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INDIAN AYURVEDIC PLANT IDENTIFICATION USING MULTI ORGAN IMAGE ANALYTICS

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Abstract

Medicinal Plants are the main resource base of Indian autochthonic health care traditions called Ayurveda. The general use of ayurvedic preparation is also common without ill effects. As advancement in Image Processing, Image Analytics techniques transpiring, researchers in the machine learning and computer vision fields are striving to achieve accurate automatic plant identification and classification. This paper focuses on the Automatic Indian Ayurvedic plant identification based on muti organ images analytics. A lot of research work has been carried out for the identification of plants by their leaves, this research carries out multi organ-based identification of Indian Medicinal plants. This paper proposes IMPINet which is a network developed for Indian Medicinal Plant Identification. IMPINet is a non-sequential deep network having multiple convolutions at the same level. A novel approach for multiorgan based plant identification is also proposed where final accuracy is calculated by score-based fusion. Comparison of IMPINet has been carried out with the state of art networks and performance of IMPINet is evaluated on benchmark dataset Flavia.

Keywords:

Indian Medicinal Plant Identification, Image Analytics, Multi-Organ based Plant Identification, Deep Learning, Image Dataset

1. INTRODUCTION

India is known for the rich biodiversity and richness in flora and fauna. Medicinal plants are one of them, the uses of plants for medicinal purpose and in the treatment of ailment is indigenous to India. But the main issue faced by the entire world is the scarcity of expert taxonomist who can identify plant species precisely and accurately.

Taxonomist in real time carry out physical observation of plant and observe multiple organs to identify the plant species. The rich biodiversity and scarcity of an experts accelerated the research in the field of automatic Indian Medicinal Plant Identification.

Image processing engineers and computer vision scientists have come up with various techniques for automatic identification of plant species but most of the solutions are based on single plant organ that is leaf. Leaf is generally green flat plant organ which is mainly responsible for photosynthesis. Most of the researchers' studies leaf because of the flat, 2D like structure and availability of leaf mostly throughout the year.

This research considered multiple organs for the identification of Indian Medicinal Plants, the organs being considered are leaf and flower. Flowers are reproductive organ of the plants. This research proposed approach for Indian Medicinal Plant identification based on multiple organs. The approach is extensible to incorporate identification based on multiple organs.

2. REVIEW OF LITERATURE

Numerous works has been carried out in order to identify plant species from organ images. Notable work in the field of medicinal plant identification had been carried out by [1], researcher extracted shape, color and texture-based features. HoG (Histogram of Gradient), GLCM (Grey Level Co-occurrence Matrix) were calculated along with Energy, Correlation, Contrast, Homogeneity, color Mean, Standard Deviation, Skewness, Kurtosis, Perimeter, Aspect Ratio, Area, Entropy, Roundness. SVM (Support Vector Machine) was used as classifier. The custom dataset of five Indian medicinal plant species each with 25 samples were used in the training phase and 40 samples have been used for testing.

The authors in [2] carried out medicinal plant identification based on the features extracted from leaf images. Some of the features extracted are perimeter, length, width, area, rectangularity, circularity along with color features. The identification was carried out based on these extracted features.

The authors in [3] proposed a system called Ayurleaf, a deep learning-based solution for medicinal plant classification. The dataset contains leaf sample from 40 medicinal plants of Kerala. In this experiment the deep neural network inspired from AlexNet was used as a feature extractor and classification was performed using SoftMax and SVM. Another notable work has been carried out by [4], the research worked on front and back side of leaves and extracted shape, color, texture, geometric features along with CR distance, HU invariant moments, Zernike moment. 38 features were selected out of 131 features identified. The researcher used custom dataset having 40 different species of plant leaf images of 1600×1200 resolution. Total 800 samples for testing and 400 samples for training were used. Experimented with Support Vector Machine and MLP (Multi-Layer Perceptron) classifiers in WEKA and obtained highest accuracy up to 99% using MLP.

The authors in [5] Extracted morphological features and used SVM, Random Forest and MLP classifiers. The prediction accuracies obtained are respectively 96% in case of SVM, 96.6% with Random Forest and 86.6% with MLP. Another interesting approach carried out by [6], the researcher proposed digital image-based approach, researcher used two methods of feature extraction 1D and 2D. For the classification of extracted features Bagging Classifier. The approach was tested on Flavia dataset containing 1907 colored leaf images and demonstrated superiority of 2D-PCA (Principal Component Analysis) and 2D-LDA (Linear Discriminant Analysis) features.

The authors in [7] proposed plant leaf classification using hybrid feature modeling. Another interesting and inspirational work has been carried out by [8], the researchers carried out fine-grained plant species classification using pretrained network adopting transfer learning techniques. The researcher used leaf image dataset for the experiment. [9] carried out two view fine grade plant species classification using Siamese network. The current research focuses on Indian Medicinal Plant identification using multi organ images as real time observation done by the taxonomists take multiple organs in consideration.

3. PROPOSED WORK

The entire experiment carried out in this research is divided in multiple sections, firstly a dataset is created with the images of multiple plant organ images. then the detailed experiment was carried out in order to find the suitable model and parameters. After obtaining optimum network architecture and hyper parameters final approach has been discussed and evaluated.

3.1 DATASET

Dataset is an important component of the machine learning and deep learning experiments. The dataset can impact the accuracy as well as generalization capabilities of the model. The dataset of Indian Medicinal Plant organ images has been created using the tool created by [10]. The Table.1 describes the dataset details.

Table.1. Total number of plant images

Scientific Name	Vernacular Name	Flower Images	Leaf Images	Total Images
Eclipta alba	Bhangro	290	567	857
Centella asiatica	Brahmi	127	689	816
Tylophora indica	Damvel	272	389	661

The Table.1 enlists the total number of leaf and flower images captured per plant species. The reason behind reasonable difference between leaf and flower image count is the availability of specific organ, in most of the cases flowers are available during specific season called “flowering season” whereas leaves are available almost throughout the year.

Fig.1. A Sample Dataset Images

The Fig.1 display some of the sample leaf and flower images from the Dataset. The total number of plant organ images capture is around 2334, but these images are not sufficient to train deep learning model. Also, one point is clearly noticeable from Table.1 that the dataset is imbalance, for example both Bhangro (Eclipta alba) and Damvel (Tylophora indica) are having comparatively a greater number of flower images but Brahmi (Centella asiatica) have almost half flower images as compared to other two plant species. Hence a technique called data augmentation is adopted to handle the issue of insufficient data as well as class imbalance problem [11].

Data augmentation is the technique of generating new data the existing data. Following data augmentation techniques have been used for this research. The Fig.2 shows sample images of the augmentation of Centella aciatica (Brahmi).

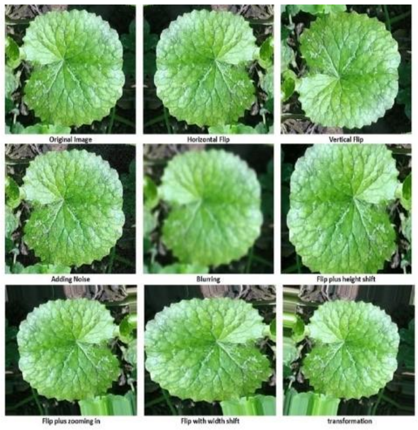

Fig.2. Sample Data Augmentation

After augmentation 20340 images of three classes were generated. Apart from data augmentation, based on the work carried out by [12] we created one more none of the above or Unknown category of labels to give regularization effect to supervised learning and reduce misclassification. Along with the plant species images we created NonFlora category to moderate misidentification, we added approximately 3000 images of nonfloral category in dataset under the separate label as NonFlora.

3.2 EXPERIMENTS

A detailed experiments have been carried out in order to derive a best suited model for Indian Medicinal Plant Identification. The researcher has created Sequential CNN model, functional branching CNN models and evaluated performance of all the models in order to find out optimum and accurate model. Once the model is finalized the next set of experiments were carried out in order to find the optimum hyperparameters for the model. The entire experiment has been divided in multiple stages, at each stage one aspect or parameter is evaluated and optimum value of the same is finalized.

3.2.1 Stage 1:

In stage 1 experiments have been carried out for discovering best suited model architecture and optimum number of layers. Experiments were carried out by developing Sequential Model with linear topology, non-linear model with single block of multiple convolutions and a model called IMPINet (Indian Medicinal Plant Identification Network), which is having a non-linear topology with multiple convolutional blocks, in other word IMPINet is a functional branching model. The result of the stage 1 is explained in Table.2.

Table.2. experiments carried out at stage 1

Model	No. of Layers	Val. Accuracy	Validation Loss	Test Accuracy
Sequential	10	0.7623	1.2260	0.6240
Functional with single block	10	0.7844	1.1926	0.7103
IMPINet	10	0.7996	1.1703	0.7200
IMPINet	20	0.8644	0.9371	0.8360
IMPINet	32	0.9665	0.3928	0.9615

The Table.2 shows that the normal sequential network with 10-layer architecture is giving accuracy of 62.40% whereas Functional branching model with single block giving accuracy of 71.03% and IMPINet with 10-layer, 20-layer and 32-layer architecture giving 72.00%, 83.60% and 96.15% accuracy respectively.

3.2.2 Stage 2:

In stage 2 researcher carried out experiments for optimizer functions, we carried out experiments with optimizer SGD (stochastic gradient descent), Adam (adaptive moment estimation), Adagrad (adaptive gradient), RMSProp (root mean square propagation) and Nadam (nesterov-accelerated adaptive moment) along with different values of Momentum/Beta/rho.

Table.3. Experiments carried out at stage 2

Optimizer	momentum / beta/ rho	Val. Accuracy	Val. loss	Test Accuracy
Adam	0.7	0.9562	0.305	0.9791
SGD	0.7	0.9509	0.648	0.9511
Adagrad	0.9	0.9335	0.716	0.9374
Nadam	0.9	0.9392	0.796	0.9356
RMSProp	0.009	0.4617	1.403	0.4843
Adam	0.9	0.9963	0.064	0.9870
SGD	0.9	0.9684	0.612	0.9654

From Table.3 its evidential that optimizer Adam with beta1 value of 0.9 giving the maximum accuracy followed by the Adam with the beta1 value of 0.7 giving accuracy of 97.9%.

3.2.3 Stage 3:

In stage 3 researcher carried out experiments for finding optimum learning rate. Different values of learning rates (0.01, 0.001, 0.004, 0.005) have been experimented and compared. The learning rate 0.001 found to give optimum results. The Table.4 below enlisted the experiment and results.

Table.4. Experiments carried out at stage 3

Optimizer	Learning Rate	Val Accuracy	Val loss	Test Accuracy
Adam	0.01	0.9630	0.106	0.9701
Adam	0.001	0.9981	0.061	0.9878
Adam	0.004	0.9847	0.081	0.9791
Adam	0.005	0.9836	0.088	0.9780

On the basis of experiment carried out in total 9 stages the IMPINet with 32 layers, having Adam as an optimizer and learning rate 0.001 with ReLU (Rectified Linear Unit) Activation function and dropout strategy as Incremental dropout had been experimented and finalized [13]. The Table.5 enlists the optimum parameters obtained in multi stage process.

Table.5. IMPINet optimum parameters

Parameter	Value
Batch size	16
Epoch	100
Optimizer	Adam
momentum/beta	0.9
learning rate	0.001
Activation	ReLU
Dropout	Incremental

3.3 IMPINET MODEL

IMPINet is a functional branching model having multiple blocks that have multiple convolution operation and carrying out concatenation of the resulting feature maps obtained after multiple convolutions followed by the activation and batch normalization.

The experiments using IMPINet and evaluation of IMPINet on created dataset (section 3.1) as well as other dataset is discussed in detail in the section 4. The experiment is carried out to compare the performance of IMPINet with the state-of-the-art models of image classification. The details of the evaluation are discussed in section 4.

3.4 PROPOSED APPROACH

Using the newly created IMPINet the following approach has been proposed for the muti organ based Indian medicinal plant identification.

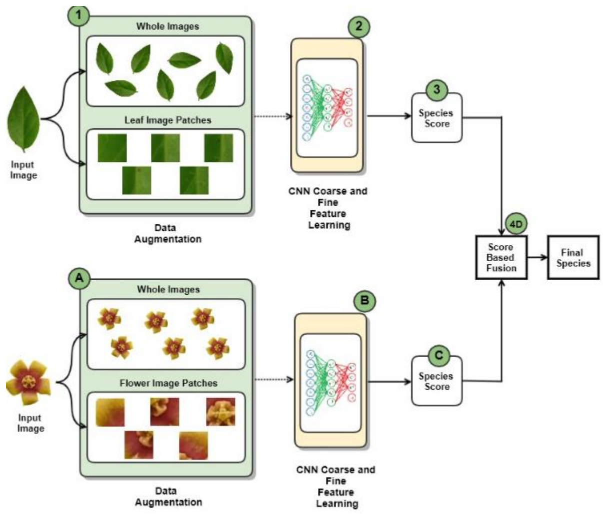

Fig.3. Proposed Approach

The Fig.3 depicts the approach where IMPINet is used as a base network for the feature learning as well as prediction. The final prediction of species is done based on the score of the leaf and flower. The score-based fusion has been carried out to calculate the final score. In the approach the network model gives identification score for the leaf and flower image respectively which are then fused to get the final score and prediction. The approach is tested on the dataset mentioned in section 3.1. The result of the experiment is discussed in the section 4.

4. RESULTS AND DISCUSSION

The proposed approach is evaluated considering IMPINet as a base network. The Leaf and Flower scores were considered for final prediction. The final score of the model is calculated after averaging out the score of the Leaf and Flower scores. Here the decision threshold was kept 70%. The Fig.4 depicts the confusion matrix obtained for four species test data. In case of Bhangro out of 310 images 300 were correctly classified and 10 were misclassified, 4 as Brahmi, 4 as Damvel and 2 as non-flora. For Brahmi out of 303 images, 297 were correctly identified, 4 were misclassified as Bhangro and 2 as Damvel. For Damvel out of 313 images 309 images were correctly classified and 2 were misclassified as Bhangro and 2 as Brahmi. For Nonflora category out of 175 images only 1 is misclassified as Brahmi. The overall accuracy obtained by IMPINet is 98.1%.

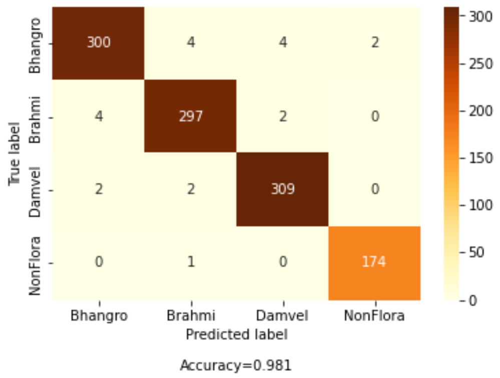

Fig.4. Confusion Matrix

The Fig.5 display class wise classification report with the measures like precision, recall and F1 score obtained by the proposed approach.

```
Confusion Matrix
[[300   4   4   2]
 [  4 297   2   0]
 [  2   2 309   0]
 [  0   1   0 174]]

Classification Report
              precision    recall  f1-score   support

     Bhangro       0.98      0.97      0.97       310
      Brahmi       0.98      0.98      0.98       303
      Damvel       0.98      0.99      0.98       313
    NonFlora       0.99      0.99      0.99       175

    accuracy                           0.98      1101
   macro avg       0.98      0.98      0.98      1101
weighted avg       0.98      0.98      0.98      1101
```

Fig.5. Class wise precision, recall and f1-score

The first set of experiment was carried out to compare the performance of IMPINet with the state-of-the-art (SOA) networks. For this experiment, two state of the art networks namely VGG16 [14] and MobileNet [15] was repurposed by the technique called transfer learning and evaluated on the same dataset. The accuracy obtained after the experiment is described in Table.6.

Table.6. Comparison of IMPINet with SOA models

Model	Accuracy
MobileNet	0.9747
IMPINet	0.9814
VGG16	0.9837

The comparison of the IMPINet with other SOA models resulted in to IMPINet achieving 98.14% accuracy, MobileNet giving 97.47% accuracy and VGG16 giving 98.37% accuracy.

The second set of experiments were carried out to evaluate performance of IMPINet on plant identification benchmark dataset. For this purpose, we carried out experiment using Flavia Dataset [16], for the evaluation purpose sample dataset containing four classes namely Bamboo, Barberry, Chestnut and Redbud have been used. The images from the sample Flavia dataset are displayed in Fig.7.

Fig.7. Sample Flavia Dataset

Using data augmentation technique mentioned in the previous section, 2402 images from four classes had been generated out of which 2200 images were used for training the IMPINet and 202 images were used for testing purpose.

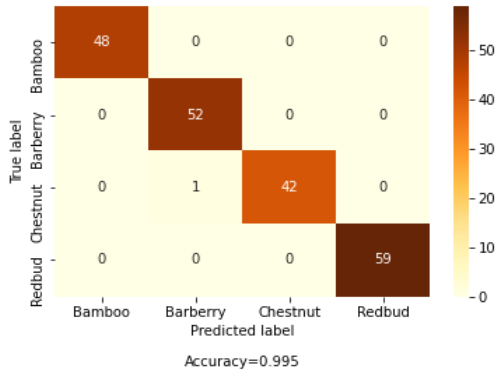

Fig.8. IMPINet performance on sample Flavia dataset

The result of evaluation is depicted in Fig.8. The confusion matrix shows the class wise performance of IMPINet. The overall accuracy achieved is 99.5%. The reason for high accuracy on Flavia dataset is because of the characteristics of dataset. Flavia dataset contains the images captured with plain white background which is less noisy whereas the dataset described in section 3.1 contains images having natural background and hence noisier as compared to Flavia dataset.

5. CONCLUSION AND FUTURE WORK

This research experimented with the multi organ image-based identification of Indian Medicinal Plant. The experiments have been carried out to create IMPINet with optimum set of hyperparameters. As part of the research a novel approach for multi organ-based identification has been proposed and evaluated and obtained overall 98.1% accuracy. The approach is extensible as it can be extended to incorporate other plant organs like fruits, stem, roots etc. Performance of IMPINet is also evaluated on Flavia sample dataset. On Flavia dataset IMPINet obtained 99.5% accuracy.

The human expert level accuracy and generalization are yet to achieve. In that direction future work includes experimenting with more algorithms and models to elevate accuracy, extending the dataset to incorporate a greater number of plant species. Extending the approach for other plant organs like stem, fruits, roots can also be done for accurate identification of medicinal plants.

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