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Estimation of Nitrogen in Rice Plant Using Image Processing and Artificial Neural Networks

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***Abstract**: This paper presents a prototype which identifies the 4-panel LCC and Spad meter values equivalent of rice plants using image processing techniques and artificial neural networks. Images of rice leaves were captured by digital camera and processed through image acquisition, color transform, image enhancement and feature extraction procedures. Suitable Features are extracted which serves as input to neural network trained to predict the LCC panel equivalent of leaf. Artificial neural network is trained using images of rice leaf with the corresponding classes using backpropogation method.*

1. Introduction

Nitrogen is one of the essential mineral which plays an important role in yield of crops. Insufficient nitrogen leads to reduced grain yield and quality, excessive N leads to environmental problems of atmospheric and water pollution .To overcome this drawback we use methods to estimate the amount of Nitrogen content in rice leaf since rice is one the most consumed grain.

One primary cause of high production cost in rice farming is the fertilizer. Farmers operate their farms in the traditional way that applies fertilizer not on the basis of plant condition but on a predetermined date upon seeding. This results to either over application or under application of fertilizer since rice growth is not uniform in every area. Both of these cases lead to damage to crops resulting to a lower yield.

Present agricultural technology researches discourage the use of traditional farming and advocate precision farming. The application adopts the functionalities and guidelines of the LCC (Leaf Color Chart) and SPAD meter device. Database system provides a continuous monitoring on rice status since it stores the readings on previous samples. It is necessary that the samples be less prone to noise for accurate results; thus filtering methods are applied as necessary.

In the recent years there has been a great revival of neural networks offering wide array of application. Backpropagation neural network has been the favorable method used by different researchers especially in image processing area such as plant diseases detection and analysis.

This prototype aims to eliminate subjectiveness in the analysis of the nitrogen level of rice plant by implementing a prototype of image processing system with training model called Artificial Neural Network using Backpropogation algorithm providing an objective, efficient and reliable system for farmers and researchers in the field of agriculture.

2. Present Systems

A. Dumas method for estimating nitrogen

The Dumas method is a method for the quantitative determination of nitrogen in chemical substances. The method consists of combusting a sample of known mass in high temperature (around 900^{o}C) chamber in presence of oxygen. This leads to release of carbon dioxide, water and nitrogen. The gases are then passed over special columns that absorb carbon dioxide and water. The thermal conductivity detector at the end is used to separate nitrogen from residual gases and calibrates the amount of nitrogen.

Major disadvantage is its high initial cost, time consuming and infeasible assessment method for farmers.

B. Spad meter (Chlorophyll meter)

Spad meter is a portable handheld device developed to measure the chlorophyll content of plant leaves. The device uses the amount of light passing through the leaf and Minolta Company

defined SPAD (Soil Plant Analysis Development) values to assess relative chlorophyll content in leaf. The linear relationship of SPAD reading and leaf nitrogen concentration has lead to its adaption as a tool to assess nitrogen status of plant
Major disadvantage is being high-priced in market, not affordable to most farmers.

Figure 1.SPAD meter

C. LCC (Leaf Color Chart)

The LCC has been jointly developed by International Rice Research Institute (IRRI) and Philippines Rice Research institute. The LCC is composed of four or more panels, ruler-shaped designed where the panel are arrayed horizontally from yellowish green to dark green. The user needs to match the middle part of rice leaf with its corresponding color strip on panel which provides the LCC reading and approximate nitrogen fertilizers to apply to the fields.
Major disadvantage of this approach is being subjective to the viewer's eye acuity variant to sunlight, environmental factors and biological age of the person.

Figure 2.Four Panel LCC chart

3. Implementation of Artificial Neural Network in Assessing Nitrogen Content.

An Artificial neural network is computational models that simulate the biological nervous system. The basic element of artificial neural networks are (1) Set of input nodes (2) a set of synaptic connections whose strengths are represented by set of weights and (3) an activation function Y that relates the total synaptic input to the output (activation) of the neuron. For implementing ANN there are three phases: Design, training and execution. In the Design phase the architecture of the network is defined: number of inputs, outputs and layers and the activation function of neurons. The training phase consists of determining the weights of the connections of the network through a learning algorithm such as Back propagation. Finally the execution phase is performed using the fixed parameters of the network obtained during the learning phase. Back Propagation BP network is the most famous and activity model in all the feed forward neural networks. Its kernel is the back propagated algorithm. BP neural network consists of input layers, hidden layers and output layers. The number of hidden layer is determined by practical situation.

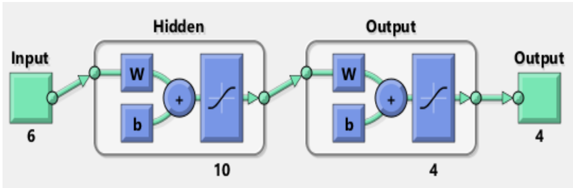

Figure 3.Architecture of Neural network of Proposed Prototype

The neural network is created with six input nodes, (one for each feature extracted from the rice leaves), hidden layers with ten neurons and four output nodes (one for each possible LCC equivalent).
The neural network is trained using backpropogation algorithm which rearranges the hidden layer neurons which eventually leads to4 output neurons representing the LCC four panel equivalent classification of Test leaf.

4. Configuration and Training the Neural Network

The database used in this study consists of the features of the rice leaf images acquired from the rice fields of GKVK institute Bangalore. Using the controlled-light module box, the images of 194 rice leaves (50 photos corresponding to Spad values range 0-29,50 photos corresponding to Spad values range 30-39, 44 photos corresponding to Spad values range 40-78 and 50 photos corresponding to Spad values range 79-120) were captured and fed to the program as input. Variability in numbers of the images per panel is due to the availability of the rice leaves that matched the Leaf Color Chart panel and Spad meter value under the guidance of GKVK institute Bangalore.
In the Confusion matrix, the rows represent the output classes and column the target classes. The diagonal cells in each table show the number of cases that were correctly classified and off-diagonal cells (red) show the misclassified cases. The database was divided into three sections. 1)70% were used for training 2) 15% for testing and remaining3)15% for validation.

Below are few sample images used for training ANN for classifying the Test image for the correct classification and suggests the approximate amount of fertilizer to apply for the farmers reference.

Figure 4. LCC 1 image

Figure 5. LCC 2 image

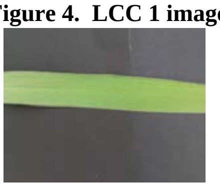

Figure 6. LCC 3 image

Figure 7. LCC 4 image

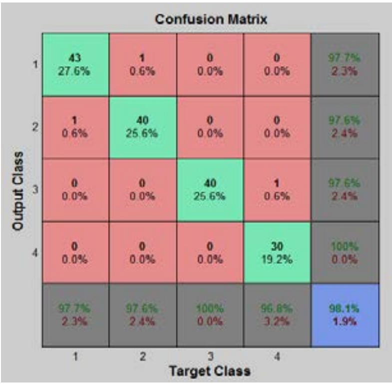

Figure 8. Confusion Matrix of Validation of Designed Neural network

5. Proposed Methodology

The image processing part comprises of image acquisition, color transformation, image enhancement, image segmentation and feature extraction as given below implemented using matlab software.

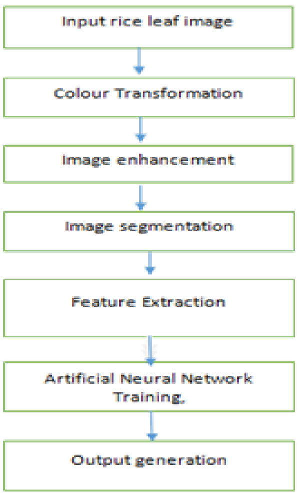

Figure 9. Proposed Methodology Flow Diagram

1) Image Acquisition

Images were acquired using a digital camera with at least five megapixels of resolution. The Leaf is placed over a black chart paper for uniform distribution of light and captured either under the shade of person, umbrella or a light controlled box depending on the availability.

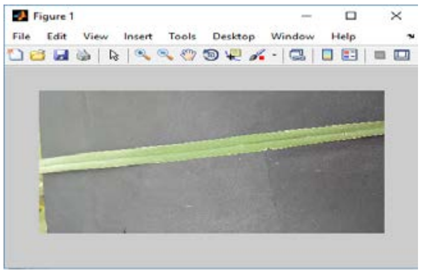

Fig 10. Input Image

2) Color Transformation

After the acquisition of image, the image is converted into HSV color space. The HSV color space model is based on Tint , Shade and Tone respectively. Hue H is the quality that refers to dominant color perceived by the observer, value runs from 0 to 360^{o}.Saturation S is the color sensation.
V color space is chosen for further processing in comparison to other color model due to the clear separation between leaf part and the background as Value ranges from 0 to 1, where 0 is the black and 1 is pure white.

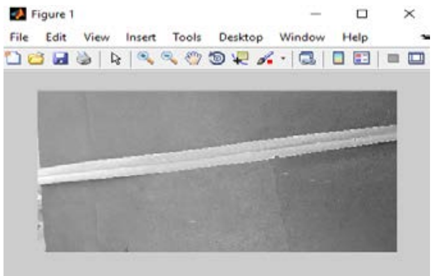

Fig 11. V color space

3) Image Enhancement

Due to variability of light and camera acquisition conditions image enhancement is required to adjusting digital images so that the results are more suitable for display or further image analysis. The image enhancement process involves noise reduction and contrast adjustment. Median filter is used for Noise reduction, linear contrast adjustment and histogram equalization are used for contrast adjustment and Otsu's method is used to produce a pure black background. The value color plane had its intensity adjusted so that the darker parts of the image go darker to aid the image segmentation process.

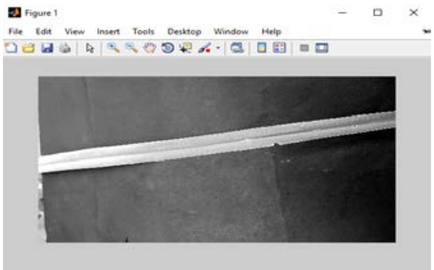

Fig 12. Contrast adjustment

Morphological operation such as imfill and erode functions are used to fill holes in the Binary image and smoothen the edges of the leaf in order to consider all the pixel of the leaf for further segmentation and avoid considering erroneous background pixels of chart paper.

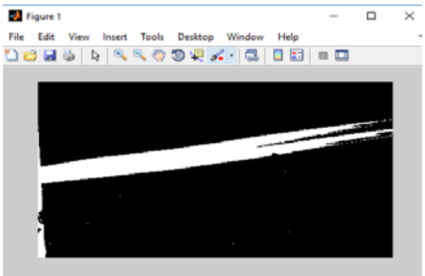

Fig 13. Morphological operation

4) Image Segmentation

After the alteration of the captured image, threshold value and morphological operations converts the processed image to binary-level image (black and white image).But still small white pixels are present after the conversion to binary-level image. Largest Blob extraction is used to extract only the desired leaf section of image. The rice leaf part of the image is considered as the largest blob and the other blobs present in the image are omitted.

Blob Extraction computes each of the blob as number of pixels of value=1(white in binary image) using 4 neighborhood property, retains the largest pixel number blob and converts other smaller blob as pixel values=0(black in binary image).After acquiring the largest blob is then converted to original RGB image and pixels of value= 0 are retained thereby having pure black color background Segmented RGB image which improves accuracy and performance of feature extraction step.

Segmented RGB image can be further enhanced using median filter for noise reduction.

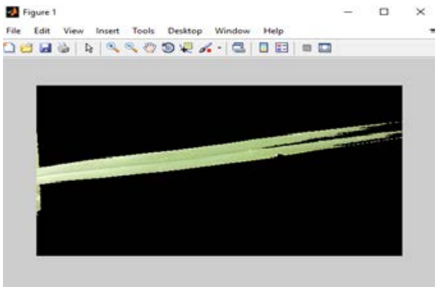

Fig 14. Image segmentation

5) Feature Extraction

For considering the suitable features all color space models were studied and analyzed to find the six most reliable features to train neural network, texture and geometric property has no relation with the problem statement.

Using the Linear regression as predictive analysis which is used to describe relationship between one dependent variable with one or more independent variables , it was found HSV and LAB color space had r^2 significantly closer to one for Independent variable being Spad meter values of Test leaves to the corresponding separated components of various color space as dependent variable. Also LCC chart panel differentiation was similar to the concept of Hue and Saturation. Matlab function cftool is used to calculate r^2 values of different color models.

Therefore In feature extraction, Six features extracted from the processed image are the mean values of the (1)Hue, (2)Saturation and (3)Value of the Leaf; and the mean values of (4) Lightness, (5) a axis and (6) b axis from Lab color space. The L axis represents Lightness. The axis extends from green (-a) to red (+a) and b axis from blue (-b) to yellow (+b).

Mean values of Hue, Saturation, Value and Lightness can be computed by removing all zero valued pixels from separated color space matrix and then using mean function in Matlab. Similarly mean values of a and b axis is computed by removing pixel value=128 from separated color space matrix which represents pure black color in a and b axis and then using mean function to calculate mean values.

6) Artificial Neural network

The extracted features were computed using basic functions provided in matlab software and stored in 6x1 matrix. This data is fed to the pre-trained neural network to identify the LCC equivalent of captured image.

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6. Prototype Software Developed for Estimating nitrogen in rice leaf.

The input of the Nitrogen Detection system is an image of the rice leaf that is given by capturing an image by a webcam or a mobile camera. The input can be a single leaf image that needs to be processed with HSV-color space for noise removal and brightness adjustment. Then it is converted pure black and white and the resulting features is extracted and subjected to training so that the system is able to and classify the image using the input. This is repeated for many images for accurate data collection. Pre-defined neural network is classifies based on Extracted features. The GUI of the prototype was build using Guide command in Matlab with a pre-requisite to import variable having the pre-trained neural network.

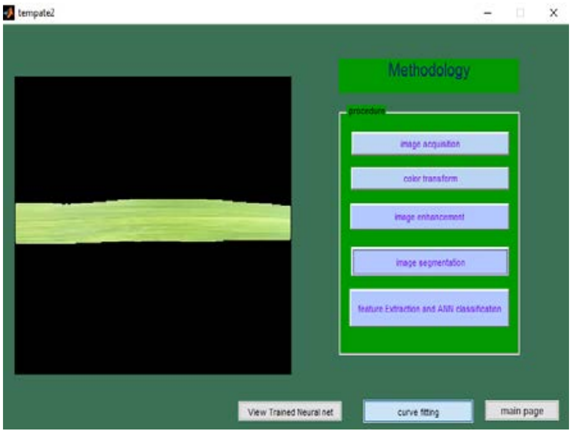

Fig 15. Prototypes build on Matlab software

6.1 Neural Network Classifier

The features of the test leaf extracted is compared with features of trained ANN using the 194 images based on Spad value ranges acquired from GKVK institute to categorize the leaves into four distinct classes. The accuracy of classification was observed to be significantly high having R=0.9461 close to 1 depicted by plotregression function.

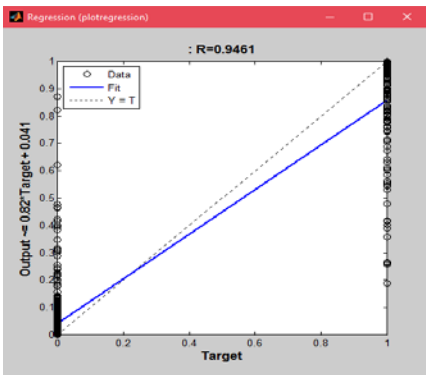

Fig 16. Plotregression of trained neural network

6.2 Final output

We get the final result after the leaf getting classified into its respective category of LCC chart and also estimate the amount of Nitrogen fertilizer that are needed to be applied.

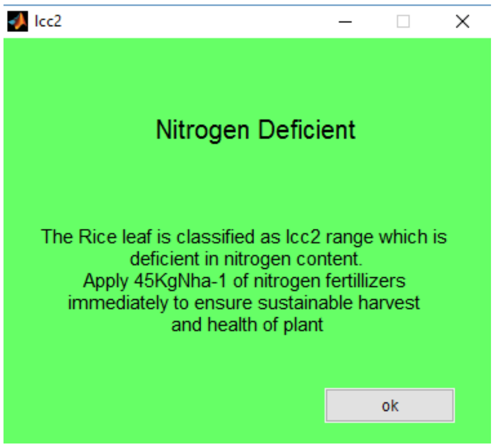

Fig 17. Final Output

7. Results and Discussion

The proposed system was validated using 37 Leaf sample from unvisited rice field for unbiased validation. The Prototype correctly classified the images to corresponding Lcc chart range cum Spad meter value ranges to 92% accuracy. The observations are given below as Test Cases.

Test Cases

Table2. SET 2 of test case

Sample	Expected output(Lcc)	Spad value	Result (1 if equal or 0)
1	1	23.2	1
2	1	21.3	1
3	1	24.3	1
4	1	28.5	1
5	1	28.5	1
6	1	22.2	1
7	1	29.9	1
8	1	21.7	1
9	1	22.3	1
10	1	19.9	1
		Average	10/10

Table2. SET 2 of test case

Sample	Expected output(Lcc)	Spad value	Result (1 if equal or 0)
1	2	31.7	1
2	2	35.9	0
3	2	35	1
4	2	32.4	1
5	2	34.6	1
6	2	34.7	1
7	2	33.1	1
8	2	33.9	1
9	2	34.6	1
		Average	8/9

Table3. SET 3 of test case

Sample	Expected output(Lcc)	Spad value	Result (1 if equal or 0)
1	3	34.7	0
2	3	43.2	0
3	3	43	0
4	3	71.3	1
5	3	56.7	1
6	3	50.4	1
7	3	55.4	1
8	3	46.6	1
9	3	44.7	1
		Average	6/9

Table3. SET 4 of test case

Sample	Expected output(Lcc)	Spad value	Result (1 if equal or 0)
1	4	79.9	1
2	4	120.9	1
3	4	82.2	1
4	4	88.5	1
5	4	101.7	1
6	4	85.9	1
7	4	100.1	1
8	4	91.9	1
9	4	106.5	1
		Average	9/9

8. Conclusion

The proposed approach is capable of detecting the Nitrogen Content in rice crops .The strength of the proposed technique is robust against color changes of the leaf due to environmental conditions. The Prototype is Objective and independent of Viewer's acuity also provides a cheaper alternative to estimating nitrogen content in rice plant via existing systems. The prototype can developed as system implemented using web interface and android technology with more accuracy in the coming years of research in this topic.

9. Acknowledgements

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