Development of Vegetation Structure Measurement System using Multi-angle Stereo pair Images

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Abstract: When the data from the artificial satellite is analyzed, recent years it is perceived to vegetation index using BRF(Bi-directional Reflectance Factor) of the observation target. To make the BRF models, it is important to measure the 3D structure of the observation target actually. In this study, it is proposed to the observation technique by using multi-angle stereo pair image, and shown the observation result in grassland area.

Also, our team has been operating the radio controlled helicopter which can fly over the tall forest canopy and it can be equipped the measurement system.

Keywords: Vegetation structure, Multi-angle stereo pair, RC helicopter

1. Introduction

For the vegetation monitoring, especially for estimating the vegetation quantity, it is required to develop the estimation model which is based on ground measurement. As well known, there are some difficulties to understand the characteristics of reflected light response against incident light on canopy caused by the influence of sun light reflection behavior by vegetation structure. For developing the model describes spectral response from vegetation canopy, the above relationship should be clarified by ground measurement.

2. Objective

For obtaining the 3D structure of the observation target, the technique of image matching for stereo pair image is widely used. In order to progress the accuracy in this technique, large B-H ratio is prefer to select. But large B-H ratio causes the following problems. 1) Increasing the invisible area and make many 'hole' in focused area. 2) Too large viewing angle difference makes large distortion of target figure in each image and increases miss-match points.

The purpose of this study is to propose the algorithm for solving above problems, and to developed ground measurement system.

3. Multi-angle stereo pair method

Our method is based on multi-angle pair of stereo pair images, shown as Fig. 1. It combines a set of small B-H ratio stereo pair taken from a series of different angle and these pairs construct the large B-H ratio pairs.

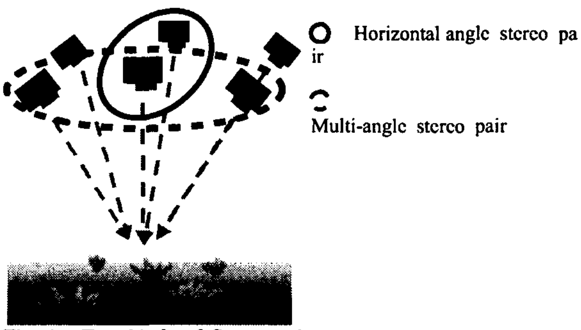


Fig. 1. Two kinds of Stereo pair.

However, Multi-angle stereo pair has large viewing angle difference, so it is difficult to apply the general template matching method. Therefore, proposed algorithm is used horizontal angle stereo pair image firstly, then matting the multi-angle stereo pair shown as Fig. 2.

Firstly, cross-correlation factor shown as Eq. (1) is used to horizontal angle stereo pair image for each observation angle, to retrieve the matting point(that becomes biggest value of cross-correlation factor), and 3D models are made every horizontal angle stereo pair images using each matting points(Fig. 2).

Those 3D models are defined as provisional model.

$$C(a,b)=\sum_{m_1=1}^{N_1-1}\sum_{n_1=1}^{N_1-1}\frac{\{I_{(a,b)}(m_1,n_1)-\bar{I}\}\{T(m_1,n_1)-\bar{T}\}}{\sqrt{I_{\sigma_{ab}}T_{\sigma}}} \quad (1)$$

$$\bar{I} = \frac{1}{N_1^2} \sum_{m_1=0}^{N_1-1} \sum_{n_1=0}^{N_1-1} I_{(a,b)}(m_1,n_1)$$

with

$$\bar{T} = \frac{1}{N_1^2} \sum_{m_1=0}^{N_1-1} \sum_{n_1=0}^{N_1-1} T(m_1,n_1)$$

$$I_{\sigma_{ab}} = \sum_{m_1=0}^{N_1-1} \sum_{n_1=0}^{N_1-1} \left\{ I_{(a,b)}(m_1,n_1) - \bar{I} \right\}^2$$

$$T_\sigma = \frac{1}{N_1^2} \sum_{m_1=0}^{N_1-1} \sum_{n_1=0}^{N_1-1} \left\{ T(m_1,n_1) - \bar{T} \right\}^2$$

(a,b) : center-point of template image in input image

$I_{(a,b)}(m_1,n_1)$: one part of input image

$T(m_1,n_1)$: template image

$C(a,b)$: cross-correlation factor

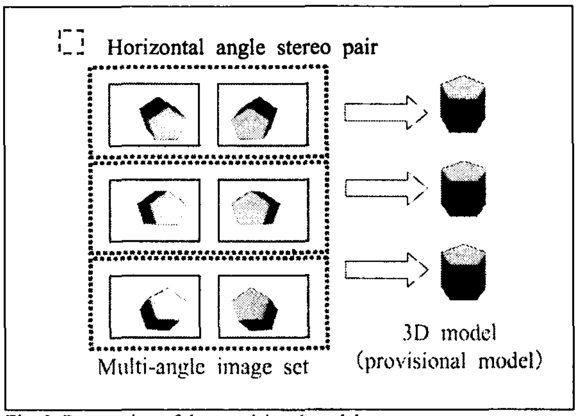


Fig. 2. Preparation of the provisional model

And next process shown in Fig. 3, searching the matting points of each provisional models, then, this point is searched from each the pixel of images. Correspondence point between 3D correspondence point to pixel of images is regard next matting point.

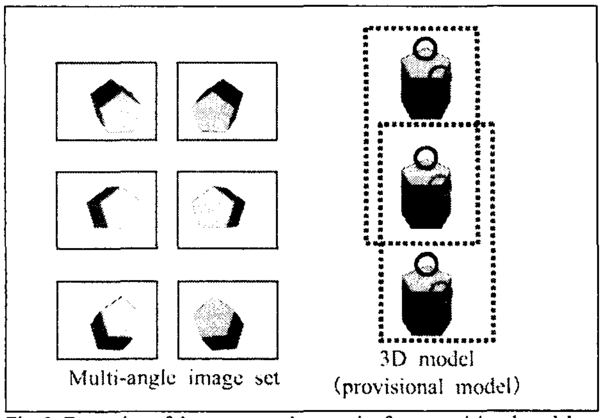


Fig. 3. Extraction of the correspondence point from provisional model

The third step(Fig. 4), image that is projected the 3D correspondence point from provisional model(below, provisional model projection image) is made, then each provisional model projection image are searched by using SSDA method (Sequential Similarity Detection Algorithm, Eq. (2)), and can be found the concur point in former images. Although this technique is the same as the method that used the cross-correlation factor as for to search the matting area for finding template matting, but this method is using the similarity instead of a cross-correlation factor.

$$R(a,b) = \sum_{m_1-1}^{N_1-1} \sum_{n_1-1}^{N_1-1} \left| I_{(a,b)}(m_1,n_1) - T(m_1,n_1) \right| \cdots (2)$$

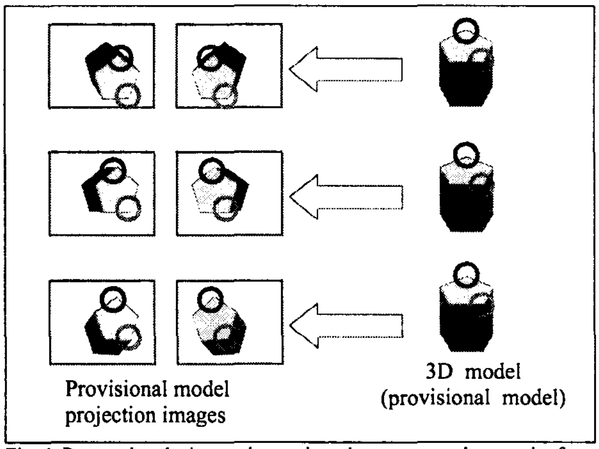


Fig. 4. Preparation the image that projected to correspondence point from the provisional model

Finally step (Fig. 5), definitive 3D model is made from multi-angle stereo pair, using above correspondence point.

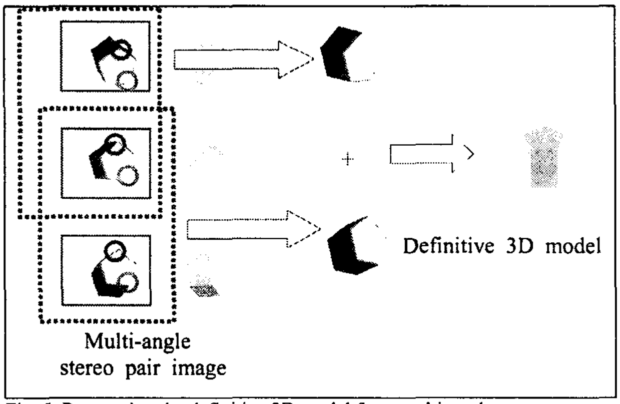


Fig. 5. Preparation the definitive 3D model from multi-angle stereo pair

4. Grassland measurement system

1) Developed grassland measurement system and result

In following, it is shown the developed measurement system that was used in Mongolia grassland (Fig. 6). In this measurement, there are 60 measurement points (area sizes are 1m square) that are called Quadrate. Then, Fig. 7 is shown the example of measuring the parse density grasses in Mongolia grassland.

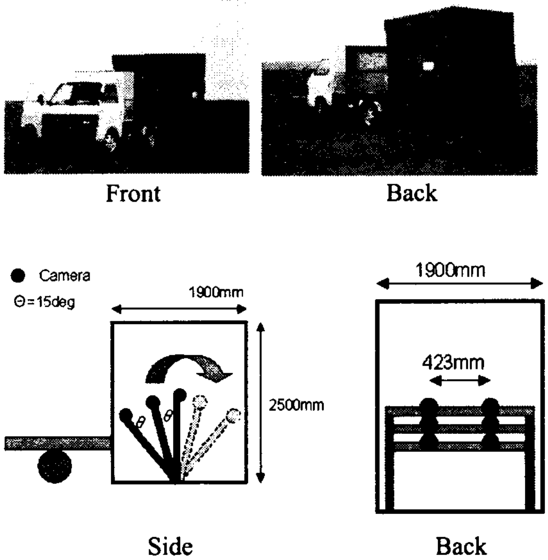


Fig. 6. Grassland measurement system

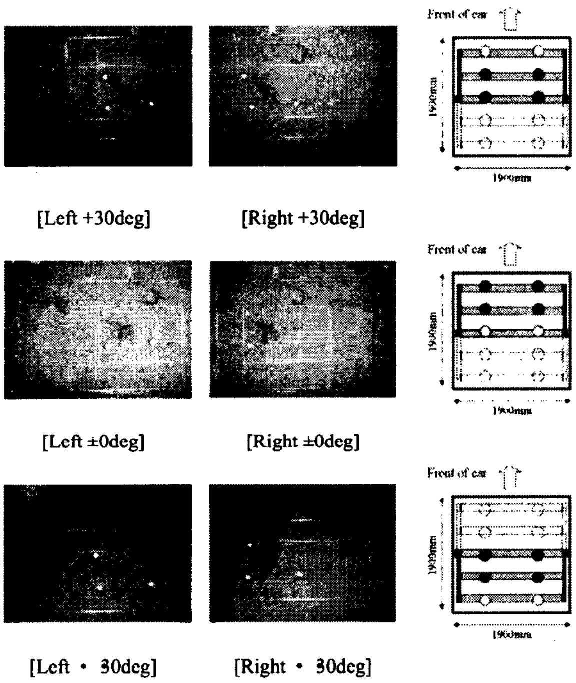
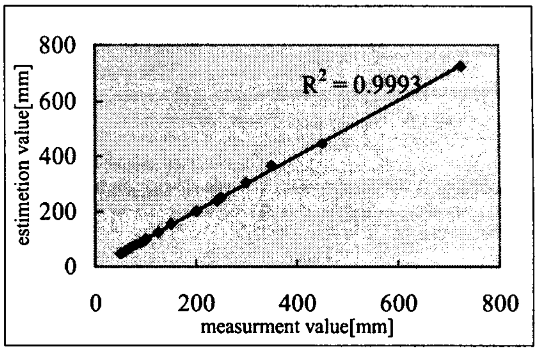
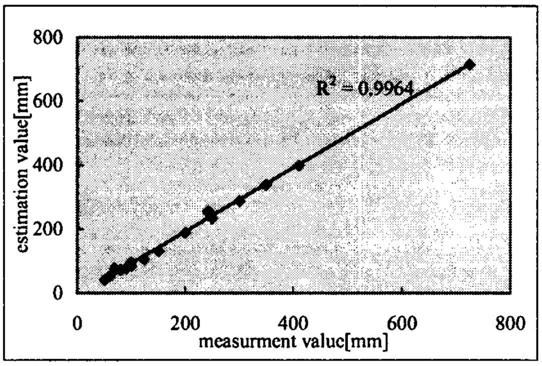


Fig. 7. Example of measurement result in Quadrate



RMS error = 4.73[mm]

(a): Estimation by using proposal method



RMS error = 12.56[mm]

(b): Estimation by using general method

Fig. 8. Comparison of 2 methods from estimation result

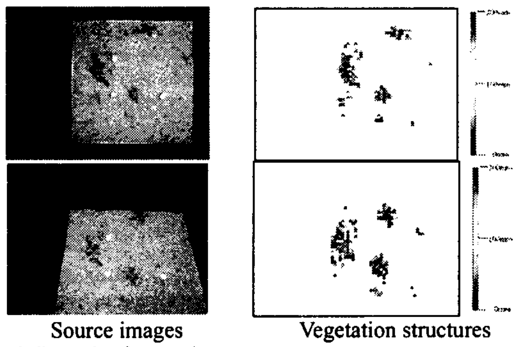


Fig. 9. Example of vegetation structure

2) Preparation and verification of the 3D model

Length is calculated from the stereo pair image to a known length object using both proposal method and general method, and it is compared with the measurement value and estimates it to vivificate about the efficacy of the proposal technique. Fig. 8(a)-(b) are shown the result.

As mentioned above, it was verified that the propo sal technique is able to estimate the length of the obj ect with a small error more than general one.

The example of the vegetation structure that was obtained by these measurements is shown below Fig. 9.

5. RC helicopter measurement system

1) Developed measurement system using RC helicopter

To measure the tall forest canopy structure, our team selected autonomous RC helicopter (YAMAHA R-MAX, Fig. 10(a)-(b)) as platform, because this platform has not only higher mobility and static stability, but also lower cost than other one. This helicopter flies in accordance with a flight plan that has been programmed in the Attitude control system) and the differential GPS system. By setting a moving direction, speed etc. on a PC monitor that is set up on Ground Station System, the helicopter can move in the three-dimensional space on a real-time basis.

Also, the RC helicopter can move automatically in accordance with the coordinates assigned in the map data on the PC. The operator can easily operate a programmed flight by combining the coordinate points.

In this measurement, RC helicopter mounted stereo arm system. This system can take stereo-image photo by 2 Digital cameras (Canon D60), both end of the stereo arm (length of this arm is 1000mm each from center to end side). And stereo arm is possible to turn toward front and back of helicopter, and Digital camera can take image at the same time. Of the flight data such as the location and speed of the helicopter, angle of cameras are memorized to the control box on system. After landing, the data of control box is used to structural analysis.

(a) Measurement system (b) YAMAHA "RMAX"
Fig. 10. RC helicopter measurement system

Fig. 11 is showing measurement flight pattern. Measurement system can get data every 5 degrees (34 points) in this flight pattern, and takes 15 minutes from start to end. This flight pattern is able to obtain the data from the various angles of observation targets, because the observation angle of sensor is changed as the same target.

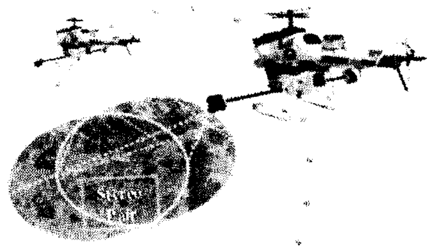


Fig.11. Measurement flight pattern

2) Verification of the development system

To examine the efficacy of the developed measuring system, the place where put the verification point in the ground was measured by this system. Fig. 12 is shown the images of measuring the stairs of the embankment from 20m height by RC helicopter in Kochi, Japan. And, the 3D structure that was made by proposal algorithm is shown below Fig. 13.

To verified the accuracy of this structure, estimate value from proposal algorithm is compared with actual value by using 5 verification points. Finally, RMS error from proposal method is less than general one as result.

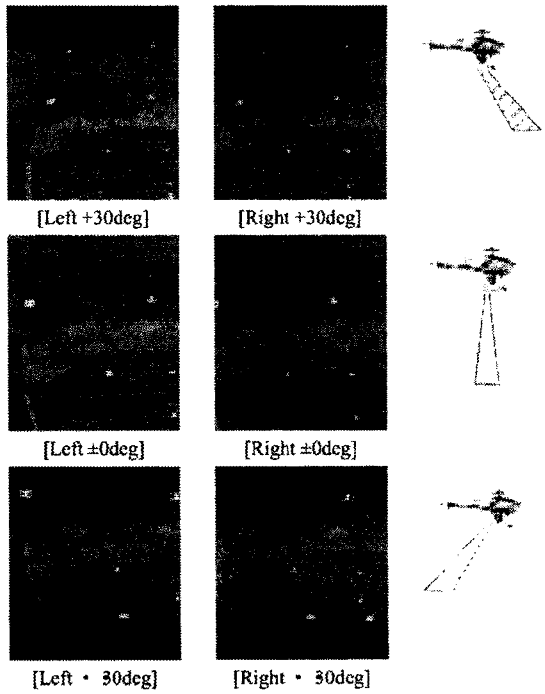


Fig. 12. Measurement images from RC helicopter measurement system

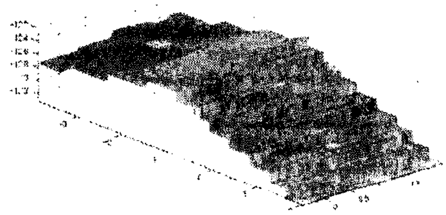


Fig. 13. 3D model by using multi-angle image from RC helicopter

6. Conclusions

In this study, vegetation structure measurement system by using multi-angle stereo pair image was developed. And, it is proposed multi-angle matting algorithm. The developed system has been tested for the sparse density grasses in Mongolian grassland. Further, Canopy structure measurement system by using RC helicopter was made, and tested in known proving ground.

Acknowledgement

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References

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