4-4-(1) Utility pole extraction

Location information for utility poles that CEPCO manages was entered beforehand, and an algorithm that recognizes columns that exist nearby as utility poles was used to extract them from 3D data. Results are listed in the **Table 3** below.

Table 3: Results of utility pole extraction

Area		A	B	C・D	total
Pole number	System	183	88	452	723
	Real	256	113	592	961
Extraction rates [%]		**71.5**	**77.9**	**76.4**	**75.2**

It is assumed that the reason of the difference between the extracting result and the number of real utility poles, is that information on the CEPCO's utility pole location information data that was used as right data did not have high precision, resulting in the lack of utility poles in the search region.

As a countermeasure, the location of utility poles was corrected by capturing images through MMS once, which reduced the error to an order of several centimetres. As a result, the missed extraction of utility poles can be minimized from next time on, and restricting the search area should reduce the system processing time.

4-4-(2) Power line extraction

For the extraction of power lines, an algorithm that recognizes lines that are above a certain height as power lines. That were extracted beforehand was used.

In order for a line to be recognized, consecutive point data must be obtained within a certain interval. However, it was found that in certain instances, the point data for a power line were missing despite the presence of a power line. **Fig 8** indicates the situation of missing point data for power lines.

Fig 8: Situation of missing point data

We tried two countermeasure for these types of missing point groups. The first was to run at slow speed to increase the density of the points, and the other was to correct the areas with missing point groups using system processing.

In order to confirm the effect of increasing the density of points by running at a slow speed, the speed was restricted to below 40km/h in Area D. In addition, for locations with right angle turns, the speed was lowered even more before images were captured again, since areas with missing data points due to ambient light tended to have right angle turns. The results are indicated in **Fig 9**. This eliminated losses due to speed, and increased density of the points reduced losses due to ambient light and obstacles, resulting in an improvement in the power line recognition rate to 97.8%.

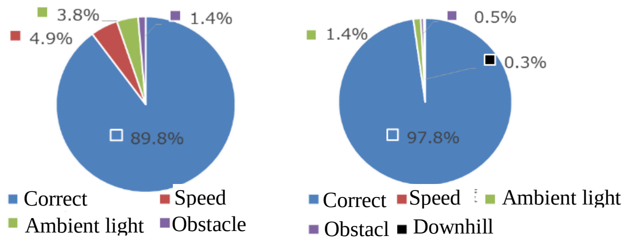

Fig9: Rate of point data failure

Next, correctional processing was carried out using software in order to apply these methods to places where obstacles, such as trees covering power lines, make it difficult to obtain point groups. This process involves automatic completion by extending the line through missing areas when consecutive point groups are obtained for a portion of the space between utility poles (**Fig 10**). Additionally, even if a line is not detected at all, it is possible to assume the existence of a power line manually specifying the starting point, intermediate point and end point.

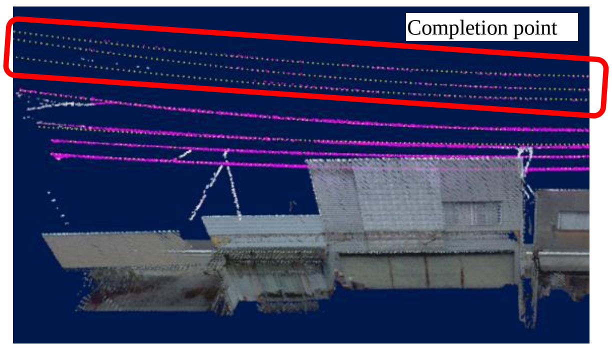

Fig10: Automatic completion image

4-4-(3) Extraction of trees and Volume Measurement
By extracting obstacles that exist within a specified range of the power lines that have been extracted, the trees that exist within this range are extracted (**Fig11**). In order to measure the volume of the corresponding trees, a cube with a specified length called a "Boxel" was used to measure the volume.

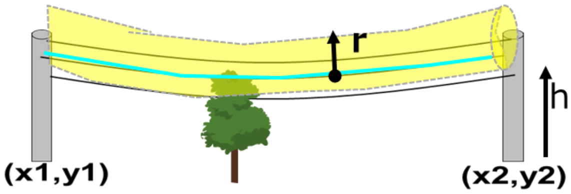

Fig11: Tree extraction algorithm

4-4-(4) Calculation of the Count of Trees
Using the shapes of the 3D data between the utility lines, the shapes of the trunks of the trees are determined in order to calculate the number of trees. In addition, individual trees can be recognized by using the trunk as a basis to connect point data that are consecutive within a certain distance in order to create tree groups (**Fig12**). Since tree groups are linked to location information, capturing images of similar trees on a regular basis enables the understanding of changes to shapes, which can be utilized to calculate the speed of the growth of trees.

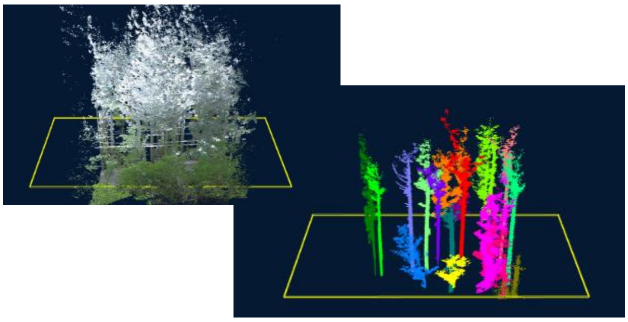

Fig12: Tree groups image

4-4-(5) Creation of instruction document
By using the automated tree extraction results, the maps that correspond to the current instruction orders can be created accurately and automatically (**Fig13**). Although the maps were drawn as views only from above in the past, being able to see images from the sides and understanding the volume of the trees allows workers to understand easily the situation at the worksite.

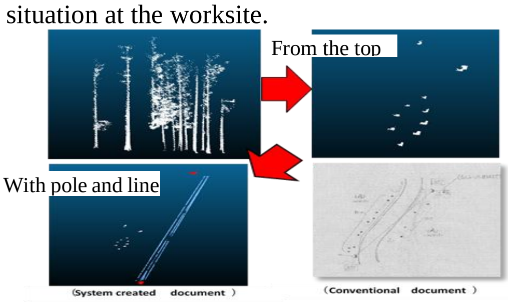

Fig13: Creation of instruction document using by MMS

4-4-(6) GIS system linkage
By plotting the automated tree extraction results in the GIS system, the distribution of trees that need trimming and their volumes can be understood visually (**Fig14**). Also, connecting these results with GIS data regarding land owner information makes it possible to easily identify the owner of the trees.

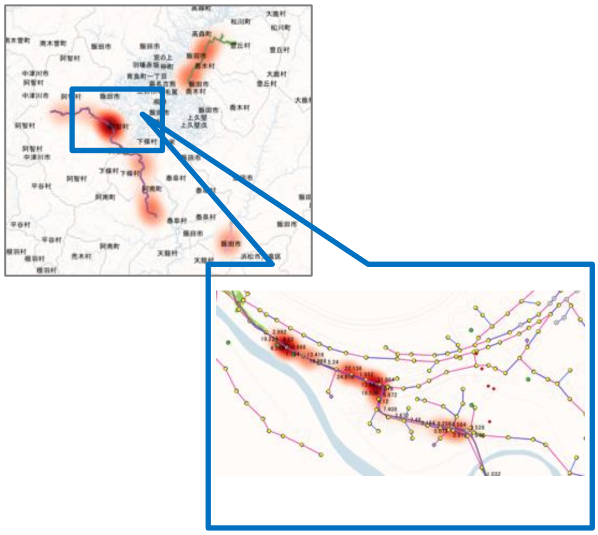

Fig14: GIS system linkage image

4-4-(6) Issues
Current issue with this method is that there have been instances when tree groups cannot be extracted accurately if obstacles prevent point data for trees from being obtained partially. In response to this, it is important to set the boxel size optimally.
Also, cost for the trimming management could be higher than they currently are due to the purchase or rental of MMS equipment, as well as storage of massive amount of data. However, it would be possible to lower cost through compression of unnecessary data and future decreases in the costs of capturing MMS images by applying them to tasks outside of trimming management and operation.

5 CONCLUSIONS

In this study, we assessed a method of utilizing MMS to gain an accurate understanding of a wide-ranging area for tree-trimming without using a lot of human resources. By utilizing the object extraction algorithm owned by Hitachi on the data acquired through MMS, we succeeded in extracting 97.8% of medium-voltage lines. Further, we created elemental algorithm of automatic creation of instruction documents by applying analysis based on the know-how of CEPCO on the extracted medium-voltage lines.
In the future, we will also evaluate portable- and drone-type MMS to assess whether this method can be applied to equipment that are not located roadside. We will also aim to bring this method to practical use by finding cost benefits through applying it outside of trimming management and operation.