Image Processing for Smart Farming: Detection of Disease and Fruit Grading

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Abstract— **Due to the increasing demand in the agricultural industry, the need to effectively grow a plant and increase its yield is very important. In order to do so, it is important to monitor the plant during its growth period, as well as, at the time of harvest. In this paper image processing is used as a tool to monitor the diseases on fruits during farming, right from plantation to harvesting. For this purpose artificial neural network concept is used. Three diseases of grapes and two of apple have been selected. The system uses two image databases, one for training of already stored disease images and the other for implementation of query images. Back propagation concept is used for weight adjustment of training database. The images are classified and mapped to their respective disease categories on basis of three feature vectors, namely, color, texture and morphology. From these feature vectors morphology gives 90% correct result and it is more than other two feature vectors. This paper demonstrates effective algorithms for spread of disease and mango counting. Practical implementation of neural networks has been done using MATLAB.**

Keywords— **Color, morphology, texture, segmentation, wavelet packet, artificial neural network,back propagation.**

I. INTRODUCTION

THE studies of plant trait/disease refer to the studies of visually observable patterns of a particular plant. Monitoring of health and detection of diseases in plants and trees is critical for sustainable agriculture. Early information on crop health and disease detection can facilitate the control of diseases through proper management strategies such as vector control through pesticide applications, fungicide applications, and disease-specific chemical applications; and can improve productivity.

For disease detection various techniques have been used in last few years. In [1] spectroscopic and imaging techniques, Molecular techniques and Profiling of plant volatile organic compounds are used for disease detection. In [1] the spectroscopic and imaging technology could be integrated with an autonomous agricultural vehicle for reliable and real-time plant disease detection to achieve superior plant disease control and management.

Smart farming is about empowering today's farmers with the decision tools and automation technologies that seamlessly integrate products, knowledge and services for better productivity, quality and profit. Technological advances in these areas gather increasing momentum and this means that maintaining an overview of latest developments becomes more and more of a challenge. It’s all about applying the latest tools for sustainably securing yield potentials in respective areas. These yield potentials should also be improved on if possible. It’s also about applying these innovations to increase crop production efficiency and thereby reduce inputs of natural resources.

The purpose of this paper is to monitor diseases on the stem/leaf/fruits of the crop and suggest solutions to them for healthy yield and productivity. For this purpose neural network concept is used. For training of this neural network a database of diseased images has been created. For extracting the features of each image color, morphology and texture features vectors are used. In [2] the process of mapping original features (measurements) into fewer, more effective features is termed feature extraction. This is used in mapping of query image with training images .This mapping is done by using Euclidean distance concept. For detection of diseases morphology feature vector gives excellent results than color and texture because it uses the high frequency boundary information.

Two fruits namely apple and grapes have been used for research in this paper. Selected infected diseases are as follows:

1. *Grapes*
   a) Black Rot
   b) Powdery Mildew

Fig 1. Black rot and Powdery mildew on grape leaf.

2. *Apple*
   a) Apple Scab
   b) Rot

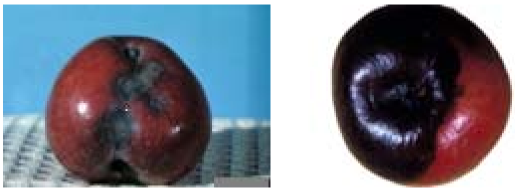

Fig 2.Apple scab and Apple Rot.

In [4] Plant diseases are because of climate change, water availability, temperature and many more.

Role of Image Processing in Smart Farming:

The image processing can be used in agricultural applications for following purposes:

1. To detect diseased leaf, stem, fruit on apple and grapes
2. Disease spreading
3. Computing weight of fruits.

Inspired by [1] [3] [5] & [9], we propose techniques to monitor diseases on the stem, leaf and fruits of the crop and also suggest solutions to them. We propose an experimentally evaluate a software solution for automatic detection and classification of plant leaf diseases and fruits.

Disease spreading and weight of fruits are used for fruit grading. We have selected mango fruit and by using some particular algorithm, calculated the weight of mango. In [7] however, mangoes grading by humans in agricultural setting are inefficient, labor intensive and prone to errors. Automated grading system not only speeds up the time of the process but also minimize error. According to Federal Agricultural Marketing Authority (FAMA) Malaysia, size of mango is determined by weight. In [6] a relationship between mango pixels and mango weights was analyzed using statistical method of regression. In [7] fuzzy logic is used for mango grading. Spread of disease is done by using K-means clustering method.

II. METHODOLOGY

A. *Features for image classification*

Color, morphology and texture three feature vectors are used for feature extraction of learning database images. These features are called low level features.

1. *Color*

Color is one of the most important properties which humans use for object discrimination.

Color image processing is divided into three principle areas:

a) Color transformation (color mapping).

b) Spatial processing of individual color planes.

c) Color vector processing.

In [8] RGB color space is affected from light and angle at which image has captured so to avoid this problem HSI color space is used.

RGB to HSI color transform:

$$H=\begin{cases} thita & if\ B < G \\ 360 - thita & if\ B > G \end{cases} \tag{1}$$

Here,

$$thita = \cos^{-1}\left\{\frac{\frac{1}{2}(R-G)+(R-B)}{[(R-G)^2+(R-B)(G-B)]^{1/2}}\right\} \tag{2}$$

$$S=1-\frac{3}{(R+G+B)}[min(R,G,B)] \tag{3}$$

$$I=\frac{1}{3}(R+G+B) \tag{4}$$

Algorithm for color feature vector:

The nearest matching database images with the query image has the least distance metric. The exact match is the one with zero distance metric.

$$hist_{dist}=\sum_{j=0}^{255}[hist(j)_{database} - hist_{query}] \tag{5}$$

Where, *j denotes the various gray levels,*
hist_query is the histogram of query image,
hist_database is histogram of the database image,
hist_dist is error difference or distance metric.

The histogram data for all images in database are computed and saved in database in advance which can be used to compare the query image with images in database. Here we have quantized H, S & V planes at 8,8,4 levels respectively. This is done in order to give less importance to V plane and have less computational time.

2. *Morphology*

Morphology term is denoted as a tool for extracting image components that are useful in the representation and description of region shape, such as boundaries. By using morphology, we are extracting disease shape feature vector from healthy leaf/fruit. Like color, RGB space is converted into HSI with quantized H, S &I planes at 30, 30, 20 levels respectively.

Algorithm for morphology feature vector:

In each plane, boundaries of all database images are obtained by using erosion concept. In this operation, the state of any given pixel in the output image is determined by applying the rule in which the value of the output pixel is the minimum value of all the pixels in the input pixel's neighborhood, i.e. as given by the following equation:

Erosion= {Z/ (B) z⊆A} (6)

Image Boundary= Original image - Eroded image (7)

In this equation, erosion of A (indicates database images) by B (input image) is the set of all points Z such that B, translated by Z, is contained in A.in morphology DCT transform is used because it represents complete shape information by using few coefficients.

3. Texture

This property describes visual patterns, each having properties of homogeneity. Here, Daubechies 2-D wavelet packet decomposition is used. In [5] the identification of specific textures in an image is achieved primarily by modeling texture as a two-dimensional grey level variation.

A wavelet is represented by the following equation:

$$\psi^{ab}(x) = |a|^{(-1/2)}\ \Psi({}^{x-b}/_{a}) \tag{8}$$

Then,

$$w_{\Psi}=\frac{1}{\sqrt{a}}\int_{-\infty}^{\infty} f(t)\Psi({}^{t-b}/_{a})dt \tag{9}$$

Where,

$\Psi(x) = mother\ wavelet$

$\psi^{ab}(x)$=*daughter wavelet*

B. Role of ANN in image classification

After feature extraction, learning database images are classified by using neural network. These feature vectors are considered as neurons in ANN. Output of neurons is a function of the weighted sum of the inputs plus a bias. The function of the entire neural network is simply the computation of the outputs of all the neurons.

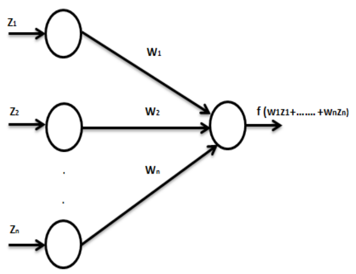

Fig 3(a).General neuron model (shows relation between input and output neurons).

Here, z_1, $z_2 \ldots z_n$ are feature vectors.

Majority of ANN's use sigmoid functions as an activation function.

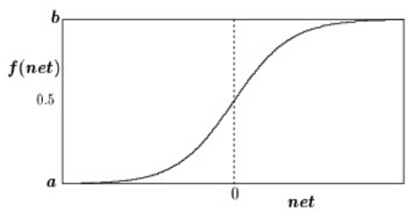

Fig 3(b) .Sigmoid functions

Here, f (net) =tanh (x.net-y) +z (10)

When $y = 0$ and $z = 0$:

$a = 0,\ b = 1,\ c = 0.$

When $y = 0$ and $z = -0.5$

$a = -0.5,\ b = 0.5,\ c = 0.$

Larger x gives steeper curve.

1. Back propagation:

Back propagation algorithm is used in a recurrent network. Once trained, the network weights are frozen and can be used to compute output values for new query images which are not in learning database.

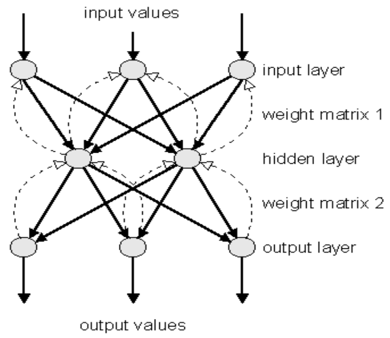

Fig 3(c).Back propagation network.

2. Testing of query image

Once the weight of learning database has been calculated then ANN is able to test for any query image which is not already in learning database.

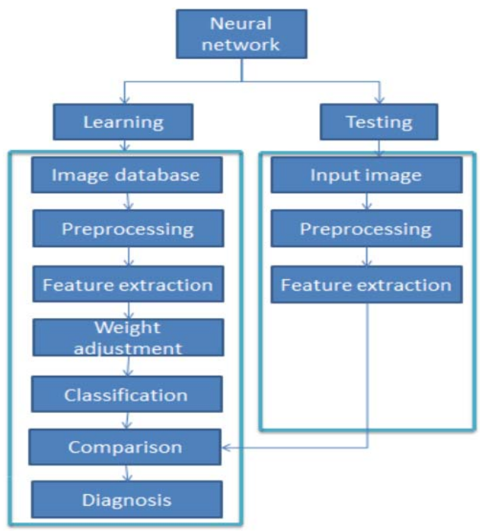

Fig 3(d).Working principle of ANN.

The above figure.3 (d) shows the basic principle at which NN system works.

C. Automated grading of fruit:

Two methods are used for fruit grading

1. Spread of disease.
2. Automated calculation of mango weight.

1. Spread of disease

Spread of disease is done by using K-means clustering.

In this clustering segmentation has done and disease area of leaf has separated.

%Percent infection= (Ad/At)*100 (11)

Where, *Ad=Total no. of pixels in disease area.*
At=Total no. of pixels.

2. *Automated calculation of mango weight*

The statistical analyses results show that the mango pixels counted has high relationship with the mango weights.

Weight of the mango by pixel count is calculated by mathematical formula given below:

Weight = 0.0029*Pixel – 17.084 (12)

This equation is only valid if following setup is used:

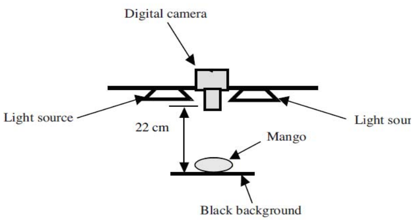

Fig 4.Setup for automated mango grading.

This setup is proposed by C.C. Teoh in [6] .He has done the constant experiments for finding maximum accuracy in mango weight and finally derived this setup.

So through these two above methods, grading of fruit can be done. If a fruit is large in weight that does not mean its quality is good, there can be some diseases on that. So weight and spread of disease finally show the quality of fruit and through this quality, grading of fruit can be done easily.

III. Results and Discussion

A. *Detection of disease*

Ninety two images are used for learning of the system. Color, morphology and texture features are used for feature extraction. Learning is a process by which the system learns the input parameter and classifies the input images into different classes. This has done by using NN toolbox in Matlab.Three hidden layers, one input and one output layer are used in this.

At the end of training, the weights will approximate the average value of the inputs in that class. We will use this weight for testing of images.

Various metrics can be used to grade the performance of the neural network based upon the results of the testing set

- Mean square error (MSE), SNR.

We are using mean square error concept in this paper. In minimum MSE condition training of database will get stop.

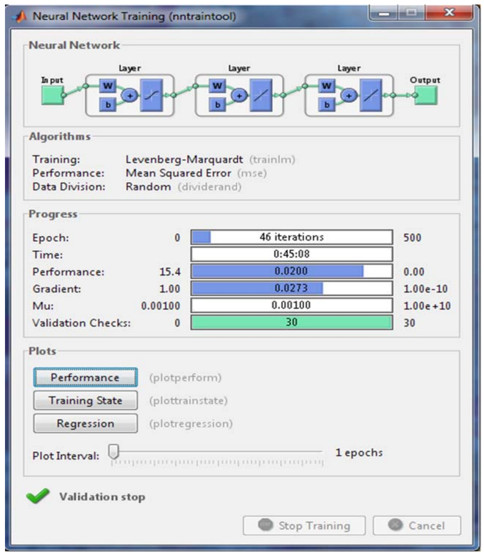

Fig 5(a).NN Training by using NN train tool

Simulation results:

The saved weights are used map every query image to the particular class. When a query image is applied then it maps it to the class which it may belong depending upon the simulation value.

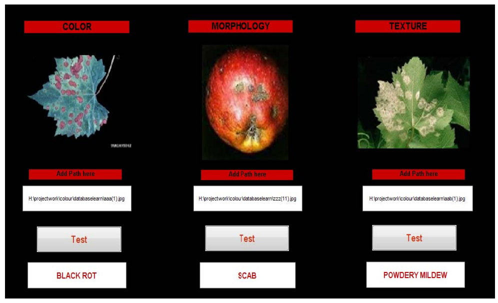

Fig 5(b). Combined result of all three feature vectors

This above figure shows the result of three disease images which are not in learning database. From all three features (color, texture and morphology), morphology shows better result.

B. *Automated grading of fruit*

Automated grading of fruit is done by finding spread of disease and weight of fruit.

1. *Spread of disease*:

In the present work fuzzy logic is used for disease spreading.

Following steps are used for finding disease spread:

- Image acquisition:

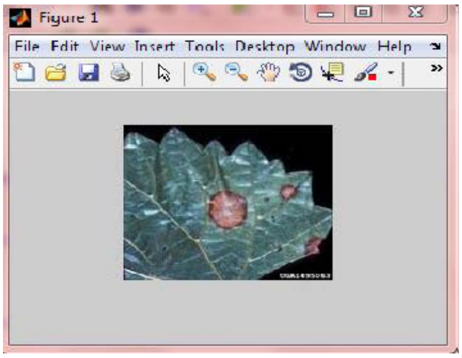

Fig 6(a). Query Image.

- Image preprocessing:

The acquired image is resized to a standard size of [200,250].

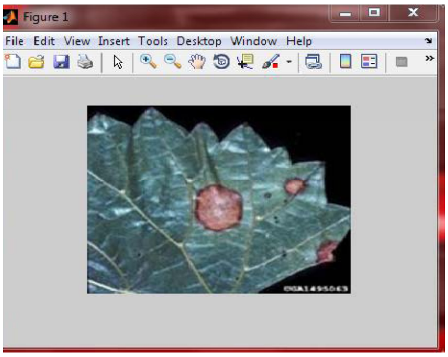

Fig 6(b).Resized image

- Color image segmentation:

The query image is segmented to separate out the diseases part and healthy part.

From the figure.6 (a) total pixel counts are:

AT= 52339 pixels

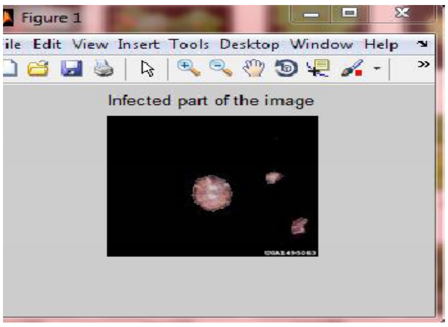

Fig 6(c).Diseased part of leaf

From figure.6 (b) disease pixels are:

AD = 4626 pixels

So percent infection is:

PI= (AD / AT) *100

= (4626 / 52339) * 100

= 8.8385 %

In [7] Fuzzy logic is used for grading based on spread of disease:

Table I: Disease Scoring Scale for Leaves

Percentage Infection	**Disease Grade**
0	0
Up to 1	1
1-10	2
10-20	3
20-40	4

So according to infection of disease grading can be done.

2. *Automated calculation of mango weight*

Again same steps are needed for calculating weight of mango.

- Image acquisition

Image of the mango is taken from a digital camera at fixed distance i.e.at 22cm above the base at which mango is kept.

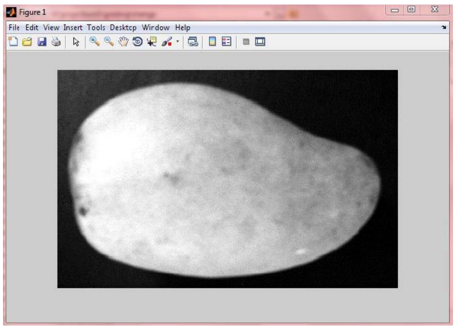

Fig 7(a). Acquired image of mango.

- Image segmentation:

The filtered image is thresholding in order to segment the area covering mango and total pixel is counted.

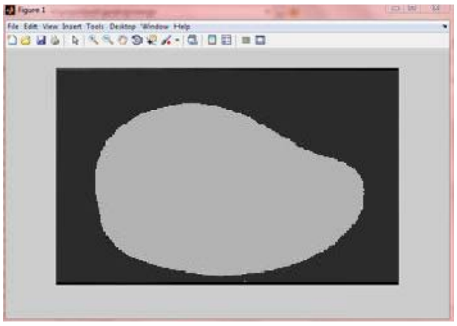

Fig 7(b).Segmented image

- Result:

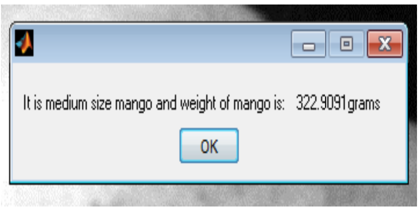

Fig 7(c).Weight of mango

This is the automatic calculation of mango weight. In this way weight of any mango can be calculated and from this, quality/type of mango can be easily known. But if any disease is there on fruit then its quality will get reduced. So through these two methods grading of any fruit can be done.

IV. CONCLUSION

1) Disease detection:

Based on our experiments, the developed neural network can successfully detect and classify the tested disease. For our network, we get better results for color and morphology as compared to texture, as the diseases are defined better by these features.

2) Disease spreading :

With the help of image processing a method for leaf disease grading has been achieved. In this depending upon the percentage ratio of diseased area on leaf over entire leaf area grading has been done. The query image is segmented into six grades depending on percentage of infection. The grade will help farmers to determine how much insecticide to be applied.

3) Mango grading depending on the weight:

This method is achieved by counting area of mango from an image taken at a fixed distance of 22 cm. the area of mango is measured by counting the pixels of mango and with the help of a mathematical formula weight of mango is calculated and classified into five different grades based on its weight.

It would promote Indian farmers to do smart farming and help take decisions from time to time for a better yield. Fruitful Interaction with agricultural units (govt/private) in nearby area and help them in agricultural research.

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