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Original article

Maize plant nutrient deficiency recognition through deep neural network

Loyd S. Echalar[1*], Sherwin B. Sapin[1] and Crisanto F. Gulay[1]

Laguna State Polytechnic University, Los Baños, Laguna, Philippines 4030

ABSTRACT

The agricultural sector is one of the most important sectors of our economy. This is one of the reasons why adopting modern technology plays a significant role in the agricultural sector particularly in managing and administering crops for sustainable production. Maize is one of the crops that the Philippines can be proud of. A modern way of producing sustainable maize crops is very essential nowadays, especially to the maize farmers. The development of a mobile application that identifies and classifies the health condition of maize crops as well as the type of diseases and pests that the maize crops have is presented in this paper. The mobile application used image processing technology with image analysis and plant feature extraction for the identification and classification of maize health conditions, diseases, and pests. Local Binary Pattern Histogram (LBPH) and Convolutional Neural Network (CNN) are the algorithms used to provide accurate and reliable findings. Different evaluation and assessment techniques are done to estimate the accuracy of performance and quality of the project. It concludes that the mobile application will greatly support the needs of the agriculture sector and could be extremely beneficial to the maize farmers in terms of addressing difficulties and needs related to maize crop management and administration.

KEYWORDS: *nutrient deficiency, symptoms recognition, image analysis, deep neural network, Convolutional Neural Network (CNN), Local Binary Pattern Histogram (LBPH)*

1 INTRODUCTION

Maize is known as the alternative food in the most productive or producing countries and it is a large contributor to the nation's economy. Maize is the other most significant crop in the Philippines, behind rice, with 1.8 million of Filipino farmers relying on it as their primary source of income. In times of rice scarcity, white maize is the most common replacement, especially among rural populations. Yellow maize is the principal source of animal feed in the Philippines, and it is increasingly being used in the manufacturing sector. Over the last two decades, maize production in the Philippines has increased at an annual pace of 1.7 percent (1980-2000). Maize production peaks in highland locations from July to September, with the lean months being January to June. Mindanao's upland regions have the most maize planted land and produce the most in the Philippines. Maize is also farmed in the rainfed lowlands, where it is sown after the rice crop has been collected during the dry season. (Gerpacio, 2004) For the agricultural sector particularly the maize crops, there is a need for modern technology that will help in the improvement of management and administration of its production. Manual identification for maize crops condition, diseases, and pests are very difficult, especially to the farmers. Diagnosing the conditions of maize crops through fungi, parasites, weather effects and other reasons to analyze is difficult, laborious, and time-consuming for the farmers. (Burgess L.W., 2008)

Modern technology in maize crop management is essential and significant not only for the farmers but also to the entire agricultural sector. One of the technologies that may help the agricultural sector in crop sustainable production is image processing. During this time, image processing was heavily used. As it aids in a specific everyday process, it becomes more useful and significant to the stakeholders. Several researchers have employed this strategy to assist specific groups of people with their problems and requirements. Image processing is a technique or procedure for converting an image to digital form and performing processes on it in order to extract relevant information. The following three processes are usually included in image processing. Importing the image by optical scanning or digital photography is the first step. Image analysis and modification is the second stage, which involves data compression, image improvement, and finding patterns that are not visible to the naked eye, such as in satellite photographs. The output is the third stage, and the outcome can be an information or analyzed image based on image analysis. (Huiyu Zhou, 2010)

Machine learning algorithms help image processing to provide accurate identification and classification of information. Machine learning algorithms provide

*corresponding author: loydechalar@lspu.edu.ph
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improvements to computer visions by analyzing the input data and providing predicted output within the acceptable range. (Bonaccorso, 2017) The deep learning algorithm is part of a machine learning algorithm termed an artificial neural network, which is concerned with algorithms inspired by the structure and function of the brain. (Szegedy, 2013) In applying deep neural networks to the image processing technology, a convolutional neural network class (CNN) was used. CNN class helps analyze, classify and identify the content of a digital image and transform it into useful information. (S. Albawi, 2017) Another algorithm used in the mobile application is the Local Binary Histogram that helps also in identifying and classifying the content of a digital image through pixel measurements. (Echalar & Subion, 2018)

A mobile application that uses image processing technology for the detection of maize plants' health conditions, as well as the diseases and pests of the maize crops is presented in this paper. With the use of machine learning algorithms particularly the deep neural network algorithm as well as the local binary pattern histogram identification and classification of the content of a digital image can be accurate and reliable.

2 MATERIALS AND METHODS

To develop the application, Agile Scrum Methodology was used. Different phases such as product backlog and sprint backlog were accomplished to identify problems and accomplishments on the project development. Other techniques and models were presented in order to identify the overall performance and functions of the mobile application.

Figure 1 shows how the detection and identification of health conditions/diseases/pests are done. The first phase is loading the digital image to the mobile application by capturing parts of the maize plant and pest to be analyzed. The second phase is the image segmentation in which the LBPH would do the measurement of all the pixel values in order to identify the content of the digital image. The third phase is image recognition in which the convolutional neural network works by comparing the value of the digital image to the set of data integrated into the system of the mobile application. Lastly, image interpretation phase in which the value of a digital image was found similar to a particular data on the system and produces the result.

Figure 2 shows that the users would use the mobile application with various modules such as the user interface, allow users to select a specific module to perform; Detection Module with submodules disease and pest detection and condition detection, that allows the users to capture/scan a particular maize plant/pest in order to identify and classify condition, disease or pest as well as the type of disease, name of pest, their possible cause, and possible actions; and History module that allows the users to reuse the previous captured image and information as a reference for aiding the detected condition disease and pest as well as the deletion of captured image and information from the history. Figure 2 also shows what specific/particular information that the mobile application has, such as the application description, condition/disease/pest description/information, which allows the users to gather, gain and understand knowledge and information about maize crop farming, management, and administration.

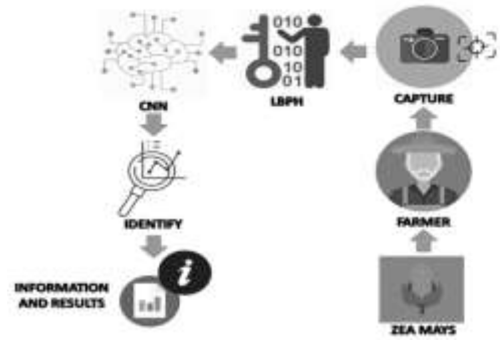

Figure 1. Process of Maize Health Condition Detection

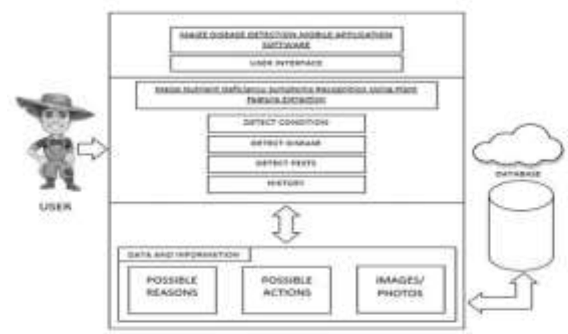

Figure 2. System Architecture

In Figure 1, it can be clearly seen that after exposure to gamma radiation, plant height and plant survival immensely decreased. The highest dosage which is 0.3 kGy produced the shortest plants (17.67±0.40SD cm) and lowest percentage survival (33%). This result also corresponds with the result of Songsri et al., (2011) wherein the highest dosage of gamma radiation resulted the shortest height, germination, and stem diameter of physic nut and also in the study of Alvarez-Holguin, (2019) which observed that seeds with high radiation doses cannot germinate, or their seedlings cannot survive beyond a few days after 4 kGy dose. As reported by Berry (2012), shorter plants have its advantages with seed establishment, which also prevents lodging and yield loss. Increased gamma radiation doses also increase free radicals' production, leading to diminished growth and sometimes to a shortened lifespan of plants (Marcu et al., 2013). Possible inhibition of cells during the germination process could have contributed to shorter growth as

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cellular mass may have also been affected.

3 RESULTS AND DISCUSSION

This section discusses the results found during the evaluation and assessment of the project. This includes the result of the deep learning algorithm used; the process and result of image analysis; and the results for different testing conducted to the project.

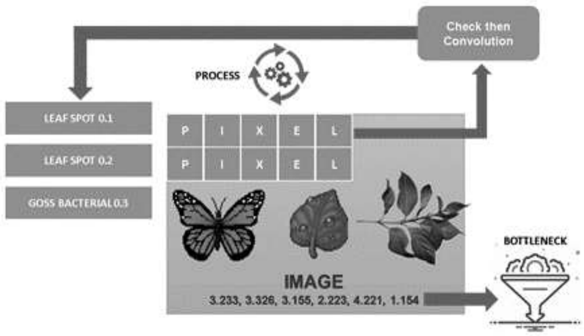

Figure 3. Convolutional Neural Network in the Background

Figure 3 shows the process of how a convolutional neural network works in application. The value of each pixel in a digital image is measured by the LBPH Tensorflow is a library with a collection of models. The data set's models were all transformed to hexadecimal values. The hexadecimal value of a captured digital image is analyzed and compared to a set of models written in hexadecimal formats as well. CNN goes through several stages to detect and classify a suspected disease or pest: (1) classification and analysis of digital visual material using convolutional layers; (2) The pooling layer combined all of the convolutional layer's analysis and compared it to the set of models; finally, (3) after passing through the convolutional and pooling layers, this fully-connected layer delivers a possible categorized result. After analyzing the content of a digital photo with CNN, a list of possible discovered and identified pests/diseases is provided. The confidence value that attained 75% would be the identified result.

Table 1. Results of Algorithm Accuracy

ALGORITHM	ACCURACY
Convolutional Neural Network	98.48%
Logistic Regression	81.73%
Multilayer Perceptron	83.62%

Table 1 shows the result of the comparison of three different image processing algorithms by using all three algorithms in the application. The algorithms fall under the so-called Deep Learning algorithm, and as indicated in the table, CNN has shown the most promising result which gained a total numerical rating of 98.48% percent while Logistic Regression only has 81.73% percent and Multilayer Perception has a total rating of 83.62% percent. It was stated in many pieces of research that a machine learning algorithm was only acceptable in a Bioinformatics application if it has gained at least 90 percent accuracy. (Baldi, 2001) Table 1 only showed that CNN was indeed acceptable for classifying Maize condition diseases and pests.

Table 2. Result of Detection by Level of Brightness

BRIGHTNESS	Dis. 1	Dis. 2	Dis.3	Pest 1	Pest 2	Pest 3
Very Dim	0.254	0.322	0.215	0.321	0.511	0.335
Slightly Dim	0.259	0.321	0.322	0.321	0.452	0.479
Correct Brightness	0.454	0.212	0.215	0.254	0.215	0.480
Slightly Bright	0.124	0.214	0.211	0.321	0.135	0.632
Very Bright	0.314	0.145	0.321	0.217	0.225	0.327

Table 2 shows that the level of brightness affects the detection of maize conditions, diseases as well as pests. The lower and brighter the level of brightness the lower the chance to detect accurate results. The normal lighting of the environment and surroundings may help the mobile application to detect accurate results.

Table 3. Result of Principal Component Analysis

	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	Test 7	Test 8	Test 9	Test 10
Dis. 1	0.25	0.32	0.21	0.32	0.51	0.34	0.25	0.33	0.33	0.34
Dis. 2	0.26	0.32	0.32	0.32	0.45	0.48	0.32	0.34	0.33	0.33
Dis. 3	0.45	0.21	0.21	0.25	0.21	0.48	0.31	0.32	0.32	0.99
Pest1	0.12	0.21	0.21	0.32	0.14	0.63	0.32	0.65	0.15	0.32
Pest2	0.31	0.14	0.32	0.22	0.22	0.33	0.33	0.32	0.33	0.32
Pest3	0.36	0.32	0.32	0.45	0.21	0.57	0.37	0.97	0.32	0.33

Table 3 shows the accuracy of detection to different diseases and pests using the principal component analysis. Each disease and pest were ten times repeatedly captured to identify if there is a big difference or nothing with one another. Once the detection has a big difference from another detection then the application is not accurate at all.

Table 4. Result of Detection by Level Distance

	Dis. 1	Dis. 2	Dis. 3	Pest1	Pest2	Pest3
1-2 Inches	0.261	0.328	0.221	0.328	0.518	0.341
3-4 Inches	0.265	0.327	0.329	0.328	0.459	0.485
5-6 Inches	0.460	0.218	0.221	0.261	0.221	0.486
7-8 Inches	0.131	0.221	0.218	0.328	0.141	0.638
9-10 Inches	0.321	0.151	0.327	0.224	0.231	0.333

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Table 4 shows that the distance in capturing a digital image may affect the accuracy of identification and classification of the result. The 7 inches and above distance to the object to capture may no longer detect an accurate result, while 1 inch to 6 inches distance to the object to capture may provide accurate results.

Table 5. Compatibility Testing

Processor	Remarks	Ram	Speed	Pixel	Image Quality
1 GHz and Below	Not Running	512MB	-	3MP	-
1.2 GHz Quadcore	Running	512MB	Very Slow	5MP	Very Low Resolution
1.4 GHz Quadcore	Running	2GB	Slow	10MP	Low Resolution
2.5 GHz,	Running	3GB	Moderate	13MP	High Resolution
4/2.0 GHz, & Higher	Running	4GB	Fast	16MP	High Resolution

Table 5 shows what phone specification is compatible with the application.

Table 6. Result of Detection Performance on the Health Condition of Maize

Condition	Healthy	%	Unhealthy	%	Total Test	%
Healthy	13	86.67 %	2	13.33 %	15	100 %
Unhealthy	10	66.67 %	5	33.33 %	15	100 %

Table 6 shows the accuracy of the detection of maize conditions through the use of a confusion matrix. The matrix was done through testing of 30 different rice plant images (15 healthy and 15 unhealthy) on different conditions. The results are: out of 15 healthy rice plants, 13 was detected as healthy, and 2 was detected as unhealthy; out of 15 unhealthy rice plants 10 was detected as unhealthy, and 5 was detected as healthy; with an accuracy rate of 76.67% and an error rate of 23.33%. The following items could be the source of detection ambiguity: unclearness of the acquired maize plant image; wrong and detailed background; too low brightness excessive brightness of surroundings; unsuitable distance to the target image/object; multicolored images; contains unclear objects and contents; and camera quality

Table 7. Result of Detection Performance on the Disease of Maize

Condition	Leaf Spot	%	Leaf Rust	%	Goss Bacterial Blight	%
Leaf Spot	7	46.67%	3	20.00%	5	33.33 %
Leaf Rust	3	20.00%	10	66.67%	2	13.33 %
Goss Bacterial Blight	5	33.33%	4	26.67%	6	40.00 %

Table 7 shows the correctness of the CNN algorithm in the recognition of maize disease through the use of a confusion matrix. The matrix was done through testing of 45 different rice plant disease images (15 each disease) on different conditions. The above table shows the true and false detection of the mobile application. Uncertainty in the captured maize plant disease image; improper and complex background; too low brightness or excessive brightness of settings; inappropriate distance to the target object and image; improper placement of the object; contains unclear objects and contents; and camera quality are all potential sources of detection ambiguity.

Table 8. Evaluation Results

Factor	Ratings	Interpretation
Functional Suitability	3.89	Strongly Acceptable
Performance Efficiency	3.63	Strongly Acceptable
Compatibility	3.62	Strongly Acceptable
Usability	3.86	Strongly Acceptable
Reliability	3.71	Strongly Acceptable
Security	3.88	Strongly Acceptable
Maintainability	3.76	Strongly Acceptable
Portability	3.48	Strongly Acceptable
Overall weighted mean	**3.73**	**Strongly Acceptable**

Based on the ISO25010 software quality standards, Table 8 illustrates the overall ratings and level of acceptability of the mobile application by respondents. “Functional Suitability” with an overall rating of 3.89 and an interpretation of “strongly acceptable”; “Performance Efficiency” with an overall rating of 3.63 and an interpretation of “strongly acceptable”; “Compatibility” with an overall rating of 3.62 and an interpretation of “strongly acceptable”; “Usability” with an overall rating of 3.86 and an interpretation of “strongly acceptable”; “Reliability” with an overall rating of 3.71 and an interpretation of “strongly acceptable”; “Security” with an overall rating of 3.88 and an interpretation of “strongly acceptable”; “Maintainability” with an overall rating of 3.76 and an interpretation of “strongly acceptable”; “Portability” with an overall rating of 3.48 and an interpretation of “strongly acceptable”, and the overall rating is 3.73 got an interpretation of “Strongly Acceptable”.

4 CONCLUSIONS AND RECOMMENDATIONS

The mobile application assists the agricultural sector, particularly farmers, in identifying and detailing maize problems, illnesses, pests, potential causes, and treatments. The mobile application assists users in detecting difficulties in an effective and efficient manner, as well as providing accurate and reliable data and

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information that assists them in determining the causes and remedies to the discovered problems. The application assists the agriculture sector, primarily farmers, with their maize crop management and administration needs. Based on the findings of the evaluation and experiment instances, the mobile application is effective for detecting health issues, infections, and pests; however, the mobile application may not be correct due to the following: unclear acquired image; improper and complex background; too low or excessive brightness of surrounds; improper distance to target image and photos; improper placement of the object; it may contain confusing contents and things such as the background; and the quality of the camera and the photographs affect the quality of the detection.

In view of the after-effects of overview and programming quality assessment and testing, coming up next are suggested to improve and advance the execution of the mobile application in order to help different partners in the farming business. The mobile application must not just rely upon the identification of maize wellbeing conditions, infections, and bugs. Future researchers may consider the accompanying capacities and actions to improve the application capability: soil health, condition detection, maize variety detection, and nutrients deficiency detection. It is better to connect the mobile application to the internet; the mobile application must work online, not only offline. Future researchers may execute this sort of utilization online for them to have exact and proficient information and data, and to utilize the application by various associates on the horticulture business in any area of the nation. The mobile application must concentrate on the maize crop cultivating as well as on other oat grains crop cultivating with the equivalent/close plant type, for example, wheat and maize crops. The mobile application must incorporate graphical introductions, for example, recordings and pictures of maize crop generation, cultivating, organization and the board rehearses to guide and help rural staff particularly ranchers all the more in fact and mentally. The study also recommends that agricultural personnel must use the application as it helps a lot in the supervision, management, and farming of maize crops as well as it provides accurate detection and consistent information for all the users. System requirements are important, to acquire correct results and quality images. It is recommended that the application must be used and installed on an android mobile phone with 2.5 GHz Octa-core and 13 MP specification and above for a well and accurate use of the mobile application.

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