Journal of Engineering and Computer Sciences
Qassim University,
Vol. 14, No. 2, pp. 25-39 (July 2021 /Dhil Qada 1442 H)

A Method of Detection and Classification of Plant Diseases Using Classifiers

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(Received 30/3/2022, accepted for publication 5/11/2022)

ABSTRACT. Agriculture is one of the main sources of income for the government of Saudi Arabia. It is included in one of the twelve pillars of the 2030 vision. The Public Investment Fund which is also known as PIF has launched its strategic plan for 2021-2025 to thrive the economy for diversity. This strategic plan consists of numerous key initiatives and one of them is food and agriculture. It focuses on enabling the growth of food and agriculture inside Saudi Arabia to reach the sustainability level of domestic food production, ensuring food strength and flexibility and having a diversity food supply sources from outside the country. Hence, having disease-free plants is a must for this initiative. In this paper, proposing an algorithm to detect diseases in plants is presented. It works based on combining the K-means and Convolutional Neural Networks (CNNs) approaches. The obtained results show that this method achieves more than 95% of accuracy. The simulation experiments are conducted using MATLAB as a simulation tool. Finally, an assessment between the proposed algorithm and some state-of-the-art works from the literature is presented. This evaluation shows that the implemented method outperforms other works in terms on accuracy, precision, and recall respectively.

Keywords: plant disease, classification, pif, artificial intelligence, vision 2030, machine learning.

1. Introduction

The strategic plan 2021-2025 for Public Fund Investment (PIF) aims to excite and stimulate the growth of the agriculture sector in Saudi Arabia. In addition, this plan tends to make the Kingdom a central distributor for the world. Furthermore, PIF has another goal which is to leverage the current partnerships with the major prominent players in the food field and to make new partnerships with more players. This will make the kingdom the main distribution center in the near future.

The plants are endured different diseases which are caused by several reasons such as environmental conditions, pests and lack of nutrition [1,2]. The traditional method to monitor the plants is to keep eye-based surveillance by farmers themselves or by consultants. This method is old fashion and due to evolving technology, using detectors is highly required to safeguard the plants from what can cause the diseases [3,4,5,6]. Herein, an algorithm to detect and classify plant disease is proposed. It can detect diseases According to the simulation tool, its accuracy exceeds 95% and several factors have been measured. Those factors are mentioned in section 2. The proposed approach is based on merging K-means and Convolutional Neural Networks (CNNs) to analyze the plants from their leaves then determine whether they are infected with diseases or not.

In recent studies, the deep learning techniques have been intensively utilized in plant disease identification and classification to improve the accuracy to improve the accuracy of this process since these methods have shown optimistic results [2, 5]. Due to the quality of the utilized and used images, the implemented algorithm uses numerous built-in tools in MATLAB to enhance the quality since the low-quality inputs affect the performance and the generated outputs as well. Plant disease identification and recognition are considered one of the main challenges that farmers and industrial companies face due to involvement of several factors. Numerous studies were conducted to specify or find out which factors play major rules and how to resolve these causes. Herein, identification and classification of plant disease are considered in this study.

A convolutional neural network (CNN) is used and utilized for the deep learning purpose which points and aims to perform self-learning from data. This process eliminates and removes any need for any type of manual intervention to extract the required features. In this research, AlexNet, a type of CNN, is being employed and used to perform the deep learning stage of the developed method. In Computer Vision (CV), CNNs are being utilized to extract features to find patterns in order to recognize and categorize the required objects [2]. Fig. 1 from [2] illustrates the utilized CNN architecture and its layers in this study and research. In the presented approach, 12 features are extracted and utilized to identify and categorize the plant diseases. These features include: the contrast, the correlation, RMS, and others.

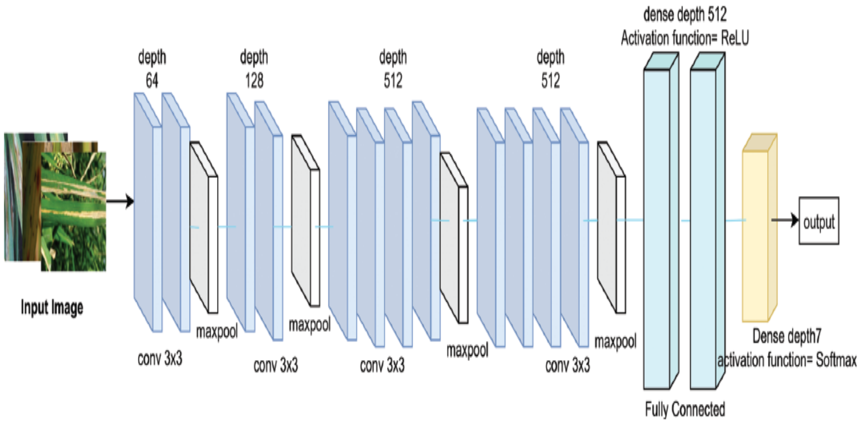

Fig. (1). CNN architecture and its layers

K-means algorithm is used to cluster and partition a number of data, refer as points, (n) into several clusters (k). Every point belongs to a cluster that its centroid is close to it. K-means method is an unsupervised algorithm since no labels are given or known prior to the classification phase.

The motivation of this research is to detect plant diseases and classify them to provide sustainability agriculture according to Saudi 2030 vision. In addition, increasing the income for farmers is considered as another motivation since the farmers will be able to identify infected plants early, so removing them is easily performed before the infection spreads. Two classifiers are used, and those classifiers are namely K-manes and CNNs. Two datasets are included in this study and were collected from the Kaggle website. The size of both datasets is roughly 3GB. There are over 7000 images for the training purpose and nearly 3000 ones for the testing.

Herein, the contribution is accomplished by developing and proposing the algorithm to detect and classify different plant diseases according to the available datasets using two classifiers. The obtained results from the simulation tool display the effectiveness of the proposed approach. The rest of the paper is organized as follows: section 2 delivers details about the developing approach. Discussion and results are described in section 3 and the conclusion is given in section 4.

J. Karthika et al. in [1] proposed an approach to detect disease in the Cotton leaf using image processing for monitoring the plant. Their goal was to identify in a quick manner any disease correctly. Their method could identify two diseases which are namely Bacteria Blight and Blackspot using multi–Support Vector Machine (mSVM). In addition, it required to have additional hardware which was an Arduino to analyze the information. Herein, four diseases are identified using the proposed algorithm. Those diseases are as follows: Bacteria Blight, Alternaria Alternata, Anthracnose and lastly Cercospora Spot. In addition, no external hardware is required since the analysis procedure is performed in the same processor. Readers can get more information in [1].

N. Alivelu and P. Sathish in [3] proposed a deep learning approach to resolve the problem of undiagnosed plants diseases by using their images. This method had the capability to detect and classify diseases using Convolutional Neural Network (CNN) and Residual Network (RN) architecture in MATLAB. In total, 38 classes were obtained when the authors trained their approach on a public dataset that had around 54000 images. furthermore, 8145 images were tested using the trained method to get their classifications and evaluated to find the accuracy, recall and precision parameters. Those parameters percentages were 90%, 89.98% and 90.44% respectively. Interested readers can have more information from [3]. In this research, the accuracy is over 95% while recall and precision are in a range between 93% and 95.78%. The minimum accuracy that occurred during the simulation was nearly 91%. The algorithm is trained using MATLAB with different diseases to detect and classify them using the two classifiers that mentioned earlier.

In [4], I.S.S. Al shabibi and S. Koottala developed a method to detect a skin disease using MATLAB. Many patients are subjected to serious skin diseases which require them to visit health care centers to get diagnosed and then get treatments, these treatments are very expensive, and a lot of patients cannot afford them. So, the authors developed a method to resolve this issue by classifying three diseases based on a vertical image segmentation approach. SVM was utilized to identify the diseases which were Acne, Cancer and Psoriasis. Nevertheless, it used more resources and required additional management and those two things are seen as the drawbacks.

R. Ramya et al. in [5] developed a system to monitor plants, detect leaf diseases and classify them using Machine Learning (ML) in MATLAB. The authors used the NN classifier to process the images of affected leaves to distinguish the types of diseases. GSM was involved to send SMS to users. This implies that hardware parts were included in the system and that made it costly. The proposed algorithm in this paper is hardware-free and its cost is almost nothing. Interested readers are referred to [5] for more information.

L. R. Priya et al. in [6] developed a system to monitor and detect crop disease. It detected disease by applying K-means and monitoring temperature, soil moisture and humidity. A microcontroller was used in that system to control all actions that were taken by the system and to send SMS to farmers. Herein, the K-means clustering approach is merged with CNN to detect the diseases and classify them. This process is performed quickly so the results are displayed immediately. Readers are advised to [6] for more information.

In [7], A. Devaraj et al. developed a mechanical system to classify plant diseases after detecting them. It worked based on image processing techniques in MATLAB. Numerous diseases were detected such as Bacterial Blight and Anthracnose. In our study, the proposed algorithm can detect those two types quickly. In addition, several performance parameters are evaluated, and their results are mentioned in the results and discussion section.

H. Modi et al. in [8] implemented an algorithm for diseases detection in fruit by using an image processing technique. The authors used MATLAB to implement the algorithm from the images of the fruits. The identification step was carried out by exploring the axis of the fruits. Etectera feature was measured from the major and minor axis to classify the diseases.

G. Kshirsagar and A. N. Thakre in [9] presented a technique to identify disease on leaf and fruit too. Multi-SVM and K-means approaches were used in MATLAB for identification and classification purposes. The authors claimed that their method was accurate and efficient as well. The features were obtained through the Gray Level Co-occurrence Matrix (GLCM). After that, a statistical distribution was evaluated to carry out the required features at a predefined position. Readers are encouraged to look in [9] for more information.

2. Materials and Methods

The developed algorithm herein has the capability to detect and classify plant diseases quickly and correctly. It consists of numerous stages or steps to achieve the main goal which is to help farmers by detecting diseases and their types early in order to save the remaining plants from being infected. Fig. 2 depicts how the proposed approach works, it starts with image acquisition and ends with the classification step. Between these two steps, there are several actions that need to be taken. The preprocessing on images is performed to remove any noise from them and change the size and shape as well. In addition, changing the color space into other spaces is included in this step.

The algorithm starts by reading images from a file or loading them from an external source such as a camera and this step is called the initiation and known as the acquisition procedure. The next step is preprocessing where several actions are performed. The purposes of these actions are to enhance the contrast, resize the considered images, reshape them and remove the noise if exists. Fig.3 and Fig.4 illustrate an image in its original form and after enhancing the contrast.

Image segmentation is the third step and in this process, every image is converted from RGB space into LAB space. This space represents the Luminosity and Chromaticity layers. Both A and B refer to Red, Green, Blue and Yellow values respectively. Since both spaces contain three different colors, then, the algorithm creates three different classes. Each color is represented by a class. Fig. 5 depicts the image after being transformed into the lab space. This procedure shows regions of interest which represent possible infected areas as depicted in Fig. 5. These areas are analyzed to classify the detected disease. In addition, this step supports analyzing the images by dividing any region into several small regions with the same characteristics.

After that, two classifiers which are K-means and CNN are merged and used. In K-means, the clustering is performed by finding the distance between colors using the Euclidean distance equation and at the same time, obtaining the index of every color is recorded too.

The output from this procedure is the extracted features of plants so that detection and classification are easily obtained. The next step is to compare the extracted features with the existing ones in the utilized DataBase (DB) which contains information about the plant diseases from conducting several experiments. All observations are recorded and stored in the database to utilize them later in the clustering and classification phases. Results from these stages are the detection and classification of diseases.

As mentioned earlier, four diseases are classified and detected. The first disease is the Bacteria Blight which is shown as tiny spots in the leaves [6,7]. The second disease is Anthracnose, which is a fungal disease type and occurs more in the plants that are found in the humid and heat regions [7]. The third one is the Alternaria Alternata disease and it is a fungal type too. Lastly is the Cercospora Spot disease, this type appears as brown spots on the leaves [6,7]. More information is found in [7]. The key contributions of this study are as follows:

1. Integrating k-means algorithm and AlexNet to idetify and categorize plant dieases properly and precisely as the observed accuracy is over 97%.
2. 10-Fold Cross-Validation procedures are performed to test and verify the implemented algorthm.
3. The conducted experimental evaluations clearly show that the presented method outperforms other mentioned works in the literature.

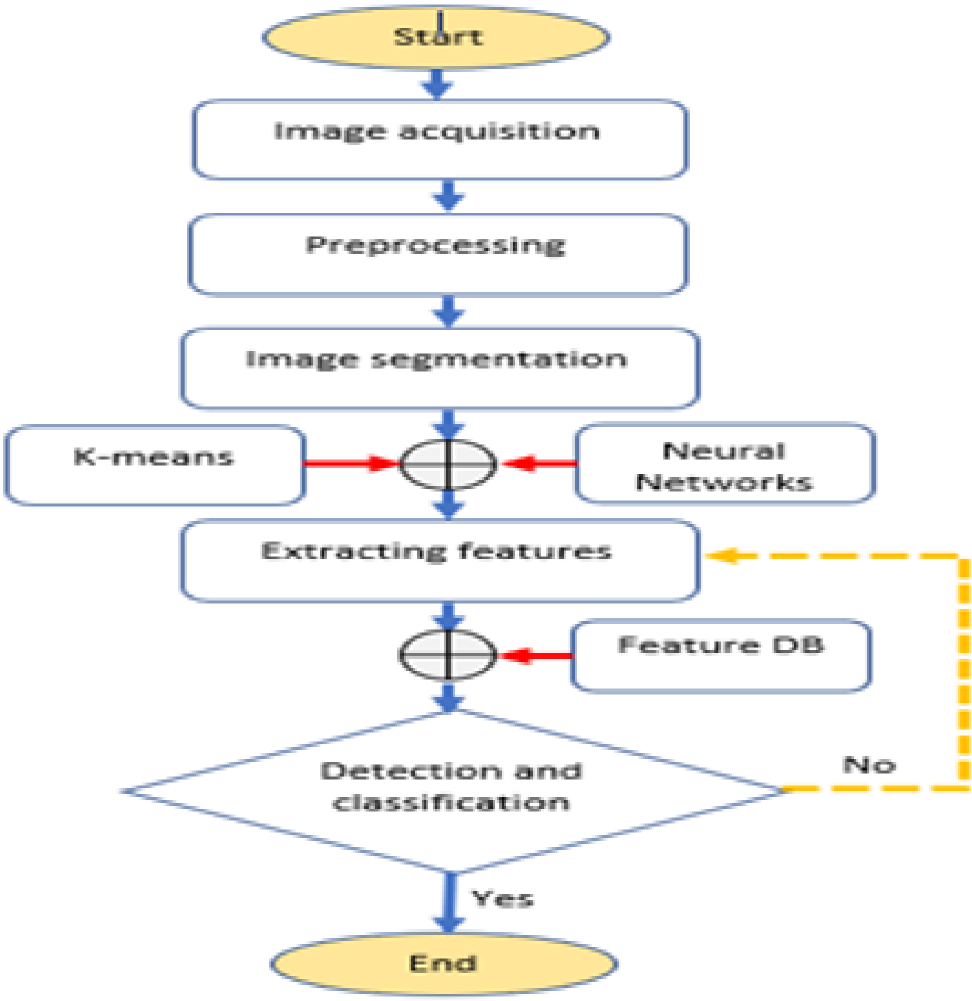

Fig. (2). Flowchart of the proposed algorithm

Fig. (3). The original image

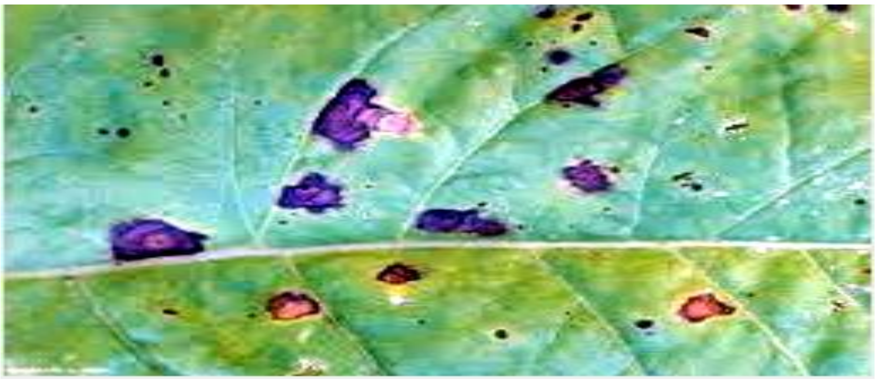

Fig. (4). The resultant enhancing image

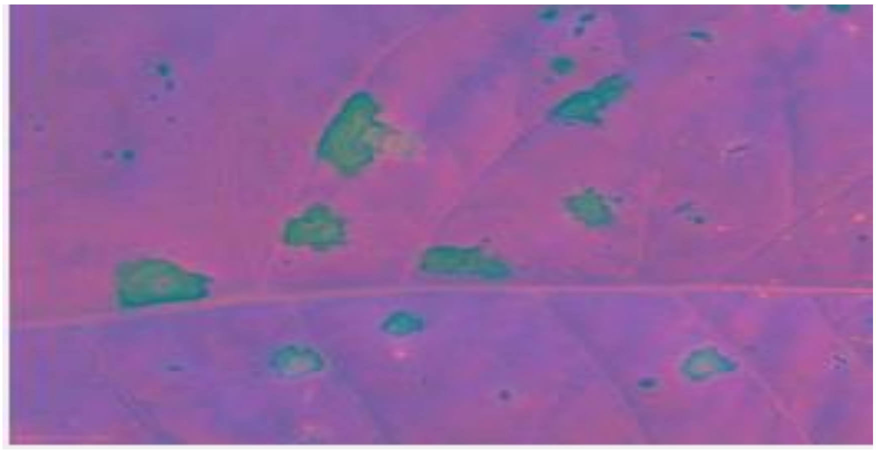

Fig. (5). The resultant image in the lab space

In this study, K-Fold Cross-Validation technique is used to validate and verify the proposed algorithm. This technique is a statistical approach which is utilized in the machine learning solutions to test their skills. It splits and partitions data into several randomly chosen subsets (K) of equal size. These subsets are also known as folds. In MATLAB, the minimum number of folds is 5 and 10 folds have been used in this research. Table 1 illustrates the scenario of using 5-fold cross-validation for different 5 distinct runs. The green color represents the testing subset while the red color refers to the training subset. The horizontal axis represents the fold number while the vertical axis refers to the distinct run number.

Table (1). Performance metrics and their values

Run#	Fold Number				
	1	2	3	4	5
1					
2					
3					
4					
5					

In the proposed algorithm, every considered plant is categorized into three main regions according to the available colors. These investogated colors are: green, yellow, and brown as shown in Fig. 3 and Fig. 4. Fig. 6 illustrates a sample of outputs that are produced during the experiments. This Fig. is a graphical representation of the clustering operation of the inputs. There are three colors which are: green, yellow, and red. The green color represents the clustering of the green color in the plant leaf, the yellow color refers to the yellow colrs that appears in the plant leaf, while the red color represents the brown color in plant leaf.

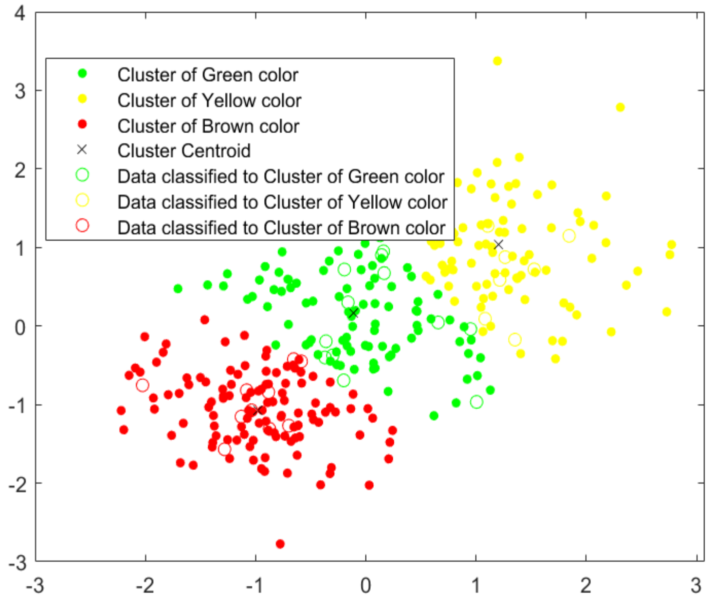

Fig. (6). Sample of generated outputs of the clustering procedures

Numerous performance metrics are measured in the developed and proposed algorithm. These metrics are listed below:

- True Positive (TP): this metric measures a number of correctly identified samples in the given dataset during the testing stage.
- False Positive (FP): it measures a number of predicted types of samples incorrectly.
- True Negative (TN): it gives an indication about a figure of the negative samples that are correctly identified by the proposed approach.
- False Negative (FN): it measures a number of negative samples that are identified incorrectly.
- Precision (PRE): it shows the ratio of the truly identified samples over the summation of the classes that were identified incorrectly plus the true samples that were correctly classified as shown in the following eq.

$$PRE = \frac{TP}{(TP+FP)} \quad (1)$$

- Recall (REC): it gives the ratio of the truly identified sample over the summation of the true samples plus the number of negative samples that were classified incorrectly as depicted in eq. (2).

$$REC = \frac{TP}{(TP+FN)} \quad (2)$$

- Accuracy: this metric shows the percentage of the summation of the true samples and the negative ones that were classified correctly by the proposed method over the summation of all metrics that were mentioned from 1 to 4 earlier as depicted in eq. (3).

$$Accuracy = \frac{(TP+TN)}{(TP+TN+FN+FP)} \quad (3)$$

In this research, the term of true identification refers to the correct and appropriate classes of the considered disease whether it is one of the four diseases while the negative samples represent the inputs that are healthy only.

3. Discussion and Results

Various experiments were conducted using the proposed algorithm to detect and classify the plants diseases. The following scenarios illustrate how the approach works and predicts the diseases. In addition, the performance measured parameters are presented too. Furthermore, a comparison evaluation between some literature works and the proposed approach is performed and provided.

MATLAB is used in all simulation scenarios since it has built-in tools for image processing purposes. These tools are utilized and employed in the developed method.

Scenario 1: detecting and classifying Anthracnose disease.

Fig. 7 illustrates the original image in (a) and it is equivalent after the contrastt being enhanced by the algorithm in (b) while (c) displays the detected regions or spots that contain the disease. Moreover, showing the classification of the detected disease and the obtained accuracy percentage are included in Fig. 7.

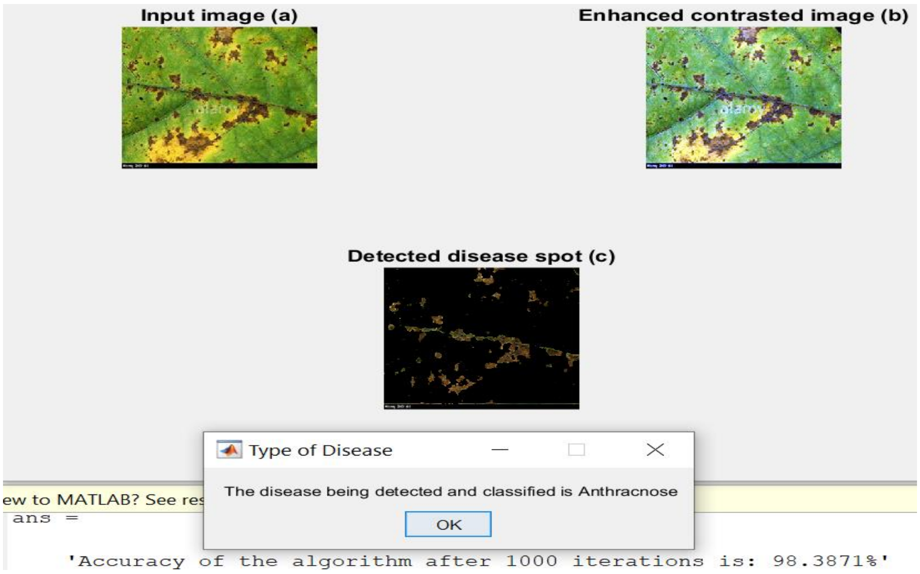

Fig. (7). The output of the proposed algorithm

The obtained accuracy from the proposed algorithm is over 98% which seems good.

Scenario 2: Detecting and classifying the Alternaria Alternata disease.

Fig. 8 displays the output of the developed method to detect and classify the second disease which is Alternaria Alternata. Fig. 8(a) and Fig. 8(b) illustrate the original image and its results after the contrast being increased while Fig. 8(c) depicts the interested detected regions which have the possible disease. Additionally, the type of the classified disease and the obtained percentage of accuracy are incorporated too.

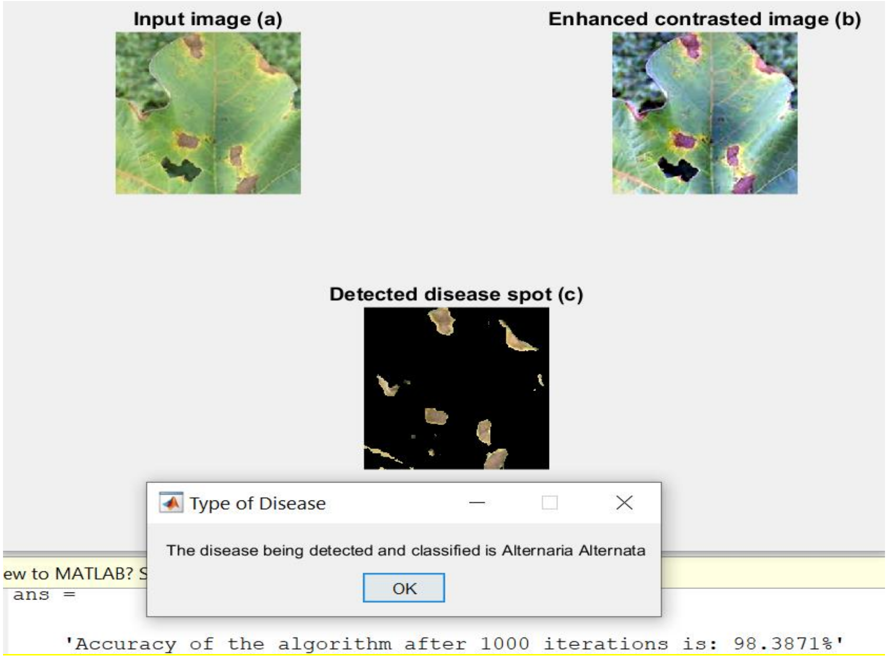

Fig. (8). Detecting and classifying Alternaria Alternata disease

The developed method detects and classifies the disease correctly, however, decreasing the number of iterations could affect and impact the accuracy as it degrades.

Scenario 3: Dectecting and classifying Cercospora Spot disease.

Fig. 9 illustrates the original image in Fig. 9(a) and the enhanced image after the contrast is increased in Fig. 9(b) while Fig. 9(c) represents the detected and classified disease. The algorithm can distinguish between healthy leaves and infected leaves by showing the interested regions either in their original colors as depicted in Figs. 7 and 8 or in black dots as illustrated in Fig. 9(c).

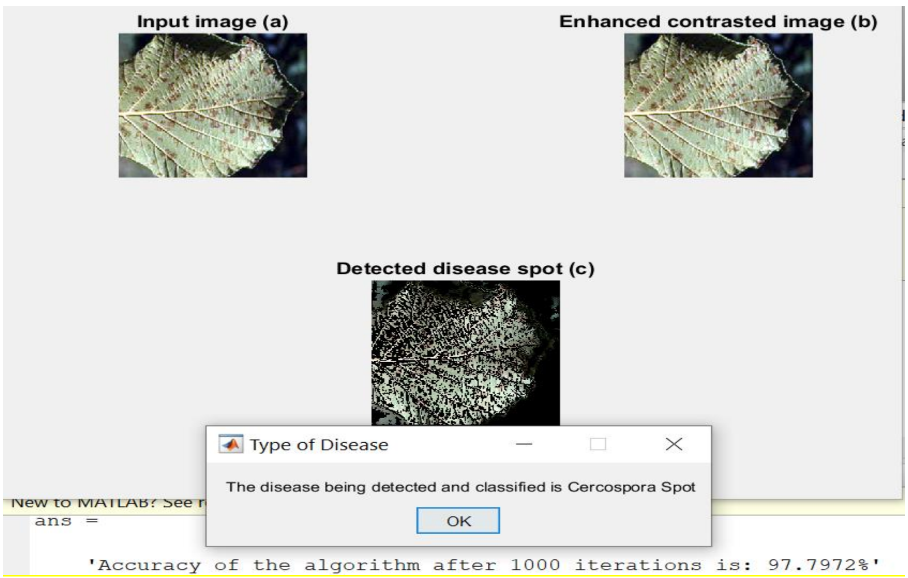

Fig. (9). The output of scenario 3

The proposed approach reaches over 97% of accuracy as shown in the previous Fig.

Scenario 4: Detecting and classifying Bacterial Blight.

Fig. 10(a) and Fig. 10(b) show the original leaves and corresponding enhanced image respectively. Fig. 10(c) illustrates the detected and classified disease which is the Bacterial Blight. Furthermore, the accuracy is computed, and it shows that the developed method performs perfectly, and its error is less than 4% which is acceptable.

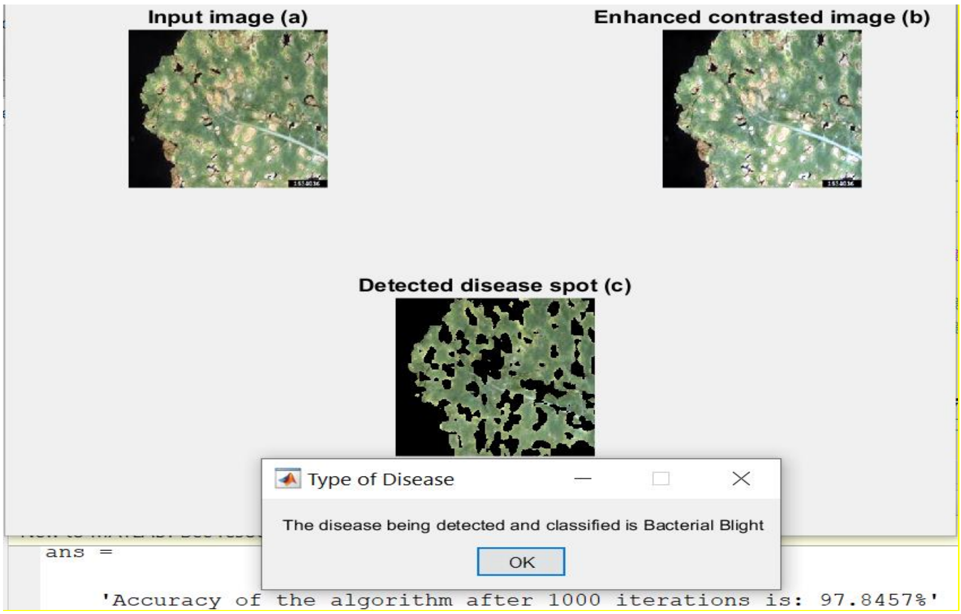

Fig. (10). Detecting and classifying Bacterial Blight disease

Table 2 lists all average values for the performance metrics parameters that being considered, evaluated and measured by the developed approach. Accuracy, precision and recall are measured in percentage. The test dataset contains 400 images of different types of disease and healthy plants too.

Table (2). Performance metrics and their values

Performance Metric	Evaluated value
TP	355
TN	38
FN	3
FP	4
Accuracy	98.25%
Precision	98.885%
Recall	99.162%

The developed algorithm can reach to an acceptable range for the accuracy, the precision and the recall as shown in table 2. However, reaching to that range affects the execution time since it results in a heavy time which is considered as the drawback. Table 3 lists the comparison results for the accuracy, the precision and the recall between the proposed algorithm and some literature works that were mentioned earlier in section 2.

Table (3). The comparison study results

Work conducted	Precision	Recall	Accuracy
K. Sathya and M. Rajalakshmi, 2022 [2]	Not mentioned	Not mentioned	96.59%
R. Patil et al., 2021 [3]	Not mentioned	Not mentioned	98.34%
N. Alivelu and P. Sathish, 2021 [4]	90.44%	89.98%	90%
S. Singn and Er. R. Rajput, 2017 [13]	Not mentioned	Not mentioned	97.7%
The proposed algorithm	98.885%	99.162%	98.25%

Fig. 11 illustrates a plot of the resultants Mean Square Error (MSE) from the proposed approach on the test dataset. The minimum reached MSE is found at epoch 3 as shown in Fig. 11. It is distinquished by drawing a circle around it as depicted in Fig. 11.

when then number of iterations increased to 10,000 times, the performance of the proposed algorithm improves significantly. However, this improvement affects the execution time. Thus, the best number of iterations is decided to be between 2000 and 3000. Beyond this figure, the presented method takes long time to identify and classify the disease.

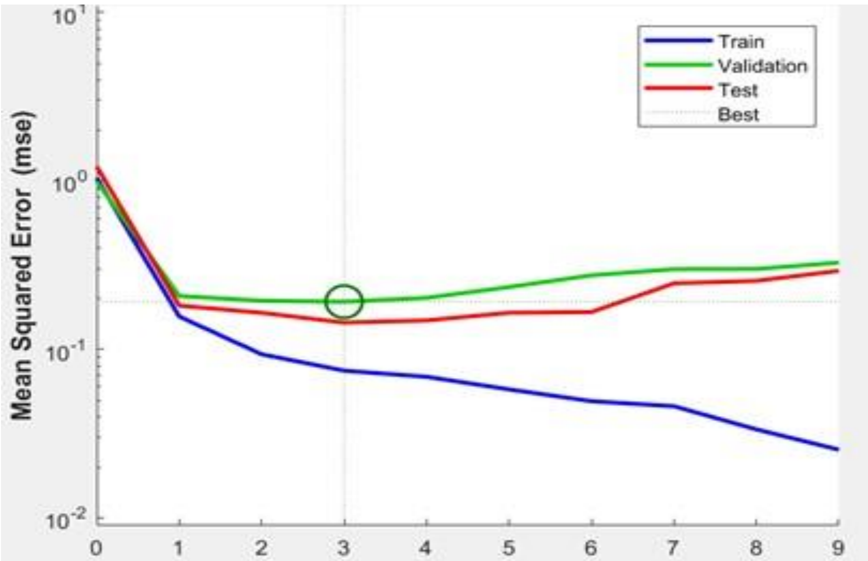

Fig. (11). The plot of MSE

The advantages that can be gained from the proposed approach are as follows:

- No special hardware is required, and it is applicable to identify and categorize any disease if it trained well.

- The accuracy increases upon increasing the number of iterations inside the algorithm.
- It detects and classifies 4 diseases as illustrated and showed in the previous Figs. precisely and accurately since its average accuracy score is around 98.25% and it can reach near 98.86% as found in some trials.
- The algorithm is capable to learn by itself and it produces promising results.

In some cases, it is possible for plant diseases to be existed without any changes in the appearance of the plants; these cases are considered in the proposed algorithm and already resolved since the presented approach considers and works on the colors that already available. Since there are no changes, then it means the color is green and the implemented method deals with this color as illustrated in Fig. 6.

4. Conclusions and Future Work

The proposed approach illustrates its effectiveness in detecting and classifying different types of plants diseases as shown in the previous figs. MATLAB is used to verify the developed method and its results show that it performs and works nicely and produces good outputs. The average accuracy is around 98.25% and its maximum value was near 99%. Furthermore, the proposed algorithm outperforms other conducted works in terms of accuracy, precision, and recall. The minimum obtained value of MSE occurred at epoch 3. However, there is one drawback from it which is the time required to complete its task. This time is found to be heavy.

The future work is to minimize the execution time for the proposed approach. In addition, considering detection and classification of more plant diseases is planned.

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أسلوب الكشف عن امراض النبات وتصنيفها باستخدام المصنفات

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(قدم للنشر في 2022/3/30؛ وقبل للنشر في 2022/11/5)

ملخص البحث. الزراعة هي أحد مصادر الدخل الرئيسية لحكومة المملكة العربية السعودية. وهي مدرجة في إحدى الركائز الاثني عشر لرؤية 2030. أطلق صندوق الاستثمارات العامة، المعروف أيضًا باسم PIF، خطته الاستراتيجية للفترة 2021-2025 لإزدهار الاقتصاد ومن أجل التنوع. تتكون هذه الخطة الإستراتيجية من العديد من المبادرات الرئيسية ومن بينها الأغذية والزراعة. وتركز على تمكين نمو الأغذية والزراعة داخل المملكة العربية السعودية للوصول إلى مستوى الاستدامة في إنتاج الغذاء المحلي، وضمان قوة الغذاء ومرونته، وتنوع مصادر الإمدادات الغذائية من خارج الدولة. ومن ثم فإن وجود نباتات خالية من الأمراض أمر لا بد منه لهذه المبادرة. في هذا البحث، يتم عرض اقتراح خوارزمية للكشف عن الأمراض في النباتات. وهي تعمل على أساس الجمع بين أساليب K-means والشبكات العصبية التلافيفية(CNNs) . أظهرت النتائج المتحصل عليها أن هذه الطريقة تحقق دقة أكثر من 95٪. يتم إجراء تجارب المحاكاة باستخدام MATLAB كأداة محاكاة. أخيرًا، يتم تقديم تقييم بين الخوارزمية المقترحة وبعض الأعمال الحديثة من بعض المراجع. يوضح هذا التقييم أن الطريقة التي تم تنفيذها تتفوق على الأعمال الأخرى من حيث الدقة الانضباط والاستدعاء على التوالي.

الكلمات الدالة: أمراض النبات ، التصنيف ، pif، الذكاء الاصطناعي ، رؤية 2030 ، التعلم الآلي.