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An Efficient Citrus Canker Detection Method based on Contrast Limited Adaptive Histogram Equalization Enhancement

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Abstract

Plant leaf disease is one of the critical causes for heavy loss of yield that reduces quantity and reduces quality of the agricultural product. Citrus plants such as lemon are mainly affected by citrus canker disease which affects the fruit production of the plants. Early canker disease identification is one of the challenging solution for increasing the plant production. This paper aims to identify and classify the canker disease accurately from the affected leaf images by adopting image processing techniques to detect plant leaf diseases from digital images. The proposed approach involves two stages to improve the clarity of leaf images. The primary stage uses Contrast Limited Adaptive Histogram Equalization (CLAHE) in pre-processing step which improves the contrast level of disease affected leaf image, segment the region of interest using K-mean Clustering and texture feature extraction using statistical GLCM. The second stage by adopting the Support Vector Machine classifier to detect the canker leaf image and implements these methods in lemon citrus canker disease detection. Experimental results show effective accuracy detection and reduced execution time of canker disease detection.

Keywords: Citrus Canker Disease, Image Processing Techniques, Histogram Equalization, Gray-Level Co-Occurrence Matrix and Support Vector Machine.

INTRODUCTION

The agricultural land mass is more than just being a feeding sourcing in today's world. Indian economy is highly dependent of agricultural productivity. The occurrence of the disease on the plant result in substantial loss in both quality as well as the quantity of agricultural product. This can create the negative impact on the countries whose economies are primarily dependent on the agriculture. Hence the detection of the disease in plants is significant to avoid the financial loss.

In recent years, the leading severe disease is citrus canker and it is considered as one of the major disease among plants. Citrus plants such as lemon, orange are a long duration crops and traditional medicine plants are affected by a canker disease which appears as bacterial spot. The proposed approach considers lemon leaves for classification of citrus canker disease because of high commercial cultivation crop. Lemon is an important source of vitamin C and contains flavonoid compounds that have distinct antioxidant and anti-cancer properties [2].

Citrus canker is a bacterial disease that affect the premature leaves and fruits of citrus plants. Initially, the infected leaves have some white spongy spots and that will turn to grey or brown later. The spots consist of oily margins or yellowish ring (lesions), which can appear on both sides of the leaves shown in figure 1. This disease can be detected by the appearance of lesion on groves, stems and leaves. The symptoms are appear as yellowish spots or halos on leaves that gradually enlarge to 2 – 4 mm dark brown pustules [7].

Figure 1 Citrus Canker Lesions in leaf and fruit

This citrus canker disease is caused by the bacterium Xanthomonas Axonopodis PV. Citric (XAC). The infection of citrus canker results in defoliation, dieback, tarnished fruit, reduced fruit quality, premature leaf and fruit and at last the trees will produce no fruits. Citrus canker is highly infectious and can be spread rapidly by wind, rain, landscaping equipment, people work in field, moving infected or exposed plants or plant parts and it is difficult to eradicate. Detecting citrus canker at the early stage is the key to control and spreading of this disease.

Digital image processing [9] and image analysis technology based on the advances in real time applications such as microelectronics, computers, medicine and biology and it able to circumvents the problems. In this paper a new model for enhancement of pre-processing image with efficient contrast and to predict the canker disease in citrus plant (lemon) by classifier is implement. This approach aims to use contrast enhancement techniques [21] to enhance the image quality and to classify the citrus canker affected leaf by Support Vector Machine classification. This system which can provide more accurate results related to the identification and classification of disease. From an innovation perspective, the research contributions are as follows,

a) To enhance the quality and contrast of citrus leaf image by adopting a Contrast Limited Adaptive Histogram Equalization (CLAHE) enhancement techniques.

b) Presenting a framework for citrus canker diseases detection in citrus lemon leaf classification by implementing Support Vector Machine.

The remainder of this paper is organized as follows; Section II reviews briefly explains about the image processing techniques employed in plant disease detection, various classifiers used for citrus detection and limitations are identified. Section III presents the image processing techniques for canker detection in citrus leaf with classifiers. Experimental Results of the proposed technique are presented in Section IV. Finally, Section V concludes the paper.

RELATED WORKS

Various techniques of image processing and classifiers techniques have been developed for detection of canker diseases occurring on plant leaves, stems, lesion etc. Yue et.al [1] introduce intrinsic image decomposition priors into deterioration models for contrast enhancement named as Contrast Limited Adaptive Histogram Equalization (CLAHE). To enhance the pictures by modifying the decomposed enlightenment layer to improve under (finished) uncovered pictures. The histogram-based strategies image contrast by altering histogram appropriations. The two fundamental modules are intrinsic image decomposition and illumination adjustment are utilized to improve the quality of image.

Thangadurai and Padmavathi [7] presented a Computer vision image enhancement utilizing hereditary algorithm in plant leaves infection. Plant leaves diseases identification is utilized caught pictures for diseases analyzes and detection. Hereditary algorithm such as Genetic algorithm is utilized to discover the optimal solution and used to tackle issues in disease detection. In which grayscale pictures are anything but difficult to process and execute for different applications since they have better clarity and suited for examination than RGB pictures Histogram equalization out is utilized to increase the images clarity. The resultant images accomplish the improvement in image quality.

Menukaewjinda *et al.* [14] developed an Artifcial Neural Network (ANN) i.e. Back Propagation Neural Network (BPNN) for grape leaf color extraction with complex background. The integration of Modified Self-Organizing Feature Map (MSOFM) and Genetic Algorithm (GA) are implemented which provide automatic adjustment in parameters for grape leaf disease color extraction.

The maize disease image recognition of corn based on Back Propagation (BP) networks effectively developed by Song Kai *et al.* [13] YCbCr color space technology is adopted to segment disease affected spot, Co-Occurrence Matrix (COM) spatial gray level layer is used to extract disease spot texture feature, BP neural network has been used to classify the maize disease. The applications of K-means clustering as well as BP neural networks are estimated for clustering and classification of diseases.

Gavhale et.al [2] presents an image processing technique for detection of unhealthy region of Citrus leaf. There are four sorts of citrus diseases specifically Citrus ulcer, Anthracnose, Overwatering and Citrus greening. The proposed system includes image acquisition is the initial step for capturing picture by computerized camera to make database. Color space conversion and image enhancement is done in picture pre-preparing. Discrete cosine transform domain is utilized for image enhancement. YCbCr color system and L*a*b* color space are decided for color space transformation. In feature extraction statistical technique, utilizing Gray-Level Co-Occurrence Matrix (GLCM) to see measurements, for example, contrast, energy, homogeneity and entropy using gray crops enhancement.

Mokhtar *et.al* [3] present image processing technique for Tomato leaves diseases detection. In pre-processing stage a few strategies are applied for image enhancement, smoothness, remove noise, picture resizing, image isolation, and background removing. Gabor wavelet change and Support vector machine are implemented for identification and classification of tomato diseases. In feature extraction stage with the assistance of Gabor wavelet change include vectors are acquired for next classification stage. In classification phase, Support Vector Machine (SVM) is prepared for distinguishing the classification of tomato diseases.

Mitkal et.al [4] introduced an image processing technique for Sugarcane leaf detection disease. In preprocessing steps RGB images are converted to grayscale and unwanted part of data from the images is removed. Segmentation fins the diseased part of given image which contains green pixels and potentially infected area. Linear SVM, Nonlinear SVM and Multiclass SVM are used in feature extraction for disease detection.

PROPOSED METHODOLOGY

Image processing [10] has play a terribly important role in agriculture field because of widely accustomed observe the crop disease with high accuracy. For classification and detection of plant disease, digital image method is extremely effective in providing better detection for characteristic diseases at its early stages. Image processing techniques [12] is applied on various applications which includes to detect plant leaf, stem, and fruit diseases and to find the edges, color of the affected area. This paper focused mainly to improve the image quality with greater clarity by CLAHE enhancement techniques [18] in pre-processing stages and to detect the canker disease by classifiers. The following image processing techniques steps are used to detect the disease and Support Vector Machine are applied to get optimal solution of the canker disease are shown in figure 2.

Image Acquisition

Image acquisition is the initial step for citrus canker detection. The canker disease affected citrus lemon leaf images are captured by high resolution digital camera and saved as image processing supported format such as JPEG, TIF, BMP, PNG etc. The input captured image is then resized to 512 x 512 pixels.

Image Pre-processing

Image pre-processing is a second step of canker detection mainly it is used to improve the captured image data which suppress the distortions and also enhances the image features for further process that is more convenient to a human observer. Pre-processing step includes various techniques like image resize, filtering, morphological operations etc.

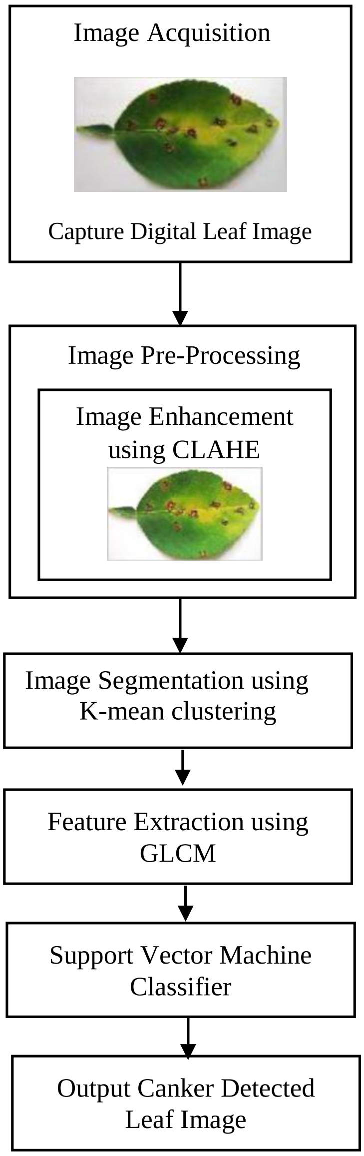

Figure 2 Flowchart for Citrus Canker Detection

The captured leaf images are resized to a fixed resolution. Since the images are captured from the fields, it contains some inevitable noises which are removed by filters such as Gaussian, median, Linear, Low pass, high pass filters etc., which will be selected depends upon the noise level of the images. Image pre-processing techniques includes image enhancement where the affected areas are enhanced with high quality. At first the damaged image should be pre-processed which reduce the effect made by the background.

Image Enhancement

The color images are observed blindingly different for human visual perception which computes the conscious representation. Image enhancement it is adopted to improve the interpretability, visibility and quality of the image. The mainstream enhancement methods are Histogram Equalization which distributes the intensities of the images by increasing image contrast from low to high. Histogram equalization [1] creates an output image with a uniform histogram which flattens and stretches the dynamic range of the intensity levels of the images due to its simplicity and effectiveness. However, it will change the brightness of the image and may result in highly contrast enhancement. To find the mapping for each pixel based on local (neighborhood) grayscale distribution in targeted image.

In some cases, the histogram equalization it not be desirable to transform very low-contrast images because of highly localized grayscale distribution. For this situation the mapping curve may include segments with high slopes, that two very close grayscales might be mapped to significantly different grayscales. This issue is resolved by limiting the contrast through histogram equalization [15]. HE faces certain constraints, such as brightness preservation, contrast limitation and weighted adjustment. The integration of this contrast limiting approach with the adaptive histogram equalization [16] results named as Contrast Limited Adaptive Histogram Equalization (CLAHE).

CLAHE

Contrast Limited Adaptive Histogram Equalization (CLAHE) has produced good statistical estimation results on medical, computer and real time applications [8]. This CLAHE is framed based on partition the targeted image to certain non-overlapping regions of equal sizes. For 512 × 512 images, the number of regions is randomly selected which is equal to 64 achieved by equally dividing the image by 8 in each direction. For an instance, the sample division is shown in figure 3. This partition results in three different groups of regions.

The first one is Corner Regions (CR) four sides of images. The second region consists of 24 regions, is the Border Regions (BR) includes all regions on the image border, excluding the corner regions. The last one consists of all the remaining 36 regions, as Inner Regions (IR). To improve the image enhancement at first, histogram for each region is calculated based on a limit for contrast expansion, a clip limit for clipping histograms. Then estimated histogram is redistributed in such a way that its height does not go beyond the clip limit. In this case, for each grayscale, number of pixels with that grayscale in the region is counted. Collection of these counts for all grayscales is referred to as histogram of that region.

Finally, Cumulative Distribution Functions (CDF) [8], is calculated for CLAHE grayscale mapping then the histogram equalization is obtained by using an estimation of the CDF. For each region the numbers of pixels and grayscales, are defined as

M and *N*, and if $h_{i,j}$ (n), for n = 0, 1, 2,..., N−1, is the histogram of (i, j) region, then an estimate of the CDF, which is scaled by (N − 1) for grayscale mapping, are represented as follows

$$f_{i,j}(n) = \frac{(N-1)}{M} \cdot \sum_{k=0}^{n} h_{i,j}\,(k) \quad n = 1,2..N-1 \qquad \text{---(2)}$$

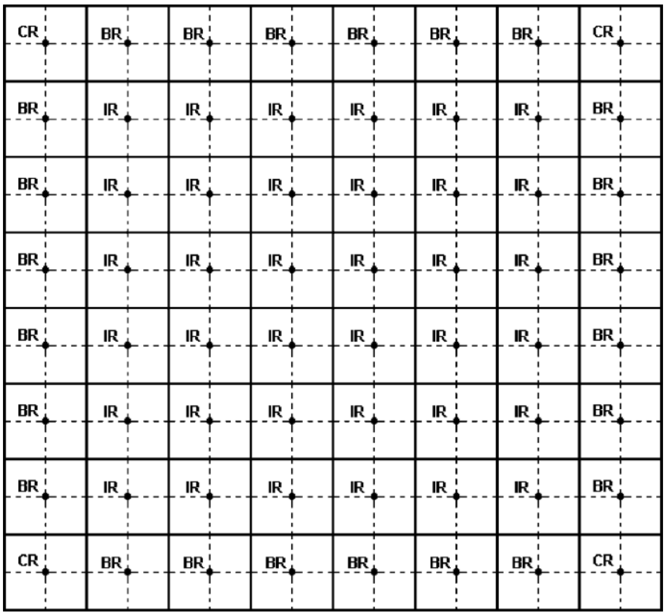

Figure 3 Structure of Leaf Regions in a 512 × 512 Square Image

This histogram function used to convert the given grayscale density function, approximately, to a uniform density function. In the CLAHE technique, each pixels are mapped by linearly combining the partition results from the mappings region of the four nearest regions. CLAHE formulation of histogram equalization for IR group is straightforward. However, for regions in CR and BR groups this formulation requires some special consideration. When the leaves images noises are removed, then by enhancement techniques the quality of the images will be improved are shown in figure 4. Finally the highly enhanced citrus leaf images are obtained. The next process is to extract leaf disease region in the image using image segmentation method.

Original Image **Enhanced Image**

Figure 4 Image Enhancement using CLAHE

Image segmentation

The citrus canker diseased leaves images are partitioned into multiple segments by using segmentation process. Segmentation is used to segment the interest disease affected portion of the leaves images. There are various techniques are used for image segmentation such as clustering methods, compression based methods, histogram-based methods, region growing methods, etc. In this system k-means clustering algorithm is used for the segmentation of image which is totally dependent on the features and characteristics of image.

In segmentation, image is divided into a small significant segment known as clusters [5]. K-means technique detects the clusters from the processed image. The input for k-means clustering image has *N* objects of citrus leaves are to be cluster (X_1, X_2, X_N) and *K* is the number of cluster. Output is the addition of dissimilar citrus leaves and finally diseased leaf portion is obtained. However, K-means clustering is used to separate the leaf image into different clusters if a leaf contains more than one disease. K-means clustering has good adaptability and also suitable for large set of information. At the end of the segmentation process, the diseased portions of the leaves are extracted.

Feature extraction

In plant diseases detection, each leaves have unique feature characteristics which play a fundamental role in classification of disease. In this approach, leaves image features include texture, color, shape are considered for disease detection. In this system by considering the texture portion which is the most significant features for image classification and retrieval. Here texture features of diseased leaf includes Contrast, Energy, Local homogeneity, Cluster shade and cluster prominence are computed by Gray-Level Co-Occurrence Matrix [7]. This method allows computing some statistics describing texture.

Gray-Level Co-Occurrence Matrix (GLCM) - GLCM is the statistical method of analytical texture which considers the spatial relationship of each pixels [2]. The GLCM characterize the texture leaf image by calculating the pixel occurrence in an image with specific values and in a specified spatial relationship. By creating a GLCM followed by extracting statistical measures from this matrix.

Contrast - It is the measure of pixel intensity contrast and its neighbor pixel of the target image. If the target image is equal to 0 the largest value of the image is obtained. It can be defined as

$$Contrast = \sum_{i,j=0}^{N-1} P_{ij}(i-j)^2$$

Energy - Energy is a measure of uniformity with squared elements summation in the GLCM, it lies in the range between 0 and 1. If the energy is 1 for a constant image then it can be represented as

$$Energy = \sum_{i,j=0}^{N-1} {P_{ij}}^2$$

Homogeneity - It is the measures of the closeness of the distribution of elements towards the diagonal in the GLCM and lies in the range between 0 and 1. Homogeneity is 1 for a diagonal GLCM and it is defined as

$$Homogenety = \sum_{i,j=0}^{N-1} \frac{P_{ij}}{1+(i-j)^2}$$

Correlation - Correlation measures how correlate a pixel to its neighbor pixel over the whole image and lies between -1 and 1 [2].

$$Correlation = \sum_{i,j=0}^{N-1} P_{ij} \frac{(i-\mu)(j-\mu)}{\sigma^2}$$

where,

P_{ij} = Element i,j of the image

N = Number of gray levels

μ = mean value of all pixels in the relationships that contributed to the GLCM, it is calculated as:

$$\mu = \sum_{i,j=0}^{N-1} i\, P_{ij}$$

σ^2= variance of the intensities of all reference pixels calculated as:

$$\sigma^2 = \sum_{i,j=0}^{N-1} P_{ij}\ (i-\mu)^2$$

After the texture features extraction, find out the stage of the disease. According to the leaves color and result of texture features, the disease level can be identified.

Classifier

The Support Vector Machine (SVM) classifiers are adopted differentiate citrus leaf disease. SVM is used to classify disease on their texture feature. It constructs a hyper plane in a high dimensional space that can be used for classification. For given citrus leaves image a set of points belonging to either one of the two classes, an SVM finds a hyperplane having the largest possible fraction of points of the same class on the same plane. This separating hyperplane is called the Optimal Separating Hyperplane (OSH) that maximizes the distance between the two parallel hyper planes and can minimize the risk of misclassifying examples of the test set.

Given labeled training data as data points of the form

$$M = \{(x_1, y_1), (x_2, y_2), \dots \dots, (x_n, y_n)\} \quad \text{------(2)}$$

where y_n =1/-1, a constant that denotes the class to which that point x_n belongs. n=number of data sample. Each x_n is a p-dimensional real vector. The SVM classifier first maps the input vectors into a decision value, and then performs the classification using an appropriate threshold value. To view the training data, by divide (or separate) the hyperplane, which can be described as:

$$\text{Mapping: } w^T.x + b = 0$$

where w is a p-dimensional weight vector and b is a scalar. The vector w points perpendicular to the separating hyperplane. The offset parameter b allows increasing the margin. When the training data are linearly separable, select these hyperplanes so that there are no points between them and then try on maximizing the distance between the hyperplane. Found out that the distance between the hyperplane as 2/ |w|. To minimize |w|, need to ensure that for all i either

$$w.x_i - b \geq 1 \text{ or } w.x_i - b \leq -1 \quad \text{------(3)}$$

Training dataset consist of 70 sample images of both citrus leave and testing dataset consist of 30 images of disease sample. The classifier trains the diseased leaf on the training set applies it to the testing set and then measure performance by comparing the predicted samples and it gives output as presence of canker disease in citrus plant.

EXPERIMENTAL RESULTS

The performance evaluation of canker detection is implemented using MATLAB under windows environment. This proposed method is evaluated on citrus (lemon) leaves to detect the canker detection. This proposed method adopted by two steps are to enhance the image quality and to detect the canker detection in citrus leaves. In pre-processing step CLAHE is applied to enhance the image quality and SVM classifier is used to detect the canker affected leaves. The various training and testing samples are used and compare with targeted citrus leaf shown in table 1.

Table 1. Training and Testing Set

Classifiers	Training Images	Testing Images
Without CLAHE Enhancement-SVM	70	30
With CLAHE Enhancement-SVM		

Performance Metrics

The proposed methods are evaluated and compared with various classifiers such as K-NN and Navies Bayes in terms of certain performance metrics such as FAR, FRR, GAR, EER and Execution Time.

Equal Error Rate (EER) - It is used to calculate the error rate of performance operating under verification task.

False Rejection Rate and False Acceptance Rate (FRR and FAR) - It is used to measure the process with the system to enroll or getting rejected. FAR defines as the system will incorrectly accept the canker leaves. FRR defines as the system will incorrectly reject the canker leaves,

$$FAR = \frac{wrongly\ accepted\ sample}{Total\ no\ of\ wrong\ match}$$

$$FRR = \frac{wrongly\ rejected\ sample}{Total\ no\ of\ corrected\ match}$$

Genuine Acceptance Rate (GAR) - This is defined as a percentage of genuine canker leaves accepted by the system.

Table 2 shows the comparison of proposed performance is evaluated in terms of without applying CLAHE enhancement and with CLAHE enhancement in pre-processing steps. Then the output of pre-processing is forwarded to other techniques and compared with various classifiers.

Table 2: Performance Comparison of Canker Detection

	Classifiers	FAR (%)	FRR (%)	GAR (%)	EER	Execution Time (ms)
Without CLAHE Enhancement	K-NN	3	2	97	0.72	0.64
	NB	4	4.5	96	0.62	0.57
	SVM	5	6	95	0.54	0.41
With CLAHE Enhancement	K-NN	4.5	4	95.5	0.43	0.33
	NB	5	6	95	0.33	0.25
	SVM	6	8	94	0.24	0.19

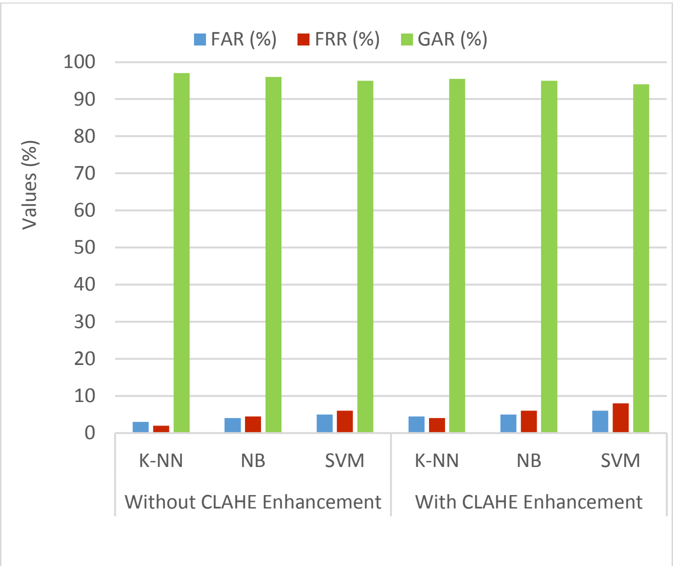

Figure 5 Accuracy Comparison for CLAHE Enhancement

The above figure shows Accuracy prediction of canker detection disease in citrus leaves in terms of FAR, FRR and GAR. It is clearly noted that the pre-processing step with CLAHE Enhancement achieves efficient result integrated with SVM classifiers. The SVM classifiers achieves the good prediction rate for differentiating the canker disease.

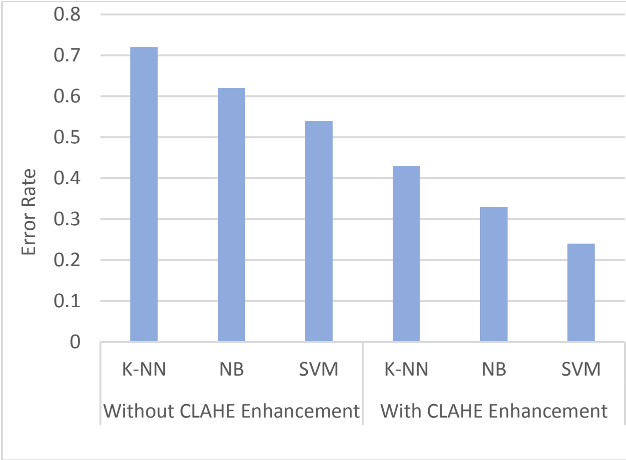

Figure 6 Error Rate Comparison

Figure 6 shows the Error rate comparison of various classifiers in terms of CLAHE Enhancement. The SVM classifiers shows less error rate when compared to other classifiers.

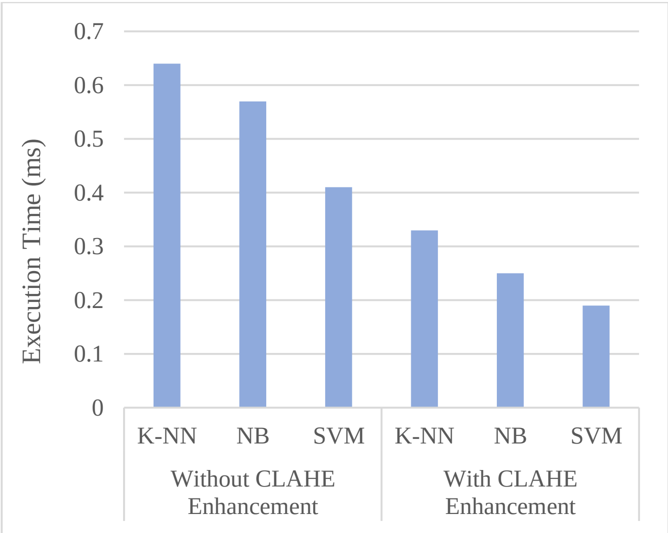

Figure 7 Execution Time Comparison

Figure 7 shows the Execution time comparison of various classifiers in terms of CLAHE Enhancement. The SVM classifiers shows less execution time for detection of canker disease in citrus plant. Less execution and high accuracy will be the effective result for canker prediction.

CONCLUSION

Citrus plant plays an important role in agriculture and medical field. So, this paper represents an approach for canker detection in citrus and enhance the image quality. Digital Image Processing techniques can be employed to detect leaf diseases with accuracy compared to the traditional methods. The paper discussed the CLAHE enhancement method to improve the image quality that can be used to detect Citrus Canker Disease. First the sample leaves images are acquired and segmented into multiple parts. Then GLCM color and textures features are extracted and SVM classifiers are applied to detect the disease of the leaves. Experimental results demonstrate that our enhancement model outperforms well in terms of image enhancement and the canker detection based classifiers achieves the efficient results of accurately detecting and differentiate the canker leaf disease.

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