Leaf area meter programming using OpenCV for smartphone application development

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ABSTRACT

This study aimed to design an accurate and practical system of leaf area determination using a smartphone. A software application for leaf area computation was developed using OpenCV (Open Source Computer Vision) library. OpenCV software was tested to estimate the accuracy of leaf area calculation. Leaf area calculations were undertaken using three different image resolutions to compare their accuracy. The results of the software calculations were then compared with the results of the laboratory leaf area meter to identify any errors. The results showed that higher image resolutions improved accuracy by reducing errors. Low image resolution data indicated an error range between approximately 9.4% to 15.4% , while higher image resolution gave an error range between 1.2% to 9.1%. It was concluded that the OpenCV algorithm gave fast and adequate accuracy for leaf area calculation, and that the the smartphone mobile application system was practical for field use.

Key words: leaf area meter, OpenCV, smartphone application, leaf area measurement.

INTRODUCTION

Leaf size and its total area can be used to measure plant growth (Sitompul and Guritno, 1995). The concept of Leaf Area Index (LAI) was first introduced by Watson in 1947 to demonstrate the relationship between light interception and plant growth. LAI is the ratio between the one-sided leaf area and the ground area under the plant canopy; this shows how much light can be intercepted by the plant for photosynthesis (Watson, 1958). Leaf are has been measured in various ways, leaf's weight per seprcific area also taken into account to calculate the product of leaf (Wolf, et.al, 1972). Hence, accurate leaf area measurements provide important information to plant scientists and other researchers.

Many methods have been developed to calculate leaf area. These methods have evolved to improve calculation accuracy or to improve practical aspects of leaf area meter use. Li *et. al.* (2008) developed a calculation method using Matlab 6.0 and compared the results with the grid square method. When tested on several types of leaves, Li's research indicated errors between 3.56%–8.01%, with a better result gained from more squared leaves. Chaudari *et. al.* (2012) developed a leaf calculation method from from a JPEG file taken using digital camera. The image file was then processed to reduce noise using

CIELAB color transformation. After taking 70 samples, the method was found to be 99% accurate, when compared with the grid calculation method.

Can *et. al.* (2012) developed an online method to compute leaf area. The research made use of Photoshop for image processing comparison. The user uploads the leaf image, which is then converted into 400x400 pixels, with an area of A4 size paper being used as a reference. Another computational method used an algorithm programmed in Java to calculate leaf area. The results indicated very high accuracy, however, the calculation process was time consuming. (Parmar, 2015)

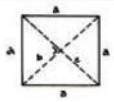
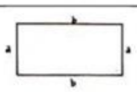
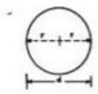
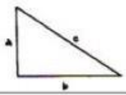
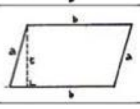
Smartphones are common devices that are equipped with cameras capable of taking good images and embedded processors powerful enough to undertake the calculations associated with leaf area measurement. It is now possible for a mobile application to turn a smartphone into an accessible and practical means of measuring leaf area. The OpenCV (Open Source Computer Vision) is a software library for image processing and computer-based vision for any platform. Formerly OpenCV was only used with PC's, but now it is also used for the development of Android applications. OpenCV library is free and has been downloaded more than five million times (Gregory, 2013).

MATERIALS AND METHODS

Based on the capability and accuracy provided by OpenCV4Android (docs.opencv.org), a smartphone application was developed for the calculation of leaf areas..

Firstly, the accuracy of OpenCV calculations in measuring various shapes of a known area was tested. Table 1 shows that the error range of the algorithm was between 2.8%–6.19%, which was sufficient for leaf area calculation. However, small, parallax and measurement errors from using a ruler for the base-line shapes also contributed to the total error calculation.

Table 1. Pixel measurements for various shapes—actual versus OpenCV method.

Shape	Area (cm^2) Calculated	Area (cm^2) OpenCV	Difference	Error (%)
	25	25.7	0.7	2.8
	21	19.7	1.3	6.19
	30.17	31.7	1.53	5.07
	6	5.83	0.17	2.83
	18.3	17.66	0.64	3.5

Using a smartphone camera, images of leaves were taken on A4 size paper to estimate the life size of the leaf. The distance between the smartphone and the paper, Figure 1, was adjusted so that the designated area of the smartphone display was filled completely to the edge of the A4 paper. This gives the best estimation of the actual size of the leaf. Most smartphone display areas are now more than 800x480 pixels or 384,000 pixels. This can be used to represent the size of A4 paper, which is 62.370 mm^2. Resolution of 210x297 pixels or 62,370 pixels is needed to use the area of A4 paper as a reference point, since this resolution simply indicated 1mm^2 per pixel. When the leaf image is converted to black, the black area is easily counted by the software, where one black pixel equals 1$mm^{2,}$, then the total area of the leaf can be found. Increasing the resolution of the reference area will increase calculation accuracy. For example, the A4 paper can also be represented by 420x594 pixels or 249,480 pixels, where one pixel equals 0.5mm^2, and so forth.

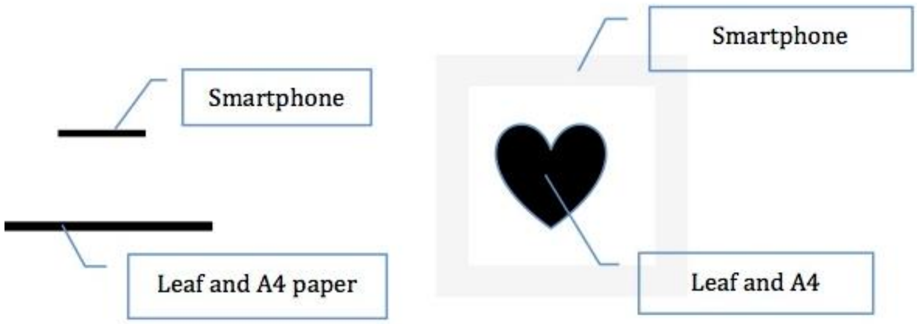


Figure 1. Image aquisition lay out

Calculating leaf area using OpenCV involved sampling and resampling the image to match the resolution of the smartphone display area. This research used three resolutions to compare calculation error. Calculations using the software were compared with readings from a lab's leaf area meter, which was calibrated using a 100x100mm area.

The calculation can be undertaken in two ways.

1. Indirect method
    1. The leaf image is taken using a smartphone camera then stored as a JPEG image in the phone's storage ,
    2. the JPEG image is resampled according to display resolution and
    3. leaf area calculated.
2. Direct method
    1. A leaf picture is taken using a smartphone camera, and
    2. leaf area is calculated directly when the image is taken.

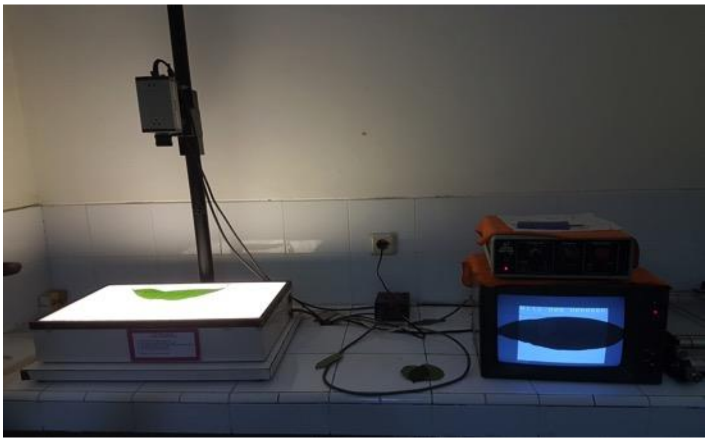


Figure 2. Lab's leaf area meter

During the research, the indirect method, images taken by the smartphone camera were converted into black and white to give better definition between the leaf area and paper area. The resolutions that were used for leaf calculations were 210x297 pixels, 420x594 pixels and 820x1188 pixels. These resolutions matched with the aspect ratio of A4 paper and can be accommodated by most smartphone cameras and displays.

RESULTS AND DISCUSSION

Calculations from the OpenCV leaf meter software were compared with the laboratory leaf area meter readings to assess their accuracy. The results of the leaf area calculations can be seen in Table 2. Higher resolutions gave better calculation accuracy. Newer smartphones support very high resolution images and more accurate leaf area measurement when using this application.

Table 2. Comparison between the laboratory leaf area meter and OpenCV using three image resolutions.

	Leaf Area meter	OpenCV 210x297	Error	OpenCV 420x594	Error	OpenCV 840x188	Error
	64	54.2	15.41	56.92	11.06	58.2	9.06
	143	129.52	9.43	133.9	6.36	135.58	5.2
	22	18.84	14.36	19.74	10.27	20.37	7.41
	23	20.48	10.96	21.97	4.48	22.73	1.17

CONCLUSION

Software developed for smartphones with the OpenCV can be used as a practical means of determining leaf area in the field, while maintaining adequate accuracy. Higher resolutions were found to give improved accuracy. A resolution of 840x1188 pixels gave an accuracy of between 90.9%-98.8% for the leaf areas of most common leaves. Recent smartphones produce very high resolution images and for better accuracy it is suggested that the image are taken with higher resolution.

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