A METHOD FOR LEAF GAP FRACTION ESTIMATION BASED ON MULTISPECTRAL DIGITAL IMAGES FROM MULTISPECTRAL CANOPY IMAGER

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ABSTRACT

Gap fraction is a very important parameter to the indirect estimation of the true Leaf Area Index. In this paper, we combined the multispectral digital imageries (RGB color imagery and Near-Infrared imagery), which were obtained from a new device called Multispectral Canopy Imager (MCI), to estimate gap fraction. A new method incorporated with CIE L’a’b’ color space has also been proposed to segment the multispectral digital imagery. The preliminary results of the estimated gap fraction have been showed in the conclusions section and been proved to be very well.

1. INTRODUCTION

The determination of gap fraction in forest monitoring by means of hemispherical photography has already been demonstrated [1]. Digital hemispherical photography analysis provides a valuable alternative for the accurate quantitative extraction of gap fraction from the digital images [2]. The estimation of gap fraction is a very important step to the indirect estimation of the true Leaf Area Index (LAI).

Efforts have been paid on the estimation of gap fraction from digital photograph, whereas data processing from traditional optical RGB imagery is still one of the technical challenges. More researches are still needed for the accurate segmentation of the gap fraction from field image, which will have significant influence on the further study of LAI.

In this paper, we will combine the multispectral digital imageries (RGB color imagery and NIR imagery), which were obtained from a new device called Multispectral Canopy Imager (MCI) [6], to estimate gap fraction. Before estimating the gap fraction from the multispectral digital imageries, image registration have been processed between the RGB and NIR digital imageries based on the normalized cross-correlation. Then, a new method incorporated with CIE L’a’b’ color space [7] has been proposed to segment the multispectral digital imagery. The preliminary results have been showed in the results and conclusions section.

2. METHODOLOGY

2.1 Data acquisition

Data used in our study is obtained from a new device called MCI (Multispectral Canopy Imager, see Figure 1) [3]. This new device was developed based on the characteristic of the strong absorbance in visible (VIS) band and the high scattering in NIR band for canopies. Multispectral digital images in NIR and VIS bands can be obtained at quasi-real-time in different observation zeniths and azimuths.

![Figure 1. Illustration of the MCI (Zou et al., 2009 (Fig. 1)]](image-url)
2.2 Image Registration

One problem is that VIS and NIR image pairs may be out of registration, when the VIS and NIR filters of MCI are exchanged manually. In this case, the VIS and NIR image pairs will have a slight offset due to the wind and the camera orientation deviation. As the identification of image features depends on that the VIS and NIR image pairs are spatially matched for the same scene, the registration must be performed accurately.

This registration process is showed in Figure 2. First of all, we pick points that identify the same features or landmarks in the VIS and NIR images using the normalized cross-correlation. Then, a spatial transformation is inferred from the positions of these control points. Finally, the spatial transformation is applied to the input image to bring it into alignment with the base map. Details are showed as follows:

\[
\gamma(u,v) = \frac{\sum_{x,y} [f(x,y) - \overline{f}(u,v) - \overline{f}]^2}{\sum_{x,y} [f(x,y) - \overline{f}]^2} \sum_{x,y} [f(x,y) - \overline{f}]^2
\]

where, \( f(x,y) \) is the pixel value of one band of sub-image pairs with line \( x \) and column \( y \), \( \overline{f} \) is the mean of another band of sub-image pairs (called template) and \( \overline{f}_{u,v} \) is the mean of \( f(x,y) \) in the region of the template.

The matrices of normalized cross-correlation are then computed to detect the control points in each sub-image pair. After deleting some bad points, effective control points are used to infer a spatial transformation.

Since the shapes of the component within image pairs are unchanged, we used a simple and effective 'nonreflective similarity' transformation (include translation, rotation and scaling) to infer the transformation matrix.

\[
\begin{bmatrix}
sc = scale \times \cos(angle) \\
ss = scale \times \sin(angle)
\end{bmatrix}
\]

\[
[u \ v] = [x \ y \ 1] \times \begin{bmatrix}
sc & -ss \\
ss & sc \\
tx & ty
\end{bmatrix}
\]

where, \( scale \) is the scale factor, \( angle \) is rotation angle, \( tx \) is the \( x \) translation and \( ty \) is the \( y \) translation, \((x,y)\) is the coordinate of a certain pixel in input image or unregistered image, \((u,v)\) is corresponding coordinate in base image or registered image.

Once the transformation matrix is determined, we can apply it to the input image to bring it into alignment with the base map.

This transformation type needs at least 2 pairs of control points, and using more than 3 pairs will produce a perfect result in our experiment. Figure 2 shows the registered multispectral images using the mentioned method in this section.
2.3 Imagery segmentation

In this section, a CIE \( L^*a^*b^* \) color space has been introduced to segment the multispectral digital images. The CIE \( L^*a^*b^* \) (abbreviated as \( L^*a^*b^* \), also as Lab) color space is an international standard for color measurements, adopted by the Commission Internationale d’Eclairage (CIE) in 1976. \( L^* \) is the luminance or lightness component, which ranges from 0 to 100 represent black and white respectively, and parameters \( a^* \) (negative values indicate green while positive values indicate magenta) and \( b^* \) (negative values indicate blue and positive values indicate yellow), which range from -120 to 120 [5]. The transformation of coordinates of the RGB color space into coordinates of the \( L^*a^*b^* \) color space can be achieved by incorporated with CIE-XYZ system [6], as described in formula (4), (5) and (6).

\[
\begin{align*}
\begin{bmatrix}
X \\
Y \\
Z
\end{bmatrix} &= 
\begin{bmatrix}
X_r & X_g & X_b \\
Y_r & Y_g & Y_b \\
Z_r & Z_g & Z_b
\end{bmatrix}
\begin{bmatrix}
R \\
G \\
B
\end{bmatrix}
\end{align*}
\]

Here, \( X_0 \), \( Y_0 \) and \( Z_0 \) are the CIE XYZ tri-stimulus values of the reference white point. \( X \), \( Y \), \( Z \) are the displayed RGB values obtained from the transfer functions and the \( 3 \times 3 \) matrix is the measured CIE tri-stimulus values for your CRT’s (Cathode Ray Tube) three channels (i.e. \( X_r \), \( Y_r \), \( Z_r \) are the measured CIE tri-stimulus values for the red channel at maximum emission).

According to the characteristic of the \( L^* \) dimension in \( L^*a^*b^* \), which describes the luminance or lightness component in multispectral digital images, we segment the synthetic multispectral photograph with a thresholding value in \( L^* \) dimension to detect sky and vegetation. First, we combined the NIR band, the RED and GREEN bands and then transformed the composited multispectral image into the \( L^*a^*b^* \) space. At last, the composited image would be segmented with a suitable thresholding value of \( L^* \) component and the gap fraction can be estimated accordingly.

3. RESULTS AND CONCLUSIONS

The main goal of our work in this paper is to estimate the gap fraction of forest by combining the multispectral digital imagery obtained from a Multispectral Canopy Imagery. A new method is proposed by using a thresholding value of \( L^* \) dimension in the \( L^*a^*b^* \) color space to segment the composited multispectral image. Figure 3 shows a RGB photograph (up) and a NIR photograph (down). Figure 4 shows the composited false color photograph (up) and the segmented result of it (down). From the preliminarily segmented photograph, the gap fraction with a value of 0.2828 was calculated. It seems to generate a good result when using our proposed new method to estimate gap fraction from the multispectral photograph.

\[
\begin{align*}
L^* &= 116 \times f(Y / Y_n) - 16 \\
a^* &= 500 \times [f(X / X_n) - f(Y / Y_n)] \\
b^* &= 200 \times [f(Y / Y_n) - f(Z / Z_n)] \\
f(t) &= \begin{cases} 
1 & \text{if } t > 0.008856 \\
7.787 * t + 16 / 116 & \text{if } t \leq 0.008856
\end{cases}
\end{align*}
\]
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5. REFERENCES


