Feature Extraction and Automatic Recognition of Plant Leaf Using Artificial Neural Network

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Abstract. Plant recognition is an important and challenging task. Leaf recognition plays an important role in plant recognition and its key issue lies in whether selected features are stable and have good ability to discriminate different kinds of leaves. From the view of plant leaf morphology (such as shape, dent, margin, vein and so on), domain–related visual features of plant leaf are analyzed and extracted first. On such a basis, an approach for recognizing plant leaf using artificial neural network is brought forward. The prototype system has been implemented. Experiment results prove the effectiveness and superiority of this method.

1 Introduction

The recognition and identification of plant has great significance to explore genetic relationship of plant and explain the evolution law of plant system. However it is a very time consuming task, which is usually done by botanist currently. When recognizing and identifying plant, people usually observe leaf, flower, stem, fruit and so on to extract discriminating feature [1]. Because such discriminating features can be directly observed and obtained by people when they observing leaf images, people expect to fulfill the recognition and identification of plant automatically or semi-automatically by computers [2].

As an important organ of plants, recognition and identification of leaves is an important step for plant recognition and identification. In addition, leaves of plants are planar and easy to be input into the computer by scanner and digital camera. At present, most of related work focuses on the study of leaf images of plant. Im. [3] recognized maple leaves by the shape. Wang. [4] represented the shape of leaf with a centroid-contour distances curve. The problem of the above methods lies in the simplicity of the description of leaves feature. Namely these methods mostly focused on contour of leaf and neglected other features such as leaf dent, leaf vein and so on. Fu. [5] extracted leaf vein from leaf images by neural network, but did not further present the features of leaf vein. Zhang. [6] retrieved the standard tobacco leaf database by the features of color, texture and shape (mainly perimeter and area). The problem of this method is the lack of representation of domain features of leaves.

We believe that the key issue of leaf recognition, which is the same to that of plant recognition, is whether extracted features are stable and can distinguish individual

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Advances in Artificial Intelligence
Research in Computing Science 20, 2006, pp. 3-10

leaves. Following this idea, features of shape, margin, dent and vein are extracted first in this paper to represent leaves; On such a basis, an approach for recognizing plant leaf using artificial neural network is brought forward. The prototype system has been implemented and the experiment result proves the effectiveness and superiority of this method.

The rest part of the paper is organized as follows. Visual features of leaf images are described in Section 2. An approach for recognizing plant leaf using artificial neural network is brought forward in Section 3. In Section 4, experimental results and discussions are presented. In Section 5, conclusions and further work are given.

2 Extraction of Leaf Image Features

Visual features of image can be classified as general visual features and domain-related visual features. General visual features, such as color, texture and shape are used to describe common features of all the images and have no relation with specific type and content of images. For leaf recognition, domain-related visual features of leaf image should be extracted. Combined with the morphology characteristic of leaves, several domain-related visual features are extracted with consideration of three aspects of leaf: shape, dent and vein.

2.1 Leaf Shape

Shape of objects is greatly helpful to object recognition and retrieval. In this paper, four visual features are defined to represent the shape of leaf.

Slimness (F1): this feature is defined as the ratio of length to width of leaves as Formula 1,

$$Shape\_slimness = \frac{l_1}{l_2}, \tag{1}$$

where, l_1 is the maximum length between the bonding point of leafstalk with leaf surface and all the points at the leaf margin. l_2 is the maximum length of line between the points on leaf margin which is vertical to l_1.

Roundness (F2): the feature is defined as Formula 2,

$$Shape\_roundness = \frac{4\pi A}{P^2}, \tag{2}$$

where, A is the area of leaf image; P is the perimeter of leaf contour. And roundness expresses the extent to which a shape is a circle [7]. A circle's roundness is 1 and a long bar's roundness is close to 0.

Solidity (F3): this feature is defined as Formula 3,

$$Shape\_solidity = \frac{S_1}{S_2}, \tag{3}$$

where, S_1 is the internal area connecting the valley points; S_2 is the external area connecting the top points(as shown in Fig. 2). Solidity expresses the degree of splitting depth in a leaf [8].

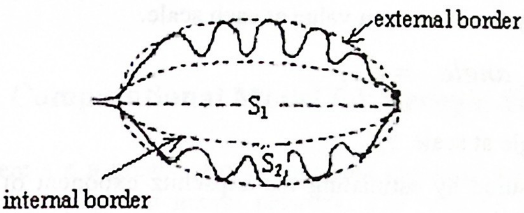

Fig 1. Internal and External Shape

t_{i+1}^6	t_{i+1}^0	t_{i+1}^1
t_{i+1}^5	t_i	t_{i+1}^2
t_{i+1}^4	t_{i-1}	t_{i+1}^3

Fig. 2. Possible Directions of Point t_{i+1}

Moment invariants (F4~F10): slimness and roundness describe the shape feature of leaf to some extent. However, such description is rough. In order to describe the leaf shape in detail, this paper adopts moment invariants as shape describer. Please refer to ref. [9] for the detailed formula.

2.2 Leaf Dent

Leaf margin and leaf dent contain rich information, and they play an important role in leaf image recognition. In the following some visual features are extracted to represent leaf margin and leaf dent.

Coarseness (F11): this feature expresses the coarseness of the leaf margin and is defined as Formula 4,

$$Dent\_margin = \frac{P}{P'}, \tag{4}$$

where, P is the perimeter of leaf contour, and P' is the length of internal border.

Features of leaf dent: leaf dent is regarded as detailed patterns on contour shapes, and wavelet maximum (*i.e.* Wavelet Local Extrema) is used to represent the features of leaf dent (for example the size, sharpness, angle)[10]. The describer can be obtained by the following wavelet transformation as shown in Formula 5.

$$W_s\theta(t) = \theta(t) * \psi_s(t), \tag{5}$$

where, $s = 2^j$, j is the level corresponding to scale s, $j = 0,\dots,n$. $\theta(t)$ is the tangential orientation change along the contour and t is the arc length from the starting point on the contour shape.

The extrema are extracted and each extremum describes a corner appearing at a certain scale. The following feature vectors are described.

Size (F12): this is the largest scale at which the WLE of a leaf dent appear.

$$Dent\_size = \log_2(s_t), \tag{6}$$

where, s_t is the top scale.

Angle (F13): this is measured by the extremum value at each scale.

$$Dent\_angle_{s_v} = e_{s_v}, \tag{7}$$

where, $Dent\_angle_{s_v}$ is the angle at scale s_v.

Sharpness (F14): This is measured by estimating the Lipschitz exponent of the WLE values.

$$\begin{aligned} e_s &\cong A * exp(-\alpha s) \\ Dent\_sharpness &= \alpha \end{aligned}, \tag{8}$$

where, α is the Lipschitz exponent and A is a constant.

2.3 Leaf Vein

As an inherent trait, the leaf vein definitely contains the important information despite of its complex modality. The venations of main vein and secondary vein are usually similar to the structure of whole plant. By analyzing the venations, more detailed characteristic of leaf, even that of the whole plant can be obtained [11]. In reference [5], modality of leaf venation can be extracted accurately. Based on this work, further features are extracted to present the leaf vein.

Ramification (F15): the number of ramification of the main vein can be used to measure the complexity of venation. By watering the main vein from the end point of leaf stem, the number of the ramification is the diffluent times of the water when it flows along the main vein. It is defined as the following Formula 9[12,13].

$$Vein\_ramification = \frac{fc_i}{l_i}, \tag{9}$$

where, l_i is the length of main vein, fc_i is the number of ramification.

Camber (F16): camber expresses the degree of crook of main vein. $T = \{t_0, t_1, \dots, t_n\}$ represents a main vein, and t_{i-1}, t_i, t_{i+1} are the three continuity point. Supposing the positions of t_{i-1}, t_i are determined, t_{i+1} may has seven directions as shown in Fig. 3. When the direction of t_{i+1} is t_{i+1}^0, t_{i-1}, t_i, t_{i+1} reveal linear relation in this domain, that is, and the main vein has no turning at the point of t_{i+1}. Otherwise, vein has turning at the point of t_{i+1} [12,13].

Camber is defined as:

$$Vein\_camber = \frac{rn_T}{n+1}, \tag{10}$$

where rn_T is the number of turning of main vein.

3 Computational Model for Recognizing Plant Leaf

There are a great many recognition methods. In this paper, we use a feed-forward back-propagation neural network. The selected neural network has 3 layers, input layer with 16 nodes, hidden layer with 32 nodes and output layer with 6 nodes. The number of nodes of input layer is the same as the number of extracted features, and the number of nodes of output layer is the same as the number of plant categories to be recognized. Back propagation algorithm is used to train the neural network [14,15]. And minimize the error between real output and expect output by adjusting the weight of connections.

The trained NN are embodied in the plant leaf recognition system. Figure 3 shows the flow chart of our approach of recognizing plant leaves.

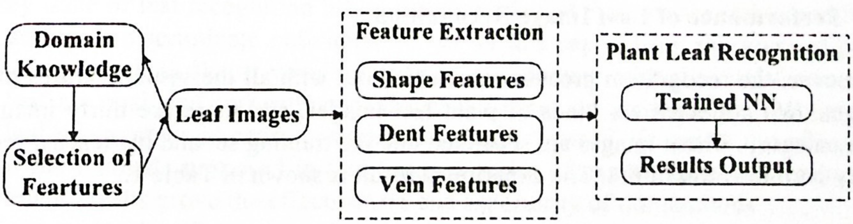

Fig. 3. Block Diagram of Plant Leaf Recognition Approach

4 Experiments and Discussions

4.1 Validity Evaluation of Visual Features

The effectiveness and stability of extracted visual features plays an important role in recognition system. So the first experiments were to examine the validity of leaf visual features discussed in this paper. Each time only one feature was used as the recognition feature. The recognition rate is shown in Fig. 4.

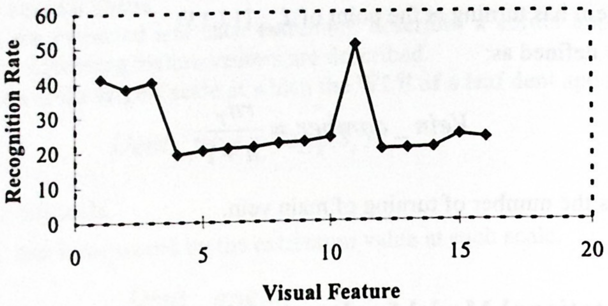

Fig. 4. Recognition Rate of Individual Feature

Based on the experimental result shown in Fig. 4, the following conclusions can be drawn: 1) Different visual feature has different ability of distinguishing leaves. Owing to it, these features can be classified into the global features and the local features. To improve the recognition performance, a hierarchical recognition method for leaf image is to be brought forward in the further work. 2) We should not use exclusive visual feature to represent image because exclusive feature doesn't have strong ability to recognize the species of plant leaf.

4.2 Performance of Leaf Image Recognition

Moreover, the recognition process was carried out with all the visual features of leaf images. We collected six kinds of plant leaf images, and there are thirty images in each category. These images are separated into the training set and the test set respectively with the ratio of 6:4. The experiment result is shown in Table 1.

Table 1. Recognition Performance of Visual Features with Different Size of Training Set

Plant Species	Recognition Accuracy Rate (%)	
	54 (50%)	108 (100%)
P1	91.0%	94.4%
P2	94.6%	95.2%
P3	89.7%	91.1%
P4	92.5%	96.8%
P5	95.2%	98.6%
P6	96.3%	97.9%

From Table 1, we can conclude that the recognition of leaves with all selected visual features is satisfying and the recognition performance is improved after trained with different size of training set. The experiment results validate the high ability of extracted features to distinguish different kinds of leaves.

4.3 Experiment of Leaf Recognition

The recognition system in C++ has been implemented on a PC (CPU: PIV 2.6GHz, RAM: 512M). Based on 1200 leaf images, the average time recognizing one image is about 0.45 seconds and the training time is about 12.3 seconds. Fig. 5 shows the first, second, third and the fourth most similar candidate to the leaf to be recognized.

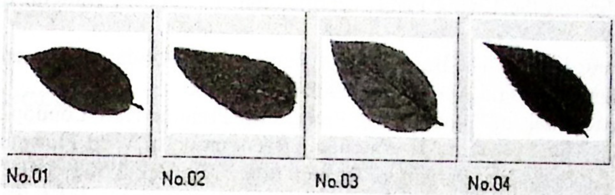

Fig. 5. Result of Leaf Image Recognition

5 Conclusions

The key issue of leaf recognition lies in whether selected features are stable and have good ability to discriminate individual leaves. In this paper, from the view of plant morphology (such as shape, vein, dent and so on), domain-related visual features of plant leaf are analyzed and extracted. On such a basis, an approach for recognizing plant leaf using artificial neural network is brought forward. To prove the effectiveness of the methods proposed in this paper, a series of experiments are conducted. Experiment results prove the effectiveness and superiority of our methods.

Our future work will focus on: 1) the extraction of plant leaf from the image with background consisting of various objects; 2) the construction of hierarchical recognition model of leaf image.

Acknowledgment

This work was supported by National Science Foundation of P.R. China (60275023).

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