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Pest Identification using Image Processing Techniques in Detecting Image Pattern through Neural Network

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Abstract—**In rice production, pest invasion is considered as the most challenging task for crop technicians and farmers. Pest invasion can cause serious losses and affect the income of farmers. It is then important to assess their density for pests forecasting decision making. Existing identification techniques of these species comprise of using different traps to detect their presence. However, these traditional methods are labor-intensive and sometimes experts on this field are not available. Another problem is that multiple site and frequent monitoring of rice pests is time consuming and tedious for a crop technician. This can lead to low accuracy and delays in obtaining accurate count of these species. In this study, an identification system was developed to automatically identify the insect pests in the paddy field. Sticky trap was used to capture the insect which continuously monitored by a wireless camera to record the video. Different image processing techniques was utilized to detect and extract the captured insect from the image, and Kohonen Self Organizing Maps neural network was used to identify the extracted insect pests. The results indicate that the proposed automated identification system is capable of accurately identifying the insect pests even though there are lots of lighting variations. The new automated identification system developed in this study provides a reliable identification and was found to be faster than a human expert in identifying the insect pests caught by a sticky trap.**

***Keywords*—paddy fields insect pests, automated pest identification, image pocessing, neural network**

I. Introduction

One of the most important crops in the Philippines is rice. This crop is a staple food for Filipinos and served in every meal of the day so it is important to food security. The increasing demand of these crops attracted the attention of different scientists and researchers to find effective methods and improve crop protection strategies. Prevention of damages or losses can increase rice production. Research efforts were directed towards the development of environment-friendly pest management strategies and dissemination of such technologies to farmers. In rice production, pest infestation is considered as the most challenging task for crop technicians and farmers, their outbreaks can cause serious losses in rice production and affect the income of farmers. Early detection of the initial presence of pests is a key-point for crop management. Integrated Pests Management (IPM) is the most accurate method used to control pests and a method that minimizes environmental impacts. This pest management strategy was developed by different entomologists and other researchers in response to widespread development in agricultural setting of pesticide resistance in pests resulting from pesticide use. IPM is focused on biological control of insect pests in agricultural system, it emphasizes the selection, integration, and implementation of complimentary pest management tactics to maintain pests at economically acceptable levels while minimizing negative ecological and social impact of pest management activities. There are three main steps in IPM; these are the detection, identification and application of the correct management [1]. From these steps, identification is the most challenging, it is important to assess whether the insects found are likely to cause serious damage and choose an appropriate control technique since many treatments are available. However, this requires continuous monitoring of experts which requires higher expenditures in large farms. Furthermore the collected samples are very difficult to identify and count because they are too small in size and the accuracy is affected by variable identification skills and causes fatigue to human observers. The challenge regarding detection and identification of the insect pests in the field is its small size which could be easily confused with other noise.

To cope with these problems, an automated pest identification system is essential as it proved beneficial in monitoring large fields of crops, and thus automatically detects the presence of insect pests as soon as they appear in paddy fields. Therefore, looking for fast, automatic and accurate method to identify insect pests in the paddy field is of great realistic significance. Early detection will help farmers to avoid huge loss. Technology support would help them in this aspect by cutting on the cost of pesticides.

The aim of this study is to make a prototype of a real-time insect pest identification system using different image processing techniques and neural network, then try to measure its accuracy.

In this study, non-specialists like farmers can now correctly identify the insect pests and apply the right pests' management which can increase both the quantity and quality of rice production. Using the proposed system, crop technicians and farmers can make the monitoring effort easier. Instead of manually checking the paddy fields to detect the existence of the insect pests, a camera will be used to easily detect and identify them. The automated insect pests' identification system can also be used by the researchers who are doing taxonomic research that requires identification of collected specimens. They can use the system to easily detect and identify the pests without going to the field regularly.

II. Related works

Previous work described the different image processing and neural learning techniques to automatically detect and identify the different insect pests that are commonly found in greenhouse and in the paddy fields.

In the study of Kumar et al. [2], the authors developed an innovative classification system that automatically detects harmful insects in greenhouse based on image analysis and scene interpretation. Their study was focused on the evaluation of three feature extraction techniques to extract the insect from captured images, these are the Gabor Filter, Pyramidal Histogram of Gradient and Color data. Support Vector Machine algorithm was also used to classify the extracted insect from the image. Based on the result of their experiments, from 1,283 whiteflies they detected 98.5% and missed 1.5% only and from 49 greenfly they detected 91.8% and they only missed 8.2%.

The study about Detection and Classification of Pests in Greenhouse Using Image Processing [3], the authors developed a software prototype for early pest detection on the infected crops in the greenhouse. In this study, they used pan tilt camera with zoom to capture the insect pests. The recorded video is delivered to a central server where processing and analyses were applied to detect and extract the insect pests from the captured video frames. Support Vector Machine algorithm was also used to classify the extracted insect pests from the image to estimate their density inside the greenhouse.

The paper of Pokharkar et al. [4] presents an automated video surveillance technology for pest detection on the infected images of rose leaves in the greenhouse. The proposed cognitive vision system is combined with image processing, learning and knowledge-based techniques which can automatically identify and count mature whiteflies captured in the images.

The paper presented by Martin et al.[5] extends the implementation of different image processing techniques to detect pests in the greenhouse. In this study they setup a network of cameras to continuously survey a greenhouse. These cameras were used to observe the sticky trap and the others were used to observe directly the plant organ and none flying insect pests. The acquired images were processed using video analysis combined with apriori knowledge about the visual appearance of the detected insects. The interpretation of the extracted insect pests from the image is done using neural learning and knowledge-based techniques.

The advancement of image analysis using different algorithm to detect insect pests in greenhouse was also presented by Cho et al.[6] Their study on automatic identification of whiteflies, aphids and thrips in the greenhouse was based on image analysis. They presented an innovative decision support system using different image processing techniques. The goal of their work is to accurately estimate the density of pests to be able to design a suitable pest management strategy and minimize the use of pesticides which affect the health of farmers and destroy the environment. To capture the insect pests, they installed wireless cameras that continuously observe the sticky trap. The captured images are then sent to the server to process and identify the extracted insect pests.

In the previous study presented by Venugoban K. et al.[7], the authors developed a framework that can classify insect pests from the paddy field using gradient-based features through the bag-of-words approach. In this study they used twenty classes of paddy field insect pests that were obtained from Google Images and images taken by their faculty in the paddy fields. The captured images were then processed through the system where different image processing algorithm and techniques were used to identify the regions of interest and represent those regions as scale-invariant feature transform (SIFT) or speeded-up robust features (SURF) descriptors. Codebooks mechanism was also used to provide a way to map the descriptors into a fixed-length vector in histogram space, and classify the feature histograms based on Histograms of Oriented Gradient (HOG) descriptors using support vector machines (SVMs) based classifier. Testing result shows that combined HOG descriptor and SURF yield around 90% accuracy in classification.

A novel segmentation method for middle-sized touching insects from the image was proposed by Yao Q. et al.[8]. The study focused on developing automated identification and counting system of different insect pests captured using rice light-trap. The specimen used in their study were obtained from the rice light-trap and were captured using a camera in a glass table in the laboratory. Normalized cuts (NCuts) together with the optical flow angle as the weight function was applied to separate the touching insects according to the number of insects in each connected region. Their study was compared to k-means and watershed methods and achieved better segmentation result.

III. Materials and Methods

Several techniques were tried to achieve the objectives of this research with varying degrees of complexity and success rates. This section outlines those methods and techniques.

A. *Dataset creations*

During the development and testing of the proposed system, a wide range of sample insects found in the paddy fields were collected. These insect were collected using swept net and captured using camera in the laboratory. Each insect was captured by CISCO Linksys Wireless-G Internet Home Monitoring Camera which can capture 10 frames per second. The raw images from the camera were processed, converted into grayscale format and scaled down to a dimension of 20x20 pixels. The processing was done using a laptop computer equipped with an Intel Core i3-2330M CPU at 2.20GHz processor and with 4 Giga Bytes of RAM. Java programming language version 1.7 was utilized for the simulations. The processed images were saved in the database and served as the reference images used in recognition part of the proposed system. In this study the authors used only 11 kinds of insect pests which are commonly found in the paddy fields to test the proposed system, these samples are listed in Table 1.

TABLE I. KINDS OF RICE INSECT PESTS BASED ON MODES OF FEEDING

No.	Insect pest Names	Mode of feeding
1	Rice whorl maggot	Defoliators
2	Rice leaffolders	Defoliators
3	Rice thrips	Defoliators
4	Rice short-horned grasshoppers	Defoliators
5	Green leafhoppers	Sap-feeders
6	Zigzag leafhopper	Sap-feeders
7	Brown planthopper	Sap-feeders
8	White-backed planthopper	Sap-feeders
9	Malaysian black bug	Sap-feeders
10	Slender rice bugs	Sap-feeders
11	Stem borers	Sap-feeders

B. *System Architecture*

In this section, the authors presented the architectural design of the proposed automated pest identification system as shown in Fig. 1. It starts with video recording using wireless cameras that continuously observe the installed sticky trap in the paddy fields. The captured videos were sent to the computer server and processed using a background modeling mechanism to detect the presence of insect pests in the image. After the detection of the insect pests in the image, the segmentation and extraction module was utilized to extract the detected insect in the image in preparation for the identification module. After the extraction of insects in the image, the extracted insects are scaled into 20x20 pixels which later feed in the neural network for identification. The identification module was used to identify the target object from the input image and generates an object candidate. When the recognition module matched an object candidate, it scores evaluation value, then send the results to the end user for the design of suitable pests management strategy.

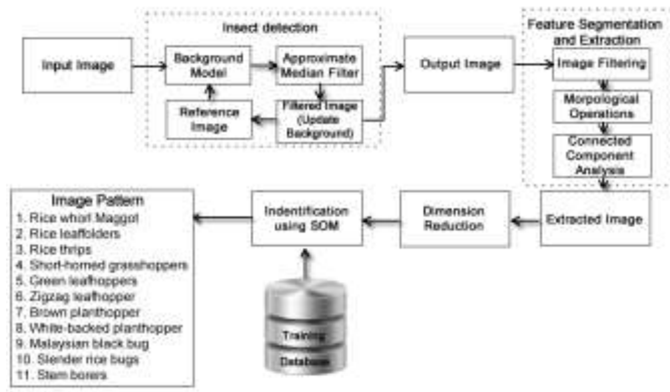

Figure 1. Block Diagram of the proposed Automated Pests Identification System

1) *Image acquisition*

The task of the proposed automated pest identification system is performed by a video recorded from camera at 320 $\times$240 frame size shown in Fig. 2. In this study, a lower frame size was used to lessen the memory during the calculation of the obtained images that easily observes the trapped insect in each frame. The converted video frames are separated into individual frame and saved as in true colour Red Green Blue (RGB) format. First, the images are in RGB format at 320x240 Pixels and later pre-processed and converted into grey-scale images. The converted images are not suitable for feature extraction because sometimes they are affected by various factors such as noise, different lighting variations caused by different weather conditions and poor resolutions of images. A filtering technique was used to filter the images to make it more presentable.

Figure 2. Video recording using wireless camera

2) *Object detection*

Background modeling was the approach used in detecting the insect pests from the image. This method determined the difference of the reference frame from the input frame on successive video frames. The input frame is subtracted from the reference frame, and if the difference in pixel values for a given pixel is greater than a threshold then the pixel is considered as part of the foreground.

There are many challenges in background modeling method especially if the system is implemented in the paddy fields where different lighting variations will be encountered. Median filter solved this problem because the algorithm has been shown to be very robust and the performance is comparable to complex methods. However, storing and processing of many frames from video requires a large amount of memory storage which can affect the performance of the proposed system. To develop a high performance algorithm for insect pest detection and identification, the authors used approximate median algorithm. The algorithm was first presented by McFarlane and C.P. Schofield [9] on their research on piglet tracking in large commercial farms and this had shown robustness in detecting object in an image.

The approximate median filter algorithm functions: if the pixel value of the input frame is larger than the pixel value of the reference frame, then the pixel value of the reference frame is incremented by one. Likewise, if the pixel value of the input frame is less than the pixel value reference frame, then the pixel value of the reference frame is decremented by one. In this manner, the reference frame eventually converges to an estimate where half the input pixels are greater than the reference pixel, and half are less than the reference pixel.

3) *Feature Segmentation and Extraction*

a) Image filtering

Image filtering is the process of enhancing the captured image caused by various factors like noise which are acquired from different lighting variations. In image processing, any measurement which is not part of the target object in the image is considered as noise. An image can acquire noise in many ways depending on how the image is created. To enhance the image which was previously affected by different noise, the authors used the median filter. In the median filter, the value of an output pixel is determined by the median value of each neighbourhood pixels.

b) Morphological operations

In image processing, morphological operation is a technique used to remove unwanted objects from the image and makes the boundary of foreground images more presentable. After filtering the image using median filter, a dilatation and closing morphological operation will be used. Dilatation is a morphological operation and its primary feature is to dilate the boundaries of the different foreground regions. These foreground objects will become bigger and the hole inside these objects become smaller. The closing morphological operation, similar with dilatation, the boundaries of foreground region will be enlarged but this technique is less destructive in the original boundary shape.

c) Connected Component labelling

Once the region boundaries have been detected, it is often useful to extract regions which are not separated by a boundary. The foreground pixels are grouped into connected regions and labeled using a connected component labeling algorithm. After finding individual regions that correspond to objects, the bounding boxes of these regions are calculated. Size thresholding will also be used to remove smaller size object. It measures the size of each object and removes the objects based on the threshold. Threshold in this case is the number of pixels in an object. Objects whose size is greater than the defined threshold are retained and remove all the unnecessary objects.

4) *Image dimension reduction*

There are several important issues to consider when loading image data into a neural network. Usually the extracted objects from the image are not square image, and its sizes are not standard so we need a further processing. The propose system will use a neural network to identify the extracted insects. The neural network design that we will use in this study has a fixed number of input layer neurons. These input neurons receive pixel values from the extracted image. Through this, the extracted image will square and reduce in size to assure the neural network input layer neurons receive a uniform set of pixel.

5) *Insect Identification*

This is the final phase in the system. Here, the detected and extracted insects from the image will be recognized by the system using Kohonen Self Organizing Maps neural network. The image database used in this study has a total of eleven images. Each image is in grayscale and of size 20x20 pixels. These feature vectors will be present in the neural network during the training and testing of the proposed system. The proposed neural network design consists of an input layer with 400 neurons receiving the input feature vectors and 11 output neurons corresponding to the eleven sample insect images. Fig. 3 shows the design of the proposed neural network. When the pattern is presented to the neural network, one single output is chosen as the output neuron and this will be the index of one of the eleven sample images.

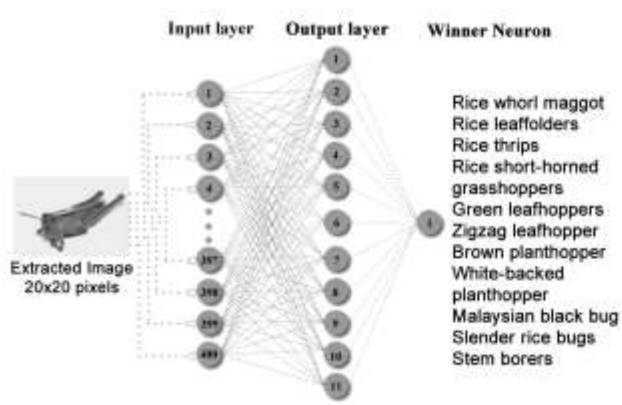

Figure 3. Neural network design for pest identification

IV. Experiment Results

The experiment on automated identification of rice insect pests was carried out in the paddy fields of Pampanga Agricultural College practice farm. It has an area of 200 square meters. The specimens were collected in the sticky traps which were continuously observed by the wireless cameras installed in the paddy field. The interconnection of the four wireless cameras and the computer server was done with the wireless router which was also installed in the paddy field.

To test the accuracy of the proposed system in identifying the trapped insects, the authors compared the recognition of an expert (rice crop technician) with the identification capability of the proposed system. The results are shown in Table 2 and were found efficient.

TABLE II. IDENTIFICATION RESULTS

Insect Name	Identification By Expert				Identification by proposed System				Accuracy %			
	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4
Rice whorl maggot	1	3	2	5	1	3	2	3	100	100	100	60
Rice leaffolders	3	2	2	4	3	2	1	4	100	100	50	100
Rice thrips	1	4	1	1	1	4	0	1	100	100	100	100
Rice short-horned grasshoppers	2	1	1	3	1	1	1	2	50	100	100	66.67
Green leafhoppers	6	5	7	2	4	5	6	2	66.67	100	85.71	100
Zigzag leafhopper	4	7	3	8	4	5	3	7	100	71.43	100	87.50
Brown planthopper	2	2	1	3	2	2	1	2	100	100	100	66.67
White-backed planthopper	2	1	1	1	1	1	1	0	50	100	100	100
Malaysian black bug	3	1	2	4	3	1	1	3	100	100	50	75
Slender rice bugs	4	3	1	3	4	3	1	3	100	100	100	100
Stem borers	8	6	4	9	7	6	4	8	87	100	100	88.89
Non Registered insects	2	1	3	3	2	1	3	3	100	100	100	100

The proposed pest identification system based on image processing and neural learning techniques were applied to four sticky traps continuously observed by cameras installed in the paddy field. Based on the results the proposed automated identification system was found accurate in identifying insects.

V. Summary and Future works

This research was a continuous effort of our earlier work, which is to develop reliable and efficient automated pest detection and identification systems that can be used in the paddy fields [10]. In this study, different image processing techniques were used to detect and extract the captured insects from the images. First the authors setup a network of four wireless cameras that continuously monitored the sticky traps. The recorded videos from the installed cameras were automatically sent to computer server and analyzed. Approximate median filter was used in creating the background model and the technique to detect the presence of insect pests from the image. The output image from the detection module was filtered using median filter algorithm to remove the noise caused by different factors such as different lighting variations due to different weather conditions. Morphological image processing was also used to enhance the boundary of the original image objects. Connected component analysis was employed to separate the object of interest from image. The neural network design used in this study contains fixed size so the authors reduced the extracted image based on the design of the neural network. Based on the initial experiment, the proposed system can accurately detect and identify the insect pests.

The result presented in this paper is promising but several improvements are recommended to reach the requirements of fully automated pest identification system. In the future, other image processing techniques and learning algorithm such as Support Vector Machine may be compared to enable the identification of the detected insect pests to be more efficient and accurate.

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