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Nitrogen Deficiency Mobile Application for Rice Plant through Image Processing Techniques

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Abstract: ***Driven by the opportunity that digital devices and robust information are readily available, the development and application of new techniques and tools in agriculture are challenging and rewarding processes. This includes techniques learned that is based on traditional methods, practices, experiences, environmental patterns and human capability. The most sought technique comes from human intelligence that is dynamic, adaptive and robust. Nitrogen deficiency in rice plants can be determined via the color of the leaves. It is dependent on the depth of the green pigment in the color spectrum present in the leaves. Based on these characteristics, the application of computational artificial intelligence and machine vision can be adopted to create assistive technologies for agriculture. In this paper, a mobile application is developed and implemented that can be used to assist rice farmers determine nitrogen deficiency, through the leaf color in rice plants. The application can be used alternatively or together with the traditional protocol of nitrogen fertilizer management. It is mobile, simple and it also addresses some drawbacks of the human eye to distinguish color depths brought about by other factors, like sunlight, shading, humidity, temperature, etc. It utilizes image processing techniques to digitally captured images represented in numerically transformed Red, Green, and Blue color formats. The digital images are then normalized to remove the effects of illumination and then compared using the image/pixel subtraction technique with the base color images converted and extracted from the leaf color chart standard. Eventually, the application determines nitrogen deficiency and suggests the concentration and volume of fertilizer to be applied to the rice plants. Accuracy of the technique is determined by computing the Z statistic score.***

Keywords: ***Algorithms, image processing, fertilizer management, mobile application.***

I. INTRODUCTION

Fertilizer management is governed by processes triggered by specific events and attributes from the environment and most especially from the crop. The method is based on a standard protocol developed by researchers together with the farmers with years of tests and trials. This fertilization protocol is a tedious activity especially for the rice (*Oryza Sativa L.*) plant, it is not as easy as just throwing nutrients into the soil and everything will just be fine. There are some issues to be considered, such as applying too much fertilizer and the plant becomes succulent and susceptible to insect and disease. Too little and the plant grows poorly and unproductive. In the Philippines, majority of the farmers cultivate their farms the traditional way. These farmers apply fertilizers not only based on plant condition but also take into consideration predetermined dates after seeding or transplanting. Not following holistically the protocols established for fertilizer management, farmers suffer the consequences of bad fertilizer management, thus lesser harvest yield. Fertilizers must be applied only when necessary and based on the crops' nutritional status. However, most farmers rely on the age (days after transplanting) of the rice plant and not on its condition. Consequently, this causes a deficiency in the required nutrient of a plant from the fertilizer in terms of growth, development, and yield. Moreover, there are some unaware farmers, that applying fertilizer too soon, will result to undesirable effects on growth and yield of rice and thus have a significant addition to the production cost which is not ideal [1].

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II. RELATED WORKS

There have been many developed methods of the proper application of fertilizer [2]. One of the most effective means to determine the volume and when to apply fertilizer is to use the developed Leaf Color Chart (LCC). The LCC is used to assess the plant Nitrogen (N) status. It is an inexpensive tool consisting of four (4) color shades from yellowish green to dark green. The color strips are fabricated with veins resembling those of rice leaves. The assessment will depend on the greenness of the leaf matched to the LCC window. Each window defines a level of N status. This method however, limits the capability of the human eye to distinguish from the colors given in the chart from the colors of the rice plant leaf as evidenced in the findings of the on-farm evaluation. The color matching is relative to the person's color perception so it is recommended that the same person should do the matching. The use of the LCC is also limited to a period of a day due to the effect of sunlight to the colors, both of the leaf and the chart [3], [4].

In the Philippines, the on-farm evaluation of the LCC technique has demonstrated its usefulness for real-time nitrogen management in rice. The increase in N-use efficiency was due to slightly less, same or higher yields grain, with lower levels of N application in the LCC-monitored fields.

Savings in N fertilizer of -14 to +53 kg per hectare were realized in farmers' fields of other collaborating countries [5].The work of P. Sanyal and U. Bhattacharya explained that rice deficiencies in the balance of mineral levels can be identified by detecting the change in the appearance of rice leaves [6]. This work is also supported by P. Murakami et al, that changes in foliar color are a valuable indicator of plant nutrition and health. The leaf color is measured with visual scales and inexpensive plant color guides that are easy to use, but not quantitatively rigorous, or by employing sophisticated instrumentation including chlorophyll meters, reflectometers, and spectrophotometers that are costly and may require special training [7].

The International Rice Research Institute (IRRI), and the Department of Agriculture (DA) in the Philippines, initiated the NM Rice Mobile application. It applies the concept of Site Specific Nutrient Management (SSNM), a set of scientific principles for optimally supplying rice with essential nutrients. The LCC is covered by SSNM. Farmers dial a toll-free number and a voice response will follow which will direct them to a set of 12 to 15 questions related to the status of the rice plant. Eventually, a text message will be sent to the farmer's phone containing recommendations on fertilizer application duly customized for his field. The mobile application is available in Tagalog, Cebuano, and Ilocano dialects [8].

The paper of S. Pongnumkol, P. Chaovalit and N. Surasvadi, presented a review of the capability of smart phones to becoming a very useful tool in agriculture, mainly to their mobility that matches the nature of farming, the cost efficiency and accessibility of computing power. It systematically reviewed smart phone applications that utilize built-in sensors to agricultural solutions [9].

Similarly, the work of V. Patodkar et al, presents a developed android software application for sustainable development for farmers. The application assists the farmer in decision making regarding selection of fertilizer, pesticide and time to do particular farming actions. It combines internet and mobile communications with Global Positioning System (GPS) [10].

The system developed by Sanjana, Sivasamy, Jayanth [11] consisted of a mobile application which enables farmers to take digital images of plants using their mobile phones and send it to a central server where the central system analyzes the pictures based on visual symptoms using image processing algorithms to measure the disease type. An expert group will be available to check the status of the image analysis data and provide suggestions based on the report and their knowledge, which is then sent to the farmer as a notification in the application.

Based on the insights from these pieces of literatures, this project aims to apply digital processing techniques in a mobile application that can be used as a tool to assist rice farmers in fertilizer management of the rice plant based on the LCC framework and its guidelines.

The project intends to implement the image normalization technique as a preprocessing method and the digital image pixel subtraction technique as the processing algorithm into a mobile phone application [12]-[14].

The application is to be used in the rice paddy field as an assistive technology for rice plant farmers. It aims also to archive data sampled from the rice field to be used as baseline comparative statistics by other researchers. The framework of the study was inclined on the use of smart mobile phone technology, image processing and rice farming technologies.

III. SYSTEM ARCHITECTURE

A. Application architecture

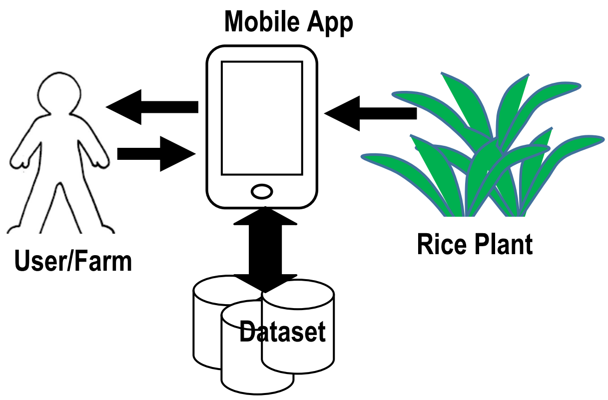

Fig. 1.A system view of the application.

Shown in Fig. 1, is the conceptual framework of the system: the mobile phone application processes sample images of leaves taken from rice plants in the field through its built-in camera device, these images are processed and eventually references the average image against the digitized LCC dataset. This process determines the nitrogen deficiency of the rice plant. The number of samples is dependent on the size of the rice field. Ideally, more samples from a large area, the better the outcome of the mobile application. However, the LCC standard suggests that five (5) leaf samples per hectare taken randomly from the field are sufficient to represent the whole area.

The intelligence of the application relies on the digitized LCC dataset that is used as the basis in determining the nitrogen content of the captured rice plant leaf color. The whole process is integrated into the mobile application: the user launches the application and through the camera of the phone, to take samples of the rice plant leaf. The application converts the images one at a time, calculates the average of the samples and performs image comparison. The method uses the color depths of the captured image from the base image and compares it from the digitized LCC database. Subsequently, the application displays the result, suggesting the amount of fertilizer to be applied. The results are archived in the database for future reference and further study.

B. Computational processing of the application

Fig. 2 presents the computational algorithm of the mobile application. The system takes sample images of rice leaves in the rice field. These images are then processed by converting it to its equivalent Red, Green, Blue (RGB) formats. By subtracting the average value of the sample images from the value of the baseline LCC images present in the application, consequently, a resulting near accurate color value is returned.

If the sample images are out the range, then the user is alerted that the image is not a rice leaf. The same procedure is done until the captured image is valid. While the application captures the images, it also records the ten greenness values of the rice leaves.

The average greenness values of the ten images are also stored. The average greenness value of the sample images is then subtracted from the baseline values per window of the digitized LCC. After this process, the indicative result based on the interpretation of the greenness value is displayed. Included in the indicative result is the fertilizer recommendation accordingly to the specified window.

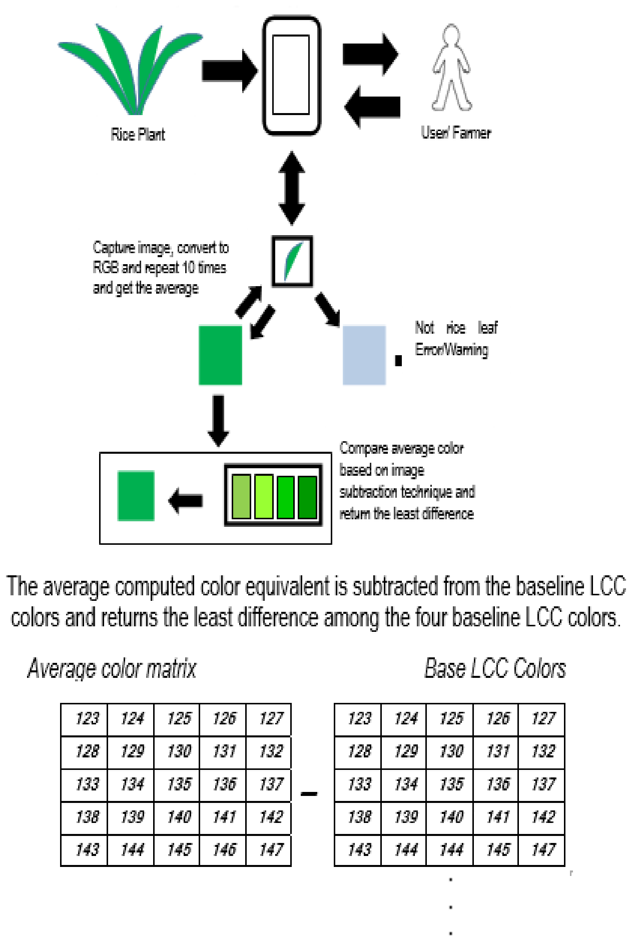

Fig. 2. Processing mechanism of the mobile application.

The RGB color space of the captured bitmap image is used as the numerical representation of the image. The RGB data value of each pixel's color sample has three numerical values to represent the colors Red, Green, and Blue. These three RGB components are three 8-bit numbers for each pixel. Each 8-bit RGB component can have 256 possible values, ranging from 0 to 255.

To get the area of concern from the image, the height and width of the bitmap is first calculated, which is denoted by:

$$Z = (0...x, 0...y) \tag{1}$$

Where:

Z = bitmap image
x = x coordinate plane
y = y coordinate plane

The color value of each pixel is represented in (2) denoted by:

$$P_{(x,y)} = (R, G, B) \tag{2}$$

Where:

$P_{(x,y)}$ = pixel in the x and y coordinate plane
(R,G,B) = (0...255, 0...255, 0...255)

Color normalization is also applied to the pixels to reduce the effects of light. Normalization of the color space of the image removes highlighted regions and shadows this makes it easier to detect the color of the leaf. Based on equation (2), the normalization method is presented below:

$$Total = (R + G + B) \tag{3}$$

$$R' = round((R / Total) * 255) \tag{4}$$

$$G' = round((G / Total) * 255) \tag{5}$$

$$B' = round((B / Total) * 255) \tag{6}$$

Thus, the normalized images are denoted by the equation in (7):

$$P1|2_{(x.y)} = (R', G', B') \tag{7}$$

The pixel subtraction technique is as simple as taking two images as input parameters, this mechanism produces a third image whose pixel values are simply the difference of the corresponding pixel values from the two images. It is also often possible to just use a single image as input and subtract a constant value from all the pixels. Some versions of this technique produce the absolute difference between pixel values, rather than the straightforward signed output.

The subtraction of two images can be performed straightforwardly in a single pass using the formula in equation (8).

$$[Q_{(i,j)} = P1_{(i,j)} - P2_{(i,j)}] \tag{8}$$

Where :

Q = the output value
P1 = the first image value
P2 = second image value

Or the absolute differences between the two input images can be computed from equation (9).

$$[Q_{(i,j)} = | P1_{(i,j)} - P2_{(i,j)} |] \tag{9}$$

Or simply subtract a constant value C from a single image if desired using the formula in equation (10):

$$[Q_{(i,j)} = P1_{(i,j)} - C] \tag{10}$$

Where:

P1 = first image value
C = baseline image value

The green (G) color component value in a pixel is simply extracted separately to produce the nearest output value.

IV. RESULTS

A. Detection Testing

Tests were conducted on the premise that the algorithm may result and interpret colors from other leaves other than of the rice leaf. Thus, a mechanism was integrated to accurately identify whether the captured image is that of a rice leaf.
Shown in Fig. 3, is the result after capturing thru the mobile phone camera the rice leaf. The image presents the confirmation of the object being a rice leaf which does not display warning or notification of an error. The application converts the image and saves it in RGB format

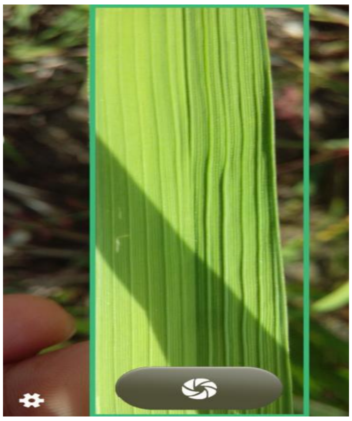

Fig. 3. Correct rice leaf image.

Fig. 4 and Fig. 5 shows the status screen of the mobile application when a different leaf or an object with the same color of a rice leaf is captured. It is capable of determining that the image taken is not a rice leaf, resulting in the notification display of an error-warning to the user. Not only the difference in color but also the difference between the two objects can be detected, even though the object captured has a similar color with a rice leaf. Fig. 6 shows the indicative results when the application correctly determines the captured image that is of a rice leaf. Consequently, the result of the detection process is displayed. In this case, the leaf is in category 4 of the LCC, which means the plant requires a certain amount of fertilizer. The application will also display the required volume of the fertilizer that should be applied in the rice field.

Fig. 4.Error detection warning for a different leaf with similar color.

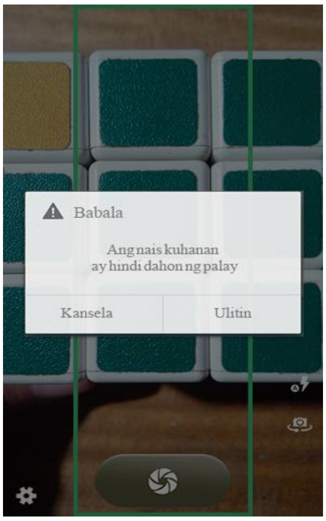

Fig. 5.Error detection warning for a different object with a green color.

Fig. 6.The indicative result when fertilizer deficiency is detected from the rice leaf.

Fig. 7.The indicative result when rice the plant is not fertilizer deficient.

Fig. 7 shows the result when the processed data from the captured image is within category 5 of the LCC, which means, not fertilizer deficient. The application will display a notification to the user that there is no need for fertilizer to be applied to the rice field.

B. Actual Field Test Results

The test data were gathered from the five (5) week actual field testing. The process was synchronized with the growth stages of the rice plant, to get the real colors of the rice plant throughout its different growth stages. The Z-test statistic was used to verify and validate the hypothesis that the developed mobile application using the image subtraction technique does not have a significant difference with the traditional LCC.

The field test consisted of a rice field of approximately three hectares. The area was divided equally into three zones (Area 1, Area 2 and Area 3) due to the geographical contours and for an equal number of samples per area sampled. Thirty (30) leaf sample pictures were taken from each area randomly, these thirty samples were also divided into three (3), so that ten (10) leaf samples for each strip one area, for a total of ninety (90) leaf samples each week.

The field test was done from the vegetation and milking stages of the rice plant, giving a total of 450 leaf samples, with an average of 45 samples. During the field tests, the researchers also synchronized the use of the traditional LCC. This was done so that readings are consistent with the LCC due to the leaf's condition for a short time. This is to lessen the effect of other factors like sunlight, moisture, wind, temperature, shading, etc.

Table- 1: The success rates of the system in the field test

Week	Area 1			Area 2			Area 3		
	a	*b*	*c*	*a*	*b*	*C*	*a*	*b*	*c*
1	6	6	6	8	8	8	6	6	6
2	6	6	6	8	8	8	6	6	6
3	6	6	6	8	8	8	6	6	6
4	7	7	7	7	7	8	9	7	9
5	7	7	7	8	8	8	9	7	10

a. $*n = 45 \quad \bar{x} = 7.08 \quad \sigma = 0.03$

Table 1, shows the success rates readings of the mobile application in comparison to the LCC. The study assumed that the null hypothesis is equal to, Ho = 5, which is the mean success rate of the mobile application and the alternate hypothesis is greater than H1 > 5. To test the hypotheses if the application has no significant difference between the traditional LCC, the z-test statistics is employed.

To compute for the z-test statistic the formula in equation (11) is used. The alpha level considered by defaults is 5% (0.05). The rejection region area in the z-table is 0.05, which is equal to a z-score of 1.645.

$$Z = \frac{\bar{X} - \mu_0}{\sigma / \sqrt{n}} \quad (11)$$

Where:

Z = the test statistic, $\bar{x}$ = mean score, σ = standard deviation, n = population, sample, and μ_0 = null hypothesis

Continuing with the computation, the equation is used straightforward. The Z statistic value is then derived in (12):

$$Z = \frac{7.08 - 5.0}{0.03 / \sqrt{45}} = 1.033 \quad (12)$$

Comparing the computed Z-statistic test result score of 1.033 with the z score of 1.645, it shows that the computed Z statistic test score is less than the Z score prescribed in the Z table. This suggests that the null hypothesis is not rejected. Further, the results imply that using the mobile application can be an effective assistive technology for rice farmers and as efficient as the LCC. The accurateness of the system is assured as it has been proven thru statistical analysis that the mobile application does provide significant and similar results compare to the traditional LCC.

V. CONCLUSION

A mobile application was developed and the proposed method was successfully implemented. The results of the field experiment demonstrated that machine vision can be a tool to assist farmers in detecting the level of nitrogen deficiency of rice plant, by implementing image processing techniques as the mechanism. Specifically, the intelligence of the developed system is the application of the image or pixel subtraction algorithm. By using digitally captured bitmap images with their corresponding RGB numerical formats. This technique was proven to be easily executed as a function in the application, using an android based smart phone.

Field test results suggested that the developed mobile application is comparable to the traditional LCC standard. Meaning, they are complementary with each other or can be used individually without a significant difference in their outputs. Similarly, the statistical test result also implies that machine vision can be used as an assistive technology to rice farmers, specific to the detection of nitrogen deficiency of rice plants presented in this study. The implemented detection algorithm for nitrogen deficiency is accurate and efficient. Future endeavors to include other variables like temperature, time of the day, and age of the plant may be considered for the improvement of the application. To cover a larger area and for faster acquisition of images, an unmanned aerial vehicle is also being considered.

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