Plant Recognition from Leaf Image through Artificial Neural Network

Shayan Hati
BTech Student, Department of Civil Engineering,
Indian Institute of Technology (IIT), Kharagpur

Sajeevan G
Centre for Development of Advanced Computing
(C-DAC), Pune University Campus, India 411007

ABSTRACT
Getting to know the details of plants growing around us is of great importance medicinally and economically. Conventionally, plants are categorized mainly by taxonomists through investigation of various parts of the plant. However, most of the plants can be classified based on the leaf shape and associated features. This article describes how Artificial Neural Network is used to identify plant by inputting leaf image. Compared to earlier approaches, new input features and image processing approach that matter in efficient classification in Artificial Neural Network have been introduced. Image processing techniques are used to extract leaf shape features such as aspect ratio, width ratio, apex angle, apex ratio, base angle, centroid deviation ratio, moment ratio and circularity. These extracted features are used as inputs to neural network for classifying the plants. Under the current research, 534 leaves of 20 kinds of plants were collected. Out of these, 400 leaves were trained. The 134 testing samples were recognised with 92% accuracy; even without considering types of leaf margins, vein and removal of the petiole. Software has also been developed to identify leaf automatically except two mouse clicks by the user.

General Terms
Pattern Recognition, Neural Network, Feature Extraction, Leaf Recognition, Plant Identification.

Keywords
Apex Ratio, Centroid Deviation Ratio.

1. INTRODUCTION
Plants are mostly identified by taxonomists and the process is usually lengthy. Plant features that help in identifying a plant are fruit, seed, leaf, flower, root, stem, etc.

Leaves play an important role in identification of a plant due to its availability nearly throughout the year; easiness to access, carry and process in computer. As the shape of plant leaves is one of the most important features for characterising various plants visually, the study of leaf image retrieval schemes will be an important stage for developing a plant identification system [1]. Leaf features like, arrangement, complexity, blade shape, size, leaf apex, base, margin, texture and venation system play an important role in identification of plant.

Recent advances in technology lead to the development of electronic herbarium. However, these systems identify species based on the taxonomic inputs from the user. This restricts the non-domain people for correct identification of plants without the help of qualified taxonomists. For general public to identify a plant swiftly and correctly, it is essential to have an automated / semi-automated leaf recognition system; thereby, the area of research in recognising plant with the help of leaf image is continuously evolving.

Some of the previous research outcomes resulted in the form of software are Leaves Recognition [2], CAPSI [3], Flavia [4] and Leafsnap [5]. Good overviews of previous works have been given in recent articles [6][7].

The key issue of leaf recognition lies in whether selected features are stable and have good ability to discriminate individual leaves [8]. In the current research, image processing is used for extracting shape features from digital leaf image and Artificial Neural Network (ANN) for classification. Software has also been developed to identify leaf automatically except two mouse clicks from the user.

2. METHODOLOGY
Methodology adapted in current experiment to identify leaves based on shape is described in subsequent sections.

2.1 Database
Database of digital images of leaves were captured on a white background through scanning and photographing with mobile phone camera.

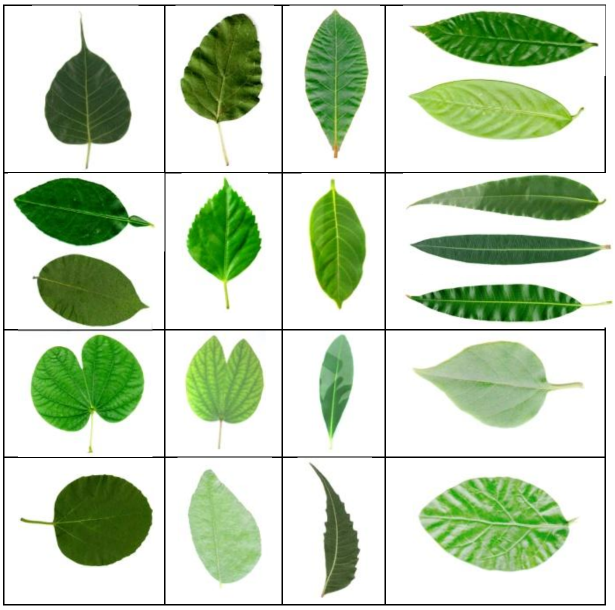

Fig 1: Leaf samples

Only good representative leaves are collected; leaves with deformity are not collected as the user can afford to collect a good quality sample while interested in recognizing it. A total of 534 leaves of 20 kinds of plants (Fig 1) were captured on white background. Out of these, 400 leaves were used for training and 134 for testing. Under the current research, leaflet of a compound leaf is also considered as a sample. The leaves images can be of any resolution and orientation.

2.2 Image Pre-Processing

Image processing is carried out to extract the leaves from the background accurately.

2.2.1 Colour to Grayscale Conversion

In general, the following formula [4][9] is used for converting RGB value of a pixel to its grayscale value

gray = 0.2989*R + 0.5870*G + 0.1140*B

However, a different approach is adapted in this experiment considering the plant leaf domain. Most of the leaves are in different shades of green; very few are in shades of red, yellow and others. The blue component is the least reflected and most absorbed. Since the leaf is captured on a white background, instead of converting the image into gray by the predefined formula, blue band is processed further. This approach helped in separating the leaf from its background easily, as the leaf (blue band) is in darkest shade and the background in lightest shade.

2.2.2 Threshold

In the histogram of leaf, there are two peaks; one for the leaf and other for the background. The main purpose of taking the blue band was to increase the distance between the two peaks, so that the thresholding can be done easily. Moreover, there would be no overlap between the pixels corresponding to the two peaks. A value between the two peaks has been taken as a threshold for the grayscale (blue band) image.

2.2.3 Binary Conversion

Taking the threshold as a level to separate the background from the leaf, the values less than threshold is taken as white and the values greater is taken as black. The leaf image is now white colour and the background black, as shown in the Fig 2.

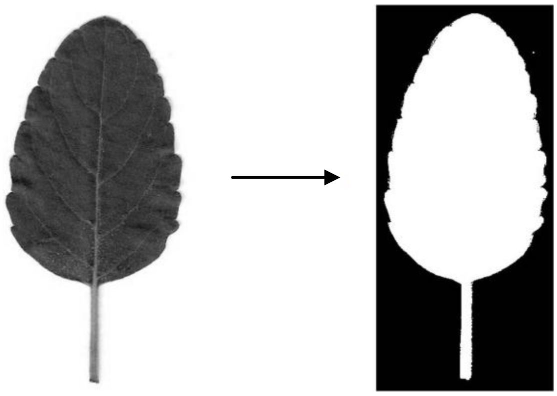

Fig 2: Binary converted image

2.2.4 Filtering

After the binary conversion, there may be noise effects on the image. To remove this noise, the standard median filtering (5x5 window) is applied on the binary image. If the number of white pixels in a window is greater than the number of black pixels, the mid-pixel is changed to white; and vice versa.

2.3 Feature Extraction

Users are expected to click on the base and apex of the leaf, which is the only manual intervention. The distance between base and apex is the physiological length and is considered to be the major axis. The image is rotated in computer memory with respect to base, making the major axis horizontal. Then, the following parameters (Fig 3) related to leaf shape are extracted:

- Major axis length (L):- The distance between base and apex.
- Max width (W):- Maximum width of the leaf.
- Width at 0.5L:- Width of the leaf at 50% of the major axis.
- Apex angle:- Angle at apex between leaf edges on width line at 75% of the major axis (measured from base).
- Apex angle at 0.9L:- Angle at apex between leaf edges on width line at 90% of the major axis.
- Base angle:- Angle at base between leaf edges on width line at 25% of the major axis.
- Centroid:- Centroid.
- Area:- Number of leaf pixels (value 1).
- Perimeter:- Number of leaf pixels along boundary.
- Mass distribution ratio (moment ratio):- The ratio between Y deviation and X deviation from the centroid of the leaf.

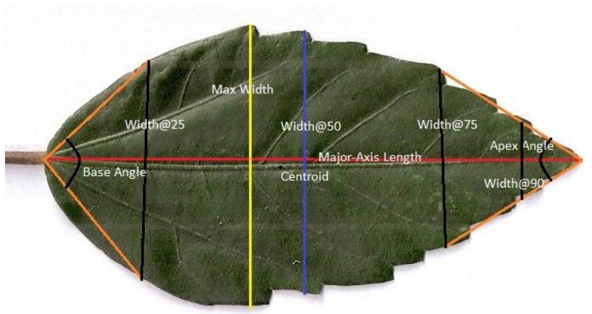

Fig 3: Leaf features extracted

2.4 Final parameters

Based on the features extracted, the following seven parameters have been derived which are the inputs for the neural network.

- ***Aspect ratio***: The ratio of maximum width to major axis length.
- ***Width ratio***: The ratio of width at half of major axis to maximum width.
- ***Apex angle***: The angle at apex between leaf edges on width line at 3/4th of the major axis.
- ***Apex ratio***: The ratio of the angle made at the apex by width at 9/10th of major axis to angle at 3/4th of major axis. This new parameter, introduced in the current research, represents how much conical the apex of the leaf is.
- ***Base angle***: The angle at base between leaf edges on width line at 1/4th of the major axis.
- ***Moment ratio***: The ratio between Y deviation and X deviation from the centroid of the leaf. It accounts for the mass distributed around the leaf, whether it is in longitudinal or lateral direction. If the value is greater than one, the leaf is longitudinal in nature; and vice versa. Whereas, a value equal to one classifies it as circular.
- ***Circularity***: The ratio of 4*PI*Area of the leaf to the square of perimeter.

These seven parameters are stored in the database (PostgreSQL) corresponding to leaf. These parameters are normalized between (0, 1) at the time of feeding into the neural network by taking the maximum and minimum among each of the parameters.

There are many other features such as leaf margin and vein structure that help in identifying leaves more accurately. However current research concentrated on a few new and other easily extractable features.

2.5 System Architecture / Implementation

The software (named LEAFilia) including implementation of ANN has been developed in Java [10]. The Fig 4 shows the whole architecture of the application and the process followed.

There are three modules, the first one for the image processing and finding the input parameters, the second one for training of the neural network and the third for matching an unknown leaf by the user.

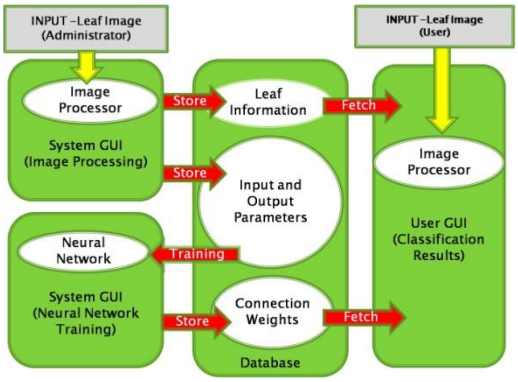

Fig 4: System architecture

With the image processing GUI (Fig 5), a leaf image is uploaded onto it. The administrator clicks on the base and apex of the leaf. The next step is to process the image for finding the parameters, and finally saving it.

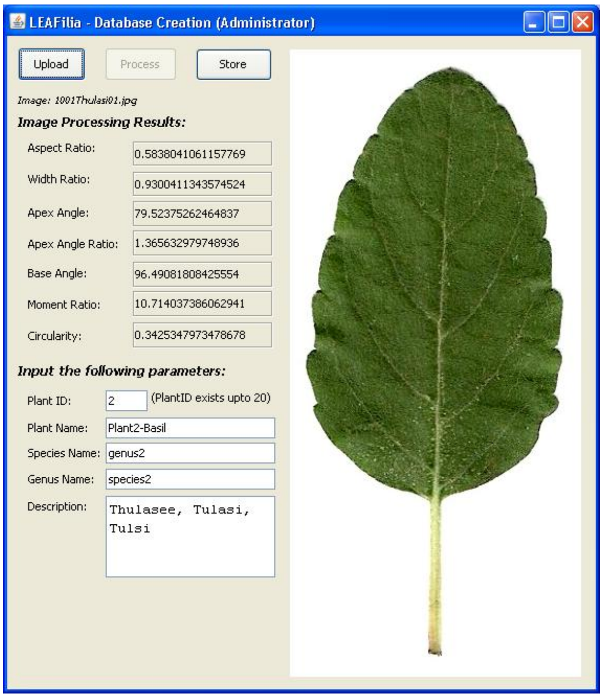

Fig 5: GUI for feature extraction

The neural network training GUI (Fig 6) takes the input from the database corresponding to data stored in input and output parameters and the training is carried out on the connection weights of the neural network which is finally stored in the database in the place of connection weights. This training is done corresponding to each of the data present in the input and output parameters table.

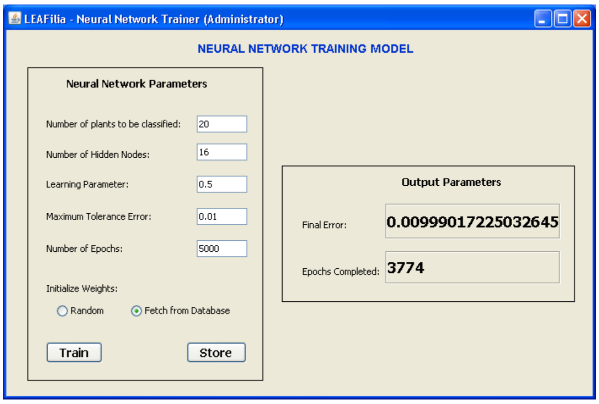

Fig 6: GUI for training

At the time of matching, an unknown image is uploaded and the base/apex clicked by the user. Processing is done on it to find the parameters which are multiplied to the connection weights fetched from the database. Finally, the output corresponding to a plant ID and related information is fetched from the database and presented to the user (Fig 7).

Fig 7: GUI for leaf matching

There are seven input parameters which constitute the input layer. There is only one hidden layer. Initially for the first epoch, the input parameters are fetched from the database for the first row of the input-output table. Random weights are assigned to all the connection weights in (0, 1). The input parameters multiplied with connection weights between input and hidden layer. An activation function which is the sigmoid function, f(x) =1/ (1+e-x), is applied on the result and this is then multiplied with the connection weights between the hidden layer and the output layer. Finally, the value of the neurons after applying the activation function is obtained. Error is calculated and transferred back, as discussed above in the algorithm. The weights are updated corresponding to the formulae and procedure is followed until the error is reduced below the tolerance level. Thus, with the help of neural networks the connection weights are obtained that get stored in the database and used at the time of classification.

3. RESULT AND CONCLUSION

Image processing techniques are used for extracting the morphological parameters that are having some significance and effect on the classification of the leaves. Out of total sample of 534 leaves of 20 kinds of plants, 400 were classified. Out of 134 testing samples, 10 were misclassified, that is, a recognition accuracy of 92%. With the seven parameters, better results are obtained even without considering types of leaf margins, veins and removal of the petiole.

The blue band of the leaf may be used as grayscale image rather than composite image created using the standard colour-gray conversion formula. The new parameter apex ratio shows how much conical the apex of a leaf is. The same species with clearly different shape feature may be processed as separate sample type. The leaflet of a compound leaf can also be considered as a sample for recognising a plant.

The new parameter (named Centroid Deviation Ratio), which is the ratio of perpendicular distance from the centroid to major axis and the major axis length, shows how much a leaf is bent or asymmetric. Concisely, the distance from centroid to the major axis/mid-vein represents the asymmetry of leaf. This parameter did not give much result while a plant type was having a mix of bent and straight leaves. This parameter needs to be studied more.

Some of the future improvements envisaged are:

- Addition of leaf margin, vein and other parameters as inputs
- Removal of shadow and complex background
- Automatic identification of base and apex
- Incorporation of a universal primary key in the database, so that it can connect to external databases of digital herbariums to access various details of the plant.

4. ACKNOWLEDGMENTS

Authors would like to thank Dr. Manish Kale and Mr. Satish Pardeshi for taxonomic inputs. Thanks are due to Mr. Nitin Rao for scanning most of the leaves.

5. REFERENCES

[1] Wang Zhi, Zheru Chi and David Feng. 2003. Shape based leaf image retrieval. Vision, Image and Signal Processing, IEE Proceedings-. Vol. 150. No. 1. IET.

[2] Jens Langner. 2001. Leaves Recognition v.1.0, http://www.jens-langner.de/lrecog.

[3] Ji-Xiang Du, De-Shuang Huang, Xiao-Feng Wang and Xiao Gu. 2006. Computer-aided plant species identification (CAPSI) based on leaf shape matching technique, Transactions of the Institute of Measurement and Control.

[4] Stephen Gang Wu, Forrest Sheng Bao, Eric You Xu, Yu-Xuan Wang, Yi-Fan Chang and Qiao-Liang Xiang. 2007. A Leaf Recognition Algorithm for Plant Classification Using Probabilistic Neural Network", IEEE International Symposium on Signal Processing and Information Technology.

[5] http://leafsnap.com. 2011. Columbia University, the University of Maryland, and the Smithsonian Institution.

[6] Abdul Kadir, Lukito Edi Nugroho, Adhi Susanto, Paulus Insap Santosa. 2011. Leaf Classification Using Shape, Color, and Texture Features, International Journal of Computer Trends and Technology.

[7] Jyotismita Chaki and Ranjan Parekh. 2012. Plant Leaf Recognition using Gabor Filter, International Journal of Computer Applications (0975–8887), Vol. 56, No. 10.

[8] Qingfeng Wu, Changle Zhou and Chaonan Wang. 2006. Feature Extraction and Automatic Recognition of Plant Leaf Using Artificial Neural Network, Avances en Ciencias de la Computación, pp. 5-12.

[9] Gurpreet Kaur and Gurpinder Kaur. 2012. Classification of Biological Species Based on Leaf Architecture, International Journal of Engineering Research and Development.

[10] Wilhelm Burger and Mark J. Burge. 2007. Digital Image Processing - An algorithmic introduction using Java, Springer.