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Fuzzy Inference System Based Unhealthy Region Classification in Plant Leaf Image

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***Abstract*—**In addition to environmental parameters like rain, temperature diseases on crop is a major factor which affects production quality & quantity of crop yield. Hence disease management is a key issue in agriculture. For the management of disease, it needs to be detected at early stage. So, treat it properly & control spread of the disease. Now a day, it is possible to use the images of diseased leaf to detect the type of disease by using image processing techniques. This can be achieved by extracting features from the images which can be further used with classification algorithms or content based image retrieval systems. In this paper, color image is used to extract the features such as mean and standard deviation after the process of region cropping. The selected features are taken from the cropped image with different image size samples. Then, the extracted features are taken in to the account for classification using Fuzzy Inference System (FIS).

***Keywords*—**Image Cropping, Classification, Color, Fuzzy Rule, Feature Extraction.

I. Introduction

IN any country, most of the population depends on agriculture and agriculture is one of the major domains which decides the economy of the nation. The quality & quantity of the agricultural production is affected by environmental parameters like rain, temperature & other weather parameters which are beyond the control of the human. Another major parameter which affects the productivity of crop is the disease in which human beings can have control to improve the productivity for quality as well as for quantity. The diseases can be controlled by proper disease management which is a challenging task. This challenge can be converted to easiest task by using image processing for detecting diseases of leaf, stem, root & fruit. Here, the tomato leaves are considered for analysis because, tomatoes are the most popular & widely grown vegetable food crops in the World. Crops of tomatoes have socioeconomic importance to families, gardeners, farmers, labors, marketers, retailers, chefs and other services in the food and restaurant industries. Many diseases and disorders can affect the tomatoes during their growth, the most common diseases such as [9]:

1. Early Blight: The tomato leaves will have one or two spots per leaf, approximately ¼ to ½ inch in diameter. Spots have tan centers with concentric rings in them and yellow halos around the edges
2. Late Blight: Spots that start out pale green, usually near the edge of tips of foliage, and turn brown to purplish-black. In humid conditions, a mold appears on the undersides of leaves
3. Septoria Leaf Spot: Numerous brown spots appear on the leaves, approximately 1/16 to 1/8 inch in diameter. The spots lack a yellow halo, and, upon close inspection, have black specks in the center.

Image processing techniques are used in diverse filed of applications. Here, it is possible to detect the affected area, type of disease & severity of the disease by using some of the image processing techniques [4]. Mostly diseases are seen on the leaves or stems of the plant. Because of the complexity of visual patterns of the diseases there has been an increasing demand for development of more specific and sophisticated image pattern understanding algorithms which can be used for studies like classifying lesion, scoring quantitative traits, calculating area eaten by insects, etc. [10]. Now a day's almost all of these tasks are processed manually or with distinct software packages [12]. It is not only a tremendous amount of work but also it suffers from two major factors

i) Excessive processing time
ii) Subjectiveness rising from different individuals

Hence to conduct high throughput experiments, plant biologist needs efficient computer software to automatically extract and analyze significant features. As far as the leaf of the plant is considered, the significant features can be obtained by

1. Color of the leaf
2. Texture of the leaf
3. Shape of the leaf

Color is one of the most widely used features [1]. Color features can be obtained by various methods like Color histogram [2], [3], Color R moment [1], [5], [6], Color structure descriptor [7]. The Color moment method has the lowest feature vector dimension and lower computational complexity. Hence it can be considered as suitable parameter to generate feature vectors which can be further used for classification purpose or for image retrieval [11].

In this paper, color feature is considered for the classification diseases affected region of the tomato leaves.

II. Proposed Methodology

There are six steps in this proposed work and it is discussed in detail given below:

1. Image Preprocessing
2. Image Cropping
3. Features Extraction
4. Fuzzy Systems

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5. Classification using Fuzzy System
6. Evaluation

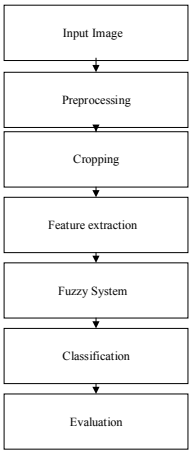

Fig. 1 Proposed method for fuzzy rule based unhealthy region classification in plant leaf

A. Preprocessing

Preprocessing methods use a small neighborhood of a pixel as an input image to get a new brightness value in the output image. Such preprocessing operation is also called filtration. Local preprocessing methods can be divided into two groups according to the goal of the processing.

Smoothing suppresses noise or other small fluctuations in the image; equivalent to the suppression of high frequencies in the frequency domain. Unfortunately, smoothing also blurs all sharp edges that bear important information about the image.

Gradient operators are based on local derivatives of the image function. Derivatives are bigger at locations of the image where the image function undergoes rapid changes. The aim of gradient operators is to indicate such locations in the image. Gradient operators suppress low frequencies in the frequency domain (i.e. they act as high-pass filters).Noise is often high frequency in nature unfortunately, if a gradient operator is applied to an image the noise level increases simultaneously.

B. Cropping

Cropping an image allows you to cut out any portion of the image you don't like or make an image smaller. This paper contains the steps performed to crop an image in each of the major image

C. Feature Extraction

There are two features are considered in this proposed work and it is calculated from the cropped image taken from the original image which contains both healthy and unhealthy region.

1. First Feature

It is called Mean. It provides average color value in the image. It is calculated using

$$Mean = \sum_{i,j=0}^{N-1} i(P(i,j)) \quad (1)$$

2. Second Feature

It is called standard deviation. It is calculated using

$$standard\ deviation = \sqrt{\sum_{i,j=0}^{N-1} iP(i,j)} \quad (2)$$

The standard deviation shows how much variation or dispersion exists from the average (mean, also called expected value). A low standard deviation indicates that the data points tend to be very close to the mean; a high standard deviation indicates that the data points are spread out over a large range of values.

D. Fuzzy Systems

Fuzzy systems propose a mathematic calculus to translate the subjective human knowledge of the real processes. This is a way to manipulate practical knowledge with some level of uncertainty. The fuzzy sets theory was initiated by Lofti Zadeh in 1965 [2].The advantages of the fuzzy systems are:

- Capacity to represent inherent uncertainties of the human knowledge with linguistic variables
- Simple interaction of the expert of the domain with the engineer designer of the system;
- Easy interpretation of the results, because of the natural rules representation;
- Easy extension of the base of knowledge through the addition of new rules;
- Robustness in relation of the possible disturbances in the system.

And its disadvantages are:

- Incapable to generalize, or either, it only answers to what is written in its rule base;
- Not robust in relation the topological changes of the system, such changes would demand alterations in the rule base.
- Depends on the existence of an expert to determine the inference logical rules.

E. Classification Using Fuzzy System

The general operation of the fuzzy system is performed based on the following process.

1. Fuzzification

The process that allows converting a numeric value (or crisp value) into a fuzzy input is called fuzzification. There are two ways to do fuzzification: 1.fuzzy singleton 2.fuzzy set Singleton fuzzification is generally used in implementation where there is no noise.

2. Defuzzification

Defuzzification is the reverse process of fuzzification. Mathematically, the defuzzification of a fuzzy set is the process of conversion of a fuzzy quantity into a crisp value, i.e. rounding off from its location in the unit hypercube to the nearest vertex. This may be necessary if we wish to output a number to the user.

3. Fuzzy If-Then Rules

Fuzzy sets and fuzzy sets operations are the subjects and verbs of fuzzy logic [8]. If-Then rule statements are used to formulate the conditional statements that comprise fuzzy logic.

A single fuzzy If-Then rule assumes the form

$$\text{If x is A1 then y is B2} \quad (3)$$

where A1 and B2 are linguistic variables defined by fuzzy sets on the ranges (i.e. universe of discourse) X and Y respectively. The If-part of the rule 'x is A1' is called the antecedent or premise and the Then-part of the rule 'y is B2' is called the consequent. In other words, the conditional statement can be expressed in a mathematical form

$$\text{If A1 Then B2 or A1} \rightarrow \text{B2} \quad (4)$$

F. Role and Types of Inference Mechanism

Inference is the process of formulating a nonlinear mapping from a given input space to the output space. The mapping then provides a basis from which decisions can be taken. The process of fuzzy inference involves all the membership functions, fuzzy logic operators and if-then rules.

There are three types of fuzzy inference, which have been widely employed in various applications. The differences between these three fuzzy inferences, also called fuzzy models, lie in the consequents of their fuzzy rules, aggregations and defuzzification procedures. These fuzzy inferences are

1. Mamdani fuzzy inference
2. Sugeno fuzzy inference
3. Tsukamoto fuzzy inference

1. Mamdani Fuzzy Inference

The Mamdani type fuzzy modelling was first proposed as the first attempt to control a steam engine and boiler by a set of linguistic control rules obtained from experienced human operator [13].

2. Sugeno Fuzzy Inference

The Sugeno fuzzy model, also known as the TSK fuzzy model, was proposed by [14], [15] in an effort to develop a systematic approach to generate fuzzy rules from a given input-output data set.

3. Tsukamoto Fuzzy Inference

In the Tsukamoto fuzzy model, the consequent of each fuzzy if-then rule is represented by a fuzzy set with a monotonic MF [16]. As a result, the inferred output of each rule is defined as crisp value included by the rule's firing strength. The overall output is taken as the weighted average of each rule's output. Since each rule infers a crisp output, the Tsukamoto fuzzy model aggregate each rule's output by the method of weighted average and thus avoids the time-consuming process of defuzzification.

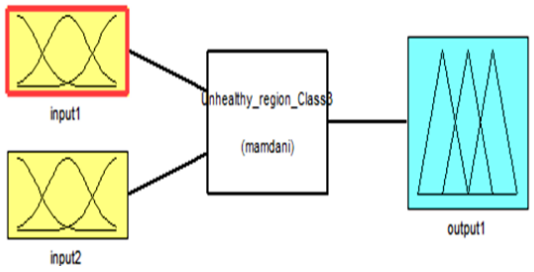

Fig. 2 Mamdani Fuzzy Inference Systems

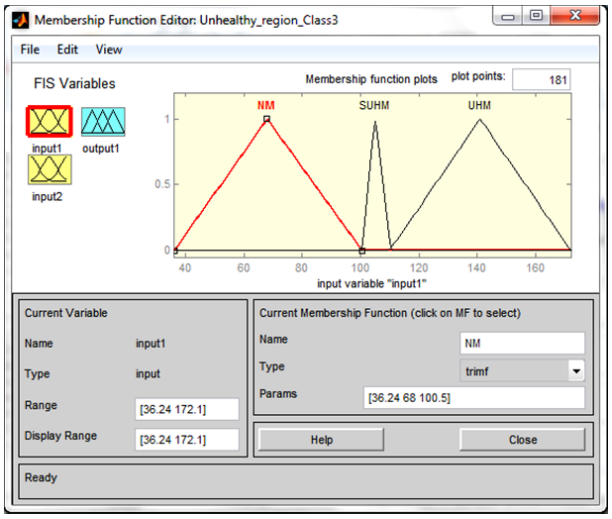

Fig .3 Triangle membership function for inputs- Mamdani Fuzzy Inference Systems

III. Experimental Results

The experiment is implemented using MATLAB image processing tools & fuzzy tools. For the experiment single leaves of the tomato affected by late blight disease is used.

Fig. 4 Disease affected tomato leaves with cropped region

Fig. 4 shows the leaf images used for experimentation. Then the image is cropped in to two categories like healthy

and unhealthy portion by implementing command (imcrop) in MATLAB [9]. Then for each of the Color component three features are obtained which are tabulated in Tables I-III.

TABLE I
FEATURES TAKEN FROM NORMAL LEAF PORTION

mean	std	size
83.93962	1.280861	66x44
70.22396	2.732773	48x106
95.87813	4.205729	120x86
67.14724	1.320914	53x90
100.1057	4.143962	154x50
36.24504	1.160413	32x42
66.37367	1.115709	34x34
66.24103	1.184303	65x84
85.27255	2.901506	68x105
104.5752	1.619852	151x30
78.66015	3.119016	62x146
100.5312	0.307905	106x99
81.18911	1.273666	22x27
96.88553	4.067064	177x84
85.47523	0.170669	21x33
36.74362	6.079918	96x73
66.83576	1.47863	49x70
66.57274	0.308427	13x97
66.30731	1.431867	48x83

TABLE II
FEATURES TAKEN FROM UNHEALTHY LEAF PORTION

Mean	Std	Size
153.5073	0.843826	39x110
160.5232	1.020096	38x61
161.8576	0.590536	68x40
158.3511	0.36301	39x26
150.7638	0.731322	42x133
137.9525	1.211503	43x36
140.9794	0.483287	40x47
151.4947	1.355746	36x97
172.1288	0.215664	46x16
163.2101	1.194176	102x20
152.865	0.779097	81x71
138.5693	0.314628	46x66
151.827	0.800212	23x23
114.2162	0.164674	8x57
119.8882	2.843669	38x28
111.1868	0.365576	104x41
120.4802	0.488656	136x65
122.9809	0.369871	101x100
117.3206	0.542204	99x65
110.5309	0.778491	38x37

TABLE III
INPUT VALUES FOR FUZZY RULE

	Normal	Unhealthy
Mean	36.24-100.53	110.53-172.12
std	0.307-6.07	0.215-2.843
Average	2.01-6.07	0.643-2.843

From Table III, the range of lightly disease affected leaf features such as mean value is from 100.53-110.53 and standard deviation is from 2.01-2.843 for different cropping image size of around 100 samples. These values are calculated from Tables I and II, which indicate the features of various healthy and unhealthy portion of a single leaf image respectively.

A. Fuzzy Rules for Classification

The following rules are created by using values of Table III which is derived from the values of Tables I and II. A fuzzy rule consists of two linguistic variables.

1. (input1==NM)&(input2==NS)=>(output1=Normal)(1)
2. (input1==UHM)&(input2==US)=>(output1=Unhealthy)
3. (input1==SUHM)&(input2==SUHS)=>(output1= slightly_ healthy)(1)
4. (input1==NM)=>(output1=Normal)(1)
5. (input1==UHM)=>(output1=Unhealthy)(1)
6. (input1==SUHM)=>(output1= Slightly_ healthy)(1)
7. (input2==NS)=>(output1=Normal)(1)
8. (input2==US)=>(output1=Unhealthy)(1)
9. (input2==SUHS)=>(output1= Slightly_ healthy)(1)

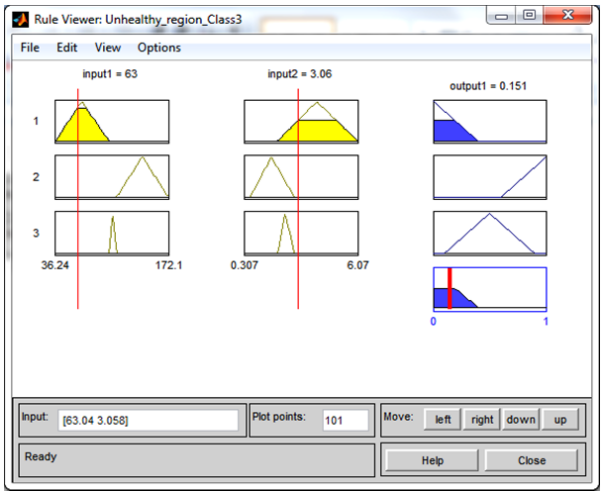

Fig. 5 Results of normal (healthy) portion of tomato leaves

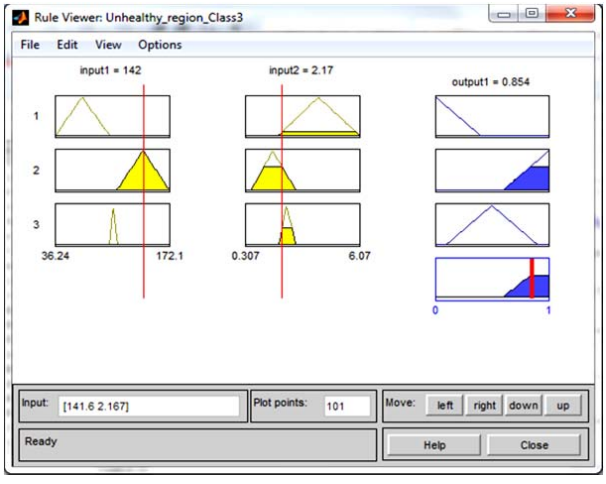

Fig. 6 Results of unhealthy portion of tomato leaves

B. Performance Evaluation

The performance of this fuzzy rule based healthy and unhealthy region classification is satisfies the expected result. There are 100 training samples are taken from the single leaf and tested with more than 20 samples. Hence the fuzzy rule based system produced more than 95% classification accuracy and it can produce minimal number of classification error rate is 5%.

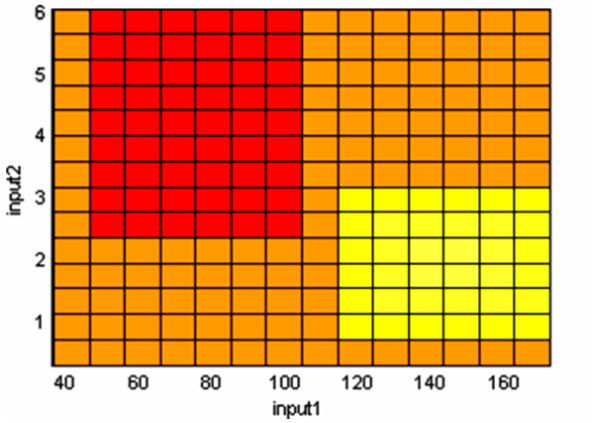

Fig. 7 Results of healthy, unhealthy and slightly unhealthy portion of tomato leaves

Fig. 7 shows the results of fuzzy rule based system can able to categories in to three regions like healthy, unhealthy and slightly unhealthy [5]. Here, the color orange indicates the leaf which is not affected (healthy portion of the leaf) by disease, temperature and whatever the factors in the environment. The color red indicates the leaf which is affected slightly. Next, the color yellow indicates the leaf which is affected more on the affected portion of the leaf.

IV. Conclusion

The main contribution of this paper was proposed an approach fuzzy rule-based system using color features for the classification disease affected plant leaf image region. The proposed method FIS using color features were clearly classified the region such as healthy, slightly affected disease portion and highly affected disease portion of the plant leaf image. This method produced the accuracy of 95% with minimum error rate of 5%. Classifying the unhealthy region is the main purpose of the proposed approach. The experimental results indicate the proposed approach can detect the leaf diseases region with little computational effort.

The extension of this work will focus on developing methodology for better feature extraction and neural networks in order to increase the recognition rate of classification process.

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