Greenhouse Insect Pest Detection Using Computer Vision

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***Abstract*—Due to the closed environment, greenhouse agriculture is prone to rapid insect and disease outbreaks, unlike traditional agricultural approaches. However, due to the commitment to organic farming techniques, the use of pesticides for insect eradication is not possible in most greenhouses. Thus, this research intends to provide an early pest detection system by applying image recognition technology that surpasses the existing systems. The study attempts to evaluate two methodologies to determine the most effective approach for the system.**

Keywords—Greenhouse, image recognition technology, pest, early pest detection, pesticides

I. Introduction

Changes in the seasonal cycle have made outdoor farming more challenging. As per Food and Agriculture Organization (FAO) data published in 2016, if the current situation of GHG emissions and climate change continues, then by the year 2100 there will be a decline in the production of major cereal crops (20–45% in maize yields, 5–50% in wheat, and 20–30% in rice) [1]. Moreover, due to the expanding human population, shrinking cultivable land, and water supplies, there is an urgent need to optimize food production from limited land and water sources. Protected agriculture, especially through greenhouse farming, is one method being used to deal with these problems. Greenhouse crop cultivation demands a great deal of attention. Over the past few decades, it has shown immense potential and has been successfully adopted for cultivating vegetable crops. In the recent past, there has been a tremendous increase in the area under protected cultivation (around 20 million hectares of area all over the world) [2].

One of the major problems in greenhouse farming is the presence of pests. In India, the yield loss due to various insect pests ranged from 30% to 40% among different vegetable crops [3]. Recently, Sri Lanka has experienced some major insect outbreaks, inflicting considerable economic losses. Most of the time, mistakes committed by farmers and the lack of quality in the infrastructure can lead to extensive insect threats within a greenhouse. Closed environments like greenhouses are prone to the rapid spread of pests, insects, and diseases compared to a regular agricultural field. Capsicum, chili, cucumber, tomato, and brinjal are the main crops grown in protected environments. The production of these crops is greatly influenced by insect pests [4]. In capsicum, whitefly caused 13.60% yield loss, whereas on cucumber plants, yield loss was approximately 26%. Moreover, whitefly caused a 54% yield loss in okra plants. The most frequent damage insect pests cause is due to the hundreds of plant viruses that they are able to transmit. The development of the whitefly was seen higher on eggplant and cucumber, followed by tomato [2]. Given the trend towards organic practices, the use of pesticides is no longer a practical option for most greenhouse producers. Integrated pest management systems have been widely applied in agricultural fields to minimize the use of pesticides and yield losses. In most situations, pest populations are identified and determined by physically counting the insect pests attached to sticky paper traps. This old approach is inefficient and exceedingly time-consuming. Furthermore, the global agricultural workforce is predicted to decline by 30% between 2017 and 2030 due to the availability of more lucrative job opportunities [5]. Given these underlying challenges linked with identifying and counting insect pests in the greenhouse, an autonomous pest detection technique is crucial to the modern agricultural business. Experimental results showed that the order of best strategies for virus suppression was integrated management (73%), biological control (58%), and chemical control (44%) [5]. Therefore, this project aims to propose a computer vision-based method to replace the manual pest detection task. Early detection of insect pest outbreaks is vital for farmers to take appropriate steps for the protection of crops. The whitefly is the major insect that is expected to be identified in this research project.

To the best of the author's knowledge, 2/3 of the research related to the identification of insect pests using modern technology uses image processing technology. Modern machine learning approaches are not common in pest detection when compared to image processing approaches. Mainly, the U-Net is used in medical image segmentation tasks. Therefore, this research aims to compare the performance of pure image processing with a modern machine learning-based system for pest detection in greenhouses.

II. Methodology

A. Research Methods

The image recognition part of this research is conducted using two main methodologies.

a) Image Processing using Python

b) U-Net in Python

First, images taken from the dataset are put in as the input for both systems, and then the output results of the systems are examined. Comparing both outputs and their accuracy and efficiency, the appropriate system is expected to be presented as the image recognition technique of the greenhouse pest detection system.

a) Image Processing Using Python

This image processing system was coded in Python using OpenCV2 as the library. The platform that is used to run the code is Google Colab. Use OpenCV2 as the library because it contains a large number of functions and algorithms for image processing and object detection tasks. Also, it supports numerous programming languages. Also, it has a strong community of users and developers, contributing to its constant improvement and maintenance. The first step was turning the picture into a grayscale image. Then it was transformed into a threshold picture and set the threshold value. The contour list was taken after that, and using that, insects were labeled using a red rectangle, and the number of labels was counted to get the number of insects in an image.

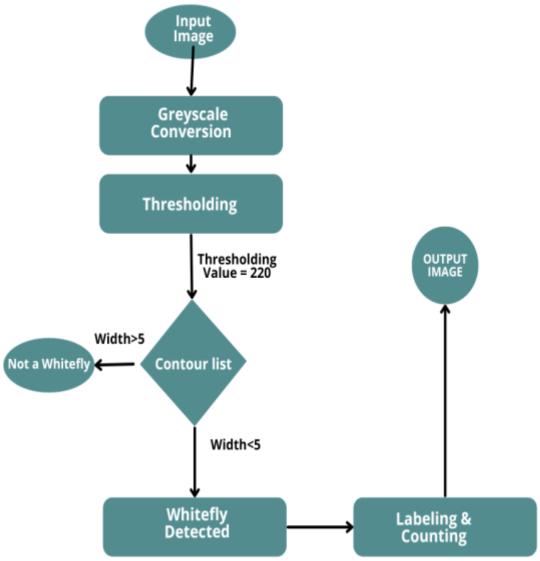

Fig. 1. Image processing method flowchart

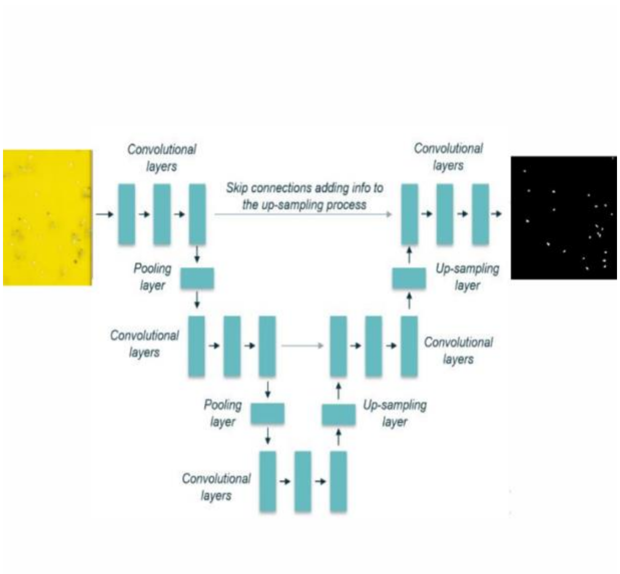

Fig. 2. Basic structure of the U-net model

The stages for pest detection on the sticky trap images using image processing are presented in the flow chart given below.

b) U-Net in Python

The U-Net architecture (Fig. 2) is a convolutional neural network (CNN) architecture that is often used for image segmentation tasks. The U-Net architecture was created to segment pictures with pixel-level precision. This design is notably employed in biological image analysis. In this procedure, resized photos of the sample dataset will be used as inputs. Following is the architecture of the U-Net model.

The U-Net model is comprised of an encoder and a decoder. The encoder is used to extract features from the input picture, and the decoder is used to upsample while concatenating the features and generating the final output. The encoder and decoder are symmetrical and connected by skip connections between them. The encoder and decoder are made up of a sequence of repeated 3×3 convolutional layers at each of the stages. After the convolutional layer, the ReLU activation function is used. The encoder is conducting the down-sampling, and the decoder is doing the up-sampling procedures. After segmenting the picture, a Python code will be used to count the number of insects in each segmented image. In this research, the U-Net model was coded using Python with Tensorflow as the library. Google Colab is used as the running platform for the U-Net model. Tensorflow is used as the library because it is widely known as a deep learning library, and most recent researches done in U-Net also used Tensorflow as the library.

B. *Data Collection*

The sample data set used in this research was published by Wageningen University & Research, Netherlands (Fig. 1). The dataset is available online at the 4TU Center for Research Data *[7]*.

Fig. 3. A zoom-in image from the sample dataset

III. Results and Discussion

A. *Image Processing Using Python*

In this method, the data set consisting of sticky trap images was used as the input. This method consists of three major parts. Grayscale conversion was done as the first step (Fig. 4).

In the second step, the image was turned into a threshold image, and the threshold value was taken as 220 (Fig. 5). In the third step, a contour list was taken. Using that contour list, a red rectangle was created around the insect. To create the rectangle, the accepted width was taken as 5 (W<5) (Fig. 6).

In this method, whitefly is the target pest that is expected to be identified. This image processing technique has a very high level of precision. A few outcomes from the method and their accuracy have been provided in the following table (TABLE I). Overall, the accuracy of this technique fluctuates between 70% and 90%.

1) Grayscale Conversion

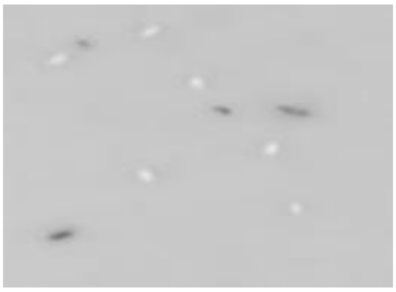

Fig. 4. Output after the Grayscale conversion

2) Thresholding

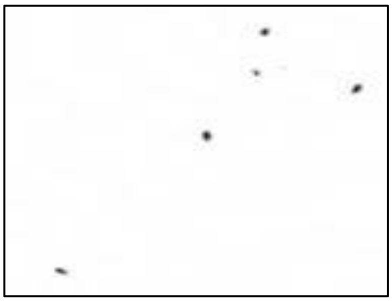

Fig. 5. Output after the Thresholding

3) Output Image

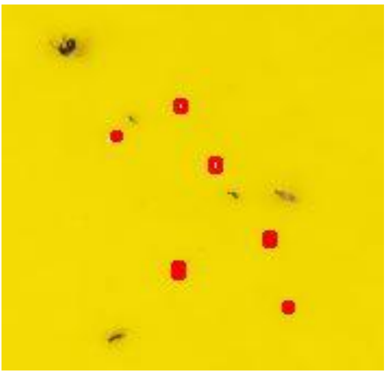

Fig. 6. Output Image of the Image Processing

TABLE 1. RESULTS OF WHITEFLY DETECTION

Image No	Whitefly in an image		
	Detected No	Actual No	Accuracy of the Method (%)
1	133	159	836
2	69	88	78.4
3	189	234	80.7
4	49	65	75.3
5	43	53	81.1
6	16	19	84.2
7	8	9	88.8
8	13	16	81.2
9	18	23	78.2
10	9	12	75.0

B. U-Net using Python

The data set was divided into training, validation, and testing according to the ratio of 70:20:10. Then, the training data set was manually annotated to create the corresponding mask image data set. In the input stage, each image in the dataset and masked set was cropped to 256×256 patches because it is easy to train the model with small images.

Fig. 7. Zoom-in image of an input testing image

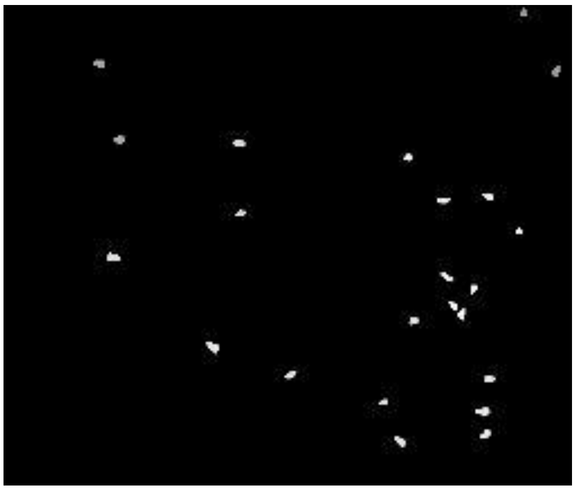

Fig. 8. Zoom-in image of an image segmentation output

This U-Net model shows a good amount of accuracy when tested with the dataset. Intersection over Union is an evaluation metric that is used to measure the accuracy of an object detection model on a dataset. For this model, the IoU score is 81%. This is a good amount for a semantic segmentation model.

IV. Conclusion

This research is about developing a computer vision-based, accurate, automated system for the identification of greenhouse insect pests. Two approaches of computer vision, Image processing and U-Net (deep learning) are used as the proposed methodologies in this research project. At the end of the research, two methodologies were evaluated, mainly considering their accuracy, efficiency, and ease of use. From the results of both methodologies, both are suitable for use in computer vision-based pest detection systems. Both testing techniques are invariant to the rotation factor. Traditional image processing method shows low accuracy of pest detection for some of the input images. This error can be minimized by improving the image quality and using a different color of sticky trap in the data collection process. This image processing method can be developed to detect other types of insects (multiclass insect detection). The U-Net model shows satisfying accuracy, which is greater than the image processing method's overall accuracy. The accuracy of the U-Net model can be improved by using more training datasets. Furthermore, the accuracy and efficiency of the model can be improved by reducing the human error that occurs in the training dataset annotation process. Multiclass segmentation can also be added to this model to detect other kinds of insects that damage greenhouse crops.

Through this research, greenhouse pest detection becomes much easier for farmers who are new to greenhouse farming and have little expertise about greenhouse pests. Also, this research is expected to benefit existing farmers who employ a large amount of labor and resources for the identification of insect pests in greenhouses. When comparing the accuracy and results of both methodologies, U-Net image segmentation is more suitable for the early pest detection system. This research is done basically to discover and detect the whitefly insect, which is typically available in a greenhouse environment. Research can be extended by developing it to detect more pest species and by developing it for use in outdoor farming as well. In further development, this research can be integrated with wireless communication methods to develop a real-time pest monitoring and alerting system for farmers.

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