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DEEP LEARNING FRAMEWORKS FOR MAIZE DISEASE DETECTION: A REVIEW

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Abstract— Image-based maize disease detection is essential to protect the crop by early detection of the diseases, and to increase its yield. Deep learning based detection systems has gained the attention of many researchers in recent times, especially with the increase in the computational power of modern Graphics Processing Units. The present study presents a comprehensive review of the deep learning frameworks for maize disease detection. The study highlighted the findings from the survey and specified its future scope. Additionally, a detailed taxonomy of important maize diseases, along with their visual symptoms in the early and later stages is presented. These symptoms are useful for classification of diseases in image-based techniques. The steps involved in a deep learning system for image classification are described, along with their pros and cons. The article will allow the reader to gain valuable insights, along with the path to follow for progress in the concerned field.
Keywords— Deep Learning, Maize Disease Detection, Convolution Neural Networks, Image Classification

I. INTRODUCTION

The world is facing a severe food shortage. That has resulted in increased cases of undernourishment and hunger [1], especially in poorer countries like India. The situation has worsened after the COVID-19 pandemic due to the decrease in global trade. As a result, many nations have increased their focus to increase the yield of crops like maize that can be used in multiple industries. Thus, it is necessary to take essential measures to increase its production. But, crop loss due to diseases hinders the farming community from fulfilling the increasing demand of the crop.

Every year, more than 20% of the maize crop, is lost, due to diseases [2], [3]. If the diseases are detected promptly, an appropriate remedy can be applied plus crop loss can be prevented. For disease detection, regular inspection of the cornfields by experts and pathologists is needed, but this is seldom possible, due to the shortage of experts. To fulfil this gap, image classification using deep learning has proven to be very helpful.

The present study presents a survey of deep learning (DL) frameworks for maize disease detection. It starts with an overview of the deep learning, in section 2. Then, the taxonomy of maize diseases and their visible symptoms, useful for these systems is presented in section 3. Further, an overview of the maize disease detection systems using deep learning is discussed, followed by the review of the deep learning frameworks for maize disease detection in sections 4 and 5, respectively. Section 6 discusses the pros and cons of using deep learning for maize disease detection. Finally, the derived conclusions and future directions are discussed in section 7.

II. DEEP LEARNING

Deep learning is a subset of machine learning (ML) and artificial intelligence (AI), illustrated in figure 1. It imitates the working of the human brain to process data and draw patterns, useful for decision making, classification and predictive modelling. Deep learning architectures having convolutional layers have proved to be very useful for the task of image classification.

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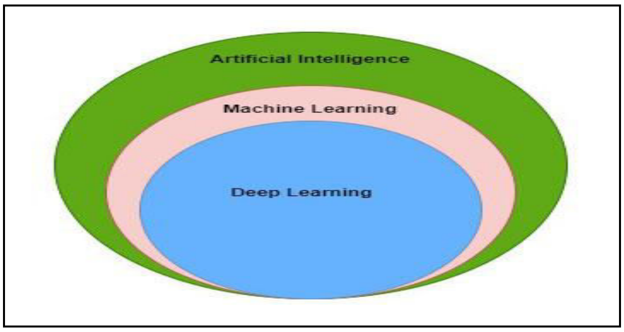

Fig. 1. Deep Learning, Machine Learning and Artificial Intelligence.

Artificial Neural Networks, having multiple hidden layers, are known as deep learning models (DLMs), an example is shown in figure 2. These have a unique characteristic of learning features directly from the data, without the need for manual feature extraction. These models are capable of extracting hundreds of features from the dataset and can achieve recognition and classification accuracies higher than traditional methods.

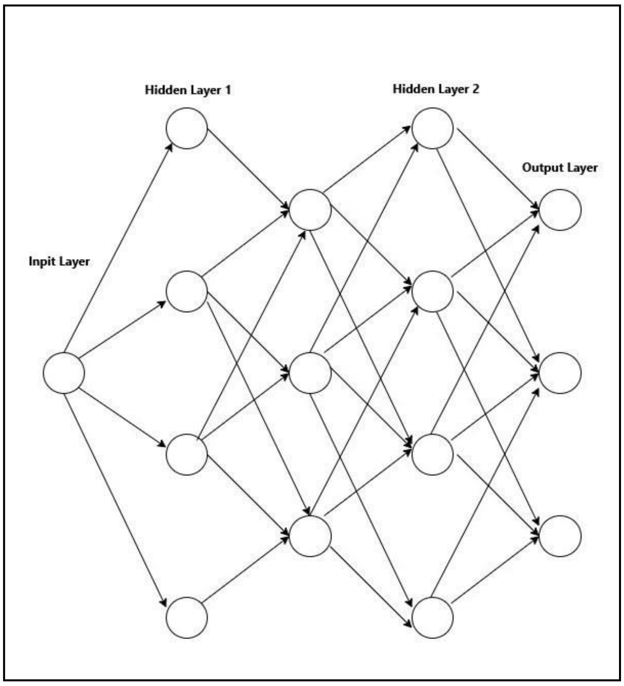

Fig. 2. Deep Artificial Neural Network having 2 hidden layers

III. MAIZE DISEASES

Maize, known as the queen of all the cereals, is well known for its use as food and fodder. It is mainly grown in Punjab, Rajasthan, Himachal Pradesh, Madhya Pradesh, Bihar, Uttar Pradesh, and Jammu and Kashmir in Northern; and Karnataka and Andhra Pradesh in Southern regions of Indian [4].

Maize grains are rich in dietary fibre, proteins, vitamins and minerals like magnesium, potassium, zinc, copper, iron, and selenium. It is widely used in the form of starch, corn-flakes, pop-corns and glucose. Maize is fed to poultry animals to get a high yield of the poultry products. Moreover, it enriches the soil with essential nutrients required by other crops to grow. It needs fewer soil nutrients to grow and 90% less water as compared to paddy and wheat [5].

After accessing the agricultural and nutritional benefits of maize, saving it from disease appears to be very important. The maize crop is susceptible to many diseases that reduce its yield. Its major diseases are discussed ahead.

A. Bacterial Stalk Rot

Bacterial Stalk Rot shown in figure 3 is found throughout the Corn Belt is caused by Erwinia chrysanthemi pv. zeae (Sabet) Victoria, a motile, gram-negative, rod-shaped bacterium. In the early stage, the leaf sheath and stalk node start discoloring. In a fully developed stage, lesions are developed on the leaves and stalk. Eventually, the foul smell starts to appear and the infected part becomes very fragile [6].

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Fig. 3. Maize crop infected with Bacterial Stalk Rot

B. Northern (Turcicum) Leaf Blight (NLB)

Northern Leaf Blight shown in figure 4 is one of the earliest diseases to be recorded on maize crop. This disease is caused by E. Turucicum fungi. In the early stage, oval-shaped water soaked small spots appear on the leaf. In a fully developed stage, the lesions become pale grey to tan and grow to the size of 1 to 6 inches [7].

Fig. 4. Maize crop infected with Northern Leaf Blight [8]

C. Maydis Leaf Blight (MLB)

Maydis Leaf Blight or Southern Corn Leaf Blight as shown in figure 5 is caused by Bipolaris Maydis fungi and is a common sight in warm tropical and sub-tropical areas with a wet temperate climate. In the early stage, small diamond shaped lesions are developed. In a fully developed stage, the lesions become elongated and coalesce, causing burning of the large portion of the leaf [4].

Fig. 5. Maize crop infected with Maydis Leaf Blight

D. Banded leaf and sheath blight

Banded leaf and sheath blight, shown in figure 6, is caused by Rhizoctonia solani f. sp. sasakii fungus and has the potential of complete wipeout of the crop. Early-stage: Spotting of leaves, lesions on the stalk, stalk breakage, clumping and cracking of styles. Later-stage: Rapid enlargement of lesions, discoloured areas alternating with dark bands, especially on the lower leaves [9]–[12].

Fig. 6. Maize crop infected with Banded leaf and sheath blight

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E. Curvularia leaf spot

Curvularia leaf spot, shown in figure 7, is caused by Curvularia lunata fungus. Early-stage: Few small round tan lesions on the surface of the leaf with brown border, surrounded by a yellow halo. Later-stage: Disease lesions cover a large area of the blade [13].

Fig. 7. Maize crop infected with Curvularia leaf spot.

IV. DEEP LEARNING BASED MAIZE DISEASE DETECTION SYSTEM

A deep learning based maize disease detection system is capable of identifying the condition of the maize plant from its images. The image of the leaf is fed as input, the system processes the image and gives an output specifying the condition of the plant, i.e. whether the plant is healthy or infected. If the plant is unhealthy, the system further stipulates the disease, based on the symptoms of the disease. Figure 8 shows a schematic diagram of such a system. The steps followed in a deep learning model while detecting diseases from the image are discussed further.

Step 1: Input: an image of a healthy or diseased maize leaf is fed to the system for training or inspection.

Step 2: Pre-processing: noise in the input image is removed and the image is enhanced for proper identification of its condition.

Step 3: Segmentation: the region of interest, i.e. the disease lesion is extraction from the image.

Step 4: Classification: the deep learning models automatically extract and select the best features from the images. Similarities between the features of the same class and the differences between the traits of different groups are identified. The output of this stage is the name of the disease that the leaf in the image is suffering from.

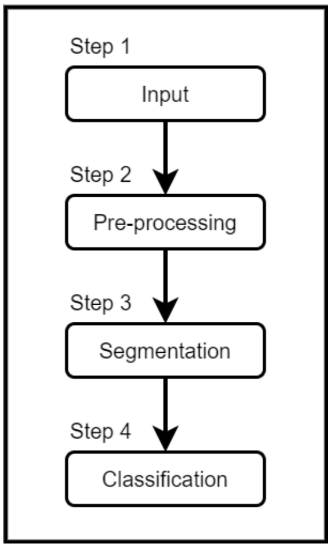

Fig. 8. Block diagram of the maize disease detection system

Fig. 9.

V. REVIEW ON DEEP LEARNING FOR MAIZE DISEASE DETECTION

Image processing for plant leaf disease detection has gained significant advancement in the past few years. Particularly with the advances in machine and deep learning. Some promising approaches for maize disease detection using deep learning have been identified by the authors. The most relevant, significant and fresh researches for maize disease detection are detailed in table 1.

S. Mishra et al. [14] experimented on a dataset covering common rust and northern leaf blight diseases. No pre-processing or segmentation was applied. Then, the dataset was divided into the ratio of 70:10:20 for training testing and validation purposes, respectively. The researchers developed a CNN containing convolution, pooling, dropout and dense layers. The experimentation gave the classification accuracy of 98.88%.

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M. Sibiya et al. [15] worked on the maize subset of the Plant Village [16] dataset, containing images of Northern Leaf Blight, Tan Spot and Grey Spot diseases. The researchers didn't use any pre-processing or segmentation techniques. The classification was done with a custom build CNN model having 50 hidden layers. The structure of the CNN used is shown in figure 9. The experimentation achieved an accuracy of 92.85%.

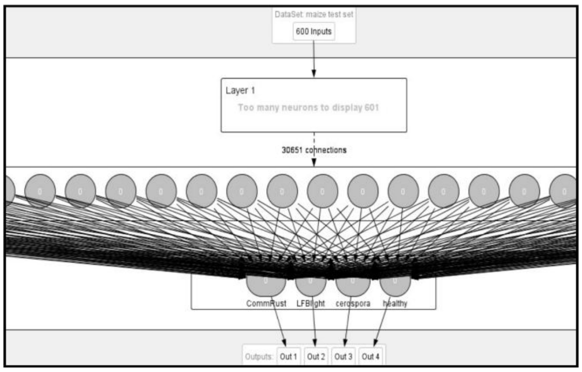

Fig. 10. Neural network classifier after the convolution and pooling [15].

B. Jiang et al. [17] worked on a dataset, consisting of self captured images of maize leaf suffering from water stress. The build dataset consisted of 1297 leaf mages in black background. The photos were first resized to a size of 648x432 pixels to improve computational efficiency. Then, the segmentation was performed using equation 1. The values of y1 and y2 and k (x, y) in equation 1, are calculated using equation 2, 3 and 4, respectively. In equation 2, R, B and G are the values of the red, blue and green components of the corresponding pixels of the image.

$$f(x) = \sum_{i=1}^{n} a_i y_i k(x, y) + b \qquad (1)$$

$$y_1 = 2G - B - R \qquad (2)$$

$$Y_2 = (B + R)/G \qquad (3)$$

$$k(x, y) = x \cdot y \qquad (4)$$

Then, Tamura (coarseness and contrast), Grey-Level-Cooccurace Matrix (angular second momentum, contrast, entropy, inverse different moment and dissimilarity), average RGB energy and morphological (average leaf angle of maize leaves and maize leaf dispersion) features were calculated. Finally, SVM classifier was used. The experimentation resulted in a classification accuracy of 98.97%.

C. DeChant et al. [18] built a dataset of Maize crop leaf images infected with Northern Leaf Blight disease. The dataset consists of 1834 images captured using Canon EOS Rebel or Sony a6000 camera over the period of 28-78 days after sowing. The researchers used CNN based architecture for identification of Northern Leaf Blight from Maize crop leaf images and achieved an accuracy of 96.7%. The study further suggested that similar systems mounted on ground or areal based vehicles will help in improving the throughput of automated plant stress phenotyping. The experimentation image dataset was uploaded to CyVerse BisQue platform [19].

Z. Zhang et al. [20] collected 500 images of diseased crop leaves from different sources including Plant Village and Google image search. The dataset consisted of 500 images, divided over 9 classes (Northern leaf blight, Southern leaf blight, Rust, Brown spot, Round spot, Curvularia leaf spot, Gray leaf spot, Dwarf mosaic and Healthy). In pre-processing, image augmentation was performed. Then, the dataset was divided into 80:20 ratio for training and validation purpose respectively.

The researchers introduced a novel approach named Genetic Algorithm - Support Vector Machines (GA-SVM) and applied to maize crop disease detection use case. The proposed method used genetic algorithms for automatically obtaining the penalty factor and kernel function. Parameter optimization was done by rotational orthogonal method. Further, classification effectiveness was enhanced using the extracted eighen value in GA-SVM classification model. The model performed its best at parameters values M=50, Pc=0.7, and Pm=0.05, and RBF kernel obtaining an accuracy of 90.25%.

S. Kai et al. [21] presented research for maize crop leaf disease detection. The approach used texture characteristics in YCbCr color space for segmenting disease spot with Grey Level Co-occurrence Matrix (GLCM). Then Back Propagation Neural Network was used for classification of the localized disease area. The setup applied on 10 pictures of corn leaf blight, sheath blight, southern leaf blight, yielded an overall accuracy of 98%. The author concluded that the same approach can be used for classification of visible diseases on image samples of other plants.

VI. PROS AND CONS OF USING DEEP LEARNING FOR MAIZE DISEASE DETECTION

Advantages of using deep learning for maize disease detection are:

- Manual feature extraction stage is not needed, as a deep learning model is capable of extracting hundreds of features automatically from the input images. Further, these features produce better results as compared to the manually extracted features.
- Data variations are automatically taken care of, therefore the system developed is much more robust as compared to traditional methods.
- A single deep learning model can be applied to different use cases.

Disadvantages of using deep learning for maize disease detection are:

- A deep learning system needs large amount of data for producing meaningful results.
- For computation, a Graphics Processing Unit is needed. Such a hardware part is quite expensive and draws a lot of electric power.
- All deep learning models are basically black boxes and their optimization is just another hit and try task.

VII. CONCLUSIONS AND FUTURE SCOPE

A comprehensive review of deep learning frameworks for image-based maize disease detection is presented. From the various studies, the following conclusions are drawn.

- Deep learning is effective for maize disease detection and can achieve remarkable classification accuracies.
- Pre-processing is not used by the majority of the researchers, since the dataset used in the studies was already pre-processed.
- Segmentation stage is crucial and helps in increasing the overall efficiency of the system.
- Majority of deep learning models like Xception [22], Inception V4 [23] and ResNeXt-50 [24] are still to be used.
- Most of the researchers have used pre-built CNN models. If specialized models are developed, then much more efficiency can be achieved.

From the above studies, it is evident that for advancing in this field, much experimentation using various deep learning models are needed to be conducted. Further, specialized models are needed to be developed for maize disease detection purposes. Additionally, a pesticide suggestion system can be coupled with this system. It will help in gaining instant remedy suggestions to cure the plant of the diseases. It will help the farmer to prevent the crop from various diseases, increase its yield and ultimately will able to reach the global demand for food.

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