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Identification, classification, and grading of plant leaf diseases using CBIR and K-means clustering

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ABSTRACT

Plant disease management involves the identification, classification, and grading of plant disease according to disease severity. It is not only a challenging task that involves human resources but also includes expertization and timely decisions to reduce the threat of reduced production and high spared of disease. The efficiency of recently developed systems depends on the selection of image features and accuracy in the segmentation of diseased portions. The research in this paper presents Content-Based Image Retrieval (CBIR) system implemented for the identification and classification of leaf diseases. The system is further upgraded with the extraction of diseased portion of the leaf using K-means clustering technique for grading the disease severity. The retrieval system is realized using of color, shape, and texture features of the leaf. It is observed that the proposed system performs the tasks of disease identification, classification, and severity grading accurately and consistently

Keywords: CBIR, Disease, Color, Shape, Texture

I. INTRODUCTION

Most of the population in agricultural countries depends on agriculture for livelihood. Because of suitable atmospheric condition in India agriculturalist have wide range of diversity for cultivation of suitable fruits and vegetable crops. However, the cultivation of these crops for optimum yield and quality produced is highly affected by crop diseases. Hence proper cultivation of crops requires close monitoring especially for the management of diseases that can affect production significantly and subsequently the post-harvest life. Disease is caused by pathogen and its symptoms are observed on plant leaves, stem, flowers and fruits and also produce different traits like change in the size and shape of leaf, stem, flowers and fruits. Identification of the disease in its early stage enables timely cure and control over it. This process requires an expert to identify and classify the disease, describe the method of treatment and protection. Identifying the plant disease is not easy task. It requires experience and knowledge of plants and their diseases. It also requires accuracy in describing the symptoms of plant diseases. Agriculturalist can depend on a system which has experience and knowledge, called an Expert System.

An expert system can be an excellent agriculturalist, agricultural advisor, Electronic or Computerized expert system. An excellent agriculturalist is able to catch the change of the crops in the growing process and they manage the cultivation in proportion to the change. This ability of catching the delicate change in crops is developed in them through the observation and long cultivation experience. It is difficult for them to transmit this knowledge to future generations [1]. If agriculturalists decide to take advice from agricultural expert regarding the treatment of pest /disease/trait to their crop/plant in order to increase the crop productivity then he may face following situations [2]:

i) Sometimes agriculturalist has to go long distances for approaching the expert.
ii) Even though they go such distances expert may not be available at that time.
iii) Sometimes, the expert whom a agriculturalist contacts, may not be in a position to advise him with the available information and knowledge.

In these cases seeking the expert advice is very expensive and time consuming.

Since disease diagnosis which includes identification classification and grading is based on visual inspection, it is possible to apply several image processing and computer vision techniques for diagnosis. The systems developed using such techniques are considered as Electronics expert systems. Electronic expert systems help agriculturalists in identifying diseases, making the right decision of treatment and selecting the best one. The expert systems are intelligent computer programs that are capable of offering solutions or advices related to specific problems in given domain, both in a way and at a level comparable to that of human expert in a field. One of the advantages of using Electronic expert systems is its ability to reduce the information that human users need to process, reduce personnel costs and increase throughput. Another advantage of expert system is that it performs tasks more consistently than human experts [3].

Since electronic expert system works on principle of image pattern understanding & recognition there is increasing demand for development of more specific and sophisticated image pattern understanding` algorithms which helps to obtain precise quantification of visually observed diseases, pests, traits which has not studied well yet because of the complexity of visual patterns. Expert systems are considered one of the most successful methods used to help & support users in making the right decisions, were they lack knowledge in diagnosing plant disease. Electronic expert system identifies given task by comparing input image of the diseased part of plant or crop with stored images. Hence Content Based Image Retrieval(CBIR) is effective technique which target fast interpreting images thoroughly describing the content (color size, shape, texture) and accurately retrieving similar ones.

The objective of such a system is to work with an image obtained by camera, to process it to identify the disease and its severity. Nowadays image acquisition by mobile cameras and its transmission to electronics expert systems is quite an easy task for agriculturalis. This can make experts advice as a single touch to mobile of the farmer which can diagnose image in a short span of time. This paper presents one of such expert disease identification systems developed by using CBIR which is the natural way by which humans diagnose and identify things.

The rest of the paper is organized as: Section 2 elaborates on other scholars' researches thoroughly in the domain of disease and severity detection of different crops. Section 3 illustrates the methodology adopted for the proposed research. Section 4 briefs sample results of the proposed system and Section 5 presents the conclusion.

II. LITERATURE SURVEY

Santanu & Jaya(2008) described a software prototype system [4] for disease detection based on the infected images of various rice plants. Prototype uses image growing and image segmentation techniques to detect infected parts of the plants. Zooming algorithm is used to extract features of the images and infected parts of image are classified using Self organizing map (SOM) neural network. Author concluded that the transformation of image in frequency domain does not yield a better classification compared to the original image.

Shen Weizheng et.al.(2008)developed[5] fast & accurate method for grading of plant disease using image processing. The plant leaf diseases are graded by calculating the quotient of disease spot & leaf area. Disease lesion edge is extracted using Sobel operator followed by morphological operations like region fill and open. Authors reported that application of image processing technology eliminates the subjectivity of traditional classification methods and human-induced errors which increases credibility and accuracy of data provided for disease studies.

System for detection of Grape leaf diseases like scab and rust is developed by Meunkaewjinda et.al.(2008) from color imagery using hybrid intelligent system[6]. Self-organizing maps & back propagation neural networks is used to recognize colors of grape leaf. Grape leaf disease segmentation is performed using modified self-organizing feature maps with genetic algorithms for optimization & support vector machines is used for classification. The segmented image is filtered using Gabor wavelet. This allows the system to analyze leaf disease color features more efficiently. The support vector machines are then used to classify types of grape leaf disease. Disease diagnosis accuracy of 86% is reported in this research.

Ying et.al. (2008) studied methods of image preprocessing for recognition of crop diseases [7]. Samples of cucumber powdery mildew, speckle and downy mildews are used for study and comparative effect of simple filter and median filter is studied. Authors stated that leaves with spots must be pre-processed firstly in order to carry out the intelligent diagnosis to crop based on image processing and appropriate features should be extracted on the basic of this. It makes extraction of characteristic parameters not to be affected by background, shape and size of leaf, light and camera and make a good foundation for the disease diagnoses as well as setting up pattern recognition system.

Qing Yao et.al.(2009) developed application of image processing techniques and Support Vector Machine (SVM) for detecting rice diseases early and accurately[8]. Rice disease spots were segmented based on color and outline of disease spots and their shape and texture features were extracted. Because the color features are influenced largely by outside light, shape and color texture features of disease spot are used for classification. The SVM method was employed to classify rice bacterial leaf blight, rice sheath blight and rice blast. Resesrch showed that SVM could effectively detect and classify these disease spots to an accuracy of 97.2%.

Di Cui et.al.(2009) developed a methods for detecting soybean rust and quantifying severity[9]. The images of soybean leaves with different rust severity were collected by using both multispectral CCD camera and portable spectrometer. Three parameters i.e. ratio of infected area, lesion color index and rust severity index were extracted from the multispectral images and used to detect leaf infection and severity of infection.

Jinghui Li, et.al.(2010) proposed a method of automatic identification of wheat diseases[10]. Otsu algorithm is used to extract the lesion area from the image. Fourteen different morphological characteristics are obtained from segmented region are filtered by using principal component analysis. Around 85% disease detection rate is reported. Authors also suggested need for further research on other diseases.

Hanife Kebapci et al. [11] developed CBIR system for plant image retrieval using color shape and texture features. Color histogram, color co-occurrence matrix and modified Gabor method based on patch based approach is proposed. Along with Scale Invariant Feature Transform (SIFT) which captures local characteristics of the plant; a novel method named as global shape descriptor is proposed. The experiment is carried for identification of house plants with the accuracy of 73%. Authors suggested scope for working on combinations of different features.

H. Al-Hiary et.al.(2011) proposed method for fast & accurate detection & classification of plant diseases[12]. Diseased images are segmented by Otsu segmentation and K-means clustering is used to cluster similar regions. Disease classification is performed using back propagation neural network. Disease detection and classification precision of 83%- 94% is reported in this research. Authors reported the need of research on disease severity estimation.

Viraj Gulhane and Gurjar(2011) developed method for detection of diseases on Cotton Leaves[13]. Features of diseased leaf are extracted from color of the disease using modified self-organization feature map and back propagation neural network. SVM is used to classify cotton leaf diseases. Disease detection efficiency of about 86% is achieved by this method.

Anand and Ashwini (2012) proposed image

processing based plant disease detection technique [14]. The technique uses Gabor filter and artificial neural network. Research is carried for sample leaf images of alterneria, anthractnose and BBD. Disease recognition rate of 91% is achieved using this technique. This is research is carried on very small database.

Kamaljot and Gurjinder (2012) developed method for identification of plant diseases using Content Based Image Retrieval [15]. The disease identification technique is based on color of the leaf. RGB color space is used to separate leaf into three color planes R, G, B. Histogram of these three image planes of the leaf is used to decide whether it is healthy or diseased by comparing it with histogram of database images. Author suggested need of working on more color features and large database. Type of the disease and disease severity is not studied in this research.

Literature survey reveals that many researchers proposed various methods for identifying disease on various crops using image processing. Methods proposed by researchers are mostly on detection and classification of disease type. Comparatively less work has been reported for detection of severity of the disease which is helpful for treatment. Most of the methods are developed using Artificial Neural Networks which take more time for training.

This research work is motivated by all above facts. It is proposed to undertake a detailed investigation of computer vision/image processing algorithms for processing plant leaf images mainly in color to identify, classify and grade diseases to improve both accuracy and throughput.

III. PROPOSED METHODOLOGY

Proposed research is intended for development of system for identifying leaf disease and its severity by using leaf image. It combines CBIR system for disease detection and K-Means clustering based system for computation of area and severity of the disease. Figure 1 shows block diagram of proposed system.

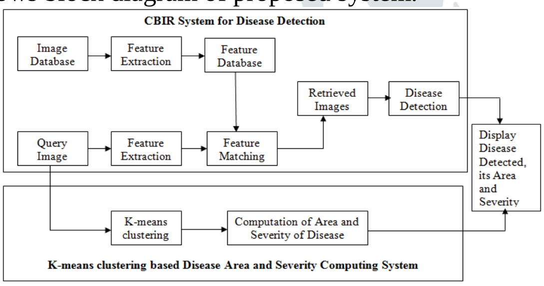


Figure 1: Block Diagram of proposed system

CBIR system involves feature extraction and feature matching. In feature extraction, image feature like color, shape and texture are extracted and stored in Feature Database. Single or multiple features can be used. When query image is given; its feature vector is extracted and compared with the feature vectors in database during Feature Matching. If distance between feature vector of query image and database image is small enough compared with predefined threshold, then corresponding image in database is considered as a match to query image. System retrieves such images. For computing diseased area of the leaf K-means clustering algorithm [16] is used to partition the leaf image into diseased and healthy portions. Depending on diseased area leaf is categorized into five different severity categories.

A. CBIR System for Disease detection

During experimentation and testing, it is found that out of tested color histograms and color moments in three color space RGB,HSV and YCbCr, the YCbCr color histogram provides better retrieval performance than RGB and HSV histogram and moments. Algorithm 1 shows detailed procedure for extraction of color feature in terms of YCbCr histogram. Shape features are extracted in the form of key points of the leaf image which are extracted using Scale Invariant Feature Transform (SIFT) algorithm[11]. Algorithm 2 shows how SIFT is used to extract shape features. Several texture features of the leaf such as LBP [17], Gabor filter[11], LGBP[18] are tested and a new texture feature called as LGGP (Local Gray Gabor Pattern) is proposed for texture extraction. It is found that LGGP provides better retrieval performance than LBP, Gabor and LGBP. Algorithm 3 shows detailed description of process of formation of LGGP Image.

Algorithm1: Color Feature Extraction

Step 1:Read input RGB image

Step 2: Convert RGB image to YCbCr image

Step 3: Find YCbCr histogram of image

Algorithm2: Shape Feature Extraction

Step 1: Read input RGB image

Step 2: Convert RGB image to Gray Image

Step 3: Find key points of image using SIFT algorithm and store it as a Shape Feature

Algorithm3: Texture Feature Extraction

Step 1: Read Query color image $I_c(x, y)$

Step 2: Convert RGB color image to Gray image I(x, y)

Step 3: Compute LBP of gray image

$$LBP = LBP[I(x, y)] \quad (1)$$

Step 4: Apply Gabor filter to gray image.

$$G_I(x, y) = g_{ab}(x, y) \quad (2)$$

Step 5: Compute LGBP i.e. LBP of real part of Gabor Filtered image

$$LBP = LBP[Re(G_I(x, y))] \quad (3)$$

Step 6: Compare each pixel in LBP and LGBP using neighborhood of (3x3) to generate LGGP as per equation (4)

$$LGGP(x, y) = \begin{cases} LBP(x.y) & \text{if } LBP(x, y) = LGBP(x, y) \\ 1 & \text{if } [A \cup B] \text{ have more } 1's \text{ than } 0's \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

Where 'A' is adjacent neighbors of LBP(x, y) and 'B' is an adjacent neighbor of LGBP(x, y).

This step decides value of new pixel in LGGP. If value of a pixel in LBP and LGBP is same then it retains as it is in LGGP. If not it becomes '1' or '0' according to equation (4). After finding values of eight pixels, find its decimal equivalent which is the value of center pixel (x, y).Using this procedure all pixels of LGGP image are computed.

Step 7: Histogram of LGGP image produced in step 6 is used as texture feature.

Algorithm4: Retrieval for Disease detection

Step 1: Create feature database using algorithm 1 through 3.

Step 2: Read Query image

Step 3: Extract features of Query image using algorithm 1 through 3 to create query feature vector.

Step 4:Final feature vector for retrieval is devised by combining following three values.

i) Compute correlation between color histogram of query image and database image.

ii) Similarly compute correlation between LGGP histogram of query image and database image.

iii) Now compute mean value of distance between SIFT key points of query image and database image.

Step 5:Find mean value of feature vector of step 4 .

Step 6: Repeat step 1 through 5 for all database images. Arrange resulting mean values in descending order and retrieve first 40 images. The disease of the query image is same as that of the disease of the maximum retrieved images.

Figure 2 shows block diagram of final feature vector generation used for retrieval.

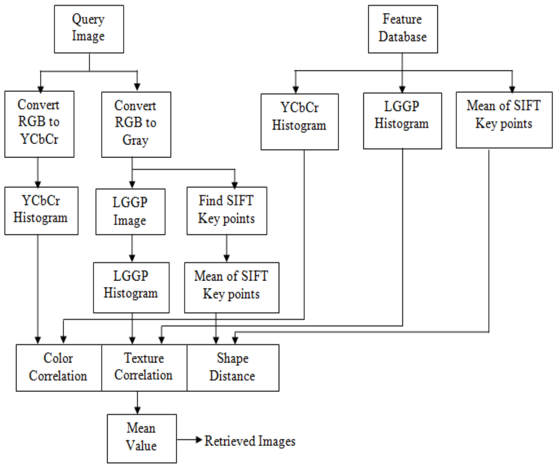


Figure 2: Block diagram of final feature vector generation used for retrieval

B. K-Means Clustering Based Disease Severity Computing System

Computation of diseased area requires the segmentation of diseased portion of the leaf from the healthy portion. Segmentation partitions the image into meaningful parts for better analysis and understanding of the image. Thresholding and region growing are two basic approaches of segmentation. Thresholding is simplest where gray image can be partitioned based on threshold value. The image is converted into binary image based on whether the image pixels fall below or above the threshold value. This approach does not provide effective segmentation of the image and hence limits the classification of the various objects of the image if the image contains multiple regions or parts or color. Further it reduces proper detection of the required area. The region growing approach is advantageous in such situations. K-means clustering is one of the popular algorithm in this approach.

Algorithm5: K-means clustering for Computation of diseased area and disease severity

Let 'p' is set of data points and 'c' is set of centers given by equation (5) & (6) respectively

$$p = \{p1, p2, p3, \ldots\ldots\ldots\ldots, pn\} \qquad (5)$$

$$c = \{c1, c2, c3, \ldots\ldots\ldots\ldots, cn\} \qquad (6)$$

Step 1: Randomly select 'N' cluster centers.

Step 2: Calculate the distance between each data point and cluster centers.

Step 3: Assign the data point to the cluster center whose distance from the cluster center is minimum of all the cluster centers..

Step 4: Recalculate the new cluster center using equation(7)

$$C_i = \left(\frac{1}{N_i}\right)\sum_{j=1}^{N_i} P_i \qquad (7)$$

where, 'N_i' represents number of data points in ith cluster.

Step 5: Recalculate the distance between each data point and new obtained cluster centers.

Step 6: If no data point was reassigned then stop, otherwise repeat from step 3.

Step 7: Partition image into two clusters using steps 2 through 6 such that one cluster contains all green portion (Healthy) of the leaf and another cluster contains diseased portion of the leaf .

Step 8:Compute disease area of leaf using equation(8)

$$\text{Diseased Area(DA)} = \frac{p_d}{p_t} * 100 \qquad (8)$$

Where,

p_d= no of pixels in diseased cluster;

p_h= no of pixels in healthy cluster

p_t= no of pixels in diseased cluster+ no of pixels in healthy cluster $=p_d+p_h$

Step 9:Compute disease severity using equation(9)

$$\text{Disease Severitya(DS)} = \begin{cases} 0 & \text{if } 0 \leq DA \leq 9 \\ 1 & \text{if } 10 \leq DA \leq 25 \\ 2 & \text{if } 26 \leq DA \leq 50 \\ 3 & \text{if } 51 \leq DA \leq 75 \\ 4 & \text{otherwise} \end{cases} \qquad (9)$$

IV. EXPERIMENTAL RESULTS & DISCUSSIONS

A. Database: Database is created using healthy and diseased leaf images of Maize, Soybean and potato. These are collected from various agricultural fields of Kolhapur and Sangali district of Maharashtra, India. The details of the database are shown in table I below:

Table I: Database

Maize	Disease	Quantity	
		Database	Query
Maize	Rust	100	130
	Leaf Blight	100	125
	*Healthy	100	110
Potato	Leaf blight with Trait	100	125
	Leaf blight	100	130
	*Healthy	100	134
Soybean	Septoria Brown Spot	100	111
	Alfalfa Mosaic Virus	100	155
	*Healthy	100	110
Total		900	1130

B. Results: The experiment is performed in MATLAB. The results are carried out by designing CBIR system for individual features like color, shape and texture. Then these features are combined to improve retrieval performance. The performance of CBIR system is evaluated using retrieval precision or Accuracy and Recall[11]. The % of retrieval precision gives the retrieval efficiency.

i) CBIR using Color features: Color histogram and moments are used as color features. It is found that Histogram in YCbCr color space provides better performance than RGB and HSV. Figure 3 shows sample result of top 40 retrieval for soybean leaf affected by Mosaic Virus.

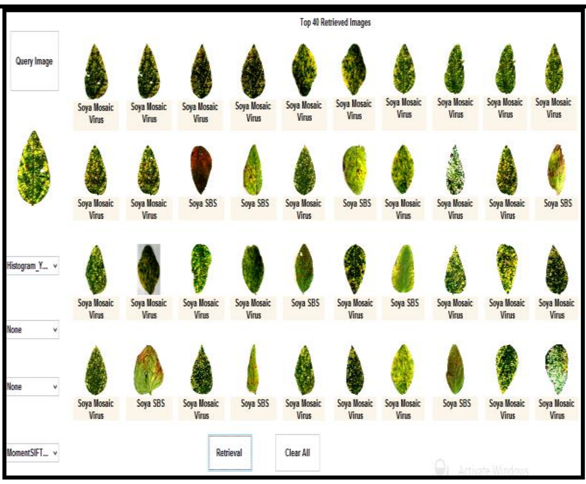
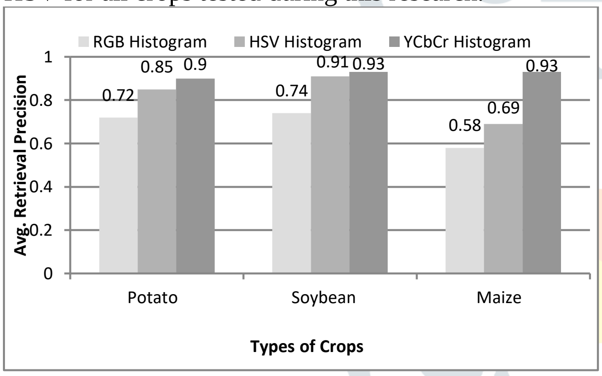
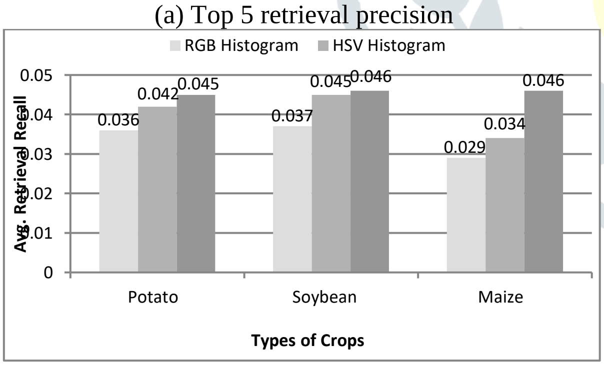


Figure 3: CBIR using YCbCr Histogram

It is observed that all retrieved images are not of the query type. This is because of the fact that different images may have the same histogram if the distributions of colors are same in the images. Hence in the retrieved results it is observe that, images which are not of query type but have color distribution which closely matches to the query color. This is the limitation of color feature during retrieving similar images. Figure 4(a) and 4(b) shows performance comparison of average precision and recall for top 5 retrieval of YCbCr color histogram with RGB and HSV for all crops tested during this research.



(a) Top 5 retrieval precision



(b) Top 5 retrieval recall

Figure 4: Performance comparison of CBIR using color histogram

ii)CBIR using Shape features: Key points of an image are extracted using SIFT algorithm. Retrieval result in figure 5 shows that all images with shape correspondent with query shape are retrieved. Average retrieval precision of 0.54 is provided by SIFT.

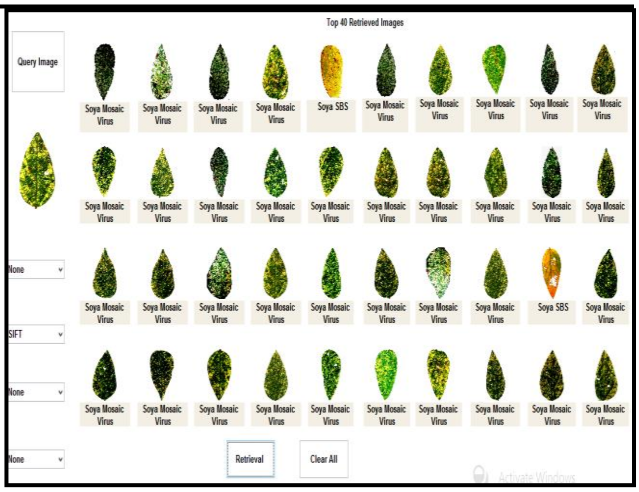


Figure 5: CBIR using SIFT

iii)CBIR using Texture features: The performance of CBIR using LBP, LGBP and LGGP are tested. It is found that LGGP provides better retrieval. Figure 6 shows sample result of LGGP based retrieval which indicates that maximum retrieved images have similar texture as query image texture. Figure 7(a) and (b) shows performance comparison of average precision and recall for top 5 retrieval of using all texture features for all crops tested during this research.

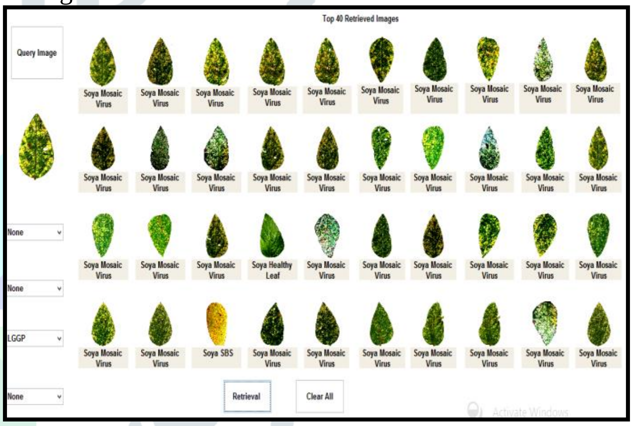
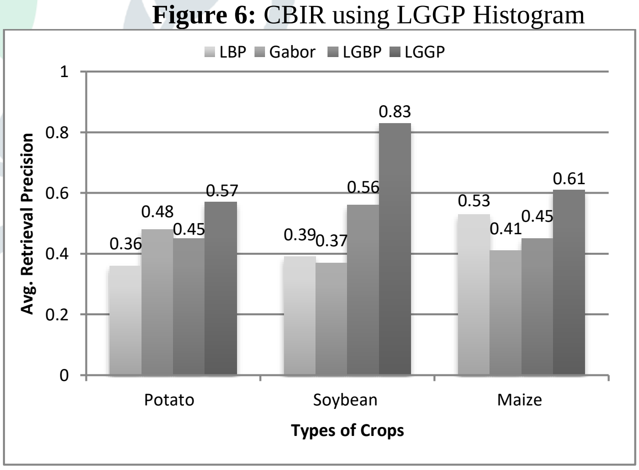
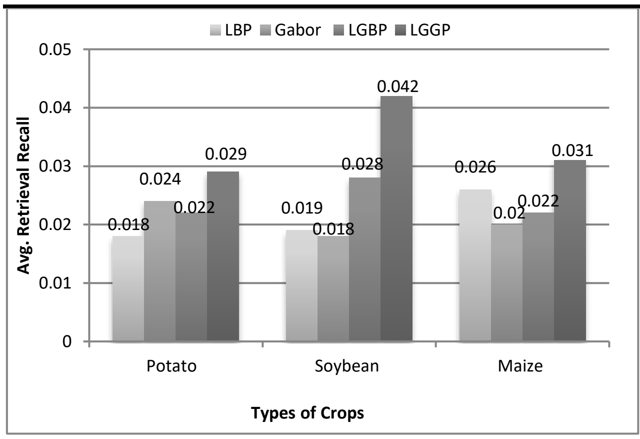


Figure 6: CBIR using LGGP Histogram



(a) Top 5 retrieval precision



(b) Top 5 retrieval recall

Figure 7: Performance comparison texture features

iv)CBIR using combined features: To take advantage of characteristic of color, shape and texture feature all feature can be combined. It is found that when YCbCr Histogram is combined with SIFT and LGGP all aspects of image i.e. color, shape and texture are considered. Hence optimized performance is achieved as shown in figure 8. It is also found that combination of color histogram and SIFT as well as combination of color histogram and LGGP histogram also provides equally good precision. Table II shows performance comparison of combination of YCbCr color histogram with SIFT and LGGP.

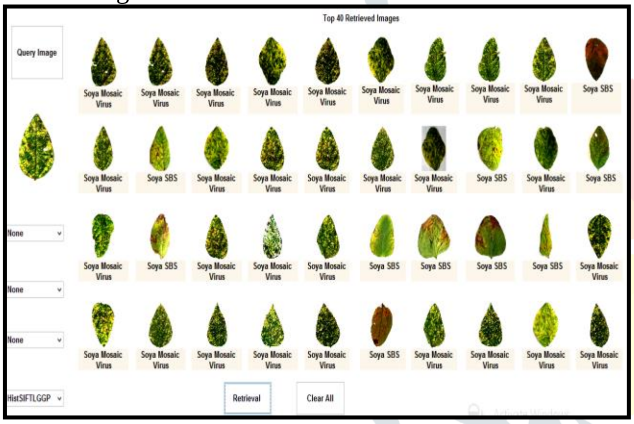


Figure 8: CBIR using combined features

Table II: Performance comparison of Feature Combination

Features	Potato		Soybean		Maize		Average	
	Precision	Recall	Precision	Recall	Precision	Recall	Precision	Recall
Histogram + SIFT	0.89	0.044	0.93	0.046	0.91	0.045	0.91	0.045
Histogram +LGGP	0.92	0.046	0.94	0.047	0.89	0.044	0.92	0.046
Histogram + SIFT+LGGP	0.78	0.039	0.91	0.045	0.91	0.045	0.87	0.043

v) Result of disease and its severity detection using K-means clustering algorithm: Proposed method also computed diseased area of leaf using K-means Clustering. It segments the diseased portion of the leaf into two clusters, one containing diseased portion and another containing healthy portion as shown in figure 9.

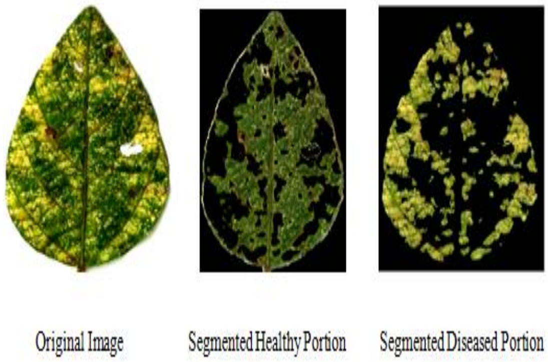


Figure 9: Disease Segmentation

When this technique is combined with CBIR system it provides severity and percentage of diseased area of leaf along with identification of type of the disease. Figure 10 shows result of final CBIR system which works as expert system showing disease detected, diseased area and severity category.

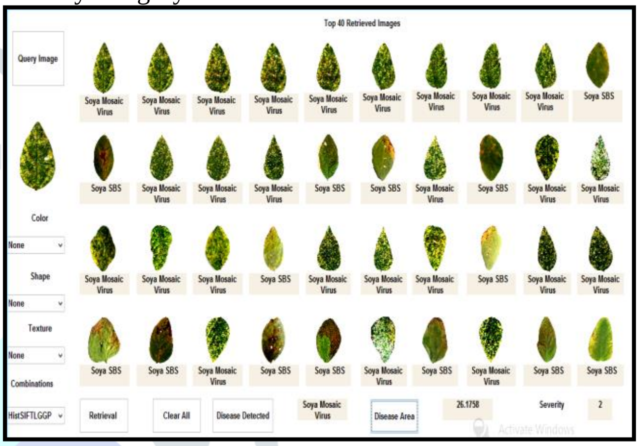


Figure 10: CBIR using combined features and K-means clustering

V. CONCLUSION

Proposed CBIR System is specifically designed for agricultural applications. Leaf diseases of three crops/plants are taken for experimentation. These are soybean, Maize and Potato. The individual performance of color, shape and texture features is analyzed. It is found that color histogram in YCbCr color space provides better performance than other color features taken for experimentation. Also it is observed that newly proposed LGGP texture feature provides better performance than LBP and LGBP. Almost all combinations of color with shape, color with texture and shape with texture are tested. It is found that three different combinations provide promising results. These are combination of YCbCr histogram and SIFT Key points, combination of YCbCr histogram and LGGP histogram and combination of YCbCr histogram, SIFT key points and LGGP histogram. Average retrieval efficiency achieved using these three combinations are 91%, 92% and 87% respectively. Combination of color shape and texture features provides optimized performance as all aspects of image i.e. color, shape and texture are utilized. Our work is similar in aspect of feature extraction and combination to work presented by Hanife Kebapci et.al [11] who developed CBIR system for recognition of household plants with precision of 73%.

Proposed method also computed diseased area of leaf using K-means Clustering. It segments the diseased portion of the leaf into two clusters, one containing diseased portion and another containing healthy portion. When this technique is combined with CBIR system it provides percentage of diseased area and disease severity along with identification of type of the disease. This resulted in a system which automatically provide information of crop disease and its severity. It is found that disease detection efficiency of 98% is obtained.

These results are tested for number of randomly selected images and compared with opinion of agricultural expert. There exist small difference in the area computed by proposed method and area observed by agricultural expert. This is because the expert opinion is based on naked eye observation which also suffers from subjectivity.

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