A Comprehensive Survey on Pest Detection Techniques using Image Processing

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***Abstract*—Agriculture is an essential source of sustenance. In India, this sector has tremendous opportunities of large-scale employment for villagers. A survey report illustrated the dependency of the Indian population on agriculture i.e. nearly 70%. Here, agriculture consist of the composition of several crops depending on the climatic nature. However, most of the Indian farmers are still unaware of technical knowledge such as what kind of crop suits their farmland. Numerous heterogeneous diseases affect the production of crops and result as a profitable loss. This paper illustrates the pest diseases specifically with their impact on the current production of the crop. In addition, it shows the survey reports based on several detection techniques of image detection. It is important to search and develop more techniques in order to identify the pest disease before it creates a serious loss in crop production. The current method for the reduction of pest disease is to spray pesticides. However, this process severely affects the health of humans directly or indirectly. The pest detection techniques at the early stages can provide less need for spraying pesticides. The image detection technique emerges as an effective measurement tool in order to fight the infestation. This technique offers better crop management with production as it delivers the maximum protection to crops. Such techniques also minimize human errors and efforts as providing the feature of automatic monitoring over large fields.**

***Keywords*—Image process, Pest detection, Image acquisition, Feature extraction, Pesticides, Plant diseases**

I. INTRODUCTION

The backbone of the Indian economy is agriculture as over 70% population depends on it for their occupation. The total Gross Domestic Product (GDP) includes 17% contributions from the agriculture sector [1]. Therefore, it becomes necessary to identify plant diseases in crops. The composition of Indian agriculture including several crops such as wheat, rice, paddy, sugarcane, vegetables, pulses, fruits, etc. Indian farmers also produce many non-food items like rubber, cotton, bamboo, tea, coffee, etc. The developments in such crops depending on the strength of roots as well as leaves [2]. There is a number of factors that develop different diseases in the roots and leaves of the plant that damaged crops and finally reduces crop production. Early identification of diseases in plants can avoid these enormous losses. Therefore, there is a requirement for accurate detection in order to save the economy and strengthen the agriculture sector of India [3]. Several kinds of diseases reduce the plant growth rate or even depriving their existence. Due to the lack of knowledge, farmers have difficulties to predict such diseases, especially at early stages. Plant disease detection includes several fields such as biomedical [4][5]. Biomedical consists the several processes out of which the image processing methods are the most suitable for the current scenario. It starts with capturing of plant leaves as data collection and then feature extraction. It is the most reliable and efficient method for disease detection. It is also the time-saving process. It precisely reduces the use of pesticides with human efforts. Scientists propose several ideas for yields measurement in agriculture by using the resources (available in the laboratory) for efficient leaf disease identification. This paper illustrated several techniques for plant disease detection suggested by different scientists/researchers.

Fig. 1. Different pests damaging the crop [5]

For example, rice is a primary source of food and the most crop in Asia especially in India, Indonesia, Philippines, etc. However, due to attack of insect pests, the quality and quantity of rice reduce or even lose. Therefore, it becomes imperative to develop effective approaches to lessen the infestation level in the paddy fields. Farmers have the most challenging task of pest control in agriculture [6]. Most of the farmers adapt regular spray programs (as traditional pest management methods) for paddy fields in place of the presence of insect pests. Another available method is the use of chemicals on crops that eliminate the pests by killing them. Pest forecasting decisions require the density assessment for the pest population of rice in paddy fields. Furthermore, insect pests can be widely trapped by using sticky traps mechanism [7]. Such insects now identify and count manually in the laboratories for knowing their type of species. Typically, crop technicians manually count the major pests followed by their segregation and identification according to their species. In paddy fields, such a process provides the pest density estimation from the resulting counts. However, rice fields require frequent counting and multiple sites of pests. However, this process is quite tedious and time consuming for crop researchers. Poor decisions on rice pest management due to accurate count delays or low count accuracy.

Researchers could solve complex problems through image processing technology. It depicts the exponential growth of digital technology in the agricultural research field. Insect pest detection automation has a realistic opportunity as image analysis. Several works provide the extension of the implementation methods through an automated detection system for the estimation of pest densities in rice fields. Rice production increases (as both quality and quantity) by applying the right pests management and pest counting from the collected specimens through crop technicians. It becomes easy to develop a highly efficient monitoring system through an automated system. Cameras can easily monitor and detect rice infestation.

II. BACKGROUND

Pest detection techniques developed after intense research on the surveying of crop loss. The pest attacks affect the economy of several countries as shown in Table 1.

Table I. Crop losses in different continents [8]

Continent	**Crop loss (%)**			
	Animal pests	**Pathogens**	**Weeds**	**Total**
Africa	16.7	15.6	16.6	48.9
N. America	10.2	9.6	11.4	31.2
Latin America	14.4	13.5	13.4	41.3
Asia	18.7	14.2	14.2	47.1
Europe	10.2	9.8	8.3	28.2
USSR	12.9	15.1	12.9	40.9
Oceania	10.7	15.2	10.3	36.2
Mean	15.6	13.3	13.2	42.1

The agricultural production mainly divided into cereals, vegetables, fruits, and non-food items. The crop loss in each field is shown in Table-2, 3 and 4 respectively.

Table II. Yield losses due to major insect pests in vegetable crops in India [9]

Crop	**Pest**	**Yield loss (%)**
Potato	Aphid (Myzus persicae (Sulzer))	3–6
	Tobacco caterpillar (S. litura)	4–8
	Potato tuber moth (Phthorimaea operculella (Zeller))	6-9
	Mite (P. latus)	4–27
Cucurbits	Fruit fly (B. cucurbitae)	20–100
Cabbage	Cabbage borer (H. undalis)	30–58
	Cabbage leaf webber (Crocidolomia binotalis Zeller)	28-51
	Cabbage caterpillar (P. brassicae)	69
	Diamondback moth (P. xylostella)	17–99
Okra	Shoot and fruit borer (E. vittella)	23–54
	Whitefly (B. tabaci)	54
	Leafhopper (A. biguttula biguttula)	54–66
	Fruit borer (H. armigera)	22
Brinjal	Fruit and shoot borer (L. orbonalis)	11–93
Chilli	Mites (Polyphagotarsonemus latus (Banks))	34
	Thrips (S. dorsalis)	12–90
Tomato	Fruit borer (H. armigera)	24–73

Table III. Losses caused by insect pests in fruit crops [10]

Year	**Crop**	**Reference**	**Insect pest**	**Loss (%)**
2007	Papaya	Tanwar et al.	Mealybug	8–33
2007	Guava	Haseeb and Sharma	Fruit fly, bark borer and fruit borer	3–38
1987	Citrus	Waterhouse and Norris	Fruit-sucking moth	95
2001		Dadmal and Pawar		10–55
1997		Cai and Geng		20–30
1983		Kumar and Lal		10–15
2013	Mango	Anonymous	Fruit fly	10–80
1990		Sohi and Sohi	Hopper	20–100
2000		Olufemi et al.	Mealybug	100
1963		Atwal		50
2004		Moore		50–90

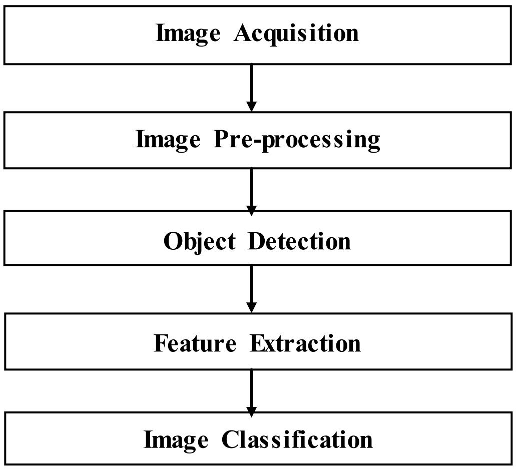
Table IV. Global estimates of crop losses due to insect pests/animal pests [10]

Crop	**Cramer (1967)**	**Oerke et al. (1994)**	**Oerke and Dehne (2004)**	**Oerke (2006)**
Wheat	5.1	9.3	9	7.9
Rice	27.5	20.7	24	15.1
Maize	13.0	14.5	15	9.6
Potatoes	5.9	16.1	18	10.9
Soybean	4.4	10.4	11	8.8
Cotton	16.0	15.4	37	12.3
Barley	3.9	8.8	7	
Sugar beet			6	
Coffee		14.9		

In India, several pests are found that severely affect crop production. The main types of pests are shown in Fig. 2.

Fig. 2. Main types of pests; (a) Gundhi bud, (b) Rice Hispa, (c) Grasshopper, (d) Rice Mites, (e) Gall Midge, (f) Case worm, (g) Rice Hispa, (h) Mealybug and (i) Moth [11]

The stages for pests detection on the leaf using image processing are presented in the flow chart given below [12].



III. Literature Review

A. Various methodologies for Pests detection

Wen, Chenglu, Daniel Guyer [14] proposed a simple model for the detection of pests. This work has shown three different methodologies, first only used local insect image feature, second used only global insect's image feature and third methodology used combination of local and global features. These features got combined in a hierarchical model of classification, the first level uses the global and second level of classifier uses the local feature. Siti N. A. Hassan et al. [15] proposed an insect detection model for Grasshoppers and Rhopalocera from digital images. They used the color of insects and the shape of the insect as a feature attribute. For determining the shape of insect RGB to binary conversion done, but this work was developed for only two insect species.

Table V. Previous work on pest detection with detection efficiency and used techniques

Year/ Reference	Plants	Techniques used	Applications	Detection Efficiency (%)
2006 [18]	Citrus leaves	CCM, HIS, SGDM	Reduces the computational time	95
2009 [19]	Wheat kernels	Near-infrared hyperspectral imaging	To investigate the potential of near-infrared (NIR) hyperspectral imaging for the detection of insect-damaged wheat kernels with highly reproducible results.	
2009 [20]	Rice leaves	SVM, Gray level co-occurrence matrix [GLCM], HSV	Classify rice disease using shape, color and texture feature	97.2
2009 [21]	Banana leaves	RGB, Color transformation, Thresholding technique	Identify diseases region	-
2011 [22]	Corn leaves	YCbCr color space, Neural network	Classification of various diseases	-
2012 [23]	Orchard species	Global feature modal	To develop an image-based automated insect identification and classification for orchard field species classification.	86.6
2013 [24]	Cucumber leaves	Median filtering, Gray level co-occurrence matrix	Detects downy mildew, powdery mildew and anthracnose disease	96
2013 [25]	Palm oil leaves	Neural networks	Detects hawar and anthracnose leaf disease	87.75
2013 [26]	Jujube tree	Neural network, Feedforwar	Classify different disease based on color,	85.33

		d, PCA	morphological and texture features	
2014 [27]	Common crop	SVM classifier	Develop an automatic insect identification framework that can identify grasshoppers and butterflies from colored images	90
2014 [28]	Cotton leaves	Skew divergence, SVM, BPN, Fuzzy classifier, EPSO (enhanced PSO), Genetic algorithm, CYMK color space	Classifies bacterial blight, fusarium wilt, leaf blight, root rot, micro nutrient disease, verticillium wilt	94
2015 [29]	Common crop	Multifracta-l analysis, Watershed and Efficient Graph-based Image Segmentation (EGBIS)	In this research, multifractal analysis was adopted for segmentation of whitefly images based on the local singularity and global image characters with the help of regional minima selection strategy.	86.9
2015 [30]	Pomegranate leaves	SVM, k-mean clustering, Color coherence vector (CCV)	Bacterial blight disease identification through mobile device	82
2018 [31]	Common crop	Otsu's method and edge detection segmentation	Color-based image segmentation using k-means clustering was used for image segmentation of various pest infected crops.	-
2019 [32]	Common crop	CNN	A diagnostic system based on transfer learning for pest detection and recognition	93.84 and 98.92

Rajan, Preetha et al. [16] proposing a color feature-based model for pest detection. The image was separated in R, G, B channels. Intensity distance among pixels calculated. If the pixel value higher than a certain threshold in all R, G, B channel images, that pixel has a high probability to be part of pest pixels. Later SVM was used for classification purposes. Javed, Muhammad Hafeez et al. [17] proposed a model to detect insects. In this model image segmentation has been performed with the help of enhancing the method of k means segmentation methodology that is used to identify insects from an image. Discrete cosine transform methodology used for feature extraction. ANN is used for classification and they achieved an accuracy of 97%.

B. Image Processing& Feature Extraction

Image processing is the analysis and manipulation of graphical images from sources such as photographs and videos. There are three main steps in image processing; first, is the conversion of captured images into binary values that a computer can process; second, is the image enhancement and data compression; and the third is the output step that consists of the display or printing of the processed image. Several applications are depending on image processing techniques such as computer-based pattern recognition, machine vision, and satellite weather mapping. Phinyomark et al. proposed a novel feature extraction [34] for interference representation by using white Gaussian noise of electromyography signal. Robust feature extraction depicts the two novel frequencies of median and mean. Alsmadin et al. [35] suggested a recognition system development for an isolated pattern of interest. It contains the composition of robust feature extraction. It is working as a classifier for fish image recognition. It can categorize and classify the subject into a non-poison or poison family.

C. Real-Life Application of Image Processing in the Fields of Agricultural Research

Automatic insect identification systems can be formed after several attempts with the help of image analysis. Samantha and Ghosh [36] performed this study at North Bengal Districts of India in tea gardens with the records of eight major insect pests. They provided the correlation results on feature selection for the reduction and extraction of features. It also gave the neural network algorithm with the help of incremental back propagation neural network used for characterizations. Do et al. [37] made a non-specialist recognition system by using computerized patterns for arthropods and arachnids resulting in accurate and easier identification of the specimen. The main objective of this method pest's detection of plant parts such as roots and leaves. The used scene interpretation and video analysis techniques by multi-camera information as in-situ support for developing an innovative decision system. Furthermore, the suggested algorithm is used for aphids and whiteflies detection with apriori technique. It can easily grab the bio-aggressors diversity by following the generic approach of design. Al-Saqer [38] worked on pecan weevils with the use of an identification system (based on neural network-based). Zhu and Zhang [39] suggested the insect identification process with a unique approach. They worked on image matching with the combination of dual-tree and region matching complex wavelet transform. They used the k-mean algorithm for feature extraction on the images of lepidopteron insects with mean shift algorithm filtering.

IV. EXISTING METHODS

A. Image Acquisition

Here, an example has been taken as of paddy field for explaining the process of pest detection. The first step is to capture the affected crops. Researchers need proper setup of the wireless camera network. They should be operable in difficult climatic conditions such as direct sunlight and water projection resistance. Such a network is connected with Sticky traps for insect pests capturing. The latest technique is the utilization of Internet Home Monitoring Camera named CISCO Linksys Wireless-G. It has a resolution of 8 megapixels with a capturing speed of 10 frames per second. A local machine can process the captured images by using the features of 4 GB RAM and Intel i3 processor [40].

B. Image Pre-processing

Image pre-processing technique requires for processing the still image with developing the image enhancement process. It starts with the appearance of each color as RGB color model primary spectral components. Such spectral components explain their respective intensities with respect to three components as Red, Green, and Blue (RGB) [40]. It has limitations as much time consumption by the process and need of large storage capacity. The large time consumption is due to the need for three different channel progressions in image processing. Next step is the grayscale image conversion from RGB image with the following formula:

$$I(x, y) = 0.2989\times R + 0.5870\times G + 0.1140\times B$$

C. Image Pest Detection Technique

This is an efficient technique for image detection of insect pests. Researchers can compare the results of pixel values of successive images shots taken by the camera. The differences can be observed and detected by taking multiple images with different angles [40]. Reference images are considered to be the first image denoting the values of reference pixels, while the input image is serving as the second image. The next step is to compare the two images based on their pixel values.

D. Filtering of the Image

The filtering process clears the noise from the image appearance due to variable lighting conditions. Filtering provides better and usable outputs by using digital image processing. It is important to know the correct methodology to apply the various filtering techniques depending on the image [40]. Several existing works used a median filter for pixel observation. The decision is made by consecutive neighbor's pixel values that the value of its surrounding pixels is taken or select the median of those values.

E. Pest Detection Extraction

An image needs the appropriate method for extraction from pest detection. The previous phase provided the image that is taken as the input of this process. It starts with the estimation of coordinates of the pest with the help of scanning (both vertically and horizontally) with the appropriate pixel values of the output image [40]. The starting and ending coordinates estimate the height and width of the image extraction technique. After this step, the matrix is formed and saved with respect to the width and height of the image matrix. Pest detection extraction has two steps. First, to scan horizontally the output image values in pixels initiating from the first x-direction. It leads to the summing up of all the corresponding columns. The next value is obtained by incrementing one value each time with the calculation of total pixel value in the next column. The process will reach up to the last value by the repetition of this step towards the x-direction. The total obtained values are getting compared in order to set the certain threshold value. Second, the same procedure is applicable for vertical coordinates in direction to obtain its threshold value.

V. CONCLUSION

This paper presents the various image processing techniques such as feature extraction and automatic detection for the image. The survey shows the efficient and simple existing methodologies. Several techniques are illustrated here to obtain the knowledge of different background modeling for pest detection such as image filtering, median filtering for noise removal, image extraction and detection through scanning. This paper depicts some promising results to present enhanced methods and tools for creating fully automated pest identification including the extraction with detection. Worldwide faces the challenge of crop production reduction by viruses, pathogens, animal pests, and weeds. Pest groups attack resulting in the loss rates and absolute losses. Under high productivity, conditions lead to a high crop grown rate in tropic and sub-tropics regions. However, in such areas, the pest can highly damage the crop because of the presence of favoring climatic conditions. Therefore, crop protection methods needed for the growth of pests. Also, farmers should aware of such techniques. Future directions of this study can be carried out to develop more advanced image processing techniques in terms of accuracy and efficiency. It can also be extended to design an efficient identification system for object extraction.

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