VEGETATION INDEX MEASUREMENT WITH TWO-WAVELENGTH LIDAR SYSTEM

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ABSTRACT: Airborne laser scanning has become leading edge technology for the measurement of topography and for mapping the Earth's surface. However, the properties of ground objects are difficult to be exactly described by the lidar with single wavelength. According to different spectral reflectance of objects in visible and infrared range, we try to acquire the properties of the objects with a two-wavelength lidar system. Vegetation index measurement with a two-wavelength lidar system was proposed in this paper. First, the problem of wavelength selection was discussed based on spectral analysis, and two wavelengths separately in red and near-infrared were determined. Second, components of the novel lidar were presented in detail. As the transmitting source, lasers with selected wavelengths were utilized for objects detection, and then back-scatter intensities were acquired through photoelectric conversion. Third, a test for ground objects was carried out in the laboratory in order to illustrate the capabilities of the lidar. The spectral reflectance was acquired after calibration based on standard whiteboard, and NDVI values of different objects were calculated. The results show that the two-wavelength lidar could capture the vegetation index and discriminate different objects effectively. Thus the properties of objects such as health condition of the vegetation could be obtained, and vegetation monitoring could also be achieved.

1. INTRODUCTION

Airborne laser scanning (ALS) has become a well-established technology for the measurement of topography and for mapping the Earth's surface (A. Wehr and U. Lohr, 2009; K. Kraus and N. Pfeifer, 1998). As an active measurement way of remote sensing, lidar also has great advantages in inferring estimates of vegetation structure and biomass (Lim, K. and Treitz, P., 2004). Thus monitoring in the growth and nutrition status of vegetation has become the primary research content in remote sensing.

However, traditional lidar is applied to detect only by a single wavelength and the backscatter intensity information of target characteristics is poor. Thus the properties of ground objects can not be exactly described by lidar remote sensing. According to great ability of hyperspectral remote sensing in detecting the characteristic of ground objects, early attempts were carried out to combine information from multiple sensors, but it just could improve the approximation in a certain extent (Hyde P et al., 2006).

In this study, we propose a two-wavelength lidar system to measure the properties of objects. In this way, available information from backscatter intensity will be increased with the addition of another wavelength for detection. And vegetation index of the object could be obtained by the lidar through measurements of spectral reflectance in visible and infrared range. As a result, the lidar system could clearly supervise the nutrition status of vegetation. In the following, the principle of the wavelength selection for detecting will be discussed and the components of new instrument will be presented in detail. Finally, the capabilities of two-wavelength lidar will be also testified.

2. WAVELENGTH SELECTION

First of all, detection wavelengths of the two-wavelength lidar system have to be correctly chosen. In visible and infrared range, all the objects have characteristic spectral reflectance as a response, and properties of objects can be availably distinguished through the different spectral reflectance. The new lidar will be designed to acquire different backscatter intensity of objects in the specific wavelengths, which can differentiate properties of objects effectively. As a result, the detection wavelengths should contain useful response information of objects as much as possible.

In order to measure the vegetation index through the lidar, two wavelengths separately in red and near-infrared are determined. By choosing the two specific wavelengths, such an instrument is successfully tested and vegetation index especially NDVI (Normalized Difference Vegetation Index) can be got. These important indexes are useful to assess the physiological status of vegetation, and to remotely measure photosynthesis. The wavelength selection of the lidar is based on the analysis of spectral data.

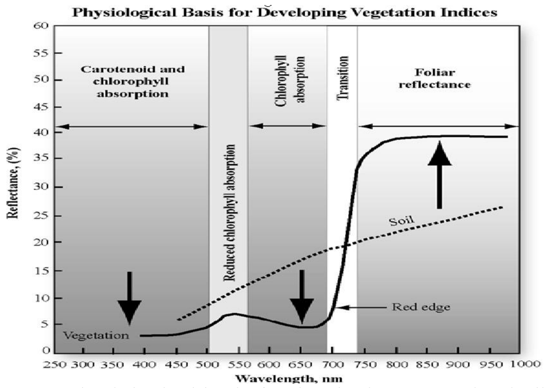

Figure 1. Physiological basis for developing vegetation indices

Figure 1 shows the physiological basis for developing vegetation indices. Typical spectral reflectance characteristics for healthy green grass and bare dry soil for the wavelength from 250nm to 1,000 nm (John R. Jensen, 2005) is presented. Many of the indices make use of the relationship between red and near-infrared reflectance associated with healthy green vegetation. As the dominant pigment in healthy green leaves, Chlorophyll-a strongly absorbs visible light in the region from 600nm to 700nm to achieve the photosynthesis. However, reflectance is high in the near-infrared region because of the strong reflection of the cell structure of the leaves. What's more, red edge around 700nm is referred as transition (P. J. Curran et al, 1997). As a whole, the red edge is very sensitive in absorption and reflectance features related to the vegetation growth status.

The vegetation is likely healthy, provided there is less reflected radiation in red wavelength than in near-infrared wavelength. The different spectral reflectance of healthy and unhealthy vegetations is exhibited in Figure 2.

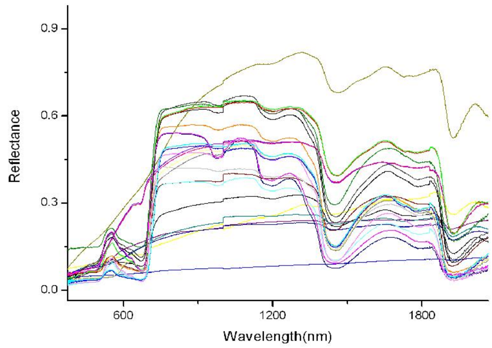

Figure 2. Spectral reflectance of healthy and unhealthy vegetations

From the picture, we can see that the detection wavelengths close to red edge are useful of discriminating healthy vegetation from the unhealthy vegetation. So, the two wavelengths in red and near-infrared are correctly chosen.

After determination of two detection wavelengths, vegetation index could be calculated. A few of the most widely adopted vegetation indices related to the red and near-infrared range are available. For example, Normalized Difference Vegetation Index (NDVI):

$$NDVI = (R_{nir} - R_{red}) / (R_{nir} + R_{red}) \tag{1}$$

Where, R_{red} is the ratio of red reflected radiant flux, and R_{nir} is the near-infrared radiant flux. The Normalized Difference Vegetation Index (NDVI) relies on the distinctive optical properties of chlorophyll containing vegetation, and has been shown to be useful in estimating vegetation properties. Finally, NDVI measured by the lidar can be used for vegetation observation.

3. SYSTEM DESCRIPTION

A new breadboard instrument of two-wavelength lidar system has been developed. The system is mainly composed of three parts: the transmitting sub-system, the optical receiver sub-system and data acquisition and processing sub-system. The block diagram of the two-wavelength lidar system is shown in Figure 3.

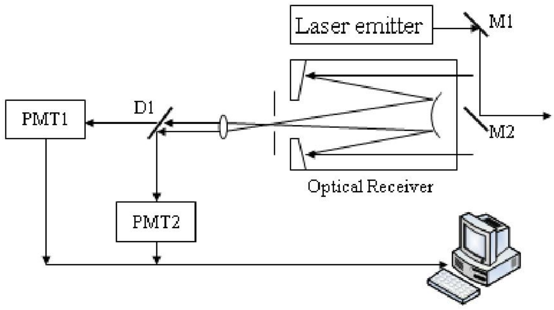

Figure 3. The block diagram of two-wavelength lidar

The two-wavelength lidar system works as follows. The laser emitter transmits the laser bean separately in red and near-infrared range. The laser light will be reflected to detect objects through the holophote composed of mirrors M1 and M2. Then backscatter signals can be received by the Schmidt-Cassegrain telescope with 200mm diameters, and be divided into two wavelengths through dichroic filters D1. Subsequently, PMT1 and PMT2 are used to transform optical to electrical as the devices of photo-electricdetection. Finally data acquisition and processing sub-system in the computer can obtain the back-scatter intensities of the objects. Figure 4 presents the demonstration system of two-wavelength lidar.

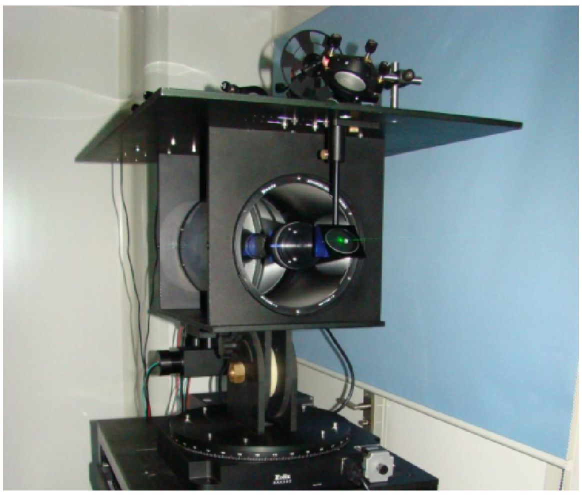

Figure 4. Two-wavelength lidar system

4. EXPERIMENT AND RESULTS

4.1 System Calibration

Backscatter intensities of the objects can be acquired with the two-wavelength lidar. In fact, we would like to obtain the backscatter reflectance in two wavelengths. Thus system calibration was carried out to get further reflectance of the objects.

Standard whiteboard (Set of grey standards, cella with BK-7 window, nominal 8°, hemispherical reflectance of 99% calibrated from 400-2400 nm) is chosen to be the target for the system calibration. In this way, the relative intensity of whiteboard could be obtained as the reference. The reflection is then calculated using the equation:

$$R = I_{mess} / I_{ref} \tag{2}$$

Where, I_{ref} is the relative intensity of whiteboard, and I_{mess} is the backscatter intensity acquired by the lidar system. As a result, the ratio is just the backscatter reflectance of the objects.

4.2 Laboratory test and Results

In order to demonstrate the feasibility and applications of the two-wavelength lidar, measurements were taken in the laboratory during October and November 2009. The instrument with two wavelengths is supposed to make an effective distinction between the different objects. And four kinds of objects including sophora healthy leaves, sophora deciduous leaves, black soil and cement were chosen. In addition, whiteboard was also used for the target of system calibration.

All the operations were carried out in the darkroom for reducing the influence of environment. After running of the two-wavelength lidar system, the laser light was transmitted horizontally towards the chosen objects in a distance of several meters. Then backscatter intensities of the different objects in the red and near-infrared range could be acquired and displayed in the computer. For example, the backscatter intensity of whiteboard was shown as the Figure 5.

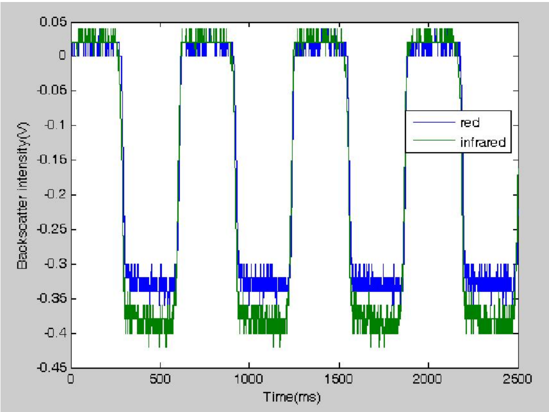

Figure 5. Backscatter intensity of whiteboard

According to the backscatter intensity of whiteboard, the spectral reflectance of the objects could be successfully calculated. Table 1 showed the average results of reflectance about the four different objects in two wavelengths.

Table 1 Backscatter reflectance of four objects in two wavelengths

	Red	NIR
sophora healthy leaves	0.0636	0.4559
sophora deciduous leaves	0.1885	0.4466
black soil	0.1062	0.1179
cement	0.1983	0.2153

The results of Table1 presented that backscatter reflectance of the objects were dramatically different in the two wavelengths. Especially, radiation in the red is significantly attenuated while radiation in the NIR is strongly reflected for sophora healthy leaves. Finally, we can calculate the NDVI with the reflectance of these two wavelengths according to the equation (1) about the NDVI evaluation. NDVI values of the four objects were shown in Figure 6.

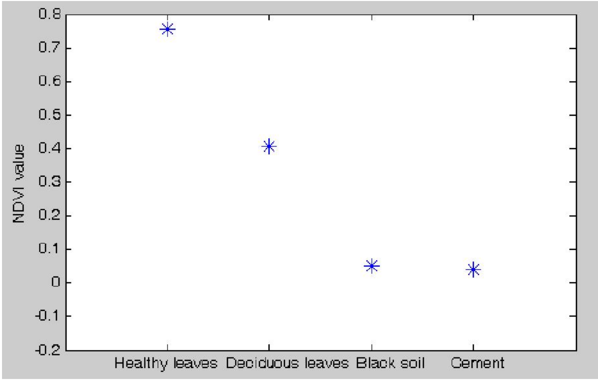

Figure 6. The NDVI values of the four objects

Thus vegetation index was successfully obtained through the measurement of two-wavelength lidar system. From the Figure 6, we could saw that all the NDVI values of the objects were different. In this way, four objects could be exactly distinguished from each other. As a result, the properties of objects were obtained and capability of the two-wavelength lidar could be testified.

5. CONCLUSION

In this paper, a two-wavelength lidar used for measuring vegetation index is presented. The principle of wavelength selection is introduced and the instrument is designed to measure the spectral reflection of objects in two specific wavelengths. The lidar has been proved efficient on object detection through laboratory test. Properties of objects such as nutrition status of the vegetation could be obtained, and we could exactly achieve vegetation monitoring. However, there are still some uncertainty factors in the system and its potential capabilities need to be better certified in the future.

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