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Fast and accurate method for estimation of leaf area index by image processing system: An innovative concept

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Abstract
Leaf is a key functional organ of photosynthesis and transpiration. Leaf area plays an important role in plant growth analysis and photosynthesis and susceptibility of different plants to insect pest attack. Leaf area index is one of the most important parameters in ecological and environmental studies. Leaf area index (LAI) is widely used to describe the photosynthetic and transpiration surface of plant leaves and also a helpful parameter in evaluating, damage caused by leaf diseases and insect pests, estimation of the diseases severity for application of pesticide and fertilizers. Thus fast and accurate estimation of leaf area is significant. Considering the cost of tools, applicability, accuracy, efficiency, and the convenience for outdoor measurement, the image processing technique can be a considerable method. In this paper we have proposed a solution to calculate single Leaf Area and Leaf Area Index based on the counting of the leaf pixels using Information Technology Application Adobe Photoshop CS software for different leaves. Results show that soft wares give above 98% accurate results and are fast and cheap compared to manual grid count method. The single leaf area can thus be computed easily based on this pixel counting method. Analysis and experimental results indicate that the proposed method is an efficient and precise method for single leaf area measurement

Keywords: Leaf area, LAI, area measurement, image processing (java and adobe photo shop), plant leaves, graphical method for leaf area

Introduction
Indian economy is agriculture based. As agriculture make great impact on Indian economy, augmentation of agricultural production is necessary. The use of Information and Communication Technology in agriculture is increasing day by day as it gave promising result by influencing agricultural production. E-Agriculture is now a hot topic of research in agriculture field, emerging with focus on the enhancement of agricultural and rural development through improved information and communication processes [1].

Leaf is a key functional organ of photosynthesis and transpiration, the size of leaf area impacts greatly on the physiological function of the plants [2].

Leaf area plays an important role in plant growth analysis and photosynthesis and susceptibility of different plants to insect pest attack. Leaf area index (LAI) is one of the most important parameters in ecological and environmental studies & widely used to describe the photosynthetic and transpiration surface of plant leaves [3]. LAI can be simply defined as the amount of leaf surface area per unit ground area, and has broad applications in eco-physiology, water balance modelling and characterization of vegetation-atmosphere interactions. Leaf area monitoring is an important tool in studying physiological features related to the growth, photosynthetic and transpiration process & evaluating damage caused by leaf diseases and insect pests, estimation of the diseases severity for application of pesticide and fertilizers [4]. Thus fast and accurate estimation of leaf area is significant.

Leaf area is measured by various methods like- Grids approximation [5], using plan meter [6], displacement regression models [6-8], image processing [9-11], and so on. Among them, using plan meter is highly accurate, however, with high cost of equipments as well. And other methods such as the grids estimation, displacement computation and regression models are low in cost techniques, but very time consuming. Grid counting method is highly accurate but it is very tideous job. As a rapid, non-destructive, accurate and low cost method, image processing technology has been widely used in determination of LAI. In this paper we have proposed a solution to calculate Leaf Area and Leaf Area Index using Adobe Photo shop CS.

2. Material and Method

A. Materials

HP LaserJet M1005 MFP scanner, standard objects of known size (here 2cmx2cm blue square paper has been taken) which act as a reference Object, standard graph paper (1mm), Leaves of Ten different plant species e.g. Jute (*Corchorus olitorius* L.), Radish (*Raphanus sativus* L.), Spinach (*Spinacia Oleracea* L.), Brinjal (*Solanum melongena* L.), Red amaranth (*Aamaranthus gangeticus* L.) Cabbage (*Brassica oleracea* L.), Potato (*Solanum tuberosum* L.), Bitter guard (*Momordica charantia* L.), Mustard (*Brassica campestris* L.) and Tomato (*Lycopersican esculentum* L.).

B. Methods

Leaves of 10 different types of plants were selected with varying shape and size. Samples are collected from crop field located at Islampur, Mursidabad, India. Leaf area is calculated using proposed algorithm and results are compared with measurements of grid count method.

2.1 Pixel counting method

Original images of plant leaf are acquired using HP laser scanner. All the images are stored in JPEG format. Leaf area is calculated using known object's area.

1.1 Image Acquisition

The images of different plant leaves are captured using a HP LaserJet M1005 MFP scanner. For image acquisition, leaf is placed on white paper sheet with 2cm ×2cm blue square as shown in figure 1. All scanned images are stored in JPEG format.

Fig 1: Image acquisition technique

1.2 Image Processing: Finally we run the software for image processing which include setting RGB threshold for background removal, pixel counting of the digital images of leaf samples and blue square object. 2

Figure 2 shows the the steps involved in the leaf image processing and pixel counting by using Adobe Photoshop CS.

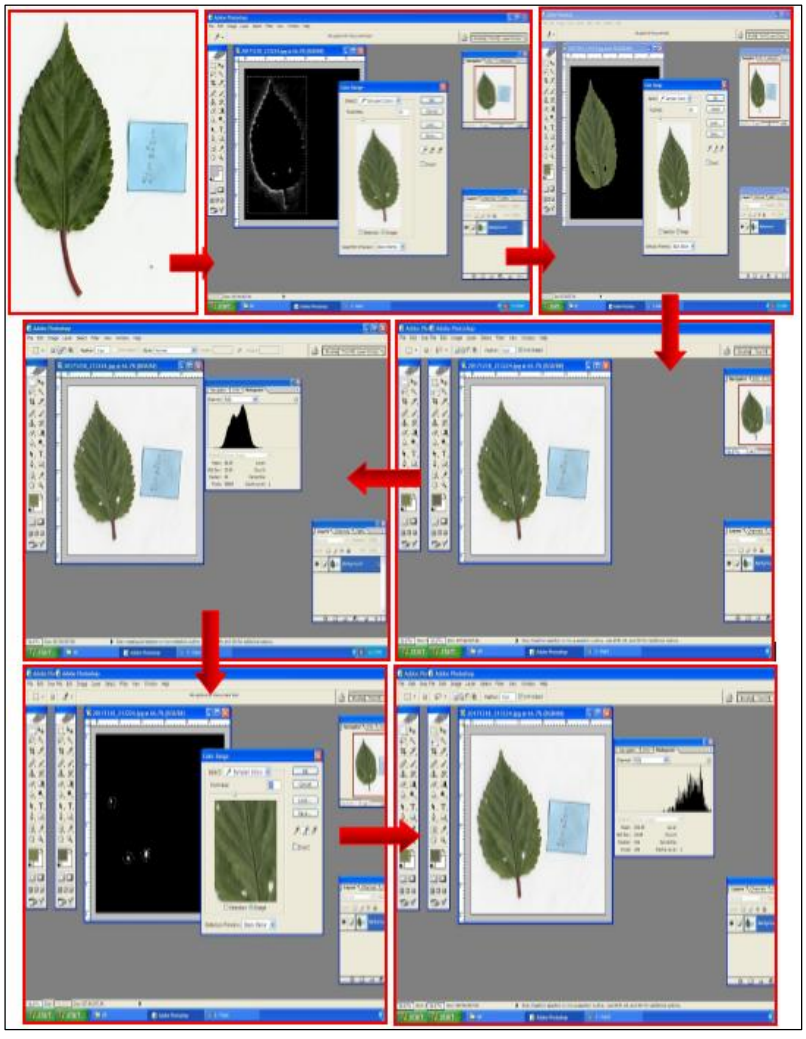

Fig 2: Image processing and pixel counting of leaf sample by Adobe Photoshop CS (arrow indicates the steps of work)

2.2.1 Steps

Select the leaf outline roughly and set RGB threshold for
↓
Background separation
↓
Background removal
↓
Count the pixels of total leaf
↓
Select the damaged parts **roughly** and set RGB threshold for
↓
Background separation
↓
Background removal
↓
Count the pixels of damaged parts

2.1.3 Leaf Area Calculation

First number of pixels in Remaining leaf region (RL), Damaged leaf region(DL),Total leaf region (TL) and known object region (blue sqare paper) are calculated using Adobe Photoshop CS. In this paper known object is 2cm ×2cm. So actual area of square object is $\mathbf{4cm2}$. Finally leaf area (A_l) is computed using following equation,

$$A_l = \frac{Pl}{Ps} \times A_s \quad (1)$$

Where A_s is area of square object, which is $4cm^2$. c is obtained by counting number of pixels in square object and P_l is obtained by counting number of pixels in leaf region.

2.2 Grid Counting Method

Leaf under experiment is first removed from plant and placed on grid paper. Grid size is $1mm^2$. Outlines of the total leaf and holes within the leaf lamina are drawn by pencil on grid paper as shown in Fig 3. Finally Total leaf area (TLA), damaged leaf area (DLA) and remaining leaf area (RLA) is measured by counting grids covered by leaf.

Fig 3: Grid approximation

Error in area, measured by proposed algorithm is calculated using formula (2),

$$\text{Error Percentage} = \left(\frac{Ag - Al}{Ag}\right) \times 100\% \quad (2)$$

Where A_l is leaf area, calculated by proposed algorithm and A_g is leaf area calculated by grid count method.

3. Result and Discussion

Experiments were carried upon 50 leaves of 10 different vegetables. Some of the sample leaves are shown in fig 4. To test the performance of new software method, leaves were selected with varying size and shape. We have selected leaves of Jute, Radish, Spinach, Brinjal, Red amaranth, Cabbage, Bitter guard, Mustard, and Tomato which have different dimensions [13]. The area of leaf calculated by two methods namely Graphical and our proposed method (Adobe Photoshop CS). Among this the Graphical method (grid count method) was considered as a standard method.

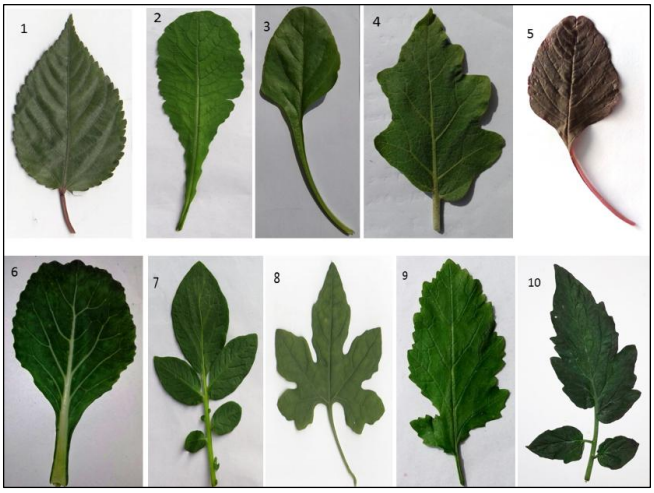

Fig: Sample leaves of 10 different species

Area of above sample leaves is measured using proposed algorithm and grid count method. The comparative results with relative error are as given in table 1.

Table 1: The comparative results of above sample leaves measured using proposed algorithm and grid count method

Image		RLA	DLA	TLA	% of damage	Error %
1	Al (Cm^2)	10.734	0.076	10.810	0.703	0.16
	Ag (Cm^2)	10.576	0.075	10.651	0.704	
2	Al (Cm^2)	102.23	4.78	107.01	4.466	0.67
	Ag (Cm^2)	102.36	4.82	107.18	4.497	
3	Al (Cm^2)	18.33	0.698	19.028	3.668	0.59
	Ag (Cm^2)	18.53	0.71	19.24	3.690	
4	Al (Cm^2)	41.71	2.73	44.44	6.143	0.77
	Ag (Cm^2)	41.67	2.75	44.42	6.190	
5	Al (Cm^2)	16.24	0.436	16.676	2.614	0.59
	Ag (Cm^2)	16.29	0.44	16.73	2.630	
6	Al (Cm^2)	262.02	4.57	266.59	1.714	0.78
	Ag (Cm^2)	258.79	4.55	263.34	1.727	
7	Al (Cm^2)	45.05	2.421	47.471	5.099	0.73
	Ag (Cm^2)	45.11	2.443	47.553	5.137	
8	Al (Cm^2)	24.64	0.782	25.422	3.076	0.31
	Ag (Cm^2)	24.75	0.788	25.538	3.085	
9	Al (Cm^2)	63.485	0.454	63.939	0.710	1.37
	Ag (Cm^2)	63.576	0.461	64.037	0.719	
10	Al (Cm^2)	36.34	1.541	37.881	4.068	0.63
	Ag (Cm^2)	36.36	1.552	37.912	4.093	

The Relative error can compare values and describe the accuracy of measured values. Relative errors of leaf area calculated by proposed image processing technique indicate that the relative error value is less than 1% and the accuracy is more than 99% (except image 9. Which showed 98% accuracy) as compared to grid approximation. Average accuracy of developed algorithm is above 99% which is confirmed by above experiment.

4. Conclusion

Leaf Area Index is an important parameter for plant growth analysis and predict the yield. Grid count method is a conventional method for leaf area measurement. Though graphical method have very high accuracy but it is more laborious and time consuming when applied on large number of leaves [12].

This paper presents an innovative method for single leaf area estimation based on the counting of the leaf pixels in digital leaf image. The image processing method also have high precision and accuracy, it takes less processing time and cost effective also [14]. The system requires a Laser scanner, a PC, $2cm \times 2cm$ blue square paper as a reference object of known area and a white sheet and sample leaves. Images are acquired in JPEG format. Images are processed by background removal followed by setting of RGB threshold and pixels are calculated by using Adobe Photoshop CS. Finally the leaf areas (RLA, DLA, TLA), Damage percentage and Error percentages are calculated using the algorithm.

Experiments were carried upon leaves of 10 different garden vegetables containing tremendous variation in laminar leaf shape. Results show that following this method leaf area is measured accurately. Average accuracy of this algorithm is above 99% (except mustard above 98% approx.) which is confirmed by comparing the results with measurements of grid count method.

So, image processing technique can be an alternative approach for easy, fast and accurate, low cost method to calculate leaf area. Future to this it is needed to compute disease severity percentage on plant leaf and integrate both results for actual prediction of yield loss and plant growth.

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