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E-Citrus: A Cloud-Based Citrus Pest and Disease Detection, Diagnostic and Prevention using Convolutional Neural Network

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Abstract: Citrus fruit yields in the Philippines have been fluctuating dramatically in recent years. Diseases, pests, and soil inadequacy have all contributed to the citrus industry's severe decline. More than 15 viruses and virus-like diseases have infected Citrus. Agricultural productivity must improve for a country to be progressive. Resources should be utilized to their full potential, diseases and pests should be controlled efficiently, and technological advancements must be adopted. This application will identify and map common pests and diseases of citrus fruits in Oriental Mindoro, apply image processing techniques to analyze diseases of citrus fruits with corresponding solutions caused by bacteria, and give information about diseases related to citrus fruits and how to cure them. The researchers used the Spiral Model as a Software Development Life Cycle (SDLC) model to develop this application. In this model, researchers can plan the flow of the application. If the application did not meet the desired result, the researchers could revise it again until it met the desired one. The researchers used the convolutional neural network to classify and process the captured images of the citrus fruits' diseases and pests. The researchers asked the selected Citrus farmers in Oriental Mindoro to evaluate the project using the different ISO 25010 criteria and rated the application as very acceptable overall.

Keywords: CNN, Citrus Fruits, e-Citrus, Image Processing, Oriental Mindoro

1. Introduction

Any nation's economic development depends heavily on agricultural productivity. Saini *et al.* [1] stated that disease identification in plants is vital in the agricultural sector, as plant disease is common. Thus, the development of tools to early detect pests and diseases would be a great tool to prevent their continuous widespread.

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Citrus has been identified as one of the most important high-value crops in the Philippines due to its high economic returns. Its industry had high demand in the domestic market and area expansion for its cultivation, which made Citrus rank fourth to banana, mango, and pineapple in terms of area and production. Citrus fruits grown in Oriental Mindoro include calamansi (Citrofortunella microcarpa), sinturis (Citus nobilis), pomelo/suha (Citrus maxima), and lemon (Citrus limon), with productivity in metric tons estimated at 11, 756.51, 214.21, 2.88, and 0.75, respectively. Calamansi, among the citrus being mentioned, is the top commodity produced by the province. Aside from being the Rice Granary of the MIMAROPA (Mindoro, Marinduque, Romblon, and Palawan) Region, Oriental Mindoro was known as the Calamansi King of the country.

Citrus fruit yields in the Philippines have been fluctuating dramatically in recent years. In addition, diseases, pests, and soil inadequacy have all contributed to the citrus industry's severe decline. Based on the study of Moriya *et al.* [2], the various diseases caused by fungi, bacteria, viruses, and pests limit citrus production. In accordance with that, Sharma *et al.* [3] identified the twenty-five critical diseases and pests identified in Citrus and aided in restricting the production and productivity controlled through chemicals. More than 15 viruses and virus-like diseases have been infected with Citrus. The highest number of insect pests is under the order of Hemiptera, which dominates about 38% of pest insects, and 52% of the total insect pests are considered major pests to citrus plants.

This application will identify and map common pests and diseases of citrus fruits in Oriental Mindoro, apply image processing techniques to analyze diseases of citrus fruits with corresponding solutions caused by bacteria, and give information about diseases related to citrus fruits and how to cure them.

This study aims to design and develop a Cloud-based Citrus Pest and Disease Detection, Diagnostic, and Prevention using a Convolutional Neural Network (CNN) with Mobile application.

Specifically, it aims to:

1. Design and develop an application that identifies common pests and diseases within a particular citrus farm in each municipality of Oriental Mindoro;
2. Develop an application to map the pests and diseases of citrus farms in the province;
3. Develop a mobile application that applies image processing techniques to analyze diseases of citrus fruits with corresponding solutions caused by bacteria;
4. Develop a mobile application that will give information about diseases related to citrus fruits and how to cure them.

2. Literature Review

According to Iqbal *et al.* [4], adopting automated detection and classification methods for citrus plant diseases is still in its infancy. Additional technologies are, therefore, required to fully automate the detection and classification processes.

For the purpose of assisting agricultural engineers in identifying plants with eight potential citrus illnesses, an expert system was developed by Ibraheem *et al.* [5]. Wherein citrus illnesses, including citrus canker, citrus scab, citrus tristeza disease, gummosis, greening or hualongbing, sooty mold, powdery mildew, and anthracnose, can be diagnosed using the Expert System feature. The proposed expert system was created and implemented using the CLIPS Object Expert System language.

Additionally, a survey by Saini *et al.* [1] regarding various approaches for detecting and classifying diseases in citrus plant leaves revealed that image preprocessing strategies contribute to increasing segmentation precision. During this survey, the k-means technique was the most critical segmentation

strategy for diseased plants. The most prominent characteristic of the picture is the texture used to depict the disease, and SVM and NN use these characteristics. This requires their efforts to incorporate an effective, fast, reliable, and automated system to recognize diseases on uninfluenced citrus leaves.

Lee *et al.* [6] proposed a computerized method for detecting citrus pests using deep-learning methods. They gathered high-resolution citrus pest images from natural plantations to create a multivariate citrus image dataset. Accordingly, it will be possible to generalize studies applicable to other varieties beyond Citrus in actual farmland.

On the other hand, through unmanned aerial vehicles (AUVs), the detection of the main fungal disease of Citrus was evaluated by two datasets: the 25-band sensor and the three-band multispectral sensor. The results indicated better performance for detecting citrus gummosis with the hyperspectral images than with three bands of multispectral images [2]. However, it could be costly for farmers to adopt this device.

The identification of the common diseased terrestrial plants present in the Philippines is also shown via an Android-based application developed with Deep Learning Neural Network classification developed by Valdoria *et al.* [7]. Whereas the Deep Learning Neural Network Algorithm is used to discern the sickness of terrestrial plants, photographs of the plant were taken using Android-based smartphones to identify the ailment of the plant.

3. Methodology

The application is developed using the Spiral Model, also known as Software Development Life Cycle (SDLC) model. In this model, developers can plan the flow of the application. If the application does not meet the desired results, the developers can revise it until it meets the desired ones. Developers will proceed to analyze the application. The developers used the convolutional neural network method. This method is a combination of deep learning and deep neural networks. It is most commonly applied to analyzing visual imagery. They are also known as shift-invariant or space-invariant artificial neural networks (SIANN) based on their shared-weights architecture and translation invariance characteristics. They have applications in image and video recognition, recommender systems, image classification, medical image analysis, and natural language processing.

3.1 System Architecture

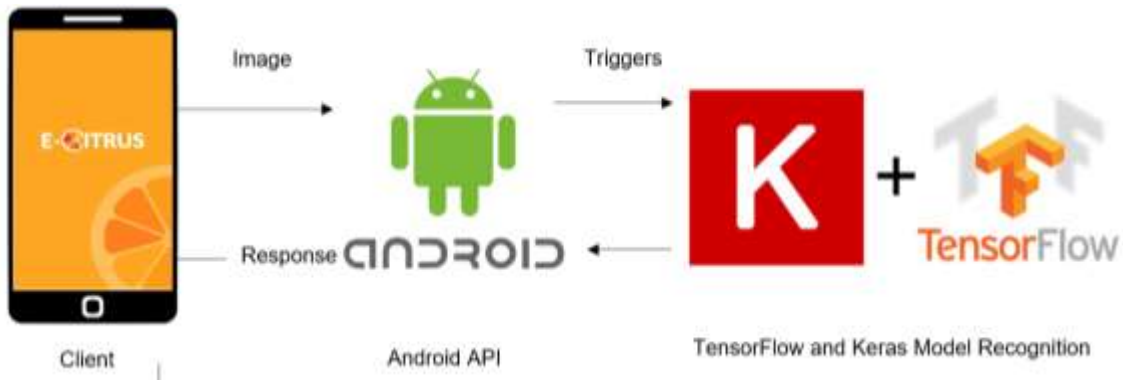

Figure 1. System Architecture

"e-Citrus" is a mobile application intended for citrus farmers. The Cloud, or the Internet, is the communication center between data analysis and the mobile application.

3.2 Graphical User Interface

This section outlines the system output for the e-Citrus mobile application. The application identifies and maps common pests and diseases of citrus fruits in Oriental Mindoro, applies image processing techniques to analyze diseases of citrus fruits with corresponding solutions caused by bacteria, and provides information about diseases related to citrus fruits and how to cure them. The output of the application is shown in the following Figures.

Figure 2. Landing Page

Figure 2 shows the e-Citrus application landing page. It will show up when the application is opened.

Figure 3. Home Page

Figure 3 shows the e-Citrus application homepage. It has different buttons with their respective functions. The "Scan Citrus" option will direct the user to a Citrus selection page that displays the different Citrus fruits, including Calamansi, Dalandan, Pomelo, and Lemon, as shown in Figure 4. The "Insects" option directs the user to the

Insects page, as shown in Figure 11. The "Trivia" option directs the user to the Trivia page, as shown in Figure 8. Finally, the "Exit" option will close the application.

Figure 4. Citrus Selection

Figure 4 shows the list of Citrus fruits available that can be scanned by the application to determine its health status. This includes Calamansi, Dalandan, Pomelo, and Lemon.

Figure 5. Capturing Citrus

Figure 5 shows the application of the device camera to capture the citrus fruit and leaves. Once the user is satisfied with the picture, they can click the "Process" button to start processing the captured photo of the application. The "Scan Again" button will give the user the authority to rescan the fruit or leaves to get a better-quality photo.

Figure 6 shows the processing of the captured photo of Citrus fruits and leaves. Once the processing is done, the health status of the captured photo of Citrus fruits and leaves will be displayed, as shown in Figure 7.

Figure 6. Processing Photo

Figure 7. Result

Figure 7 shows the result of the processed photo of Citrus fruit or leaves that the user has captured. In the figure, it shows that the leaves had a disease called Sooty Mold, with 80% of probable disease.

Figure 8. Trivia

Figure 8 shows the trivia about the different Citrus fruits available in the application. The user can select the Citrus fruit for which they want to find more information.

Figure 9. Citrus Trivia

Figure 9 shows the trivia of the specific Citrus fruit that the user has selected, in this case, Calamansi. The user can then view the information regarding Calamansi which includes its health benefits. If the user selects the Diseases tab, the common diseases for Calamansi fruits and leaves will be displayed, as shown in Figure 10.

Figure 10. Citrus Diseases

Figure 10 shows the Citrus diseases page that displays the common diseases of fruits and leaves of the specific Citrus fruit that the user selected.

Figure 11. Insects

Figure 12. Insect/Pest Mapping

Figure 11 shows Insects page that displays the list of insects that cause diseases on Citrus fruits or leaves. Figure 12 shows the information about the selected insect in the Insects page. It shows more elaborate details on the insect and the mapping of insects and citrus plantations where the specific insect can be found.

4. Evaluation of the System

The system was evaluated by 90 respondents from 5 Agriculture Faculty and 95 Citrus farmers in Oriental Mindoro. The researchers asked the respondents to evaluate the system using the eight criteria based on ISO 25010.

As a result of the evaluation, the system's functionality got an overall mean of 4.62, which verbally describes Very Acceptable, implying that the system achieved its expected output. In terms of performance efficiency, it got an overall mean of 4.66, which indicates that the system is efficient. Regarding compatibility, the system got an overall mean of 4.71, equivalent to the Very Acceptable rating; it only shows that it is compatible with Android smartphones. Most respondents rated the system as very acceptable regarding usability and got a computed mean of 4.74. This proved that the system was usable for the users.

Most of the respondents favored the Very Acceptable rating in the system's Reliability. This result shows that the system is effective in terms of Reliability, with an average of 4.70. The respondents rated the system as very acceptable regarding security and got a computed mean of 4.73. This proves that the user's information and the system itself are secure. The users rated the maintainability as 4.60, which has the verbal description of Very Acceptable, which implies that the system is maintainable. The system's portability shows that the evaluation results favored the rating of Very Acceptable with an overall mean of 4.79; it shows that the system is portable.

Overall, users rated the system as very acceptable based on the different criteria set.

Table 1. Overall Results of the System

Criteria	Mean	Verbal Interpretation
Functionality	4.62	Very Acceptable
Performance Efficiency	4.66	Very Acceptable
Compatibility	4.71	Very Acceptable
Usability	4.74	Very Acceptable
Reliability	4.70	Very Acceptable
Security	4.73	Very Acceptable
Maintainability	4.60	Very Acceptable
Portability	4.79	Very Acceptable
Overall Mean	**4.69**	**Very Acceptable**

5. Conclusion and Recommendations

Based on the program testing, the researchers concluded that:

1. The application can identify common pests and diseases within a particular citrus farm in the municipality of Oriental Mindoro;
2. The application can map the pests and diseases of citrus farms in the province;
3. The application applies image processing techniques to analyze diseases of citrus fruits with corresponding solutions caused by bacteria;
4. The application gives information about diseases related to citrus fruits and how to cure them.

After testing the system, the following recommendations were formulated:

1. Future researchers could expand the scope of the study, such as by adding more features to the system that will improve and provide a better user experience.
2. The application must also be integrated with an iOS mobile operating system.
3. The application must be implemented, and it is recommended to be pushed through a partnership with a local government unit for funding and full implementation.

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