

Method of Non-destructive Measurement for Living Leaf Area and Its Instrument Development

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Abstract

A new leaf area measuring instrument was developed by using poly-Si photoelectric sensor board and uniform lighting slab with light source systems for the fast, nondestructive and accurate measurement of living leaf area. In this paper, the measuring instrument are introduced from two aspects: hardware and system structure. It provide a new blade clamping device to effectively measure living blades, and this system can repeatedly analyze data and automatic record analysis data. Besides, a non-destructive measurement is provided to measure leaf area on live, and the factors influencing the precision are analyzed, which are used to reduce the measurement error. It was concluded that a new measuring method and instrument were developed for the detection of leaf area.

Keywords

Blade clamp, instruments, living leaf area, non-destructive measurement, error analysis.

1. Introduction

Leaf area plays a key role in growth status diagnosis and prediction model of green plants. And it is an important basis for the practical management for the crops [1-3]. Leaf area is one of the most important factors affect the photosynthesis of plant and has certain correlation with the nitrogen content of plant. T.L etc. proposed the relationship between leaf area and nitrogen content in [4], they established the corresponding model and got a convincing validation. In addition, leaf area is an important index reflecting the crops growth and physiological state, and it is also the essential reference factors while research on crop cultivation, genetics and breeding [5-7].

The accurate measurement of leaf area is the premise of the research. With the development of science and technology, the method of leaf area measurement experiences from the coordinate paper method, the coefficient method, copy-weighing method, the estimate method and other traditional methods [8-9] to modern methods which based on computer technology. So far, there are several methods using computer for leaf area measurement: Digital image processing and spectral scanning etc. S.J etc. proposed a kind of leaf area measurement method based on digital image processing [10]. This method has high accurate and non-destructive. But the image acquisition is complex: Every shooting picture, it requires the same detection distance of the leaf, and the difficult operation, poor reliability and high-cost make it impracticalness. F.C and Z.L etc. proposed a method of measurement based on analyzing digital image which captured by Canopy analyzer (CI2110) and fisheye lens respectively [11-12]. It overcomes the defect existing in the conventional image processing method. However, the new method has its shortcomings: High-cost, complex operation and difficult to promote. D.E [13] studied a kind of portable precision photoelectric scanning leaf area meter which greatly improves the measurement accuracy, but it is sensitive to the external factors. Therefore, developing a kind of portable, easy to operate, reliable, high precision and low-cost plant leaf area meter is significant.

This paper proposed a new measurement solution and designed measuring instrument accordingly. It includes the following aspects: detection system constituted by a double-crystal silicon photoelectric sensor board and luminescent panel; calculate the leaf area through the model; the analysis of factors affecting the measurement accuracy.

2. Overall Design of Instrument

2.1 The Computer

Normally, a computer that can run VC6.0 programs can run this measurement software stably. Because the analysis image needs to occupy more memory, at the same time, in order to improve the speed of analysis, the CPU is required to have higher running speed. This paper uses the computer is that the CPU is above PIV, the memory is more than 1g, the remaining space on hard disk is more than 5g, the operating system is above Windows XP and install the Microsoft.Net framework program running environment.

2.2 The Camera

The camera is a key device in this method, which is used to collect digital images. When measuring the common plant leaves, it requires the camera with a resolution of 1M or more and smaller image distortion. If there is a special case, the camera resolution and other indicators can be selected according to the accuracy requirements of the measurement. The Logitech C270 HD camera are used in this paper, and it can shoot up to 300M pixels of digital photos, and its storage format can be *.jpg, *.bmp and other commonly used formats, which can be used in the calculation process.

2.3 The Laser Source

In this research, the red point laser source are used. The laser is red (the wavelength is nm), and the projected facula of point laser source is regular circle with higher brightness and less power, and it doesn't injure living blades when irradiating leaves.

2.4 The Blade Holder

The blade holder is a folder device that the upper plate is the transparent plexiglass, the lower plate is the white plexiglass, as shown in Fig.1. It retain a certain distance between the two plates, which can effectively flatten the leaves while not damaging the living body Leaves. The back panel is white, which compared with the leaf color (mostly green, cyan) and the laser spot color is obvious. The blade holder size is determined by the blade to be measured.

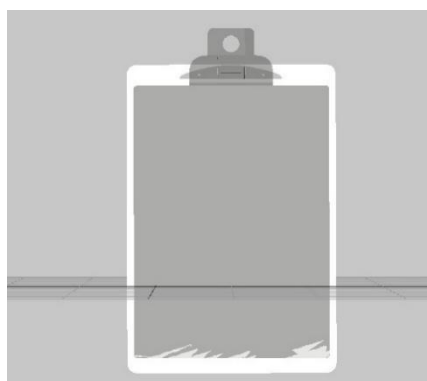


Fig.1 Sketch of the blade holder

In the system hardware, the image acquisition device is composed by the camera. The measurement principle of the first part claims that it must make the camera and the laser source center axis is parallel and fixed during the installation process, as shown in Fig.2.

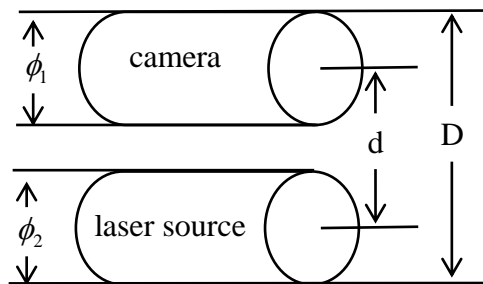


Fig.2 Image acquisition device

The camera diameter is ϕ_1 , the laser source diameter is ϕ_2 , the distance between them is D , and the actual distance d between the two axes of them can be calculated by the formula(1).The acquisition device connects computer by USB, drives by UVC, and the windows system does not need to install the driver.

$$d = D - \frac{\phi_1 + \phi_2}{2} \tag{1}$$

3. The System Construction

The structure of the non-destructive leaf area measurement system in this paper is shown in Fig.3. Firstly, using the blade holder, camera and laser source to collect the blade images, using the computer analyze the images and identify the leaves and laser spots position, and then calculating the leaf area according to the whole image center coordinates, laser spot center and the total number of leaf pixels, finally, analyzing and correcting the error.

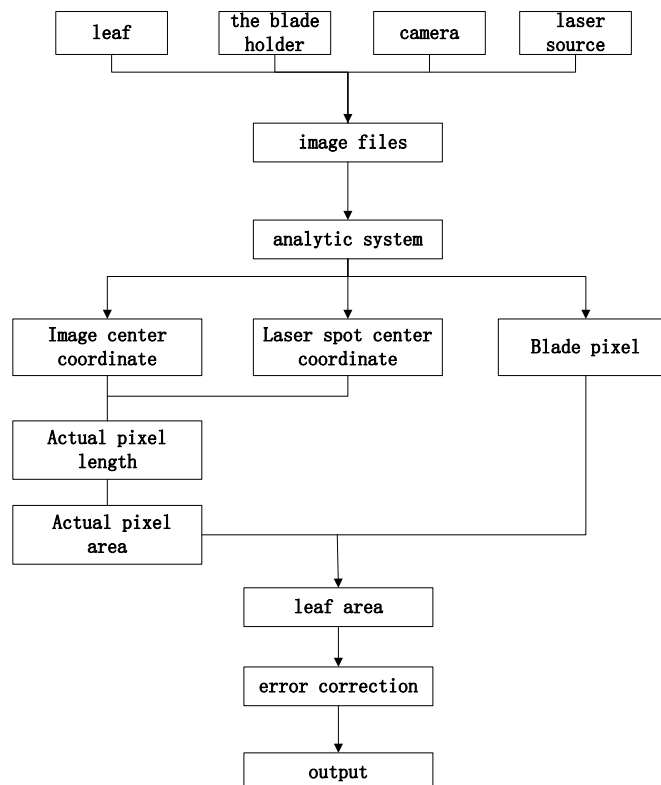


Fig.3 Structure of non-destructive leaf area measurement system

3.1 The Digital Image Collection

The collection of leaf image is the basic work of leaf area calculation, and it requires the collection method is simple and the acquisition speed is fast. This work needs 1 to 2 people, firstly, select the suitable blade holder according the shape and size of the leaf, and gently put the leaf into the blade

holder as far as possible to make the blade flattened. At this time, make the image rubbing device access to the computer, and open the digital camera and laser source, adjust the position, shoot the image when the lens is aligned with the blade and the laser spot is projected onto the blade. Note: flattening the blade and making the lens and the blade holder plane as vertical as possible during the shooting process.

3.2 Recognition of Laser Spot and Leaf

The color patterns commonly used in computer can be divided into three categories: RGB, CMYK and HSI, which can be converted to each other. In order to reduce the computational complexity, this paper takes the RGB model, and the data collected by the image acquisition device default format is JPG, and get the image R (red) component, G (green) component, B (blue) component.

Laser spot region extraction: on a white background plate, the laser spot is regular and red circle spot, the leaf is green, so in the R (red) component of image, the corresponding value of laser spot area is high, and the leaf region is low; on the contrary, in the G (green) component of image, the corresponding value of laser spot area is low, and the leaf region is high. In this paper, using the difference method to subtract the G component from the R component of the image to magnify differences between the two regions, the background is disappear at the same time, and then recognizing the laser spot area by the threshold segmentation algorithm and binarization, the result is shown in Fig.4.

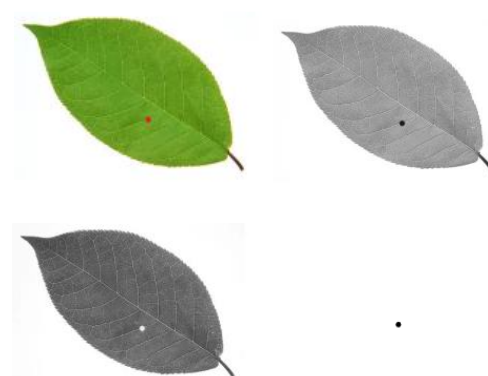


Fig.4 diagram of laser spot extraction

Similar to the laser spot identification method, in the B (blue) component, the corresponding value of the red laser spot and green leaf area are smaller, and can simply use the threshold segmentation and binarization to recognize the blade area.



Fig.5 the blade area by threshold segmentation and binarization

3.3 The Leaf Area Calculation

According to the principle of measurement, it needs the central coordinates of the whole image, the center of the laser spot and the total number of blade pixels to calculate the leaf area. Method is as follows:

1) Calculate the image central coordinates: the camera parameters are set up and the image resolution is fixed, that is to say the number of image pixels in horizontal direction (x axis) and vertical direction (Y axis) is known, assume L_x and L_y , then the central coordinate of the image (x_c, y_c) can be calculated as follows:

$$\begin{aligned}x_c &= L_x / 2 \\y_c &= L_y / 2\end{aligned}\quad (2)$$

2) Calculate the center coordinate of laser spot: after the laser spot region extraction and image noise filtering, it can get a binarization and regular laser spot image, as shown in Fig.4, and the centroid of the image is the laser spot center. The centroid of regular planar graph (x_r, y_r) is calculated as follows:

$$\begin{aligned}\bar{x} &= \frac{\int x dA}{A} \\ \bar{y} &= \frac{\int y dA}{A}\end{aligned}\quad (3)$$

Where the A is the area of a plane figure. One pixel is 1 Units, it is dA , then the area of an image is the number of pixels; the integral is the sum of the pixel coordinates, so the formula for calculating the laser spot image center can be written as:

$$\begin{aligned}x_r &= \frac{\sum_{i=1}^{N_r} x_i}{N_r} \\ y_r &= \frac{\sum_{i=1}^{N_r} y_i}{N_r}\end{aligned}\quad (4)$$

Where (x_r, y_r) is the centroid coordinate, (x_i, y_i) is the i th pixel point coordinate, N_r is the number of pixel point.

Then, calculating the image distance (the number of pixel differences in image) $(\Delta x, \Delta y)$ between the center coordinates of image and the central coordinate of laser spot. And the actual distance between them is d , so the length of each pixel l can be calculated by formula:

$$l = \frac{d}{\sqrt{\Delta x^2 + \Delta y^2}}\quad (5)$$

Then calculating the actual area of each square pixel s by formula:

$$s = l^2\quad (6)$$

3) Calculate the leaf area: similar as the extraction of laser spot, firstly making the G component minus the R component of image, then separating the leaf area and background by threshold segmentation, binaryzation and filler white dots etc, as shown in Fig.5. Counting the total number pixels of blade N , and then calculating the actual area of leaves S by formula:

$$S = N \times s\quad (7)$$

3.4 Recording Data

This system can be repeatedly analysis, after analysis, it can automatic store analysis data in chronological order. Besides, it can be exported as Excel file according to requirements and be convenient to query historical data.

4. The Error Analysis and Correction

The visual image analysis method is analysing the actual area of single pixel point and the number of pixels, and other methods of measuring leaf area is not very accuracy, so in order to accurately check the accuracy of this method, the indirect method is used in this paper. Measured with green colored paper(it is dark green and light green stripes, and its color close to the true leaves, and its area can be accurately measured) instead of real blades, to verify the effects of various factors on leaf area measurement. Here is a detailed analysis of the blade on the standard area plate.

4.1 The Effect of Camera Resolution

In digital images, the resolution refers to the amount of information stored in the image, and is the number of pixels in each inch of the image. Then, the higher the resolution, the more pixels in each image, the more accurate of the object description, and the more accurate of the leaf area calculation. However, as the resolution increases, the computation time is growing, which is obviously detrimental to rapid measurements.

The calculation results and computational processing time in different resolutions are analysed, and the result shows that the resolution is not the higher the better, it should consider the combined effects of computational accuracy and actuarial speed, and take a compromise value. So, this paper take the resolution is 640*480, under this condition, the error is in the allowable range and the calculation speed is better.

4.2 The Image Noise Error

In order to reduce the influence of noise during the image acquisition process, using the continuous shooting technique and filtering algorithm. In each shot, 5 images are collected and the average of 5 images is taken as the final acquisition result.

The laser intensity is relatively high, when it irradiate the blade folder will produce a circle of red halo forming image noise, which will affect the calculation of the coordinates of the spot center. In this paper, the spatial domain median filtering algorithm is used to remove halos effectively, and obtaining the edge details of laser spot and correct the distortion of laser spot image. The result is as follows:

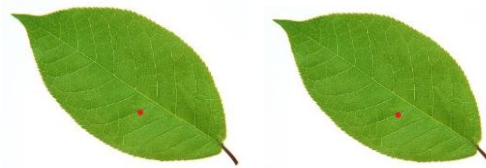


Fig.6 Contrast before and after halo removal

4.3 The Shooting Angle Error

It is difficult to ensure the camera axis perpendicular to the blade plane when blade digital image acquisition, there will always be a certain angle. Tilt the camera to 5 degrees, 10 degrees, 15 degrees, 20 degrees to take a photo of the base area (1cm reference paper) and compared with the photo taken under vertical condition, the results show that the shooting angle tilts within 20 degrees, the maximum error between shooting angle and base conditions is $\pm 2.0\%$.

4.4 The Influence of Image Distortion

As the camera is shooting, there is some distortion on the edge of the lens. To solve this problem, respectively using the central area and the corner part of the camera to shoot the image under the reference area condition and compared, its maximum relative error is within 3.2%. If using wide-angle or fisheye lens, it will produce greater distortion and difficult to measure, it can not be used in image acquisition process.

5. Conclusion

Compared with existing methods of measuring leaf area, the measurement system of leaf area based on laser and image processing technology can measure the living area of various shapes, sizes blades in real time, quickly and accurately. It can retain the original image of the measured blade, the calculation process is completed by the computer automatically to avoid the influence of artificial factors, and reduce the labor intensity of the operator. The calculation speed is fast, the data is accurate, the precision is high, the price is cheap, and the technology is feasible, so it is especially suitable for a lot of measurement work about leaf area, and it is a kind of method of application value.

With the continuous development of computer and stereo photogrammetry technology, the further research is about a single measure method for the whole plant including leaf area, leaf area density, biomass, and many other factors to achieve a more accurate quantitative study of agricultural and forestry sciences.

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