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Applied of color image processing system to detect plant disease using clustering algorithms

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Abstract

In recent times, after the changing of weather conditions and the pollution of water resources and air, the green cover of the earth has got many infections and the agricultural crop started to suffer many diseases. These diseases are able to catch and decide the suitable medicine in many ways. Maybe one of the most important ways is to check the change of plants' leaves. Plant leave disease detection uses several methods like image processing and deep learning. All of these methods suffer from the high similarity of some diseases, the different sizes of leaves, and the colors of them. Which caused the lower accuracy of detecting the right disease. Neural network methods were used too, but needed a higher computation time and more computation power. All of above provides image processing techniques superior advantages over other techniques. Other techniques, such those employing KNN, MLP, and Gaussian classifiers, provide accuracy that is lower than that of SVM techniques when using applications.

Introduction

Worldwide, plant diseases pose a serious danger to food security; thus, it is crucial to identify them early in order to stop their spread and minimize the harm they may do. For plant diseases with insect vectors, early diagnosis is especially crucial because of how fast they spread and the significant harm they may do. Looking for disease-related symptoms in plants, such as drooping leaves, discolouration, and reduced development, is the traditional method for identifying plant diseases. To establish the existence of a specific pathogen, laboratory testing may occasionally be employed. Many plant diseases can also be found via eye inspection, however remote sensing methods like thermal imaging or satellite images are more commonly used. Early intervention is made possible by being able to immediately identify disease-affected regions. Genetic testing can sometimes be used to identify a specific strain of illness. And last, new technologies like artificial intelligence, machine learning, and others are being developed to aid in the quicker and more precise detection of plant diseases. Although these technologies are still in their infancy, they might completely alter how plant diseases are identified and treated in the future. We trained the system on data using a neural network using a particular class of AI algorithms [1,5] to boost system accuracy.

By observing alterations in the colour of the leaves, plant diseases can be identified. The primary organ of plants that engages in photosynthetic activity is the leaf, which is vital to the health of the plant. A sign that anything is awry is when some plant diseases alter the colour of the leaves. For instance, a fungal illness might make the leaves brown and withered, but a bacterial condition may cause the leaves to yellow. Other plant diseases may result in the leaves developing irregularly shaped patches or becoming mottled. The leaves may occasionally become entirely yellow or even white.

Plant diseases can also alter the colour of the leaves or make them twisted or coated in a thin, white webbing. The leaves might also develop tiny black patches or brittleness. To stop the illness from spreading if these signs appear, action must be taken right away. If the disease is left untreated, it can cause serious damage to the plant and its leaves.

The plant and its leaves may suffer significant harm if the illness is not addressed. It is possible to identify the existence of a disease and take action to stop it from spreading by keeping an eye out for modifications in the colour, shape, or texture of plant leaves. Due to the possibility of plant disease, it is crucial to routinely check plants and note any changes in their leaves.

The following illnesses can be identified:

• Al tern aria Alternate: this disease, which results in a distinctive leaf spot, has been reported to affect 360 species.

Anthracnose is a disease that affects warm-climate plants and leaves spots on trees including sycamores, ash, oak, and maple. Annuals and grasses may be the results. Plant tissue might perish as a result.

• Bacterial Blight: this disease is caused by bacterium Pseudomonas syringae pv. which can leave on stem tissue (cankers), and soil moisture.

• Cercospora Leave Spot: this disease effects on multiple types of hydrangeas in all areas like landscapes and nurseries.

Related Works

Many studies were used to build an auto detection system of a plant disease. The first of them was in 1980 when the Indian areas by Punjab and Haryana were affected by Xanthomonas Oryza. It is a bacterial disease affected by bacterial blight on rice. Many algorithms were used, starting with image processing, pure techniques and then using classification algorithms, ending with neural networks [6].

To detect the pip fruits, as example, wavelets were used here for disease detection. This work was done by Woodford, Kasabov with the research titled “Fruit Image Analysis using Wavelets” [7,8].

Another study used for detection of leave disease [9], was used by Prasad Babu and Srinivasa Rao using a type of neural network called back propagation neural network. This network is able to find the species from all the leaves, the authors used a Prewitt edge detector and then a thinning algorithm with a leave token as input. So, they were able to recognize the leave with the pest and rotten leaves, but it was a very hard job because of the large size of the dataset [10].

Another study was by using a segment of agricultural land fields using neural networks. In this study a remote sensing data was used [12]-[15]. They have used an active recognition method and an easy extract features algorithm. To increase the system efficiency, they used probabilistic neural networks for plant leave detection. This algorithm was able to classify several plants with an accuracy of 90%.

Antanu and Jaya [13] create a computer system that can recognize a series of diseases from the images of the rice plants. To detect the affected areas, the authors used to grow and image segmentation.

Another study to detect and classify rice leave disease, used Self-Organize Map (SOM) neural network. This network was used on segmented leave regions; this segmentation was done by the Otsu algorithm. The results were calculated as a percentage of the area infected to the area healthy. The author detects the disease from color image [14] using a hybrid intelligent system image this intelligent system used a self-organizing map and a back propagation neural network.

In [17] the researchers used a genetic algorithm with a self-organizing feature map of the disease areas segmentation, and then the disease was classified using area of the SVM algorithm and the Gabor wavelet filter. Histogram generation was used to catch the plant disease too, with the Gray level image which is processed to extract features and used, sharpening. The image was processed to enhance edges with a median filter and a canny edge algorithm, then thresholding was done to run morphological operations like dilation, erosion, and opening. Another algorithm used was image processing with a support vector machine. This method was used specially for early and accurate detection of rice disease. This method was able to be used in all situations of leave condition for more than one plant where we condition the color and the texture of the disease and classify it as a template for the specific type. As example, in the condition of rice bacterial leave blight, the accuracy of SVM classification was 97.2%. The most used algorithms in leave disease detection were classification and clustering algorithms, several types of neural networks [16, 24].

Method

Data analysis is one of the most important strategies in recent times which aims to study required data and get information about its structure. This analysis tries to divide data into subgroups (or sometimes named clusters) which have the same features, so the different clusters must have different features. These clusters are built by using similarity measures such as Euclidean distance or correlation distance. This clustering is widely used in marketing, as an example, where the behaviour of customers is similar, or in image parts segmentation or in image compression systems.

We have in AI two types of learning. supervised, and unsupervised learning. One of the unsupervised learning methods is clustering, where we do not have any previous knowledge about data that we must compare with for grouping. Here we try to understand the data structure to build the clusters.

To solve the leave bending problem, the solutions to deal with color image processing to detect plant disease using clustering algorithms are conventional methods, as the dependence of plant disease detection on clustering is well known. Moreover, in the analysis, the correlation between color and plant type should be discussed. Most importantly, how to change the plant type to remain algorithms work perfectly. (i.e. simulate more plants). Fig.1 shows a flowchart of the proposed method.

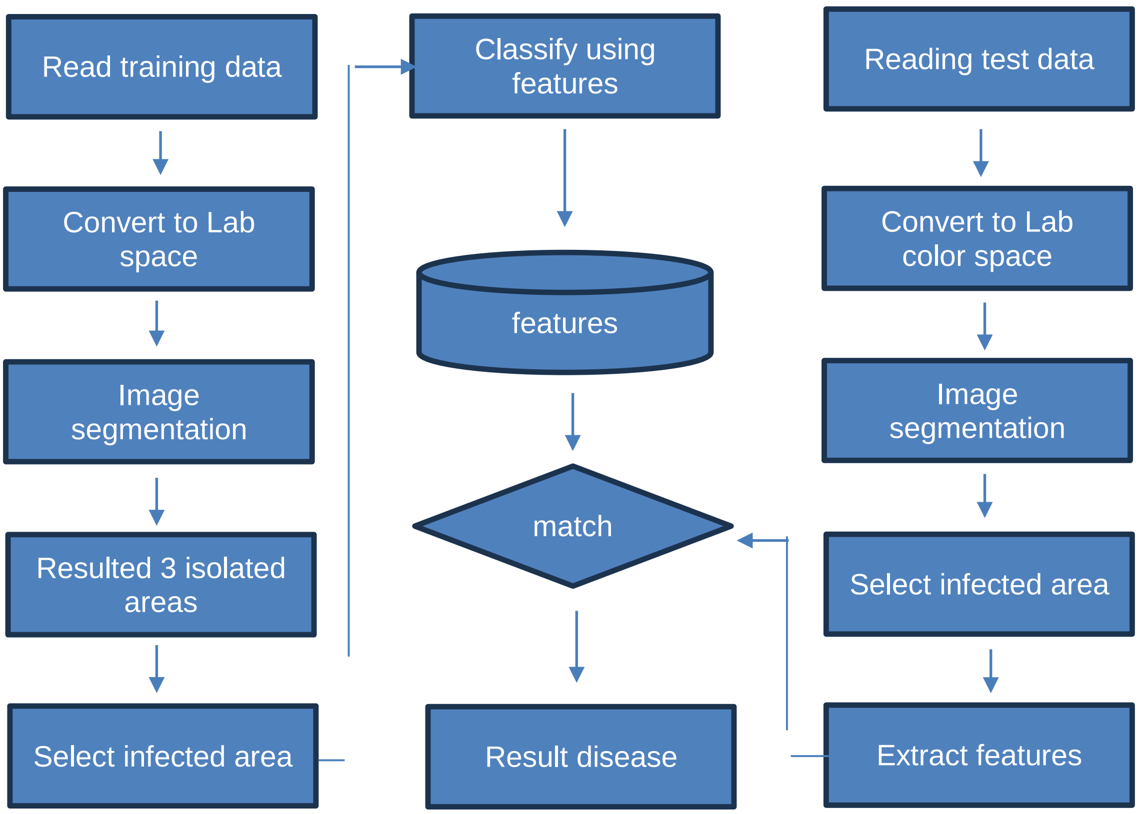

Fig.1: shows a flowchart of the proposed method.

There are many features used in this method, but the main features are the mean, entropy, standard deviation, and other statistical measurements.

The main difference between this proposed method and the other methods underlying the same scope is using another color space. For example, a proposed method by Mr. Manjunatha S. [26], the researchers used the RGB color space to isolate specific areas, while in this research the Lab color space was used. In the specified research, the researcher chooses the infected area by the system, but in this proposed method the user needs to select the infected area manually.

The proposed method was able to work on many types of plants in one condition that the leave must keep in a specific orientation. Other conditions are not important as an isolation of the green area (or yellow green area) and then split the brown areas then computes the disease area deciding what type of disease the leave is infected.

K means Classifier

k-means is one of the clustering algorithms that tries to partition the dataset into k-subgroups which must nor overlapped together to increase the accuracy of clustering. Every point in the system must belong to one group only. Inside the group (or cluster), points must be as similar as possible, and points in different clusters must be as far from each other as possible.

This algorithm works as follows:

- First, we must define the clusters we want to divide the data into. The number of clusters is K.
- Then we can shuffle or not the data and select primary centroids randomly where the number of randomly selected centroids must be equal to K.
- We start iterations on these centroids until the assignment of the points to the clusters becomes stable.
- Then we compute the squared distance between the points of the dataset and the centroids.
- After that, we re-assign each data point to the cluster with the minimum distance between its centroid.
- Then we re-compute the new centroids by computing the average of all the points in each cluster.

The objective function of k-means can be calculated using an equation where it depends on the Euclidian distance between the samples in the dataset, taking into mind the sum of the distances between each sample and the arithmetic average of all the data in the specific cluster

$$J = \sum_{i=1}^{m} \sum_{k=1}^{K} w_{ik} \left\| x^i - \mu_k \right\|^2 \quad (1)$$

Where w_{ik} is a value defines if the sample belongs to a specific cluster, it can be 1 for data point x if it belongs to cluster k; otherwise, w_{ik} has the value of 0. Also, μ_k is the centroid of the x_i cluster. In this algorithm we must take the importance of two things:

- First, data must have a mean of zero and a standard deviation of 1 because we use a distance-based calculation to define the similarity of data points.
- We must know that choosing different random centroids will lead to different clusters because the k-means is a type of algorithm that may achieve a optimal local solution and not a global one. So, we can choose different centroids every time and re-calculate the sum of squared distances and then choose the lower distance at all.

Support vector machine algorithm

Support vector machine (or SVM) is a machine learning algorithm which can give us higher accuracy and less power fewer computations. This algorithm can be used in both sides; regression and classification. SVM can find a hyper plan with N-dimensional space which can classify data points powerfully with a line for even the smallest distances between points [12,18]. As shown in Fig.2

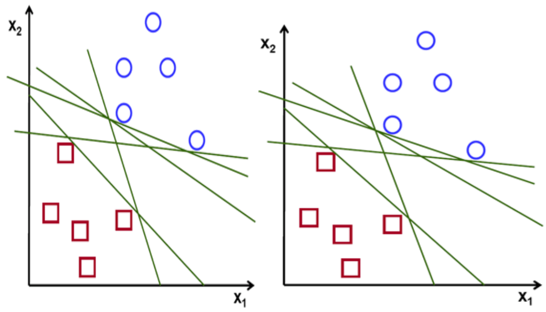

Fig. 2: Borders in support vector machine

When we want to separate data into two classes, as example, we may get many hyper plans, so we must choose the plan with the maximum margin for this means that we will choose the plan with the maximum distance between each class point. SVM increases confidence of new points classifying into classes even with small changes in the dataset.

The main difference between logistic regression and SVM is that logistic regression depends on a sigmoid function to squash data between 0 and 1, then we choose the threshold to be 0.5 and any value above it will be classified as class 1, else it will be class 0. In SVM we use functions arrange data as it is greater than 1 as class 1 and the values when output -1 as class 0 so the values are arranged in range (-1,1).

The cost function that maximizes the margin between hyperplanes has two conditions using the equation:

$$c\big(x, y, f(x)\big) = \begin{cases} 0 & if\ y * f(x) \geq 1 \\ 1 - y * f(x) & elseyhere \end{cases} \qquad (2)$$

Where c is the cost function, x the input point, y the output point, $f(x)$ is the predicted point. This equation means that the cost is equal to zero when the actual and predicted values has the same sign, if they are not then the value of loss must be calculated. a regularization value added to balance the maximized margin and loss. So, the equation after regulation will be:

$$min_w \gamma \|w\|^2 + \sum_{i=1}^{n}(1 - y_i\langle x_i, w\rangle) \qquad (3)$$

Where γ is a weight value to control the distance between values in each side of the split area, w is the weight resulted from each point y. then, the updated weights are:

$$\frac{\delta}{\delta w_k}\gamma\|w\|^2 = 2\gamma w_k \qquad (4)$$

$$\frac{\delta}{\delta w_k}(1 - y_i\langle x_i, w\rangle) = \begin{cases} 0 & if\ y_i\langle x_i, w\rangle \geq 1 \\ -y_i x_{ik} & else \end{cases} \qquad (5)$$

And in each loop the weight update if there is no mistake in classification, where α is a regulation value:

$$w = w - \alpha(2\gamma w) \qquad (6)$$

And if we have a mistake in classification, then:

$$w = w - \alpha(y_i . x_i - 2\gamma w) \quad (7)$$

The support vector machine is used in image classification in a wide range. Each image consists of pixels defining the width and the height of it, with a third size that can be 1 for a grey image and 3 for an RGB image. The value of it can be 0-255 in an 8-bit image.

In order to classify an image using an SVM, we first need to extract features from the image. These features can be the color values of the pixels, edge detection, or even the textures present in the image. Once the features are extracted, we can use them as input for the SVM algorithm.

Image pre-processing

Before starting leave disease detection, we need several pre-processing steps. This pre-processing is needed to remove noise from images because of its background, so the background must be removed or put on a constant color.

After that, we need to enhance the image color depth using histogram equalization, which can enlarge the range of intensities for a more distribution range, and then compute the cumulative distribution function. This can be done using the equation:

$$H'(i) = \sum_{0 \le j \le i} H(j) \quad (8)$$

$$equalize(x, y) = H'(pixel(x, y)) \quad (9)$$

Where $H(j)$ is the intensities of the input pixels as a histogram plot, and the H' is the equalized value resulted as a histogram equalization.

Segmentation

The next step is making the segmentation. The segmentation is performed on each layer of the three RGB layers of the image. This segmentation is an important step for the next classification task in the next stage.

Clustering Task

Data clustering is a technical method used on a wide range of artificial intelligence and pattern recognition. The clustering job is known as joining objects that have the same features in one group. These objects' features must be different from another cluster’s features.

There are many clustering techniques, like K-means, Fuzzy K-means, basis of density clustering, hierarchical clustering, …etc. In these algorithms, K is the number of clusters.

To define how the clustering task is done, we have in image processing a large number of pixels to be clustered. First of all, the algorithm chooses three random pixels as three clusters’ centers. These centers must be an infected and non-infected area, so the infected areas of the disease will have their special color and that is for the non-infected too. This grouping of the pixels helps to define the type of the disease.

In the second step, we will start to compute the pixel situation near the centers and how similarity is this pixel color with the healthy and non-healthy areas and we recompute the centers again after adding these pixels, we continue the computing task until the centers became stable[19]-[21].

After clustering all the pixels, we can isolate the areas in one image for each cluster so we can compute the area infected in the leave and how much the disease is affecting the plant.

Effect of bending the leaves

In some cases, the leave might bend if it grows older, or by the user. When that is happened there will be a problem of calculating the right area of the leave or even parts of the disease spots will hide resulting the decrease of the whole system accuracy. To solve this problem, a flat leaves where chosen, and if the leaves were bend, they were put in a glass cover before imaging it to make sure of the leave flatness.

Programming sequence

First of all, we need to read the specific image of the plant leave which must be RGB image, then we need to resize it to let the algorithm work on all images, then we need to enhance the image contrast using stretchlims. Contrast stretching will attempt to improve the contrast in an image by `stretching' the intensity values to a long range.

In the second stage, we need to change the image form into lab form to detect the important colors in the image. The makeform command will change the color space equation for the task of color changing. This command has a multiple color space conversation defined by CIE (international commission of illumination) and has the ability to converse with the RGB color systems.

In our work we will classify the colors at color pace using clustering and the algorithm used is K-means. Since the image has 3 colors, it creates 3 clusters. Then we will measure the distance using the Euclidean Distance Metric. Then labeling every pixel in the image using results from K means.

After the isolating task of each area, we need to extract the important features defined in table (1). Then we will use SVM to cluster data into accurate areas. That means all the classes are different in just two areas. So, if the area has a different color than a specific size and color, we will find the disease of it. First of all, we need to get a dataset of images, so we will use a dataset consisting of five types of conditions (e.g. four of infected leaves and the fifth is for the healthy ones). The data set has about 25 images in each class used to train the SVM classifier to get the best accurate result.

Results and Discussion

This method was trained on 5 types of plants that have similar types of disease and the same effect. All the images were encoded and the trained data was saved on a mat file for all the statistical measurements of all the images and then we will compute the correlation with the new image entered and compute the accuracy of the system. We use MATLAB2014 as a working environment with the help of its ready libraries.

Fig. (3) shows one of the images infected with Alternaria Alternata disease and, as we can see, the image has a brown spot and a large yellow area.

Fig. 3: infected leave with Alternaria Alternata

Because of the imaging task, the colors of the leave may be different from the reality, to make sure that the colors are right, we need to enhance the image contrast because some of colors may change when they are shot in a high or low light conditions. The enhancement task is important to give a split between different colors areas. Fig. (4) shows the enhanced image resulted.

Fig. 4: Contrast enhancement of the above image

The next task will be dividing the image into three areas with color ranges; an area for the brown gradients, the second for yellow gradients, and the third is for green gradients. All the three areas have a black background, as the colors of the leave is between green, yellow, and brown, then the Lab color space will help to isolate the areas required. Then the computation of the percentage of each area to the whole size of the image can be done, then choosing the region of interest (ROI) which will segment as the area which will be studied. Fig.5 shows the segmentation task of the leaves into clusters where the user will select the specific cluster of the disease. Areas of interest in the image are divided into three important clusters using the color gradients. Fig. 6 shows the segmented ROI in the image.

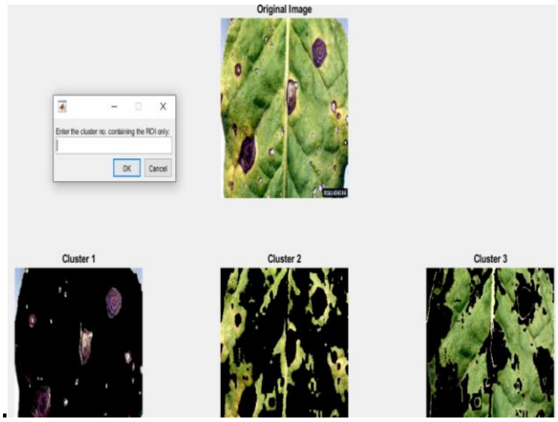

Fig. 5: Shows how we will get the area wanted with the disease affected.

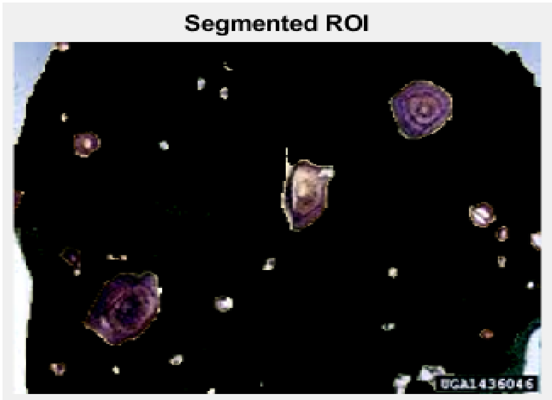

Fig. 6: Segmented ROI of an image

After segmentation, we need to extract the features of the image, which are the statistical calculations of the image desired, which will be saved in an array and then saved in a mat file which can be used again to study the location of the newly entered image. And the program will give the result of the affected leave as an area computation. The algorithm used in our study was an easy one with high accuracy. Some studies used neural networks and others used many classification algorithms, and the results were compared using the accuracy of finding the disease affecting the leave. Instead of using the RGB color system in some studies, we decided to use a Lab color space system which gives a good accuracy result.

After using the system, we have the accuracy results shown in table (1). As shown in the table, the system was able to classify the plant disease with high accuracy. The missing classified diseases resulted from the bad imaging conditions that resulted in the difference in colors. And some images used were closer to one disease than another. The similarity of effects of some disease on the plant is a missing classification error which is in the acceptable range.

Another challenge facing this research is the effect of the imaging angel that affects the size of it and results in wrong values too. The plant leave picture must be in front form.

The method is able to detect disease types using one leave and not able to detect the total plant or tree conditions. Table 1 defined an important features of accuracy results

Table 1: features of accuracy results

situation	Total number	Right classify	accuracy
Alternaria Alternata	20	18	90%
Anthracnose	23	20	86.9%
Bacterial Blight	6	6	100%
Cercospora Leave Spot	9	8	88.8%
Healthy Leaves	15	14	93.3%

The classifier split the space into 5 categories of disease and marked them with labels from 1 to 5, and used the KNN to classify the pixels of the leaves into one of these clusters using the Euclidian distance. This task was done using the training set, and the SVM was used after each training loop to increase the accuracy of the system and decrease the mistake rate. After the features were extracted and connected with the specific labels. The testing images were entered to evaluate the system. The evaluation task depends on the input image disease label and the predicted label.

As shown in the table 1, it is clear that the system was able to predict the disease with high accuracy. The main advantage of the method is that it is fast and not complicated depending on just the image processing task and the normal classifiers. On another hand, there were disadvantages for this method that the leave must keep flat and imaged in a specific pose (i.e. the picture must be taken from above and there in no bend on it). Some methods used the deep learning methods which has a higher accuracy but needs for a more powerful computational power.

The accuracy can be increased by using some of deep learning algorithms like conventional neural networks.

Comparing with other studies uses the same techniques, this method gives a good high accuracy, but it needs the user support to choose the specific cluster. As shown in table 2.

Table 2: Gives a comparison between proposed method and study proposed in [26].

situation	Accuracy of study [26]	Accuracy of proposed method
Alternaria Alternata	95%	90%
Anthracnose	96%	86.9%
Bacterial Blight	97%	100%
Cercospora Leave Spot	95%	88.8%
Healthy Leaves	96%	93.3%

Compared with other studies used different methods, this method was good enough to classify the plant disease, (table 3).

Table 3: Gives a review of different methods.

Study	method	Average accuracy
[1]	RGB images, SVM classifier	95.71%
[6]	RGB images, CNN networks	92%
[9]	RGB images, Morphological features	98%
[10]	CNN, AlexaNet	90.85%, 98.33%
[26]	RGB images, K-means	95.8%
Proposed Method	Lab color space, K-means, SVM	92%

Conclusions

The new algorithm used gives a good result with high accuracy and time to predicate a collection of diseases that could affect a plant. There were many problems solved using this algorithm. The main problem was the light conditions that could affect the result. Using the Lab color system helps to detect the disease more powerfully because the green color is on one axis of the color space. In addition to the gendered brown color of all the diseases. Using several types of filters helps too, to enhance the color of the plant and remove the small spots of colors that can affect the result. Using these methods makes the disease detection system active for any type of plant.

The results found that the k-means was good at clustering and defining the healthy leave from the affected one. Joining it with other clustering algorithms like SVM, random forests or neural networks to enhance the accuracy of the total system. This method can be developed to take a picture of the tree or a branch of it and detect the disease, but in this case, it is important to use more advanced methods to isolate leaves from each other to detect the right area. The best method that can be used here is neural networks like conventional, or deep neural networks.

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تطبيق نظام معالجة الصور الملونة للكشف عن أمراض النبات باستخدام خوارزميات التجميع

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معلومات المؤلف

الايميل:
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الخلاصة:

في الآونة الأخيرة، وبعد تغير الظروف الجوية وتلوث الموارد المائية والهواء، أصيب الغطاء الأخضر للأرض بالعديد من الإصابات وبدأ المحصول الزراعي يعاني من العديد من الأمراض. هذه الأمراض قادرة على التقاط واختيار الدواء المناسب بعدة طرق. ربما تكون إحدى أهم الطرق هي التحقق من تغير أوراق النباتات. يستخدم الكشف عن أمراض أوراق النبات عدة طرق مثل معالجة الصور والتعلم العميق. وتعاني جميع هذه الطرق من التشابه الكبير بين بعض الأمراض واختلاف أحجام الأوراق وألوانها. مما تسبب في انخفاض دقة اكتشاف المرض المناسب. تم استخدام أساليب الشبكة العصبية أيضًا، ولكنها كانت تحتاج إلى وقت حسابي أعلى وقوة حسابية أكبر. كل ذلك يمنح طرق معالجة الصور مزايا أفضل مقارنة بالطرق الأخرى. بعض الطرق الأخرى تستخدم أنواع أخرى من المصنفات مثل KNN، MLP، ومصنفات Gaussian مما يعطي دقة أقل من طرق SVM التي تستخدم التطبيقات