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RESEACH ARTICLE

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CLASSIFICATION OF PLANT LEAVES AND FLOWERS USING IMAGE PROCESSING AND DEEP NEURAL NETWORKS

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Abstract: Plants have shown an important role for our life and industry. In nature, there exists a large number of species of plants. The recognition and classification of plants is a challenging task. The understanding of plants allows us to develop various useful applications in our life. The paper presents a classification method of plant leaves and flowers using the image processing and deep neural networks (e.g., Alexnet, VGG, Resnet-50). The proposed method has been applied for leaves and flowers images that are collected and normalized from multiple sources. We have evaluated the proposed method on two public datasets: plant leaves and flowers. The large dataset is collected and prepared from various sources. The classification accuracies of 94% and 95% are obtained for the plant leaves and flowers, respectively. The obtained results have shown the effectiveness of our proposed method.

Keywords: Plant classification, Machine learning, Feature extraction, Deep neural networks

1. INTRODUCTION

Plants have a significantly role in our life and industry. Plants provide us a rich resource of food, materials and medicine [1] The recognition and classification of plants allows us to develop several applications (e.g., smart agriculture, e-commerce) [2]. The recognition of plants based on the features of leaves and flowers are considered the effectiveness methods. The automatic classification of plants allows us discriminate plants using collected data and machine without using expert knowledge [3].

The automatic classification of has attracted a huge number of researches in recent years [4]. The accuracy of the classification of plant has been improved, however, there still need to be improved. Figure 1 demonstrates Different classes of plant leaves (a) and flowers (b) in nature.

There exist several difficulties of the recognition and classification of plant leaves and flowers:

(1) The similar between plant leaves and flowers caused the errors of the classification.

(2) The challenges of the conditions when capturing plant leaves and flowers caused the errors of the classification.

(3) The lack of data caused many difficulties of training and testing deep learning models.

One of the challenges of the classification of plant leaves and flowers is the lack of data. In the paper, we collect and prepare data from multiple sources. After that, we apply the image processing to normalize collected images of plant leaves and flowers. Then, various advanced convolutional neural networks (CNN) have been fine-tuned to classify images efficiently.

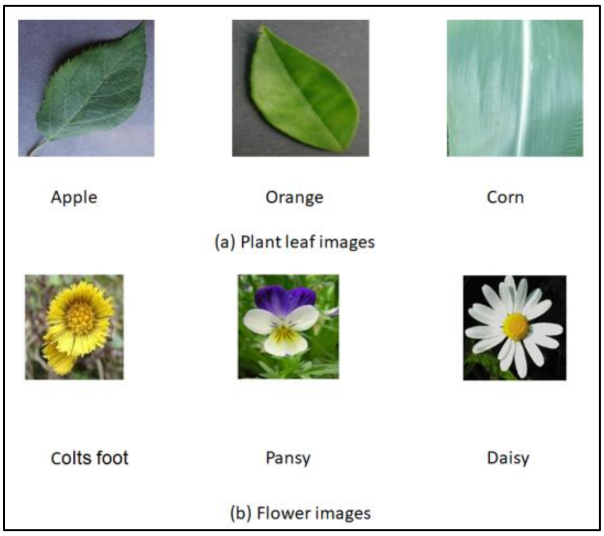

Figure 1 Examples of different species of plant leaves and flowers.

The contributions of our work are described as follows:

We collect data from several sources. Then, we normalize the data using image processing for the use of deep neural networks [5].

We evaluate and compare the performance of various classification methods on plant flowers and leaves to show the strengths and weaknesses of several methods.

This paper is structured as follows. A survey on research sources is presented in section 2. Section 3 presents our proposed framework. Experimental settings and numerical results are displayed in section 4. The last section concludes our contributions and draws some future works.

2. RELATED WORK

The recognition and classification of plants based on flowers and leaves are considered as the effective methods [2]. This section reviews the significant approaches for the classification of flowers and plant leaves.

2.1 The classification of plant leaves.

The early work in [6] proposes a method to classify leaf disease images using the K-means and support vector machine (SVM) algorithms. The work in [7] firstly extracts morphological features of leaf images. Then, the probabilistic neural network is applied to classify the images. The classification accuracy of 91.41\% is obtained and the evaluation of the method is carried out on a small dataset of 1200 images. The work in [8] relies on the shape selection to classify leaf images.

In recent years, the CNNs have been implemented to obtain higher performance of the leaf disease classification [9]. Particularly, with the large datasets of leaf images were released [10] the CNNs are widely investigated for the classification. The CNNs have shown better performance compared to traditional methods, however, we need to collect and prepare a large numbers of leaf images. The work in [9] applies the Double GAN (a double generative adversarial network) to generate unhealthy leaf images to balance and enlarge the training datasets.

2.2 The classification of plant flowers

The work in [11] proposes four different features (e.g. shape/texture, the shape of the boundary, color features) of flowers for classification purposes. Then, the multiple kernel framework with Support Vector Machine (SVM) classifier is applied. The obtained classification accuracy is 88.33\% on the Oxford-102 flower dataset.

The work in [12] extracts color and textual features of flowers. Then, the multi-layer perceptron (MLP) is used to classify flower images. The performance evaluation is performed on a private dataset.

In the study [13], the fine-grained classification was proposed on the two datasets that are Oxford-7 and Oxford-102 flower datasets. The work gained the accuracy of 93.14\% and 79.1\% on the Oxford-17 and Oxford-102 flower datasets, respectively.

In 2017, the work in [1] applied Google's pre-trained Inception-v3 network for flower classification. They obtained the classification accuracy of 95\% and 94\% on the Oxford-17 and Oxford-102 flower datasets, respectively. The work in [14] firstly segments flower regions in images to improve the quality of images. Then, a CNN is proposed to classify flowers. Recently, the work in [2] investigates neural networks with the attention mechanism to improve the accuracy of flower classification.

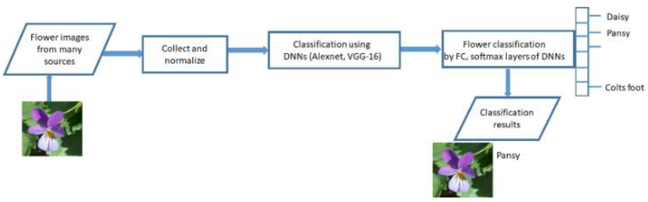

Figure 2 The flowchart of the classification of flowers

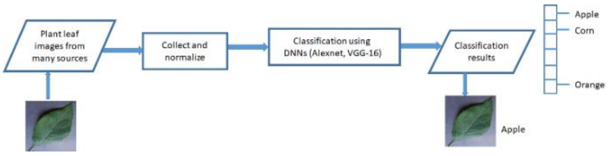

Figure 3 The flowchart of the classification of plant leaves

3. PROPOSED METHOD FOR THE CLASSIFICATION OF PLANT LEAVES AND FLOWERS

The overall framework of our proposed method for the classification of flowers and leaves is described in Figure 2 and 3, respectively.

The framework consists of the following steps:

(1) One of the difficulties in flower and plant classification is the lack of datasets. Moreover, the number of flower and plant species is imbalanced. Therefore, the collection and normalization [15] of data is applied to solve the issue.

(2) We fine-tune various deep neural networks (DNN) to improve the classification accuracy.

(3) The methods are evaluated and compared on plant and flowers datasets to point out the strengths and weaknesses of each method.

3.1 Data collection and preparation

The flower and leaf images are collected. The images are collected from the Kaggle repository [16]. We have applied the image processing techniques to pre-process the input images. Then, the images are normalized as the requirements of deep neural networks. In the paper, we fine-tune and compare the Alexnet [17] VGG-16 [18], VGG-19 [18] and Resnet-50 [19]

The size of images varies for the input of deep neural networks. The data is divided into the training, validation and testing to train, validate and test the DNN models. The data collection from multi sources has been applied to solve the lack of data for learning methods [20].

3.2 The classification of plant flowers and leaves using deep neural networks

In the paper, we have fine-tuned advanced DNNs to classify flower images in an end-to-end way. The feature extraction and classification are performed by using DNNs including Alexnet [17], Resnet [18], VGG-16 and VGG-19 [19]. Detail information of the DNNs is described in Table I. Figure 4 demonstrates the accuracy and the loss values of the Alexnet during the training and validation processes. Input flower and leaf images are resized as the requirement of the DNNs. The implementation of the DNNs is supported by the Python environment with Keras library. The computer consists of the 8GB RAM and core-i5 processor. We apply the SGDM optimization solver during the training of DNNs. The cross-entropy loss function [21] is applied during the training of DNNs.

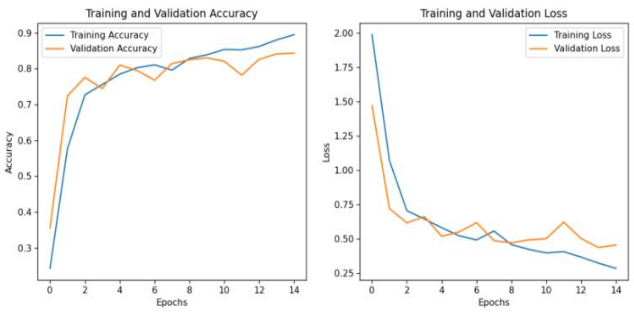

Figure 4 The accuracy and loss values of the training and validation of Alexnet for the classification of flower.

Table I Parameters of the DNNs that are fine-tuned for the classification of flower and leaf images.

DNNs	Number of layers	Sizes of input images	Number of extracted features
Alexnet [17]	25	227x227x3	4096
Resnet-50 [19]	50	224x224x3	512
VGG-16 [18]	16	224x224x3	1000
VGG-19 [18]	19	224x224x3	1000

Table II Information of flower datasets

Flower Species	Training	Validation	Testing
Colts foot	900	300	300
Daisy	900	300	300
Pansy	900	300	300

Table III Information of plant leaf datasets

Plant leaf Species	Training	Validation	Testing
Orange	600	200	200
Corn	600	200	200
Apple	600	200	200

4. EXPERIEMENTAL RESULTS

4.1. Dataset and evaluation metrics

The proposed method has been evaluated on two large datasets of plant leaves and flowers. The flower dataset consists of three species of flowers: Colt's foot, daisy and pansy. The plat leaf dataset consists of three species of leaves: apple, orange and corn. Table II and III describe detail information of the flower and leaf datasets.

To obtain a clear evaluation of the proposed method, the precision (P), recall (R) and F1 score metrics are applied in the work. The evaluation metric is widely used for the classification task [22] The F1 score is the harmonic mean of precision and recall that can be calculated as follows:

$$F1 - score = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \quad (1)$$

4.2. Performance evaluation

Tables IV and V compare the performance of various classification methods of flowers and leaves. The data augmentation technique allows the DNNs to perform better. The classification of flowers using the Resnet-50 achieves the highest accuracy thanks to the powerful network architecture. The VGG-19 obtains higher performance compared to VGG-16 and Alexnet because of the deeper layers. Figure 5 shows examples of the classification of flowers and leaves. The performance comparison shows that the classification of plants using flowers is more effective than that of leaves.

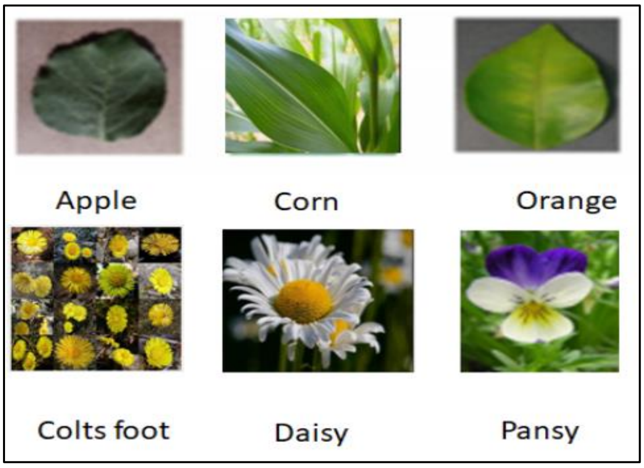

Figure 5 Examples of the classification of flowers and leaves.

Table IV Performance comparison of the classification of flowers using DNNs

Methods	P	R	F1
Alexnet	91%	89%	89.99%
VGG-16	93%	92%	92.50%
VGG-19	95%	93%	93.99%
Resnet-50	95%	93%	93.99%

Table V Information of plant leaves datasets

Methods	P	R	F1
Alexnet	90%	89%	89.50%
VGG-16	92%	91%	91.50%
VGG-19	92.5%	91.5%	92%
Resnet-50	94%	93%	93.50%

5. CONCLUSION AND FUTURE WORKS

The paper investigates and proposes the classification method for the plant leaves and flowers. The data is collected and normalized from multiple sources to overcome the lack of data. Various deep neural networks have been fine-tuned to improve the classification accuracy. The obtained results show that Resnet-50 obtains the highest accuracy compared to Alexnet and VGG networks. In the future, the data of plant leaves and flowers is collected from other sources. The classification results can be combined with Internet of Things modules to develop various applications in smart agriculture.

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