AyurLeaf: A Deep Learning Approach for Classification of Medicinal Plants

Dileep M.R.
Department of Computer Science and Engineering
National Institute of Technology Calicut, India
dileeepmr@gmail.com

Pournami P.N.
Department of Computer Science and Engineering
National Institute of Technology Calicut, India
pournamipn@nitc.ac.in

***Abstract*—Ayurvedic medicines have a vital role in preserving physical and mental health of human beings. Identification and classification of medicinal plants are essential for better treatment. Lack of experts in this field makes proper identification and classification of medicinal plants a tedious task. Hence, a fully automated system for medicinal plant classification is highly desirable. This work proposes AyurLeaf, a Deep Learning based Convolutional Neural Network (CNN) model, to classify medicinal plants using leaf features such as shape, size, color, texture etc. This research work also proposes a standard dataset for medicinal plants, commonly seen in various regions of Kerala, the state on southwestern coast of India. The proposed dataset contains leaf samples from 40 medicinal plants. A deep neural network inspired from Alexnet is utilised for the efficient feature extraction from the dataset. Finally, the classification is performed using Softmax and SVM classifiers. Our model, upon 5-cross validation, achieved a classification accuracy of 96.76% on AyurLeaf dataset. AyurLeaf helps us to preserve the traditional medicinal knowledge carried by our ancestors and provides an easy way to identify and classify medicinal plants.**

***Index Terms*—Deep Learning, Convolutional Neural Network, Classification, Medicinal plant, Leaf features.**

I. Introduction

Plants play a crucial role in preserving life and maintaining biodiversity on earth by facilitating air and water for living beings. Medicinal plants, one of the important class of plants, serve as medicine for many diseases. The knowledge about medicinal plants carried by generations must be preserved and protected. Computer vision, pattern recognition, and image processing technologies provide promising results for identification and classification of medicinal plants. Identifying a medicinal plant with required medicinal values is one of the major challenging tasks. Even though herbal medicine has no side effects, treatment using a wrongly identified medicinal plant may claim the life of a patient. Hence, a fully automated system to correctly classify the medicinal plants is inevitable at this point of time.

Identification and classification of medicinal plants play a crucial role in the preparation of ayurvedic medicines. Also, proper classification of medicinal plants is important for agronomist, botanist, ayurvedic medicinal practitioners, forest department officials and those who are involved in the preparation of ayurvedic medicines. But lack of expert taxonomists is a major issue in this area. Nowadays there is a potential class of customers who prefer ayurvedic medicines than other medicines. Features of leaf, flower, trunk, and branch are used by the taxonomists for classification purposes [1]. Since the leaves are available on all seasons, it is the best choice for plant classification.

Computer vision and image processing methods can bridge the gap between the lack of expert taxonomists and potential requirement in identification and classification of the medicinal plants. Shape, color, and textures are the important spatial and morphological features used by the researchers to classify the plants [1]–[3]. But the color feature is not a judicious feature for classification since it varies on seasons and also different stages of the same leaf will have a different color. Taxonomists use the variations in leaf characteristics as a tool for the classification of medicinal plants. Many research works have been done in this area. But the high rate of inter-class similarity in shape, color and texture features make this problem still a challenging and unsolved one.

The rest of the paper is oraganised as follows. Section II briefly describes and analyses few related works on identification and classification of plant species. Section III narrates the tools, techniques and methodology used in the proposed work. Section IV reports the results and finally, Section V concludes the work. Possible future directions are also mentioned here.

II. Review of Literature

Jing Wei Tan et al. [1] proposed a venation based CNN model, DLeaf for plant leaves classification. DLeaf used CNN for feature extraction and ANN for classification. Sobel edge detection algorithm is used for venation segmentation from the resized leaf images. D-Leaf model achieved a classification accuracy of 94.88%.

Gopal A et al. [2] proposed an automatic identification system for selected medicinal plant leaves. The boundary-based features, moment features and colour features are used for identification of various leaves. The software is trained with 100 leaves and tested with 50 leaves and exhibited a classification efficiency of 92%.

R. Janani et al. [3] developed an ANN-based model to classify the medicinal plant species using color, texture and shape of leaves. The model used 63 leaves in total, 36 for training, 7 for validation and 20 for testing. Out of 20 different features of leaves, 8 minimal prominent features were identified to classify the leaves.Compactness, eccentricity, skewness,

978-1-7281-1895-6/19/$31.00 ©2019 IEEE

kurtosis, energy, correlation, sum-variance and entropy are those minimal 8 features. This method achieved an accuracy of 94.4%.

D.Venkatarama et al. [4] proposed a computer vision based approach to find the feature set to classify the given medicinal plant leaves and to retrieve its medicinal details. This method uses a Probabilistic Neural Network classifier to identify the leaf class. The method consists of the following steps: pre-processing, feature extraction, classification, and retrieval of medicinal values. The classification involves the feature vector calculation and similarity matching.

Shitala Prasad et al. [5] presented an efficient technique for leaf acquisition and methods to transform the acquired image to device independent l color space, further used to compute VGG-16 feature map. Finally, this feature map is reduced and optimized by Principle Component Analysis(PCA). ImageNet is the dataset used. The output of the Fully Connected layer is a feature vector of dimension 3x4096. On this feature set applied the SVM and obtained the accuracy of 97.6% for l-VGG-16 and 98.2% for l-VGG-16 with PCA methods.

Amala Sabu et.al [6] employed a machine learning, and computer vision based method to classify the medicinal plants found in the Western Ghats. The method used the SURF and HoG features extracted for classification with the help of k-NN classification algorithm. HoG features are used to model the leaf veins and twenty different points of interest on the leaves are modeled using SURF feature descriptor. the k-NN classification algorithm is used in this method to classify the leaves with k value equal to 1. Even though the method gives an accuracy of more than 96%, the method used for feature extraction in this model is computationally expensive.

Manojkumar P et al. [7] proposed a method to find the optimum combination of features required to classify the medicinal leaves which maximize the classification accuracy. Geometric features, Color features, Texture features, HU invariant moments and Zernike moments are the features used for the classification. Multi-Layer Perceptron(MLP) and SVM are the classifiers used and the maximum of 99% of accuracy is obtained on MLP classifier for Geometric-Colour-Texture-Zernike combination with 38 features.

A. Salima et al. [8] implemented a Hessian matrix based leaf vein segmentation. The method involves the following steps: pre-processing, Hessian matrix segmentation, Thinning and visual evaluation. Totally 80 leaves are used for testing and evaluation. The segmentation scoring techniques were applied in this method to evaluate the segmentation result. 53.75% of leaf images attained a segmentation score of 2, and 42.5% of leaves scored 1.

Guillermo et al. [9] proposed a deep Convolutional Neural Network model to classify the plants using leaf venation. The unconstrained version of Hit or Miss Transform used for vein segmentation. A central patch of 100x100 pixels extracted from the segmented vein pattern and extracted the features of interest. The Support Vector Machine(SVM), Penalized Discriminant Analysis (PDA) and Random Forests (RF) are the classification method and algorithms used in this method. A 5 layer CNN and 6 layers CNN were developed and tested against S1 and S2 two variations of the dataset. The 5 layer network outperformed the 6 layer network for S1 and S2 with an average accuracy of 96.9%.

Pavoloiu et al. [10] proposed an important method to extract shape features of medicinal leaves using RELIEF feature selection algorithm. PCA is used to refine the features collected. Flavia and RMH dataset were used for training and testing. k-NN with four neighbors and Multi-Layer Perceptron Neural Network(MLP NN) are the classification methods applied. The MLP NN classifier outperforms all the other methods with an accuracy of 47.08%.

Mostafa Mehdipour Ghazi et al. [11] used various deep convolutional neural networks to identify the plant species. A comparative study on popular Convolutional Neural Networks like AlexNet, GoogLeNet and VGGNet has been done to determine the parameters affecting the performance of these networks. These networks trained with various parts of the plants such as branch, entire, flower, fruit, leaf, and stem. Fine-tuned VGGNet attained highest performance with an overall accuracy of 78.44%.

Guillermo L Grinblat et al. [**?**] proposed a deep Convolutional Neural Network model to classify the plants using leaf venation. The unconstrained version of Hit or Miss Transform used for vein segmentation. A central patch of 100x100 pixels extracted from the segmented vein pattern and extracted the features of interest. The Support Vector Machine(SVM), Penalized Discriminant Analysis (PDA) and Random Forests (RF) are the classification method and algorithms used in this method. A 5 layer CNN and 6 layers CNN were developed and tested against S1 and S2 two variations of the dataset. The 5 layer network outperformed the 6 layer network for S1 and S2 with an average accuracy of 96.9%.

Many researches have been taken place in this area of plant species classification using various technologies. Classification using deep learning promises good results and high accuracy over classical classification methods. The classification of compound leaves is still to be addressed. An efficient method to address the classification of all types of medicinal plant leaves is yet to develop.

III. Materials and Methods

A. Deep Learning

Identification and classification of plants have been carried out for the last few decades using classical image processing and classification methods. These methods were used shape, texture and color based features to perform classification. Aspect ratio, eccentricity, kurtosis, skewness, energy, correlation, sumvarience, entropy and compactness are some of these features. Excessive computation time required for handcrafted feature extraction is the major problem associated with these classical methods. Nowadays all the classical methods are replaced by machine learning techniques.

Deep learning is a class of machine learning in which a computational model learns to perform classification tasks directly from images. Higher accuracy, ability to handle huge volume of image data, inbuilt ability to use GPUs for parallel computation and availability of inbuilt pre-trained Convolutional Neural Networks contribute towards the popularity of deep learning. Since AyurLeaf performs classification on huge volume of image data, deep learning approach is the best choice.

B. AyurLeaf Dataset

AyurLeaf is the proposed dataset which consists of 2400 images of medicinal plant leaves commonly found across Kerala. More than 30 leaves from 40 different plant species were collected and performed sampling on it. The leaves with severe deformities are removed and selected 30 leaves with a significant difference in the shape, color, and size. Apparently, 30 leaves of each class are selected for the further scanning process. Both the top and bottom sides of these selected 30 leaves are scanned to create 60 leaf images per species.

Only the leaf area is selected and cropped using GIMP image editor and saved each image in jpg format. A common naming convention is used to label each image, plant species name followed by a unique sequence number. Sampling ensures the diverse nature of the dataset in plant species level and helps the model to provide more accurate classification results.

C. AlexNet

AlexNet [12] is a pre-trained CNN model trained with images of ImageNet dataset. It can classify 1000 different species. It consists of 5 Convolutional layers, three fully connected layers, and a softmax classification layer. Each convolutional layer performs a basic convolution operation on the input images by using a fixed number of kernels having different dimensions in each layer. The starting convolutional layers are responsible for extracting edge and color features of the input images. These layers generate the feature maps of the input images given to it.

The size of the feature maps depends on the number and size of the filter applied in a specific convolutional layer. The output of the last convolutional layer is passed as the input to the first fully connected layer. The output from the last fully connected layer passed to the softmax layer for classification and softmax layer calculates the probability values for each species. There are 4096 neurons in first two convolutional layer and last fully connected layer consists of 1000 neurons. ReLU layer and Pooling layer applied on these feature maps to keep all feature values positive and to reduce the size of the feature set respectively. These two layers play a key role in between every two convolutional layers.

D. AyurLeaf - Proposed CNN Architecture

AyurLeaf CNN architecture is designed and developed based on the AlexNet architecture. The abstract model of our proposed system is given in Fig.1.

The first layer is the input layer which specifies the dimension of the input images. The second layer, the convolution layer used 90 (7x7) filters with a stride size of 2. This layer is followed by a ReLU layer which thresholds output, and then a max pooling layer with filter size 2x2. This layer reduces the size of its output exactly by half. This max pooling layer is followed by a second convolution layer which operates on 512 kernels with the dimension 5x5 and a stride of 2. Next layer is a ReLU layer followed by a max pooling layer with filter size 3x3 and stride 1.

The next two layers are two back to back convolution layer with the following configurations. Both use 3x3 kernels with a stride of 2 and the number of kernels in first and second is 480 and 512 respectively. These layers are again followed by a ReLU layer and a max pooling layer with filter size 2x2 and stride 2. The output from the last max pooling layer is given to the first fully connected layer which consists of 6144 neurons. The second fully connected layer is also comprised of 6144 neurons. And the third fully connected layer has 40 neurons, which is equal to the number of classes of the medicinal plant to be classified. Finally, the output of the third fully connected layer is given to the softmax classification layer which calculates classification probabilities for each species.

The proposed CNN model performs the following four steps.

1) Image Acquisition: The leaf samples of medicinal plants were collected from ayurvedic practitioners and tropical forests of Kerala. Atleast 30 leaves of 40 different medicinal plant species were collected. Perform a basic manual sampling and remove severely damaged leaves. Select 30 leaves of each species for scanning and 60 image samples per medicinal plant species are generated. To ensure the quality of the images in the dataset the leaf images are scanned using a flatbed scanner in 1200 or 600 dpi. The top and bottom face image sample of an Adalodakam medicinal plant is given in Fig.2.

2) Image Pre-processing: The objective of the pre-processing phase is to transform the scanned images into a dimension of 227x227x3 which is one of the acceptable formats of input images of CNN. We have used the images in RGB format and if the images are not in the required format converted it into the specified 227x227x3 format. Since the dimension of the images in our dataset varies, first converted the images into an NxN dimension by performing padding on it. And finally, resized the padded image to 227x227x3 dimension. Fig.3 shows sample pre-processed images.

3) Feature Extraction: A good number of CNN models were designed with different number of layers, number of filters and filter size with various training options. All the designed models are trained and tested with AyurLeaf dataset and results are compared against the results of Alexnet and Dleaf [1] CNN models. The performance of these models clearly depends on the quality of the dataset, a number of convolutional, max-pooling, ReLU layers, training options and a number of neurons in the first two fully connected layers. Finally the proposed Ayurleaf CNN is designed.

AyurLeaf CNN utilised 80% of the image samples from the data set for training and the remaining 20% for testing. The accuracy of the model highly depends on the number of images used for training the model and number of iterations

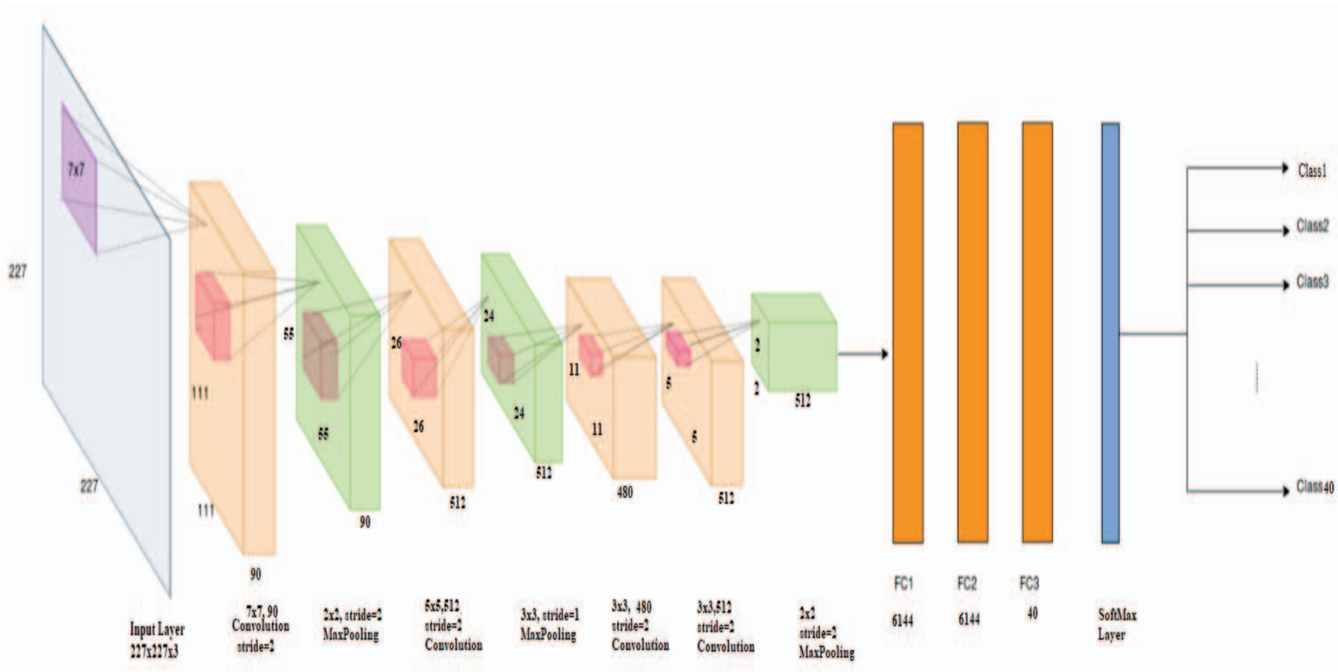

Fig. 1. AyurLeaf CNN - Proposed CNN Architecture

Fig. 2. Top and bottom faces of Adalodakam leaf

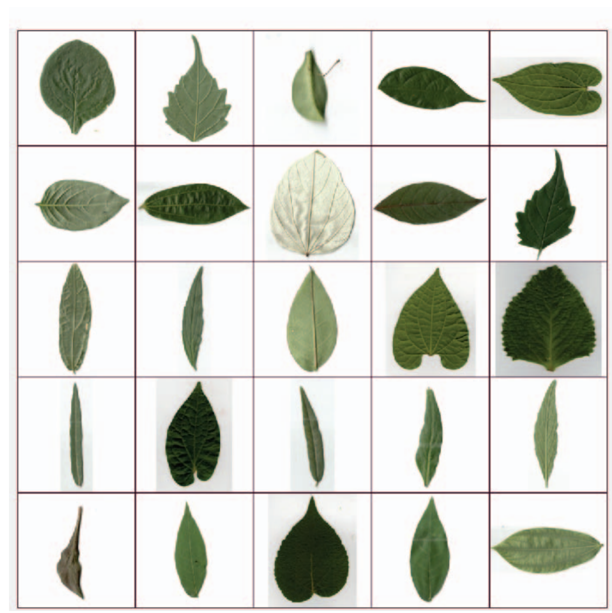

Fig. 3. Sample set of pre-processed training images

the CNN is trained. After the training process is done, the images from the test set are given for obtaining the accuracy of the model. And finally AyurLeaf model outputs the training and validation accuracy during training using the accuracy-loss graph, and classification accuracy using confusion matrix.

IV. RESULTS AND DISCUSSION

The training and testing of AyurLeaf CNN model are done using our own AyurLeaf dataset. The training progress is displayed using the training graph as shown in Fig.4. The graph narrates the progress of accuracy and loss functions during the training process. A five-fold cross validation is performed on AyurLeaf dataset, maximum accuracy achieved for a single run out of five consecutive runs is 98.46%. Totally, 6000 iterations are performed by the algorithm on the dataset.

The percentage of training accuracy and validation accuracy during training are given in the graph. The growth of training and validation accuracy graph function of a good CNN model should follow each other synchronously.

The AyurLeaf CNN model is tested and compared with AlexNet, DLeaf and fine-tuned AlexNet models. In cross-validation training and testing, we specifically have gone for the three-fold cross-validation and five-fold cross-validation. Our model outperforms the above-mentioned models with a classification accuracy of 96.76%. The results of five trial runs

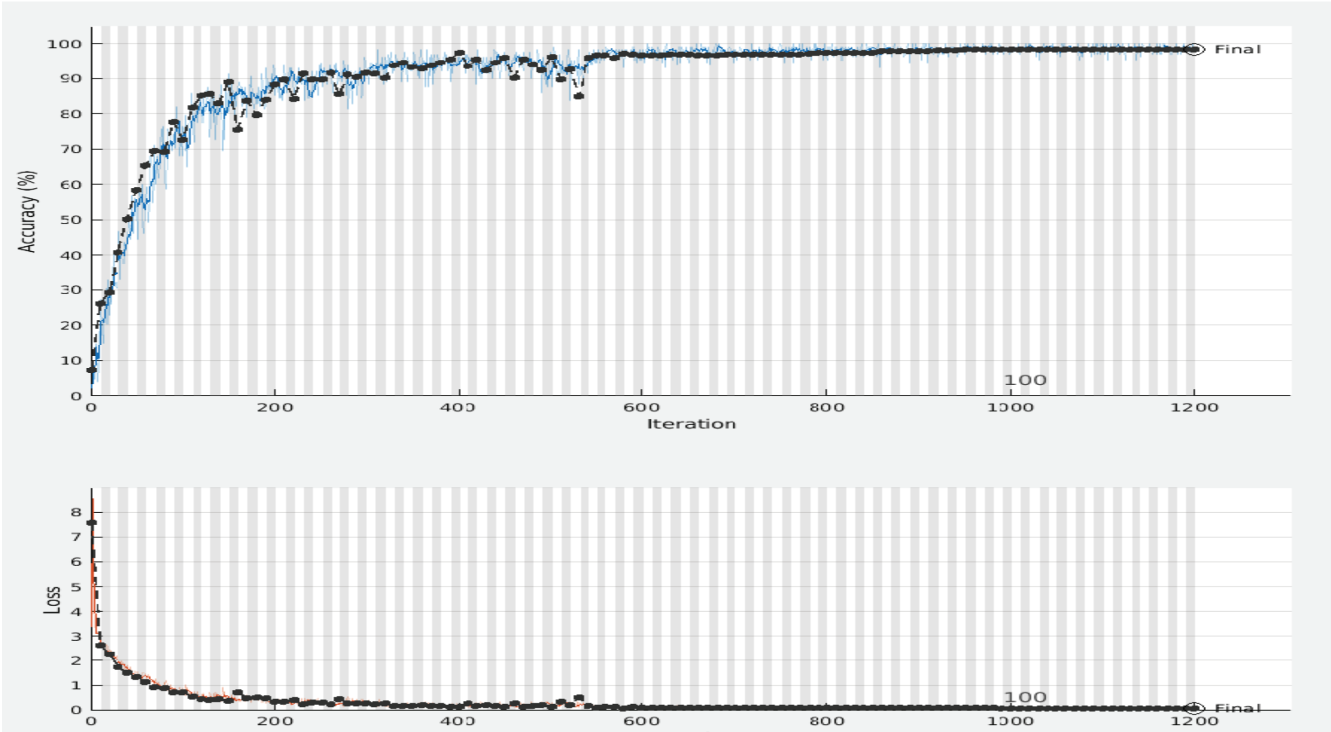

Fig. 4. Training phase - Accuracy (above) and Loss (below) curves

are given in the Table I.

Model	No. of Classes	Classifier	Accuracy (%)
Alexnet	40(2000 Images)	CNN	94.87
DLeaf	43(1290 Images)	CNN	93.16
AyurLeaf	40(2000 Images)	CNN	95.06
AyurLeaf	40(2000 Images)	SVM	96.76

TABLE I
PERFORMANCE OF AYURLEAF, ALEXNET, DLEAF

It is evident that the proposed CNN architecture achieves better performance than the state-of-the-art CNN models for classifying the leaf samples in the AyurLeaf dataset.

V. CONCLUSION AND FUTURE WORK

AyurLeaf is a CNN-based classification model which is trained and tested on its own dataset and DLeaf dataset. SVM classifier brought out the best classification accuracy on AyurLeaf dataset. AyurLeaf model can upgrade to make it suitable for classifying leaf images in which a single image contains leaves of more than one plant species and more than one leaves of the same plant species in different orientations.

REFERENCES

[1] J. W. Tan, S. Chang, S. Binti Abdul Kareem, H. J. Yap, and K. Yong. Deep learning for plant species classification using leaf vein morphometric. pages 1–1, 2018.

[2] A. Gopal, S. Prudhveeswar Reddy, and V. Gayatri. Classification of selected medicinal plants leaf using image processing. In *2012 International Conference on Machine Vision and Image Processing (MVIP)*, pages 5–8, Dec 2012.

[3] R. Janani and A. Gopal. Identification of selected medicinal plant leaves using image features and ann. In *2013 International Conference on Advanced Electronic Systems (ICAES)*, pages 238–242, Sept 2013.

[4] D. Venkataraman and N. Mangayarkarasi. Computer vision based feature extraction of leaves for identification of medicinal values of plants. In *2016 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)*, pages 1–5, Dec 2016.

[5] S. Prasad and P. P. Singh. Medicinal plant leaf information extraction using deep features. In *TENCON 2017 - 2017 IEEE Region 10 Conference*, pages 2722–2726, Nov 2017.

[6] A. Sabu, K. Sreekumar, and R. R. Nair. Recognition of ayurvedic medicinal plants from leaves: A computer vision approach. In *2017 Fourth International Conference on Image Information Processing (ICIIP)*, pages 1–5, Dec 2017.

[7] P. M. Kumar, C. M. Surya, and V. P. Gopi. Identification of ayurvedic medicinal plants by image processing of leaf samples. In *2017 Third International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN)*, pages 231–238, Nov 2017.

[8] A. Salima, Y. Herdiyeni, and S. Douady. Leaf vein segmentation of medicinal plant using hessian matrix. In *2015 International Conference on Advanced Computer Science and Information Systems (ICACSIS)*, pages 275–279, Oct 2015.

[9] Guillermo L. Grinblat, Lucas C. Uzal, Mnica G. Larese, and Pablo M. Granitto. Deep learning for plant identification using vein morphological patterns. *Computers and Electronics in Agriculture*, 127:418 – 424, 2016.

[10] I. Pvloiu, R. Ancuceanu, C. Enache, and A. Vasileanu. Important shape features for romanian medicinal herb identification based on leaf image. In *2017 E-Health and Bioengineering Conference (EHB)*, pages 599–602, June 2017.

[11] Mostafa Mehdipour Ghazi, Berrin Yanikoglu, and Erchan Aptoula. Plant identification using deep neural networks via optimization of transfer learning parameters. *Neurocomputing*, 235:228 – 235, 2017.

[12] Alex Krizhevsky, Ilya Sutskever, and Geoffrey E. Hinton. Imagenet classification with deep convolutional neural networks. In *Proceedings of the 25th International Conference on Neural Information Processing Systems - Volume 1*, NIPS'12, pages 1097–1105, USA, 2012. Curran Associates Inc.