Reflectance Distribution Function Measurements with Near Infrared Cameras

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Abstract: In this paper, a new Method for estimation of grow index based on Reflectance Distribution Function measurements with Near Infrared cameras is proposed. Due to a fact that Near Infrared camera data is proportional to total nitrogen while that shows negative correlation to fiber contents, it is possible to estimate nitrogen and fiber contents with ground based camera data and remote sensing satellite data. Through regressive analysis between measured total nitrogen and fiber contents, it is found that there is a good correlation between both then regressive equations are created. Also it is found that monitoring of a grow index measured with networks cameras is valid.
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1. Introduction

Vitality monitoring of vegetation is attempted with photographic cameras [1]. Grow rate monitoring is also attempted with spectral reflectance measurements [2]. Total nitrogen content corresponds to amid acid which is highly correlated to Theanine: 2-Amino-4-(ethylcarbamoyl) butyric acid so that total nitrogen can be used for a measure of the quality of plant leaves. Also fiber content in plant leaves is highly correlated to the grow rate of plant leaves. Both total nitrogen and fiber content in plant leaves are highly correlated to the reflectance in the visible and near infrared wavelength regions and vegetation index derived from visible and near infrared data so that it is possible to determine most appropriate plant leaves harvest date using the total nitrogen and fiber content in the plant leaves which are monitored with ground based visible and near infrared cameras and with visible and near infrared radiometers onboard remote sensing satellites. Namely the most appropriate time for harvesting plant leaves is whenever total nitrogen shows the maximum and fiber content shows the minimum. It, however, is not so easy because no one knows the minimum and maximum and because grow rate cannot be estimates with fiber content which is monitored with just cameras and radiometers perfectly. Therefore, it is required to monitor grow rate with the other method with a much precise manner [3].

Bidirectional Reflectance Distribution Function gives the reflectance of a target as a function of illumination geometry and viewing geometry. The method depends on wavelength and is determined by the structural and optical properties of the surface, such as shadow-casting, multiple scattering, mutual shadowing, transmission, reflection, absorption and emission by surface elements, facet orientation distribution and facet density method of plant leaves has a good correlation to grow index of plant leaves so that it is possible to monitor an expected harvest amount of plant leaves. It can be done with network cameras. Method monitoring is well known as a method for vegetation growth [10], [11]. On the other hand, degree of polarization of vegetation is attempted to use for vegetation monitoring together with new plant leaves growth monitoring with method measurements [10].

2. Proposed Method

The proposed method for method measurements is illustrated in Figure 1. Visible and NIR network cameras are equipped on the pole in order to look down with 0-90 degrees of incident angle which depends on the location. The pole is used for avoidance of frosty damage to plant leaves using fan mounted on the pole (approximately 6 m above the ground). With these network cameras, reflectance in the wavelength region of 550nm (red color) and 870nm (NIR) at the several elevation angles are measured results in method measurements assuming that vegetated areas are homogeneous and flat. From the acquired image, four portions of small pieces are extracted for elevation angles of Spectralon (almost 0 degree), 25.5, 51 and 76.5 degrees. From the first portion of image, reflected radiance from the Spectralon is estimated. Meanwhile, almost flat plant leaves are extracted from the other second to fourth portion of images for estimation of Bidirectional Reflectance Distribution Function. There are many plant leaves angles and also plant leaves angle is changed depending on wind direction and speed. Through visual perception, it is possible to extract such plant leaves which looks almost flat situation. Taking a ratio between Spectralon of radiance and plant leaves radiance, the reflectance at the plant leaves at the location which corresponds to 25.5, 51 and 76.5 degrees of elevation angles is estimated then method can be calculated.

Look angle of the cameras with wide viewing angle (100 degree for both horizontal and vertical directions) of lens are fixed at 45 degree of elevation angle so that the camera acquire the field from 0 to 90 degree of elevation angle (Angle is measured with a digital angle meter with 0.1 degree accuracy). The geometric relation between camera and plant leaves is known so that we can calculate method. The cameras acquire the image every 20 minutes.

In order to express un-isotropic characteristics of angle dependency of reflectance of plant leaves with one parameter, Minneart coefficient is calculated with the measured method characteristics at 0, 25.5, 51 and 76.5 degrees of elevation angles through regression analysis. Minneart coefficient is used for estimation of Grow Index. Minneart coefficient is assumed to be increased with growing new plant leaves. Old plant leaves used to be shown Lambertian surface (Menneart coefficient=1). From the surface of the old plant leaves, new plant leaves is grown results in increasing of Menneart coefficient. It is obvious that reflectance of new plant leaves is greater than that of old plant leaves, in particular, in the near infrared wavelength region. Cross section of new plant leaves in the field of view at each viewing angle; in particular, for the large off-nadir angle is increased so that Minneart coefficient is increased with growing of new plant leaves.

In the proposed method, visible and near infrared cameras are used for reflectance and method measurements. The cameras are mounted on the pole which is used for fan which is mainly used for frost damage avoidance. Also cameras are connected each other with wireless LAN (Local Area Network) and make measurements automatically. Also we put the Spectralon on the plant leaves manually once a day just before measurements for calibration purpose. In order to avoid influences of pixel-to-pixel sensitivity difference, spectral response difference, out-of-band response, vignetting, a limited portion of camera images are used. Also only the pixels data situated in the center of the optics viewing angle are used for reflectance and method measurements assumed to be directed to the normal and zenith direction is selected). Sensitivity stability is key issue. Because Spectralon is measured only once a day so that spectrometer sensitivity has to stable enough for one hour (reflectance and method measurements takes about one hour). It is also obvious that meteorological conditions have to be monitored. Meteorological conditions are fundamental characteristics of the plant leaves grow.

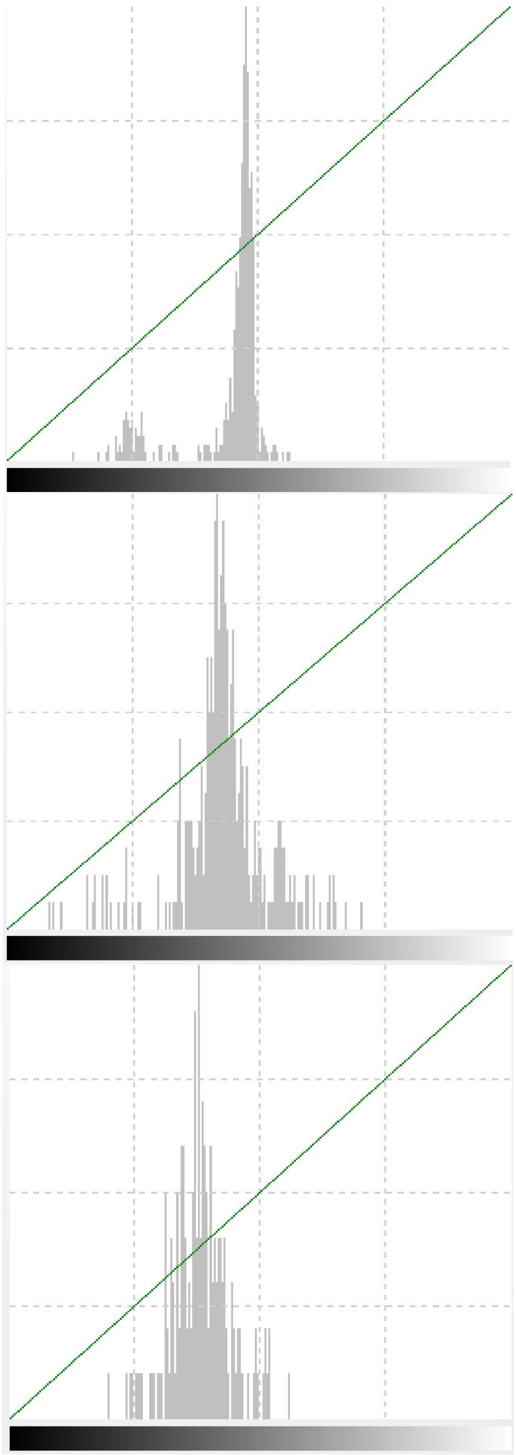
3. Experimental Results

Examples of the acquired camera images of off-nadir angles of 25.5, 51 and 76.5 degrees (portion of images) are shown in Figure 1(a), (b) and (c), respectively. Through visual perception, one piece of plant leaves which is situated in the horizontal and zenith directions is extracted from the image as is shown in Figure 1(d), (e) and (f) for 25.5, 51 and 76.5 degrees of off-nadir angles. Figure 1 (g), (h) and (i) also shows histogram of the piece of plant leaves of the green colored image for Figure 1 (d), (e) and (f), respectively. Through a histogram analysis, reflectance can be calculated with mean of pixels of the one piece of plant leaves and pixel value of the Spectralon. Histogram in the Figure 1.

(a) 25.5degree

(b) 51 degree

(c) 76.5 degree



(d) Extracted plant leaves from 25.5 degree of image (e) That from 51 degree image (f) That from 76.5 degree image
(g) 25.5 degree (0.97) (h) 51degree (0.8) (i) 76.5 degree (0.75)

Figure 1: Histogram of green color of a plant leaves extracted from the acquired image and reflectance at the off-nadir angle of 25.5, 51 and 76.5 degrees

Usually, new plant leaves start to grow in the begging of April and grow-up rapidly. Theanine in new plant leaves increases in accordance with grow-up. Then Theanine changes to Catechin due to sun light so that Theanine decreases for the time being. This paper focuses Bidirectional Reflectance Distribution Function monitoring results for the firstly harvested plant leaves only. Figure 2 shows the Bidirectional Reflectance Distribution Function changes.

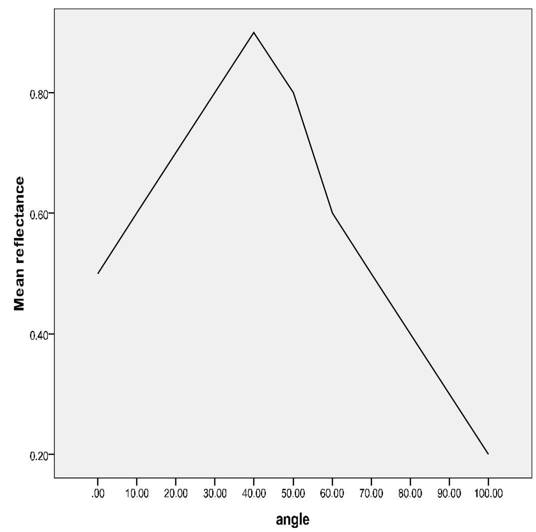


Figure 2. Approximated Minneart reflectance function derived from regression analysis with the measured reflectance at the four off-nadir angles

4. Conclusions

In this paper, Acquired images with visible and near infrared web cameras mounted on the pole that is used to avoid frosty damage with fan for convection of the boundary atmospheric layer are also useful to monitor the mass and quality of new grow plant leaves because observation angle ranges from zero (Nadir) to 76degree which is very sensitive to the size (length) of new plant leaves in the sense on method changes. Also it is possible to estimate mass and quality of new plant leaves based on monitored camera imagery data and satellite imagery data derived total nitrogen and fiber contents in the new plant leaves. Theanine: 2-Amino-4-(ethylcarbamoyl) butyric acid that is highly correlated to nitrogen contents in new plant leaves are changed to Catechin [11], [12] due to sun light.

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