SEMARAK ILMU PUBLISHING
202103268166(003316878-P)

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

A Smart Application as Solution for Diagnosis of Rice Diseases in Pakistan: An Image Processing Approach

Asia Mumtaz[1], Ahmad Shukri Mohd Noor[1,*], Saba Farzeen[2], Muhammad Rabbah Khan[2], Maryam Afzaal[2]

[1] Department of Computer Science, University Malaysia Terengganu, 21300 Kuala Terengganu, Terengganu, Malaysia
[2] Department of Computer Science, University of Sialkot, Sialkot, Pakistan

ARTICLE INFO

Article history:
Received 8 December 2023
Received in revised form 4 April 2024
Accepted 24 June 2024
Available online 25 July 2024

Keywords:
Image processing; CNN; VGG; Transfer learning

ABSTRACT

Rice production in Pakistan, once a dominant force in Asia's rice industry, has seen a significant decline due to various diseases and the continued reliance on traditional farming methods. The lack of education and awareness among farmers about modern agricultural techniques and applications further exacerbates the challenges faced by the industry. To address these issues, this research presents an innovative application based on image processing techniques, offering a platform to assist farmers with information on rice diseases and disease diagnosis. The solution utilizes Convolutional Neural Networks (CNN), powered by deep learning, to enhance the accuracy of rice disease classification using a dataset from Sialkot, Pakistan. The user-friendly and reliable nature of the application eliminates the need for additional machinery or installations, making it a practical and accessible tool for the farming community. The results demonstrate the potential of the application in empowering farmers with knowledge and aiding in the betterment of crops and overall production, the accuracy of CNN is 99.9%, and fostering a path towards revitalizing Pakistan's rice industry.

1. Introduction

According to the UN, in 2050 authors are going to need double the amount of food that has today [1]. About 70% of the population of Pakistan sustains agriculture directly or indirectly [2]. Pakistan produces production of wheat per acre is 3.1 tonnes, compared to 8.1 tonnes in France, and 2.5 tons of cotton compared to 4.8 tons in China. The solution to generating the highest crop production is intelligent and precision agriculture [3]. The world is using modern technologies like IoT devices, in the agricultural product manufacturing process, processing of images, and ML methods are used like image processing [4]. Figure 1 elaborates on the basic architecture of systems that rely on image processing.

* *Corresponding author.*
E-mail address: ashukri@umt.edu.my

https://doi.org/10.37934/araset.49.1.6376

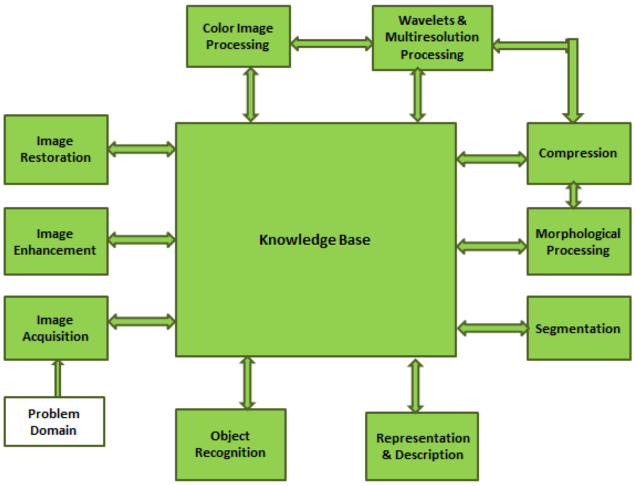

Fig. 1. Digital Image Processing Steps

Based on the results of our literature review, the study has begun developing a machine learning-based android application that provides farmers with agriculture recommendations, and guidelines related to crop yield and diseases. Improvements in information distribution systems for farmers with low levels of literacy were also discussed [3]. Bangladesh ranks as one of the largest 5 rice cultivation and consumption countries in the world. Its economy is heavily dependent on the production of rice. Rice leaf rot is the most serious problem confronting the agriculture industry. This study describes a lightweight artificially intelligent system for detecting diseases in rice leaves. All of the data processing was done on a Raspberry Pi. study looks at three diseases that affect rice plants: Brown Spot, Hispa and Leaf Blast. In Bangladesh, They're among the most prevalent kinds of rice leaf disease. By incorporating different attributes into several machine learning techniques, it created an image categorization model. The Random Forest algorithm had the best performance. On edge devices, 97.50% accuracy was utilizing the image classification model [9].

India and Bangladesh are two of the major paddy-growing nations in the world. Rice is the principal crop in Bangladesh grown for export. The contribution of farming to Bangladesh's Gross Domestic Product over the past 11 years has been roughly 15.08%. Regrettably, agricultural workers who labour so hard to cultivate this produce must endure significant losses due to crop damage brought on by different paddy illnesses. There are more than 30 different rice leaf diseases in Bangladesh, and 7-8 of them are rather prevalent. Among the various paddy leaf illnesses, Bacterial Leaf Blight, Blast Disease, Brown Spot Disease, etc., are the most common and devastating. These diseases are stopping the grains from developing and manufacturing as they ought to thereby cause severe economic and environmental losses. Crop damage can be significantly avoided if these diseases are identified swiftly and properly at a young age. This article examined four different disease kinds and one group of healthy paddy leaves. It has examined four models' accuracy of 92.68% [11].

AI is ushering in a new era for agriculture, with the potential to significantly boost yields and efficiency [28]. This technological revolution relies on AI algorithms guiding robots, drones, and sensors to automate crucial tasks like irrigation, pest control, and soil monitoring. These automated systems not only reduce waste and labour costs but also contribute to maintaining healthy soil and ultimately increasing crop production. However, challenges such as affordability, the need for technical expertise to operate and maintain these systems, and the requirement for large datasets to train the AI models still need to be addressed [26].

In recent years, there's been a surge in using internet-connected devices (IoT) in farming. These smart-systems collect real-time data on things like temperature and moisture, which are crucial for healthy crops. In rice farming especially, this technology has been successful in improving irrigation, pest control, and overall crop management. Sensors placed in the field give farmers valuable information so they can take quick action and make better decisions about resource use. Machine learning, a type of artificial intelligence, is another game-changer in precision agriculture. By analysing past data, it can predict crop yields, disease outbreaks, and irrigation needs. This helps farmers optimize watering schedules, reduce water waste, and ultimately increase their rice harvests [27].

The core countries of the Indian subcontinent are a subregion of South Asia that includes India, Pakistan, and Bangladesh, which were part of British India before gaining independence in 1947 and these countries have the same land properties. However, nobody thought to incorporate user choices into the interface design for agricultural guidelines updates on Android apps up to such an extent. The remainder of the work is divided into three sections: section II about the literature review, section III about the suggested approach, IV about discussion, section V conclusion, and section VI about limitations and future work.

2. Literature Review

Agricultural researchers are actively exploring the potential of Artificial Intelligence (AI) and Machine Learning (ML) for improving various aspects of crop production, particularly in rice farming. One key area of focus is early and accurate disease detection. Several studies have investigated the use of image processing and deep learning techniques to classify rice leaf diseases from images captured on smartphones or drones [14,16,19,22,23,29]. Convolutional Neural Networks (CNNs) have been particularly successful in this area, achieving accuracy rates as high as 98% for identifying diseases like rice blast, bacterial blight, and brown spot [14,19,22]. These CNN-based systems typically involve capturing images of rice leaves, pre-processing them to remove noise and enhance relevant features, and then training the CNN model to distinguish between healthy and diseased leaves. An example is a recent study that developed an Android app called "Rice Disease Detector" which utilizes a MobileNetV2 model to diagnose rice diseases directly from smartphone images. This highlights the potential for AI-powered solutions to empower farmers, especially in resource-limited settings, to effectively diagnose rice diseases in their fields [29].

Another area of application for AI in rice farming is precision irrigation. Machine learning models can be trained on historical data on factors like weather, soil conditions, and crop growth stages to predict irrigation needs and optimize water use. This can help farmers minimize water waste and maximize crop yields [27]. Furthermore, researchers are exploring the use of AI and sensor technology for real-time monitoring of crop health and pest control [30]. For instance, one study proposed a system that combines deep learning models with sensors to monitor bean crops, detect diseases and weeds, and even control irrigation and pesticide application [30]. This integrated approach has the potential to improve farm efficiency and productivity.

Traditional machine learning techniques have also been successfully applied in rice disease detection. For instance, a study compared various machine learning algorithms, including Decision Tree, Random Forest, Support Vector Machine, and Naive Bayes, for classifying rice leaf diseases based on image features. The Random Forest classifier achieved the best accuracy of 69.44% [6]. Another study using a similar approach with a Random Forest decision tree classifier reported an accuracy rate of 91.47% for identifying rice diseases in their early stages [24].

Spectral analysis of rice crops using satellite imagery or portable spectral radiometers has also been explored as a method for detecting rice diseases like bacterial leaf blight (BLB) [12]. Vegetation indices derived from spectral reflectance data can be used to identify areas with potential disease outbreaks. However, this approach may not be as effective for early disease detection compared to AI-based image analysis techniques. Fuzzy logic systems have also been investigated for rice disease diagnosis. Fuzzy system with an accuracy of 94.792% for classifying rice leaf diseases based on image features extracted from rice plants [15].

2.1 Worst Applications of Pakistan

These are some worst applications of Pakistan agriculture department for example Kisan Zar Zameen**,** AgriApp,Bakhabar Kissan, Kisan Sahulat**,** Kisan Pakistani etc. Every app has missing important points. Example of AgriApp is given below as shown in Figure 2, 3, 4 and 5 [25]:

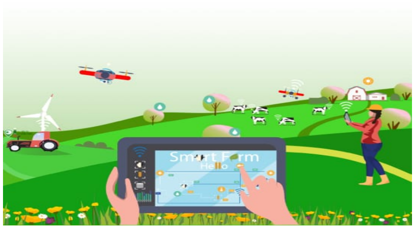

Fig. 2. Home page of AgriApp

Fig. 3. Voice recognition and Camera sign option is missing in search bar

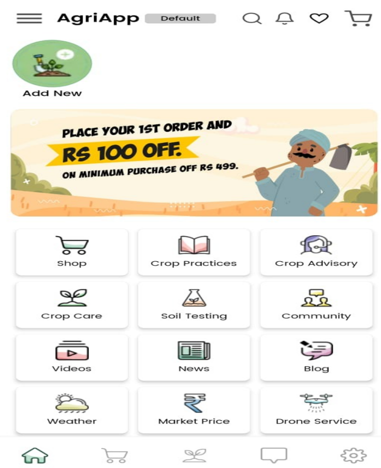

Fig. 4. Shopping cart repeated three times on home page

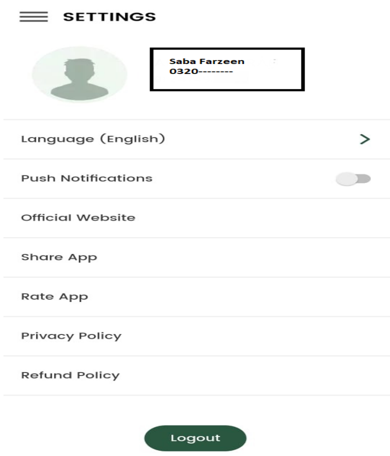

Fig. 5. About us, Help and Log Out option are missed in settings

3. Proposed Framework

Different areas of the rice plant are affected by rice diseases in Pakistan. Their incidence is influenced by several variables, including Moisture, temperature, precipitation, the type of paddy plant, season, and diet. To gather pictures of rice infections from fields in Sialkot, Pakistan, a thorough effort was made and Images from three types of rice sickness have been gathered from real-world scenarios, as illustrated in the image below as shown in Figure 6. Figure 7, 8 and 9 displays the class titles Leaf Smut, Bacterial Leaf Blight, and Brown Spot together with the all number of photos gathered for each class.

Fig. 6. Real-life images from fields

Fig. 7. Bacterial leaf blight

Fig. 8. Leaf Smurt

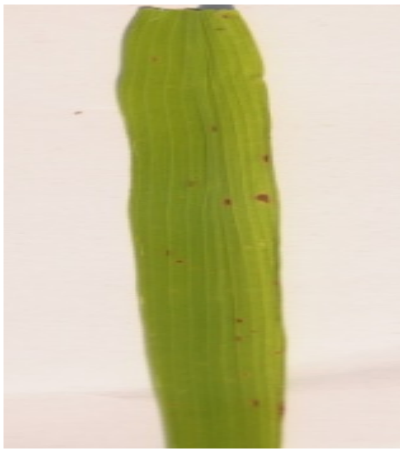

Fig. 9. Brown Spot

The main phases in the rice leafy detection system, as described in the provided information, are as follows:

i. <u>Image Capture:</u> The process starts with capturing photos of rice leaves, both healthy and ill. The set of data includes pictures of healthy rice leaves as well as images of dead leaves, stems, and grains to avoid confusion between dead parts and diseased parts.

ii. Image Pre-processing: In this phase, the captured images are pre-processed before feeding them into the models. The images are resized to a standardized size of 300x300 pixels, and they are transformed from RGB (colour) images to grayscale images.
iii. Feature Extraction: After pre-processing, the mining of features is carried out. Feature extraction involves converting the input images into a set of meaningful features that facilitate more efficient and effective calculations. This process aims to represent the images in a format suitable for model training and classification.
iv. Data Splitting: The set of data is split into two separate sets: The sample information and the evaluation information. 70% of the total data is contained in the training set of data, while the remaining 30% is used for testing and evaluating the trained models.
v. Model Selection: Several deep learning models are employed for training and classification. The models used include Convolutional Neural Network (CNN), Transfer Learning EfficientNet, Transfer Learning Inception V3, Transfer Learning Resnet 50, and Transfer Learning VGG 16.
vi. Model Training: The selected models are trained using the training dataset and an experimental configuration that combines the Keras frame with the Tensorflow backend. The training aims to optimize the model's parameters to achieve accurate classification.
vii. Model Testing: Once the models are trained, they are evaluated based on their efficacy on the test sample and accuracy in classifying rice leaf diseases.
viii. Evaluation and Comparison: The performance of different models is compared, and the convolutional neural network (CNN) is identified as producing the best results among the alternative training techniques.

Overall, the main steps involve data preparation, pre-processing, feature extraction, model training, and model evaluation to create an effective rice leaf disease detection system using deep learning techniques. The system utilizes a diverse dataset and various deep-learning models to accurately classify and diagnose rice leaf diseases based on the input images.

The system for diagnosing rice leaf disease entails several steps, including the capture of a rice leaf picture, pre-processing of the image, feature extraction from those images, and image categorization by the name of the disease. When taking pictures, all these factors have been taken into account. Images of dead leaves, dead stems, and dead grains of rice plants have been included in the collection to prevent classification models from conflating dead portions with diseased parts of the rice plant. Two separate sets of data are created. 1400 original photos and the remaining 200 augmented images, or 2200 total images, make up the dataset's two-thirds of the data that are available for training. The training dataset is 70% of the dataset. The accusation phase is the initial stage.

Images from the dataset, which includes three different types of rice leaf illnesses (Leaf Smut, Bacterial Leaf Blight, and Brown), are used in the image accusation phase of the research. The second phase is image pre-processing; during this phase, displaying larger images can occasionally cause storage difficulty. Therefore, this image must be resized to 300*300 pixels, and the RGB image must be transformed into a greyscale image. The third phase is featuring extraction. During this phase, input data containing sample records with a large input data size can be modified into a collection of features for improved calculation and feature extraction to provide results that are both efficient and useful.

Row sampling and feature sampling of rice leaf datasets are conducted using various models after these features have been extracted. The models are as follows: Convolutional neural network, transfer learning EfficientNet, transfer learning Inception V3, transfer learning Resnet 50, and transfer learning VGG 16. These models with dataset are available on Github [25].

To test, 30% of the dataset was used. The models were trained using the experimental configuration, which combines the Keras framework with the Tensorflow back-end. Transfer Learning Inception V3, Transfer Learning Resnet 50, Transfer Learning VGG 16, and convolutional neural network are used from deep learning algorithms. These three alternative training techniques have been used; however convolutional neural networks produced the greatest results. Convolutional neural networks (CNN) powered by deep learning have significantly increased the accuracy with 99.9% of picture classification.

In this section, we proposed an android application as a solution for rice disease detection. The first and more important thing is easy to use. This application is easy to use because it has three options to get into the application. Login, Sign Up, and Guest User. A user can sign up for the app and then log in to interact with the application or simply interact as a guest user. The home page can be seen in Figure 10.

Fig. 10. Home page

This application takes images as input and with the assistance of computational imaging techniques; we predict and diagnose the disease. This application is capable of diagnosing only three rice diseases. These are Leaf Summit, Bacterial Leaf Blight, and Brown Spot. There are three main functionalities offered by the application:

i. Diagnose via capturing the image: Users can use their device's camera to capture photos of a paddy plant that they suspect may be affected by a disease. The application will then analyse the image and attempt to diagnose the specific disease as shown in Figure 11.

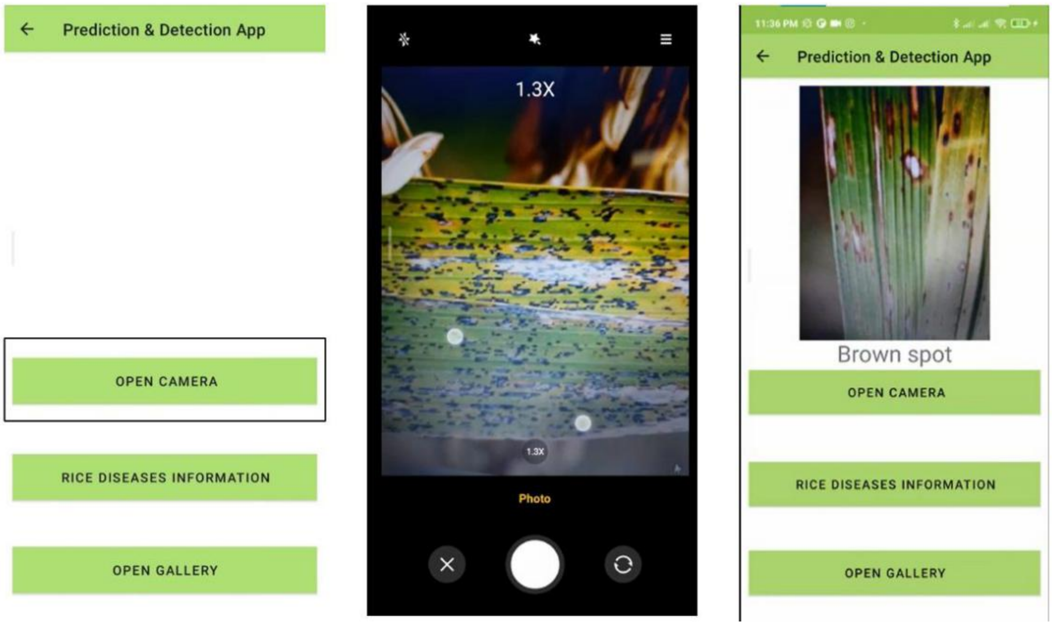

Fig. 11. Capture Image and Diagnose

ii. <u>Diagnose via uploading an image from Gallery:</u> This feature is much similar to the first one. Alternatively, users can also diagnose the disease by uploading a pre-captured image of the rice crop from their phone's gallery. Figure 12 depicts feature one.

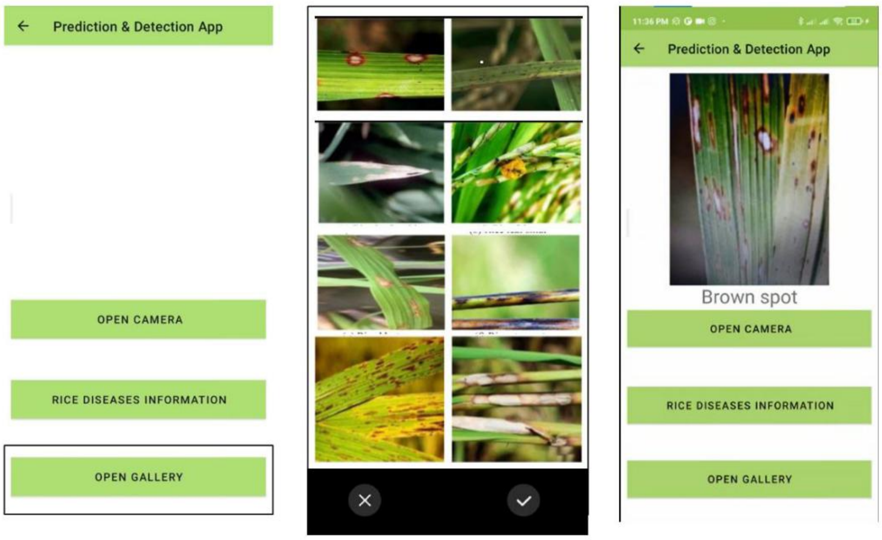

Fig. 12. Uploading an Image and Diagnose

iii. <u>Disease Information Portal:</u> This is a generic portal where users can get information about rice diseases. The application provides information about the diagnosed disease, including details about the specific disease, its symptoms, and possible treatments or solutions. This treatment information contains two sections. One of them is a brief introduction to the disease and the other is how to manage that disease as shown in Figure 13.

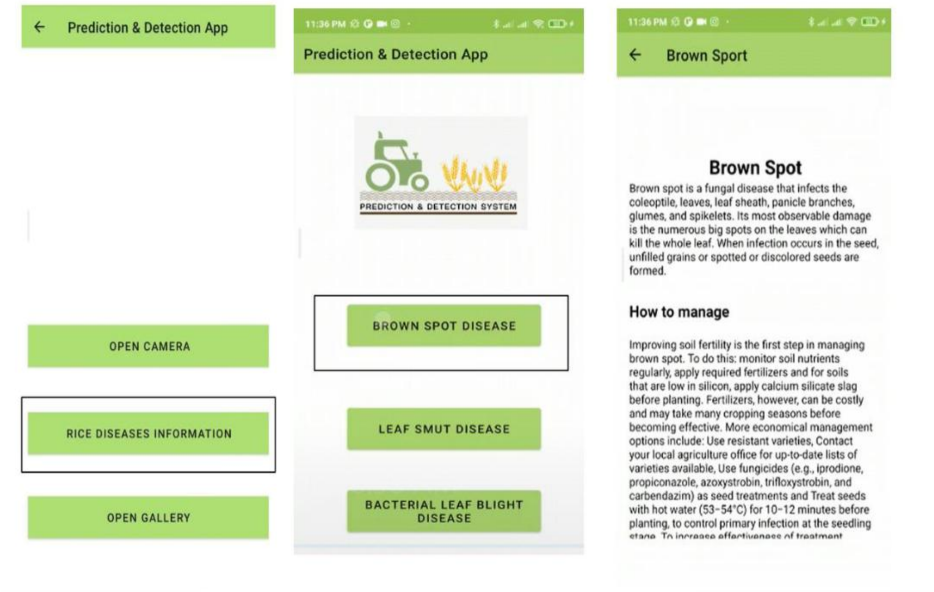

Fig. 13. Disease Information Portal

iv. <u>Implementing on the Application:</u> The main purpose of the application is to help farmers or users identify and manage diseases in rice crops more effectively and efficiently. By utilizing image recognition and processing, the app automates the diagnosis process, making it easier for users to detect diseases without extensive knowledge or expertise in plant pathology. The application works in three steps. Importing the image: The first step involves importing the image using image acquisition tools. These tools could include camera devices scanners or any other method of capturing an image. The application likely provides functionality to import images from various sources. Analysing and manipulating the Image: Once the image is imported it undergoes pre-processing. In the case of infected images, specific pre-processing techniques are applied to enhance the analysis of diseases. One such technique mentioned is segmentation using the k-means algorithm, which partitions the image into distinct regions. After segmentation, colour and texture features are extracted from segmented regions. These extracted features are then passed through a support vector machine which is a machine learning algorithm used for classification or regression tasks. The SVM is likely trained to detect diseases based on the extracted features. Output generation: After the diseases are detected using the SVM the application retrieves information related to the identified disease. The information may include details about the diseases, symptoms, suitable fertilizers, and possible diagnoses. The retrieved disease information is then compared or matched against the symptoms available in the application providing a diagnosis for the problems. The output of the application can be in form of an altered image, where the problems regions are highlighted or detailed report that includes the disease diagnosis and relevant information. Figure 14 shows the basic workflow of the Application step by step that problems of diseases are being examined.

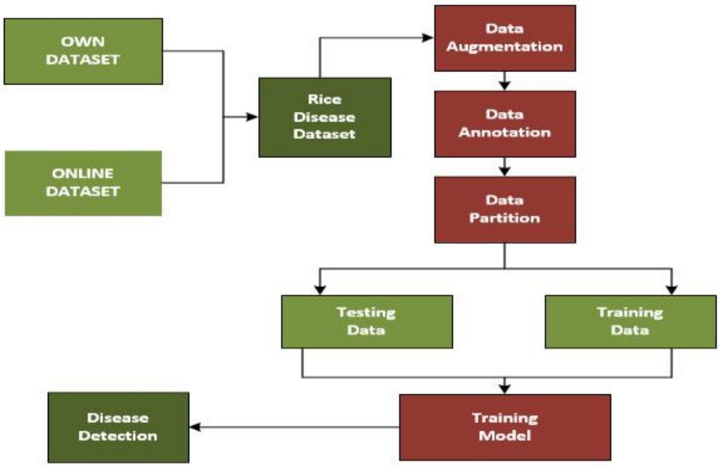

Fig. 14. Basic Workflow of the application

4. Results

This research proposes a system for detecting rice leaf diseases using deep learning techniques. The proposed framework aims to develop an effective rice leaf disease detection system using deep learning techniques as shown in Table 1. Here's a detailed breakdown of the workflow:

i. Data Acquisition: The system starts by capturing images of rice leaves. These images likely contain the rice plant along with any potential diseases present on the leaves.
ii. Pre-processing: Once captured, the images undergo pre-processing steps. This might involve tasks like resizing the images to a standard size, removing irrelevant background noise, or adjusting lighting variations to ensure consistency.
iii. Feature Extraction: After pre-processing, the system extracts meaningful features from the images. These features could be specific patterns, textures, or colour variations that distinguish healthy leaves from those infected with different diseases.
iv. Deep Learning Model Training: With the pre-processed data and extracted features, the system trains multiple deep learning models. Deep learning models are powerful algorithms that can learn complex relationships between data and outcomes. In this case, the models will learn to identify the specific features associated with the three targeted rice diseases: Leaf Smut, Bacterial Leaf Blight, and Brown Spot.
v. Model Evaluation: Once trained, the performance of the different deep learning models is evaluated. This might involve testing the models on a separate dataset of rice leaf images and measuring their accuracy in correctly diagnosing the diseases. The model Convolutional Neural Network (CNN), Transfer Learning EfficientNet, Transfer Learning Inception V3, Transfer Learning Resnet 50, and Transfer Learning VGG 16 are applied but CNN with the highest accuracy 99.9% would be chosen for the final application.
vi. Android App Development: To make the disease detection system user-friendly, an Android application is developed. This app allows users to diagnose diseases by either capturing images of rice leaves directly through the phone's camera or uploading images from their device storage.
vii. App Functionality: The app offers two main functionalities:
   a. Image-based diagnosis: Users can capture or upload an image of a rice leaf suspected of having a disease. The app then utilizes the chosen deep learning model to analyse

the image and identify any present diseases from the three categories programmed (Leaf Smut, Bacterial Leaf Blight, and Brown Spot).

b. Disease Information: Along with the disease diagnosis, the app provides relevant information about the identified disease. This information might include details about symptoms, causes, and potential treatment methods.

Table 1
Results of proposed Work

Phase	Description
Image Capture	Photos of rice leaves (healthy and diseased) collected, including images of dead leaves, stems, and grains to avoid confusion between dead and diseased parts.
Image Pre-processing	Captured images resized to 300x300 pixels and transformed from RGB to grayscale.
Feature Extraction	Mining meaningful features from pre-processed images for efficient calculations.
Data Splitting	Dataset split into training (70%) and testing (30%) sets.
Model Selection	Deep learning models used: Convolutional Neural Network (CNN), Transfer Learning EfficientNet, Transfer Learning Inception V3, Transfer Learning Resnet 50, Transfer Learning VGG 16.
Model Training	Models trained using Keras and Tensorflow backend with experimental configurations.
Model Testing	Trained models evaluated for accuracy and effectiveness on the test dataset.
Evaluation & Comparison	Performance of different models compared, with CNN identified as the most effective.
Android App	Android app developed for rice disease detection with user-friendly features.
Capture via Camera	Users can capture images using device's camera for disease diagnosis.
Upload from Gallery	Users can upload pre-captured images for diagnosis.
Disease Info Portal	App provides information about diagnosed diseases, including symptoms and treatments.
Implementation Steps	App helps users identify and manage rice crop diseases using image recognition and processing.
Importing the Image	Users import images from camera devices, scanners.
Analysing the Image	Pre-processing techniques applied, segmentation with k-means, feature extraction, SVM classification.
Output Generation	Disease information retrieved, compared with symptoms, and diagnosis provided.

5. Conclusion and Future Work

The main contribution of this paper is the collection and analysis of a comprehensive dataset on prevalent rice diseases in Sialkot, Pakistan (brown spot, leaf smut, and bacterial leaf blight), enabling the development of an advanced, IoT-enabled application that utilizes image processing and deep learning for accurate disease diagnosis, empowering farmers with effective tools for disease management and sustainable agriculture. By gathering data on the prevalence of these diseases, the researchers have made a crucial contribution to the field of agriculture. One of the key benefits of this dataset is its potential to pave the way for developing new methods for detecting and preventing these diseases. With a better understanding of the prevalence and patterns of these illnesses in the region, agricultural experts and researchers can devise targeted and efficient strategies to combat them. This can lead to a reduction in the reliance on harmful pesticides and chemicals, promoting more sustainable and eco-friendly farming practices.

The proposed solution, which is an application integrating image processing and machine learning techniques, in comparison to existing solutions in the market. Convolutional neural networks (CNN) powered by deep learning have significantly increased the accuracy with 99.9% of picture classification and the application is equipped with Internet of Things (IoT) capabilities, making it a modern and advanced tool for disease diagnosis and information dissemination. Its advantages over other solutions lie in its cost-effectiveness, efficiency, and ability to create a better understanding of diseases. The comprehensive comparison indicates that the proposed solution is superior due to its broader set of features, ease of use, and potential for creating better awareness and knowledge among farmers. By empowering them with valuable information on rice diseases, the application can significantly improve their decision-making processes, leading to enhanced crop management and higher yields.

The overall impact of this research and dataset is crucial for the efficiency and sustainability of rice production, not just in Sialkot, Pakistan, but also beyond. The knowledge gained from this study can be shared and applied in other regions facing similar challenges, benefiting rice farmers globally. Moreover, the adoption of eco-friendly practices and targeted treatments can contribute to the reduction of environmental risks associated with excessive chemical usage. Ultimately, this research has the potential to transform rice farming practices, ensuring food security, and contributing to the economic well-being of farmers and communities.

Although our application is much more precise than the other available applications still it has some limitations and areas for improvement. Moreover, it doesn't support for native language or voice support mechanism as our agrarians are illiterate mostly and cannot understand much in English. In future we should consider incorporating native language support into the application. This could involve providing translation of the application interface, instructions and disease information into local languages. Additionally, we could integrate a voice support mechanism. Existing we are focusing on single disease of rice crops but in future more diseases related to the rice datasets will be covered.

Furthermore, in the future, we are looking forward to further extend by using hydroponic rice cultivation. Hydroponic rice cultivation, which involves growing rice without soil in a nutrient-rich water solution, is an innovative and sustainable approach to rice production. However, just like traditional rice farming, hydroponic systems are also susceptible to diseases that can adversely impact crop yields and overall production. By leveraging the dataset and research findings on brown spot disease, leaf smut disease, and bacterial leaf blight disease, farmers practicing hydroponic rice cultivation can gain valuable insights into disease management and prevention. The knowledge gained from this study can be adapted and applied to develop hydroponic-specific disease detection and treatment methods, tailored to the unique environment and characteristics of hydroponic rice systems.

Acknowledgement
This research was not funded by any grant.

References

[1] Poornappriya, T. S., and R. Gopinath. "Rice plant disease identification using artificial intelligence approaches." *International Journal of Electrical Engineering and Technology* 11, no. 10 (2020): 392-402.

[2] Upadhyay, Santosh Kumar, and Avadhesh Kumar. "A novel approach for rice plant diseases classification with deep convolutional neural network." *International Journal of Information Technology* 14, no. 1 (2022): 185-199. https://doi.org/10.1007/s41870-021-00817-5

[3] Yang, Ning, Kangpeng Chang, Sizhe Dong, Jian Tang, Aiying Wang, Rubing Huang, and Yanwei Jia. "Rapid image detection and recognition of rice false smut based on mobile smart devices with anti-light features from cloud database." *Biosystems Engineering* 218 (2022): 229-244. https://doi.org/10.1016/j.biosystemseng.2022.04.005

[4] Islam, Md Nahidul, Fahim Ahmed, Md Tanvir Ahammed, Mamunur Rashid, and Bifta Sama Bari. "Rice disease identification through leaf image and IoT based smart rice field monitoring system." In *Enabling Industry 4.0 through Advances in Mechatronics: Selected Articles from iM3F 2021, Malaysia*, pp. 529-539. Singapore: Springer Nature Singapore, 2022. https://doi.org/10.1007/978-981-19-2095-0_45

[5] Shrivastava, Vimal K., Monoj K. Pradhan, and Mahesh P. Thakur. "Application of pre-trained deep convolutional neural networks for rice plant disease classification." In *2021 international conference on artificial intelligence and smart systems (ICAIS)*, pp. 1023-1030. IEEE, 2021. https://doi.org/10.1109/ICAIS50930.2021.9395813

[6] Mekha, Panuwat, and Nutnicha Teeyasuksaet. "Image classification of rice leaf diseases using random forest algorithm." In *2021 joint international conference on digital arts, media and technology with ECTI northern section conference on electrical, electronics, computer and telecommunication engineering*, pp. 165-169. IEEE, 2021. https://doi.org/10.1109/ECTIDAMTNCON51128.2021.9425696

[7] Chen, Shuo, Kefei Zhang, Yindi Zhao, Yaqin Sun, Wei Ban, Yu Chen, Huifu Zhuang, Xuewei Zhang, Jinxiang Liu, and Tao Yang. "An approach for rice bacterial leaf streak disease segmentation and disease severity estimation." *Agriculture* 11, no. 5 (2021): 420. https://doi.org/10.3390/agriculture11050420

[8] Krishnamoorthy, N., LV Narasimha Prasad, CS Pavan Kumar, Bharat Subedi, Haftom Baraki Abraha, and V. E. Sathishkumar. "Rice leaf diseases prediction using deep neural networks with transfer learning." *Environmental Research* 198 (2021): 111275. https://doi.org/10.1016/j.envres.2021.111275

[9] Rumy, SM Shahidur Harun, Md Ishan Arefin Hossain, Forji Jahan, and Tanjina Tanvin. "An IoT based system with edge intelligence for rice leaf disease detection using machine learning." In *2021 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS)*, pp. 1-6. IEEE, 2021. https://doi.org/10.1109/IEMTRONICS52119.2021.9422499

[10] Senan, Norhalina, Muhammad Aamir, Rosziati Ibrahim, NSA M. Taujuddin, and WHN Wan Muda. "An efficient convolutional neural network for paddy leaf disease and pest classification." *International Journal of Advanced Computer Science and Applications* 11, no. 7 (2020). https://doi.org/10.14569/IJACSA.2020.0110716

[11] Islam, Md Ashiqul, Md Nymur Rahman Shuvo, Muhammad Shamsojjaman, Shazid Hasan, Md Shahadat Hossain, and Tania Khatun. "An automated convolutional neural network based approach for paddy leaf disease detection." *International Journal of Advanced Computer Science and Applications* 12, no. 1 (2021). https://doi.org/10.14569/IJACSA.2021.0120134

[12] Yudarwati, Rani, Chiharu Hongo, Gunardi Sigit, Baba Barus, and Budi Utoyo. "Bacterial leaf blight detection in rice crops using ground-based spectroradiometer data and multi-temporal satellites images." *J. Agric. Sci* 12, no. 2 (2020): 38-49. https://doi.org/10.5539/jas.v12n2p38

[13] Rallapalli, SethuMadhavi, and M. A. Saleem Durai. "A contemporary approach for disease identification in rice leaf." *International Journal of System Assurance Engineering and Management* (2021): 1-11. https://doi.org/10.1007/s13198-021-01159-y

[14] Daniya, T., and S. J. T. C. J. Vigneshwari. "Deep neural network for disease detection in rice plant using the texture and deep features." *The Computer Journal* 65, no. 7 (2022): 1812-1825. https://doi.org/10.1093/comjnl/bxab022

[15] Rifa'i, Anwar, and Deni Mahdiana. "Image processing for diagnosis rice plant diseases using the fuzzy system." In *2020 International Conference on Computer Science and Its Application in Agriculture (ICOSICA)*, pp. 1-5. IEEE, 2020. https://doi.org/10.1109/ICOSICA49951.2020.9243274

[16] Sethy, Prabira Kumar, Nalini Kanta Barpanda, Amiya Kumar Rath, and Santi Kumari Behera. "Deep feature based rice leaf disease identification using support vector machine." *Computers and Electronics in Agriculture* 175 (2020): 105527. https://doi.org/10.1016/j.compag.2020.105527

[17] Ihsanuddin, Eka Wahyu Hidayat, and Alam Rahmatulloh. "Identification of Bacterial Leaf Blight and Brown Spot Disease In Rice Plants With Image Processing Approach." *Jurnal Ilmiah Teknik Elektro Komputer dan Informatika (JITEKI)* 5, no. 2 (2019): 59-67. https://doi.org/10.26555/jiteki.v5i2.14136

[18] Pothen, Minu Eliz, and Maya L. Pai. "Detection of rice leaf diseases using image processing." In *2020 fourth international conference on computing methodologies and communication (ICCMC)*, pp. 424-430. IEEE, 2020. https://doi.org/10.1109/ICCMC48092.2020.ICCMC-00080

[19] PrajwalGowda, B. S., M. A. Nisarga, M. Rachana, S. Shashank, and BS Sahana Raj. "Paddy crop disease detection using machine learning." *International Journal of Engineering Research & Technology* 8, no. 13 (2020): 192-195.

[20] Chen, Junde, Jinxiu Chen, Defu Zhang, Yuandong Sun, and Yaser Ahangari Nanehkaran. "Using deep transfer learning for image-based plant disease identification." *Computers and electronics in agriculture* 173 (2020): 105393. https://doi.org/10.1016/j.compag.2020.105393

[21] Chen, Junde, Defu Zhang, Yaser A. Nanehkaran, and Dele Li. "Detection of rice plant diseases based on deep transfer learning." *Journal of the Science of Food and Agriculture* 100, no. 7 (2020): 3246-3256. https://doi.org/10.1002/jsfa.10365

[22] Bari, Bifta Sama, Md Nahidul Islam, Mamunur Rashid, Md Jahid Hasan, Mohd Azraai Mohd Razman, Rabiu Muazu Musa, Ahmad Fakhri Ab Nasir, and Anwar PP Abdul Majeed. "A real-time approach of diagnosing rice leaf disease using deep learning-based faster R-CNN framework." *PeerJ Computer Science* 7 (2021): e432. https://doi.org/10.7717/peerj-cs.432

[23] Saha, Sristy, and Sk Md Masudul Ahsan. "Rice disease detection using intensity moments and random forest." In *2021 International Conference on Information and Communication Technology for Sustainable Development (ICICT4SD)*, pp. 166-170. IEEE, 2021. https://doi.org/10.1109/ICICT4SD50815.2021.9396986

[24] Saba Farzeen. "CropPrediction_DiseaseDetection." *Github,* (2022). https://github.com/SABA12031999/CropPrediction_DiseaseDetection

[25] AgriApp. "Smart Farming App." (2014). https://play.google.com/store/apps/details?id=com.criyagen

[26] Dawn, Nabarun, Tania Ghosh, Souptik Ghosh, Aloke Saha, Pronoy Mukherjee, Subhajit Sarkar, Sagnik Guha, and Tanmay Sanyal. "Implementation of Artificial Intelligence, Machine Learning, and Internet of Things (IoT) in revolutionizing Agriculture: A review on recent trends and challenges." *Int. J. Exp. Res. Rev* 30 (2023): 190-218. https://doi.org/10.52756/ijerr.2023.v30.018

[27] Mujawar, Riyajuddin Yakub, R. Lakshminarayanan, A. P. Jyothi, Sumagna Patnaik, and K. Dhayalini. "IoT-Enabled Intelligent Irrigation System with Machine Learning-Based Monitoring, for Effective Rice Cultivation." *International Journal of Intelligent Systems and Applications in Engineering* 12, no. 11s (2024): 557-565.

[28] Javaid, Mohd, Abid Haleem, Ibrahim Haleem Khan, and Rajiv Suman. "Understanding the potential applications of Artificial Intelligence in Agriculture Sector." *Advanced Agrochem* 2, no. 1 (2023): 15-30. https://doi.org/10.1016/j.aac.2022.10.001

[29] Nayak, Anshuman, Somsubhra Chakraborty, and Dillip Kumar Swain. "Application of smartphone-image processing and transfer learning for rice disease and nutrient deficiency detection." *Smart Agricultural Technology* 4 (2023): 100195. https://doi.org/10.1016/j.atech.2023.100195

[30] Devi, Nilakshi, Kandarpa Kumar Sarma, and Shakuntala Laskar. "Design of an intelligent bean cultivation approach using computer vision, IoT and spatio-temporal deep learning structures." *Ecological Informatics* 75 (2023): 102044. https://doi.org/10.1016/j.ecoinf.2023.102044

[31] Ahmed, Imtiaz, and Pramod Kumar Yadav. "Plant disease detection using machine learning approaches." *Expert Systems* 40, no. 5 (2023): e13136. https://doi.org/10.1111/exsy.13136