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Deep Features Based Approach for Fruit Disease Detection and Classification

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***Abstract*—** Fruit disease detection and classification plays vital role in agriculture area and separation of disease and non-diseased fruits take more time. In this paper, we propose quad tree method to detect the diseased region from the fruit to facilitate effective classification. To detect diseased region we explored to check homogeneity of the sub-tree image pixel of quad tree. Subsequently, the diseased area is used for classification using deep learning approach. In deep learning six hidden layers are used. Further, we have collected 1000 samples of diseased and 1000 samples of non-diseased images from the 20 fruits class to conduct extensive experiment on both detection and classification. In experimentation, we compared the proposed method results with SVM and KNN classifier, the proposed method results shows that compared to SVM and KNN classifiers deep learning gives better results.

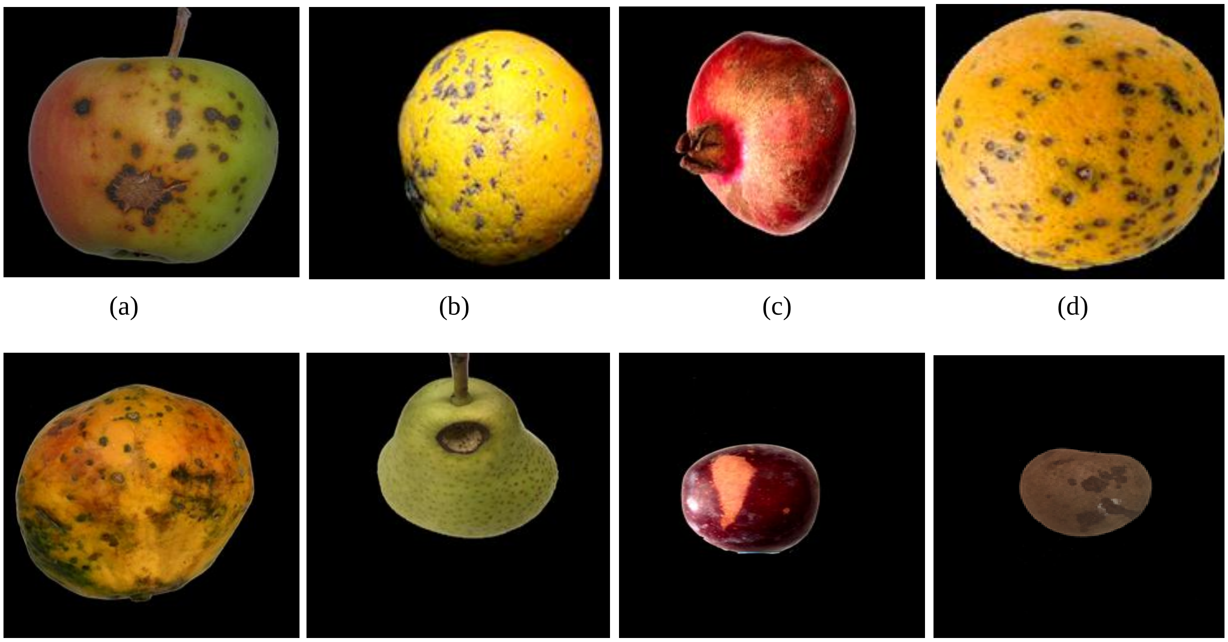
***Keywords*—**Deep Learning, Detection, Quad tree, Sementaion, Classification

I. INTRODUCTION

Recent survey shows that automatic classification of various classes of fruits images to their particular classes as become very important research area these days. It is not only the area of research in the field of academics but also plays a vital role for industrial applications. Tracking the diseases in fruits is also a crucial topic for sustainability in the field of agricultural sciences, such data and information are in the form of images and to retrieve such data mathematically Digital image processing is adopted. Identifying the disease in fruits is very difficult for farmers at early stage and also leads to loss in the revenue to farmers and the country. Detection of the disease in fruits can control quality, quantity and the stability of the yield. These kind of disease in fruits will affect the yield and get worse in variety which also leads for withdrawal from cultivation. Timely detection of disease in fruits will accelerate the control of fruit diseases through proper management process like, pesticide applications, fungicide applications and disease specific chemical applications for improved productivity. Nowadays, the best way to for identification and detection of fruit diseases is based on visual perception by expert peoples which is very expensive [1].

Most experienced personnel will handle the quality evaluation processes but also due to various considerations such as level of fatigue, various working conditions, personal judgment and grading results will be differing from individual personnel. In this order, the industry should think for secure future of their reputation in fruit quality and how increase the fruit handling capacity of current facilities. to execute this objective the visual inspections ways should be completely automated. Fruit industry demands such real time quality assessment tools that is efficiently working conditions. From recent years automation and intelligent sensing technology have transformed our fruit production and processing routines that leads to increase in the quality of fruits and safety. Due to increasing cost of the labors and shortage of skilled workers are dependent on producers and processors for improved production process. In this process automation becomes important factor for reducing the costs and also boosts production efficiency. Monitoring and quality grading, robotics and post harvest product sorting are the automated solutions in the field of operations that are integrated with machine vision technology for sensing as it is non-destructive and exact measuring capability [2].

For effective classification of the images the most recent evolution is the Deep Convolution Neural Network (DCNNs) that has led an impressive progress in computer vision techniques. In this paper we propose fruit disease image classification based on Deep Learning. Some the samples of fruit disease images with different classes are shown in Fig.1.



(a) (b) (c) (d)

(d) (e) (f) (g)

Figure. 1. Shows samples of fruit diseased images (a) Apple (b) Citrus-limetta (c) Pomegranate (d) Orange (e) Papaya (f) Pear (g) Plum (h) Sapota.

The organization of the paper is as follows section 2 describes a brief explanation the literature survey of fruit disease image classification and section 3 gives detail explanation of proposed methodology of fruit image classification based on deep learning and section 4 demonstrates experimentation and results and section 5 gives conclusion and future work.

II. Related Work

M S Hossain et. al., [3] proposed a novel method for classification of fruits based on deep learning. This framework consists of two types of deep learning architecture, one is light model which consists of 6 convolutional neural network layers and another one is a fine tuned visual geometry group (VGG) 16-pretrained deep learning model. The proposed method is compared with other two existing methods and shows good results. S K Behera et. al., [4] proposed a novel method for disease classification and grading of orange fruit images based on machine learning and Fuzzy logic. Presented model observes the external surface of the fruit image and using k-means clustering it identifies the flaw in the fruits, then the features are extracted from the segmented images and classification is done by using Multiclass Support Vector Machine. Grading of the fruit image is carried out using k-means clustering and Fuzzy logic. A S M Shafi et. al., [5] proposed a novel method based on Machine learning for recognition and automatic classification of fruit disease using multiclass support vector machine and multiple features. Segmentation is done to identify the region of interest and features are extracted from these segmented images and images are trained using multi class SVM. Finally the classification of the image to their respective classes is done using the segment image part and trained image from the multiclass SVM. Dakshayini Patil, [6] proposed a method for detecting fruit disease in Apple, Papaya, Watermelon, Banana and mango fruit images using image processing techniques. Segmentation of the image is done by using k-means clustering method and color, texture, structure and morphology are considered as feature vectors and feature are extracted using gray level co-event matrix. Classification is done using KNN classifier. S A Gaikwad et. al., [7] proposed novel method for detection and classification of disease in fruits. Segmentation of the fruit images are done using k-means clustering method and from theses segmented images the features are extracted and finally training and classification is done using support vector machine classifier and produce good accuracy detection and classification of fruit diseases. S Panda et. al., [8] proposed a new method by making use of image segmentation and soft computing for grading of carica papaya fruit. This framework make use of artificial bee colony algorithm grading of carica papaya fruits and to classify them into defected and non defected. Classification method is also compared with other method such as SVM, Naive bays classifier and fuzzy logic and SVM classifiers gives better results. A S Nadarajan et. al., [9] proposed a novel method for identification of bacterial disease in alphonso mango fruit using image processing techniques. Based image color intensity the defected area of the mango fruit is identified and then classification is done as normal mango fruit and defected mango fruit. S Varughese et. al., [10] proposed a novel method detection of fruit disease of learning based by using image processing techniques. Segmentation is performed using k-means clustering algorithm and then train the system for learning the feed forward back-propagation algorithm is used and classified fruits as diseased and non diseased. S T khot et. al., [11] proposed a novel method for identification of disease is pomegranate fruit images using digital image processing techniques. Segmentation of the image is done based on color image and from these segmented images feature are extracted using color, texture and morphology. classification of pomegranate fruit image of diseased and non diseased are done using minimum distance classifier. B J Samajpati et. al., [12] proposed a novel method for detection and classification of apple fruit diseases in images. Three types of apple diseases are considered apple blotch, apple scab and apple rot and first color and texture features are extracted from the images and for better results feature fusion is conducted and to classify the images random forest classifier is used and diseased images are segmented using k-means clustering method. A Awate et, al., [13] proposed a novel method for detection of disease in fruit images based on artificial neural networks. This framework uses Open CV library for implementation and segmentation of the image is done by using k-means clustering method and features extracted using color, structure, morphology and texture. Classification of disease and pattern matching is done using Artificial Neural Networks. M Dhakate et. al., [14] proposed a novel method for identification of disease of pomegranate fruit images and also pomegranate plant disease based on neural networks. Segmentation of the images are done using k-means clustering and feature extraction are done using GLCM methods. Classification of the fruit disease image are done using artificial neural networks by making use of back propagation algorithm. S H Mohana et. al., [15] proposed a novel method for automatic detection of surface defects of fruit Citrus fruit images using computer vision techniques. Removing background and fruit are extraction is done using k-means clustering method and mean shift algorithm for fruit region segmentation and multi-threshold segmentation for detecting candidate objects that are presented on the fruit surface. A Mizushima et. al., [16] proposed a novel automatic method for apple fruit image segmentation and grading. For segmentation of color images linear support vector machine and Otsu's thresholding method is used. This framework used for apple sorting and grading automatically adjusts classification hyper plane intended by linear support vector machine requires less time and minimum training. M Jhuria et. al.,[17] proposed a novel method for smart farming based on image processing techniques by detecting diseases and d grading of fruits. This framework consists of disease detection of fruit images, for detecting and classifying theses tested disease images using neural networks by considering three feature vectors color, texture and morphology. Leaf disease grading to identify the percentage of infected area and grading of mango fruit to classify them into different grades based on its weight. S R Dubey et. al., [18] proposed a novel method for apple fruit disease detection and classification of based on complete local binary patterns. Three types of apple diseases are considered such as apple rot, apple scab and apple blotch. Segmentation of the images are done using k-means clustering method and features are extracted from these images and finally classification of the image s are done using multi-class support vector machine. D G kim et. al., [19] proposed a novel method for grape fruit peel disease classification based on color texture feature analysis. HSI, HS and I color combinations are selected with 13, 9 and 11 texture features and for classification the model uses 13 and HSI texture features gives better performance then intensity texture feature model. J Blasco et. al., [20] proposed a novel method for automatic quality of grading of fruits based on machine vision system. This system is developed for online estimation of quality of fruits such as oranges, peaches and apples color, stem location and also identification of external blemishes. Segmentation is done using Bayesian discriminant analysis. Machine classification achieved good results. V Leemans, et. al., [21] proposed a novel method for segmentation of defects in Jonagold apple fruit based on Bayesian techniques. Bi-color fruit image defect segmentation is done by using Bayesian classification method by considering pixel's color and also achieved good results for poorly contrasted images.

III. METHODOLOGY

The methodology consists of two parts, In section III A. Quadtree based disease detection on fruit images and B. Deep learning for fruit disease Detection.

In quadtree based segmentation, we used splitting image regions based quadtree division, after division of quadtree, it produce sub-nodes from the tree for each level then for each sub-tree region we check the homogenous or inhomogeneous if all sub-trees are homogeneous we consider that as region of interest. In subsequent section, we proposed deep learning for the detection of fruit diseases. For classification, we consider clean fruits and diseased fruits, training and testing details are described in section III. B.

A. Fruit disease segmentation and detection through Quadtree

For an effective classification of fruit disease it is necessary to conduct proper image segmentation otherwise features of

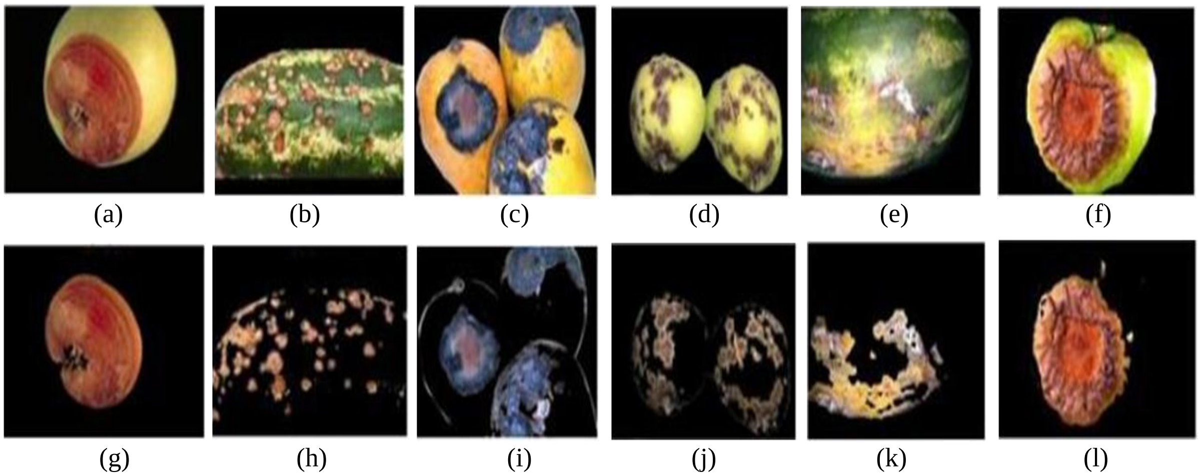


Figure. 2. Shows before segmentation (a) to (f) and from (g) to (l) after segmentation images.

non infected regions will influence by infected regions. This model make use Quadtree approach of segmentation for fruit disease classification to remove background based on split and merge algorithm [22]. This processes will start from the root of the tree that is represented by the whole image. In splitting process if the sub-squares were found to inhomogeneous, then it would been split into four non-quares and during merging process if the four sub-squares were homogenous it will be merged as several connected components. Segmented node ids the node in the tree and the process will persist repetitively unless no further split and merge takes place. Then the square window is used to capture the fruit and this fruit will be lying at the centre of the window. At last the images will be down sampled to 256x256. Fig.1. shows you the before and after segmented images.

B. Deep Learning for fruit disease classification.

Disease classification of fruit images have created more awareness to computer vision techniques from past decades. From recent survey we can see that Convolution Neural Network (CNN) performs better when compared to other conventional methods because of its self learning ability which can perform on various types of complex and huge data. This motivated us to utilize the CNN for disease classification of fruit images [23].

From the image patches of the given kernel size the information is obtained and it is gained by Convolution Neural Network. Hence CNN plays a vital role in designing the kernel size for each layer and also the size of kernel is directly proportional to the information gained. Normally, the local information is extracted from small kernel of the given patches and this is helpful to capture minute information.

In this presented work, the kernel size is fixed to 3x3 that is minimum for all the convolution layers to obtain the minute spatial information. Table.1 shows the six layer CNN architecture designed for disease classification training model. For training the images are scaled to 100x100 and the same size is used for testing the sliding window to map the input features.

Table 1. Parameter setting for CNN Input Size(In), Kernel(K), Stride(S), Padding(P) and Feature Maps(FM).

Type	Parameters
Input	100x100x3
$Conv_1$	In=100x100, K=3x3, S=1, P=1, FM=16
Batch Normalization	
ReLU	100x100
Maxpool	In=100x100, W=2x2, S=2
$Conv_2$	50x50, K=3x3, S=1, P=1, FM=32
Batch Normalization	
ReLU	50x50
$Conv_3$	50x50, K=3x3, S=1, P=1, FM=64
Batch Normalization	
ReLU	50x50
Maxpool	In=50x50, W=2x2, S=2
$Conv_4$	25x25, K=3x3, S=1, P=1, FM=128
Batch Normalization	
ReLU	25x25
$Conv_5$	12x12, K=3x3, S=1, P=1, FM=256
Batch Normalization	
ReLU	12x12
$Conv_6$	6x6, K=3x3, S=1, P=1, FM=256
Batch Normalization	
ReLU	6x6
Fully connected layer Input size	
Softmax prediction for labels	

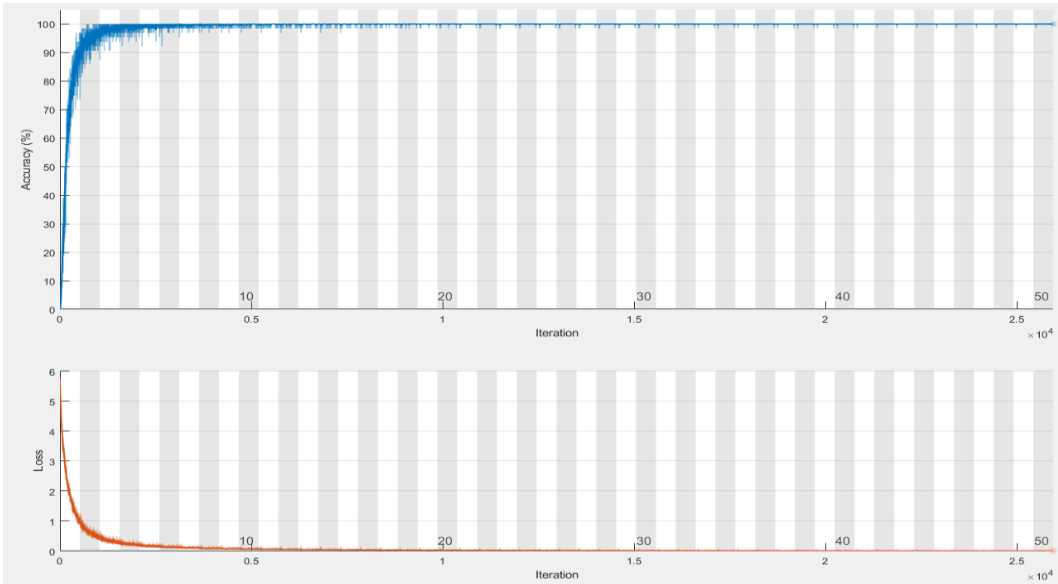


Figure. 3. Illustration of learning and accuracy graph of CNN training.

In the entire phase of training, a set of hyper parameters are designed with the segmented training images of the size 100x100 and according to the datasets to be utilized. Hyper parameters plays an important role in facilitating the process of learning in efficient and effective manner. For setting up an extensive experimentation we define some of the Hyper parameters like, padding, momentum, stride, learning rate, kernel size (ideally small), number of output from each layer, to learn a small batch of images, batch normalization (BN) factor, activation function Rectified Liner unit (ReLU) and pooling. The input images is convolved with the size of kernels 3x3 and the padding is done of the size 1x1 and it is defined as *(k-1)/2*, where 'k' is kernel size that is use to capture the local path information in the form of extracting weights. Mini batch BN layers are used to reduce the internal covariance between the set of all images. As the input images are small in size, it is ensured that with a small stride the loss of information will be negligible less. Hence the striding is fixed to one in our proposed model. To preserve the size of input image further we make use of non-linearity ReLU is added to output of the convolution layer. The fastness and the influence of the ReLU will leads to reduce the vanishing gradient issue and it also acts as element gradient function in the network and is given by Eq. (1).

$$f(x) = \begin{cases} x, & x \geq 0 \\ 0, & x < 0 \end{cases} \tag{1}$$

To improve the performance of classification, we have reduce the dimension of feature map, a max-pooling layer with a window size 2x2, stride and padding of one is fixed after the ReLU process. To train the CNN we have used Stochastic Gradient Decent Momentum (SGDM) by fixing learning rate to 10^{-1}. Huge number of data overfitting problem will occur and model does not gain stable after 20 epochs, in Fig. 3 shows how the learning rate is decreased and convergence rate will be achieved at 10^{-5} with 50 epochs. Eventually, for effective detection of the test input image softmax layer is used.

IV. Results and Discussion

In this section, we demonstrated the experimental result on both segmentation and detection. For segmentation and detection we have collected 20 fruits class show in Fig. 1 and from the each class 1000 non-diseased and 1000 diseased images totally 40000 images from all the classes.

A. Pefromance Evalution of Segmentation and Detection

It is quiet essential to measure the performance of the segmentation algorithm one is performance metric since good parameters can be found for segmentation algorithm and another one is various segmentation techniques are compared. To detect the disease in the fruit based on location and measurement area the main objective of the segmentation is to make use of region based measures. The region based measures used to evaluate the segmentation algorithm is explained in following equations [24]. In Table 2. shows the all the measures performance.

Table 2. Performance evaluation of segmentation results of Quad tree method.

MeasOverSeg	MeasUnderSeg	Error rate	Dice Similarity Measure	Measure of Overlap
0.1852	0.3524	0.5821	0.6578	0.8913
0.1754	0.4127	0.5622	0.6358	0.8754
0.1637	0.3578	0.5773	0.6527	0.8725
0.1832	0.4567	0.5162	0.6972	0.8637
0.1462	0.4789	0.4863	0.7289	0.8817
0.1657	0.2789	0.5789	0.7108	0.8745
0.1591	0.4789	0.5972	0.7265	0.9176
0.1832	0.2703	0.5463	0.6936	0.9042
0.1655	0.2790	0.5372	0.6982	0.9078
0.2781	0.3275	0.5971	0.7411	0.8753
0.1732	0.3385	0.4627	0.6387	0.8967
0.1758	0.4178	0.5525	0.6914	0.9237
0.1845	0.3875	0.5478	0.6978	0.9478
0.1924	0.4754	0.5934	0.6844	0.9056
0.1856	0.3872	0.4972	0.7512	0.9123
0.2354	0.2584	0.5892	0.6321	0.9274
0.2876	0.4967	0.4963	0.7126	0.8764
0.1845	0.4952	0.5726	0.6842	0.9156
0.1866	0.4822	0.5823	0.6418	0.8563

Table 3. Proposed method performance evaluation on classification for Before Segmentation (BS) and After Segmentation (AS).

Proposed Method			SVM classifier		KNN classifier	
Training Samples	BS	AS	BS	AS	AS	BS
80	0.86	0.93	0.74	0.82	0.66	0.70
50	0.72	0.85	0.68	0.73	0.62	0.67
20	0.56	0.68	0.48	0.57	0.42	0.46

- Measure of Overlap (Jaccard Similarity Measure)

$$\text{MOL} = \frac{s \cup g}{s \cap g} \qquad (2)$$

where,
MOL = measure of overlap,
s= Segmented area,
g= Ground truth area.

- Measure of Under Segmentation

$$\text{M} \cup \text{S} = \frac{|U|}{|G|} \qquad (3)$$

where,
U =Unsegmented lesion area,
G= Groundtruth area,

$$\text{U} = |G/(\text{S} \cap \text{G})|$$

Where,
S = Segmented area.

- Measure of Over Segmentation

$$\text{MOS} = \frac{|V|}{|S|} \qquad (4)$$

where,
V = Segmented non lesion area,
S = segmented lesion area,

$$\text{V} = |S/(S \cap G)|$$

Where,
G = Groundtruth area.

- Dice Similarity Measure (DSM)

$$\text{DSM} = \frac{2 \times |\text{A(C)} \cap \text{A(C}_r)|}{|\text{A(C)+A(C}_r)|} \qquad (5)$$

- Error Rate (ER)

$$ER = \frac{|A(C) \oplus A(C_r)|}{|A(C)+A(C_r)|} \quad (6)$$

B. Pefromance Evalution on Disease Classification

To evaluate disease classification, we have accompanied three set of experimentations. Firstly, we considered 30% of samples for training and 70% of samples for testing. Secondly, we considered 50% of images for training and 50% of images for testing. In the last set, we used 80% for training and 20% for testing. For all the set we used average of 20 trails to obtain results and in Table 3. shows the results of all set of experimentation for before the segmentation and after the segmentation. However, from all the set of experimentation we can observe that 80:20 gives better performance compared to other set and also we can observe compared to before the segmentation after the segmentation gives better performance. In Table 3. we have compare the results of our method with Support Vector Machine (SVM) and K- Nearest Neighbour classifier. To set gamma value for SVM classifier 10 cross fold validation is used and gamma and *c* values are varied for 2^{-15} to 2^{15} and for KNN classifier *k=1* is used with 10 cross fold validation to obtain classification results. However, from the Table 3. proposed method outperform compared to SVM and KNN classifier.

V. Conclusion and Future Scope

In this work, we proposed two segments, first we explored the segmentation of fruit disease using quad tree approach, after apply quad tree division for each sub tree image we check homogeneity of the pixel to merge the homogeneous area of interest and segment the fruit diseased part. Secondly, we used segmented images to classification the fruit are diseased or not diseased using deep learning approach. We have collected different fruits diseased image for our experimentation. In experimentation we have shown how the proposed method gives the better results for both detection and classification with comparative study on SVM and KNN classifier. In future, we planned for use Deep features for segmentation and improve the fruit diseased dataset and classification results.

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