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Applications of Pattern Recognition Algorithms in Agriculture: A Review

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--ABSTRACT--
Pattern recognition has its roots in artificial intelligence and is a branch of machine learning that focuses on the recognition of patterns and regularities in data. Data can be in the form of image, text, video or any other format. Under normal scenario, pattern recognition is implemented by first formalizing a problem, explain and at last visualize the pattern. In contrast to pattern matching, pattern recognition algorithms generally provide a fair result for all possible inputs by considering statistical variations. Probabilistic classifiers have supported Agricultural statistical inference for decades. Potential applications of this technique in agriculture are numerous like pattern recognition from satellite imagery, identifying the type of disease from leaf image, weed detectionetc. This paper explores employment of pattern recognition in an agricultural domain.
Keywords**: Classification, Feature Extraction, Feature Selection, Pattern Recognition, Pattern Recognition Models, Agriculture.**

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I. INTRODUCTION

Agriculture industry reflects a large portion of economic output. Together with the breeding industry, researchers try to identify, improve, and breed key traits to satisfy the growing demands, increase resistance to parasites and diseases, reduce environmental impact (less water, less fertilizer), always striving for a more sustained agriculture.

These can be satisfied if precision farming is implemented. Looking at the scientific literature on precision farming, it appears that, most efforts so far were focused on the development and deployment of sensor technologies rather than on methods for data analysis tailored to agricultural measurements. In other words, up to now, contributions to computational intelligence in agriculture mainly applied off-the shelf techniques available in software packages or libraries but did not develop specific frameworks or algorithms. Yet, efforts in this direction are noticeably increasing and in this paper we review recent work on pattern recognition in agriculture.

Pattern recognition is a multi-disciplinary subject covering the fields of statistics, engineering, artificial intelligence, computer science, psychology, physiology, etc. [[1][2][3]]. The field of pattern recognition is concerned with the automatic discovery of regularities in data through the use of computer algorithms and with the use of these regularities to take actions such as classifying the data into different categories [4]. In simple terms, one can say that Pattern recognition prominently used for classification or clustering. From centuries, human beings are solving a number of problems by analogical reasoning.

However, computer-based automated pattern recognition systems are required when the human senses fail to recognize patterns, or if there is a need for automating and speeding up the recognition process[5].Pattern reasoning employs same paradigm in solving problems in different domains by scrutinizing relevant patterns. Its main notion is to elicit patterns from the study area and to bifurcate the study area in to classes. Application of Pattern recognition systems can be trained or untrained. Trained methods are known as supervised learning and untrained is categorized as unsupervised learning.Solutions provided by pattern recognition can be found everywhere. For example it can be used in disease categorization, prediction of survival rates for patients withspecific disease[6], fingerprint verification[7], face recognition[[8][9]], iris

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discrimination[10], chromosome shape discrimination[11], optical character recognition[12], texture discrimination[13]and many more.Pattern recognitionsystem implements three major steps viz. preprocessing, feature extraction, and classification for solving any problem on hand.

Pattern recognition system should consider the application domain for selecting pattern. Same pattern recognition system cannot be employed for all domains. For most practical applications, the original input variables are typically preprocessed to transform them into some new space of variables where, it is desired. For instance, in the digit recognition problem, the images of the digits are typically translated and scaled so that each digit is contained within a box of a fixed size. This greatly reduces the variability within each digit class, because the location and scale of all the digits are now the same, which makes it much easier for a subsequent pattern recognition algorithm to distinguish between the different classes.

II. PATTERN RECOGNITION PROCESS

Pattern

There are various definitions of the term pattern:
According to Wordweb dictionary; pattern is a perceptual feature, a customary way of operation or behavior, a decorative or artistic work, something regarded as a normative example, a model considered worthy of imitation, something intended as a guide for making something else or graphical representation of the spatial distribution of radiation from an antenna as a function of an angle.

"A pattern is essentially an arrangement. It is characterized by the order of the elements of which it is made, rather than by the intrinsic nature of these elements," is a definition given by Norbert Wiener [14]. Watanabe [15] defines a pattern as "opposite of a chaos; it is an entity, vaguely defined, that could be given a name". "It can also be defined by the common denominator among the multiple instances of an entity. For e.g., commonality in all fingerprint images defines the fingerprint pattern; thus, a pattern could be a fingerprint image, a handwritten cursive word, a human face, a speech signal, a bar code, or a web page on the Internet" [16].

Pattern recognition system

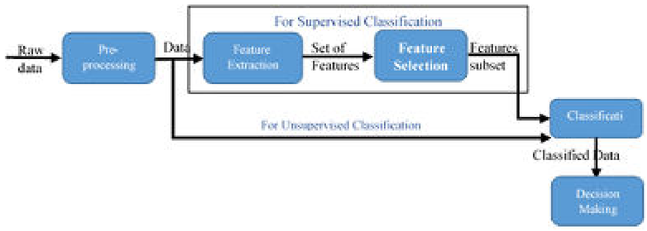

figure -1: General steps required for supervised and unsupervised classification

First process of any pattern recognition system is dimensionality reduction. Dimensionality reduction process deals with the removal of noise (i.e. irrelevant) and redundant features.

The design model of a pattern recognition system essentially involves the following steps [[17][18]]:

1) Preprocessing: Here the data from the surrounding environment is taken as an input. The raw data is then processed by either removing noise from the data or extracting pattern of interest from the background so as to make the input readable by the pattern recognition system.
Next two steps viz. feature extraction and feature selection are capable of improving learning performance, lowering computational complexity, building better generalized models, and decreasing required storage[19].

2) Feature extraction: Feature is the measurable or observable data corresponding to the pattern. Feature extraction eliminates redundant data and retrieves characteristic information about the pattern. Elimination of redundant information is of vital importance for the reduction of processing time in the recognition process [5].Form processed data identical and relevant features are extracted. These relevant features collectively form identity of an object to be recognized or classified. Many methods of feature extraction exist like Fourier transform, Radon transform, Gabor Wavelets transform, Fuzzy invariant transform, principal component analysis, Semidefinite embedding, Multifactor dimensionality reduction, Multilinear subspace learning, Nonlinear dimensionality reduction, Isomap, Kernel PCA, Multilinear PCA, Latent semantic analysis, Partial least squares, Independent component analysis, Autoencoder etc.

3) Feature selection: The objective of variable selection is three-fold: improving the prediction performance of the predictors, providing faster and more cost-effective predictors, and providing a betterunderstanding of the underlying process that generated the data[20].
List of feature extracted from the feature extraction step are passed through a one more filtering process to obtain more discriminative or representative subset of

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feature vector. During this process, filtering is done without any transformation and maintains the physical meaning of the original features. Feature vector/subset available at the end of this step is also known as training data set. Feature selection allows us to better understand the domain and cost cutting can be achieved by reducing set of predictors.

These properties of feature selection ultimately help in improving performance of classification algorithms. This process aims not only to increase dimension reduction rate but also to prevent the effect of curse of dimensionality [21][2]**.** Feature selection is different from dimensionality reduction. Both methods seek to reduce the number of attributes in the dataset, but a dimensionality reduction method do so by creating new combinations of attributes, whereas feature selection methods include and exclude attributes present in the data without changing them [22]. Feature selection techniques at top level are bifurcated in to wrappers, filters and embedded.

Wrapper methods use a predictive model to score feature subsets. Each new subset is used to train a model, which is tested on a hold-out set. Counting the number of mistakes made on that hold-out set (the error rate of the model) gives the score for that subset. As wrapper methods train a new model for each subset, they are very computationally intensive, but usually provide the best performing feature set for that particular type of model.

Filter methods use a proxy measure to score a feature subset. This measure is chosen to be fast to compute. Common measures include the mutual information,[20] the point wise mutual information,[23] Pearson product-moment correlation coefficient, inter/intra class distance or the scores of significance tests for each class/feature combinations.[23][24] Filters are usually less computationally intensive than wrappers, but they produce a feature set which is not tuned. Filters can be uses are pre-processing part of wrapper methods.

Embedded methods perform variable selection in the process of training and are usually specific to given learning machines.

Feature selection techniques include methods like Information Gain, Relief, Fisher Score and Lasso.

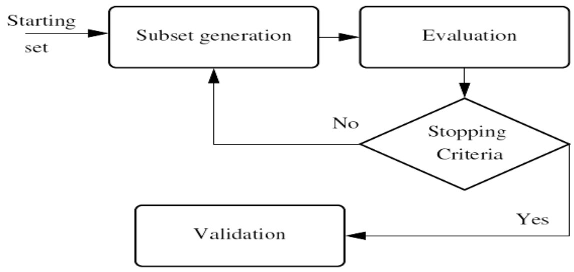

figure -2: General feature selection structure [25]

4) Classification: Classification is the problem of identifying, i.e. to which set of categories (subpopulations) a new observation belongs, on the basis of a training set of data containing observations (or instances) whose category membership is known [19]. Performance of pattern recognition algorithm is dependent on this step, so it is one of the crucial process in pattern recognition systems. Inputs of this process are resultant refined feature vector/set obtained at the end of feature selection processes and classification dataset which is to be classified based on former feature vector or in some scenario it can be only classification dataset only. In case if classification algorithm accepts refined feature set from step 3 as input then it is known as supervised classification algorithms and in its absence it is known as unsupervised classification algorithms. Supervised and unsupervised algorithms are enlisted in Table-1.Sometimes unsupervised is also meansgrouping the input data into *clusters* based on some implicit similarity measure, rather than assigning each input instance into one of a set of predefined classes [26]. So in case of clustering or unsupervised classification algorithm feature extraction and feature selection processes are not mandatory. Figure-3 displays flow of unsupervised and supervised classification algorithms.

Applications in which the training data along with target data are employedare known as supervised learning problems. The problems in which each input vector is assigned to one of a finite number of discrete categories, are called classification problems [4]. Regression is in which the desired output consists of one or more continuous variables.

In other category, the training data consists of a set of input vectors without target values. The motto in such unsupervised learning problems is to identify groups of similar sets within the data.This is called clustering, or density estimation (to determine the distribution of data within the input space), or visualization (to project the data from a high-dimensional space down to two or three dimensions)[4].

Unsupervised Methods	Supervised Methods
1. Categorical mixture models 2. Deep learning methods 3. Hierarchical clustering 4. K-means 5. Clustering 6. Correlation clustering 7. Kernel PCA	1. Linear discriminant analysis 2. Quadratic discriminant analysis 3. Maximum entropy classifier 4. Decision trees, decision lists 5. Kernel estimation and K-nearestneighbor 6. Naive Bayes classifier 7. Neural networks (multilayer perceptrons) 8. Perceptrons 9. Support vector machines 10. Gene expression programming

Table 1– List of supervised and unsupervised methods

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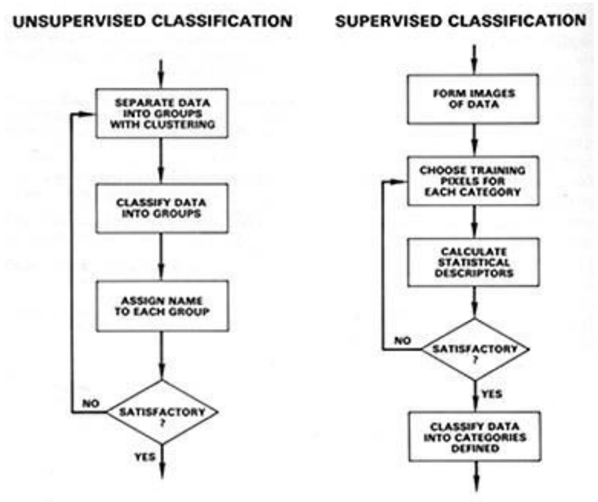

figure-3: Unsupervised and supervised classification [27]

5) Decision making: Input of this process is classified data. In any case i.e. (supervised or unsupervised classification) this step is preceded by post processing which help in better inferring and decisiveness [28].

III. Pattern Recognition Models

Pattern recognition models are bifurcated in to four major categories viz. statistical approach, syntactic approach,template matching & neural network[29][18].

Statistical Model

Statistical pattern recognition systems are extensively used in today's world because of its simplicity. It is based on statistics and probabilities. In these systems, traits are recoded in form of numbers and these numbers vectors are used to create a pattern. Thus, each pattern can be represented by specific multidimensional vector, which in turn is used for pattern recognition.Approximately about 80% of agricultural research is supported by this approach.

Syntactic Model

Syntactic approach is widely used in theory of computation. It is also known as a structural pattern recognition model or rule based pattern recognition. In this approach, patterns are represented by definite structures like sentences belonging to language. In this model, the patterns to be recognized are called primitives and the complex patterns are represented by the inter-relationship formed between these primitives and the grammatical rules associated with this relationship[29]. The patterns are the sentences belonging to a language, primitives are the alphabet of the language, and using these primitives, the sentences are generated according to the grammar. Thus, the very complex patterns can be described by a small number of primitives and grammatical rules [30].

Template matching

Template matching is extensively used in image processing domain. In this model pattern can be recognized by clusters of pixel or curves to localize and identify shapes in image. Thus patterns are in form of templates. So from this it can be stated that supervised classification algorithm will be mostly used. Scenario in which pre-defined pattern are not known unsupervised classification algorithm will be engaged.

Neural Network

Neural networks were originally inspired as being models of the human nervous system. They have shown many intelligent abilities, such as learning, generalization and abstraction.Neural networks are large networks of simple processing elements or node which process information dynamically in response to external inputs. The nodes are simplified models of neurons or processing elements (PE). The knowledge in a neural network is distributed throughout the network in the form of internode connectionsand weighted links (or synapse) which form the inputs to the nodes. The link weights server to enhance or inhibit the input stimuli values which are then added together at the nodes. If the sum of all the inputs to a node exceeds some threshold value T, the node executes and produces an output which is passed on to other nodes or is used to produce some output response.

IV. Applications of Pattern recognition in Agriculture

Pattern recognition is used in many area of science and engineering that studies the structure of observations. It is now frequently used in many applications in manufacturing industry, health care and military[16].Image processing based on morphology, color and textural features of grains is necessary for different applications in the grain industry including assessing grain quality and variety classification. In grain classification process, several techniques such as statistical, artificial neural networks and fuzzy logic have been used. Below listed is the some of the contribution of pattern recognition in agriculture domain:

Ankur M Vyas [31]surveyed different techniques used to identify fruits based on colour. According to them "In the automated fruit grading system the most important feature is its colour. So for any automated fruit grading system one should have the idea of colour space and segmentation needs to be performed. This paper provides a review of various colour feature extraction techniques in detail."

S. Arivazhagan et al.[32] proposed system as a software solution for automatic detection and classification of plant leaf diseases. The proposed algorithm's efficiency can successfully detect and classify the examined diseases with an accuracy of 94%. Experimental results on a database of about 500 plant leaves confirm the robustness of the proposed approach.

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J. Rajendra Prasad et al. [33] describe the DM Framework development, description, components used for crop prediction; planting strategist test results are very much useful to the farmers to understand market needs and planting strategies.

Victor Rodriguez-Galiano et al. [34] assessed groundwater vulnerability to nitrate pollution using *Random Forest algorithm*. Showed method of a feature selection approach to reduce the number of explicative variables. Developed predictive modeling of nitrate concentrations at or above the quality threshold of 50mg/L.

Christian Bauckhage Kristian and Kersting [35] surveyed recent work on computational intelligence in precision farming. From the point of view of pattern recognition and data mining, the major challenges in agricultural applications appear to be the following:

1. The widespread deployment and ease of use of modern, (mobile) sensor technologies leads to exploding amounts of data. This poses problems of BIG DATA and high-troughput computation. Algorithms and frameworks for data management and analysis need to be developed that can easily cope with TeraBytes of data.
2. Since agriculture is a truly interdisciplinary venture whose practitioners are not necessarily trained statisticians or data scientists, techniques for data analysis need to deliver interpretable and understandable results.
3. Mobile computing for applications "out in the fields" has to cope with resource constraints such as restricted battery life, low computational power, or limited bandwidths for data transfer. Algorithms intended for mobile signal processing and analysis need to address these constraints.

They opted an approach based on a distributional view of hyper-spectral signatures which they used for Baysian prediction of the development of drought stress levels. They also presented a cascade of simple image processing and analysis steps of low computational costs that allows for reliably distinguishing different fungal leaf spots in natural, unconstrained images of leaves of beet plants, that allows farmers in the field to take pictures of plants they suspect to be infected and have them analyzed in real time.

Dr. D. Ashok Kumar & N. Kannathasan [36] surveyed utility of data minning and pattern recognition techniques for soil data minning and its allied areas. The recommendations arising from this research survey are: A comparison of different data mining techniques could produce an efficient algorithm for soil classification for multiple classes. The benefits of a greater understanding of soils could improve productivity in farming, maintain biodiversity, reduce reliance on fertilizers and create a better integrated soil management system for both the private and public sectors.

Farah Khan & Dr. Divakar Singh [37] endeavour to provide an overview of some previous researches and studies done in the direction of applying data mining and specifically, association rule mining techniques in the agricultural domain. They have also tried to evaluate the current status and possible future trends in this area. The theories behind data mining and association rules are presented at the beginning and a survey of different techniques applied is provided as part of the evolution.

Amina Khatra [38] showed that using color based image segmentation it is possible to extract the yellow rust from the wheat crop images. Further, the segmented yellow rust images can be exposed to measurement algorithm where the actual penetration of the yellow rust may be estimated in the yield. This kind of image segmentation may be used for mapping the changes in land use land cover taken over temporal period in general but not in particular. The success of the segmentation and actual penetration of yellow rust mainly depend upon the positioning of the cameras installed in order to acquire the images from the field.

Archana A. Chaugule and Dr. Suresh Mali[39] in their research Shape-n-Color feature set outperformed in almost all the instances of classificationfour Paddy (Rice) grains, viz. Karjat-6, Ratnagiri-2, Ratnagiri-4 and Ratnagiri-24. They used Pattern classification was done using a Two-layer (i.e. one-hidden-layer) *back propagation supervised* neural networks with a single hidden layer of 20 neurons with *LM training functions*.The fifty-three features were used as inputs to a neural network and the type of the seed as target.

Abirami et al. [40] used *canny edge detection, thersolding and scaled conjugate gradient* training with 9 neurons in hidden layer for grading basmati rice granules. Scaled Conjugate Gradient Training based Neural Network was able to classify granules with the accuracy of 98.7%.

Various grading systems have been developed [[41],[42],[43],[44]] which use different morphological features for the classification of different cereal grains.

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Utku, 2000[45] developed a system to identify 31 bread wheat and 14 durum wheat cultivars usingCCD video camera.

Majumdar and Jayas [46][47][48][49] used digital image processing and discriminate analysis to do identification of different grain species. They used morphological, color, textural and combination of these features to describe physical properties of the kernels.

Computer vision system offers an objective and quantitative method for estimation of morphological parameters and quality of agricultural products to obtain quick and more reliable results [[50][51][52]].

Visen, 2004[53]has compared classification performances of different neural network topology by using morphological features of Canada Western Amber Durum (CWAD) wheat, Canada Western Red Spring (CWRS) wheat, oats, rye and barley.

Algorithms were developed to acquire and process color imagesof bulk grain samples of five grain types, namely barley, oats, rye,wheat, and durum wheat by [54]. The developed algorithms were used toextract over 150 color and textural features. A back propagation neuralnetwork-based classifier was developed to identify the unknown graintypes. The color and textural features were presented to the neuralnetwork for training purposes. The trained network was then used toidentify the unknown grain types. Classification accuracies of over98% were obtained for all grain types.

R. D. Tillett [55] in his review highlighted multiple areas of agriculture domain in which image processing and different methods of pattern recognition was implemented, viz. Harvesting of oranges, tomatoes, mushrooms, apples, cucumbers, Plant growth monitoring and grading of oranges, potatoes, apples, carrots, green peppers, tomatoes, peaches.

V. CONCLUSION

This paper is an attempt to provide an overview of some previous research and studies done in the direction of applying pattern recognition techniques in the agricultural domain. A unique and proper combination of pre-processing, feature extraction, feature selection and classification process is required for each domain or problem in order to optimize accuracy, speed and reduce cost by minimizing feature set used for training and classification. The theories behind pattern recognition are presented at the beginning and a review of different techniques applied in grading, remote sensing, diseases detection etc.is provided as part of the evolution.

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