MOBILE APPLICATION FOR TREE HEIGHT ESTIMATION USING PIXEL-BASED RATIO MEASUREMENT

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ABSTRACT: Tree growth provides information on the dynamics of the ecosystem; it reflects availability of water, carbohydrates or nutrients. However, one aspect of tree's growth that can be hard to measure is tree height since it requires triangulation and other mathematical computations. Conventionally, tree height is measured through the use of a range finder however it is in a certain amount. This paper present another means in estimating tree height using an android mobile devices through pixel-based ratio measurement. A camera calibration technique is integrated to standardize different camera resolutions and pixels and be proportionate with the real setting. Geometric method is used in the estimation process. Pixel height was identified based on the camera resolution and multiplied with the result of the calibration technique. Images along with the other information will be saved to a server for monitoring purposes. Mobile application results are being compared to ground survey data using range finder tree height measurement. Thus, this study suggest an ease and portable way in estimating tree height and could be used in ground validation for any tree height endeavor.

1. INTRODUCTION

Forests are one of the most precious natural resources in the Philippines. In 1934, it comprised more than half (57%) of the Philippine archipelago’s total land area. Food and Agriculture Organization (FAO) reported that from 1990 to 2000, Philippines had lost 1.4% or 89,000 hectares of the forest area annually due to increasing agricultural and housing needs, commercial and illegal logging, and *kaingin* and forest fires. This sustained loss caused severe soil erosion and threatened the country’s rich biodiversity.

To alleviate this environmental threat, the Philippine Government initiates National Greening Program (NGP): Visioning a Green Renaissance in the Philippines. The project seeks to grow 1.5 billion trees covering about 1.5 million hectares of forestlands, mangrove and protected areas, ancestral domains, civil and military reservations, urban areas under the greening plan of Local Government Units (LGUs), inactive and abandoned mine sites, and other suitable lands of the public domain. There are 683,481 (DENR, 2013) reported areas reforested in the Philippines by the National Greening Program. In the study conducted by the Philippine Institute for Development Studies showed that the NGP implementation is generally a success in attaining its targets of area planted. However, monitoring and enforcement was perceived as setback in all areas covered in the NGP (Israel & Lintag, 2013). The Department of Environment and Natural Resources (DENR) had initiated and conducted various monitoring activities. However, one of the important factor in monitoring was overlooked - the tree height. The measurement of tree growth in a forest over time provides information on the dynamics of the ecosystem; it reflects availability of water, carbohydrates or nutrients (Beals, Gross & Harrell, 2000). Furthermore, it attests the survival rates and growth of the planted seedlings within the jurisdiction of the NGP project. Thus, this paper proposed this system to enhance the current monitoring process using android mobile phone highlighting the tree height using pixel-based ratio computation. These pixels are small dots that make up the images on smart phone screens (techterms.com, 2015). Pixel-ratio on the other hand, is a mathematical ratio that describes how the width of a pixel in a digital image compares to the height of that pixel. Moreover, it will be a tool for ground validation for the tree height captured used in the Phil-LiDAR 2.2.14: LiDAR Data Processing, Modelling and Validation by Higher Education Institutions (HEIs) for the Detailed Resources Assessment in Mindanao, Caraga State University research undertaken funded by DOST-PCIEERD.

Part of the objective of the study is to design a mobile application that could estimate the height of the tree, devise an application that automates the monitoring process maximized the current available technology and devise a system that integrates information and readily available for use.

2. TREE HEIGHT ESTIMATION

Tree height is the vertical distance between the base of the tree and the tip of the highest branch on the tree, and is difficult to measure accurately (Hemery, 2015). It can be measured in number of ways with varying degrees of accuracy such as using trigonometric methods and geometric methods.

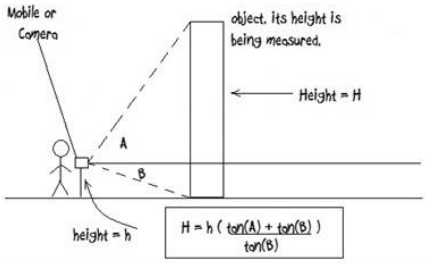

Fig. 1. KDD's solution in getting the height of an object

KDD (2012) used trigonometric methods in his answer to an inquiry as shown in Fig.1. A vertical tree of Height H is located on flat ground and observer's eye level O with some viewing device. He noted that calculating the height of any object requires knowledge on mathematics and triangulation. In the solution, height(h) should be known. But accordingly, getting the value A and B is very challenging in an android smartphone because there are lots of issues especially the camera sensor built-in in the smart phone are consider as low-end camera sensor. Moreover, he recommended that to get with something real value, baseline or the distance from the tree must be known.

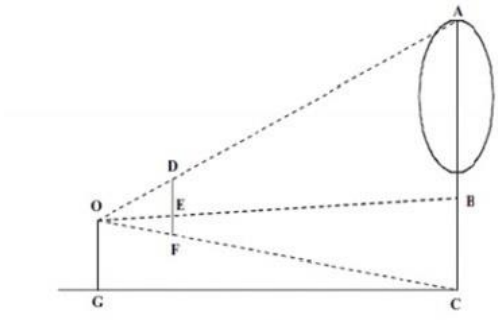

Fig.2 Geometric method principle in computing height

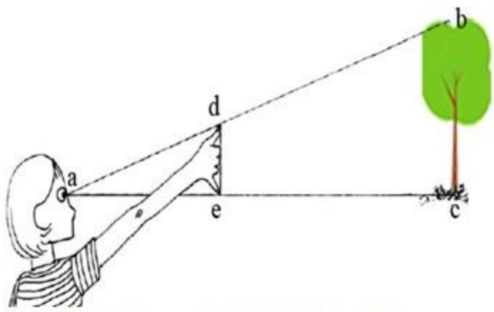

Fig.3. Geometric Method Illustration

Geometric method of measurement is illustrated in Fig.2 A vertical tree of height hT=AC, is standing on flat ground. A straight stick of known length lT=BC is positioned vertically at the base of the tree. An observer is standing a convenient distance away from the tree, with his or her eye at O. The observer holds a graduated ruler DF, positioned so that the line of sight OC to the base of the tee is coincident with the zero mark of the ruler. Without moving the head up or down, the observer reads from the ruler the distance lR=FE, which coincides with the line of sight OB to the top of the stick against the tree. Using a straightforward geometry, the height of the tree can be then be calculated from these measurements shown in Eq. (1).

$$hT= \quad hR(lT/lR) \qquad \text{Eq. (1)}$$

Eq. (1) was employed in the height estimation application with little modification as illustrated in Fig. 3. It maximized the geometric methods where two triangles are formed. Two triangles are formed, one triangle is by the eye a, the thumb d, and the little finger e; the other is formed by the eye a, the top of the tree b, and the bottom of the tree c. These two geometrical objects are called similar triangles. Triangles ade and abc have the same shape, or one has the same shape as the mirror image of the other. All the corresponding sides have lengths in the same ratio as stated in AAA similarity theorem that if two objects are similar, each is congruent to the result of a particular uniform scaling of the other. A modern and novel perspective of similarity is to consider geometrical objects similar if one appears congruent to the other when zoomed in or out at some level as shown in Eq. (2).

$$\frac{AB}{BC} = \frac{BC}{B'C'} = \frac{AC}{A'C'} \qquad \text{Eq. (2)}$$

3. METHODOLOGY

Geometric method of measurement was employed in the height estimation process with the concept of AAA similarity theorem in the ratio and proportion implementation.

A whole tree must be focused in the camera. Applying the concept of similar triangles and ratio and proportion as well as the geometric method, the following algorithm must be observed in estimating the tree height:

1. Choose a tree.
2. Position the Android phone to capture the image. Bottom of the Smartphone should be in line with the observer's eye;
3. Observer should walk toward or away from the tree until the image captured in the screen is like as shown in Fig. 3 where the whole tree with the top and bottom of the tree;
4. Input the distance;
5. Calculate the height based on the following formula: Height = d * (1/x);
   where d is the distance of observer from the tree; x distance of observer to his hand.

Figure 4 shows the conceptual framework of the system. Two applications were implemented: the mobile application and the web-based application. Enumerator used the mobile app in estimating the tree height. It includes various features like camera calibration, height estimation, GPS enabled and it maximized offline storage capabilities of mobile phone. The mobile app accessed data from the server and send information to the server. These information includes the tree height, latitude, longitude, variety and other information that is relevant in the monitoring process. If network is not available, data were saved in the *SQLiteDatabase*, an android offline facility and sent in the server if the connection is present using the synchronization technique.

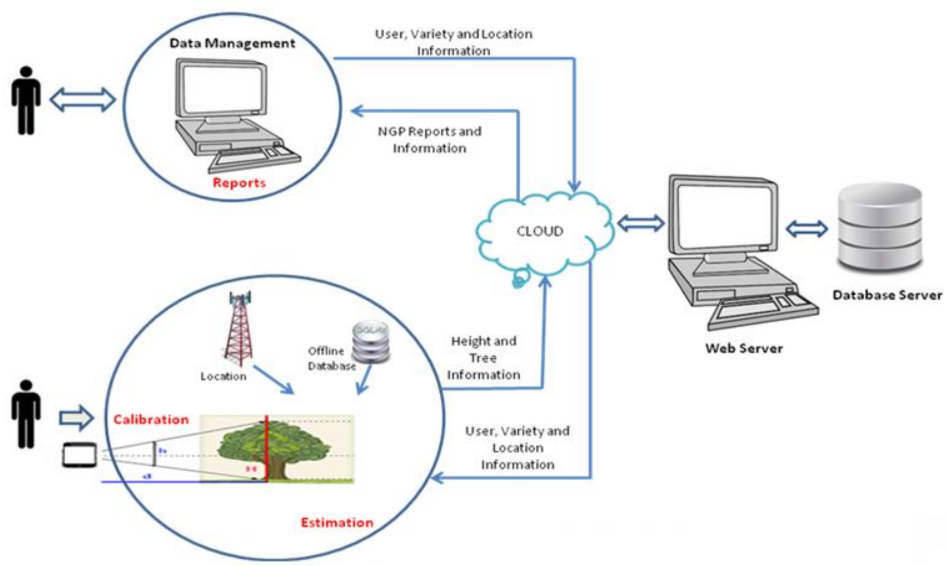

Fig. 4. Systems Conceptual Framework

Web application on the other hand, caters the registration and data management process. Registration of the authentic systems' user as well as the plant varieties and the location where these varieties planted were entered. Reports are viewed in the web application in various formats. Mapping facility features also is available in web facility.

4. RESULTS

4.1 Tree Height Mobile Application

Tree height can be measured in various ways. Each method comes with different formulas. All these can be generalized into two methods: trigonometric and geometric methods. The trigonometric method involves the angle of elevation and depression. However, determining angles is still a limitation in the current technology that is built-in in android devices. On the other hand, the geometric method maximized ratio and proportion concepts. This method was used in the estimation process. It is implemented using Eclipse with android SDK.

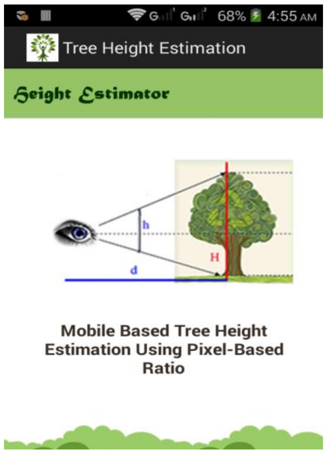

Fig.5. Mobile Application Main Page

The image in Fig. 5 depicted on how a tree should be captured. The whole plant should be focused in a camera with a full screen view and using the quick picture settings. All the default camera settings: resolution, zoom level and pixels are used in capturing the trees and should not be changed.

The mobile application was intended for general use for all android devices. It supported all android phone screen sizes from small screen to extra large screens and at any density. For better functionalities, it used various permissions like *Internet, access-wifi_state* and *access_network* state for the connection and service, camera permits to capture images; *write_external_storage* allows the saving of captured images in the SD memory card and the Global Positioning System (GPS) let the application use the global positioning system

4.1.1 Camera Calibration

Smart phones come with different specifications along with camera sizes and resolutions. Say, Lenovo A535 has a camera size of 5 inches and the rear camera has 5-mega pixels while a Huawei model has 6-mega pixels. This means that a larger megapixel rating allows users to print their pictures at larger sizes without a reduction in image quality called as distortions and noises.

Camera calibration is the most crucial and important process in height estimation. The accuracy of the height estimation depends on the accurateness of the results during the calibration process. Moreover, it standardized the camera's phone aspect ratio to the real setting.

To calibrate, it must be regulated first, known height and a known distance should be entered in the application. This can be done only once because the value was saved in *SharedPreferences* as settings of the application. Result of the calibration will be the basis in the height computation as the multiplier. Estimation coefficient is the result calibration process. The more test captured during the calibration, the better is the results. The mechanics in the calibration process is shown in Fig.6 .

```
1   function calibration(previous_calibration )
2       I←  Capture tree using Quick Picture Camera Settings
3       Calibration coefficient  ← camera pixel height
4       Distance ←  known distance
5       Height ← known height
6       Estimation coefficient ←(P * (Height/No. of pixels of I))/Distance
7       If previous _calibration ← 0
8           save estimation coefficient as application setting
9       Else
10          Estimation coefficient  ←previous_calibration +
                                  current Calibration coefficient
11          Save new value estimation coefficient as application setting
```

Fig. 6. Camera Calibration Pseudo code

The result of the calibration is called as the estimation coefficient. This value serves as the multiplier in getting the tree height. It will be saved as settings variable calibration in the Android phone device in line 8 and line 11. If the user wanted to add additional calibration for better results, the average value of the previous and previous coefficients will be the value that is considered as the new result.

4.1.2 Height Estimation

Estimation coefficient result served as the multiplier in approximating the tree height. A quick capture was used and the whole tree (base to highest leaf of the tree was focused in the camera. Distance then is estimated and inputted in the application.

Fig. 7 shows the sample outputs in the estimation process. After capturing the image, entering the distance and clicking of Get Estimation Result button, an estimated height was displayed both in inches and in meters format. The procedure for tree height estimation is highlighted in Fig. 8. Estimated height could be sent in the server as part of the monitoring feature of the NGP project along with the other information. *Send Data* button should be clicked to access the system.

```
function estimation (Calibration coefficient )
    I←  Capture tree using Quick Picture Camera Settings
          with full screen view
    Tree pixel ← camera pixel height
    Distance ←   known distance
    Estimated height ← (Calibration coefficient *
                        (Distance * (I (number of pixel)/Tree pixel))
    Display estimated height
```

Fig.8. Height Estimation Pseudo code

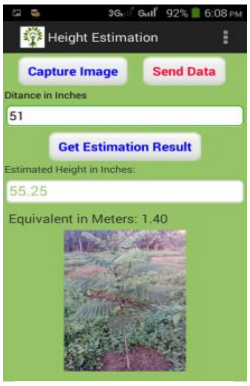

Fig. 7 Tree Height Estimation

4.2. Automation of the Monitoring Process

Automation of the monitoring process minimized the working loads and the cumbersome process of recording the field data. Using an android phone device, data were recorded in the SQLite Database and could be sent to the server.

Current location of the observer was tracked using built-in Global Positioning System (GPS) technology in an android device. Latitude and longitude was accessed using the *mLocationClient.getLastLocation()* that returns the current location of the observer. These latitude and longitude data will be then used in future reference in monitoring the tree growth. User's were tracked using their *userid*. Along with the other information will be sent to server. Moreover, mobile application allows users authentication package.

4.2. Web Integration

Online application was created using *HTML 5* and *jQuery* for the web development. The application was intended for the data management which includes the entry for the users, varieties and location and report generation as shown in figure below. Information collected in the field will be viewed online. Web mapping facility is integrated in the system.

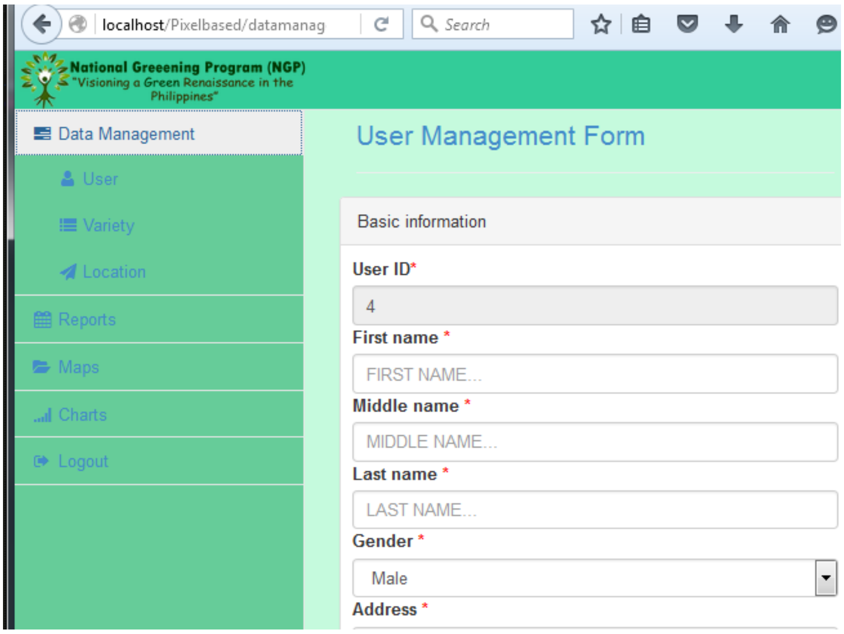

Fig. 9 Users Registration Form

4.3. Height Estimation Validity

Field validation was conducted to validate the mobile application results. It was conducted in some barangays in Butuan City, Philippines. Mango trees within the area serves as the sample of the project. Mango tree height is being measured using Laser Range finder and the mobile application. As shown in the graph, mobile application height results has comparable results with the tree height result using the mobile application. Land elevation affects the mobile application results. The application is best recommended to use in plain areas. Results are shown in Fig. 10.

Error field was computed using Eq(3) and represent the discrepancy between the height measurement using laser rangefinder and mobile application height measurement, where $_i$ represented the sample, *rangefinder* is the rangefinder height measurement. *MobileApp* signify the estimated height or the result of the mobile tree height estimation with the input of distance measured in a tape measure.

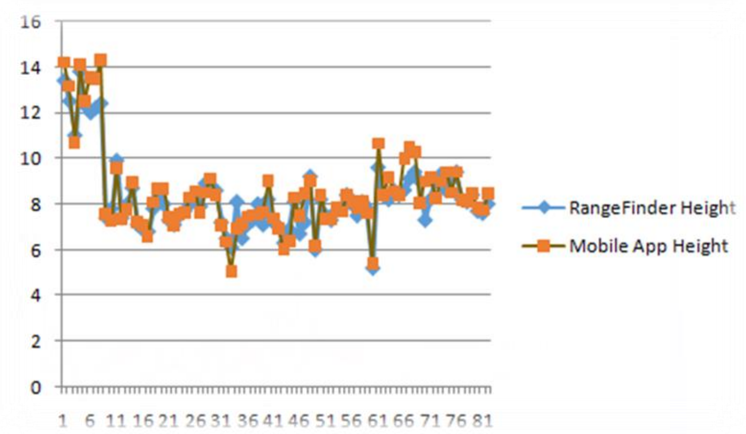

Figure 10. Software Testing Results

$$Error\ field_i = rangefinder_i - mobileApp_i \qquad \text{Eq(3)}$$

Error mean was computed to get average discrepancy of the samples. This mean was computed from the sum of differences of the actual height and estimated height of all samples, and then the result was divided by the number of tests conducted. This value represents the mean error of the estimated height of the Android application to real height measured based on the gathered samples. The formula that was employed in computing the error mean is shown in Eq.4.

$$\text{Error Mean} = \frac{\sum_{k=0}^{n} |\text{Estimated}_k - \text{Actual}_k|}{n} \qquad \text{Eq (4)}$$

As shown in Fig. 10, estimated height is very close to the measured height using laser rangefinder. The error mean is only 0.197778.

5. CONCLUSIONS

Android phone devices are considered as the fastest growing mobile Operating System. It provides powerful and innovative applications by using latest mobile technologies. With the rising popularity and boom in the usage of android smartphones, it is very convenient to build a mobile application that can estimate tree height.

By the use of Android Development Tools bundles and various API with MySQL, the mobile application had been accomplished using these powerful tools. The proponent had successfully created the database using MySQL database management system, Apache for the web-server and PHP scripting language for the processing of queries and making connection to the database. Also, through the use of Eclipse (IDE) software development, interfaces were built mostly written in Java language. The application now, can estimate tree height, access and send data to the server. To test the mobile application, the researcher used wifi connection as the tool for the Internet connection. To validate results, field validation test were conducted. Thus, the processes had successfully tested, executed and validated.

The height estimation is best applicable in plain areas with no barriers during the tree image capture process. The whole tree image should be captured from the base to the highest crown of the tree. Calibration process plays vital rule in the estimation process. Such errors in the calibration will have a great impact in the estimate results.

6. RECOMMENDATIONS

The Mobile Application for Tree Height Estimation Using Pixel-Based Ratio Measurement can be improved and extended in several ways. There are some of the utilities from this application that must be developed and apply accordingly for future modifications.

- Estimate tree height even in sloppy areas
- Image processing for more accurate results
- If connection is unavailable, SMS could be used in sending data to the server
- The application must run on cross-platform such as iOS and Windows platforms.

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