

Design and Development of Software for the Implementation of Image Processing Approach for Leaf Area Measurement

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Abstract-Several commercial softwares are available for plant leaf area measurement. But no freeware was available for leaf area calculation. This study proposed a freeware for calculating the plant leaf area. It was hypothesized that if the error between the calculated leaf area and the actual leaf area is low then it could be used for agronomical research. Leaves of brassica species, turmeric, soyabean and wheat with different size and shape were selected for the study. The platform used for image processing and leaf area calculation was DOTNET framework at the front end and SQL server at the back end. A digital scanner was utilized to obtain leaf images. The user can browse the scanned image of a leaf in any image format and the freeware automatically convert it into web compatible image format Joint Photographic Group. For color tonal distribution the histogram of images was computed. The colored image was converted into monochrome image by setting the threshold value in the color matrix. In image processing method leaf area was calculated through pixel number statistic. The results were compared with the results of Hewlett-Packard Scan Jet 7400C scanner and concluded that the error rate between them was less than $\pm 3\%$, $\pm 1.5\%$, $\pm 0.8\%$ and $\pm 2.5\%$ for brassica species, turmeric, soyabean and wheat leaves respectively.

Key words: Leaf Area, Image Processing, C#.NET, SQL, Freeware.

I. INTRODUCTION

Leaf is an organ of a plant. Monitoring leaf area is important for many physiological and agronomic studies, such as plant growth, photosynthesis and transpiration. Measuring leaf area removed as a result of insect herbivory can be useful for evaluating host-plant resistance, pesticide activity and plant-insect interactions. It is also helpful in evaluating the damage caused by leaf diseases and in analyzing fertilizer deficiency and environmental stress. Leaf area can be calculated by using direct and indirect methods. Direct methods are destructive. They are the most accurate, but they have the disadvantage of being extremely

time-consuming and as a result large-scale implementation becomes marginally feasible. Indirect methods have been developed that are nondestructive, inexpensive and fairly rapid (Baret *et al* 2004) but they are not very accurate.

Leaf area meters have been widely adopted for these measurements because of their ease of operation. But they are expensive and measuring leaf area by hand with a sampling grid is time consuming (Landis *et al* 2002). Also, Leaf area meter cannot handle large leaves. A large leaf has to be cut into smaller pieces and the area for each piece will have to be measured individually so that one can later obtain the area of the whole leaf; however this process can cause measurement errors. Experience has shown that the other methods are tedious, particularly when a large number of leaves are to be measured. Methods involving image processing based on video camera images and computer programs for analysis of these images permit automatic calculation of leaf areas, and of areas lost to herbivores or disease, depending on the computer programs used.

Landis *et al* (2002) used the public domain software (Image 4.0.2 for Windows) for measuring the surface area of objects in a digital format. The user was required to be familiar with the inbuilt image processing tools of the software to convert an image into monochrome image. Only then one could be able to calculate the leaf surface area. Cunha (2003) used the digital scanner to acquire leaf images with a resolution of 150 dpi. But this system was unable to deal with images having different resolutions. Hernandez-Hernandez *et al* (2009) examined the accuracy of two leaf area determination methods using digital photographs processed in Matlab and Computer Aided Design (CAD) software. While measuring, leaves should be kept as flat as possible to avoid area measurement errors due to curved leaves.

This study aimed to present an alternative image processing method for estimation of the plant leaf area by using computer programs. These computer programs were developed to process the images automatically having different resolutions. The user only needs to browse the scanned image of a leaf to calculate its area. A unit centimeter square (cm²) was selected to convert pixels to a unit of measurement. In image processing method leaf area was calculated through pixel number statistic. Also an image histogram was plotted to represent the tonal distribution in a digital image. It facilitated to check whether an image detail had been lost to blown-out highlights or blacked-out shadows.

II. MATERIALS AND METHODOLOGY

Leaf images of brassica species, turmeric, soyabean and wheat with different shapes and sizes were used to validate the proposed method. Leaf area calculated by commercial software dependent on Hewlett-Packard Scan Jet 7400C scanner was considered as standard area.

Existing Commercial Software:

The existing commercial softwares have many limitations. For example, commercial software developed by infotech sky drive India Pvt Ltd is dependent on Hewlett-Packard Scan Jet 7400C scanner. It is not compatible with any other scanner. It deals with only black and white bitmap images. Bitmap (.bmp) files are usually not compressed and, therefore, are not well suited for transfer across the Internet. It is unable to handle other image formats like .jpg, .png, .tif, .gif etc.

Proposed Freeware:

A freeware is software that is available for use at no monetary cost, but with one or more restricted usage rights such as source code being withheld or redistribution prohibited. For this, the platform used for image processing and leaf area calculation was DOTNET framework at the front end and SQL (Structured Query Language) server at the back end. Microsoft Visual Studio 2010 was used for making the user friendly interface. C#.NET language was used for writing the source code. SQL Server was used to create backup for the freeware. Leaf's height, width, resolution, area, date and time were saved in the database to maintain the record. A user can go through the record anytime to recover information if the system fails. This freeware is compatible with 32-bit as well as 64-bit processors.

In image processing method, leaf area was calculated through pixel number statistic. The digital images of leaves of brassica species, turmeric, soyabean and wheat with different size and shape were obtained by using a MP Navigator EX-CanoScan LiDE 100 scanner. These leaves can be scanned in any form such as colored, sepia, grayscale or black and white. The freeware automatically converted the colored image into black and white image by setting the threshold value in the color matrix. The digital images of leaves obtained can be saved in any image format i.e. .JPG, .BMP, .PNG, .TIF, .GIF etc. The new

freeware automatically converted any inputted image format into .JPG format so as to make it web-compatible.

The user only needs to browse the scanned image of a leaf to calculate its area. The leaf area was calculated in centimeter square (cm²) using the resolution of the images. The term resolution is often used for a pixel count in digital imaging. Resolution of an image depends upon the size of the pixel. The smaller the size of the pixel, the higher the resolution will be and the clearer the object in the image will be. Images having smaller pixel sizes occupy more space on the disk. Resolution is expressed in Dots per Inch (DPI). After processing, the black pixels of an image were counted as Pixel_{count}.

$$Leaf\ Area\ (Sq.\ cm) = \left(\frac{Pixel_{count}}{dpi^2} \right) * 6.4516$$

The error formula adopted was presented by Ali *et al* (2012), which is:

$$Error\ Rate\ (\%) = \left[\frac{A1 - A2}{A2} \right] * 100$$

Where: A1 is the estimated area by the proposed method, A2 is the actual area estimated by commercial software.

Also a histogram of an image was plotted to check whether an image detail had been lost to blown-out highlights or blacked-out shadows. An image histogram is a type of histogram that serves as a graphical representation of the tonal distribution in a digital image. It plots the number of pixels for each tonal value. By looking at the histogram for a specific image a viewer will be able to judge the entire tonal distribution at a glance.

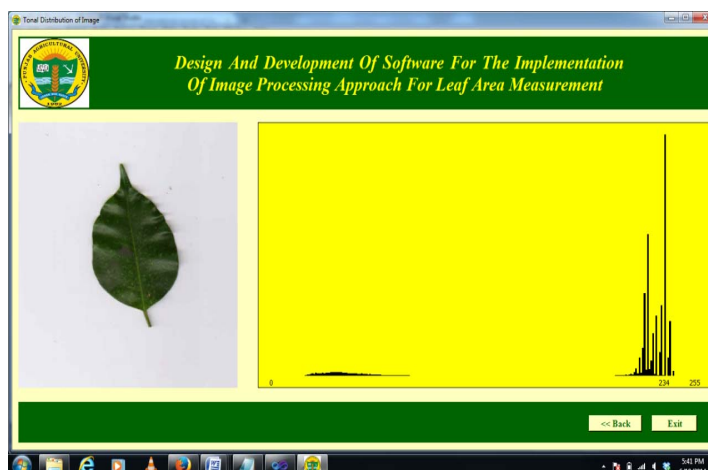


Fig. 1: Histogram of a leaf image

III. RESULTS AND TABLES

Test 1:

To test the performance of the new proposed freeware, leaves of brassica species, turmeric, soyabean and wheat with different size and shape were scanned by using Hewlett-Packard Scan Jet 7400C scanner. Area of same set of scanned leaves was calculated by using commercial software as well as proposed freeware. Leaf area calculated by commercial software dependent on Hewlett-Packard Scan Jet 7400C scanner was considered as standard area. Figure 2,3,4,5 compares the leaf area brassica species,

turmeric, soyabean and wheat leaves respectively, calculated by commercial software and proposed freeware. The results of proposed freeware and commercial software were compared and found that the relative error value was

typically less than $\pm 3\%$, $\pm 1.5\%$, $\pm 0.8\%$ and $\pm 2.5\%$ for brassica species, turmeric, soyabean and wheat leaves respectively. Figure 6 shows the graphs plotted to compare the error rate variations for the leaf samples.

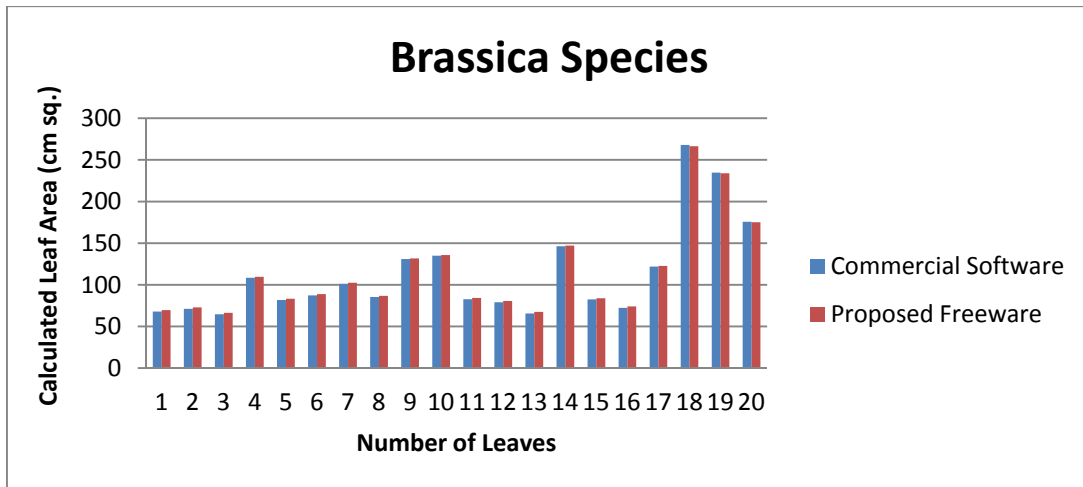


Fig 2: Comparison of Leaf Area of Brassica Species Leaves Calculated by Commercial Software and Proposed Freeware.

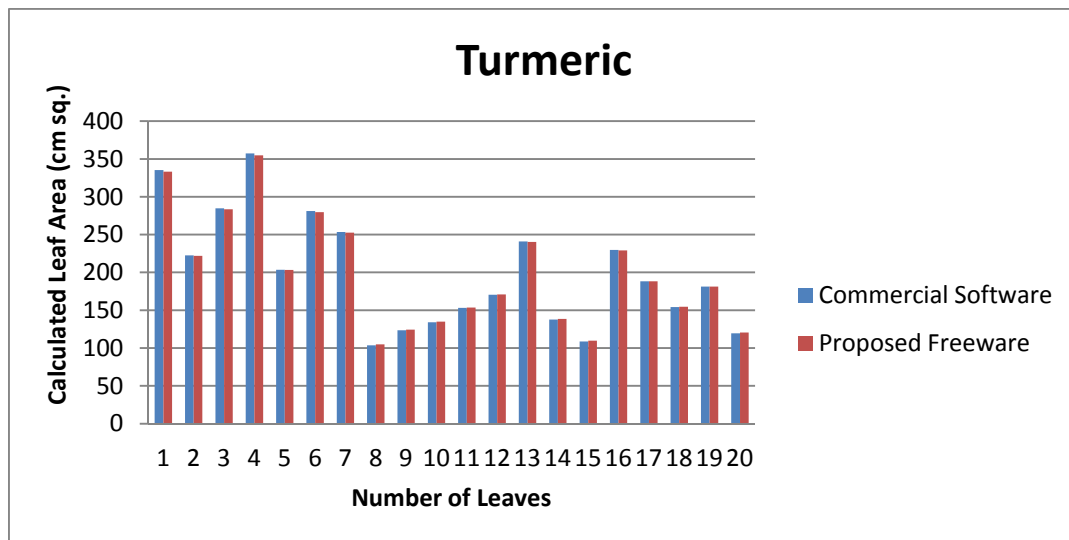


Fig 3: Comparison of Leaf Area of Turmeric Leaves Calculated by Commercial Software and Proposed Freeware.

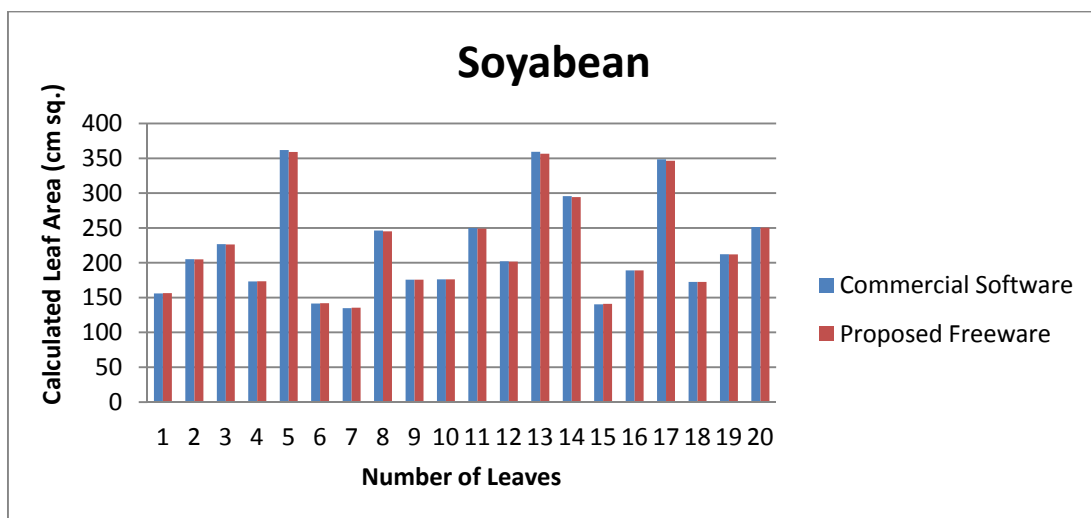


Fig 4: Comparison of Leaf Area of Turmeric Leaves Calculated by Commercial Software and Proposed Freeware.

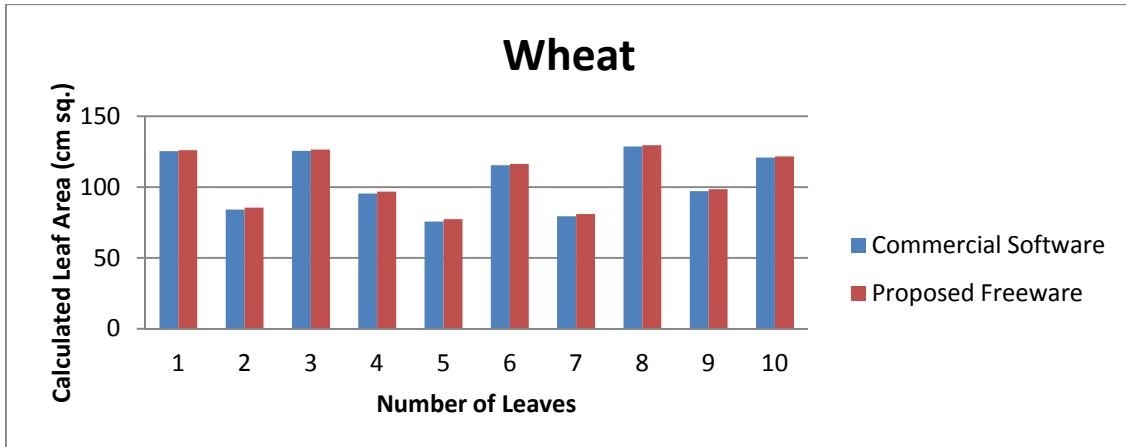


Fig 5: Comparison of Leaf Area of Turmeric Leaves Calculated by Commercial Software and Proposed Freeware.

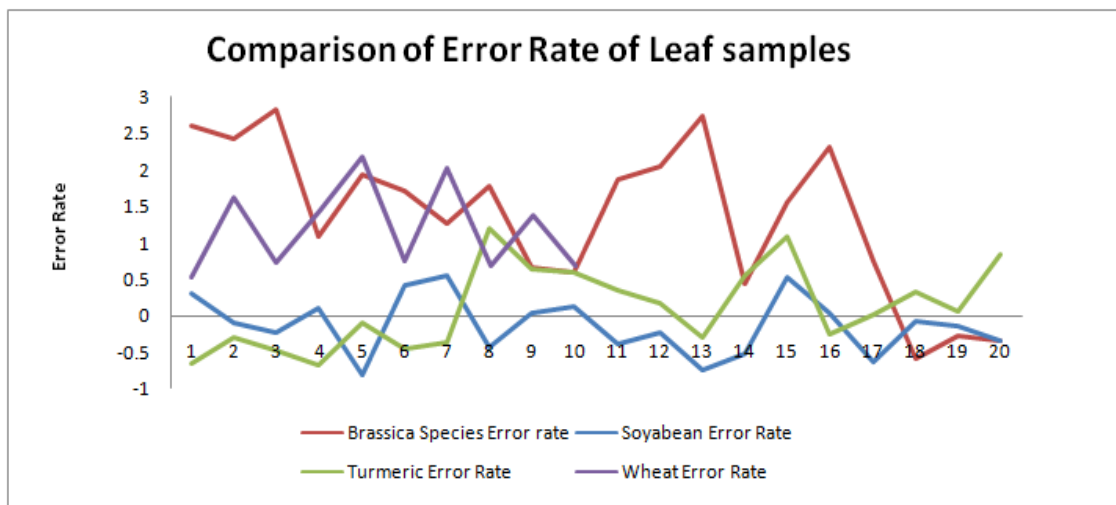


Fig 6: Comparison of Error Rate of Leaf Samples

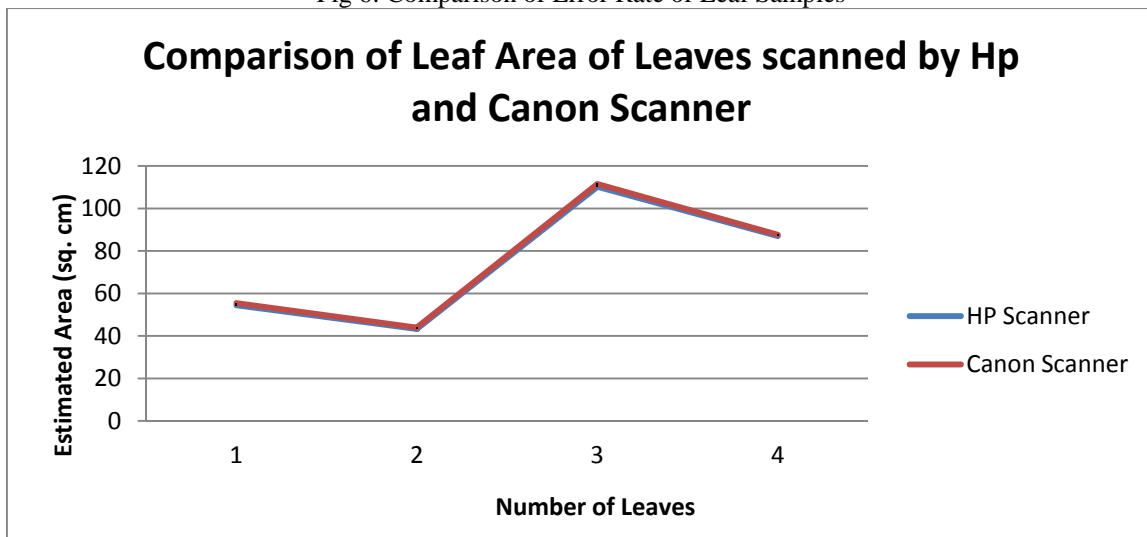


Fig 7: Comparison of Leaf Area of Leaves Scanned by Two Different Scanners.

Test 2:

A sample of 4 leaves was scanned by using Hewlett-Packard scan Jet 7400C scanner and MP Navigator EX-CanoScan LiDE 100 scanner with resolution of 150dpi. Figure 7 depicted the comparison of leaf area of leaves scanned by two different scanners. The leaf area was

calculated using new proposed freeware and discovered that relative error value range between ± 1.4 percent. This means that the new proposed freeware is independent of the scanner used.

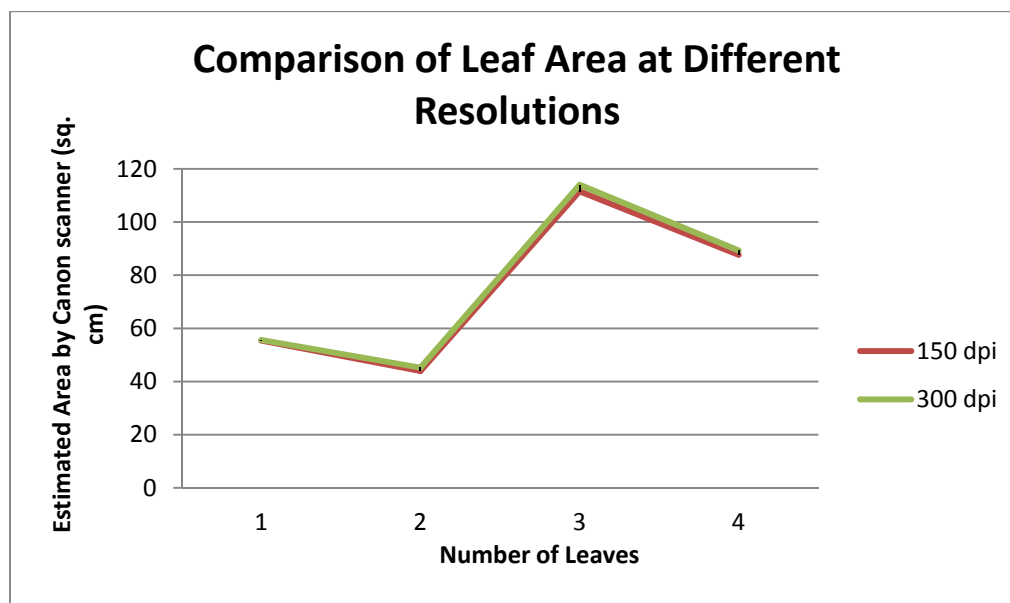


Fig 8: Comparison of Leaf Area at Different Resolutions.

Test 3:

A sample of 4 leaves was scanned by using MP Navigator EX-CanoScan LiDE 100 scanner at resolution of 150dpi and 300dpi. The leaf area was calculated using new proposed freeware as portrayed in figure 8 and it suggested that the error rate between the areas of scanned leaves of different resolution ranges between ± 3 percent. Figure 8 shows the comparison of leaf area of leaves scanned at different resolutions.

IV. CONCLUSION

A new freeware developed using image processing approach can be considered as an inexpensive, scanner independent methodology that is good enough to calculate the area of scanned leaves with different resolution. The error rate seems to be varying because of plant disease and insect pests. Insects remove the area from the leaf or make the color of the area different from healthy leaf. While scanning, leaves should be kept as flat as possible to avoid area measurement errors due to curved leaves.

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