IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-7, Issue-5, May 2019 E-ISSN: 2347-2693

Image Processing Technology Application for Early Detection and Classification of Plant Diseases

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DOI: https://doi.org/10.26438/ijcse/v7i5.9297 | Available online at: www.ijcseonline.org

Accepted: 12/May/2019, Published: 31/May/2019

***Abstract* —** Various diseases are caused by fungi, bacteria, viruses, insects and nematodes on agricultural and horticultural crop plants. These diseases reduce the crop yield by 20 to 40 percent annually worldwide. Therefore, these pathogenic microorganisms and insect pests are major threat to sustainable agriculture. For detection recognition and classification of plant diseases, agriculture experts carry out the inspection of field crops visually or microscopically, which is time consuming and laborious. Recently, rapid detection of plant diseases is being done by image processing of disease affected leaves, roots and fruits of agriculture and horticultural crops using machine vision technology. Expert systems involving computer vision image processing (CVIP), colour co-occurrence matrix (CCM), neural network classifier, fuzzy clustering and image segmentation algorithms etc. have been developed for diagnosis of diseases and disorders in various crops. In addition, artificial intelligence, artificial neural network, Bayer's classifier, fuzzy logic and hybrid algorithms have been found to reduce large work of disease monitoring in big farms at very early stage. Using these expert systems involving artificial intelligence and image processing, disease recognition rate and accuracy rate has been achieved upto 96.2 and 92.3 per cent, respectively. Furthermore, the development of novel computational and bioinformatics tools could help in the analysis of large biological databases related to plant diseases and their control using pesticides. The image processing system can be used as agricultural robot to inspect the field using artificial intelligence for detection, diagnosis and classification of crop disease. Thus, the use of computational and bioinformatics tools will help in minimizing the disease occurrence and severity on crop plants, which will prevent environmental pollution by reducing the quantities of pesticides applied for disease control.

***Keywords* —** Plant disease, Image processing, Artificial intelligence, Expert systems, Disease detection, Agriculture crops

I. INTRODUCTION

Plant diseases, water scarcity and climate changes are the future threats to food production for ever-increasing world population. Therefore, early detection of diseases in plants is an important criterion to improve agricultural crop productivity [1]. Various pathogenic microorganisms viz. bacteria, fungi, viruses as well as nematodes cause different diseases on the leaves, fruits, stem/stalk, grains, roots. Disease-causing fungi are responsible for a great deal of damage in agriculture and horticultural crops, and are characterized by wilting, scabs, moldy coatings, rusts, smuts, blotches and rotted tissue [2]. Moreover, insect pests are also causing significant losses in agricultural productivity. The visual symptom-based identification and classification of diseases in agriculture/horticulture crops has been developed to assist the farmers technologically. However, there is need for design of a machine vision system that automatically recognizes and classifies the plant disease symptoms.

Till now, farmers and agriculture experts carry out inspection of disease affected agriculture and horticulture crops by visual recognition and classification. This evaluation process is however, laborious, tedious and time consuming. Moreover, the decision-making capability of a human agriculture expert/scientist also depends on his/her physical/health conditions. It is being influenced by fatigue, eyesight, work pressure, mental state caused by biases and on the working conditions in the field such as improper lighting, moisture and climatic conditions. Therefore, development of advanced computer vision system is necessitated for detection, recognition and classification of diseases affected on agriculture/horticulture crops [3]. These automation techniques will avoid human interference and will lead to précised unbiased decisions about disease infection and its further evaluation. The development of an automated system will also help farmers to avoid consulting of agriculture experts.

Recently, the computer and communication technologies have been widely explored in science, engineering, medicine, commerce, agriculture and horticulture [4]. Significant progress in the area of computer vision and image processing (CVIP), Artificial intelligence, Pattern recognition, Neural networks, etc., promise the required technological support to tackle the various issues in computer vision. The computation

of agriculture data and data mining techniques can be used as a tool for knowledge management in agriculture [5]. Moreover, remote sensing technologies have advanced rapidly in recent years for site-specific management in crop protection and production. Recently, robots control vision applications are slowly making their way in the fields of agriculture and horticulture. The major advantage of using image processing technology is that they are more accurate, precise and efficient as compared to human beings.

II. RELATED WORK

The large amount of data related to agriculture-related activities has been recently stored as organized database for creation of agricultural information system. Data mining techniques use the specific methods and algorithms to extract patterns, weather forecasting and prediction. Expert systems or knowledge-based systems have been developed using computer programmes that utilizes artificial intelligence, which attempts to replicate the reasoning processes of a human expert [6]. These expert systems utilize specific algorithms and data mining techniques to derive their input for decision making from data files stored on the computer (Fig. 1). A few successful expert systems have been developed in agriculture by utilizing information and knowledge in agricultural activities from different interacting fields of science and engineering [7].

The application of agriculture related information under field conditions needs technical awareness and specializations of human agriculture experts, who can help the farmers in decision-making. But, these agriculture experts/scientists with agricultural specialization are not always available to all the farmers in the villages and if available, their consultation may be very expensive. The use of data mining techniques and information technologies may reduce the threat and uncertainty, and can improve the efficiency of decision making leading to better management policies for improving the agricultural production on the farms [8]. Based on the knowledge of disease related information collected from various sources such as agricultural scientists and farmers, different expert systems were developed [9]. This information could also be retrieved from specialized databases and electronic websites. Thus, different expert systems were developed for plant disease diagnosis and crop management based on visual observations of symptoms expressed by the infected plant [10, 11]. Similarly, an integral intelligent system JAPIEST was developed [12] for the diagnosis and control of diseases and pests in tomatoes in the hydroponics greenhouses.

Different image processing techniques were developed to identify and classify fungal disease symptoms affected on different agriculture and horticulture crops (Table 1). Image segmentation by Fuzzy C-Means (FCM) clustering algorithm with a Novel Penalty term was developed, which takes into account the influence of neighbourhood pixels on the central axis [13]. Subsequently, software was developed for detection and characterization of diseases, which calculated percentage of leaf area diseased using digital image processing [14]. Advanced techniques namely spectroscopic and imaging techniques, and profiling-based technique using volatile organic compounds were reviewed for recognizing plant diseases [15].

Based on Color Co-occurrence Matrix (CCM) and neural network classifier, a software solution was evaluated for automatic detection and classification of plant leaf diseases [3]. Al Bashidh *et al.* [16] proposed detection and classification of leaf diseases using K-Means based segmentation and neural networks based classification. Finally, classification was done through pre-trained neural network and K-means clustering technique was found to provide efficient results in segmentation of RGB image. Barbedo [17] presented a survey on methods that use digital image processing techniques for detection, severity quantification and classification of plant diseases from digital images in the visible spectrum. Marathe and Kothe [18] described leaf disease detection using image processing techniques. This system implemented in MATLAB which makes calculation easy to extract the infected area. Bhange and Hingoliwala [19] proposed a web-based tool for identification of fruit disease on pomegranate by uploading the images to the system. The input image given by the user undergoes several processing steps to detect the severity of disease by comparing with the trained dataset images. The image features are extracted on parameters such as colour, morphology and CCV, and clustering is done by using small k-means algorithm. Next, SVM is used for classification to classify the image as infected or non-infected and the proposed approach revealed 82% accuracy to identify the pomegranate disease.

Fungal disease symptoms, namely, anthracnose, powdery mildew, downey mildew affected on fruit crops like mango, pomegranate and grapes were categorized based on disease severity using statistical methods [20]. Statistical features using block-wise, Gray Level Co-occurrence Matrix (GLCM) and Grey Level Run length Matrix (GLRLM) were extracted from image samples. The nearest neighbor (NN) classifier using Euclidean distance was used to classify images into partially affected, moderately affected, severely affected and normal. It was reported that the average classification accuracy increased to 94.085% using block-wise features. Similarly, Radon Transform (RT) and Support Vector Machine based detection was developed for classification of visual symptoms affected by fungal disease, namely, leaf blight, leaf spot, powdery mildew, leaf rust and smut on cereal crops like wheat, maize and jowar. Algorithms were developed to acquire and process color images of fungal disease affected on cereal crops. Fungal disease symptoms were classified using Support Vector Machine. Color, shape

and color texture features were extracted from disease affected areas and were then used as inputs to SVM classifier. The average classification accuracy of 80.83% occurred with all the image types using color features.

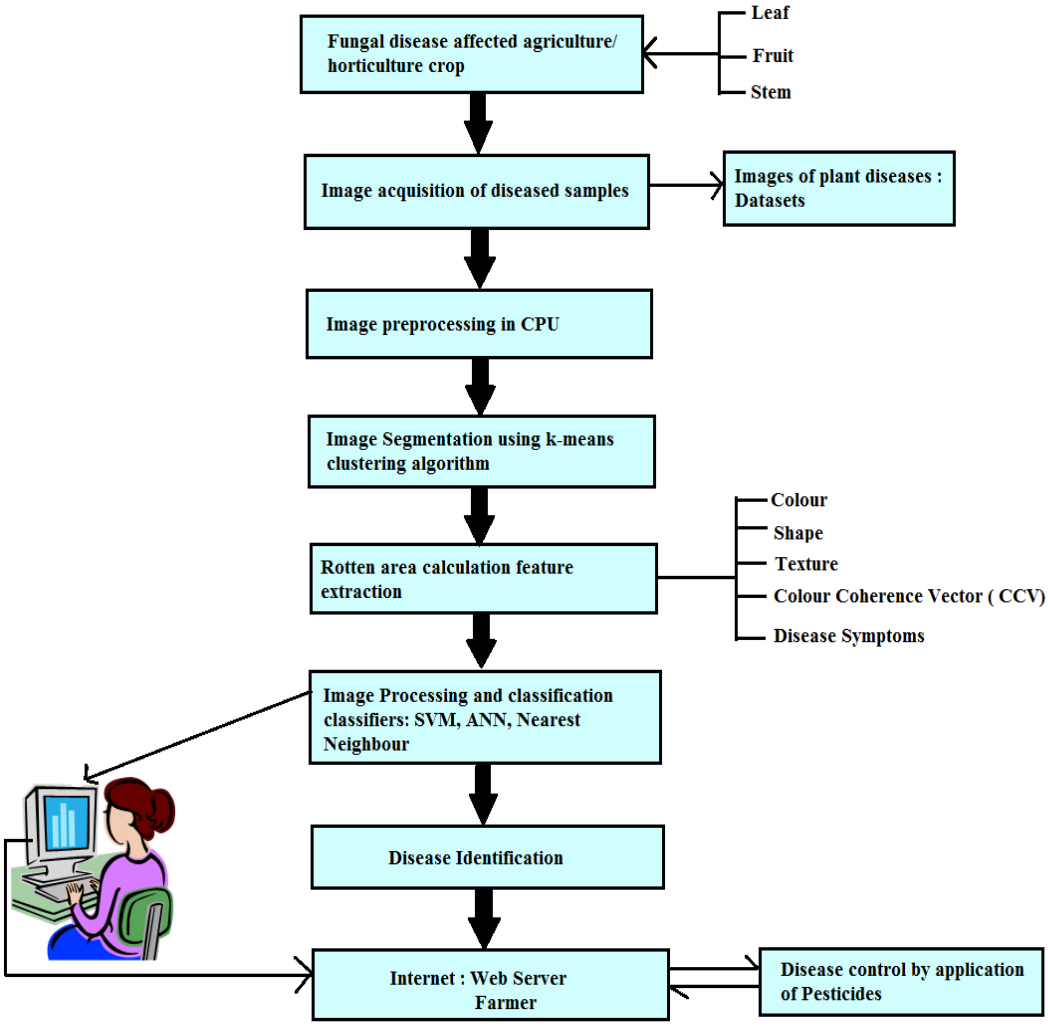

Fig. 1. Various steps involved in image processing and disease detection for fungal diseases

Xu *et al.* [21] designed a leaf disease detection system in wheat based on embedded image recognition technology. The system adopted the ARM9 processor with the embedded Linux platform as the main body and the program was developed in the Qt integrated environment. By using this method, the recognition reached to 96.2% and accuracy rate reached to 92.3% with the method of image processing, approximately equal to the result of human vision. Singh and Chetia [22] developed automatic disease detection system for identification of anthracnose disease (caused by fungus *Colletotrichum lindemuthianum*) in *Phaseolus vulgaris* L. (Beans) and leaf rot disease in another crop *Camellia assamica* (Tea) caused by the fungus *Alternaria alternata* using image processing techniques. It involved image acquisition, image preprocessing, image segmentation, feature extraction and classification. Development of automatic detection system helped the farmers in the identification of diseases at an early or initial stage and provided useful information for its control. Based on multiple linear regression, a new image recognition system was developed recently [23]. In image segmentation, an improved histogram segmentation method was proposed, which can calculate threshold automatically and accurately. Meanwhile, the regional growth method and true color image processing were combined with this system to improve the accuracy and intelligence. After evaluating the results of different image training libraries, the system was proved to have effective image recognition ability with high precision and reliability.

Table 1. Different methods used for diseases detection in various crop plants

Disease	Crop	Affected part	Image processing methods used	Reference
Leaf brown spot and blast disease at early stages	Rice	leaves	Colour texture analysis utilizing pattern recognition and color texture classification	Sanyal and Patel [24]
Rust disease	Soybean	Leaves and grains	Using multi-spectral images	Di Cui *et al.* [25]
Leaf diseases	Rice	Leaf	Colour image analysis automated system	Pugoy and Mariano [26]
Leaf spot disease	Olive	leaf	Auto-cropping segmentation and fuzzy C-Means classification	Al-Tarawneh [27]
Leaf rot disease	Betel vine	Leaves	Image processing algorithms	Dey *et al.* [28]
Bacterial and fungal diseases on leaves	Beans, rose, lemon and banana	Leaves	Algorithm for image segmentation technique	Singh and Misra [29]

IV. RESULTS AND DISCUSSION

The symptoms of the different diseases on the plants vary according to the disease, plant tissue affected and the disease causing fungi or bacteria (causative agent). Usually**,** the early detection of plant diseases is being carried out from visual symptoms appeared on the leaves, stem or fruits. As a first step, images of bacterial and fungal disease symptoms affected on different agriculture/horticulture crops are collected from department of Plant Pathology (Table 2; Fig. 2). For example, in wilt disease, droopiness occurs due to loss of turgor. Death of plant cells occur in rots and disease spots may appear in localized areas. In chlorosis, loss of photosynthetic ability occurs due to bleaching of chlorophyll. Loss of foliage occurs in the blight disease. In Karnal bunt disease in wheat, the fungus causes partial replacement of individual kernels into masses of black coloured teliospores enclosed by pericarp in the grains. In powdery mildew disease caused by *Botrytis* fungus, white thread like fungal growth develops on leaves, stems, buds and flowers, which later develops into a white to gray powdery coating that can be rubbed off with fingers.

The symptoms of the disease and the images of the disease affected plants are loaded in the computers. Subsequently, the work comprises the tasks like image acquisition, pre-processing of images, feature selection, development of methodologies for identification of disease symptoms affected on different agriculture and horticulture crops (Fig. 1). Finally, the disease identification is carried out by trained algorithms in computers. The causative agent of the particular disease i.e., fungi or bacteria are identified and specific pesticides responsible for killing of disease-causing agents are recommended by the computer systems for application in the field conditions.

Computer scientists and plant pathologists have uploaded a huge datasets of over 50,000 images for identification of 26 different diseases on 14 different plant species, as part of PlantVillage system. In this system, the use of trained algorithms has made this program fast, efficient and compact enough to pack into a smartphone. Similarly, Plantix–mobile app is another great example of artificial intelligence and machine learning in farming which help to identify plant diseases quickly. Using these expert systems involving artificial intelligence and image processing, disease recognition rate and accuracy rate has been achieved upto 96.2 and 92.3 per cent, respectively.

Table 2. Some of the important bacterial and fungal diseases and their causative agents

Bacterial diseases	Black rot of crucifers, Blight of soybeans, Wilt of corn, Halo blight of beans, Scab of potato, Fire blight of apples
Fungal diseases	Take-all disease of wheat. Karnal bunt disease of wheat, Damping off disease, Rust disease of cereals, Wilt of chickpea, Late blight of potatoes
Bacterial causative agent	*Xanthomonas campestris, Pseudomonas glycinea, Erwinia stewartii, Pseudomonas phaseolicola, Streptomyces scabies, Erwinia amylovora*
Fungal causative agent	*Gaeumannomyces gramini* var. *tritici, Neovossia indica, Pythium aphanidermatum, Puccinia graminis, Fusarium oxysporum, Phytophthora infestans*
Bactericides and fungicides used	Mancozeb, dithiocarbamates, triazoles, thiocarbamates, thiovit, Bayleton, copper oxychloride, metalaxyl, chlorothalonil, metalaxyl

Alternatives to pesticides	Biological control agents, Botanical/plant derived extracts, Transgenic plants

In the ICT (Information and communication technology) system, farmers get registered in information-providing office of Agriculture Department. The experts or extension workers are involved in providing the crop status through images of the diseases and text data using GPS and GIS system. These images are analyzed by trained algorithms and computers, and the farmers are advised by the agriculture experts about the control measures. Recently, mathematical equations have been optimized for early prediction and forecasting of disease occurrence in particular area based on the humidity, temperature, rainfall, soil type and crop varieties. Moreover, officials/ agriculture experts keep sending the information about soil health, weather conditions and crop diseases. The farmers follow the advice and spray of the appropriate pesticide is done. The feedback is provided by the farmers to the extension workers and agriculture scientists.

Wilt disease on Chickpea (caused by *Fusarium oxysporum*)	Blight disease in Mustard (caused by *Alternaria brassicae*)	Rhizoctonia disease on cobbage (caused by *Rhizoctonia solani*)	Gray mold on straw berries (caused by *Botrytis cinerea*)

Fig. 2. Symptoms and causative agents of the diseases on different crops and fruits

V. CONCLUSION

Different algorithms and techniques have been developed for image segmentation and image processing, and soft computing techniques [15, 30]. The innovative approach of image processing utilizes extraction of disease features and uses machine vision and machine intelligence for precision agriculture. For further improving recognition rate in classification process, Artificial Neural Network, Bayes classifier, Fuzzy Logic and hybrid algorithms can also be used. Accurate disease detection results in recognition and classification of diseases on leaves, stem and fruits were obtained with computational approach, which showed the efficiency of proposed algorithms with very high precision. Another advantage of using this image processing and soft computing methods is that the plant diseases can be identified at the initial stage. This early detection will regulate the amount and frequency of specific quantities of pesticide application based on the disease severity levels, which will reduce the cost of pesticides used for treatment of the disease. Thus, disease identification using image processing and soft computing techniques is helpful in reducing environmental pollution due to controlled application of pesticides.

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