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Leaf Image Processing and Detection: Computer-based Aid for Plant Identification and Classification

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Abstract
Identification/recognition of leaf is the first choice for plant taxonomist as well as common men. Plant taxonomists use different criteria for selection and identification of any plant species. Over the years, scientists used different processing tools to recognize plant images for identification of plant characteristics. To unveil the differences in the leaf Morphology with respect to plant identification, Faisalabad district was visited and surveyed for distribution of plant species. We developed leaf recognition software to facilitate the novice to understand the taxonomy of plant by just highlighting the attributes of plant leaves. A pipe and filter software architecture were applied and executed to implement this software. After precise confirmation, data regarding leaf attributes was extracted and used as a base for this software. We evaluated our system in a very extensive manner and also checked the impact. 153 leaf images prototype data was evaluated both with as well as without considering leaf self-intersection. The objective was to know whether an unknown leaf falls in one of the families and represent which plant group. Our system detected the most similar plant to the input options and can facilitate the users to reach a final conclusion. The final results pointed out a capable presentation of this software and its advantage over the classical method.
Keywords: Classification, Image, Plants, Processing.

INTRODUCTION

Plant systematics is the study of plants classification in a descending order of groups and clads in terms of their common attributes (Hameed and Ashraf, 2008; Noman *et al.*, 2014). Such tasks are usually very time consuming and knowledge demanding in Botany and agriculture (Hussain *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 systematics experts (Hameed *et al.*, 2011). Identification/recognition of leaf is the first choice for plant taxonomist as well as common men (Noman *et al.*, 2017). 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 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 plant or genome attributes by using given processing program (Prasad *et al.*, 2011; Islam *et al.*, 2017; Noman *et al.*, 2017; Islam *et al.*, 2018). By adopting a computer-supported plant identification strategy, all and sundry can also recognize different plant species. This will boost interest in studying plant biology, taxonomy,and ecology, and increment the use of information technology for modernizing the herbarium management, botanic gardens and natural arboreta (Wang *et al.*, 2003; Zaynab *et al.*, 2017).

Over the years, scientists used different processing tools to recognize plant images for identification of plant characteristics. For example, Wu et al. (2007) converted the input images into gray for processing and transformed them into a binary image. Extraction of leaf features from image database is laborious work (Wang *et al.*, 2005; Fu and Chi, 2006). From digital leaf image, all attributes can be automatically extracted (Du *et al.*, 2007). Feature extraction and classification of leaves by recognition algorithms can make it easy to extract features and apply well-versed recognition algorithms. The complete algorithms are simple to apply and execute by adopting a mutual approach (Du *et al.*, 2007; Prasad *et al.*, 2011). Generally, two methods are employed for image processing. These include analogue and digital image processing. Image analysts make use of different fundamentals of interpretation while applying these techniques to images. Digital image processing helps to manipulate digital images with the help of computers. The three routine stages that all kinds of data must undergo information extraction during digital image processing include pre-processing, enhancement and display(Blaschke *et al.*,;2000; Fu and Chi, 2006).

Computer-based image recognition is one of the best and emerging strategies to computerize human visualization (Du *et al.*, 2007). Our study introduces digital leaf image processing as a helping hand in plant systematics. Normally, the digital morphological attributes are most traditional, reliable and extensively used. Therefore, this efficient method is adopted in our study. By computing the digital leaf morphological characteristics of selected species, plants can be identified by botanists as well as common men and comprehensively studied for taxonomy oriented knowledge.

MATERIALS AND METHODS

This study was conducted in the department of computer science, Government college university Faisalabad. Data were collected, analyzed and processed during 2016-2018. Different plants were surveyed in Faisalabad region for their leaf imaging and identification. Care was taken in recording digital images.

Plant identification and leaf imaging

To unveil the differences in the leaf Morphology with respect to plant identification, Faisalabad district was visited and surveyed for distribution of plant species. Plants were first identified with the help of flora of Pakistan (Ali, 2008). Not all plants were native to this region. After confirmation of identification, leaves were selected for imaging. A total of 153 plants belonging to different families were observed on different sites of Faisalabad and adjoining regions. Upper, healthy and leaves of approximately same age were selected among all plant species. Plants belonging to different families were taken into consideration for leaf identification. To maintain the integrity of data we recorded every leaf image in triplicate and at its original habitat. Not all plants were native to the Faisalabad region.

Leaf characteristics

Detailed study of literature with respect to leaf characteristics reveals that these attributes can be significantly linked to plant systematics for taxonomic description. Although leaves have many characteristics but some of them are commonly used for identification and classification (Ali, 2008). For this study, we selected eight important leaf attributes to be identified before reaching a final identification stage. These attributes include

- Leaf stalk
- Leaf arrangement
- Leaf form

- Leaf type
- Leaf blade shape
- Leaf blade length
- Presence/absence of spines/stipules
- Leaf blade width

After getting values of these attributes and leaf image processing, we were able to know about plant identification having following points

- Group of the plant (Angiosperm, Gymnosperm, Pteridophytes, Bryophytes)
- Habitat
- Common plant name
- Botanical name
- Family of plant

Plant Detection Software

Plant detection software was developed for the facilitating the novice to understand the taxonomy of plant by just highlighting the attributes of a plant leaf. A novel searching technique was aimed to find out relevant botanical names of plants. A pipe and filter software architecture were used to implement this software. The working algorithm of proposed software was developed and implemented. Prototype Software was developed in Microsoft visual studio 2010 and Microsoft Access 2012 was used as the backend database.

Image pre-processing

Image pre-processing was performed in the following steps

- Filtering image
- Crop the image
- Resized Image

Steps in image recognition

As first step image was loaded in built software. In the second step, all possible attributes that can be easily observed by anyone such as leaf shape, plant habitat, and stalk type were supplied in search option place. If we kept all search options empty, the software will search all available options. Each parameter was kept and treated as a separate filter of the result. By giving information about attributes observed, recognition results got more accuracy.

The accuracy of plant detection

The accuracy of this system was evaluated by the given accuracy percentage formula.

$$Accuracy\ \% = \frac{(N - P) + 1}{N} \times 100$$

Where N is the number of total leavesin therepository, P is the position of relevant leaf detail in the list of results. By using this formula we can find the accuracy of proposed plant detection system on the basis of relevant leaf detail position such that after searching if the relevant leaf is at the top of the result list, it means accuracy is 100%.

RESULTS

We developed leaf recognition software to facilitate the novice to understand the taxonomy of plant by just highlighting the attributes of plant leaves. A novel searching technique was built to find out relevant plant botanical name. A pipe and filter software architecture were applied and executed to implement this software. Before developing this software, all plants were properly identified with the help of expert botanists and consulting flora of Pakistan. Before using images for processing and plant recognition, we pre-processed all recorded leaf images. This is also termed as image restoring. By using this we enhanced the image features. The image was converted in feasible testing form. This method separated the background from the foreground image.

After precise confirmation, Data regarding leaf attributes was extracted and used as a base for this software. Working with this software is given in Figure 1. To make this software simple and user-friendly, we divided recognition of leaves based on their easily observable attributes such as leaf shape, size, plant habitat etc. In the next step, built in software search windows demand loading of leaf attribute values. By giving values of leaf characteristics, recognition accuracy increases and plant is properly identified (Figure 2).

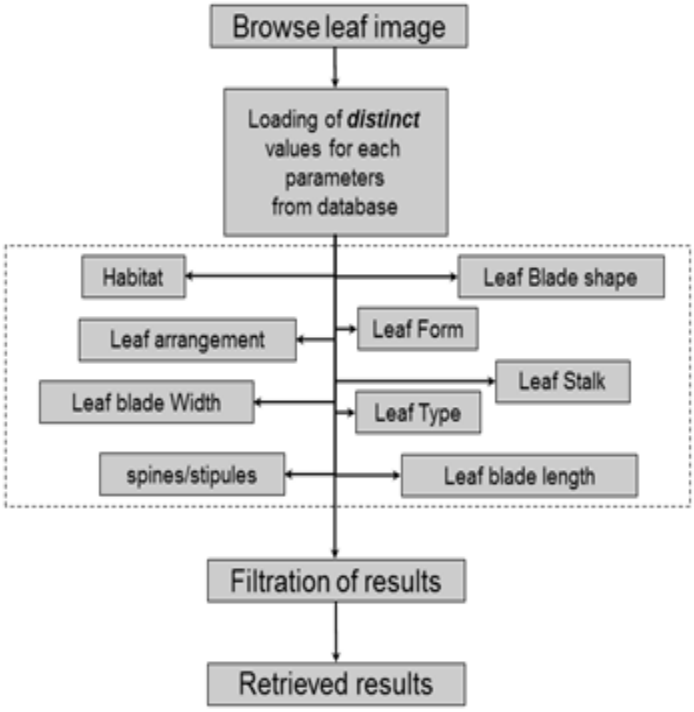

Fig. 1. Flow sheet depicting working of plant detection software identification.

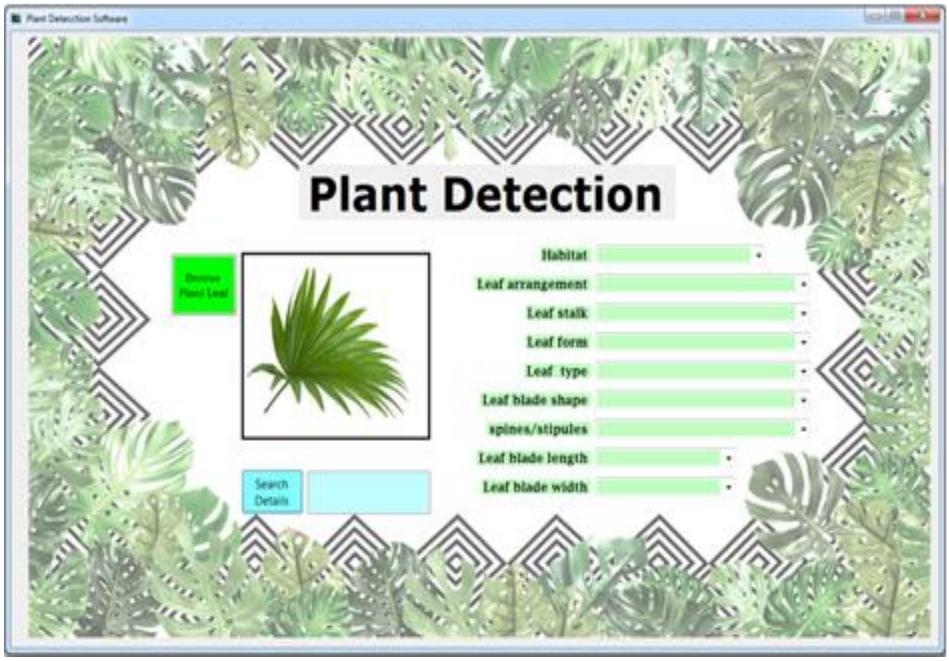

Fig. 2. Front-end design of plant leaf recognition software having all relevant search options for proper identification of plants.

We tested this software for identification of different plant types. We used diverse leaf images data set of 153 images from all different categories. The main reason to choose a diverse dataset of leaves of different plant was just to evaluate whether each category had some effects on the other category or not. We evaluated our system in a very extensive manner and also checked the impact. For the evaluation of proposed plant detection system, we also introduced a new measure of accuracy percentage given below.

$$Accuracy\ \% = \frac{(N - P) + 1}{N} \times 100$$

Where N is the number of total leaves in the repository, P is the position of relevant leaf detail in the list of results. By using this formula we can find the accuracy of proposed plant detection system on the basis of relevant leaf detail position such that after searching if the relevant leaf is at the top of the result list, it means accuracy is 100% . We have determined the accuracy by supplying values of different attributes. When we provided 1 attribute to detect plants, software accuracy was at least i.e. 23.2%. Similarly by providing 2, 3 and 4 leaf attributes to software accuracy was 46.4%. 67.5% and 74 % respectively. By providing all five attributes accuracy was 100%

We also found if a user can provide more input to software it leads to more accurate results. It is shown that accuracy is less if one parameter is given while it increases if multiple parameters are given. By parameter, we mean the associated knowledge. Keeping the ease, values for each parameter are already loaded only the user has to choose from the options that can be seen in Figure 3.

Fig. 3. Working search options of different types in leaf recognition software for plant identification.

We have used different attributes at plant as well as leaf level. These all attributes have been mentioned. For proper identification, leaf morphological traits were focused as our objective was to identify plant on the basis of leaf. For search options, we provided options for different attributes. By giving maximum leaf characteristics such as leaf form, stalk, presence /absence of stipules software started working. It evaluated all the options available in the data repository. By evaluating maximum possible search options, it completed its working and yieldedan appropriate answer in form of leaf image, plant name,and its appropriate features.

We evaluated our technique on a prototype data of 153 leaf images belonging to different families both with as well as without considering leaf self-intersection. The objective was to know whether an unknown leaf falls in one of the families, represent which plant group. Our system detected the most similar plant to the input options and can facilitate the users to reach a final conclusion. The final results pointed out a capablepresentation of this software and its advantage over the classical method (Figure 4).

Plant data base was developed in MS Access. This database management system integrated our supplied/available database with a graphical user interface for development of plant detection software.We constructed MS Access library. This MS Access connector library provided different means to combine data from software with data sources to drive this software. Incorporated scenarios for recent data banksproducecumulative visuals and informationby means ofrecognizableaccess interface.

This software has the capacity to be integrated with other data sources.

Plant taxonomic data was stored in Access Jet Database Engine. This can also import data if we link other sources with this software. For this, provided access tables help diverse standard field categories, index and repertoire of updates and deletions. Plant detection software developed on the basis of MS Access also possess a query interface, display outlines, data entry and final result for use. The fundamental Jet database for this software can be used by multiple users and holds record-locking. Automation of repetitive tasks can be performed by means of macros with point-and-click options. For this detection software, it is not difficult to put its database on a network with multi-users share and keep posted data without overwriting. At the record level, Data was locked that was considerably different from Excel.

To increase data trustworthiness, safety, scalability and manageability, we have stored this data in SQL Server and Microsoft Azure SQL. Access applications leverage standard SQL syntax and a true mission-critical back endwas in focus. Each option concises the final output as results. The maximum selection of options gave more precise results. For example, if only one option is selected it showed all result that have the same value as of selected option.

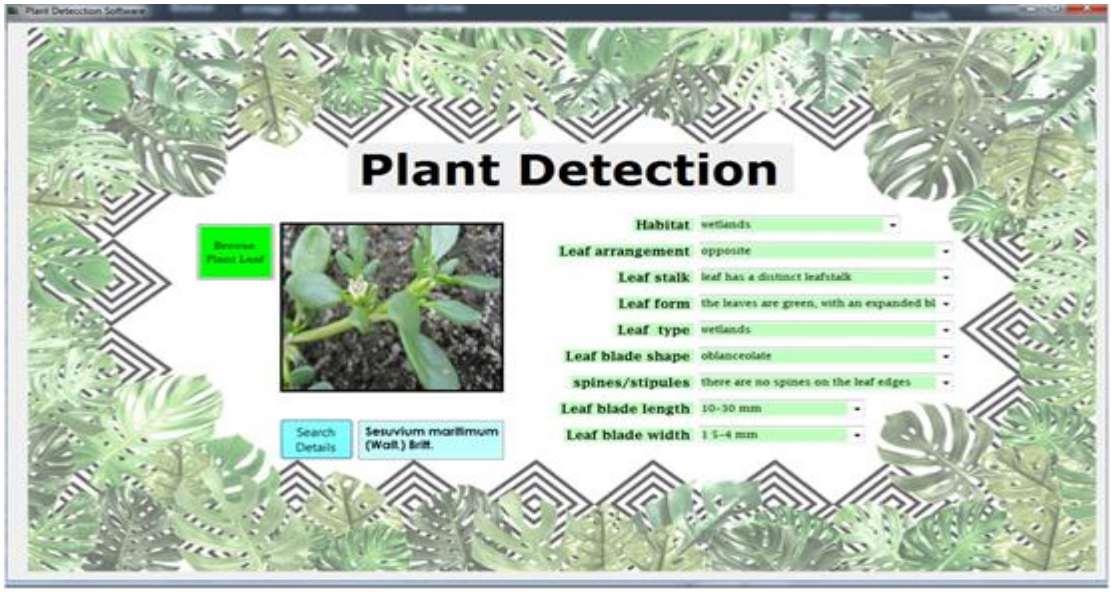

Fig. 4. Figure showing fully detected plants with help of leaf attributes.

DISCUSSION

Healthy, green and properly inserted leaves are crucial for plant survival. For physiological or ecological and taxonomic experimentation, precise leaf identification is the prime step of immense significance (Easlon *et al.*, 2014). Recently plant systematics has taken gigantic leaps for appropriate and easy ways to identify plants. Leaf is the first identity of any plant irrespective of plant type. With recent advances in computer science, aid has been provided to different aspects of plant biology. Researchers are now more interested in developing tools and apps to be used in plant science research e.g. genomic data analysis, RNA sequencing (Hussain *et al.*, 2018; Noman *et al.*, 2018). As far as ecology and taxonomy of plants is concerned, different studies have highlighted the role of computer-based apps and software's for plant distribution and identification. For leaf identification, many omnipresent digital cameras as well as scanners in combination with digital image processing softwares, have mostly replaced earlier used methods for leaf and plant identification (Jensen and Lulla, 1987; Duygulu *et al.*, 2002).For example, ImageJ, the commonly used software measure leaf area by using a threshold-based pixel count measurement(Schneider *et al.*, 2012; Easlon *et al.*, 2014). However, there are some limitations. For example, ImageJ needsconsiderable user input and face hurdle indifferentiating a leaf from its background by using thresholding alone (Davidson, 2011). Soil physical covering with paper collars prior toleaf photography or software based removal of image background can resolve issues before ImageJ analysis. But these things require much time

consumption before leaf recognition (Kimball and Mattis, 2012).

Plant leaf identification is first point of systematics (Katzir *et al.*, 1994; Noman *et al.*, 2014; Khalid *et al.*, 2018;Khan *et al.*, 2018). We have developed leaf image recognition based software for plant detection. Digital leaf image processing is a method used and applied in plant identification.The images are pre-processed to obtain understandable, clear andimproved leaf images. The enhanced leaf images are used for leaf attribute detection and further analyses. Different image types are used in image pre-processing. Normally, color and texture of leaf image are considered as exclusive features for detecting and analyzing the attributes of leaves. Different studies have highlighted the use of Grayscale and RGB leaf images for plant detection and their analysis for pathology, taxonomy and ecological purposes (Katzir *et al.*, 1994; Bui *et al.*, 2001). We developed leaf recognition software to facilitate the novice to understand the taxonomy of plant by just highlighting the attributes of plant leaves. A novel searching technique was built to find out relevant plant botanical name. A pipe and filter software architecture were applied and executed to implement this software. Before developing this software, all plants were properly identified with the help of expert botanists and consulting flora of Pakistan.

Shape recognition and its description is a chief and daunting challenge in Image Processing and computer vision. This appears in different apps becausethe shape is an inherent character of many objects e.g. leaves. Several shape illustration methods are on record with respect to leaf recognition and identification (Mehrotra and Gary, 1993; Sclaroff and Pentland, 1995; Wimmer *et al.*, 2000). Such techniques are in use and several representation techniques recognize object shapes i.e. leaf under affine transformation (Wimmer *et al.*, 2000; He *et al.*, 2016). We evaluated our technique on a prototype data of 153 leaf images belonging to different families both with as well as without considering leaf self-intersection. The objective was to know whether an unknown leaf falls in one of the families, represent which plant group. Our system detected the most similar plant to the input options and can facilitate the users to reach a final conclusion. The final results pointed out a capable presentation of this software and its advantage over the classical method.

CONCLUSION

This article offer plant detection with the help of leaf images. The objective was to know whether an unknown leaf falls in one of the families, represent which plant group. Our system detected the most similar plant to the input options and can facilitate the users to reach a final conclusion. The final results pointed out a capable presentation of this software and its advantage over the classical method. This work can be used for developing hybrid algorithms along with neural networks for increasing the leaf recognition for final classification of plants.

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CONFLICT OF INTEREST

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

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