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A Survey on Applications of Fuzzy Logic in Agriculture

[1] Sanjeev S Sannakki, [2] Vijay S Rajpurohit [3] Arunkumar.R

Abstract— **The sole area that serves the food needs of the entire human race is the Agriculture sector. Research in agriculture is aimed towards increase of productivity and food quality at reduced expenditure and with increased profit. The challenge of the precision approach is to equip the farmer with adequate and affordable information and control technology. Methods for identification of diseases found in any parts of the plant play a critical role in disease management. Consequently minimizing plant diseases allows substantially improving quality of the products. Many methods and techniques of image processing and soft computing are applied on a number of plants for early detection and diagnosis of different plant diseases. Since fuzzy logic can effectively handle the vague image data, present paper discusses several aspects and techniques of precision agriculture which employ Fuzzy logic.**

Index Terms— **Fuzzy Logic, Support Vector Machine (SVM).**

I. INTRODUCTION

The objectives of precision agriculture are profit maximization, agricultural input rationalization and environmental damage reduction, by adjusting the agricultural practices to the site demands. Plant disease is one of the crucial causes that reduces quantity and degrades quality of the agricultural products. The ability of disease diagnosis in earlier stage is very important task. There are numerous characteristics and behaviors of such plant diseases in which many of them are merely distinguishable. Hence an intelligent decision support system for Prevention and Control of plant diseases is needed which is an integrated agricultural information platform, that uses some high-tech and practical technology, such as fuzzy logic, neural networks, support vector machines and such other soft computing techniques to appropriately detect and diagnose the plant diseases.
Fuzzy set theory is an extension of conventional set theory that deals with the concept of partial truth. Fuzzy logic aims to model the vagueness and ambiguity in complex systems. In many image processing applications, expert knowledge must be used for applications such as object recognition and scene analysis. Fuzzy set theory and fuzzy logic provide powerful tools to represent and process human knowledge in the form of fuzzy IF-THEN rules.

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Sanjeev S Sannakki,, Department of CSE,Gogte Institute of Technology, Belgaum, Karnataka, India. (e-mail :sannakkisanjeev@yahoo.co.in)
Vijay S Rajpurohit, Department of CSE, Gogte Institute of Technology, Belgaum, Karnataka, India. (e-mail : vijaysr2k@yahoo.com)
Arunkumar.R, Department of CSE, Gogte Institute of Technology, Belgaum, Karnataka, India. (e-mail : kumararun37@gmail.com)

II. RELATED WORK

Over the past few decades, fuzzy logic has been used in a wide range of problem domains. The areas of applications are very wide: process control, management and decision making, operations research, economies and pattern recognition and classification. In the lack of precise mathematical model which will describe behavior of the system, Fuzzy Logic is a good "weapon" to solve the problem: it allows using logic if-then rules to describe the system's behavior.
In the paper of "Image Classification Based on Fuzzy Logic" a prior knowledge about spectral information for certain land cover classes is used in order to classify SPOT image in fuzzy logic manner. More specifically, input (image channels) and output variables (land classes) are introduced in Matlab's environment, membership functions are defined using results from supervised classification which was conducted with PCI ImageWorks®, Matlab's Fuzzy Logic Toolbox was then used in definition of fuzzy logic inference rules, these rules are tested and verified through the simulation of classification procedure at random sample areas and at the end, SPOT image classification was conducted.
Output images coming from PCI maximum likelihood (ML) and fuzzy classification can be compared which is shown in fig 1. These grayscale images are produced in such a way that pixels coming from the same class have the same digital numbers in both images: water (50), urban (100), crop 1 (150), crop 2 (200) and vegetation (250). This is the basis for image comparison. Percentage of classified pixels in both methods is given in the following table:

TABLE I. PERCENTAGE OF CLASSIFIED PIXELS IN ML AND FUZZY CLASSIFICATION

Method class	**PCI**	**Fuzzy**	**Difference**
Water	1.25	1.39	0.14
Urban	15.62	13.95	1.67
Crop1	13.1	17.24	4.14
Crop2	28.82	34.11	5.29
Vegetation	37.90	29.99	7.91

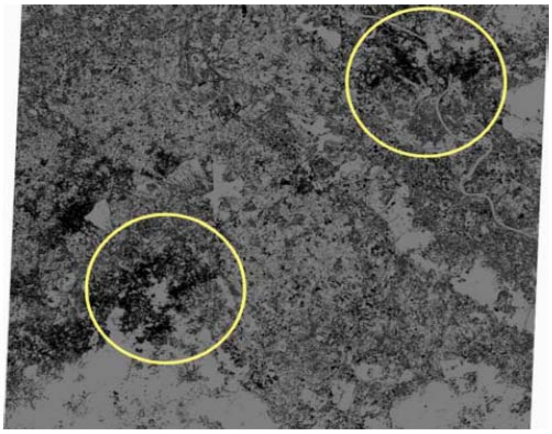

Figure.1 ML and Fuzzy classification comparison image Courtesy: Reference [1]

The experimental results showed that fuzzy logic can be satisfactorily used for image classification providing a greater level of classification accuracy.

The main objective presented in the paper "Recognition of Weeds with Image Processing and Their Use with Fuzzy Logic for Precision Farming" is to develop a methodology for processing digital images taken from cornfields in order to determine a weed map. Based on the weed map, a program was then developed to simulate the control of an herbicide sprayer. Given that information concerning economic thresholds of weed impact on crop productivity cannot easily be adapted to a given region or even to a given farm, the researchers decided that the fuzzy logic approach should be employed to convert image data into sprayer command and the existing fuzzy logic controller was limited to the control of one nozzle. The Fuzzy Logic Toolbox v2.0 of MATLAB was used to develop the fuzzy logic model for the herbicide application. In this project, a fuzzy logic system was developed to simulate human decision-making in determining herbicide application based on greenness and patch size. There are three components in a fuzzy logic system: fuzzy values for inputs and outputs, a set of fuzzy rules, and fuzzy inference mechanism. In fuzzy inference, several fuzzy membership functions are developed to generate a degree of truth. The fuzzy logic herbicide application model was tested on a hypothetical field to determine the potential herbicide savings. The reductions in herbicide use compared to a uniform application for different combinations of weed coverage and weed patch thresholds are listed in the following table:

TABLE II. RESULTS FOR REDUCTION IN HERBICIDE USE (%) BY VARIABLE-RATE APPLICATION USING DIFFERENT THRESHOLD VALUES

Weed Patch Threshold	Weed coverage threshold 1%	2%	3%	4%	5%
1%	4.86	6.44	8.28	10.33	12.76
2%	5.41	7.32	9.34	11.52	13.91
3%	6.39	8.74	11.38	14.19	16.71
4%	7.80	10.60	13.93	17.43	20.32
5%	9.78	12.82	16.66	20.72	24.03
On/Off Application	14.56	24.97	39.69	53.57	63.72

The results of this study have shown that weeds can be located by the greenness method and a fuzzy logic controller automatically manages herbicide applications to obtain effective weed control, reduce costs, and minimize soil and water pollution.

In "Agricultural Produce Sorting and Grading using Support Vector Machines and Fuzzy Logic" an automated grading system has been proposed and designed to overcome the problems of manual grading. It combined three processes – feature extraction, sorting and grading without any human intervention. Initially the images were taken using a regular digital camera. The feature extraction process was done using the MATLAB image processing toolbox. Following is the resultant image with extracted features.

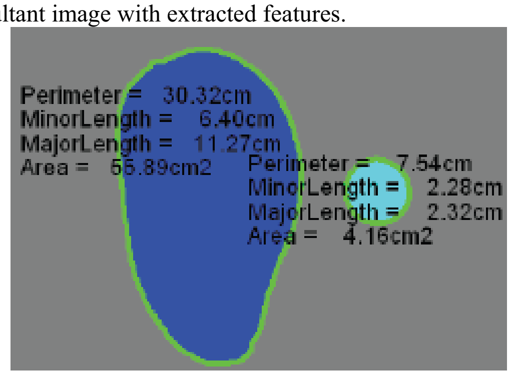

Figure.2 Image with extracted features Courtesy: Reference [3]

Then shape sorting was done using the SVMs that has the ability to recognize the shape of an object. The sorting task involves two sets of data; i.e., training data and validation data. Each instance of training data consists of one 'target value' (class) and several features. The most important role in shape recognition is feature extraction. The features are normalized by

$$Xnorm = \frac{Xraw - X\min}{X\max - X\min} \quad (1)$$

where Xraw, Xnorm, Xmax, Xmin are the raw, normalized, minimum and maximum values of the features. This ensures that Xnorm lies in (0, 1), which is very important for SVM classification.

Table III shows the classification accuracies of five fruits:

TABLE III CLASSIFICATION RESULT

Specimen	Classificatio

	n Accuracy
Apple	96.25%
Banana	81.25%
Carrot	0%
Mango	98.75%
Orange	6.25%

Fuzzy Logic was then applied for the agriculture produce grading. This technique was chosen because it represents a good approach when human experience needs to be incorporated into the decision making process. The grade is determined based on fruit type and fruit features. Following figure shows the Fuzzy grading system that uses 3 inputs to determine the output (size) of the fruit: major length, minor length and area.

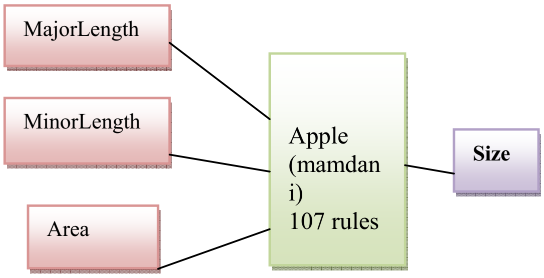

Figure.3 Fuzzy Grading System

Following table shows the grading result of the fruits, which represents very good grading accuracy:

TABLE IV. GRADING RESULT

Specimen	**Grading Accuracy**
Apple	98.85%
Banana	98.75%
Mango	89.74%

III. CONCLUSION

So far we have discussed various image processing techniques, which employ fuzzy techniques and inference rules, and their role in wide range of precision agriculture applications such as feature extraction, texture analysis, agriculture produce grading, effective use of herbicide sprayers in disease control etc. Reference [1] infers that considering the level of classification accuracy, fuzzy logic can be satisfactorily used for image classification. It is recommended to use a fuzzy logic controller for effective weed control as proved in reference [2]. In a new technique for sorting and grading [3] fuzzy logic has been employed for grading whose results were proven to be good for three of the five chosen fruits. In all the research papers discussed above, authors have shown that fuzzy based approaches outperformed comparatively.

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BIOGRAPHY

Sanjeev S Sannakki, Research Scholar, Visvesvaraya Technological University (VTU), has completed his post graduation with the specialization in Computer Networking. His career spans over a decade in the field of teaching, research and other diversified in-depth experience in academics. He is currently working as Assistant Professor in the Department of CSE, Gogte Institute of Technology, Belgaum. He has published various papers in national/international conferences and journals. He is also guiding the projects of UG/PG students of VTU.

Vijay S Rajpurohit is working as Professor, in the department of Computer Science and Engg at Gogte Institute of Technology, Belgaum. He did his B.E. in 1997, M.Tech at N.I.T.K Surathkal in 2003 and PhD from Manipal University, Manipal in 2009. He has presented papers in various national/international conferences and published papers in international journals. He is the reviewer for three international conferences and 05 international journals. Currently he is carrying out research under the grant of Visveswaraya Technological University Belgaum,India, in the Agricultural domain.

Arun Kumar R secured B.E. Degree in Computer Science & Engineering stream from Bapuji Institute of Engineering and Technology, Davangere in the year 2009 and pursuing M.Tech degree in Computer Science & Engineering stream in Gogte Institute of Technology, Belgaum under Visvesvaraya Technological University. His areas of interest include image processing and machine learning.