Fast and Accurate Method for Leaf Area Measurement

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ABSTRACT

Leaf area plays an important role in plant growth analysis and photosynthesis. Traditionally leaf area is measured by regression equitation, grid count method, gravimetric method and planimeter.

In this paper a simple, fast and accurate algorithm for leaf area measurement using image processing is implemented. Image is acquired using digital camera and stored in JPEG format. RGB image is color transformed into CIELAB color space. Color transformed image is segmented using threshold technique. Threshold is calculated using OTSU's method. Holes in leaf region are filled using region filling technique. Number of pixels in square object and leaf region are calculated and leaf area is measured by number of pixels statistics. Accuracy of algorithm is above 99% which is confirmed by comparing the results of proposed algorithm with grid count method.

General Terms

Digital Image Processing, Image Segmentation.

Keywords

Image Segmentation, Color Transform, Plant Leaf Spot Disease, Leaf Area Measurement...

1. INTRODUCTION

Indian economy is based on agriculture. In total GDP agriculture contributes around 22% and 65% of Indian population is directly depend on agriculture [1]. As agriculture make large impact on Indian economy, it is necessary to increase agriculture production. Yield production depends on plant growth which is affected by light, temperature, water and mineral nutrients. Plant growth is depends on leaf area, number of leaf and stem, stem width and plant height.

Leaf area plays an important role in plant growth analysis and photosynthesis. Leaf area is measured using different destructive and non-destructive methods. In destructive methods first the leaf is removed from plant and then measured. In non-destructive methods dimensions of leaf are measured without removing the leaf. Traditionally leaf area is measured by regression equitation, grid count method, gravimetric method and planimeter.

Montgomery (1911) [2] suggested a formula for leaf area measurement which is, $A = b \times l \times w$. Where b is leaf shape coefficient, l is length of leaf and w is width of leaf. This method is non-destructive, quick and easier. But problem is that formula is not uniform for all plants as coefficient b differs among species.

In grid counting method [3] first the leaf is removed from plant and placed on a grid paper. Outlines of the leaf are drawn by pencil on grid paper. Finally leaf area is measured by counting grids covered by leaf. This method is accurate but laborious and time consuming when applied on large number of leaves.

Gravimetric method is also used for leaf area measurement [4]. In this method leaf is first removed from plant and placed on white paper. Paper is cut-out according to the shape of leaf. Now weight of this paper is compared to the weight of known area on the same paper. This method is also laborious and time consuming when applied on large number of leaves.

The planimeter offers a less time-consuming technique, but the precision is limited, especially for relatively small leaves [3].

Some researchers have used image processing techniques for fast and accurate measurement of leaf area [5-8]. Leaf area is measured using following steps: image acquisition, image pre-processing, leaf region segmentation, region filling and area calculation. Some researchers use contour extraction technique [5,6,7] for leaf region segmentation and others use threshold based segmentation [8].

In this paper an image processing based algorithm is implemented for leaf area measurement. The hardware used is a digital camera, a $2cm \times 2cm$ black square, PC and a white paper sheet. The leaf and square object are placed on white paper sheet and the image is taken using digital camera. Software is implemented in MATLAB 2010a. Experiments were carried upon 70 leaf samples which are different in shape and size.

This paper is organized in four sections. Methodology used is described in section 2 that includes 4 steps as follows, Image acquisition, image color transform, leaf region segmentation and leaf area calculation. Experimentation and results are presented in section 3. Conclusion to the paper is given in last section.

2. METHODOLOGY

Figure 1 shows the flowchart of the steps involved in the leaf area measurement. First images of plant leaf are acquired using digital camera. All the images are stored in JPEG format. To minimize the noise these images are color transformed from RGB image to CIELAB color spaces. Threshold is calculated by applying Otsu method on 'L' component of CIELAB color space for image segmentation. Segmented binary image is inverted in color and holes in leaf region are filled using region filling technique. In last leaf area is calculated using known object's area.
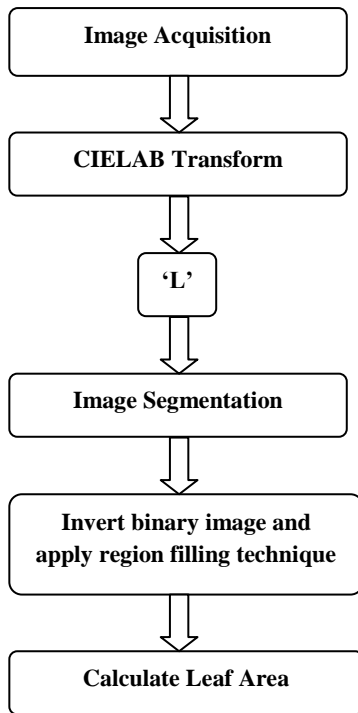
Fig. 1: Flow Chart for Leaf Area Measurement using Image Processing

2.1 Image Acquisition

The images of different plant leaves are captured using a CCD color camera (Soney: 16.1 mega pixels). Leaves are collected from field of Agriculture Research Station (A.R.S.) located at Fatehpur Shekhawati, Rajasthan, India. For image acquisition, leaf is placed on white paper sheet with 2cm × 2cm black square as shown in fig 2. All images are stored in JPEG format.

Fig. 2: Image acquisition system

2.2 Image Color Transform

To wipe out the noise which is introduced because of background, camera flash and veins RGB image is color transformed into CIELAB color space [9].

CIELAB system is device independent in which brightness and color information is independent of each other. In CIELAB color model brightness information is described by 'L' component. 'A' and 'B' describe color information. Conversion Formulas for LAB color model are [9],

$$L = 0.2126 * R + 0.7152 * G + 0.0722 * B \qquad (1)$$

$$A = 1.4749 * (0.2213 * R - 0.3390 * G + 0.1177B) + 128 \qquad (2)$$

$$B = 0.6245 * (0.1949 * R + 0.6057 * G - 0.8006 * B) + 128 \qquad (3)$$

2.3 Leaf Region Segmentation

Accuracy of leaf area measurement technique is depends on how accurate leaf and known object are detected. In this paper image is segmented using threshold technique. Threshold is applied on 'L' component of CIELAB color space. Threshold is calculated using OTSU's method [10]. Segmented image is binary image in which leaf and known object are segmented as same color and background is segmented as different color. This segmented image is inverted in color. There may be some cuts and spots on leaf because of diseases and insects. In segmented binary image background and these spots are in same color. Leaf area can't be measured accurately without filling these spots. These holes are filled using region filling technique.
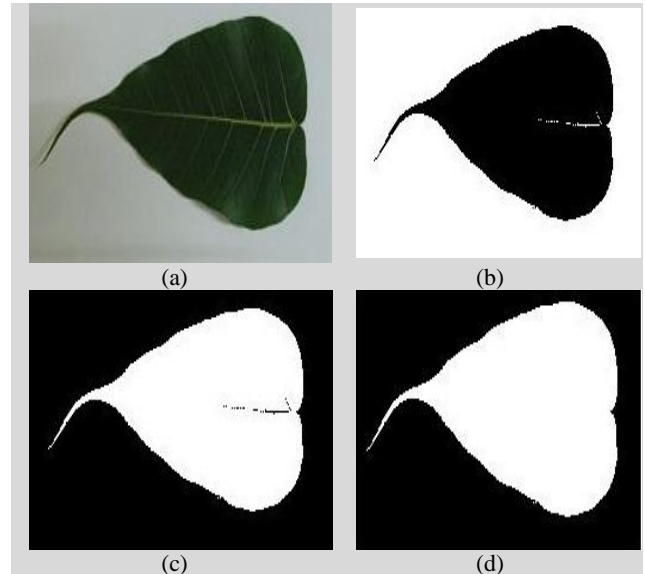

Fig. 3: RGB image of "Ficus Religiosa" (peepal) leaf (a), segmented image (b), inverted binary image (c), image after applying region filling technique (d).

2.4 Leaf Area Calculation

First number of pixels in leaf region and known object region are calculated. In this paper known object is 2cm × 2cm square. So actual area of square object is **$4cm^2$**. Now leaf area is calculated using following formula,

$$A_l = \frac{P_l}{P_s} \times A_s \qquad (4)$$

Where A_s is area of square object, which is $4cm^2$. P_s Is obtained by counting number of pixels in square object and P_l is obtained by counting number of pixels in leaf region. Finally leaf area (A_l) is calculated using above formula.

3. EXPERIMENTATION

Experiments were carried upon different shaped plant leaves. Area is calculated using proposed algorithm and results are compared with measurements of grid count method. Leaf is first removed from plant and placed on grid paper. Grid size is$1mm^2$. Outlines of the leaf are drawn by pencil on grid paper. Finally leaf area is measured by counting grids covered by leaf.

Error in area, measured by proposed algorithm is calculated using formula (5),

$$Error\ Percentage = \left(\frac{A_g - A_l}{A_g}\right) \times 100\% \qquad (5)$$

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

Experiments were carried upon 70 leaves of different species. Some of the sample leaves are shown in fig 4,
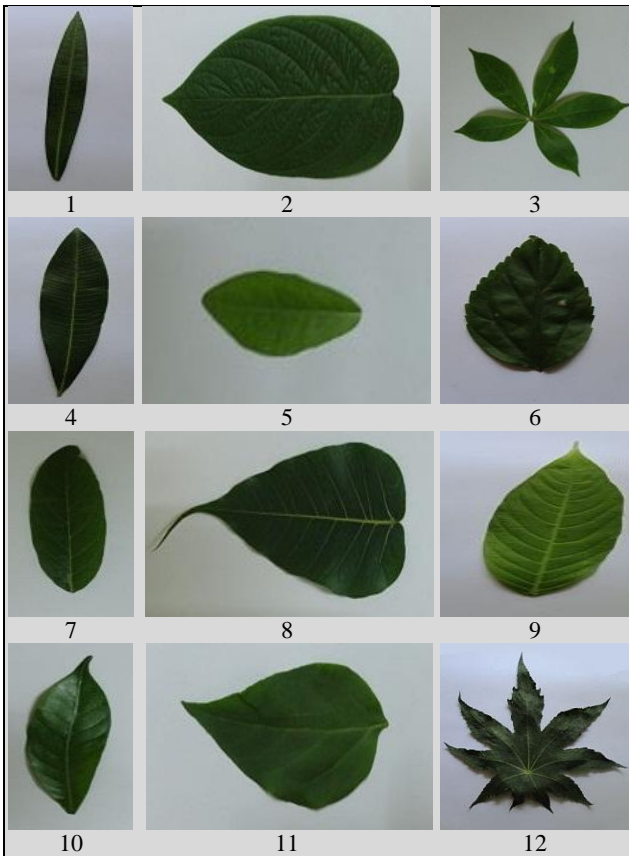

Fig. 4: Sample leaves of different species

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

Table 1: Comparison of results, measured by proposed algorithm and grid count method.

Image	$A_l(cm^2)$	$A_g(cm^2)$	Error
1	23.993	24.14	0.60
2	78.648	78.96	0.39
3	40.714	40.57	0.35
4	47.374	47.72	0.72
5	9.905	10.12	0.21
6	30.937	30.86	0.24
7	32.137	31.89	0.77
8	87.714	87.88	0.18
9	90.214	90.37	0.17
10	24.061	24.27	0.86
11	32.985	33.11	0.37
12	224.661	223.86	0.35

Average accuracy of developed algorithm is above 99% which is confirmed by above experiment.

4. CONCLUSION

Leaf area is an important part of plant to analyze the growth and predict the yield. Grid count method and gravimetric method are generally used for leaf area measurement. But these methods are laborious and time consuming when applied on large number of leaves.

An image processing based algorithm is implemented for leaf area measurement. The system requires a digital camera, a PC, $2cm \times 2cm$ black square object and a white sheet. Images are collected in JPEG format. Images are color transformed into CIELAB color space to wipe out the noise. Threshold is calculated on 'L' component of CIELAB color space by OTSU's method. Segmented binary image is inverted in color and holes in leaf region are filled using region filling technique. Finally leaf area is measured by pixel number statistic. The results are compared with measurements of grid count method

Experiments were carried upon 70 leaves of different species. Experimental results show that following this method leaf area is measured accurately. Average accuracy of this algorithm is above 99% which is confirmed by comparing the results with measurements of grid count method.

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.

5. ACKNOWLEDGEMENT

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