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Developing Ground Truth Measurement System using RC Helicopter and BRDF Model in Forest Area

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ABSTRACT: It was difficult to compare the ground truth data to the estimated data using bi-directional reflectance model of vegetative canopy, because most of ordinary measurement systems could not use in forest area except using airplane. This study adopts Radio Control Helicopter (RC Helicopter) as new platform of ground truth measurement, and developed the measurement system, and measured in some forest areas with this system, and compared the measured data to estimated data. As the results, it was made known that the change of VCR (Vegetation Coverage Ratio) of field of sensor view from each angles is most important factor of bi-directional reflectance model in forest area.

1. INTRODUCTION

For the environmental problems, the importance of remote sensing data of vegetation areas is increasing. In the analysis of the earth environmental variation, NDVI (Normalized Differential Vegetation Index), calculated from reflected spectrum, is used to know amount and activity of vegetation. Consequently it is important to know fundamental principal of BRDF (Bi-directional Reflectance Distribution Function) of vegetation area.

Some studies had developed bi-directional reflectance models of vegetative canopy. However it was difficult to compare the data estimated by those models to the ground truth data, because some parameters describing those models are difficult to measure in ground truth observation, and most of ordinary measurement systems could not use in forest area except using airplane.

This study adopts Radio Control Helicopter (RC Helicopter) as new platform of ground truth measurement, and developed the measurement system using RC Helicopter

2. OBJECTIVES

The Objectives of this study are developing the measurement system and method using RC Helicopter, and measuring ground truth data in forest area using this system, and comparing the ground truth data to estimated data.

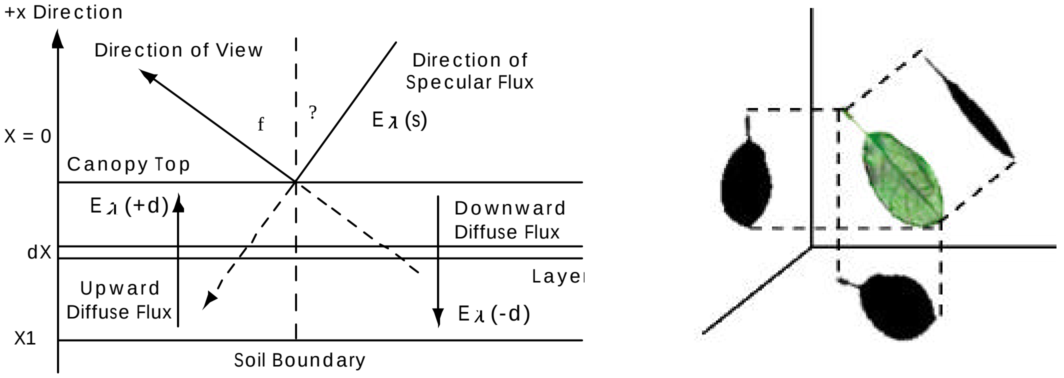
3. MODELS OF BI-DERECTIONAL REFLECTANCE

The Suits model (Suits 1968) is a one of the bi-directional reflectance models of vegetative canopy. The Suits model in essence is four-flux theory. In the following calculations, the spectral flux density is symbolized by $E_? (s)$ for specular flow and $E_? (+d)$ for upward diffuse flow and $E_? (-d)$ for downward diffuse flow. Figure 1 shows schematic of The Suits model. The differential equations of this model is given by

$$E_? (+d, i, x) \;/\; dx = -a_i \, E_? (+d, i, x) + b_i \, E_? (-d, i, x) + c_i \, E_? (s, i, x), \qquad (1)$$

$$E_? (-d, i, x) \;/\; dx = a_i \, E_? (-d, i, x) - b_i \, E_? (+d, i, x) - c_i ' E_? (s, i, x), \qquad (2)$$

$$E_? (s, i, x) \;/\; dx = k_i \, E_? (s, i, x). \qquad (3)$$



(A) Schematic of The Suits model (B) Projection of Leaf

Figure 1. The Suits Model

The constants a_i, b_i, c_i, c_i', and k_i are derived from measurements of canopy components of the *i* th layer, then

$$a_i = s_h n_h (1 - t) + s_v n_v (1 - ?/2 + t/2), \quad (4)$$

$$b_i = s_h n_h ? + s_v n_v (?/2 + t/2), \quad (5)$$

$$c_i = s_h n_h ? + s_v n_v (?/2 + t/2)(2/p) \tan ?, \quad (6)$$

$$c_i' = s_h n_h t + s_v n_v (?/2 + t/2)(2/p) \tan ?, \quad (7)$$

and

$$k_i = s_h n_h + s_v n_v (2/p) \tan ? . \quad (8)$$

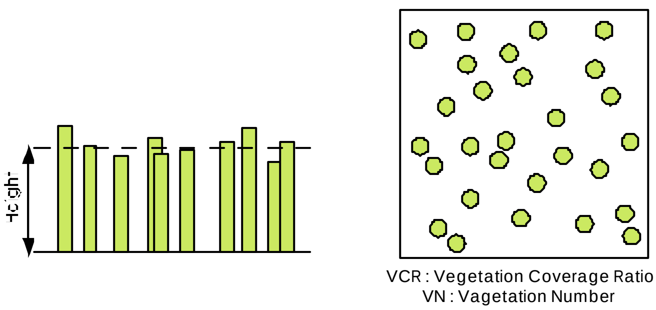
where s_h is the average area of the projection of the canopy component of a horizontal plane, s_v is the average area of the projection of the canopy component on two orthogonal vertical planes, n_h and n_v are the number of each projections per unit volume. And $?$ is the polar angle for incident specular flux, f is the polar angle of view. And t is the spectral transmittance of canopy component, $?$ is the spectral reflectance of canopy component.

The angular response of this model is caused by the function $\tan ?$ as a multiplier of the vertical leaf area projection.

The SAIL (Scattering by Arbitrarily Inclined Leaves) model (Verhoef, 1984) is an extension of The Suits model. This model focuses on the estimation of the Suits coefficients for a canopy layer, because Suits's approach of taking horizontal and vertical leaf area projections to calculate the scattering and extinctions coefficients is too drastic. The SAIL model introduces leaf area index and leaf area orientation density function instead of projection of the canopy component.

However, there is a problem that it is too difficult to measure average area of the projection of the canopy component and leaf area orientation density function in ground truth observation.

The Cylinder model (Watanabe, 1997), Figure 2 shows, is also an extension of The Suits model. In this model, shape of grass is expressed by cylinder, and described by *VCR* (Vegetation Coverage Ratio) and *VN* (Vegetation Number), which are easy to measure in ground truth observation. And coefficients s_h and s_v are given by



(A) Profile View (B) Top View

Figure 2. The Cylinder Model

$$s_h = VCR / VN \quad (9)$$

$$s_v = 2 v(VCR / p\ VN)\ height \quad (10)$$

The Cylinder model is able to express bi-directional reflection of the simple and flat vegetation area, like Mongolian grassland, and easy to compare the estimated data to the ground truth data.

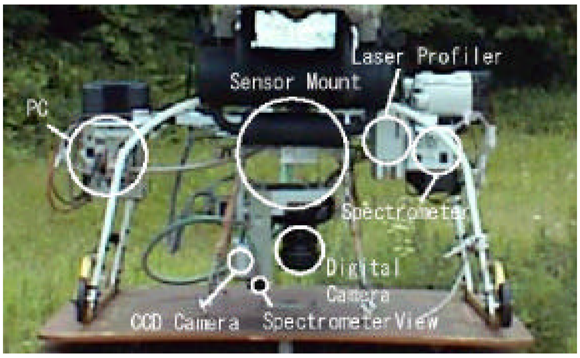
4. INSTRUMENTS

The RC helicopter using in this study is actually for industrial product (RMAX YAMAHA Figure 3 (A)). It has hovering system to keep its position by using GPS. And Figure 3 (B) shows measurement instruments.

・ Spectrometer (S2300, Soma optics): It is multi spectral spectrometer that has dual port. It can get both data, the data of the target and that of white at the same time.

・ Digital Camera (DSC560, Kodak): It is 6 million pixels digital camera. Images are recorded into 1 GB HD card. It can take pictures 160 times.

(A) RC Helicopter



(B) Sensor Mount

Figure 3. Instruments

5. METHOD

Figure 4 shows the flight pattern of BRDF measurement. It has 2 lines of flight routine that principal line (?) and vertical line (?). Because change of reflectance that measured toward sun direction are largest than other data, and perpendicular data are most different from sun direction data in past observation.

This system can get data every 34 points in this method, and takes 15 minutes from start to end, and the sun moves less than 3 degrees.

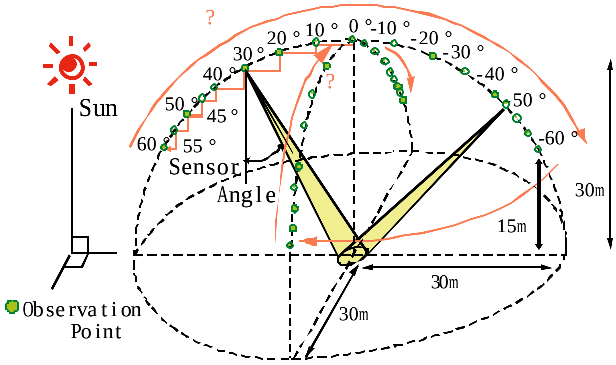


Figure 4. Flight pattern of BRDF measurement

6. OVSERVATION

The observation has been carried out in US and Canada since May 31 until July 9, 2000. Table 1 shows observation places and targets.

Table 1. Observation Places and Targets

Place	Date	Latitude	Longitude	Target
Arizona	2000/6/2~ 4	N31° 36' 25.956?	W110° 30' 7.200?	Yellow Grassland, Wood
New Mexico	2000/6/7~ 10	N32° 35' 24.972?	W106° 50' 38.400?	Desert
Kansas	2000/6/16	N39° 6' 3.627?	W96° 36' 29.291?	Grassland
Montana	2000/6/21~ 23	N46° 53' 38.947?	W113° 26' 15.320?	Grassland, Bush, Broadleaf Forest, Coniferous Forest
British Colombia	2000/6/27~ 29	N48° 37' 1.475?	W123° 43' 24.467?	Coniferous Forest
Oregon	2000/7/2~ 3	N44° 15' 5.074?	W122° 12' 37.073?	Coniferous Forest

7. COMPARISON BETWEEN GROUND TRUTH DATA AND ESTIMATED DATA

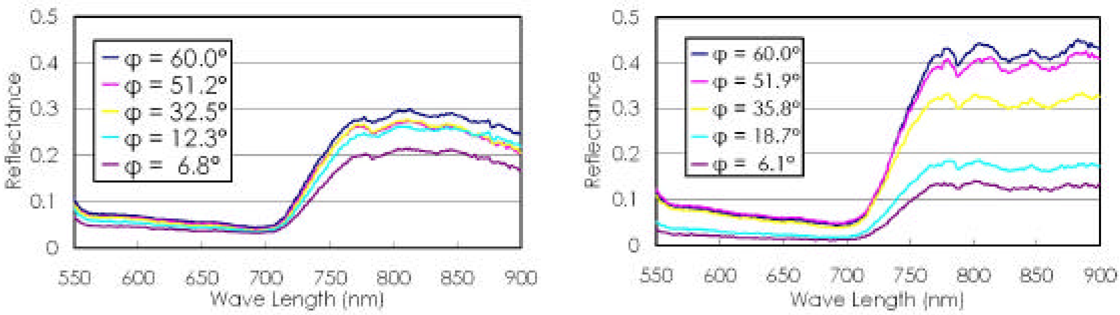
This chapter shows ground truth data taken by RC helicopter measurement system, and comparison between ground truth data and data estimated using The Cylinder model and VCR. Table 2 shows conditions of two observations in the grassland and broadleaf forest.

Table 2. Conditions of Observation

	(A)	(B)
Target	Grassland	Broadleaf Forest
Place	Montana	Montana
Date	2000/6/21	2000/6/22
Time	13:21	9:11
Latitude	N46° 53' 40.556?	N46° 53' 38.450?
Lontitude	W113° 26' 18.996?	W113° 26' 21.588?
Sun Azimuthal Angle	168.08944	90.62791
Sun Zenithal Angle	23.82891	56.40494

(A) Grassland (B) Broadleaf Forest

Figure 5. Digital Image Data



(A) Grassland (B) Broadleaf Forest

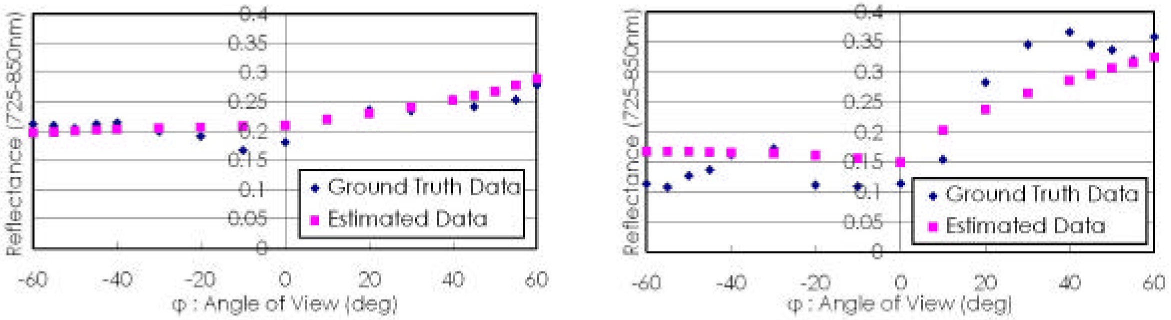
Figure 6. Spectral Reflectance data

Figure 5 shows digital images taken fro m RC Helicopter. Figure 6 shows spectral reflectance data taken from each angle of sensor view *f* . Spectral reflectance data indicate a characteristic of vegetation; reflectance of red band (580-680nm) is low, and reflectance of near infrared band (725-850n m) is high.

Table 3 shows parameters to estimate using The Cylinder model. Figure 7 shows relation between angle of sensor view and reflectance of ground truth data and estimated data.

Table 3. Parameters to Estimate

	(A)	(B)
VCR (f =0)	0.9395	0.2945
VN	1500	3
Grass Height	0.30	21.00
? (Soil)	0.15	0.10
? (Vegetation)	0.21	0.15
t (Vegetation)	0.00	0.00
Sun Zenithal Angle	23.83	56.40



(A) Grassland (B) Broadleaf Forest

Figure 7. Relation between Angle of View and Reflectance

The estimated data of the grassland fits in with the ground truth data. On the other hand, the estimated data of the broadleaf forest doesn't fit with the ground truth data well. Table 4 shows RMS error. This result is due to the definitions of the layer used reflectance model; the layer is horizontal, infinitely extended and homogenous.

Table 4. RMS Error between Ground Truth Data and Estimated Data

	(A)	(B)
RMS Error	0.016349	0.046595

The vegetative condition of grassland is similar to the layer. However, the three-dimensional structure of forest is not fit in with the structure of the layer. Figure 8 shows that relation between reflectance and VCR calculated by digital image taken from each angle. It shows that VCR is very correlated with reflectance. The estimate equation of reflectance from VCR is derived from this relation.

Figure 9 shows that relation of the ground truth data and the estimated data from VCR. It shows that using VCR is better than using The Cylinder model to estimate reflectance of forest canopy. Table 5 shows RMS error of estimation using The Cylinder model and VCR.

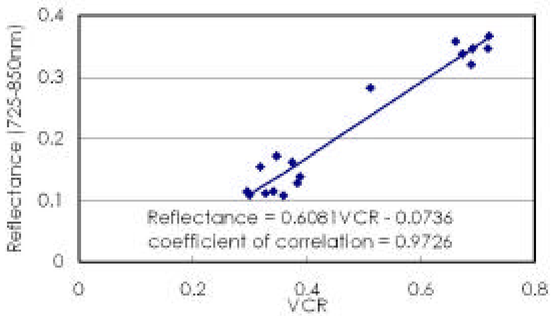


Figure 8.

Relation between VCR and Reflectance

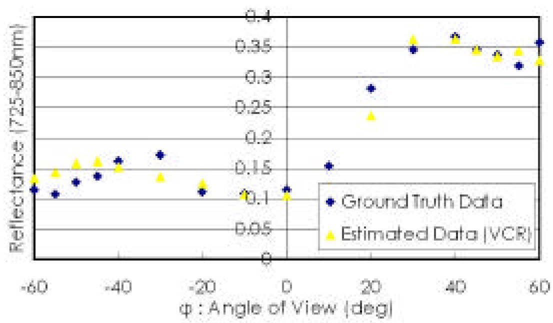


Figure 9.

Relation between Angle of View and Reflectance

Table 5. RMS Error of Estimation using The Cylinder model and VCR

Estimated by	Cylinder model	VCR
RMS Error	0.046595	0.024172

8. CONCLUSIONS

This study developed the ground truth measurement system using RC helicopter, and measured some vegetative area with this system. The result of observation shows that The Cylinder model is available to estimate reflectance of grassland, however VCR is better than The Cylinder model to estimate reflectance of forest canopy.

9. REFERENCES

Suits, G. H. (1972), The calculation of the directional reflectance of a vegetative canopy, *Remote Sensing of Environment 2*: 117-125.

Verhoef, W. (1984), Light Scattering by Leaf Layers with Application to Canopy Reflectance Modeling: The SAIL Model, *Remote Sensing of Environment 16*:125-141

Watanabe, C. (1997), Study of BRDF in the Grassland, Center for Environmental Remote Sensing, Chiba University