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Leaf Image Recognition Based Identification of Plants: Supportive Framework for Plant Systematics

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Abstract
Plant life is incomplete without proper leaf orientation and morphology**.** Leaf is the first identity of any plant species. Identification of leaf is the first choice for plant taxonomist as well as common men. Generally, taxonomists and common people face difficulties of different nature during plant identification. Botanists are overwhelmed with fresh data e.g. DNA sequencing to the complex appearance of traits, species phylogeny, environmental influences and outcomes, molecular phenotyping etc. Advancements in biological sciences over last three decades and amplified significance of determining the relationship between structure and function have proved worth of imaging technology as an emerging discipline. Leaf image classification is the best choice for plant taxonomy. Generally, one can easily make over the images of leaves to a system and that computer automatically generates attributes by processing images. Earlier, input images were first converted into grayscale and then transformed to a binary image. Other than plant classification studies with help of image recognition, the same technique can be very supportive for detecting diseased plants in a field. In this article, we have focused on the developments related to image processing and its implementation for plant science research. Leaf image processing has been focused with the help of reported literature in related scientific domains.
Keywords: Biological research, Image processing, Plants, Systematics.

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INTRODUCTION

No one can deny the importance of plants (Khalid *et al.,* 2018a; Khalid *et al.,* 2018b). In this world, plants are commonly used as food, medicine, industrial products and especially important for environmental protection (Islam *et al.,* 2018; Noman *et al.,* 2016; Noman *et al.,* 2013). Plants have three main parts described as root, stem, and leaves. A leaf is defined as a structure having a bud in its axil (Noman *et al.,* 2014). Leaf is the first identity of any plant species(Bahadar *et al.,* 2018). Plant life is incomplete without proper leaf orientation and morphology (Noman *et al.,* 2017). Plant taxonomy is a study leading to the classification of related plants in a descending order of groups and clads in terms of their common attributes(Hameed and Ashraf, 2008). Such tasks are usually very time consuming and knowledge demanding in Botany and agriculture(Khan *et al.,* 2018). For instance, the observation of new plant species, phytogeographical surveys and species abundance, herbarium management, and all related time-consuming tasks have been carried out by plant biologists and systematic experts (Hameed *et al.,* 2011).

Identification of leaf is the first choice for plant taxonomist as well as common men. Generally, scientists and common people face difficulties of different nature during plant identification. Plant taxonomists use different criteria for selection and identification of any plant species (Prasad *et al.,* 2011). Considerable developments can be expected with the help of a computer-based automatic or semi-automatic plant identification assisted by plant image processing and vision techniques (Wang *et al.,* 2003). With advancements in computer science generally and data processing particularly, technologists can process a plant image or genomic data and a computer can automatically elaborate and identify a plant or genome attributes by using given processing program (Prasad *et al.,* 2011).

Advancements in biological sciences over last three decades and amplified significance of determining the relationship between structure and function have proved worth of imaging technology as emerging discipline. The ubiquitous digital revolution from digital cameras to the latest CT scanners have presented images as an integral part of research areas (Russ, 2016). Methods for image object extraction able to scrutinize images into useful image objects sets are mandatory for the automated image interpretation (Blaschke *et al.,* 2000). Generally, two methods are employed for image processing. These include analog and digital image processing. The first method is applied processing of printouts and photographs. Image analysts make use of different fundamentals of interpretation while applying these techniques to images. Digital image processing is a useful way to operate digital images with the help of computers. Data preprocessing is a fundamental process to enhance the accurateness of data mining algorithms (Pyle, 1999). Selection of features and their reduction are common data preprocessing methods that increase the performance of the learning model by deleting superfluous features and keep only the imperative ones. Therefore, this efficient method of leaf image detection for plant classification has gained immense importance. In this article, we have focused on the developments related to image processing and its implementation for plant science research. Leaf image processing has been focused with the help of reported literature in related scientific domains.

Plant Biology and computer science in one core

Around the world, many biologists, as well as botanists today, are trying to counter the daunting agricultural and environmental challenges. From food to increasing human population or creation of renewable energy, trends in plant science aims at delivering comprehensive solutions to such problems. Authentic approaches to address likely challenges may be carried out through modern molecular techniques, understanding of the evolution of plant genetic attributes, and by predicting the impact of environment on plant life. The science of living organisms is a data-driven, data dependent as well as a data-intensive branch of science (Smith and Nair, 2005; Thuiller *et al.,* 2011). Botanists and Zoologists both are overwhelmed with fresh data e.g. DNA sequencing to the complex appearance of traits, species phylogeny, environmental influences and outcomes, molecular phenotyping etc. (Yesson and Culham, 2006). Botanical data ranges from full genome sequences of different plant types to geographical distribution of plant species throughout the biosphere (Hughes, 2006). Such data differ largely from the results in published manuscripts to actual data entries in databases. Diverse Analytical methods for data analysis are developing at a considerable pace (Lyons *et al.,* 2008). Contrarily, most data sets are not simple enough to put together and means to analyze such data are `not often accessible or poorly in access. These data integration problems are much difficult for any single lab to handle (Lyons *et al.,* 2011). Solution to such problems demands Inter-disciplinary approach with knowledge from computer science, information technology, and the Biology. The development and up-gradation of already available analysis programs and datasets are very significant and must be enhanced for future activities (Altintas *et al.,* 2006; Hirayama and Shinozaki, 2010; Perianayagam *et al.,* 2010).

Today rapid progress in plant biology research is usually assessed by the capability to collect and analyze multifarious complex data sets of gigantic volume termed as big data. For detailed elucidation of basic principles of plant structure and function, the genomic data such as a number of genes, their structures, expression patterns, and regulation should essentially be supplemented with proteomic data inclusive of number and type of proteins in the single proteome, their interactive partners and biochemical as well as signaling pathways. In model and non-model crops, NGS (next-generation sequencing) and mass-spectrometry have added significant data in the volume of plant data sets during the last ten years. Due to increments in data acquisition, the presence of existing computational strategies and classical bioinformatics techniques have appeared insufficient to deal with mega-data inputs and analyses. For efficient big data processing, many challenges, inclusive of data storage, data analysis, visualization and sharing datasets, must be tackled by accommodating current frameworks and developing new resources (Al-Hiary *et al.,* 2011).

During the last three decades, analysis of plant genome is a focused area of plant biology receiving much attention and benefits from the applications of the latest technologies. As a part of scientific progress, colossal gene expression data sets had been obtained with the help of DNA microarray assays. This field has extracted tremendous benefits from technology advances allowing progression from different protocols such as chip sequencing and other deep sequencing techniques. The augmented accuracy and amount of sequenced data has made available precise reconstruction of genetic networks and the combination of topological knowledge of gene expression with its regulatory elements (Abu-Naser *et al.,* 2010).

Plant image recognition and processing for different purposes is the best option for plant systematics.

Pattern recognition with the help of computer vision is an emerging technique to automate human vision. Leaf image Classification is the best choice for plant taxonomy. Generally, one can easily make over the images of leaves to a system and that computer automatically generates attributes by processing images. Earlier, input images were first converted into intograyscale and then transformed to a binary image(Gu *et al.,* 2005; Wu *et al.,* 2007). This may incur data loss. Parsad *et al.* (2011) described well efficient algorithms for leaf recognition. They extracted features and classified plant successfully. It is not easy to extract the leaf features from image database (Fu and Chi, 2006).All attributes/features must be automatically extracted from digital images. The complete algorithms can be easily implemented by adopting the mutual approach. Classifier selection also holds an important position in the output (Prasad *et al.,* 2011). An image processing technique based on flower wavelet and neural network was recommended for developing a way of online recognition and assessment of pest attack in pip fruit. Three most prevalent pests in orchards were chosen for this study. Fast wavelet transforms having a particular set of Daubechies wavelet was employed for extracting the significant characteristics. The image search was executed in two tairs. Firstly, SD was compared for three different color components to match images. Secondly, a weighted version of the Euclidean distance between the feature coefficients of the earlier selected image and querying image was calculated. The image the least distance was selected and sorted as matching images to the particular query.

Different methods are in use to determine and compare fruit images for traits like fruit shape, size, accessory structures etc. (Hirayama and Shinozaki, 2010; Patil and Kumar, 2011). The stereomicroscopic approach was opted for convenience with in image analyses as a competent and accurate technique by (Mix *et al.,* 2003). Generally, image analysis based fruit size was comparatively higher than that observed with the stereomicroscopic technique. It is interesting to note that not only fruit length differs between the two methods but other traits might have different recorded values showing the accuracy of these techniques. The highly significant correlation was observed between fruit length observations recorded by both of mentioned methods for all species described in the earlier sentence. This point out accurately discriminated different fruits sizes determined by stereomicroscopic and image analysis. Following the observations, image analysis proved to be more advantageous. Firstly, the high number of fruit attributes can be obtained with one measurement. Secondly, the human error can be minimized. Thirdly, large data sets about fruit characteristic variability can be obtained in a short time. The possibility to estimate variability in fruit attributes complex shapes can be increased. Pests have destructive effects on plants like leaf rolling the plant destruction. The sucking pests reduce the leaf water content. All these damaging effects alter the chlorophyll contents with correlated changes in its image. Studying the harmful effects of pest attack on plant leaves can be performed by spectral images taken with the help of satellite imagery, remote sensing or by using airborne images through helicopters and aeroplanes. A multifunctional technique was proposed (Ei–Helly *et al.,* 2004) for integration of image analysis with a diagnostic expert technique for cucumber crop e.g. CLASE (Central Lab. of Agricultural Expert System). This system sorts out the plant disease symptoms that can be observed with naked eye. For diagnosing a diseased leaf from the image, four image processing steps were employed i.e. enhancement, segmentation, feature extraction, and classification. Three different disease attacks i.e. Leaf miner, Powdery and Downey mildews were focused in earlier approach. This technique had reduced error probability between user and system. The leaf physical attributes are commonly targeted for taxonomy and in the early recognition of pathogen attack. The design and application of an artificial visual system that can pull out particular features of leaves can be a feasible strategy for plant image analysis for different purposes(Kumar and Kumar, 2015; Zhang and Zhang, 2008). It was proposed that integration of an artificial vision system (camera), image processing algorithms and feed forward neural network can yield better output as compared to the rest of techniques used or applied previously. Similarly, Kaundal et al. (2006) predicted an approach by using support vector machines (SVM) to develop climatic conditions dependent prediction models of plant disease detection. In a comparison between conventional multiple regression, artificial neural network and SVM dependent regression technique led to a comprehensive description of the inter-link between the environmental conditions and disease level for disease management. Back propagation neural network for leaf detection can be useful in advanced systematic and plant pathology (Babu and Rao, 2007). The system attested that simply back propagation network and leaf shape is sufficient to specify the plant species. As input for back propagation algorithm, Prewitt edge detection, as well as thinning algorithm, can be applied to search leaf tokens. Studies have reported a large scope for increasing the work involving more experimentation with massive training sets to identify different leaves with pathogen attack or damaged ones because of pasts/ diseases. This will be definitely helpful in developing an expert system.

Plant image processing can be amalgamated with other techniques.

Researchers have suggested neural network technique for segmentation of farming fields in remote sensing data (Doudkin *et al.,* 2007). In this technique, disease infected colorful segments of lands were analysed through neural network algorithm based on back propagation. The theme of the study was to identify on the basis of color changes in normal and diseased plants. The strategy implemented color change recognition algorithm for extracting leaf characteristics and highly efficient recognition algorithm. Later on, in another study, PNN (Probabilistic Neural Network) was used for plant identification (Wu *et al.,* 2007). The extracted and processed attributes by PCA formed input to PNN. They reported that the algorithm presented an accuracy of 90% on 32 plants. A system was employed for computer management of farming process in the greenhouse (Maliappis *et al.,* 2008). This system implemented as a web-based program that used open source technologies/ subsystems with modules providing precise information about the crop farming, simulation and forecast models for common people, collaboration environment and support. The expert system is a web-based application and adaptation of the VEGES system. It can be used for recognizing pest, disease and nutrition issues.

A prototype software was used for detection of plant disease in rice leaves. Two types of techniques i.e. image growing and image segmentation were applied for detecting diseased plant parts. Zooming algorithm extracted features in images. Self-Organize Map (SOM) neural network was also employed to classify infected rice leaf images (Al-Hiary *et al.,* 2011).

The fast and accurate technique is developed on the basis of image processing to check disease attack intensity on the plant. Otsu segmentation was applied to make segments of Leaf region. The quotient of disease spot & leaf area were calculated for grading disease index. Similarly, *Vitis* leaf infection was detected in color imagery using a hybrid intelligent system (Meunkaewjinda *et al.,* 2008; Weizheng *et al.,* 2008). SOMs and BPN networks were used to identify different colors in leaf after disease spread. This can be applied to segment grape leaf pixels within the image. The segmented image was filtered with the help of Gabor wavelet for analyzing leaf disease color features in an efficient way. The SVM was later applied to grade types of grape leaf disease. Ying et al.(Ying et al., 2009) used powdery mildew, speckle & downy mildews in cucumber plant and reported comparative effects of simple filter and median filter. According to them, leaves with spots should be firstly processed before carrying the image processing based intelligent crop diagnosis and apt attributes must be extracted based upon this (Abu-Naser *et al.,* 2010).

Other than plant classification studies with help of image recognition, the same technique can be very supportive for detecting diseased plants in a field (*Abbasi et al.,* 1997; Zhang et al., 2007). This has been applied over cotton plants affected by cotton leaf spot disease. Bernardes et al. (2013) proposed Edge detection based leaf Image segmentation for analyses and later classification of diseases can be performed by using HPCCDD Algorithm (Homogeneous Pixel Counting Technique for Cotton Diseases Detection). In this technique, computer systems analyzed the images with the help of RGB pixel counting attributes value for disease wise identification and next using homogenization techniques. The cotton leaf spot affected parts were identified and white disease boundary ending were recognized for disease as final output (Gulhane and Gurjar, 2011). The leaf disease detection is a threefold method. First, it identifies the infected part based on k-means clustering. Secondly, it extracts the charcaters set of the diseased objects for texture analyses by using color co-occurrence methodology. Finally, it detect as well as classify the disease type with the help of NNs. Furthermore, this technique divides the plant leaves into diseased and healthy clads. In the first step of this technique, a color transformation structure for the RGB (Red, Green, Blue) leaf image is developed, and a device-independent color space transformation for the color transformation structure is applied. Then image segmentation is carried out with the help of K-Means clustering technique. These all steps identify the pixels in green color. In next step, specified and varying threshold value is computed for these pixels by Otsu‟s method, Finally, the recognition process extract attributes by means of a pre-trained neural network (Gulhane and Gurjar, 2011; Gurjar and Gulhane, 2012).

During recent years, BP neural network has appeared as a decision-making system for Cotton Disease Control. Cotton shoot system disease feature extraction has been done by Wavelet transform energy and classification done with SVM (Support Vector Machine). Different features can be extracted with the help of self-organizing feature map and a back-propagation neural network recognizes the image color. Additionally, fuzzy feature selection i.e. fuzzy curves (FC) or fuzzy surfaces (FS) - may choose aspects of diseased cotton leaf image (Al-Hiary *et al.,* 2011). The segmentation of infected cotton leaf disease can be performed by using modified self-organizing feature map with genetic algorithms for optimization and SVM for classification (Revathi and Hemalatha, 2012).

Currently, advanced computation techniques can benefit farmers/agrarians to check the apt progress of their crops. In routine agriculture and particularly during the harvesting, the naked eye observation of farmers is the chief strategy practiced for the recognition and identification of disease attacks in the lab. Sometimes experts may not be available or have to go long distances and consultancy may become expensive as well as time-consuming. Precise and accurate disease identification and classification are needed by inspecting the diseased images. Performance and accuracy being two main attributes of plant-disease identification ML methods should be achieved. This system can provide more benefits in monitoring large agricultural fields and monitor the disease symptoms (Meunkaewjinda *et al.,* 2008; Revathi and Hemalatha, 2012).

CONCLUSION

From the mentioned facts and data it is evident that leaf image recognition has emerged as the best support for solving plant life-related tasks. Performance and accuracy of existing software and data management tools need to be revisited for enhancing their working capacity. Although some pitfalls have been reported in some studies but this is high time is to resolve such rigmaroles improve the application of such programs for the general public. Parallel with this, not only leaf image recognition but the flower and fruit image recognition as a combined approach should be streamlined for appropriate and error-free identification of plant species.

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CONFLICT OF INTEREST

All the authors have declared that no conflict of interest exists.

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