Forest structural information derived from multi-angular FIFEDOM (Frequent Image Frames Enhanced Digital Ortho-rectified Mapping) data

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Abstract— **Information on the distribution of forest species is critical to sustainable management of the forest resources. However, forest species structure information accuracy remains low. Most of the current multi-angle data algorithms are based on the satellite-borne or simulated datasets. In this study, we exploited the use of structural information derived from air-borne data to compare the signatures from the ground survey. This investigation was carried out by using FIFEDOM (Frequent Image Frames Enhanced Digital Ortho-rectified Mapping) data [1].**

This study used FIFEDOM data collected over the Algoma forest, Ontario Canada, which has four dominant species, Jack Pine (PJ), Black Spruce (SB), Poplar (PO) and White Birch (BW).

The accuracy of the radiometric and geometric multi-angle signature results were assessed against CASI (Compact Airborne Spectrographic Imager) data, which was collected at the same time and also compared to SPRINT model simulation results.

Keywords: multi-angle signature, structure information

Introduction

Forest management and environmental monitoring requires accurate forest stand information, such as spatial distributions of individual tree species and descriptors of tree structures. Multi-spectral and hyperspectral remote sensing methods have been well explored and are considered as a cost-effective means of classifying forest species and estimating forest structural characteristics in a spatially and temporally continuous manner. However, multi-angle data could derive valuable vertical forest canopy structure that 2-D spectral data could not deliver.

Currently, there are two major categories of multi-angle datasets: the satellite-borne sources, such as CHRIS and MISR and the simulation results, such as by using SPRINT. An airborne dataset would bridge the gap in spatial detail, which would have higher spatial resolution than former and more realistic details than the latter. This was one of the primary motivations of the development of FIFEDOM (Frequent Image Frames Enhanced Digital Ortho-rectified Mapping) camera [1].

I. FIFEDOM Camera and Its Datasets

The FIFEDOM camera has several unique features: (1) it collects image data in the visible bands (550 nm and 670 nm), as well as in the near-infrared band (800nm); (2) it has a frame rate of up to 3 frames per second with a frame size of 3500 x 2300 pixels; and (3) it has a wide angular field view measuring 150 degrees along track and 78.8 degrees across track. Its high frame rate and wide angular field view allow it to obtain a sequence of images that over-sample ground target areas, which can be used to generate the multi-angular data sets.

The wide field view provides a great advantage but at the same time poses a great challenge to re-project the image from a frame fish eye view into a normal central prospective view. The FIFEDOM camera had also gone through a series of calibrations, both radiometric and geometric. A set of FIFEDOM data is shown in Figure 1.

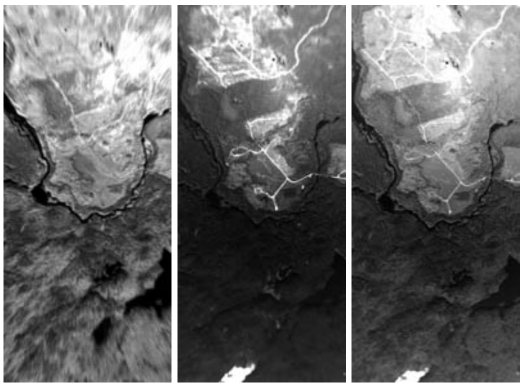


Figure 1: A sample FIFEDOM dataset after re-projection and calibrations, from left to right 800 nm, 550 nm and 670 nm over the same site and the same time

The accuracy of the FIFEDOM datasets was validated against CASI data, which was collected simultaneously.

For ground feature categories, namely road, vegetation, water, had good agreement between CASI and FIFEDOM exhibiting R2 correlation of 0.9223 in Green band and 0.9535 in Red band, as shown in Figure 2.

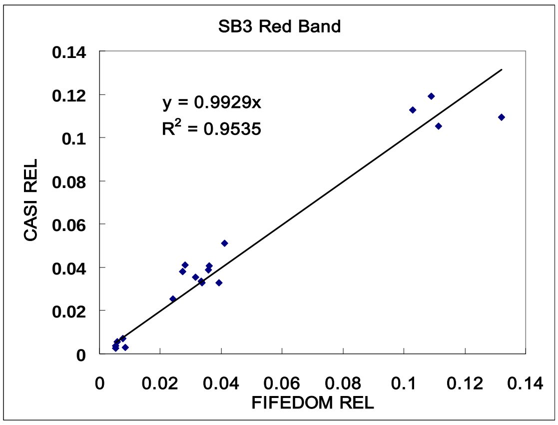
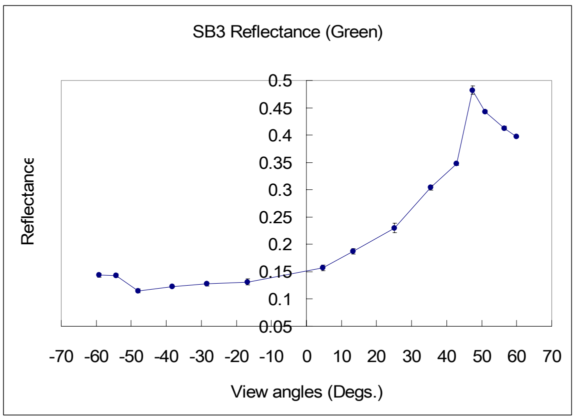


Figure 2: The comparisons of the FIFEDOM reflectance versus the CASI reflectance collected, SB3 indicates it is Black Spruce site # 3

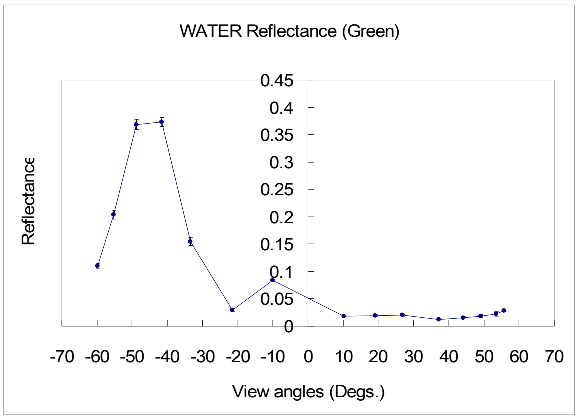
II. Multi-angle Signatures Generated from FIFEDOM Images

After all of these calibrations and corrections, the FIFEDOM data generate the canopy multi-angle signatures. These signatures were validated against simulation data, namely the SPRINT model and GHOST [2]. The SPRINT model simulation parameters were either directly measured from the field, such as tree height, crown size etc. or simulated using PROSPECT model, such as black spruce leaf level reflectance and transmittance [3].

A BRDF shape agreement had been obtained from the comparison results. As samples, one canopy (SB) and water signatures are shown in Figure 3.



a



b

Figure 3: Multi-angle signatures generated by FIFEDOM data (a: SB Green band, b: Water Green band)

III. Angular Indices Studied from Simulation Data and Derived from FIFEDOM

The angular signatures of vegetation canopies are considered to be correlated with their structures. In this study, an angular index sensitive to the crown shape was developed. This index, which describes the Normalized Hot Spot Depth (NHSD), is calculated by the two nearest neighbor points to the hot spot along the solar principal plane. The two points are denoted as the Hot spot Right (HR) and the Hot spot Left (HL). The NHSD is defined as:

$$NHSD = \frac{x_{HR} - x_{HL}}{x_{HR} + x_{HL}} * \frac{y_{HR} - y_{HL}}{y_{HR} + y_{HL}}$$

where x is the view zenith angle and y is the reflectance

The NHSD is sensitive to the tree structural parameter, the Ratio of Crown Radius and half vertical Height (RCRH). The relationship can be expressed as:

$$\mathrm{RCRH} = a * Shape * C\_LAI * NHSD$$

where a is an empirical coefficient; *Shape* equals to 1 and 2 for cone-shaped and ellipsoid-shaped canopies, respectively. C_*LAI* is the canopy leaf area index

For the FIFEDOM data used in this study, a = 3 and C_LAI (Canopy LAI) was measured from the field. In future study, the C_LAI would be derived from the general shape of the angular signatures. The predicted RCRH were compared with field measurements and the result is shown in Figure 4.

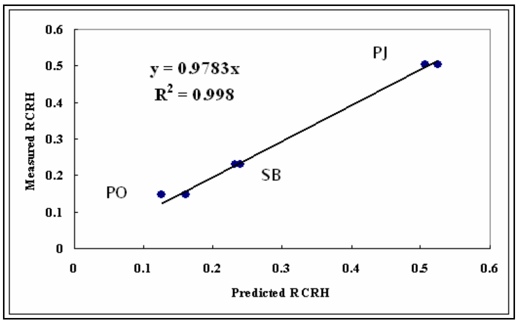


Figure 4: The comparison results of RCRH calculated by the index and the field measurement

IV. Conclusions

FIFEDOM had completed its hardware and software development. It had completed its data calibrations and corrections processing implementations. The future study will focus on its applications, such as in forestry structural parameters retrievals.

The study of RCRH, which is a very useful parameter in forest modeling, had demonstrated FIFEDOM data's potential in multi-angle structure research. It also had shown the existence of the correlation between the angular index and the canopy structures.

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References

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