iTALONG: A Mobile Application for Measuring Eggplant Leaf Dimension using Image Processing

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***Abstract*— iTalong is a mobile application that automates the measuring of the dimensions of eggplant leaves. It was built using Android Studio with OpenCV library for image processing and SQLite3 for database. The accuracy of the results from using the application was tested using independent samples t-test. The test found that the mean of the results from manual and automated measuring are equal at 95% confidence level.**

***Index Terms*— Image processing**

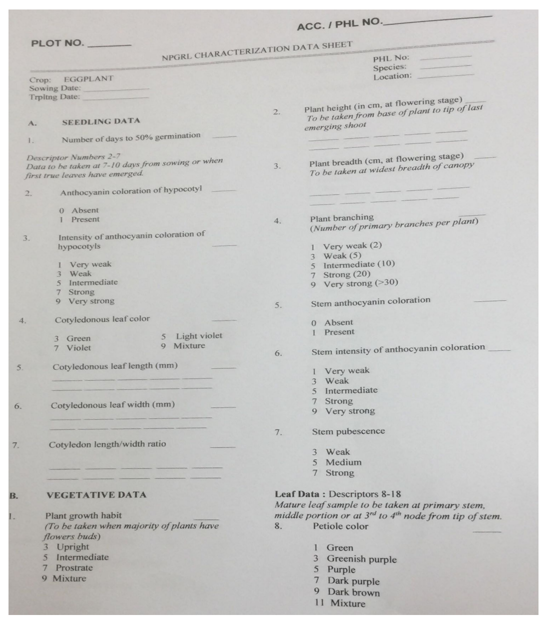
I. Introduction

A. Background of the Study

Eggplant is considered to be an important, economical, and popular harvest in most parts of Asia. Since it is inexpensive, it is also one of the most consumed vegetable. Furthermore, the production of eggplant is a popular source of income of farmers and it can be planted almost anywhere. In the Philippines, eggplant production represents over 30% of the total volume of production of vegetables of the country [15]. But the greatest constraint of growers in eggplant production is the infestation of the eggplant fruit-and-shoot borer (EFSB) [16]. The larvae damage the eggplant by boring into the petiole and midrib of leaves and soft shoots resulting in wilting and stem desiccation. Flowers also are fed upon resulting in flower drop or misshapen fruit. The maximum damage that EFSB can be done is when it generates holes to the fruit, feeding tunnels and frass (or larval excrement), making it unmarketable and not safe for human consumption. At high pest strain, EFSB damage inside the Philippines results in yield loss of up to 80% of the crop [5]. To aid the problem, most of the farmers apply chemical insecticides [4] to the eggplants to get rid of EFBS because other method such as manual removal of EFSB is inefficient and impractical. But the use of insecticides also increases the production cost of the eggplant and it is also risky to human health and environment [7].

Studies are being conducted to solve this problem. Researchers from Institute of Plant Breeding focus on improving the eggplant varieties. To be able to do this, they will need to identify the genes first, improve it and propagate it with new plant defense genes for multiple insect-resistant. They need to know the plant genetic resources and one of these is the leaf dimension. Gathering these data takes a lot of time and effort since it is done manually using ruler for measuring and pen and paper for taking note of the data gathered.

In the Philippines, the process of gathering the data from eggplants for plant genetic resources characterization is done manually. Manual data collection is prone to human error and inefficient because it will consume a very large amount of time because of the large amount of eggplants that data will be collected from. This study presents a solution to the problem by developing an automated system that can measure the dimensions of the leaf.



PLOT NO. ______
ACC. / PHL NO. ______

NPGRL CHARACTERIZATION DATA SHEET

Crop: EGGPLANT
Sowing Date: ______
Trplting Date: ______

PHL No: ______
Species: ______
Location: ______

A. SEEDLING DATA

1. Number of days to 50% germination ______

Descriptor Numbers 2-7
Data to be taken at 7-10 days from sowing or when first true leaves have emerged.

2. Anthocyanin coloration of hypocotyl ______
   0 Absent
   1 Present

3. Intensity of anthocyanin coloration of hypocotyls ______
   1 Very weak
   3 Weak
   5 Intermediate
   7 Strong
   9 Very strong

4. Cotyledonous leaf color ______
   3 Green
   5 Light violet
   7 Violet
   9 Mixture

5. Cotyledonous leaf length (mm) ______

6. Cotyledonous leaf width (mm) ______

7. Cotyledon length/width ratio ______

B. VEGETATIVE DATA

1. Plant growth habit ______
   (To be taken when majority of plants have flowers buds)
   3 Upright
   5 Intermediate
   7 Prostrate
   9 Mixture

2. Plant height (in cm, at flowering stage) ______
   To be taken from base of plant to tip of last emerging shoot

3. Plant breadth (cm, at flowering stage) ______
   To be taken at widest breadth of canopy

4. Plant branching ______
   (Number of primary branches per plant)
   1 Very weak (2)
   3 Weak (5)
   5 Intermediate (10)
   7 Strong (20)
   9 Very strong (>30)

5. Stem anthocyanin coloration ______
   0 Absent
   1 Present

6. Stem intensity of anthocyanin coloration ______
   1 Very weak
   3 Weak
   5 Intermediate
   7 Strong
   9 Very strong

7. Stem pubescence
   3 Weak
   5 Medium
   7 Strong

Leaf Data : Descriptors 8-18
Mature leaf sample to be taken at primary stem, middle portion or at 3rd to 4th node from tip of stem.

8. Petiole color ______
   1 Green
   3 Greenish purple
   5 Purple
   7 Dark purple
   9 Dark brown
   11 Mixture

Fig. 1: Characterization Data Sheet for collecting Seedling data & Vegetative Data

B. Significance of the Study

The system makes the manual process of measuring leaf dimension from eggplant easier by automating the whole process. And since the approach of the study is computer vision, human error is minimized because of minimal human action needed in this experiment.

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C. Objective of the Study

The main objective of the study is to develop a system that automates the measuring of the leaf dimension of the eggplants.

Specifically, this study aims to:

1) develop a mobile application where the user can add, view, update, delete, and export characterization (leaf dimension) entries
2) create a module that uses image processing techniques to detect the leaf on the image and get its length and width
3) evaluate and verify the results by comparing it with the actual measurements or results

D. Scope and Limitations

This study is to create a mobile application that will automate the measuring of leaf dimension for the study of improving the defense genes for multiple insect-resistant of eggplants by Institute of Plant Breeding. The app is only available for those who are involved in the research. Moreover, the mobile application can only be run on Android at minimum API level 19.

II. REVIEW OF RELATED LITERATURE

Several studies have been conducted focusing on automated data gathering using image processing algorithms.

One of the studies that involve automated data collection is the automated counting of chromosomes present in the image that was implemented by *Wenzhong* and *Shuqun* from the School of Electronic Engineering, Beijing University of Posts and Telecommunications [17]. The algorithm for this study consists of several image processing techniques. First, they used histogram equalization to the input image for better contrast. Then, using thresholding, they binarized the image. After that, they implemented erosion to remove false negative. Then, they performed the labeling algorithm to distinguish objects present in the image. However, the algorithm used was unsuitable in counting the human diploid cell resulting into a greater or lesser number than the actual number of chromosomes. With so, they proposed the used of iterative thresholding and mathematical morphology for edge detection method [18]. First, they performed iterative thresholding to enhance the edges of the chromosomes and improve contrast. Then, they implemented contour extraction algorithm to detect the edges and count the detected regions or the chromosomes. Using iterative thresholding and edge detection algorithm, they found out that it is more efficient than using the commonly differential operators for the study. The image processing techniques implemented in the said research could be used in this study for the detection of the object in the image since the contrast between the background and the foreground of the image was high, similar to the images that this study will used for characterization.

Another study involving automated data gathering is the detection of abnormalities in red blood cells using shape analysis conducted by *Manalang* in 2009. The research automated the manual process that observes the sample under the microscope, and the professionals examine the shape and color of the cells to tell whether there are abnormalities present [9]. He used various image processing techniques namely binarization, component filling, and shape analysis. Because of the promising result of the said research, the study will also make use of binarization on pre-processing images, to remove the noise in the images.

Mustafa et al. [10] attempted to determine the quality of the banana using its size and ripeness from its image using a certain image processing toolbox on his study. He proposed using a reference object and its dimension must be known to be able to determine the size of the banana. There had been studies that were similar to this. A similar technique was also implemented by *Canare* and *Reyes* [3]. They used flatbed scanner instead of camera for capturing the images of the rice seeds. They performed various image processing techniques in pre-processing the images such as binary operations and filtering methods to enhance the objects in the image and for better detection. Also, they found out that linear regression is a good method in determining the measurement of a rice seed and that ellipse fitting is also a good method for getting the dimensions of the rice seed. Furthermore, a study made by *Paje* in 2010 also involved getting the distance between veins of rice seed leaf in an image with the use of ruler as a guide to pixels to metric system conversions [12]. The objective of this said research was very similar to this study; getting measurements using image processing. The formula of getting the measurements will be based on the said methods of this study since the results of this research were accurate.

Another study that used image processing for automating data gathering was conducted by *Peralta* [14]. He presented his solution to the problem in the process of wood characterization. He also used image processing algorithms to solve this. In pre-processing the images, he performed histogram stretching and filtering method. Then, he used connected component algorithm to determine the pores on the wood that are important in evaluating the wood. The image processing techniques used in the said research are very similar to the techniques used in the former researches; performing connected component algorithm for detection. This could be used for detecting the object of interest in the image.

There are also studies that focus on performing the non-contact measurement techniques with the help of image processing. However, the main approach that these studies used to solve the problem is more of machine vision than computer vision. But this review will focus mainly on to the image processing techniques the studies used. *Bharathi, Sathiyamoorthy* from the Indian Institute of Technology Madras conducted a study about non-contact measurement using machine vision [2]. The objective of their study is to make usual process of monitoring the condition of the rubber gaskets in a faster way. They implemented edge detection algorithm in other to find the edges of the rubber gaskets.

Then, they performed contour analysis to find the texture defects on the rubber gaskets. The study was able to increase the speed of manufacturing process. The said research only proves that automation of the process of getting dimensions is possible, but it was implemented through machine vision. Unlike the said research, this study will be implementing the automation through computer vision.

All the studies cited above used image processing techniques and successfully automated the process of data gathering or collection. Variables used in the cited researches and objectives were quite similar with the variables that will be used in this study; it all used images and then extracted the object from the image to further study that particular object.

With the promising results of the said researches, this study will also mainly use image processing for automating the data collection.

III. Materials and Methods

A. *Materials*

The following were used for development the application:

1) Laptop
   - Intel i7-3537U 2.50 GHz
   - 64-bit processor
   - 8.00GB RAM
   - Windows 7
2) Software technologies
   - Android Studio 3.4.2
   - OpenCV 4.1.0
   - Java 7
   - SQLite3

For testing the application, a mobile phone was used with the following specifications:

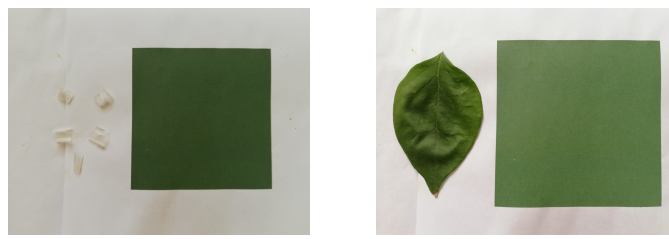
- Android 9.0 (Pie)
- 4.00GB RAM
- 16 MP Main camera

B. *Methods used on Measuring Leaf Dimension*

1) *Image capture*
   a) The leaf is placed parallel to the side of the reference object, a 4 in x 4 in, green-colored square printed on a white sheet of paper *(see Fig. 2)*. when capturing its image. The user must rotate the device horizontally (landscape orientation) *(see Fig. 3)*. to fit the objects in the frame and minimize the distance of the camera from the objects.

   b) The dimension of the reference object is known since it is the basis for getting the actual dimension[6].

Fig. 2: Collecting the leaf samples



(a) The use of tape to stick the leaf to the background

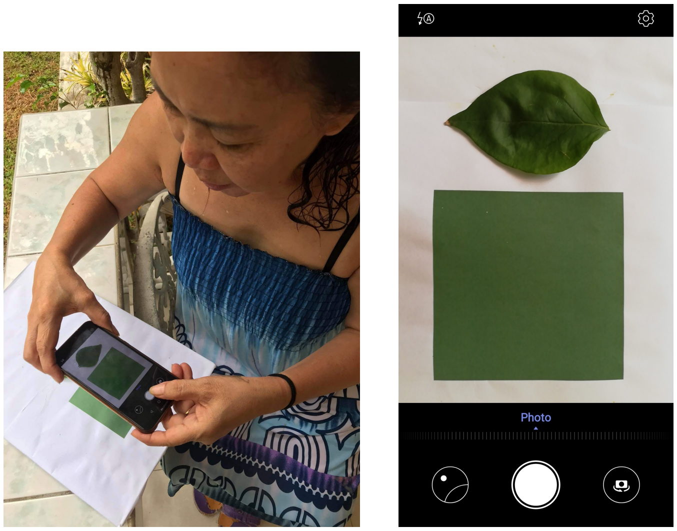
(b) Image capture setup

Fig. 3: Image capture background

2) *Image Processing*
   In processing the image, built-in functions from OpenCV libraby were used and applied.
   After capturing the image, it was converted from RGB to LAB color space, then channels were split to get the L-channel (lightness). CLAHE or Contrast Limited Adaptive Histogram Equalization was applied on the L-channel to enhance illumination. The A and B channels were merged with the CLAHE-enhanced L-channel.

   To further enhance the illumination, the image was converted to YUB color space, then the Y-channel (brightness) was extracted and histogram equalization was applied on the said channel. After that, all the Y, U, B channels were merged.

   The enhanced image was converted to grayscale before segmentation. For image segmentation, the application combined built-in functions of OpenCV for thresholding, the *THRESH_OTSU* for otsu thresholding and *THRESH_BINARY_INV* for inverted binary thresholding. This was done to partition the foreground, the leaf and the reference object; and the background



(a) Capturing the image in landscape orientation

(b) Camera view

Fig. 4: Image capture

of the image. After the segmentation, morphological operation, opening, was applied to remove noise in the image.

The built-in function called *Canny* which implements Canny Edge Detection was done to prepare the image for finding the contours. The significance of finding the contours was to detect the leaf and the reference object in the image.

3) *Computation of dimension of the leaf*
The built-in function *boundingRect* was used to mark the connected components or regions in the list of contours found in the image. It was also used to get the area of each detected regions.

The width of the reference object was known and fixed at 10.16 cm, since this would be the basis for converting the acquired dimension of the leaf from pixel to its approximate real-world dimension.*approxPolyDP* was used to detect the square and to assure that it was the reference object. Then, the next detected region with the largest area would be the leaf.

The width of the bounding rectangle that marks the reference object was also the width of the reference object in pixel. Finally, to get the approximate width and approximate length of the leaf, the dimension of the bounding box of the leaf in pixel was divided by the width of the reference object in pixel, and was then multiplied to 10.16 to convert it to cm. The values needed to set up the formula were the following:

$$\frac{width\ or\ height\ of\ bounding\ box\ of\ leaf\ in\ px}{width\ of\ bounding\ box\ of\ square\ in\ px} \times 10.16\ cm \tag{1}$$

4) *Testing*
Manual measurements of the leaves was compared to the automated measurements from using the app. When measuring the length of the leaf manually, from the base of the leaf blade (petiole not included) down to the tip. On the other hand, width was measured on the widest portion of the leaf. While measuring using the app, the leaf was captured next and parallel to the reference object or the green square.

The researcher conducted two independent samples, from the actual measurements and from the resulting computed measurements from the mobile app, for t-tests for unequal variances. This was to test if there is any significant difference between the means of two data vectors[19]: one for the length of the leaf, and one for the width of the leaf; manually computed and automatically computed by the app.

The null hypothesis H_o assumed that the mean of the manually obtained dimensions of the leaves will be equal to the automatically computed dimensions of the leaves at a 95% confidence level. The alternative hypothesis H_a suggested the opposite of the null hypothesis. We accept the null hypothesis if the t-value is less than the critical value and reject the null hypothesis otherwise[19].

C. *Flow of The System in Application View*

User is directed to the Home page *(see Fig. 5)* when the application is opened. "START" button will take the user to the Menu page *(see Fig. 6)* displaying the options to choose from; add entry, search entry, delete entry, and export records.

In the Add Entry page, it will first ask for accession no., plot no. and plant I.D. of the entry *(see Fig. 7.a)* before proceeding to capturing image of the leaf *(see Fig. 7.b)*. After capturing the image *(see Fig. 7.c)*, image processing techniques would be applied, then the processed image will be shown along with the result. The user may press "SAVE" button to save the result to the records, or "RETAKE" button to retake the image.

With search entry option *(see Fig. 8)*, the user can search a specific entry or display all entries. When searching for a specific entry *(see Fig. 8.a)*, the app will ask for the plant I.D. of the entry being searched for. Then, click "SEARCH" button to display the all the information of the entry*(see Fig. 8.b)*. The user may delete the entry or edit the accession no. or plot no. of the entry. On the other hand, when the user opt to view all the entries, the app will display all the entries together with the information of each one in a list view *(see Fig. 8.c)*. The user may delete an entry by long pressing that listed item.

Clear all records option allows the user to delete the entire record of entries. Three dialog boxes will pop out showing the confirmation message before deleting all entries.

Under the export records option, press the tab of the option to export records to a csv file that will be saved in the storage of the device.

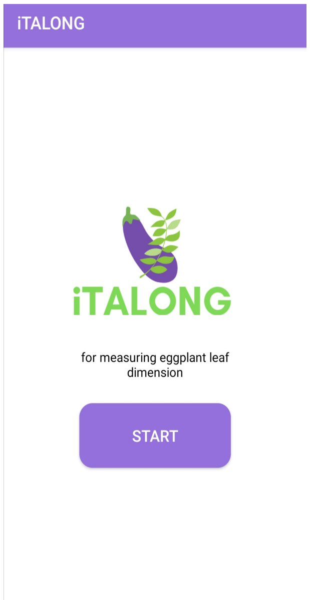


Fig. 5: Home Page

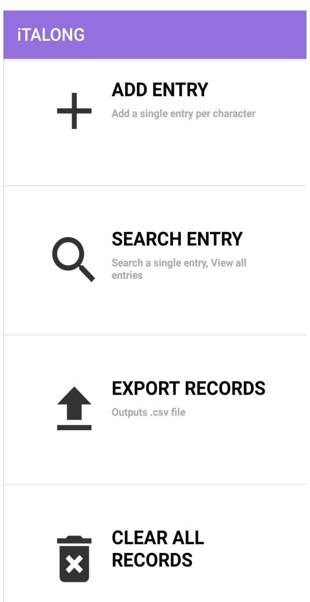
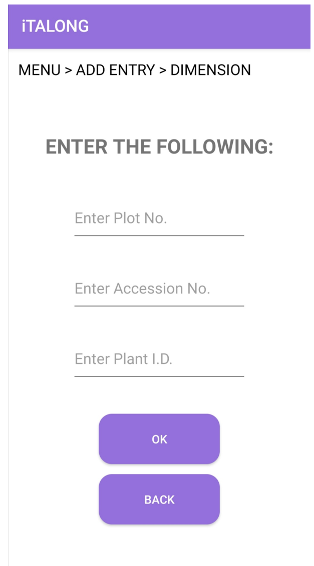
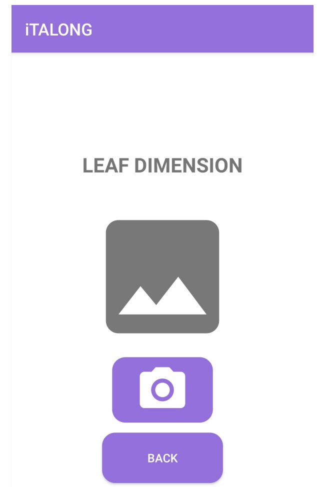


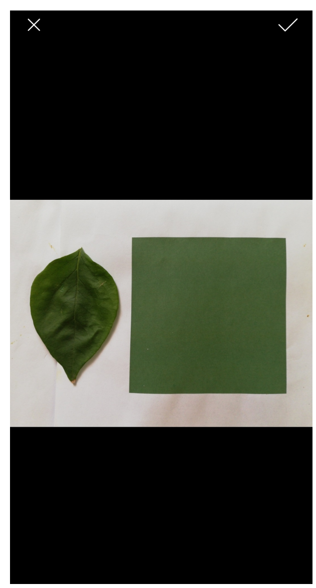
Fig. 6: Menu Page



(a) Info Page

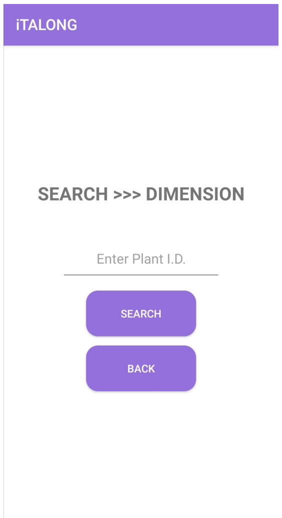


(b) Capturing Image for Dimension Entry Page

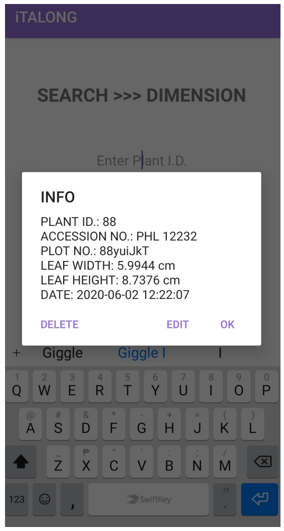


(c) Captured image

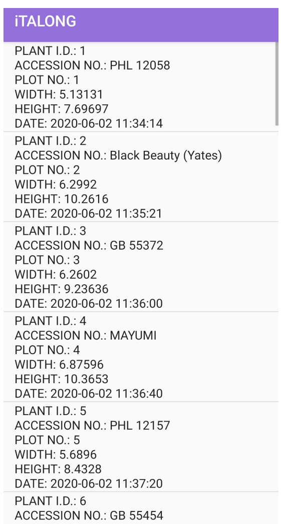
Fig. 7: Add Dimension Entry



(a) ”Search an entry”; asks for plant I.D. of the specific entry



(b) Displaying more info about the entry

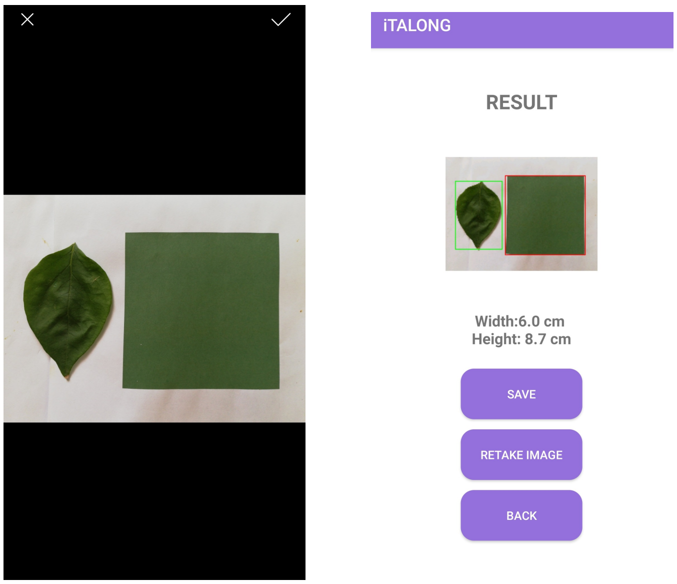


(c) ”View all entries”

Fig. 8: Search Entry

IV. Results and Discussion

iTalong was able to capture image and to process it to compute the measurements *(see Fig. 9)*. Image processing techniques applied were able to detect the objects and data needed for measuring the dimension were gathered *(see Fig. 10)*. Also, the app could store the records in the database making it useful for the users to view and retrieve the records anytime they need it *(see Fig. 15)*.



(a) Captured image (b) Result Page

Fig. 9: Add feature of iTalong; used image processing for computing dimension

Manual measuring of the leaves *(see Fig. 11)* for testing was done by the researcher using a ruler. The process of measuring was instructed by an expert. Thirty leaves from bougainvillea tree were set as the samples for the test.

After manual measuring, the researcher used the application to get the dimension of the leaves. The distance of the camera or the device used for taking the images was approximately from 12cm to 20 cm away from the objects. The distance of the camera depends on the size of the leaf; the whole leaf should be inside the camera frame. However, the camera view should be within the white background. The result of measuring the dimension of the leaf using the application was compiled in a csv file *(see Fig. 15)*.

The data from manual measuring *(see Fig. 14)* and from the csv file generated from using the application *(see Fig. 15)* were combined to compute for the t-value. The statistical test was done using the Microsoft Excel 2007.

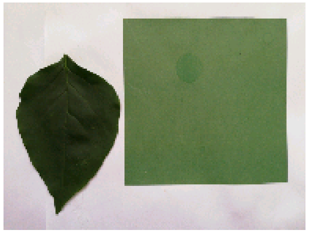
The t-values computed from the t-test for the widths and lengths were 0.32 and 0.21 respectively. Both values are less than the critical value, therefore, accept the null hypothesis that stated the means of the widths and lengths from manual and automated measuring has no significant difference *(see Table I)*.

Accuracy was also computed individually to determine the errors occurred when measuring using the app. The lowest accuracy in measuring the width was at 93.15% and error was suspected to be caused by alignment of the objects in the image. The midrib of the leaf and the side of the square must be perfectly parallel to avoid increasing or decreasing the size. *(see Fig. 12)* This error can also be observed from the other entries. On the other hand, the lowest accuracy in measuring the length was at 94.10% and the error was observed to be caused by the the tip of the leaf blade being too thin that it was identified as a noise *(see Fig. 13)*.

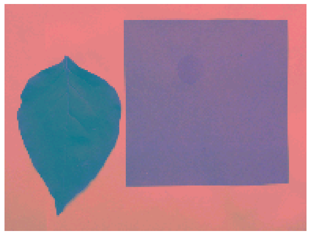
Most of the errors at measurements might be caused by the creases on the background and the alignment of the objects in the image (as mentioned above). Appearance of wrinkles was unavoidable because the background was a paper. It was responsible for the deformation of the sides of the square, decreasing the measurement of the side of the square and increasing the result measurements.

TABLE I: RESULTS OF INDEPENDENT SAMPLES T-TEST

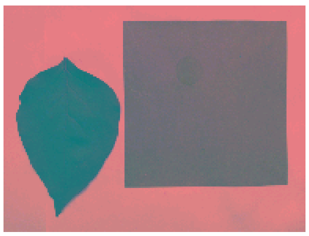
	t-value	Critical Value	Analysis	Decision	Accuracy
Width	0.32	2.05	$0.32<2.05$	Accept H_o	97.76%
Length	0.21	2.05	$0.21<2.05$	Accept H_o	97.66%



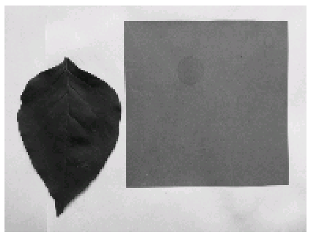
(a) Input image



(b) CLAHE applied to L-channel (from rgb to LAB color space)



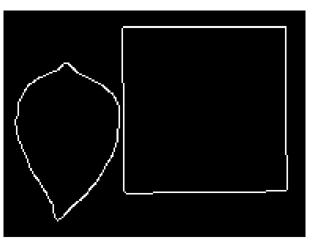
(c) Histogram equalization applied to Y-channel (from LAB to YUV color space)



(d) Enhanced YUV to Grayscale

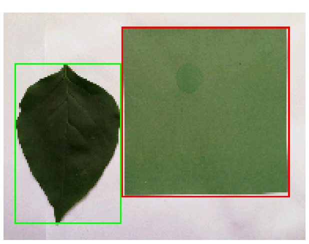
(e) Otsu thresholding

(f) Opening



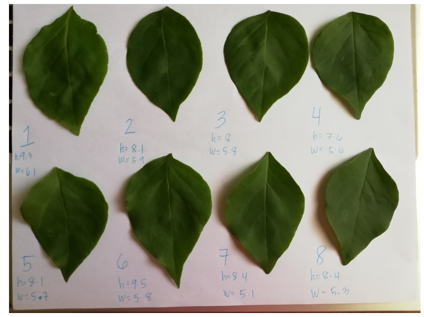
(g) Canny edge detection

(h) Contours

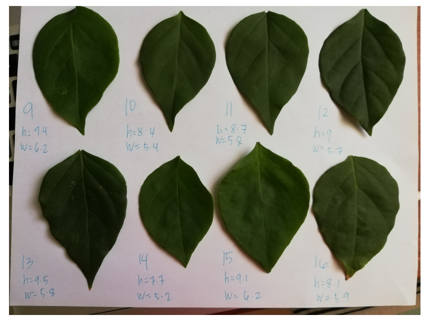


(i) Output image; bounding boxes marked the leaf and the reference object

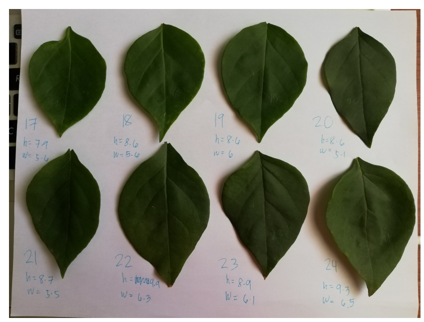
Fig. 10: Image processing techniques applied; accuracy of 99.66% (width) and 98.78% (length)



(a)



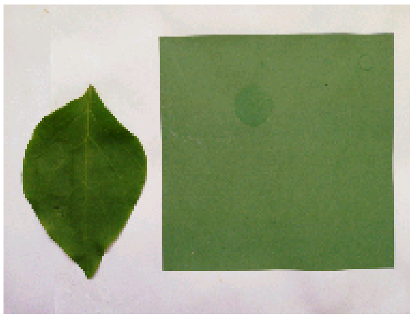
(b)



(c)

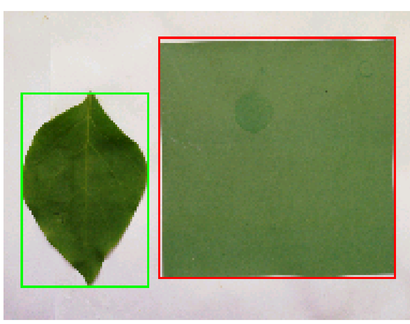
(d)

Fig. 11: Dimensions of the leaf samples obtained from manual measuring



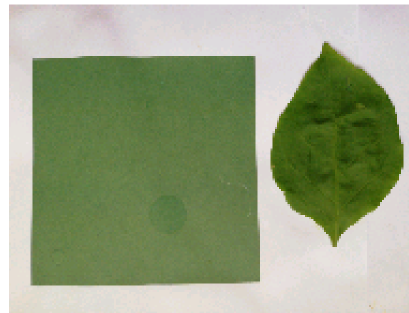
(a) Input image

(b) Contours



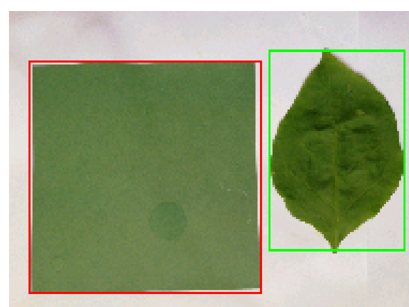
(c) Output image

Fig. 12: plantID: D7 (93.15% accurate at measuring width)



(a) Input image

(b) Contours



(c) Output image

Fig. 13: plantID: D1 (94.10% accurate at measuring length)

plantID	width	height
1	6.1	9.3
2	5.9	8.1
3	5.8	8
4	5.6	7.6
5	5.7	8.1
6	5.8	9.5
7	5.1	8.4
8	8.4	5.3
9	9.4	6.2
10	5.4	8.4
11	5.8	8.7
12	5.7	9
13	5.8	9.5
14	5.2	7.7
15	6.2	9.1
16	5.9	8.1
17	5.6	7.9
18	5.6	8.6
19	6	8.6
20	5.1	8.6
21	5.5	8.7
22	6.3	9.9
23	6.1	8.9
24	6.5	9.3
25	6.8	10.5
26	6.4	9.8
27	7.2	10.5
28	6.7	10.5
29	6.5	11.1
30	6.2	8.8

Fig. 14: Results of manual measuring the leaves

plantID	accessio	plotNo	width	height	date	position
D1	D1	D1	5.92667	8.74889	#######	36
D2	D2	D2	5.50729	7.78617	#######	37
D3	D3	D3	5.92667	7.80815	#######	38
D4	D4	D4	5.35214	7.52929	#######	39
D5	D5	D5	5.60224	7.78617	#######	40
D6	D6	D6	5.98714	9.07143	#######	41
D7	D7	D7	5.44945	8.31273	#######	42
D8	D8	D8	5.27538	8.30385	#######	43
D9	D9	D9	6.07701	9.11551	#######	44
D10	D10	D10	5.31738	8.07103	#######	45
D11	D11	D11	5.73128	8.42325	#######	46
D12	D12	D12	5.76649	8.78703	#######	47
D13	D13	D13	5.91845	9.37087	#######	48
D14	D14	D14	5.3219	7.64419	#######	49
D15	D15	D15	6.15758	8.92848	#######	50
D16	D16	D16	5.88211	8.28842	#######	51
D17	D17	D17	5.64444	7.81538	#######	52
D18	D18	D18	5.57451	8.18195	#######	53
D19	D19	D19	6.00364	8.40509	#######	54
D20	D20	D20	5.12577	8.4209	#######	55
D21	D21	D21	5.26815	8.74889	#######	56
D22	D22	D22	6.17196	9.78019	#######	57
D23	D23	D23	6.15462	8.59692	#######	58
D24	D24	D24	6.26692	9.40037	#######	59
D25	D25	D25	6.63921	10.3612	#######	60
D26	D26	D26	6.42189	9.68075	#######	61
D27	D27	D27	6.83664	10.3499	#######	62
D28	D28	D28	6.70757	10.2586	#######	63
D29	D29	D29	6.25231	10.6485	#######	64
D30	D30	D30	5.98206	8.7357	#######	65

Fig. 15: Generated csv file from the app

V. Conclusion and Future Work

The application, iTalong, is feasible to automate the measuring of the dimension of the leaf. Combined image processing techniques from OpenCV Library used was able to detect the leaf and the reference object. Also, necessary data for computing the dimension were gathered with the help of the image processing techniques. Hence, the means of the measurements done manually and using the app has no significant difference.

Errors observed were mostly caused by the creases on the background since it was made of paper. Creases reduced the measurement of the square; increasing the computed measurements of the app. The alignment of the objects in the image were also observed to cause errors in computing the measurements.

To further enhance the application, future developers can extend and expand the modules of the application to cater all the characters.They can also make the same application except that the user will not need to use a reference object or background when capturing images. Furthermore, they can opt to improving the image segmentation by using different techniques aside from thresholding for greater accuracy.

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